DASSAULT SYSTEMES

SIMULIA

Abaqus 6.13

Analysis User's Guide
Volume I: Introduction, Spatial Modeling, Execution & Output

3DEXPERIENCE

Abaqus Analysis

User's Guide

Volume I

Legal Notices

Preface

This section lists various resources that are available for help with using Abaqus Unified FEA software.

Support

Both technical software support (for problems with creating a model or performing an analysis) and systems support (for installation, licensing, and hardware-related problems) for Abaqus are offered through a global network of support offices, as well as through our online support system. Regional contact information is accessible from the **Locations** page at www.3ds.com/simulia. The online support system is accessible from the **Support** page at www.3ds.com/simulia.

Online support

SIMULIA provides a knowledge database of answers and solutions to questions that we have answered, as well as guidelines on how to use Abaqus, SIMULIA Scenario Definition, Isight, and other SIMULIA products. The knowledge database is available from the **Support** page at www.3ds.com/simulia.

By using the online support system, you can also submit new requests for support. All support incidents are tracked. If you contact us by means outside the system to discuss an existing support problem and you know the support request number, please mention it so that we can query the database to see what the latest action has been.

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We welcome any suggestions for improvements to Abaqus software, the support program, or documentation. We will ensure that any enhancement requests you make are considered for future releases. If you wish to make a suggestion about the service or products, refer to www.3ds.com/simulia. Complaints should be made by contacting your support office or by visiting the **Quality Assurance** page at www.3ds.com/simulia.

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1. Introduction

1.1 Introduction

- “Introduction: general,” Section 1.1.1

1.1.1 INTRODUCTION: GENERAL

Overview of the Abaqus finite element system

The Abaqus finite element system includes:

- Abaqus/Standard, a general-purpose finite element program;
- Abaqus/Explicit, an explicit dynamics finite element program;
- Abaqus/CFD, a general-purpose computational fluid dynamics program;
- Abaqus/CAE, an interactive environment used to create finite element models, submit Abaqus analyses, monitor and diagnose jobs, and evaluate results; and
- Abaqus/Viewer, a subset of Abaqus/CAE that contains only the postprocessing capabilities of the Visualization module.

Several add-on options are available to further extend the capabilities of Abaqus/Standard and Abaqus/Explicit. The Abaqus/Aqua option works with Abaqus/Standard and Abaqus/Explicit. The Abaqus/Design and Abaqus/AMS options work with Abaqus/Standard. Abaqus/Aqua contains optional features that are specifically designed for the analysis of beam-like structures installed underwater and subject to loading by water currents and wave action. The Abaqus/Design option enables you to perform design sensitivity analysis (DSA). Abaqus/AMS is an optional eigensolver that works within Abaqus/Standard providing very fast solution of large symmetric eigenvalue problems. The Abaqus co-simulation technique provides several applications, available as separate add-on capabilities, for coupling between Abaqus and third-party analysis programs. Abaqus/Foundation is an optional subset of Abaqus/Standard that provides more cost-efficient access to the linear static and dynamic analysis functionality in Abaqus/Standard. These options are available only if your license includes them.

For a comprehensive list of Abaqus products, utilities, and add-on options, see "Abaqus products," Section 1.2 of the Abaqus Release Notes.

Overview of this guide

This guide is a reference to using Abaqus/Standard (including Abaqus/Aqua, Abaqus/Design, and Abaqus/Foundation), Abaqus/Explicit (including Abaqus/Aqua), and Abaqus/CFD. Abaqus/Standard solves a system of equations implicitly at each solution "increment." In contrast, Abaqus/Explicit marches a solution forward through time in small time increments without solving a coupled system of equations at each increment (or even forming a global stiffness matrix). Abaqus/CFD provides a computational fluid dynamics capability with extensive support for preprocessing, simulation, and postprocessing in Abaqus/CAE.

Throughout the guide the term Abaqus is most commonly used to refer collectively to both Abaqus/Standard and Abaqus/Explicit and, when applicable, Abaqus/CFD; the individual product names are used to indicate when information applies to only that product. Product identifiers appear

at the beginning of each section in the guide (excluding overview sections) indicating the products to which the information in the section applies.

The guide is divided into several parts:

- Part I, "Introduction, Spatial Modeling, and Execution," discusses basic modeling concepts in Abaqus, such as defining nodes, elements, and surfaces; the conventions and input formats that should be followed when using Abaqus; and the execution procedures for Abaqus/Standard, Abaqus/Explicit, Abaqus/CFD, Abaqus/CAE, and several utilities that are provided with the Abaqus system.
- Part II, "Output," describes how to obtain output from Abaqus and the format of the results (`.fil`) file. It also describes the output variable identifiers that are available.
- Part III, "Analysis Procedures, Solution, and Control," describes the analysis types (static stress analysis, dynamics, eigenvalue extraction, etc.) that are available. Detailed discussions of the differences between how Abaqus/Standard and Abaqus/Explicit solve finite element analyses are provided in this chapter.
- Part IV, "Analysis Techniques," discusses various analysis techniques available in Abaqus such as submodeling, removing elements or surfaces, and importing results from a previous simulation to define the initial conditions for the current model.
- Part V, "Materials," describes the material modeling options and how to calibrate some of the more advanced material models.
- Part VI, "Elements," describes the elements available in Abaqus.
- Part VII, "Prescribed Conditions," describes the use of prescribed conditions, such as distributed loads and nodal velocities.
- Part VIII, "Constraints," discusses the use of constraints, such as multi-point constraints.
- Part IX, "Interactions," discusses the contact and interaction models available in Abaqus.

The guide also includes indexes of all of the output variables and elements available in Abaqus/Standard, Abaqus/Explicit, and Abaqus/CFD.

Using Abaqus

Abaqus/Standard, Abaqus/Explicit, and Abaqus/CFD can be run as batch applications (see "Abaqus/Standard, Abaqus/Explicit, and Abaqus/CFD execution," Section 3.2.2, for details)or through the interactive Abaqus/CAE environment (see "Abaqus/CAE execution," Section 3.2.6, for details on how to start Abaqus/CAE). The main input to the Abaqus/Standard, Abaqus/Explicit, and Abaqus/CFD analysis products is a file containing the options required for the simulation and the data associated with those options. There may also be supplementary files, such as restart or results files from previous analyses, or auxiliary data files, such as a file containing an acceleration record or an earthquake record for dynamic analysis. The input file is usually created by Abaqus/CAE or another preprocessor. Both input file usage and Abaqus/CAE usage information are provided in this guide.

As described in "Defining a model in Abaqus," Section 1.3.1, the main input file consists of two sections: model input and history input. The input is organized around a few natural concepts and conventions, which means that even though input files for complex simulations can be large, they can

be managed without difficulty. The basic syntax rules that govern an Abaqus input file are discussed in "Input syntax rules," Section 1.2.1. The Abaqus Keywords Reference Guide contains a complete description of all the input options available in Abaqus/Standard, Abaqus/Explicit, and Abaqus/CFD. For a detailed introduction to using Abaqus for your analyses, it is recommended that you follow the self-paced tutorials in Getting Started with Abaqus: Interactive Edition. Refer to the Abaqus/CAE User's Guide for detailed information on working with Abaqus/CAE.

In addition, many analyses that demonstrate the numerous capabilities of Abaqus are discussed in the Abaqus Example Problems Guide, the Abaqus Benchmarks Guide, and the Abaqus Verification Guide. As a supplement to the Abaqus Analysis User's Guide, these examples can help you become familiar with the functionality that Abaqus provides and the structure of the Abaqus input file. For example, "Beam impact on cylinder," Section 1.6.12 of the Abaqus Verification Guide, discusses the various modeling techniques that can be used to analyze the dynamic response of a cantilever beam.

Reviewing the results of an Abaqus simulation

Information on requesting output from an Abaqus simulation is discussed in "Output," Section 4.1.1. Requested results from an Abaqus simulation are viewed through the Visualization module in Abaqus/CAE (also licensed separately as Abaqus/Viewer). The output database file is read by the Visualization module in Abaqus/CAE to create contour plots, animations, *X*–*Y* plots, and tabular output of Abaqus results. See Part V, "Viewing results," of the Abaqus/CAE User's Guide for detailed information on using the Visualization module in Abaqus/CAE.

1.2 Abaqus syntax and conventions

1.2.1 INPUT SYNTAX RULES

Products: Abaqus/Standard Abaqus/Explicit

Reference

- "Defining a model in Abaqus," Section 1.3.1

Overview

This section describes the syntax rules that govern an Abaqus input file.

All data definitions in Abaqus are accomplished with option blocks—sets of data describing a part of the problem definition. You choose those options that are relevant for a particular application. Options are defined by lines in the input file. Three types of input lines are used in an Abaqus input file: *keyword* lines, *data* lines, and *comment* lines. Only 7-bit ASCII characters are supported, and a carriage return is required at the end of each line in an input file.

- Keyword lines introduce options and often have *parameters*, which appear as words or phrases separated by commas on the keyword line. Parameters are used to define the behavior of an option. Parameters can stand alone or have a value, and they may be required or optional.
- Data lines, which are used to provide numeric or alphanumeric entries, follow most keyword lines.
- Any line that begins with stars in columns 1 and 2 (**) is a comment line. Such lines can be placed anywhere in the file. They are ignored by Abaqus, so they will be printed only in the initial listing of the file. There is no restriction on how many or where such lines occur in the file.

Relevant parameters and data lines (including the number of entries per data line) are described in the sections of the Abaqus Keywords Reference Guide describing each option. This section describes the general rules that apply to all keyword and data lines.

Keyword lines

The following rules apply when entering a keyword line:

- The first non-blank character of each keyword line must be a star (*).
- The keyword must be followed by a comma (,) if any parameters are given.
- Parameters must be separated by commas.
- Blanks on a keyword line are ignored.
- A line can include no more than 256 characters, including blanks.
- Keywords and parameters are not case sensitive.
- Parameter values usually are not case sensitive. The only exceptions to this rule are those imposed externally to Abaqus, such as file names on case-sensitive operating systems.
- Keywords, parameters, and, in most cases, parameter values need not be spelled out completely, but there must be enough characters given to distinguish them from other keywords, parameters,

and parameter values that begin in the same way. Abaqus first searches each associated text string for an exact match. If an exact match is not found, Abaqus then searches based upon the minimum number of unique characters in each keyword, parameter, or parameter value, as the case may be. Embedded blanks can be omitted from any item in a keyword line. If a parameter value is used to provide a number or a file name, the complete value should be provided.

- If a parameter has a value, the equal sign (=) is used. The value can be an integer, a floating point number, or a character string, depending on the context. For example,

```
*ELASTIC, TYPE=ISOTROPIC, DEPENDENCIES=1
```

- When the parameter value is a character string that represents the name of an item, you should not use case as a method of distinguishing values unless the values are enclosed within quotation marks. For example, Abaqus does not distinguish between the following definitions:

```
*MATERIAL, NAME=STEEL
*MATERIAL, NAME=Steel
```

- The same parameter should not appear more than once on a single keyword line. If a parameter has multiple settings on a single keyword line, Abaqus ignores all but one of the settings.
- Continuation of a keyword line is sometimes necessary; for example, because of a large number of parameters. If the last character on a keyword line is a comma, the next line is interpreted as a continuation of the line. For example, the *ELASTIC keyword line above could also be given as

```
*ELASTIC, TYPE=ISOTROPIC,
DEPENDENCIES=1
```

- Certain keywords must be used in conjunction with other keywords; for example, the *ELASTIC and *DENSITY keywords must be used in conjunction with the *MATERIAL keyword. These related keywords must be grouped in a block in the input file; unrelated keywords cannot be specified within this block.
- Some options allow the INPUT or FILE parameter to be set equal to the name of an alternate file. Such file names can include a full path name or a relative path name. Relative path names must be with respect to the directory from which the job was submitted. If no path is specified, the file is assumed to be in the directory from which the job was submitted. A substructure library must be in the same directory from which the job was submitted; a full path name cannot be used to specify a substructure library name.

  For files referenced by the INPUT parameter, the file name must include any extension (e.g., **elem.inp**). For files referenced by the FILE parameter, the name must be given without an extension in most cases since Abaqus assumes that the file to be read has the correct extension for the file type that is relevant to the option: **.res** for restart files ("Restarting an analysis," Section 9.1.1) and **.fil** for results files ("Output," Section 4.1.1). However, special rules may apply when a results file (**.fil**) or an output database file (**.odb**) is relevant for the option (see "Initial conditions in Abaqus/Standard and Abaqus/Explicit," Section 34.2.1, and "Sequentially coupled thermal-stress analysis," Section 16.1.2, for details).

The file or substructure library name must have the correct case on computers with case-sensitive operating systems. Regardless of whether the user specifies only a file name, a relative path name, or a full path name, the complete name including the path can have a maximum of 256 characters.

Data lines

Data lines are used to provide data that are more easily given in lists than as parameters on an option. Most options require one or more data lines; if they are required, the data lines must immediately follow the keyword line introducing the option. The following rules apply when entering a data line:

- A data line can include no more than 256 characters, including blanks. Trailing blanks are ignored.
- All data items must be separated by commas (,). An empty data field is specified by omitting data between commas. Abaqus will use values of zero for any required numeric data that are omitted unless a default value is specified.
- A line must contain only the number of items specified.
- Empty data fields at the end of a line can be ignored.
- Floating point numbers can occupy a maximum of 20 spaces including the sign, decimal point, and any exponential notation.

  Floating point numbers can be given with or without an exponent. Any exponent, if input, must be preceded by E or D and an optional (−) or (+). The following line shows four acceptable ways of entering the same floating point number:

  ```
  -12.345    -1234.5E-2   -1234.5D-2   -1.2345E1
  ```

- Integer data items can occupy a maximum of 9 digits.
- Character strings can be up to 80 characters long and are not case sensitive.
- Continuation lines are allowed in specific instances (see “Element definition,” Section 2.2.1). If allowed, such lines are indicated by a comma as the last character of the preceding line. A single data item cannot be entered over multiple lines.

In many cases the choice of parameters used with an option determines the type of data lines required. For example, there are five different ways to define a linear elastic material (“Elastic behavior: overview,” Section 22.1.1). The data lines you specify must be consistent with the value of the TYPE parameter given on the *ELASTIC option.

Sets

One of the most useful features of the Abaqus data definition method is the availability of *sets*. A set can be a set of nodes or a set of elements. You provide a name (1–80 characters, the first of which must be a letter) for each set. That name then provides a means of referencing all of the members of the set. As an example suppose that, for the structure shown in Figure 1.2.1–1, we wish to apply symmetry boundary conditions at all of the nodes in the set **MIDDLE** and that the edge **SUPPORT** is pinned. We assemble the relevant nodes into sets and specify the boundary conditions by

```
*BOUNDARY
```

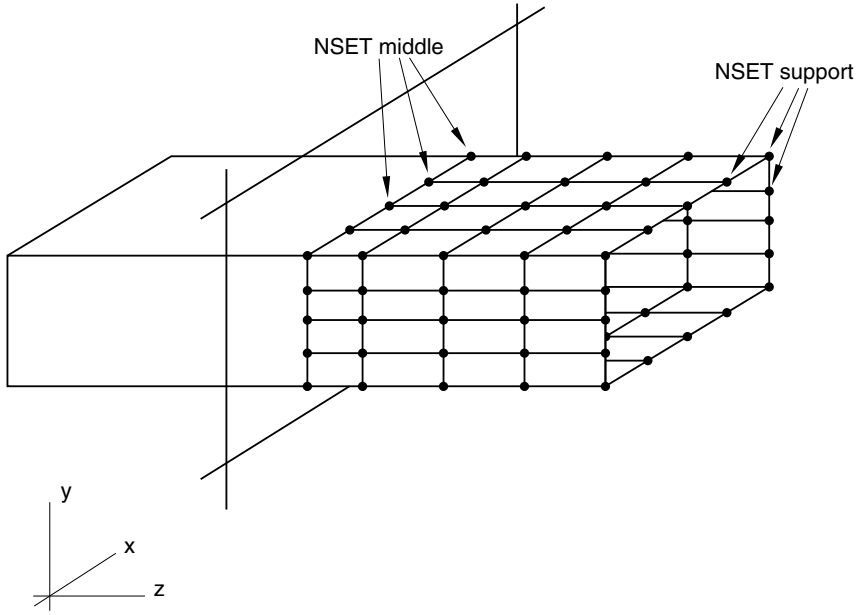


Figure 1.2.1–1 Example of the use of sets.

```
MIDDLE, ZSYMM
SUPPORT, PINNED
```

Sets are the basic reference throughout Abaqus, and the use of sets is recommended. Choosing meaningful set names makes it simple to identify which data belong to which part of the model. Further discussion of sets is provided in "Node definition," Section 2.1.1, and "Element definition," Section 2.2.1.

Labels

Labels such as set names, surface names, and rebar names are case insensitive unless enclosed within quotation marks (except when they are accessed from user subroutines; see "User subroutines: overview," Section 18.1.1). Labels can be up to 80 characters long. All spaces within a label are ignored unless the label is enclosed in quotation marks, in which case all spaces within the label are maintained. A label that is not enclosed within quotation marks must begin with a letter, may not include a period (.), and should not contain characters such as commas and equal signs. These restrictions do not apply to labels enclosed within quotation marks except if the label is a material name. A material name must always start with a letter, even if the name is enclosed within quotation marks.

Labels cannot begin and end with a double underscore (e.g., __STEEL__). This label format is reserved for internal use by Abaqus.

The following are examples of labels entered with and without the use of quotation marks:

```
*ELEMENT, TYPE=SPRINGA, ELSET="One element"
1,1,2
*SPRING, ELSET="One element"
1.0E-5,
*NSET, ELSET="One element", NSET=NODESET
*BOUNDARY
nodeset,1,2
```

Repeating data lines

Some options list only a single data line. In cases where only one data line is allowed, this is indicated by the data line title "First (and only) line." An example of this is the ∗DYNAMIC option. In many cases the single data line shown can be repeated to define one variable as a function of another; this choice is indicated by a note after the data line. For example, a table of biaxial test data can be given to define a hyperelastic material:

∗BIAXIAL TEST DATA
T_B^1, ϵ_B^1
T_B^2, ϵ_B^2
T_B^3, ϵ_B^3
Etc.

There is no limit on the number of data lines allowed, but the data must be given in a certain order, as explained below.

Many options require more than one data line; these are indicated by the data line titles "First line:", "Second line:", etc. For example, exactly two data lines must be used to define a local orientation for a shell element (∗ORIENTATION), and at least three data lines are required to define anisotropic elasticity (∗ELASTIC).

In many cases the data lines can be repeated, which is indicated by a note after the data lines. As with repetition of a single data line, it is important that sets of data lines be given in the correct order so that Abaqus can interpolate the data properly.

Example: Multiple data lines due to field variable dependence

Any time an option can be defined as a function of field variables, you must determine the number of data lines required to define the option completely. (See "Specifying field variable dependence" in "Material data definition," Section 21.1.2 for more information.) For example, two data lines are required if stress-based failure criteria (∗FAIL STRESS) are defined as a function of two field variables. This pair of data lines is repeated as often as necessary to define the failure criteria completely:

```
*FAIL STRESS, DEPENDENCIES=2
```

first pair
$X_t^1,\ X_c^1,\ Y_t^1,\ Y_c^1,\ S^1,\ \ ,\ \sigma_{biax}^1$
$fv_1^1,\ fv_2^1$

second pair
$X_t^2,\ X_c^2,\ Y_t^2,\ Y_c^2,\ S^2,\ \ ,\ \sigma_{biax}^2$
$fv_1^2,\ fv_2^2$

third pair
$X_t^3,\ X_c^3,\ Y_t^3,\ Y_c^3,\ S^3,\ \ ,\ \sigma_{biax}^3$
$fv_1^3,\ fv_2^3$

```
Etc.
```

(In this example the last field on the first data line of each pair was omitted, which means that the stress-based failure criteria are not temperature dependent.)

If the stress-based failure criteria were defined as a function of nine field variables, a set of three data lines would be repeated as often as necessary:

```
*FAIL STRESS, DEPENDENCIES=9
```

first set
$X_t^1,\ X_c^1,\ Y_t^1,\ Y_c^1,\ S^1,\ \ ,\ \sigma_{biax}^1$
$fv_1^1,\ fv_2^1,\ fv_3^1,\ fv_4^1,\ fv_5^1,\ fv_6^1,\ fv_7^1,\ fv_8^1$
fv_9^1

second set
$X_t^2,\ X_c^2,\ Y_t^2,\ Y_c^2,\ S^2,\ \ ,\ \sigma_{biax}^2$
$fv_1^2,\ fv_2^2,\ fv_3^2,\ fv_4^2,\ fv_5^2,\ fv_6^2,\ fv_7^2,\ fv_8^2$
fv_9^2

```
Etc.
```

Ordering the data lines

Whenever one variable is defined as a function of another, the data must be given in the proper order so that Abaqus can interpolate for intermediate values correctly. The variable being defined is assumed to be constant outside the range of independent variables given, except for nonlinear elastic gasket thickness behavior involving damage where the data are extrapolated based on the last slope computed from the user-specified data.

If the property being defined is a function of only one variable (such as the *BIAXIAL TEST DATA shown above), the data should be given in the order of increasing value of the independent variable.

If the property being defined is a function of multiple independent variables, the variation of the property with respect to the first variable must be given at fixed values of the other variables, in ascending values of the second variable, then of the third variable, and so on. The data lines must always be ordered so that the independent variables are given increasing values. This process ensures that the value of the

material property is completely and uniquely defined at any values of the independent variables upon which the property depends.

As an example, consider isotropic elasticity defined as a function of three field variables (but not of temperature):

```
*ELASTIC, DEPENDENCIES=3
E1, ν1,  , 1, 1, 1
E2, ν2,  , 2, 1, 1
E3, ν3,  , 1, 2, 1
E4, ν4,  , 2, 2, 1
E5, ν5,  , 1, 3, 1
E6, ν6,  , 2, 3, 1
E7, ν7,  , 1, 1, 2
E8, ν8,  , 2, 1, 2
E9, ν9,  , 1, 2, 2
E10, ν10, , 2, 2, 2
E11, ν11, , 1, 3, 2
E12, ν12, , 2, 3, 2
E13, ν13, , 1, 1, 3
E14, ν14, , 2, 1, 3
E15, ν15, , 1, 2, 3
E16, ν16, , 2, 2, 3
E17, ν17, , 1, 3, 3
E18, ν18, , 2, 3, 3
```

1.2.2 CONVENTIONS

Products: Abaqus/Standard Abaqus/Explicit Abaqus/CFD Abaqus/CAE

References

- Chapter 2, "Spatial Modeling"
- Part II, "Output"
- "Boundary conditions in Abaqus/Standard and Abaqus/Explicit," Section 34.3.1
- "Boundary conditions in Abaqus/CFD," Section 34.3.2

Overview

The conventions that are used throughout Abaqus are defined in this section. The following topics are discussed:

- Degrees of freedom
- Coordinate systems
- Self-consistent units
- Time measures
- Local directions on surfaces in space
- Stress and strain conventions
- Stress and strain measures in geometrically nonlinear analysis
- Conventions for finite rotations
- Conventions for tabular data input

Degrees of freedom

Except for axisymmetric elements, fluid continuum elements, and electromagnetic elements, the degrees of freedom are always referred to as follows:

1 x-displacement
2 y-displacement
3 z-displacement
4 Rotation about the x-axis, in radians
5 Rotation about the y-axis, in radians
6 Rotation about the z-axis, in radians
7 Warping amplitude (for open-section beam elements)
8 Pore pressure, hydrostatic fluid pressure, or acoustic pressure
9 Electric potential

10 Connector material flow (units of length)

11 Temperature (or normalized concentration in mass diffusion analysis)

12 Second temperature (for shells or beams)

13 Third temperature (for shells or beams)

14 Etc.

Here the x-, y-, and z-directions coincide with the global X-, Y-, and Z-directions, respectively; however, if a local transformation is defined at a node (see "Transformed coordinate systems," Section 2.1.5), they coincide with the local directions defined by the transformation.

A maximum of 20 temperature values (degrees of freedom 11 through 30) can be defined for shell or beam elements in Abaqus/Standard.

Axisymmetric elements

The displacement and rotation degrees of freedom in axisymmetric elements are referred to as follows:

1 r-displacement

2 z-displacement

5 Rotation about the z-axis (for axisymmetric elements with twist), in radians

6 Rotation in the r–z plane (for axisymmetric shells), in radians

Here the r- and z-directions coincide with the global X- and Y-directions, respectively; however, if a local transformation is defined at a node (see "Transformed coordinate systems," Section 2.1.5), they coincide with the local directions defined by the transformation.

Fluid continuum elements

Fluid continuum elements in Abaqus/CFD are used to define the element shape and to discretize the continuum. Degrees of freedom in a fluid flow analysis are not determined by the element type but by the analysis procedure and options specified (e.g., turbulence models and auxiliary transport equations).

Electromagnetic elements

Electromagnetic elements in Abaqus/Standard are used to define the element shape and to discretize the continuum. The eddy current and magnetostatic analyses formulations use magnetic vector potential as a degree of freedom (see "Boundary conditions" in "Eddy current analysis," Section 6.7.5, and "Boundary conditions" in "Magnetostatic analysis," Section 6.7.6).

Activation of degrees of freedom

Abaqus/Standard and Abaqus/Explicit activate only those degrees of freedom needed at a node. Thus, some of the degrees of freedom listed above may not be used at all nodes in a model, because each element type uses only those degrees of freedom that are relevant. For example, two-dimensional solid (continuum) stress/displacement elements use only degrees of freedom 1 and 2. The degrees of freedom actually used at any node are the envelope of those needed in each element that shares the node.

In Abaqus/CFD the active degrees of freedom in a fluid flow analysis are determined by the analysis procedure and the options specified. For example, using the energy equation in conjunction with the incompressible flow procedure activates the velocity, pressure, and temperature degrees of freedom. For more information, see "Active degrees of freedom" in "Boundary conditions in Abaqus/CFD," Section 34.3.2.

Internal variables in Abaqus/Standard

In addition to the degrees of freedom listed above, Abaqus/Standard uses internal variables (such as Lagrange multipliers to impose constraints) for some elements. Normally you need not be concerned with these variables, but they may appear in error and warning messages and are checked for satisfaction of nonlinear constraints during iteration. Internal variables are always associated with internal nodes, which have negative numbers to distinguish them from user-defined nodes.

Coordinate systems

The basic coordinate system in Abaqus is a right-handed, rectangular Cartesian system. You can choose other systems locally for input (see "Node definition," Section 2.1.1), for output of nodal variables (displacements, velocities, etc.) and point load or boundary condition specification (see "Transformed coordinate systems," Section 2.1.5), and for material or kinematic joint specification (see "Orientations," Section 2.2.5). All coordinate systems must be right-handed.

Units

Abaqus has no units built into it except for rotation and angle measures. Therefore, the units chosen must be self-consistent, which means that derived units of the chosen system can be expressed in terms of the fundamental units without conversion factors.

Rotation and angle measures

In Abaqus rotational degrees of freedom are expressed in radians, and all other angle measures are expressed in degrees (for example, phase angles).

International System of units (SI)

The International System of units (SI) is an example of a self-consistent set of units. The fundamental units in the SI system are length in meters (m), mass in kilograms (kg), time in seconds (s), temperature in degrees kelvin (K), and electric current in amperes (A). The units of secondary or derived quantities are based on these fundamental units. An example of a derived unit is the unit of force. A unit of force in the SI system is called a newton (N):

$$1 \text{ newton} = 1 \text{ kg m/s}^2.$$

Similarly, a unit of electrical charge in the SI system is called a coulomb (C):

$$1 \text{ coulomb} = 1 \text{ A s}.$$

Another example is the unit of energy, called a joule (J):

$$1 \text{ joule} = 1 \text{ N m} = 1 \text{ A volt s} = 1 \text{ kg m}^2/\text{s}^2.$$

The unit of electrical potential in the SI system is the volt, which is chosen such that

$$1 \text{ joule} = 1 \text{ volt C} = 1 \text{ volt A s}.$$

Sometimes the standard units are not convenient to work with. For example, Young's modulus is frequently specified in terms of megapascals (MPa) (or, equivalently, N/mm^2), where 1 pascal = 1 N/m^2. In this case the fundamental units could be tonnes (1 tonne = 1000 kilograms), millimeters, and seconds.

American or English units

American or English units can cause confusion since the naming conventions are not as clear as in the SI system. For example, 1 pound force (lbf) will give 1 pound mass (lbm) an acceleration of g ft/sec^2, where g is the value of acceleration due to gravity. If pounds force, feet (ft), and seconds are taken as fundamental units, the derived unit of mass is $\text{lbf sec}^2/\text{ft}$. Since density is commonly given in handbooks as lbm/in^3, it must be converted to $\text{lbf sec}^2/\text{ft}^4$ by

$$1 \text{ lbm/in}^3 = \frac{12^3}{g} \text{ lbf sec}^2/\text{ft}^4.$$

Frequently it is not made clear in handbooks whether lb stands for lbm or lbf. You need to check that the values used make up a consistent set of units.

Two other units that cause difficulty are the slug, defined as the mass that will be accelerated at 1 ft/sec^2 by 1 lbf, and the poundal, defined as the force required to accelerate 1 lbm at 1 ft/sec^2. Useful conversions are

$$1 \text{ slug} = g \text{ lbm}$$

and

$$1 \text{ lbf} = g \text{ poundals},$$

where g is the magnitude of the acceleration due to gravity in ft/sec^2.

Symbols used in Abaqus for units

Units are indicated for the value to be given on load and flux types as follows:

Dimension	Indicator	Example (S.I. units)
length	L	meter
mass	M	kilogram

Dimension	Indicator	Example (S.I. units)
time	T	second
temperature	θ	degree Celsius
electric current	A	ampere
force	F	newton
energy	J	joule
electric charge	C	coulomb
electric potential	φ	volt
mass concentration	P	Parts per million

Time

Abaqus has two measures of time—step time and total time. Except for certain linear perturbation procedures, step time is measured from the beginning of each step. Total time starts at zero and is the total accumulated time over all general analysis steps (including restart steps; see "Restarting an analysis," Section 9.1.1). Total time does not accumulate during linear perturbation steps.

Local tangent directions on surfaces in space

Local tangent directions are needed on surfaces in space; for example, to provide a convention for describing components of slip on an element-based contact surface or components of stress and strain in a shell. The convention used in Abaqus for such directions is as follows.

The default local 1-direction is the projection of the global x-axis onto the surface. If the global x-axis is within 0.1° of being normal to the surface, the local 1-direction is the projection of the global z-axis onto the surface. The local 2-direction is then at right angles to the local 1-direction, so that the local 1-direction, local 2-direction, and the positive normal to the surface form a right-handed set (see Figure 1.2.2–1). The positive normal direction is defined in an element by the right-hand rotation rule going around the nodes of the element. The local surface directions can be redefined; see "Orientations," Section 2.2.5.

The local 1- and 2-directions become local 2- and 3-directions, respectively, when considering gasket elements or the local systems associated with integrated output sections ("Integrated output section definition," Section 2.5.1) or user-defined sections ("Section output from Abaqus/Standard" in "Output to the data and results files," Section 4.1.2).

For "line"-type surfaces defined on beam, pipe, or truss elements in space, the default local 1-direction and 2-direction are tangential and transverse to the elements. In this case the local surface directions can also be redefined as described in "Orientations," Section 2.2.5.

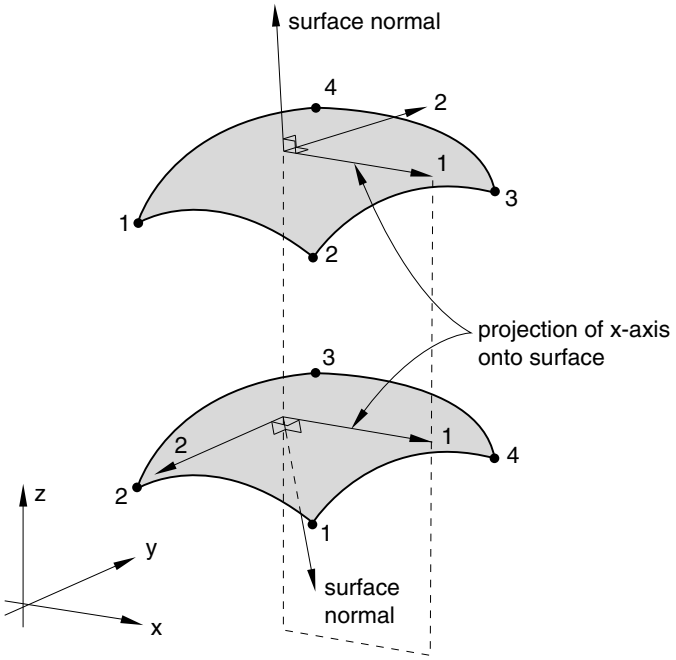


Figure 1.2.2–1 Default local surface directions.

Rotation of the local directions

For geometrically linear analysis, stress and strain components are given by default in the material directions in the reference (initial) configuration.

For geometrically nonlinear analysis, small-strain shell elements in Abaqus/Standard (S4R5, S8R, S8R5, S8RT, S9R5, STRI3, and STRI65) use a total Lagrangian strain, and the stress and strain components are given relative to material directions in the reference configuration. Gasket elements are small-strain small-displacement elements, and the components are output by default in the behavior directions in the reference configuration.

For finite-membrane-strain elements (all membrane elements, S3/S3R, S4, S4R, SAX, and SAXA elements) and for small-strain shell elements in Abaqus/Explicit, the material directions rotate with the average rigid body motion of the surface to form the material directions in the current configuration. Stress and strain components in these elements are given relative to these material directions in the current configuration.

For a more thorough discussion of the definition of the rotated coordinate directions in membrane elements; S3/S3R, S4, and S4R elements; S3RS, S4RS, and S4RSW elements; and SAXA elements, see:

- "Membrane elements," Section 3.4.1 of the Abaqus Theory Guide,
- "Finite-strain shell element formulation," Section 3.6.5 of the Abaqus Theory Guide,

- "Small-strain shell elements in Abaqus/Explicit," Section 3.6.6 of the Abaqus Theory Guide, and
- "Axisymmetric shell element allowing asymmetric loading," Section 3.6.7 of the Abaqus Theory Guide.

You can determine whether the local system associated with a user-defined section is fixed or rotates with the average rigid body motion; see "Section output from Abaqus/Standard" in "Output to the data and results files," Section 4.1.2, for details.

You can determine whether the local system associated with an integrated output section is fixed, translates with average rigid body motion, or translates and rotates with the average rigid body motion; see "Integrated output section definition," Section 2.5.1, for details.

See "Contact formulations in Abaqus/Standard," Section 38.1.1, for information on how the local tangent directions evolve during an Abaqus/Standard contact analysis.

Convention used for stress and strain components

When defining material properties, the convention used for stress and strain components in Abaqus is that they are ordered:

σ_{11} Direct stress in the 1-direction

σ_{22} Direct stress in the 2-direction

σ_{33} Direct stress in the 3-direction

τ_{12} Shear stress in the 1–2 plane

τ_{13} Shear stress in the 1–3 plane

τ_{23} Shear stress in the 2–3 plane

For example, a fully anisotropic, linear elasticity matrix is

$$\begin{pmatrix} \sigma_{11} \\ \sigma_{22} \\ \sigma_{33} \\ \tau_{12} \\ \tau_{13} \\ \tau_{23} \end{pmatrix} = \begin{bmatrix} D_{1111} & D_{1122} & D_{1133} & D_{1112} & D_{1113} & D_{1123} \\ & D_{2222} & D_{2233} & D_{2212} & D_{2213} & D_{2223} \\ & & D_{3333} & D_{3312} & D_{3313} & D_{3323} \\ & \text{symm.} & & D_{1212} & D_{1213} & D_{1223} \\ & & & & D_{1313} & D_{1323} \\ & & & & & D_{2323} \end{bmatrix} \begin{pmatrix} \varepsilon_{11} \\ \varepsilon_{22} \\ \varepsilon_{33} \\ \gamma_{12} \\ \gamma_{13} \\ \gamma_{23} \end{pmatrix}.$$

The 1-, 2-, and 3-directions depend on the element type chosen. For solid elements the defaults for these directions are the global spatial directions. For shell and membrane elements the defaults for the 1- and 2-directions are local directions in the surface of the shell or membrane, as defined in Part VI, "Elements." In both cases the 1-, 2-, and 3-directions can be changed as described in "Orientations," Section 2.2.5.

For geometrically nonlinear analysis with solid elements, the default (global) directions do not rotate with the material. However, user-defined orientations do rotate with the material.

Abaqus/Explicit stores the stress and strain components internally in a different order: σ_{11}, σ_{22}, σ_{33}, τ_{12}, τ_{23}, τ_{13}. For geometrically nonlinear analysis, the internally stored components rotate with the material, regardless of whether or not a user-defined orientation is used. This distinction is important when a user subroutine (such as **VUMAT**) is used.

Nonisotropic material behavior

When nonisotropic material behavior is defined in continuum elements, a user-defined orientation is necessary for the anisotropic behavior to be associated with material directions. See "State storage," Section 1.5.4 of the Abaqus Theory Guide, for a description of how material directions rotate.

Zero-valued stress components

Stress components that are always zero are omitted from storage. For example, in plane stress Abaqus stores only the two direct components and one shear component of stress and strain in the plane where the stress values are nonzero.

Shear strains

Abaqus always reports shear strain as engineering shear strain, γ:

$$\gamma_{ij} = \varepsilon_{ij} + \varepsilon_{ji}.$$

Stress and strain measures

The stress measure used in Abaqus is Cauchy or "true" stress, which corresponds to the force per current area. See "Stress measures," Section 1.5.2 of the Abaqus Theory Guide, and "Stress rates," Section 1.5.3 of the Abaqus Theory Guide, for more details on stress measures.

For geometrically nonlinear analysis, a large number of different strain measures exist. Unlike "true" stress, there is no clearly preferred "true" strain. For the same physical deformation different strain measures will report different values in large-strain analysis. The optimal choice of strain measure depends on analysis type, material behavior, and (to some degree) personal preference. See "Strain measures," Section 1.4.2 of the Abaqus Theory Guide, for more details on strain measures.

By default, the strain output in Abaqus/Standard is the "integrated" total strain (output variable E). For large-strain shells, membranes, and solid elements in Abaqus/Standard two other measures of total strain can be requested: logarithmic strain (output variable LE) and nominal strain (output variable NE).

Logarithmic strain (output variable LE) is the default strain output in Abaqus/Explicit; nominal strain (output variable NE) can be requested as well. The "integrated" total strain is not available in Abaqus/Explicit.

Total (integrated) strain

The default "integrated" strain measure, E, output by Abaqus/Standard to the data (`.dat`) and results (`.fil`) files for all elements that can handle finite strain is obtained by integrating the strain rate numerically in a material frame of reference:

$$\boldsymbol{\varepsilon}^{n+1} = \Delta\mathbf{R} \cdot \boldsymbol{\varepsilon}^{n} \cdot \Delta\mathbf{R}^{T} + \Delta\boldsymbol{\varepsilon},$$

where $\boldsymbol{\varepsilon}^{n+1}$ and $\boldsymbol{\varepsilon}^{n}$ are the total strains at increments $n+1$ and n, respectively; $\Delta\mathbf{R}$ is the incremental rotation tensor; and $\Delta\boldsymbol{\varepsilon}$ is the total strain increment from increment n to $n+1$. For elements that use

a corotational coordinate system (finite-strain shells, membranes, and solid elements with user-defined orientations), the above equation simplifies to

$$\varepsilon^{n+1} = \varepsilon^n + \Delta\varepsilon.$$

The strain increment is obtained by integration of the rate of deformation $\mathbf{D}$ over the time increment:

$$\Delta\varepsilon = \int_{t^n}^{t^{n+1}} \mathbf{D}\, dt.$$

This strain measure is appropriate for elastic-(visco)plastic or elastic-creeping materials, because the plastic strains and creep strains are obtained by the same integration procedure. In such materials the elastic strains are small (because the yield stress is small compared to the elastic modulus), and the total strains can be compared directly with the plastic strains and creep strains.

If the principal directions of straining rotate with respect to the material axes, the resulting strain measure cannot be related to the total deformation, regardless whether a spatial or corotational coordinate system is used. If the principal directions remain fixed in the material axes, the strain is the integration of the rate of deformation,

$$\varepsilon^{n+1} = \int_0^{t^{n+1}} \mathbf{D}\, dt,$$

which is equivalent to the logarithmic strain discussed later.

Green's strain

For small-strain shells and beams in Abaqus/Standard, the default strain measure, E, is Green's strain:

$$\varepsilon^G = \frac{1}{2}(\mathbf{F}^T \cdot \mathbf{F} - \mathbf{I}),$$

where $\mathbf{F}$ is the deformation gradient and $\mathbf{I}$ is the identity tensor. This strain measure is appropriate for the small-strain, large-rotation approximation used in these elements. The components of ε^G represent strain along directions in the original configuration. The small-strain shells and beams should not be used in finite-strain analysis with either elastic-plastic or hyperelastic material behavior, since incorrect analysis results may be obtained or program failure may occur.

Nominal strain

The nominal strain, NE, is

$$\varepsilon^N = \mathbf{V} - \mathbf{I} = \sum_{i=1}^{3} (\lambda_i - 1)\, \mathbf{n}_i\, \mathbf{n}_i{}^T,$$

where $\mathbf{V} = \sqrt{\mathbf{F} \cdot \mathbf{F}^T}$ is the left stretch tensor, λ_i are the principal stretches, and $\mathbf{n}_i$ are the principal stretch directions in the current configuration. The principal values of nominal strain are, therefore, the ratios of change in length to length in the reference configuration in the principal directions, thus giving a direct measure of deformation.

Logarithmic strain

The logarithmic strain, LE, is

$$\boldsymbol{\varepsilon}^L = \ln \mathbf{V} = \sum_{i=1}^{3} \ln \lambda_i \, \mathbf{n}_i \, \mathbf{n}_i{}^T,$$

where the variables are as defined earlier for nominal strain. This is also the strain output for hyperelastic materials. For a hyper-viscoleastic material, the logarithmic elastic strain EE is computed from the current (relaxed) stress state, and the viscoelastic strain CE is computed as LE − EE.

Stress invariants

Many of the constitutive models in Abaqus are formulated in terms of stress invariants. These invariants are defined as the equivalent pressure stress,

$$p = -\frac{1}{3}\mathrm{trace}\,(\boldsymbol{\sigma});$$

the Mises equivalent stress,

$$q = \sqrt{\frac{3}{2}(\mathbf{S} : \mathbf{S})};$$

and the third invariant of deviatoric stress,

$$r = (\frac{9}{2}\mathbf{S} \cdot \mathbf{S} : \mathbf{S})^{\frac{1}{3}};$$

where $\mathbf{S}$ is the deviatoric stress, defined as

$$\mathbf{S} = \boldsymbol{\sigma} + p\,\mathbf{I}.$$

Finite rotations

The following convention is used for finite rotations in space: Define ϕ_x, ϕ_y, ϕ_z as "rotations" about the global *X*, *Y*, and *Z*-axes (that is, degrees of freedom 4, 5, and 6 at a node). Then define

$$p_x = \phi_x/\phi, \quad p_y = \phi_y/\phi, \quad p_z = \phi_z/\phi,$$

where

$$\phi = \sqrt{\phi_x^2 + \phi_y^2 + \phi_z^2}.$$

The direction $\mathbf{p}$ is then the axis of rotation, and ϕ is the angular rotation (in radians) about the axis $\mathbf{p}$ according to the right-hand rule (see Figure 1.2.2–2).

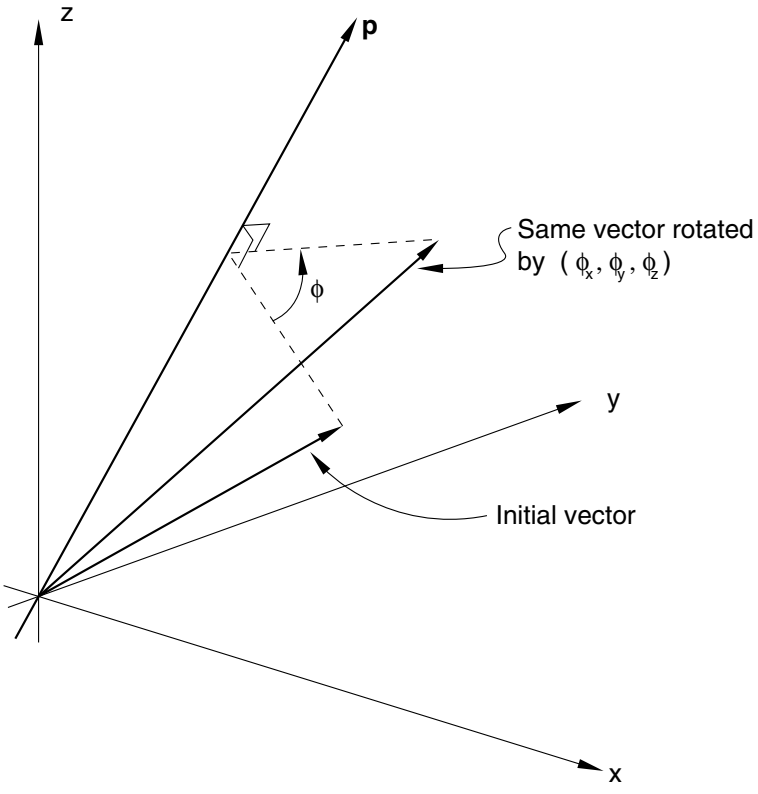


Figure 1.2.2–2 Definition of finite rotation.

The value of ϕ is not uniquely determined. In large-rotation problems where the overall rotation exceeds 2π, any multiple of 2π can be added or subtracted, which may lead to discontinuous output values for the rotation components. If rotations larger than 2π about one axis occur in the positive (negative) direction in Abaqus/Standard, the rotation output varies discontinuously between *0* and 2π (-2π). In Abaqus/Explicit the rotation output varies in all cases between -2π and 2π.

This convention provides straightforward input of kinematic boundary conditions and moments in most cases and simple interpretation of the output. The rotations output by Abaqus represent a single rotation from the reference configuration to the current configuration about a fixed axis. The output does not follow the history of rotation at a node. In addition, this convention reduces to the usual convention

for small rotations, even in the case of small rotations superposed on an initial finite rotation (such as might be considered in the study of small vibrations about a predeformed state).

Compound rotations

Because finite rotations are not additive, the way they must be specified is a bit different from the way other boundary conditions are specified: the increment in rotation specified over a step must be the rotation needed to rotate the node from the configuration at the beginning of the step to that desired at the end of the step. It is not enough to rotate the node over this step to a total rotation vector that would have taken the node into its final configuration if applied on the node in some other initial reference configuration. If an increment of rotation $(\Delta\phi_x, \Delta\phi_y, \Delta\phi_z)$ is needed to rotate from the rotation boundary condition $(\phi_x, \phi_y, \phi_z)^t$ at the beginning of the step (and at the end of the previous step) to its final position at the end of the step, the boundary condition must be specified such that the rotation vector is $(\phi_x^t + \Delta\phi_x, \phi_y^t + \Delta\phi_y, \phi_z^t + \Delta\phi_z)$ at the end of the step. If the direction of the rotation vector is constant, this method of specifying rotation boundary conditions and the total rotation vector will be the same.

Example

As an example of how to specify compound finite rotations and to interpret finite rotation output, consider the following example of the rotation of a beam.

The beam initially lies along the x-axis. We want to perform the compound rotation, where (Step 1) the beam is rotated by 60° about the z-axis, followed by (Step 2) a 90° spin of the beam about itself, followed by (Step 3) a 90° rotation of the beam about an axis perpendicular to the beam in the x–y plane, such that the beam finishes on the z-axis.

This compound rotation is achieved in three steps with applied rotation vectors $\boldsymbol{\phi}_1$, $\boldsymbol{\phi}_2$, and $\boldsymbol{\phi}_3$, where

$$\begin{aligned}
\boldsymbol{\phi}_1 &= \phi_1 \mathbf{e}_z = \{\, 0 \quad 0 \quad 1.047198 \,\}^T \,, \\
\boldsymbol{\phi}_2 &= \phi_2(\cos\phi_1 \mathbf{e}_x + \sin\phi_1 \mathbf{e}_y) = \{\, 0.785398 \quad 1.360350 \quad 0 \,\}^T \,, \quad \text{and} \\
\boldsymbol{\phi}_3 &= \phi_3(\sin\phi_1 \mathbf{e}_x - \cos\phi_1 \mathbf{e}_y) = \{\, 1.360350 \quad -0.785398 \quad 0 \,\}^T \,.
\end{aligned}$$

For this example $\phi_1 = \pi/3$, $\phi_2 = \pi/2$, and $\phi_3 = \pi/2$. Here ϕ_i represents the magnitude of each finite rotation about the (unit length) rotation axis. The rotation vectors above are applied in each of the three steps on the configuration at the beginning of that step. It is most straightforward to prescribe these rotations with velocity-type boundary conditions. For convenience, the default amplitude reference in Abaqus for a velocity-type boundary condition is a constant value of one.

A typical Abaqus step definition for this example, where node 1 is pinned at the origin and the rotation is applied to node 2, is as follows:

```
*STEP, NLGEOM
Step 1: Rotate 60 degrees about the z-axis
*STATIC
*BOUNDARY, TYPE=VELOCITY
```

```
 2, 4, 5
 2, 6, 6, 1.047198
*END STEP
**
*STEP, NLGEOM
Step 2: Rotate 90 degrees about the beam axis
*STATIC
*BOUNDARY, TYPE=VELOCITY
 2, 4, 4, 0.785398
 2, 5, 5, 1.36035
 2, 6, 6
*END STEP
**
*STEP, NLGEOM
Step 3: Rotate beam onto z-axis
*STATIC
*BOUNDARY, TYPE=VELOCITY
 2, 4, 4, 1.36035
 2, 5, 5, -0.785398
 2, 6, 6
*END STEP
```

The above method for applying finite-rotation boundary conditions (using a velocity-type boundary condition with the default constant amplitude definition) is strongly recommended. However, if the rotation boundary conditions are applied as displacement-type boundary conditions, the input syntax would change.

The Abaqus/Standard convention for boundary condition specification within a step is to specify the total or final boundary state. In such a case the specified boundary conditions from all of the previous steps must be added to the incremental rotation vector components. The Abaqus/Standard step definitions from above would change to:

```
*STEP, NLGEOM
Step 1: Rotate 60 degrees about the z-axis
*STATIC
*BOUNDARY
 2, 4, 5
 2, 6, 6, 1.047198
*END STEP
**
*STEP, NLGEOM
Step 2: Rotate 90 degrees about the beam axis
*STATIC
*BOUNDARY
```

```
 2, 4, 4, 0.785398
 2, 5, 5, 1.36035
 2, 6, 6, 1.047198
*END STEP
**
*STEP, NLGEOM
Step 3: Rotate beam onto z-axis
*STATIC
*BOUNDARY
 2, 4, 4, 2.145748
 2, 5, 5, 0.574952
 2, 6, 6, 1.047198
*END STEP
```

The boundary conditions in Steps 2 and 3 are the sum of the incremental rotation components plus the rotation boundary conditions specified in the previous steps.

In Abaqus/Explicit references to amplitude definitions should be used such that there are no jumps in displacement across the steps. It is often convenient to use amplitude definitions given in terms of total time for this purpose. The displacement boundary conditions will be applied incrementally based on the increment in the value of amplitude curve over the time increment. Therefore, any sudden jumps in displacement at the beginning of a step introduced either without the amplitude curves or with two amplitude curves will be ignored (see "Boundary conditions in Abaqus/Standard and Abaqus/Explicit," Section 34.3.1). The Abaqus/Explicit step definitions for the above example would change to:

```
*AMPLITUDE, TIME=TOTAL TIME, NAME=RAMPUR1
 0., 0., 0.001, 0., 0.002, 0.785398, 0.003, 2.145748
*AMPLITUDE, TIME=TOTAL TIME, NAME=RAMPUR2
 0., 0., 0.001, 0., 0.002, 1.36035, 0.003, 0.574952
*AMPLITUDE, TIME=TOTAL TIME, NAME=RAMPUR3
 0., 0., 0.001, 1.047198, 0.002, 1.047198, 0.003, 1.047198
*STEP
Step 1: Rotate 60 degrees about the z-axis
*DYNAMIC, EXPLICIT
 , 0.001
*BOUNDARY, AMP=RAMPUR1
 2, 4, 4, 1.0
*BOUNDARY, AMP=RAMPUR2
 2, 5, 5, 1.0
*BOUNDARY, AMP=RAMPUR3
 2, 6, 6, 1.0
*END STEP
**
*STEP
```

```
Step 2: Rotate 90 degrees about the beam axis
*DYNAMIC, EXPLICIT
 , 0.001
*END STEP
**
*STEP
Step 3: Rotate beam onto z-axis
*DYNAMIC, EXPLICIT
 , 0.001
*END STEP
```

The boundary conditions in Steps 2 and 3 are the sum of the incremental rotation components plus the rotation boundary conditions specified in the previous steps.

The Abaqus output of the rotation field at the end of Step 3 is

$$\mathtt{UR1} = 1.927\,,\ \mathtt{UR2} = -0.5163\,,\ \mathtt{UR3} = 1.927\,.$$

We see that none of the individual components of the specified boundary conditions appears in the final rotation output. The final rotation output represents the rotation vector required to obtain the final orientation in a single step.

Suppose that in Step 3 of the previous example we want to apply the rotation vector ϕ_3 at node 1 instead of at node 2. If the rotation is applied incrementally, the Abaqus/Standard step definition is as follows:

```
*STEP, NLGEOM
Step 3: Rotate beam onto z-axis
*STATIC
*BOUNDARY, TYPE=VELOCITY, OP=NEW
 1, 1, 3
 1, 4, 4, 1.36035
 1, 5, 5, -0.785398
 1, 6, 6
*END STEP
```

and the Abaqus/Explicit step definition is similar. It is necessary to remove the rotation boundary conditions that are in effect at node 2.

As mentioned previously, using velocity-type boundary conditions is the preferred method for applying finite-rotation boundary conditions. If the rotation boundary condition is to be applied as a displacement-type boundary condition, we must first retrieve the rotation field at node 1 at the end of Step 2. The Abaqus output of this rotation field is

$$\mathtt{UR1} = 1.412\,,\ \mathtt{UR2} = 0.8155\,,\ \mathtt{UR3} = 0.8155\,.$$

These rotation vector components must then be added to the incremental rotation vector components we wish to prescribe in Step 3. The Abaqus/Standard step definition would change to

```
*STEP
Step 3: Rotate beam onto z-axis
*STATIC
*BOUNDARY, OP=NEW
 1, 1, 3
 1, 4, 4, 2.772
 1, 5, 5, 0.0301
 1, 6, 6, 0.8155
*END STEP
```

and the Abaqus/Explicit step definition would change to:

```
*STEP
Step 3: Rotate beam onto z-axis
*DYNAMIC, EXPLICIT
 , 0.001
*AMPLITUDE, TIME=STEP TIME, NAME=NODE1UR1
 0., 1.412, 0.001, 2.772
*AMPLITUDE, TIME=STEP TIME, NAME=NODE1UR2
 0., 0.8155, 0.001, 0.0301
*AMPLITUDE, TIME=STEP TIME, NAME=NODE1UR3
 0., 0.8155, 0.001, 0.8155
*BOUNDARY, OP=NEW
 1, 1, 3
*BOUNDARY, OP=NEW, AMP=NODE1UR1
 1, 4, 4, 1.
*BOUNDARY, OP=NEW, AMP=NODE1UR2
 1, 5, 5, 1.
*BOUNDARY, OP=NEW, AMP=NODE1UR3
 1, 6, 6, 1.
*END STEP
```

The boundary conditions are again specified in the Abaqus/Explicit input using amplitude curves to avoid any sudden jump in their values at the beginning of the step. As stated above and in "Boundary conditions in Abaqus/Standard and Abaqus/Explicit," Section 34.3.1, any jumps in the displacement values will be ignored and the boundary will be maintained at the previous values.

As this last procedure clearly demonstrates, it is simpler to apply finite-rotation boundary conditions as velocity-type boundary conditions rather than as displacement-type boundary conditions. The recommended method of specifying finite-rotation boundary conditions is also described in "Boundary conditions in Abaqus/Standard and Abaqus/Explicit," Section 34.3.1. For further discussion of how finite rotations are accumulated, see "Rotation variables," Section 1.3.1 of the Abaqus Theory Guide.

1.3 Abaqus model definition

- “Defining a model in Abaqus,” Section 1.3.1

1.3.1 DEFINING A MODEL IN Abaqus

Products: Abaqus/Standard Abaqus/Explicit Abaqus/CFD

References

- "Input syntax rules," Section 1.2.1
- Abaqus Keywords Reference Guide
- Abaqus/CAE User's Guide

Overview

An analysis in Abaqus is defined by an *input file*, which

- contains *keyword lines* and *data lines*; and
- is divided into *model* data and *history* data.

The input file

An Abaqus input file is an ASCII data file. It can be created by using a text editor or by using a graphical preprocessor such as Abaqus/CAE. The input file consists of a series of lines containing Abaqus options (keyword lines) and data (data lines). The input syntax for keyword and data lines is described in "Input syntax rules," Section 1.2.1.

Most input files have the same basic structure. The following portions of the input file are specified to define a finite element model:

1. An input file often begins with the *HEADING option, which is used to define a title for the analysis. Any number of data lines can be used to give the title; they will appear at the beginning of the output files ("Output," Section 4.1.1). The first heading line will appear as a heading at the top of each page of the output.

   While including a title can be helpful for users examining your input file, the *HEADING option is not required.
2. After the heading the input file usually contains a *model* data section to define nodes, elements, materials, initial conditions, etc. The model data section is explained below.
3. If the model is organized into an assembly of part instances, the model data are further categorized and must fall within the proper level: part, assembly, instance, or model. Models defined in terms of an assembly of part instances are discussed in "Defining an assembly," Section 2.10.1.
4. Finally, the input file contains *history* data to define the analysis type, loading, output requests, etc. Step definitions divide the model data from the history data in an input file: everything appearing before the first step definition is model data, and everything appearing within and following the first step definition is history data. The history data section is explained below.

The input file is processed by the "analysis input file processor" prior to executing the appropriate analysis product, Abaqus/Standard, Abaqus/Explicit, or Abaqus/CFD. The functions of the analysis input file processor are to interpret the Abaqus options, to perform the necessary consistency checking, and to prepare the data for the analysis products.

Most computational mechanics modeling options (element types, loading types, etc.) are available in both Abaqus/Standard and Abaqus/Explicit, although some options are available in only one analysis product or the other. All of the step procedure types used in an input file must be from the same analysis product; however, it is possible to import a solution from Abaqus/Standard into Abaqus/Explicit and vice versa (see "Importing and transferring results," Section 9.2), which allows each analysis product to be used at the various stages of an analysis for which it is best suited (for example, a static preloading in Abaqus/Standard followed by a dynamic analysis in Abaqus/Explicit).

Model data

Model data define the nodes, elements, materials, initial conditions, etc.

Required model data

The following model data must be included in an input file to define a finite element model:

- **Geometry:** The geometry of a model is described by elements and their nodes. The rules and methods for defining nodes and elements are described in "Node definition," Section 2.1.1; "Element definition," Section 2.2.1; and "Defining an assembly," Section 2.10.1. Cross-sections for structural elements (such as beams) must be defined. Special features can be defined with special elements such as springs, dashpots, point masses, etc. The element types available for modeling are described in Part VI, "Elements," along with explanations of how to define the elements. You can view the initial mesh or the configuration after adjustment for initial overclosure in the Visualization module of Abaqus/CAE after a data check run (see "Abaqus/Standard, Abaqus/Explicit, and Abaqus/CFD execution," Section 3.2.2).
- **Material definitions:** A material type must be associated with most portions of the geometry. The material library is described in Part V, "Materials." Special elements such as springs or dashpots do not have an associated material, but their properties must be defined.

Optional model data

The following model data can be included as necessary:

- **Parts and an assembly:** The geometry of a model can be defined by organizing it into parts, which are positioned relative to one another in an assembly ("Defining an assembly," Section 2.10.1).
- **Initial conditions:** Nonzero initial conditions such as initial stresses, temperatures, or velocities can be specified ("Initial conditions," Section 34.2).
- **Boundary conditions:** Zero-valued boundary conditions (including symmetry conditions) can be imposed on individual solution variables such as displacements or rotations ("Boundary conditions in Abaqus/Standard and Abaqus/Explicit," Section 34.3.1).

- **Kinematic constraints:** Equations involving several of the fundamental solution variables in the model ("Linear constraint equations," Section 35.2.1) or multi-point constraints ("General multi-point constraints," Section 35.2.2) can be defined.
- **Interactions:** Contact and other interactions between parts can be defined ("Contact interaction analysis: overview," Section 36.1.1).
- **Amplitude definitions:** Amplitude curves can be defined for later use in specifying time-dependent loading or boundary conditions ("Amplitude curves," Section 34.1.2).
- **Output control:** You can control model definition output to the data file ("Output," Section 4.1.1).
- **Environment properties:** Environment properties, such as the attributes of a fluid surrounding the model, may have to be defined.
- **Analysis continuation:** It is possible to write restart data or to use the results from a previous analysis and continue the analysis with new model or history data ("Restarting an analysis," Section 9.1.1), with a new mesh ("Submodeling: overview," Section 10.2.1; "Mesh-to-mesh solution mapping," Section 12.4.1; and "Symmetric model generation," Section 10.4.1), or with the same or a different Abaqus program ("Transferring results between Abaqus analyses: overview," Section 9.2.1).

History data

The purpose of an analysis is to predict the response of a model to some form of external loading or to some nonequilibrium initial conditions. An Abaqus analysis is based on the concept of *steps*, which are described in the history data portion of the input file. (For more information on steps, see "Defining an analysis," Section 6.1.2.) The history input data are combined within a step as needed to define the history of the analysis.

Multiple steps can be defined in an analysis. Steps can be introduced simply to change the output requests or to change the loads, boundary conditions, analysis procedure, etc. There is no limit on the number of steps in an analysis.

There are two kinds of steps in Abaqus: general response analysis steps, which can be linear or nonlinear; and, in Abaqus/Standard, linear perturbation steps (see "General and linear perturbation procedures," Section 6.1.3). A general analysis step contributes to the response history of the system; a linear perturbation step allows the investigation of the linearized response of the system at any stage during the response history.

The state at the end of a general step provides the initial conditions for the next step, making it easy to simulate consecutive loadings of a model, such as a dynamic response following a static preload or the loading of a product during its usage following a simulation of the manufacturing process.

The optional history data described below prescribing the loading; boundary conditions; output controls; auxiliary controls; and, in Abaqus/Explicit, contact conditions are continued from one general analysis step to the next general analysis step unless modified. For example, the solution controls prescribed in a general analysis step in Abaqus/Standard (see "Convergence and time integration criteria: overview," Section 7.2.1) will remain in effect for all subsequent general analysis steps until they are modified or reset. For linear perturbation steps only the output controls are continued from one linear perturbation step to the next if there are no intermediate general analysis steps and the

output controls are not redefined (see "Output," Section 4.1.1). Similarly, conditions specified in an Abaqus/CFD analysis are continued from one step to the next unless modified.

Input File Usage: Use the following option to begin a step definition:

*STEP

Use the following option to end a step definition:

*END STEP

Required history data

The following history data must be included in an input file to define an analysis procedure:

- **Response type:** An option to define the analysis procedure type must appear immediately after the beginning of the step definition.

  Abaqus can perform many types of analyses—linear or nonlinear, static or dynamic, etc. (see "Defining an analysis," Section 6.1.2). The type of analysis can be changed from step to step. For example, in Abaqus/Standard a static preload can be analyzed first, then the response type can be changed to transient dynamic. In this way a linear or nonlinear dynamic analysis can be performed based on the conditions at the end of the static solution.

Optional history data

The following history data can be included as necessary:

- **Loading:** Usually some form of external loading is defined. For example, concentrated or distributed loads can be applied ("Applying loads: overview," Section 34.4.1), temperature changes leading to thermal expansion can be prescribed ("Thermal expansion," Section 26.1.2), or contact conditions can be used to apply loads ("Contact interaction analysis: overview," Section 36.1.1).

  The loading can be prescribed as a function of time ("Amplitude curves," Section 34.1.2). This feature can be used to prescribe loadings such as the ground motion during a seismic event, known accelerations, or the temperature and pressure history during a transient in an engine. If an amplitude curve is not defined, Abaqus assumes either that the loading varies linearly over the step or that the load is applied instantaneously at the beginning of the step, depending on the chosen response type (see "Defining an analysis," Section 6.1.2).
- **Boundary conditions:** Boundary conditions can be added, modified, or removed during an analysis ("Boundary conditions," Section 34.3).
- **Output control:** Quantities such as stress, strain, reaction force, temperature, and energy are available as output. The output options are described in "Output to the data and results files," Section 4.1.2, and "Output to the output database," Section 4.1.3; and all of the output variables are listed in "Output variables," Section 4.2. The available output files are described in "Output," Section 4.1.1.
- **Contact:** Contact surfaces and contact interactions can be added, modified, or removed as step-dependent history data during an Abaqus/Explicit analysis (see "Contact interaction analysis: overview," Section 36.1.1).

- **Auxiliary controls:** You can overwrite the solution controls that are built into Abaqus. In some procedures these values are given in the procedure definition. More generally in Abaqus/Standard they are given by defining solution controls ("Commonly used control parameters," Section 7.2.2). Solution controls for contact problems ("Adjusting contact controls in Abaqus/Standard," Section 36.3.6; "Common difficulties associated with contact modeling using contact pairs in Abaqus/Explicit," Section 39.2.2; or "Contact controls for general contact in Abaqus/Explicit," Section 36.4.5) can also be defined.
- **Element and surface removal/reactivation:** In Abaqus/Standard portions of the model can be removed or reactivated from step to step. See "Element and contact pair removal and reactivation," Section 11.2.1.
- **Co-simulation:** The steps in the Abaqus model must be defined such that the co-simulation fits entirely within a single Abaqus step. Further, there can be only one co-simulation in the Abaqus job.

Including model or history data from an external file

You can specify an external file that contains a portion of the Abaqus input file. This file can include model and history definition data, comment lines, and other references to external files. When a reference to an external file is encountered, Abaqus will immediately process the data within the specified file. When the end-of-file is reached, Abaqus will return to processing the original file.

A maximum of five levels of nested external file references can be used. UNIX environment variables can be used to specify the file names.

Input File Usage: *INCLUDE, INPUT=*file_name*

Including an encrypted data file

You can include an encrypted file by reference in an Abaqus input file or in another data file. When you refer to the encrypted file, you must also provide the file's password. If the password is correct, Abaqus processes the data within the specified file as it would for an unencrypted external file. Material and connector behavior definitions within an encrypted input file are not written to the output database. In addition, all material and connector behavior definitions output to the data file are suppressed if an encrypted file is used as input for any portion of the model. See "Encrypting and decrypting Abaqus input data," Section 3.2.35, for details about the encryption utility.

Some encrypted files are eligible for inclusion only by users with a license for a particular Abaqus feature (such as Abaqus/Explicit) or to users at a particular site. If you attempt to include an encrypted file for which you do not have the proper privileges, Abaqus issues an error message.

You cannot include encrypted input files that contain parametric input.

Input File Usage: *INCLUDE, INPUT=*file_name*, PASSWORD=*password*

1.4 Parametric modeling

1.4.1 PARAMETRIC INPUT

Products: Abaqus/Standard Abaqus/Explicit

References

- "Scripting parametric studies," Section 20.1.1
- "Parametric shape variation," Section 2.1.2
- *PARAMETER
- *PARAMETER DEPENDENCE
- *PARAMETER SHAPE VARIATION
- Chapter 4, "Introduction to Python," of the Abaqus Scripting User's Guide

Overview

The parametric input capability allows you to create an Abaqus input file in which:

- Any number of input parameters is defined by assigning a value to each one of them.
- The parameters defined in the input file are used in place of input quantities.
- The parameters are evaluated according to their definition and are substituted for the parametrized input quantities before an analysis is run.

Parametric input allows greater flexibility in building and manipulating models. The different kinds of parameters and the different ways of parametrizing the Abaqus input quantities are discussed in this section.

Introduction

You must define all the parameters you wish to use in an analysis by assigning a value to them. The Python language (Lutz, 1999) is used to perform parameter evaluation and substitution; hence, parameter definitions are required to follow the Python syntax rules discussed later in this section. These parameters can then be used in place of input quantities.

Input File Usage: Use the following option to define parameters:

*PARAMETER

Use these parameters in place of input quantities by delimiting them with < >.

For example, the following input defines the two parameters **width** and **height**, which are then used to define beam section properties:

```
*PARAMETER
width = 2.5
height = width*2
*BEAM SECTION, SECTION=RECT, ELSET=name,
```

MATERIAL=*name*
<width>, <height>

In this simple example models with beams of different cross-sections can be obtained simply by changing the values of the parameters.

Parameters

Parameters are user-named variables to which you assign values. When a parameter is used instead of a value, the value of that parameter is substituted. There are two basic types of parameters: independent parameters and dependent parameters.

Independent parameters

Independent parameters are those that do not depend on any other parameters. The following are examples of independent parameters:

```
thickness = 10.0
area = 5.0**2
length = 3.0*sin(45*pi/180.0) # convert degrees to radians
```

Python expressions using numbers and numerical operations (such as addition, multiplication, and exponentiation) can be used to define independent parameters. Arithmetic support in Python is discussed later in this section.

Dependent parameters

Dependent parameters are those that depend on other parameters (dependent or independent). Dependent parameters can be defined in one of two ways: using a mathematical expression or using a tabular dependence.

Expressional dependence

Python parametric expressions involving operations between numbers and parameters are used to define expressionally dependent parameters. In the following example **area** and **mom_inertia** are dependent parameters:

```
width = 2.0
height = 5.0
area = width*height
mom_inertia = area*height**2/12.0
```

Tabular dependence

Tabular dependence between parameters is defined by specifying the dependent and independent parameters as well as a dependence table. The table that defines the dependence between the parameters must have as many values per line as the number of dependent parameters plus the number of independent parameters for which it is going to be used. The table must contain only real values;

dependent parameter values are given first, followed by independent parameter values. Parameter names and character strings cannot be used in a table.

The evaluation of tabularly dependent parameters by interpolation between values in a table will result in these parameters being assigned real values. If it is necessary that the tabularly dependent parameters be integer numbers, the real numbers must be converted to integer numbers as described later in the Python language section.

When the tabularly dependent parameters are functions of only one independent parameter, the tabular data must be given in order of increasing values of the independent parameter. Abaqus then interpolates linearly for values between those given. The dependent parameters are assumed to be constant outside the range of the independent parameters used in a table. When the tabularly dependent parameters depend on several independent parameters, the variation of the dependent parameters with respect to the first independent parameter must be given at fixed values of the other independent parameters, in ascending values of the second independent parameter, then of the third independent parameter, and so on. The table lines must always be ordered so that the independent parameters are given increasing values. This process ensures that the value of each dependent parameter is completely and uniquely defined for all values of the independent parameters.

The fact that the definition of the dependence table is separate from the assignment of the dependence to particular parameters means that the same table can be used for multiple sets of dependent/independent parameters. This is useful when there are different instances of the same kind of input data; for example, multiple material definitions that use the same dependence but different sets of parameters.

Because the evaluation of parameters is procedural (see “Parameter evaluation” below), a parameter dependence table must always be defined before it is used to specify tabular parameter dependencies.

Independent parameters in tabular dependence definitions are treated as independent for the purpose of defining this dependency; however, these “independent” parameters can be defined to depend on other parameters in a preceding parameter definition.

Input File Usage: Use the following option to define a parameter dependence table:

∗PARAMETER DEPENDENCE, TABLE=*name*, NUMBER VALUES=*n*
table with n values per line

Use the following option to define the dependent and independent parameters that are used in the dependence table:

∗PARAMETER, TABLE=*name*, DEPENDENT=*(parList)*, INDEPENDENT=*(parList)*

Rules for parameters

Some general rules apply to all parameters used in Abaqus input files. These rules are described in the following subsections.

Parameter evaluation

Parameters are evaluated by ordered execution of the parameter definitions as they appear in the input file. For example, the input

```
*PARAMETER
x = 2
y = x + 3
x = 4
```

gives **x**=4 and **y**=5, not **x**=4 and **y**=7. The input

```
*PARAMETER
y = x + 3
x = 4
```

is flagged as an error because **y** cannot be evaluated by ordered execution of the input. In other words, there is no deferred execution of the parameter definitions.

It is possible to define parameters anywhere in the input file, even after parameters have been used in place of input quantities, since the parameter definitions are always processed before any other input options are processed.

Parameters can also be defined and used in place of input quantities in an input file used for a restart analysis. However, parameters defined in the input file for the original analysis (from which the restart run is continued) are not available in the restart analysis.

Parameter substitution

When the parameterized data are processed, Abaqus assigns the parameter values as determined at the end of parameter evaluation. An error is reported if a parameter used in place of input quantities has not been assigned a value. Later, the analysis input file processor performs its usual checks on the validity of the parameter values with respect to the options in which they are being used.

Data given to define a parameter, a parameter dependence table, or a parameter shape variation cannot be parameterized. For example, the input

```
*PARAMETER SHAPE VARIATION
<x>
```

is not valid; however, the analysis input file processor will not report an error for this input.

Data types

The data type of a parameter is deduced from its definition. An integer parameter results from assigning an integer literal value to the parameter. Similarly, a real parameter arises from assigning a real literal value to the parameter. Integers are promoted to reals if they are used in operations containing reals. A character string parameter results from assigning a character string literal value to the parameter.

The input option context in which the parameter is used dictates the data type that the parameter must have. Parameters of real data type should be used in place of real Abaqus input quantities. Parameters of integer (or character string) type should be used in place of integer (or character string) type input quantities, respectively. In some instances, mismatches between the input context and the type of the substituted parameter will cause the analysis input file processor to flag these instances as input errors. For example, the input

```
*PARAMETER
int_pts = 5.0
*SHELL SECTION
10.0, <int_pts>
```

will cause the analysis input file processor to report an error because the number of integration points specified for a shell section must be an integer. However, the input

```
*PARAMETER
thick = 5/4
*SHELL SECTION
<thick>,
```

will be accepted by the analysis input file processor without a warning being flagged; as a result of doing integer division, this input gives a shell thickness of 1 (not 1.25). In conclusion, you can rely on the analysis input file processor to catch only some data type errors.

Continuous and discrete parameters

From the point of view of design activities (sensitivity analysis, parametric studies, etc.) parameters can be continuous valued or discrete valued. A continuous-valued parameter is differentiable and can, thus, be used for design sensitivity analysis purposes. A discrete-valued parameter is not differentiable and can, thus, not be used for design sensitivity analysis purposes; however, it can be used for parametric studies. Examples of continuous-valued parameters may be a shell thickness or a material property. Examples of discrete-valued parameters may be the number of integration points through the thickness of a shell, or an element type. Continuous-valued parameters generally coincide with physical (design) input quantities, while discrete-valued parameters generally coincide with finite element (numerical approximation) input quantities.

Auxiliary input files

Parameters can be defined in *INCLUDE input files but not in any other auxiliary input files. Names of auxiliary input files can be parameterized, except those used in the *INCLUDE option.

Parametrization of input quantities

Abaqus treats parametrization of "size" and "shape" quantities somewhat differently. Parametrization of shape input quantities is discussed in a separate section (see "Parametric shape variation," Section 2.1.2).

Size input quantities are understood to include all Abaqus input quantities except those that relate to shape. Size input quantities include section properties, material properties, orientation properties, prescribed conditions, interaction definitions and properties, and analysis procedure data.

Parametrizing individual input quantities

The following example shows the parametrization of shell section input using three independent parameters of differing data types:

```
*ELSET, ELSET=<shell_set>, GEN
1, 111, 10
*PARAMETER
shell_set = 'lining'
shell_thick = 1.E2
num_int_pts = 5
*SHELL SECTION, ELSET=<shell_set>, MATERIAL=name
<shell_thick>, <num_int_pts>
```

Parametrizing groups of input quantities (expressional dependence)

The following example shows the parametrization of a three-layer composite shell section using expressional-dependent parameters. In this example the **thickness** parameter can be used to change the thickness of the layers of the composite section uniformly.

```
*PARAMETER
thickness = 10.
layer1_thick = 0.15*thickness
layer2_thick = 0.6*thickness
layer3_thick = 0.25*thickness
*SHELL SECTION, ELSET=, COMPOSITE
<layer1_thick>,num int pts, material name, orientation
<layer2_thick>,num int pts, material name, orientation
<layer3_thick>,num int pts, material name, orientation
```

This parametrization requires that dependent parameters be created for the three input quantities (**layer1_thick**, **layer2_thick**, **layer3_thick**) that each depend on the independent parameter (**thickness**).

Parametrizing groups of input quantities (tabular dependence)

The following example shows the parametrization of the section properties of a box beam. The height and wall thicknesses of the beam section are parameters that depend tabularly on the section width.

```
*PARAMETER
a = 60.
*PARAMETER DEPENDENCE, TABLE=sectprop, NUMBER VALUES=6
25.0, 1.04,  1.04, 1.04, 1.04, 50.0
50.0, 4.17,  3.13, 2.08, 2.50, 100.0
75.0, 9.38,  6.24, 3.13, 4.90, 150.0
*PARAMETER, TABLE=sectprop, DEPENDENT=(b, t1, t2, t3, t4),
INDEPENDENT=(a)
*BEAM SECTION, SECTION=BOX, ELSET=beams, MATERIAL=steel
<a>, <b>, <t1>, <t2>, <t3>, <t4>
```

The above parametrization creates dependent parameters (**b**, **t1**, **t2**, **t3**, **t4**) that each depend on the independent parameter (**a**). Usage of tabular dependence allows the definition of the dependencies of input quantities on parameters to be confined to the parameter definitions; i.e., separate from the options where parametrization of input quantities is done. An advantage of this method of parametrization is that the same parameter dependence table can be used for different parameters in different input options. For example, you may wish to use beams of different cross-section dimensions in different parts of the structure being modeled. The parameter dependence table can be reused with new dependent (**bb**, **tt1**, **tt2**, **tt3**, **tt4**) and independent (**aa**) parameters.

```
*PARAMETER
aa = 65.
*PARAMETER, TABLE=sectprop, DEPENDENT=(bb, tt1, tt2, tt3, tt4),
INDEPENDENT=(aa)
*BEAM SECTION, SECTION=BOX, ELSET=columns, MATERIAL=steel
<aa>, <bb>, <tt1>, <tt2>, <tt3>, <tt4>
```

In options where predefined field variable dependence is supported, this method of parametrization provides a clear separation between predefined field variable dependence and parameter dependence; therefore, field variable and parameter dependence can never be confused. Consider, for example, the case of perfect plasticity properties for a metal where the yield stress depends on a field variable and is also parametrized to depend tabularly on the carbon content of the metal alloy.

```
*PARAMETER
carbon = 0.01
*PARAMETER DEPENDENCE, TABLE=yield_data, NUMBER=4
ys_fv1 val 1, ys_fv2 val 1, ys_fv3 val 1, carbon val 1
ys_fv1 val 2, ys_fv2 val 2, ys_fv3 val 2, carbon val 2
ys_fv1 val 3, ys_fv2 val 3, ys_fv3 val 3, carbon val 3
ys_fv1 val 4, ys_fv2 val 4, ys_fv3 val 4, carbon val 4
*PARAMETER, TABLE=yield_data, DEPENDENT=(ys_fv1, ys_fv2, ys_fv3),
INDEPENDENT=(carbon)
*MATERIAL, NAME=alloy
*PLASTIC, DEPENDENCIES=1
<ys_fv1>, , , fv val 1
<ys_fv2>, , , fv val 2
<ys_fv3>, , , fv val 3
```

Consider, for example, the case of metal creep properties where the creep material data are parameters that depend tabularly on the carbon content of the metal alloy. In addition, one of the creep parameters, **A**, also depends on a predefined field variable.

```
*PARAMETER
carbon = 0.01
*PARAMETER DEPENDENCE, TABLE=creepdata, NUMBER=6
A_fv1 val 1, A_fv2 val 1, A_fv3 val 1, n val 1, m val 1, carbon val 1
```

A_fv1 val 2, A_fv2 val 2, A_fv3 val 2, n val 2, m val 2, carbon val 2
A_fv1 val 3, A_fv2 val 3, A_fv3 val 3, n val 3, m val 3, carbon val 3
A_fv1 val 4, A_fv2 val 4, A_fv3 val 4, n val 4, m val 4, carbon val 4
***PARAMETER, TABLE=creepdata, DEPENDENT=(A_fv1, A_fv2, A_fv3, n, m), INDEPENDENT=(carbon)**
***MATERIAL, NAME=alloy**
***CREEP, DEPENDENCIES=1**
<A_fv1>, <n>, <m>, *, fv val 1*
<A_fv2>, <n>, <m>, *, fv val 2*
<A_fv3>, <n>, <m>, *, fv val 3*

This example shows that any combination of dependencies on predefined field variables and/or dependent parameters can be defined.

Python language

Parameter statements in parameter definitions are required to follow the syntax and semantics of the Python language (note that the parameter dependence table and parameter shape variation definitions follow the usual Abaqus input syntax rules). The subset of the Python language that is endorsed is documented here.

Statement length and continuation lines

Python statements in parameter definitions can be continued over multiple lines by terminating each line with a backslash character (\). The *PARAMETER keyword lines can be continued onto the following line using a trailing comma since they are treated like other Abaqus keyword lines.

Comments

Comments in a parameter definition start with the number character (#) and continue to the end of the line. However, comments in a parameter dependence table or parameter shape variation definition are indicated by the usual Abaqus input syntax convention (**).

Parameter names

Parameter names must begin with a letter and can contain the underscore character (_) and numbers. Parameter names are case sensitive.

Data types

Data types are limited to character strings, integers, and reals.

Strings are delimited with single or double quotation marks (' ' or " "). Backward single quotation marks (` `) are not permitted. Character strings should not contain the backslash character (\).

Integers are created by assignment to integer literals (for example, *aInt* = 2).

Reals are created by assignment to real literals (for example, *aReal* = 1.0). Real numbers can be given with or without an exponent. Any exponent must be preceded by **E** or **e**. The following line shows five acceptable ways of entering the same real number:

```
-12.345, -1234.5E-2, -0.12345E+2, -0.12345E2, -0.12345e2
```

The syntax

```
-0.12345D+2
```

(allowed elsewhere in the Abaqus input file) is not valid in Python.

Type conversion

If integers and reals are mixed in expressions, integers are promoted automatically to reals. Explicit type conversion can be obtained using:

int(*aReal*)	*aReal* converted to integer type
float(*anInt*)	*anInt* converted to real type (float is the same as real)
str(*anIntOrReal*)	*anIntOrReal* converted to character string type
'*anIntOrReal*'	*anIntOrReal* converted to character string type

Numeric operators

Standard support for operators is provided:

− x	x negated
+ x	x unchanged
x + y	sum of x and y
x − y	difference of x and y
x * y	product of x and y
x / y	quotient of x and y
x**y	x to the power y

Functions

The following utility functions are supported:

abs(x)	absolute value of x
acos(x)	arc cosine of x (result is in radians)
asin(x)	arc sine of x (result is in radians)
atan(x)	arc tangent of x (result is in radians)
cos(x)	cosine of x (x is in radians)
log(x)	natural logarithm of x
log10(x)	base 10 logarithm of x
pow(x,y)	x to the power y (equivalent to x**y)

sin(x)	sine of x (x is in radians)
sqrt(x)	square root of x
tan(x)	tangent of x (x is in radians)

Character string operators

'abc' + 'def'	concatenation of character string 'abc' and character string 'def'

Execution of parametrized input

Jobs with parametrized input files are submitted to Abaqus in the usual way; for example,

abaqus job=*job-name* **input=***input-file*

where it is assumed that an input file named *input-file*`.inp` exists.

Abaqus searches *input-file*`.inp` and any *INCLUDE input files for parameter, parameter dependence table, and parameter shape variation ("Parametric shape variation," Section 2.1.2) definitions, as well as parameter names inside < > that may have been used in place of input quantities. If any of the above are found, Abaqus will interpret the parametrized input file and perform the tasks of parameter evaluation and substitution.

As a result, a modified input file that is free of parameter and parameter dependence table definitions and <*parameter*> instances is produced. This file is named *job-name*`.pes` and is subsequently submitted for execution of an analysis. The execution procedure of a parametrized input file, except for the additional processing of parameter shape variation definitions in the analysis input file processor, does not differ from that of a non-parametrized input file. All the files generated by the parametrized input job will be named *job-name* with the appropriate extension appended to it.

Parameter check jobs

You can specify an execution mode in which only parameter processing (evaluation and substitution) is carried out. The parameter check execution mode is mutually exclusive of other execution modes, such as complete analysis, data check, continuation of a data check, conversion of results, or recovery (see "Abaqus/Standard, Abaqus/Explicit, and Abaqus/CFD execution," Section 3.2.2).

A parameter check run is useful in situations where you have defined complex parametrization in the input. In these cases you may want to study the results of parameter evaluation and substitution before proceeding further.

A parameter check run does not permit continuation of the execution in a subsequent run; the job must be rerun from the beginning.

Input File Usage: Enter the following input on the command line:

abaqus job=*job-name* **input**=*input-file* **parametercheck**

Display of parametric input

Display of the results of parameter evaluation and substitution in the data file is described in this section. Visualization of parameter shape variations is described in "Parametric shape variation," Section 2.1.2.

Data file display

The data (**.dat**) file contains information about the model definition generated by the analysis input file processor. You can control the amount of output generated by the analysis input file processor; see "Controlling the amount of analysis input file processor information written to the data file" in "Output," Section 4.1.1, for details. In particular, you can specify whether or not the original input (**.inp**) file is echoed to the data file (by default, it is not).

In the case of parametric input this file will generally contain a number of parameter, parameter dependence table, and parameter shape variation definitions, as well as a number of <*parameter*> instances. To verify the definition of parametric input, you can create a modified version of the original input file showing the parameters and their values (this file is named *job-name*.**par**). You can also create the *job-name*.**pes** file, which is the modified version of the original input file that is free of parameter and parameter dependence table definitions, as well as <*parameter*> instances.

Input File Usage: Use the following option to print the contents of the *job-name*.**par** file to the data file:

∗PREPRINT, PARVALUES=YES

Use the following option to print the contents of the *job-name*.**pes** file to the data file:

∗PREPRINT, PARSUBSTITUTION=YES

Additional reference

- Lutz, M., and D. Ascher, *Learning Python,* O'Reilly & Associates, Inc., 1999.

2. Spatial Modeling

2.1 Node definition

2.1.1 NODE DEFINITION

Products: Abaqus/Standard Abaqus/Explicit

References

- *NCOPY
- *NFILL
- *NGEN
- *NMAP
- *NODE
- *NSET
- *SYSTEM

Overview

This section describes the methods for defining nodes in an Abaqus input file. In a preprocessor such as Abaqus/CAE, you define the model geometry rather than the nodes and elements; when you mesh the geometry, the preprocessor automatically creates the nodes and elements needed for analysis. Although the concepts discussed in this section apply in general to the node definitions in the input file that is created by Abaqus/CAE, the methods and techniques described here apply only if you are creating the input file manually.

Node definition consists of:

- assigning a node number to the node;
- optionally specifying a local coordinate system in which to define nodes;
- defining individual nodes by specifying their coordinates;
- grouping nodes into node sets;
- creating nodes from existing nodes by generating them incrementally, by copying existing nodes, or by filling in nodes between the bounds of a region; and
- mapping a set of nodes from one coordinate system to another.

If any node is specified more than once, the last specification given is used.

Abaqus will eliminate all unnecessary nodes before proceeding with the analysis. This feature is useful because it allows points to be defined as nodes for mesh generation purposes only.

Assigning a node number to the node

Each individual node must have a numeric label called the node number, which is assigned when the node is defined. The node number must be a positive integer, and the maximum node number allowed is 999999999 (for information on integer input, see “Input syntax rules,” Section 1.2.1). The nodes do not need to be numbered continuously.

An Abaqus model can be defined in terms of an assembly of part instances (see "Defining an assembly," Section 2.10.1). In such a model all nodes must belong to either a part, part instance, or, in the case of reference nodes, to the assembly. Node numbers must be unique within a part, part instance, or the assembly; but they can be repeated in different parts or part instances.

Specifying a local coordinate system in which to define nodes

Sometimes it is convenient to define nodal coordinates in a local coordinate system and then transform these coordinates to the global coordinate system. You can define a nodal coordinate system; Abaqus will translate and rotate the local (X^1, Y^1, Z^1) coordinate values into the global coordinate system. The transformation is done immediately after input and will be applied to all nodal coordinates entered or generated after the nodal coordinate system is defined.

The transformation affects only the input of nodal coordinates in node definitions. Nodal coordinate system definitions cannot be used

- for applying loads and boundary conditions—see "Transformed coordinate systems," Section 2.1.5, instead; or
- for output of components of stress, strain, and element section forces—see "Orientations," Section 2.2.5, instead.

In addition to defining nodal coordinate systems, you can define individual nodes or node sets in local rectangular, cylindrical, or spherical systems (see "Specifying a local coordinate system for the nodal coordinates"). If a nodal coordinate system is in effect and you specify a local coordinate system for a particular node or node set definition, the input coordinates are first transformed according to the local system specified in the node definition and then according to the nodal coordinate system.

Defining the nodal coordinate system

You set up the coordinate system specification by specifying the global coordinates of three points in the local system: the origin of the local system (point *a* in Figure 2.1.1–1), a point on the local X^1-axis (point *b* in Figure 2.1.1–1), and a point in the (X^1, Y^1) plane of the local system on (or near) the local Y^1-axis (point *c* in Figure 2.1.1–1).

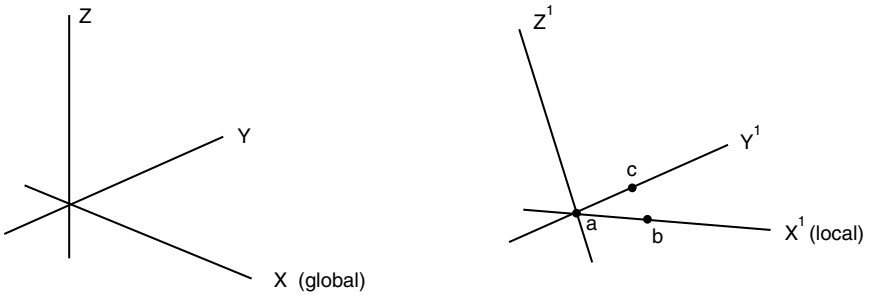


Figure 2.1.1–1 Nodal coordinate system.

If only one point (the origin) is given, Abaqus assumes that you need a translation only. If only two points are given, the direction of the Z^1-axis will be the same as that of the *Z*-axis; that is, the X^1-axis will be projected onto the (X, Y) plane.

To change the nodal coordinate system that is in effect, define another nodal coordinate system; to revert to input in the global coordinate system, use a nodal coordinate system definition without any associated data.

Input File Usage: Use the following option to define a nodal coordinate system:

*SYSTEM
$X_a, Y_a, Z_a, X_b, Y_b, Z_b$
$X_c,\ Y_c,\ Z_c$

For example, in the following input, nodes 1 through 3 are defined in the first nodal coordinate system, nodes 4 and 5 are defined in the second nodal coordinate system, and nodes 6 and 7 are defined in the global coordinate system:

```
*SYSTEM
0, 0, 0, 5, 5, 5
*NODE
1, 0, 0, 1
2, 0, 0, 2
3, 0, 1, 2
*SYSTEM
2, 3, 4
*NODE
4, 0, 0, 1
5, 1, 4, 0
*SYSTEM
*NODE
6, 1, 0, 1
7, 0, 4, 2
```

Defining a nodal coordinate system within part definitions

When you define a nodal coordinate system within a part (or part instance) definition, it is in effect only within that part (or part instance) definition. Nodes defined in other parts are not affected.

You specify the local (X^1, Y^1, Z^1) coordinate values relative to the part coordinate system, which subsequently may be translated and/or rotated according to the positioning data given for the instance (see "Defining an assembly," Section 2.10.1).

Defining individual nodes by specifying their coordinates

You can define individual nodes by specifying the node number and the coordinates that define the node. Abaqus uses a right-handed, rectangular Cartesian coordinate system for all nodes except for

axisymmetric models, when the coordinates of the nodes must be given as the radial and axial positions. For more information about direction definitions, see "Conventions," Section 1.2.2.

In a model defined in terms of an assembly of part instances, give nodal coordinates in the local coordinate system of the part (or part instance). See "Defining an assembly," Section 2.10.1.

Input File Usage: *NODE

Reading node definitions from a file

Node definitions can be read into Abaqus from an alternate file. The syntax of such file names is described in "Input syntax rules," Section 1.2.1.

Input File Usage: *NODE, INPUT=*file_name*

Specifying a local coordinate system for the nodal coordinates

You can specify that a local rectangular Cartesian, cylindrical, or spherical coordinate system be used for a particular node definition. These coordinate systems are shown in Figure 2.1.1–2.

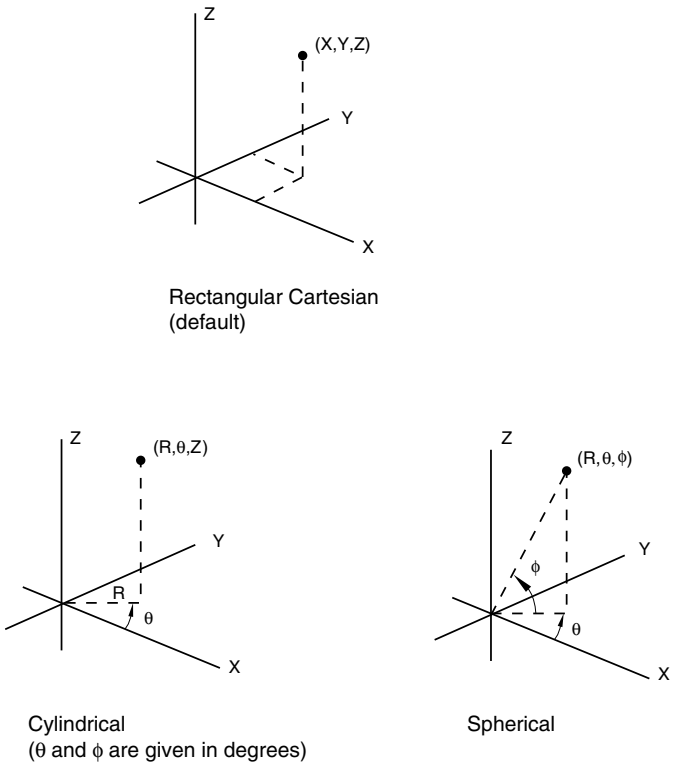


Figure 2.1.1–2 Coordinate systems.

This coordinate system specification is entirely local to the node definition. As the nodal data are read, the coordinates are transformed to rectangular Cartesian coordinates immediately. If a nodal coordinate system is also in effect (see "Specifying a local coordinate system in which to define nodes"), these are local rectangular Cartesian coordinates as defined by the nodal coordinate system, which are subsequently transformed to global Cartesian coordinates.

Input File Usage: Use the following option to specify the nodal coordinates in a rectangular Cartesian system (this is the default):

∗NODE, SYSTEM=R

Use the following option to specify the nodal coordinates in a cylindrical system:

∗NODE, SYSTEM=C

Use the following option to specify the nodal coordinates in a spherical system:

∗NODE, SYSTEM=S

For example, the following lines define node number 1 with coordinates (10cos20°, 10sin20°, 5.) in a local cylindrical system (R, θ, Z):

```
*NODE, NSET=DISC, SYSTEM=C
1, 10., 20., 5.
```

If the following lines appeared in the input file before the above node definition, the coordinates of node 1 would be transformed first to rectangular Cartesian coordinates in the nodal coordinate system defined by the ∗SYSTEM option and then to coordinates in the global system:

```
*SYSTEM
2, 0, 2
```

Grouping nodes into node sets

Node sets are used as convenient cross-references when defining loads, constraints, properties, etc. Node sets are the fundamental references of the model and should be used to assist the input definition. The members of a node set can be individual nodes or other node sets. An individual node can belong to several node sets.

Nodes can be grouped into node sets when they are created or after they have already been defined. In either case each node set is assigned a name. Node set names can be up to 80 characters long.

The same name can be used for a node set and for an element set.

By default, the nodes within a node set will be arranged in ascending order, and duplicate nodes will be removed. Such a set is called a sorted node set. You may choose to create an unsorted node set as described later, which is often useful for features that match two or more node sets. For example, if you define multi-point constraints ("General multi-point constraints," Section 35.2.2) between two node sets, a constraint will be created between the first node in Set 1 and the first node in Set 2, then between the second node in Set 1 and the second node in Set 2, etc. It is important to ensure that the nodes are

combined in the desired way. Therefore, it is sometimes better to specify that a node set be stored in unsorted order.

Once nodes are assigned to a node set, additional nodes can be added to the same node set; however, nodes cannot be removed from a node set.

Creating an unsorted node set

You can choose to assign nodes to a new node set (or to add nodes to an existing node set) in the order in which they are given. The node numbers will not be rearranged, and duplicates will not be removed.

This unsorted node set will affect node copies, node fills, linear constraint equations, multi-point constraints, and substructure nodes associated with retained degrees of freedom. An unsorted node set can be created only by directly defining an unsorted node set as described here or by copying an unsorted node set. Any additions or modifications to a node set using other means will result in a sorted node set.

Input File Usage: *NSET, NSET=*name*, UNSORTED

Assigning nodes to a node set as they are created

There are several ways that nodes can be assigned to node sets as they are created.

Input File Usage: Use any of the following options:

*NODE, NSET=*name*
*NCOPY, NEW SET=*name*
*NFILL, NSET=*name*
*NGEN, NSET=*name*
*NMAP, NSET=*name*

Assigning previously defined nodes to a node set

You can assign nodes that you have defined previously (by specifying their coordinates, by filling in nodes between two bounds, or by generating them incrementally) to a node set by listing the nodes forming the set directly, by generating the node set, or by generating a node set from an element set.

Listing the nodes that define the set directly

You can list the nodes that form a node set directly. Previously defined node sets, as well as individual nodes, can be assigned to node sets.

Input File Usage: *NSET, NSET=*name*

For example, the following lines add nodes 1, 3, 10, 11, and all the nodes in set **A11** to set **A12**:

```
*NSET, NSET=A12
1, 3
10, 11,
A11
```

Node set **A11** can be assigned to node set **A12** only if the definition of **A11** occurs before the definition of **A12**.

All the nodes in node set **A12** will be sorted into ascending numerical order. If the UNSORTED parameter were included on the *NSET option, node set **A12** would contain the nodes in the order in which they are specified on the data lines.

Generating the node set

To generate a node set, you must specify a first node, n_1; a last node, n_2; and the increment in node numbers between these nodes, *i*. All nodes going from n_1 to n_2 in increments of *i* will be added to the set. Therefore, *i* must be an integer such that $(n_2 - n_1)/i$ is a whole number (not a fraction). The default is $i = 1$.

Input File Usage: *NSET, NSET=*name*, GENERATE

For example, the following lines add all nodes from 100 to 120 in increments of 10 to set **A13**:

```
*NSET, NSET=A13, GENERATE
100, 120, 10
```

Generating a node set from an element set

You can specify the name of a previously defined element set ("Element definition," Section 2.2.1), in which case the nodes that define the elements contained in this element set will be assigned to the specified node set. This method can be used only to define sorted node sets.

Input File Usage: *NSET, NSET=*name*, ELSET=*name*

For example, the following lines add all nodes that define elements 50 and 100 (nodes 1, 2, 3, and 4) to node set **A14**:

```
*ELEMENT, TYPE=B21
50, 1, 2
100, 3, 4
*ELSET, ELSET=B1
50, 100
*NSET, NSET=A14, ELSET=B1
```

Element set **B1** can be assigned to node set **A14** since the definition of **B1** occurs before the definition of **A14**.

Limitation on updating node sets that are used to define other node sets

If a node set is constructed from previously defined node sets, subsequent updates to these sets are not taken into account.

Input File Usage: *NSET, NSET=*name*

For example, the following lines add nodes 1 and 2, but not 3, to the set **SET-AB** while adding nodes 1 and 3 to set **SET-A**:

```
*NSET, NSET=SET-A
```

```
1,
*NSET, NSET=SET-B
2,
*NSET, NSET=SET-AB
SET-A, SET-B
*NSET, NSET=SET-A
3,
```

Defining part and assembly sets

In a model defined in terms of an assembly of part instances, all node sets must be defined within a part, part instance, or the assembly definition. If a node set is defined within a part (or part instance) definition, you can refer to the node numbers directly. To define an assembly-level node set, you must identify the nodes to be added to the set by prefixing each node number with the part instance name and a "." (as explained in "Defining an assembly," Section 2.10.1). An assembly-level node set can have the same name as a part-level node set.

Example

The following input defines a node set, **set1**, that belongs to part **PartA** and will be inherited by every instance of **PartA**:

```
*PART, NAME=PartA
   ...
   *NSET, NSET=set1
    1,3,26,500
*END PART
```

A node set with the same name is defined at the assembly level as follows:

```
*ASSEMBLY, NAME=Assembly-1
   *INSTANCE, NAME=PartA-1, PART=PartA
    ...
   *END INSTANCE
   *INSTANCE, NAME=PartA-2, PART=PartA
    ...
   *END INSTANCE
   *NSET, NSET=set1
    PartA-1.1, PartA-1.3, PartA-1.26, PartA-1.500
    PartA-2.1, PartA-2.3, PartA-2.26, PartA-2.500
*END ASSEMBLY
```

Assembly-level node set **set1** contains all the nodes from node sets **set1** belonging to part instances **PartA-1** and **PartA-2**. Therefore, the nodes are assigned to two separate node sets: one at the part instance level and one at the assembly level. An assembly-level node set called **set1** could be created with entirely different nodes than those that belong to the part set; part- and assembly-level node sets

are independent. However, since in this example the same nodes are assigned to both the part- and assembly-level node sets **set1**, the assembly-level set could alternatively be defined by

```
*ASSEMBLY, NAME=Assembly-1
   *INSTANCE, NAME=PartA-1, PART=PartA
    ...
   *END INSTANCE
   *INSTANCE, NAME=PartA-2, PART=PartA
    ...
   *END INSTANCE
   *NSET, NSET=set1
    PartA-1.set1, PartA-2.set1
*END ASSEMBLY
```

This node set definition is equivalent to the previous example, where the nodes are listed individually.

Alternate method for defining assembly-level node sets

Sometimes it is not convenient to define an assembly-level node set by referring to part-level node sets. In such cases a set definition containing many nodes can get quite lengthy. Therefore, an alternate method is provided.

Input File Usage: ∗NSET, NSET=*NsetName*, INSTANCE=*InstanceName*

The following example shows two equivalent ways to define an assembly-level node set; once by prefixing each node number with a part instance name (as shown above) and once using the more compact INSTANCE notation:

```
*ASSEMBLY, NAME=Assembly-1
   *INSTANCE, NAME=PartA-1, PART=PartA
    ...
   *END INSTANCE
   *INSTANCE, NAME=PartA-2, PART=PartA
    ...
   *END INSTANCE
   *NSET, NSET=set2
    PartA-1.11, PartA-1.12, PartA-1.13, PartA-1.14,
    PartA-2.21, PartA-2.22, PartA-2.23, PartA-2.24
   *NSET, NSET=set3, INSTANCE=PartA-1
    11, 12, 13, 14
   *NSET, NSET=set3, INSTANCE=PartA-2
    21, 22, 23, 24
*END ASSEMBLY
```

When the ∗NSET option is used more than once with the same name, as it is with **set3**, the nodes in the second use of ∗NSET are appended to the set created by the first use of ∗NSET.

Internal node sets created by Abaqus/CAE

In Abaqus/CAE many modeling operations are performed by picking geometry with the mouse. For example, a concentrated load can be applied by picking a point on a geometric part instance. Since the *CLOAD option refers to a node set, this "picked" geometry must be translated into a node set in the input file. Such sets are assigned a name by Abaqus/CAE and marked as internal. You can view these internal sets using display groups in the Visualization module of Abaqus/CAE (see Chapter 78, "Using display groups to display subsets of your model," of the Abaqus/CAE User's Guide).

Input File Usage: *NSET, NSET=*NsetName*, INTERNAL

Transferring of node sets

If the results of an Abaqus/Explicit analysis are imported into an Abaqus/Standard analysis (or vice versa) or results from an Abaqus/Standard analysis are imported into another Abaqus/Standard analysis (see "Transferring results between Abaqus analyses: overview," Section 9.2.1), all node set definitions in the original analysis are imported by default. Alternatively, you can import only selected node set definitions; see "Importing element set and node set definitions" in "Transferring results between Abaqus analyses: overview," Section 9.2.1, for details.

If a three-dimensional model is generated from a symmetric model (see "Symmetric model generation," Section 10.4.1), all node sets in the original model will be used (and expanded) in the generated model.

Creating nodes from existing nodes by generating them incrementally

You can generate nodes incrementally from existing nodes. All of the nodes along a straight or curved line can be generated by giving the coordinates of the two end nodes and defining the type of curve.

The two end nodes must already be defined, usually by specifying their coordinates, but it is also possible to have them defined by an earlier generation.

Defining a straight line between the two end nodes

To define a straight line between the two end nodes, specify the number of the first end node, n_1; the number of the last end node, n_2; and the increment in node numbers between each node along the line, i. Therefore, i must be an integer such that $(n_2 - n_1)/i$ is a whole number (not a fraction). The default is $i = 1$.

Input File Usage: *NGEN

For example, in the following input node number 1 with coordinates (0., 0., 0.) and node number 6 with coordinates (10., 0., 0.) are defined and nodes 2, 3, 4, and 5 with coordinates (2., 0., 0.), (4., 0., 0.), (6., 0., 0.), and (8., 0., 0.), respectively, are generated automatically:

```
*NODE
1, 0., 0., 0.
6, 10., 0., 0.
```

```
*NGEN
1, 6, 1
```

Defining a circular arc between the two end nodes

To define a circular arc between the two end nodes, specify the number of the first end node, n_1; the number of the last end node, n_2; and the increment in node numbers between each node along the arc, *i*. Therefore, *i* must be an integer such that $(n_2 - n_1)/i$ is a whole number (not a fraction). The default is $i = 1$.

In addition, you must specify the coordinates of one extra point, the center of the circle, either by giving the node number of a node that has already been defined or by giving the nodal coordinates directly. If both are supplied, the node number will take precedence over the coordinates.

If the coordinates are defined directly, they can be specified in a local coordinate system as described later.

The coordinates of the end nodes will be adjusted radially if the circle cannot be passed through both points. An arc of a circle of 180° through 360° will require more extensive definition. For this case you must define the plane of the circular disc by giving the normal to the disc; the nodes will then be numbered according to the right-hand rule about this normal.

Input File Usage: *NGEN, LINE=C

Defining a parabola between the two end nodes

To define a parabola between the two end nodes, specify the number of the first end node, n_1; the number of the last end node, n_2; and the increment in node numbers between each node along the parabola, *i*. Therefore, *i* must be an integer such that $(n_2 - n_1)/i$ is a whole number (not a fraction). The default is $i = 1$.

In addition, you must specify the coordinates of one extra point, the midpoint on the arc between the two end points, either by giving the node number of a node that has already been defined or by giving the nodal coordinates directly. If both are supplied, the node number will take precedence over the coordinates.

If the coordinates are defined directly, they can be specified in a local coordinate system as described later.

Input File Usage: *NGEN, LINE=P

Defining the extra point and the normal direction in a local coordinate system

You can specify the coordinates of the extra point that is required for a circle or a parabola in a local rectangular Cartesian system, a cylindrical system, or a spherical system. These coordinate systems are shown in Figure 2.1.1–2.

If a nodal coordinate system is in effect (see "Specifying a local coordinate system in which to define nodes"), the coordinates and normal direction specified in the node definition are assumed to be in the nodal coordinate system. If a nodal coordinate system is in effect and you specify the extra point for a circle or parabola in a local coordinate system, the input is first transformed according to the local system specified in the node definition and subsequently according to the nodal coordinate system.

Input File Usage: Use the following option to specify the extra point in a rectangular Cartesian system (this is the default):

∗NGEN, SYSTEM=RC

Use the following option to specify the extra point in a cylindrical system:

∗NGEN, SYSTEM=C

Use the following option to specify the extra point in a spherical system:

∗NGEN, SYSTEM=S

Creating nodes by copying existing nodes

You can create new nodes by copying existing nodes. The coordinates of the new nodes can be translated and rotated, reflected from the nodes being copied, or projected from the nodes being copied by using a polar projection with respect to a pole node.

You must identify the existing node set to copy and specify an integer constant, *n*, that will be added to the node numbers of existing nodes to define node numbers for the nodes being created.

You can assign the newly created nodes to a node set. If you do not specify a node set name for the newly created nodes, they are not assigned to a node set.

Input File Usage: ∗NCOPY, OLD SET=*name*, CHANGE NUMBER=*n*, NEW SET=*new_name*

Translating and rotating the coordinates of the old nodes

You can create new nodes by translating and/or rotating the nodes in the old node set (see Figure 2.1.1–3). You specify the value of the translation in the *X*-, *Y*-, and *Z*-directions.

In addition, you specify the coordinates of the first point defining the rotation axis (point *a* in Figure 2.1.1–3), the coordinates of the second point defining the rotation axis (point *b* in Figure 2.1.1–3), and the angle of rotation (in degrees) about the *a*–*b* axis. The rotation can be applied multiple times as described later.

If you specify both translation and rotation, the translation is applied once before the rotation.

Input File Usage: ∗NCOPY, OLD SET=*name*, CHANGE NUMBER=*n*, SHIFT

Applying the rotation multiple times

You can specify the number of times the rotation should be applied, *m*. For example, if nodes are to be created at angles of 30°, 60°, and 90°, set *m*=3. The identifiers of the nodes created are incremented sequentially by the value of *n*, as described above.

Input File Usage: ∗NCOPY, OLD SET=*name*, CHANGE NUMBER=*n*, SHIFT, MULTIPLE=*m*

Reflecting the coordinates of the old nodes

You can create new nodes by reflecting the coordinates of the old nodes through a line, a plane, or a point.

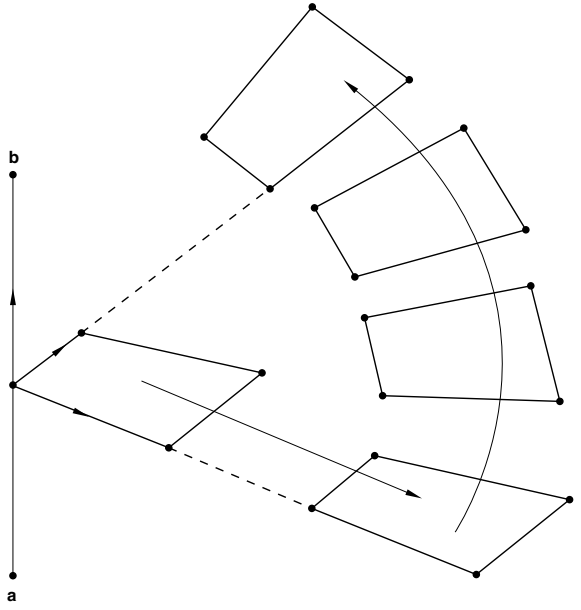


Figure 2.1.1–3 Translation and rotation of existing nodes.

Reflecting the coordinates through a line

To reflect the old nodal coordinates through a line, you specify the coordinates of points *a* and *b* (see Figure 2.1.1–4).

Input File Usage: *NCOPY, OLD SET=*name*, CHANGE NUMBER=*n*, REFLECT=LINE

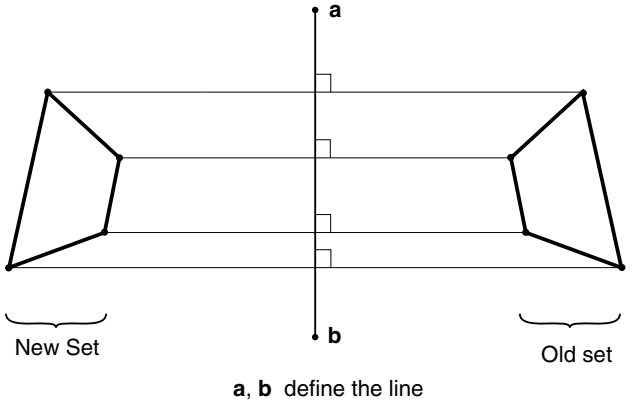


Figure 2.1.1–4 Reflection of coordinates through a line.

Reflecting the coordinates through a plane

To reflect the old nodal coordinates through a plane, you specify the coordinates of points *a*, *b*, and *c* (see Figure 2.1.1–5).

Input File Usage: ∗NCOPY, OLD SET=*name*, CHANGE NUMBER=*n*, REFLECT=MIRROR

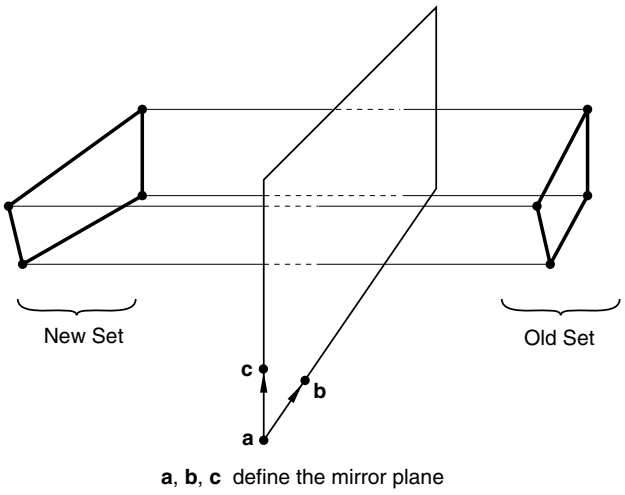


Figure 2.1.1–5 Reflection of coordinates through a plane.

Reflecting the coordinates through a point

To reflect the old nodal coordinates through a point, you specify the coordinates of point *a* (see Figure 2.1.1–6).

Input File Usage: ∗NCOPY, OLD SET=*name*, CHANGE NUMBER=*n*, REFLECT=POINT

Projecting the nodes in the old set from a pole node

You can create new nodes by projecting the nodes in the old set from a pole node. Each new node will be located such that the corresponding old node is equidistant between the pole node and the new node. The pole node (see Figure 2.1.1–7) is identified by giving its number or, alternatively, its coordinates.

This method is particularly useful for creating nodes that are associated with infinite elements ("Infinite elements," Section 28.3.1). In this case the pole node should be located at the center of the far-field solution.

Input File Usage: ∗NCOPY, OLD SET=*name*, CHANGE NUMBER=*n*, POLE

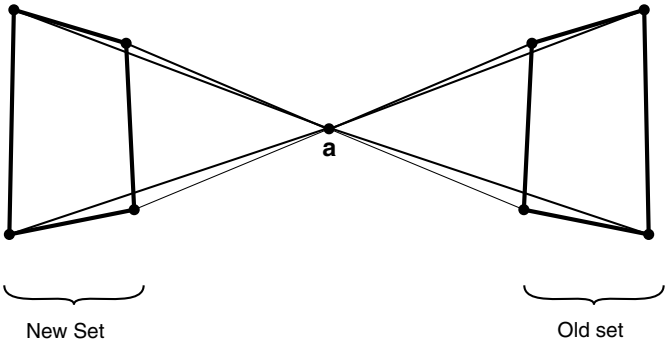


Figure 2.1.1–6 Reflection of coordinates through a point.

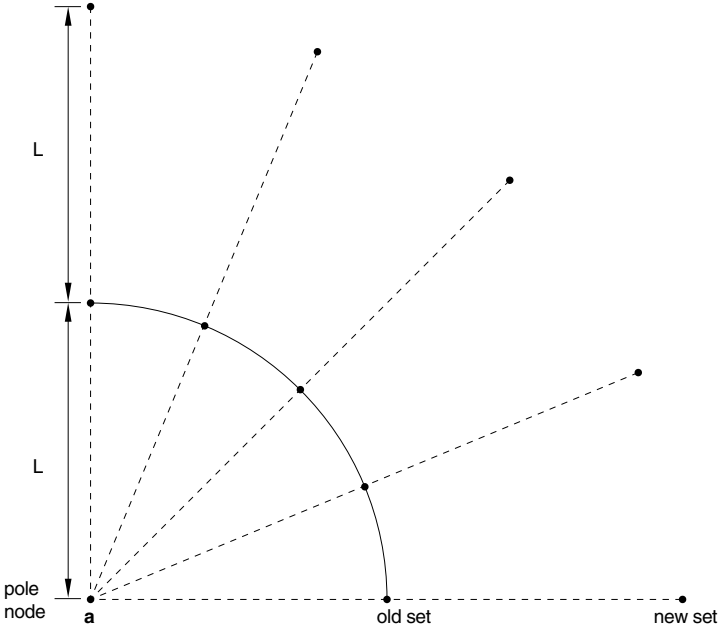


Figure 2.1.1–7 Projection of existing nodes from a pole node.

Creating nodes by filling in nodes between two bounds

You can create nodes by filling in nodes between two bounds. In this case you specify the two node sets whose members form the bounds, the number of intervals along each line between the bounding nodes, and the increment in node numbers from the node number at the first bound set end.

Let l equal the number of lines of nodes to be created between the two bounding node sets; the number of intervals along each line between the bounding nodes is then given by $l + 1$.

Let n equal the increment in node numbers from the node number at the first bound set end; for each node (n_{A_i}) in the first bounding node set, the corresponding node in the other bounding node set (n_{B_i}) must be numbered such that $(n_{B_i} - n_{A_i})/n$ is a whole number.

The node sets that define the bounds of the region are used as they exist at the time the node fill definition appears in the input file: only those nodes that have been added to the sets prior to the node fill definition are used. Both sorted and unsorted node sets can be used. Nodes that have not yet been given coordinates are assumed to be at the origin, (0.,0.,0.).

The nodes created by this method lie on straight lines between corresponding nodes in the two sets. If the sets do not have the same number of nodes, the extra nodes in the longer set are ignored. By default, the spacing between nodes along the lines is uniform.

Input File Usage: *NFILL

Example

For example, Figure 2.1.1–8 shows a simple quarter-cylinder model.

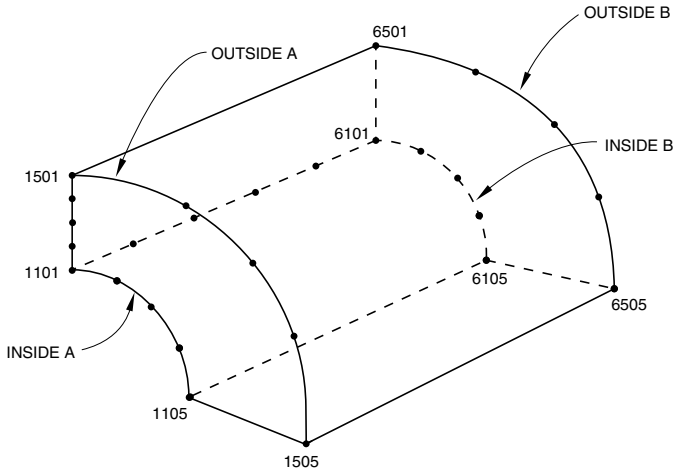


Figure 2.1.1–8 Filling a three-dimensional region.

The quarter circles **INSIDEA** (nodes 1101–1105), **OUTSIDEA** (nodes 1501–1505), **INSIDEB** (nodes 6101–6105), and **OUTSIDEB** (6501–6505) have already been defined by specifying their coordinates

directly or generating them incrementally. The region is filled by first filling the end planes and placing the nodes on those planes into sets **A** and **B** and then filling between those sets with the following options:

```
*NFILL, NSET=A
INSIDEA, OUTSIDEA, 4, 100

*NFILL, NSET=B
INSIDEB, OUTSIDEB, 4, 100
*NFILL
A, B, 5, 1000
```

Concentrating the nodes toward one bound or the other

You can concentrate the nodes toward one bound or the other by specifying b, the ratio of adjacent distances between nodes along each line of nodes generated as the nodes go from the first bounding node set to the second.

Thus, if b is less than one, the nodes are concentrated toward the first bounding node set; if b is greater than one, the nodes are concentrated toward the second bounding set. The value of b must be positive.

The bias intervals along the line from the first bounding node are L, L/b, L/b^2, L/b^3, L/b^4, L/b^5, … (where L is the length of the first interval). In Abaqus/Standard the bias value can be applied at every interval along the line or at every second interval along the line as described later.

Input File Usage: *NFILL, BIAS=b

Example

For example, suppose the lines of nodes shown in Figure 2.1.1–9 have already been generated by other methods and placed into node sets **INSIDE** and **OUTSIDE**. The following option will fill the region as shown in Figure 2.1.1–10:

```
*NFILL, BIAS=0.6
INSIDE, OUTSIDE, 5, 100
```

Applying the bias value at every second interval along the line

In Abaqus/Standard you can apply the bias value at every second interval along the line. In this case the nodes will be positioned along the line correctly for use with second-order elements, so that the midside nodes are at the middle of the interval between the corner nodes of the elements.

The bias intervals along the line from the first bounding node are L, L, L/b, L/b, L/b^2, L/b^2, … (where L is the length of the first interval).

Input File Usage: *NFILL, BIAS=b, TWO STEP

Creating quarter-point spacing

In Abaqus/Standard you can create quarter-point spacing for fracture mechanics calculations with second-order isoparametric elements (“Fracture mechanics: overview,” Section 11.4.1). This spacing

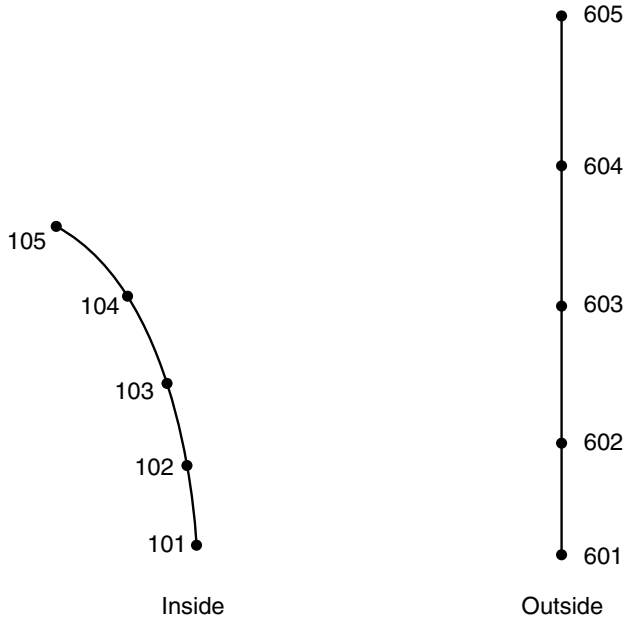


Figure 2.1.1–9 Node sets defining bias example.

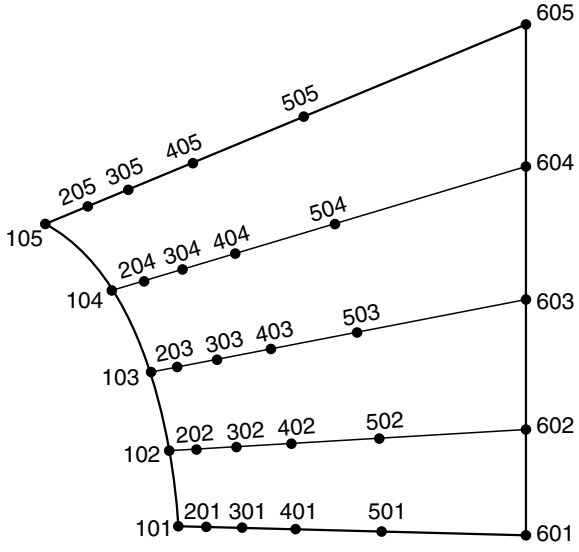


Figure 2.1.1–10 Result of bias example.

gives a square root singularity in the strain field at the crack tip by placing the first node away from

that point at one-quarter of the distance to the second point. The remaining nodes on each line are spaced so that the size of the elements will grow as the square of the distance from the singularity, with the midside nodes exactly at the midsides of the elements. This spacing produces a reasonable mesh gradation for this type of problem; however, better results can be obtained for crude meshes by making the size of the crack element smaller than the quarter-point spacing technique does.

Input File Usage: *NFILL, SINGULAR

Example

Figure 2.1.1–11 shows a simple fracture mechanics example.

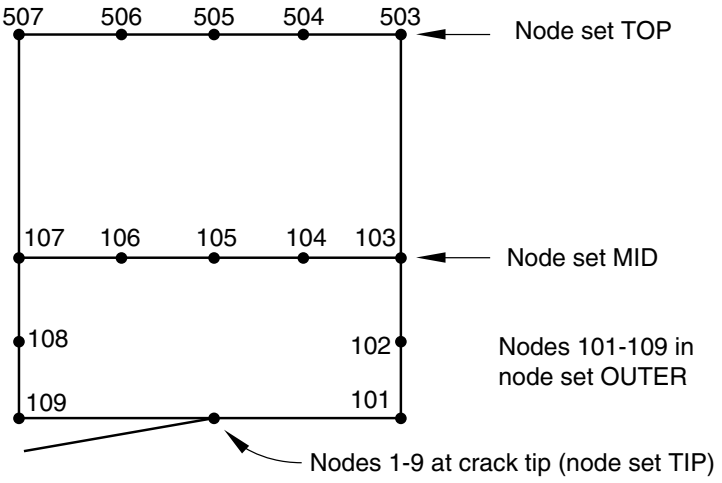


Figure 2.1.1–11 Node fill used in a singular problem.

(The mesh shown is very coarse, and a finer mesh would probably be used in an actual case.) The nodes on the top edge have been placed in node set **TOP**, those on the horizontal line at the upper end of the focused region are in node set **MID**, all of the nodes around the focused region are in node set **OUTER**, and there are multiple nodes at the crack tip in node set **TIP**. The following options are used to fill in the region as shown in Figure 2.1.1–12 (note the quarter-point nodes adjacent to the crack tip):

```
*NFILL, BIAS=0.8
MID, TOP, 4, 100
*NFILL, SINGULAR=1
TIP, OUTER, 5, 20
```

Mapping a set of nodes from one coordinate system to another

You can map a set of nodes from one coordinate system to another. You can also rotate, translate, or scale the nodes in a set by using a more direct method instead of coordinate system mapping. These capabilities

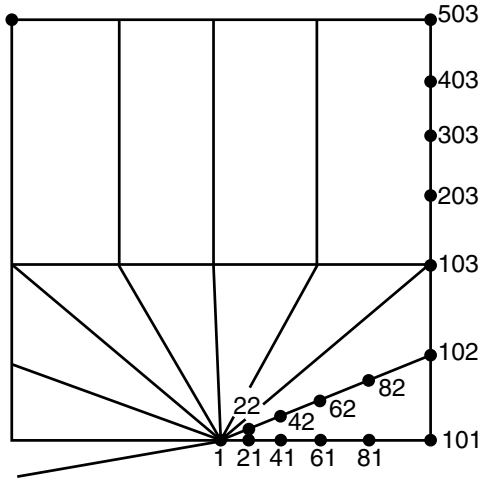


Figure 2.1.1–12 Node fill used in a singular problem.

are useful for many geometric situations: a mesh can be generated quite easily in a local coordinate system (for example, on the surface of a cylinder) using other methods and then can be mapped into the global (X, Y, Z) system. In other cases some parts of your model need to be translated or rotated along a given axis or scaled with respect to one point.

The mapping capability cannot be used in a model defined in terms of an assembly of part instances.

The following different mappings are provided: a simple scaling; a simple shift and/or rotation; skewed Cartesian; cylindrical; spherical; toroidal; and, in Abaqus/Standard only, blended quadratic. The first five of these mappings are shown in Figure 2.1.1–13. Blended quadratic mapping is shown in Figure 2.1.1–14.

In all cases the coordinates of the nodes in the set are assumed to be defined in the local system: these local coordinates at each node are replaced with the global Cartesian (X, Y, Z) coordinates defined by the mapping. All angular coordinates should be given in degrees.

You can use either coordinates or node numbers to define the new coordinate system, the axis of rotation and translation, or the reference point used for scaling.

The mapping capability can be used several times in succession on the same nodes, if required.

Scaling the local coordinates before they are mapped

For all mappings except the blended quadratic mapping, you can specify a scaling factor to be applied to the local coordinates before they are mapped.

This facility is useful for "stretching" some of the coordinates that are given. For example, in cases where the local system uses some angular coordinates and some distance coordinates (cylindrical, spherical, etc.), it may be preferable to generate the mesh in a system that uses distance measures in the angular directions and then scale onto the angular coordinate system for the mapping.

Two different scaling methods are available.

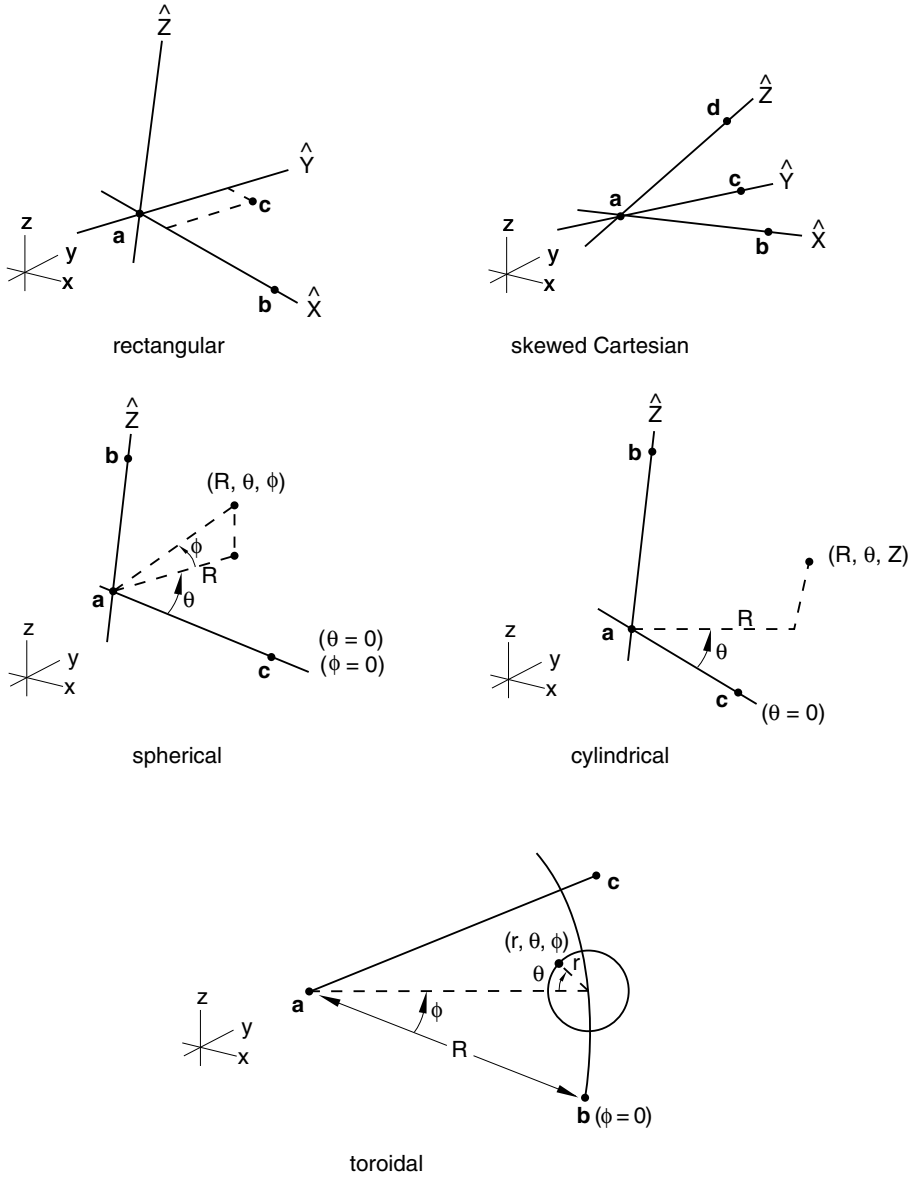


Figure 2.1.1–13 Coordinate systems; angles are in degrees.

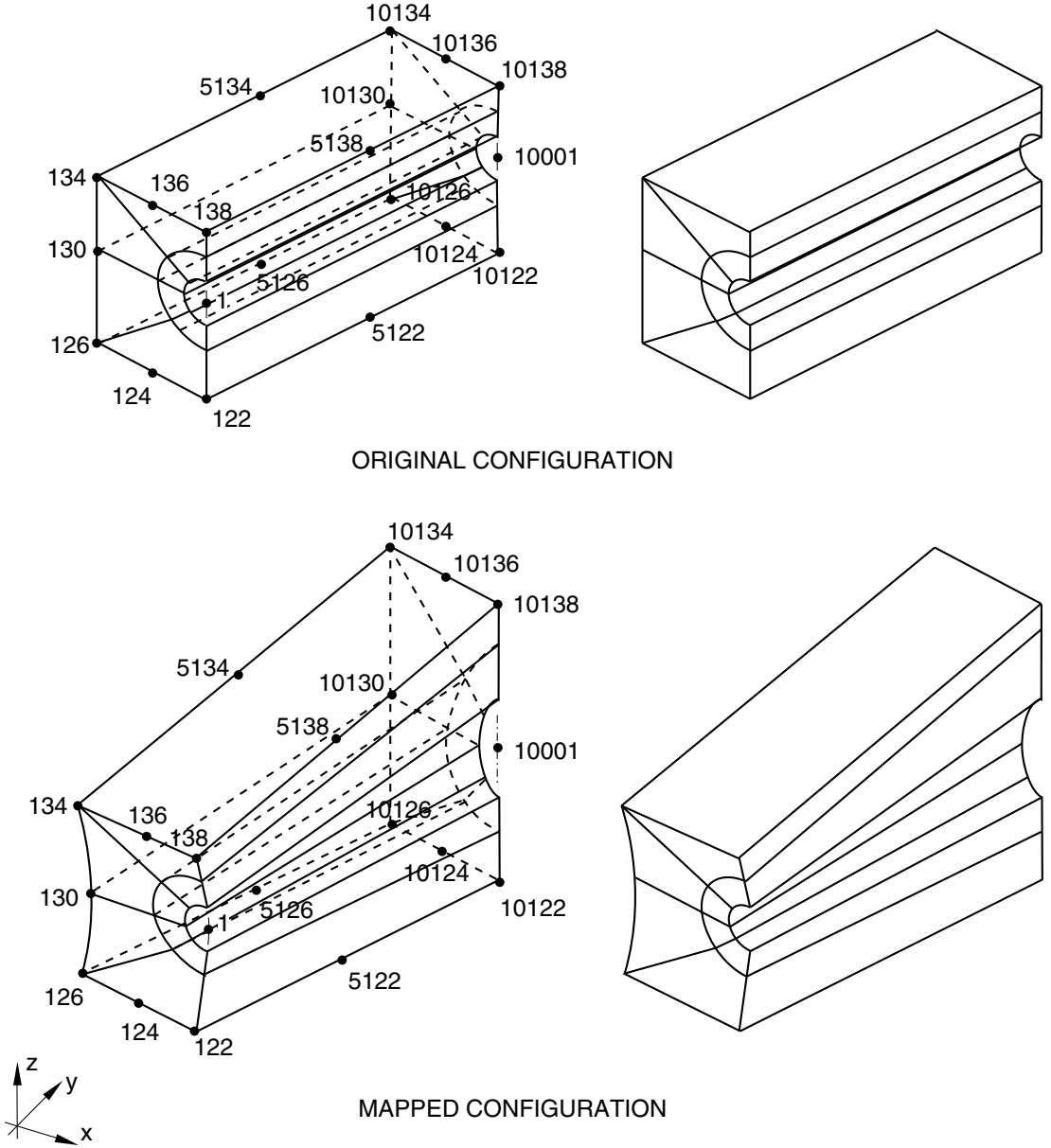


Figure 2.1.1–14 Use of blended quadratic mapping to develop a solid mesh onto a curved block.

Specifying the scaling factors directly

A first method of scaling the nodes with respect to the origin of the local system is to specify the scale factors directly. In this case the scaling is done at the same time as the mapping from one coordinate system to another.

Input File Usage: ∗NMAP, NSET=*name*
first data line
second data line
scale factor for first local coord, scale factor for second local coord,
scale factor for third local coord

Specifying the scaling with respect to a reference point

Alternatively, you can scale with respect to a point other than the origin. The reference point with respect to which the scaling is done can be defined by using either its coordinates or the user node number.

Input File Usage: Use the following option to define the scaling reference point by using its coordinates (default):

∗NMAP, TYPE=SCALE, DEFINITION=COORDINATES
X-coordinate of reference point, Y-coordinate of reference point,
Z-coordinate of reference point
scale factor for first local coord, scale factor for second local coord,
scale factor for third local coord

Use the following option to define the scaling reference point by using its node number:

∗NMAP, TYPE=SCALE, DEFINITION=NODES
Local node number of the reference point
scale factor for first local coord, scale factor for second local coord,
scale factor for third local coord

Introducing a simple shift and/or rotation by mapping from one coordinate system to another

In the case of a simple shift and/or rotation, point a in Figure 2.1.1–13 defines the origin of the local rectangular coordinate system defining the map. The local $\hat{x}$-axis is defined by the line joining points a and b. The local $\hat{x}$–$\hat{y}$ plane is defined by the plane passing through points a, b, and c.

Input File Usage: ∗NMAP, NSET=*name*, TYPE=RECTANGULAR

Introducing a pure shift by specifying the axis and magnitude of the translation

You can define a pure translation (or shift) to move a set of nodes by a prescribed value along a desired axis. You must specify the axis of translation by providing either the coordinates or the two node numbers defining this axis, and you must prescribe the magnitude of the translation.

Input File Usage: Use the following option to specify the axis of translation using coordinates (default):

∗NMAP, NSET=*name*, TYPE=TRANSLATION,
DEFINITION=COORDINATES

Use the following option to specify the axis of translation using node numbers:

∗NMAP, NSET=*name*, TYPE=TRANSLATION, DEFINITION=NODES

Introducing a pure rotation by specifying the axis, origin, and angle of the rotation

You can define a rotation of a set of nodes by providing the axis of rotation, the origin of rotation, and the magnitude of the rotation. You must specify the axis of rotation by providing either the coordinates or the two node numbers defining this axis. You must specify the origin of the rotation by providing either the coordinates or the node number at the origin of rotation. Finally, you must specify the angle of the rotation in degrees.

Input File Usage: Use the following option to specify the axis of rotation using coordinates (default):

∗NMAP, NSET=*name*, TYPE=ROTATION,
DEFINITION=COORDINATES

Use the following option to specify the axis of rotation using node numbers:

∗NMAP, NSET=*name*, TYPE=ROTATION, DEFINITION=NODES

Mapping from cylindrical coordinates

For mapping from cylindrical coordinates, point *a* in Figure 2.1.1–13 defines the origin of the local cylindrical coordinate system defining the map. The line going through point *a* and point *b* defines the $\hat{z}$-axis of the local cylindrical coordinate system. The local $\hat{r}$–$\hat{z}$ plane for $\theta = 0$ is defined by the plane passing through points *a*, *b*, and *c*.

Input File Usage: ∗NMAP, NSET=*name*, TYPE=CYLINDRICAL

Mapping from skewed Cartesian coordinates

For mapping from skewed Cartesian coordinates, point *a* in Figure 2.1.1–13 defines the origin of the local diamond coordinate system defining the map. The line going through point *a* and point *b* defines the $\hat{x}$-axis of the local coordinate system. The line going through point *a* and point *c* defines the $\hat{y}$-axis of the local coordinate system. The line going through point *a* and point *d* defines the $\hat{z}$-axis of the local coordinate system.

Input File Usage: ∗NMAP, NSET=*name*, TYPE=DIAMOND

Mapping from spherical coordinates

For mapping from spherical coordinates, point *a* in Figure 2.1.1–13 defines the origin of the local spherical coordinate system defining the map. The line going through point *a* and point *b* defines the polar axis of the local spherical coordinate system. The plane passing through point *a* and perpendicular

to the polar axis defines the $\phi = 0$ plane. The plane passing through points *a*, *b*, and *c* defines the local $\theta = 0$ plane.

Input File Usage: *NMAP, NSET=*name*, TYPE=SPHERICAL

Mapping from toroidal coordinates

For mapping from toroidal coordinates, point *a* in Figure 2.1.1–13 defines the origin of the local toroidal coordinate system defining the map. The axis of the local toroidal system lies in the plane defined by points *a*, *b*, and *c*. The *R*-coordinate of the toroidal system is defined by the distance between points *a* and *b*. The line between points *a* and *b* defines the $\phi = 0$ position. For every value of ϕ the θ-coordinate is defined in a plane perpendicular to the plane defined by the points *a*, *b*, and *c* and perpendicular to the axis of the toroidal system. $\theta = 0$ lies in the plane defined by the points *a*, *b*, and *c*.

Input File Usage: *NMAP, NSET=*name*, TYPE=TOROIDAL

Mapping by means of blended quadratics

To map by means of blended quadratics in Abaqus/Standard, you define the new (mapped) coordinates of up to 20 “control nodes”: these are the corner and midedge nodes of the block of nodes being mapped. The mapping in this case is like that of a 20-node brick isoparametric element. Any of the midedge nodes can be omitted, thus allowing linear interpolation along that edge of the block. Abaqus/Standard does not check whether the nodes in the set lie within the physical space of the block defined by the corner and midedge nodes: these control nodes simply define mapping functions that are then applied to all of the nodes in the set.

The control nodes should define a “well”-shaped block; for example, midedge nodes should be close to the midpoint of the edge. Otherwise, the mapping can be very distorted. For example, the nodes of a crack-tip 20-node element with midside nodes at the quarter points will not map correctly and, therefore, should not be used as the control nodes.

Blended mapping is only available for three-dimensional analyses.

Input File Usage: *NMAP, NSET=*name*, TYPE=BLENDED

2.1.2 PARAMETRIC SHAPE VARIATION

Products: Abaqus/Standard Abaqus/Explicit

References

- "Parametric input," Section 1.4.1
- *PARAMETER SHAPE VARIATION

Overview

Shape parametrization can be accomplished in an Abaqus input file by:

- parametrizing nodal coordinates; or
- relating nodal coordinates to shape parameters using shape variations.

The different approaches to shape parametrization are described in this section.

Parametrization of nodal coordinates

Any individual nodal coordinates can be parametrized directly. This is usually of limited value because it often leads to designs with irregular shape that cannot be manufactured easily. In addition, parametrization of individual nodal coordinates generally requires an excessive number of parameters to define the parametrized shape.

Parametrization of nodal coordinates used in conjunction with node generation in Abaqus provides a more practical method of shape parametrization. However, this method is still of somewhat limited practical use because the simple node generation capabilities available in Abaqus cannot describe complex shapes.

Direct parametrization of individual nodal coordinates

The simplest form of parametrization of nodal coordinates is to define individual parameters and use them in place of the nodal coordinates to be parametrized, as described in "Parametric input," Section 1.4.1. For example,

```
*PARAMETER
x_coord_node_1 = 10.
y_coord_node_1 = 20.
*NODE
1, <x_coord_node_1>, <y_coord_node_1>
```

Parametrization of nodal coordinates using node generation

Shape parametrization can be accomplished by parametrizing the coordinates of some nodes, then using these nodes to generate other nodes and their coordinates. For example:

```
*PARAMETER
x_coord_node_1 = 10.
x_coord_node_11 = 20.
*NODE
1, <x_coord_node_1>, 50.
11, <x_coord_node_11>, 50.
*NGEN
1, 11, 1
```

This method of shape parametrization reduces the number of user-defined parameters necessary for shape parametrization by implicitly making the nodal coordinates of the generated nodes dependent on the shape parameters.

Shape change by linear combination of shape variations

The definition of shape in Abaqus includes a basic shape plus any number of additional shape variations that are added to the basic shape using a linear combination. Mathematically, we can express the nodal coordinates, $\boldsymbol{x}$, as

$$\boldsymbol{x} = \boldsymbol{x}_0 + \sum_{i=1}^{N} \boldsymbol{s}_i \, p_i,$$

where $\boldsymbol{x}_0$ is the basic shape, $\boldsymbol{s}_i$ is the i^{th} shape variation, and p_i is the value of the i^{th} shape parameter. This calculation is always done in the global rectangular Cartesian coordinate system. Although it is not necessarily so, it is frequently the case that the input to define a shape variation is simply the gradient of the basic shape $\boldsymbol{x}_0$ taken with respect to the corresponding shape parameter.

You specify the basic shape of a model in the Abaqus input file by providing nodal definitions either directly or through node generation; see "Node definition," Section 2.1.1.

You can specify shape variations and associated shape parameters, as described here.

In addition, you can specify perturbations of the shape as a linear combination of other shapes (for example, buckling mode shapes); see "Introducing a geometric imperfection into a model," Section 11.3.1.

The definition of the nodal coordinates for a model in the Abaqus input file is then possible using a combination of four types of methods:

- You can directly define individual nodes and their respective coordinates; these coordinates are part of the definition of the basic shape, $\boldsymbol{x}_0$, and can be parametrized.
- Node generation can be used to create nodes and their coordinates according to geometrically simple mappings that rely on existing node definitions; these generated coordinates are also part of the definition of the basic shape, $\boldsymbol{x}_0$. If necessary, the node generation input can be parametrized.
- Parameter shape variations can be used to vary the coordinates of nodes defined using the above methods.

- Geometric imperfections can be used to perturb nodal coordinates previously defined using any combination of the above three types of methods.

Shape parametrization using shape variations

Instead of parametrizing nodal coordinates directly, you can specify shape variations. Each shape variation must be associated with a single shape parameter. The names of the parameters associated with the shape variations must be chosen such that the names remain unique when interpreted in a case-insensitive manner. The values of the shape parameters are assigned using parameter definitions.

A parameter shape variation can be defined more than once for the same parameter so that different parts of a shape variation can be specified separately. In these cases if the same node is specified in multiple parameter shape variation definitions, the last definition for the node prevails.

A node that is specified under a parameter shape variation definition that has not also been defined directly or through node generation will be ignored.

You can specify shape variations using a combination of three possibilities: directly specifying them, reading them from an alternate input file, and reading them from the results files of auxiliary analyses. These methods are described in the following sections.

Defining shape variations directly or reading them from an alternate input file

You can define the shape variation data directly by specifying the node number and corresponding variations of coordinate components. Alternatively, the data can be given in an ASCII file.

Input File Usage: Use the following option to specify the shape variation data directly:

∗PARAMETER SHAPE VARIATION, PARAMETER=*name*

Use the following option to specify the shape variation data in an alternate input file:

∗PARAMETER SHAPE VARIATION, PARAMETER=*name*, INPUT=*input file*

Defining shape variations in alternative coordinate systems

By default, the shape variation data are interpreted in the global rectangular Cartesian coordinate system. You can specify the shape variation data (either directly or in an alternate input file) in cylindrical or spherical coordinate systems. In such cases the computation of the shape variation is done as follows. The nodal coordinate components that define the basic shape are first transformed from the global rectangular Cartesian coordinate system in which they are stored to the specified coordinate system. The shape variation coordinate components are then added to give updated coordinate components, which are transformed back to the global rectangular Cartesian coordinate system. Finally, the shape variation is taken as the difference between the updated coordinate components and the original coordinate components, using the components expressed in the global rectangular Cartesian coordinate system. The value of the shape parameter associated with the shape variation is not used at any point in the calculation of the shape variation.

Input File Usage: Use the following option to specify the shape variation data in a rectangular coordinate system (the default):

*PARAMETER SHAPE VARIATION, PARAMETER=*name*, SYSTEM=R

Use the following option to specify the shape variation data in a cylindrical coordinate system:

*PARAMETER SHAPE VARIATION, PARAMETER=*name*, SYSTEM=C

Use the following option to specify the shape variation data in a spherical coordinate system:

*PARAMETER SHAPE VARIATION, PARAMETER=*name*, SYSTEM=S

Using auxiliary analyses to generate shape variations

Auxiliary models are additional finite element models that are used to generate shape variations for a primary model. Rather than defining shape variations directly on a node-by-node basis, auxiliary models can be used to simplify this process. Auxiliary analyses are finite element analyses of these auxiliary models.

An auxiliary model usually has the same geometry, element connectivity, and material type as the primary model. However, the boundary conditions are usually different. Applying loading to an auxiliary model results in sets of displacements that we may interpret as shape variations. For example, we may be interested in studying the sensitivity of the nonlinear buckling behavior of a structure with respect to imperfections in the structure. In this case we could perform an auxiliary eigenvalue linear buckling analysis and then use the resulting mode shapes as shape variations to be added to the basic geometry of the primary model. (This particular problem could also be addressed by using a geometric imperfection.)

Abaqus reads the shape variation data from auxiliary analyses through the user node labels. Abaqus does not check model compatibility between both analysis runs. Shape variation data cannot be read from the results file for models defined in terms of an assembly of part instances (“Defining an assembly,” Section 2.10.1).

Reading shape variations from a static analysis results file

To define a shape variation based on the deformed geometry of a previous static analysis, specify the results file and step from a previous static analysis. Optionally, you can specify the increment number from which displacement data are read. (By default, Abaqus will read data from the last increment available for the specified step on the results file.) In addition, you can read shape variation data for a specified node set.

Input File Usage: *PARAMETER SHAPE VARIATION, PARAMETER=*name*,
FILE=*results file*, STEP=*step*, INC=*inc*, NSET=*name*

Reading shape variations from an eigenvalue analysis results file

To define a shape variation based on a mode shape from a previous eigenvalue analysis, specify the results file and step from a previous eigenfrequency extraction or eigenvalue buckling prediction analysis. Optionally, you can specify the mode number from which eigenvector data are read. (By default, Abaqus

will read data from the first eigenvector available for the specified step on the results file.) In addition, you can read eigenmode data for a specified node set.

Input File Usage: *PARAMETER SHAPE VARIATION, PARAMETER=*name*,
FILE=*results file*, STEP=*step*, MODE=*mode*, NSET=*name*

Shape parametrization and design sensitivity analysis

For the purpose of design sensitivity analysis with Abaqus/Design ("Design sensitivity analysis," Section 19.1.1) if the parameter specified for a parameter shape variation is also specified as a design parameter, the shape variation is used to define the design gradient of the nodal coordinates and nodal normals with respect to the design parameter. If you wish to perform design sensitivity analysis for the basic shape, all shape parameters must be given a value of zero. In addition, if *any* parameter specified in a parameter shape variation definition is also specified as a design parameter, the parameters of *all* parameter shape variations must be specified as design parameters.

In DSA calculations for shell and beam elements Abaqus always computes the design gradients of nodal normals using the design gradients of nodal coordinates. To overwrite the gradients computed by Abaqus, you must provide the nodal normal as part of the node definition and design gradients of the normals using a parameter shape variation. To prescribe a design-independent normal, you must provide a zero design gradient explicitly. For shape variations read from the results file, Abaqus computes the gradients of the normals based on the displacements and ignores the nodal rotations.

For beam elements Abaqus computes the design gradients for the $\mathbf{n}_1$-direction of the beam cross-section using the gradients of the node coordinates and the gradients for the $\mathbf{n}_2$-direction specified using a parameter shape variation. You cannot provide the shape variation for the $\mathbf{n}_1$-direction. Abaqus ignores any such design gradients implicitly provided in either the beam section definition or as an extra node in the beam element connectivity.

In cases where the data defining a shape variation are given in a cylindrical or spherical coordinate system it is important that you understand how the shape variation is calculated from the data. This calculation is described in the previous section.

Visualization of shape variations

Shape variations can be visualized only after the parametrized input file has been processed by the analysis input file processor. Therefore, at least a data check run must be executed before parameter shape variations can be visualized using Abaqus/CAE.

The shape variations associated with each individual shape parameter can be visualized as displaced shape plots at step zero of the analysis. The basic shape is interpreted as the undeformed shape, and the shape generated by adding the i^{th} shape variation to the basic shape is interpreted as the i^{th} displaced shape.

The combination of all shape variations added to the basic shape represents the true undeformed shape of the analysis.

Using Abaqus/CAE to compute shape variations

A capability for computing shape variations is provided by the Abaqus Scripting Interface command **`_computeShapeVariations( )`**. Using the command requires some familiarity with the Abaqus Scripting Interface and the execution of scripts in Abaqus/CAE. The procedure that must be followed is described and illustrated in "Design sensitivity analysis: overview," Section 14.1.1 of the Abaqus Example Problems Guide.

2.1.3 NODAL THICKNESSES

Products: Abaqus/Standard Abaqus/Explicit Abaqus/CAE

References

- "Membrane elements," Section 29.1.1
- "Using a shell section integrated during the analysis to define the section behavior," Section 29.6.5
- "Using a general shell section to define the section behavior," Section 29.6.6
- *NODAL THICKNESS
- *MEMBRANE SECTION
- *RIGID BODY
- *SHELL GENERAL SECTION
- *SHELL SECTION

Overview

Nodal thicknesses are used to define continuously varying thicknesses for:

- shell structures;
- membrane structures; or
- in Abaqus/Explicit rigid elements.

Defining nodal thicknesses

You can specify the thickness of a shell, membrane, or rigid element at a particular node or node set.

Input File Usage: *NODAL THICKNESS
node_number or node_set_name, *thickness*

Abaqus/CAE Usage: Use the following option for a conventional shell composite layup:

Property module: composite layup editor: **Shell Parameters**: **Nodal distribution**: select an analytical field or a node-based discrete field

Use the following option for a homogeneous shell section:

Property module: shell section editor: **Basic**: **Nodal distribution**: select an analytical field or a node-based discrete field

Use the following option for a composite shell section:

Property module: shell section editor: **Advanced**: **Nodal distribution**: select an analytical field or a node-based discrete field

Reading nodal thicknesses from an alternate file

The nodal thickness data can be stored in a separate file and read from there at the start of the analysis. For details on the syntax of such file names, see "Input syntax rules," Section 1.2.1.

Input File Usage: ∗NODAL THICKNESS, INPUT=*file_name*

Abaqus/CAE Usage: Reading nodal thicknesses from an alternate file is not supported in Abaqus/CAE.

Generating continuously varying thicknesses between two nodes or node sets

Abaqus can linearly interpolate the thickness between two bounding nodes or node sets. The thicknesses at the bounding nodes must first be defined.

Input File Usage: Use the following options:

∗NODAL THICKNESS
first bounding node or node set, *thickness*
second bounding node or node set, *thickness*
∗NODAL THICKNESS, GENERATE
first bounding node or node set, second bounding node or node set, number of intervals, increment in node numbers

Abaqus/CAE Usage: Generating thicknesses between bounding nodes or node sets is not supported in Abaqus/CAE.

Specifying a continuously varying thickness for shell, membrane, and rigid elements

You must specify that a shell or membrane element is going to have a continuously varying thickness rather than a homogeneous thickness when you define the element section. See "Membrane elements," Section 29.1.1; "Using a shell section integrated during the analysis to define the section behavior," Section 29.6.5; and "Using a general shell section to define the section behavior," Section 29.6.6, for details.

In Abaqus/Explicit you must specify that a rigid element is going to have a continuously varying thickness when you define the rigid body to which the element belongs; see "Rigid elements," Section 30.3.1. In Abaqus/Standard rigid elements cannot have a continuously varying thickness.

Every node that is part of a shell, membrane, or rigid element using a continuously varying thickness must have a nodal thickness defined. Abaqus will issue an error message if there is a node with no nodal thickness in an element that is using a continuously varying thickness.

Specifying a continuously varying thickness for a composite shell

When a composite shell structure has a continuously varying thickness, the total thickness of the shell at any node is defined by the nodal thickness value. The total thickness at an integration point is interpolated from the nodal thicknesses. The layer thicknesses given in the shell section definition are used as relative thicknesses and are scaled proportionally such that the sum of the layer thicknesses equals the total thickness at the integration point.

Example

For example, if a composite shell section were defined with the following input:

```
*SHELL SECTION, COMPOSITE, NODAL THICKNESS, ELSET=name
1.5, 3, STEEL
2.5, 3, FOAM
1.0, 3, STEEL
```

and the total thickness at a point was only 1.0, the thicknesses of the individual layers at the point would be 0.3 for the first steel layer, 0.5 for the foam layer, and 0.2 for the second steel layer.

Creating a discontinuity in the shell, membrane, or rigid element thicknesses

You can specify only a single thickness at each node. Therefore, use separate nodes along the interface on shell, membrane, or rigid elements where there is a discontinuity in the thickness and assign the appropriate thickness to each group of nodes. For elements that are not part of a rigid body, multi-point constraints must be used to make the displacements (and rotations, for shells) the same at corresponding nodes.

2.1.4 NORMAL DEFINITIONS AT NODES

Products: Abaqus/Standard Abaqus/Explicit

References

- *NORMAL
- *NODE

Overview

Normals can be defined at nodes:

- with a user-specified normal definition;
- following the nodal coordinates as part of the node definition for beam and shell elements;
- on rigid master surfaces used in contact pairs in Abaqus/Standard;
- in beam and shell elements;
- for line spring elements to give the direction normal to the flaw in the structure;
- for gasket elements to give the thickness direction of the elements; and
- for contour integral evaluation.

The normals defined at nodes do not affect the element face normals, which are defined by the element connectivity. They need not be of unit length.

Contact surfaces in Abaqus/Standard

User-specified surface normals for contact surfaces in Abaqus/Standard are relevant only when the small-sliding contact approach is used or when the finite-sliding contact approach is used with rigid elements that make up the master surface. User-specified surface normals defined on deformable master surfaces in contact pairs are ignored when finite sliding is used.

The small-sliding contact formulation uses the surface normals at each node along the master surface to define a normal vector that varies smoothly from point to point on the surface. For a detailed discussion on how the "master plane" is constructed for each slave node using the surface normals, see "Contact formulations in Abaqus/Standard," Section 38.1.1.

For master surfaces composed of rigid elements Abaqus/Standard smooths any discontinuous surface normal transitions between the rigid elements. The surface normals at the nodes are used to control the surface normal interpolation. For a detailed discussion on the smoothing of such master surfaces, see "Analytical rigid surface definition," Section 2.3.4.

To define the normal, specify the components of the normal in the global coordinate system.

Input File Usage: *NORMAL, TYPE=CONTACT SURFACE

Elements

User-specified normals may be necessary for beam and shell elements, line spring elements, gasket elements, or elements involved in contour integral evaluations. In such cases specify the components of the normal in the global coordinate system.

Input File Usage: *NORMAL, TYPE=ELEMENT

Beam and shell elements

User-specified normals may be needed to define the desired normal directions at shell surface intersections or at beam intersections where the automatically determined normals may be inappropriate for the model (see "Beam element cross-section orientation," Section 29.3.4, or "Defining the initial geometry of conventional shell elements," Section 29.6.3).

The nodal normals can also be defined as part of the node definition. While you can define a single normal for all elements connected to a node as part of the node definition, a user-specified normal definition defines a normal for a particular element at a node, thus allowing you to define separate normals for each element connected to a node. User-specified normal definitions supersede normals defined as part of a node definition.

Input File Usage: *NODE

Specify the normals in the fifth, sixth, and seventh positions on the data line.

For example, the following lines define some normals as part of node definitions; the normal to be used at node 7 in element 2 is then redefined using a user-specified normal definition:

```
*NODE
6, 5., 5., , -0.5, .8
7, 10., 8., , -0.5, .8
9, 14., 4., , .6, .6
*NORMAL
2, 7, .6, .6
```

Line spring elements

For line spring elements user-specified normals can be used to give the direction normal to the flaw in the structure. See "Line spring elements for modeling part-through cracks in shells," Section 32.9.1, for a description of these elements.

Gasket elements

For gasket elements user-specified normals can be used to specify the thickness direction of the elements. The nodal thickness directions can also be defined as part of the gasket section definition. Thickness directions defined by user-specified normals supersede thickness directions defined as part of the gasket section definition. See "Defining the gasket element's initial geometry," Section 32.6.4, for a description of the definition of the thickness direction for these elements.

Contour integral evaluation

For contour integral evaluations (“Contour integral evaluation,” Section 11.4.2) surface normals should be specified at all surface nodes lying within the bounds of the requested contours. These nodes are printed out under the “Contour Integral” information in the data (`.dat`) file. For accurate contour integral evaluation it is important that the virtual crack extension direction is in the plane of the surface for the following cases: when a crack front intersects the external surface of a three-dimensional solid, when the crack front intersects a surface of material discontinuity, or when the crack is in a curved shell. If no normals are specified, Abaqus will calculate the normals automatically.

The nodal normal data specified as part of a node definition will not be activated for solid elements unless a user-specified normal definition is used in the model; it suffices to include a user-specified normal definition for only one node to activate the utilization of the nodal normal data specified as part of a node definition.

The coordinate system in which normals are defined

Abaqus models can be defined in terms of an assembly of part instances (see “Defining an assembly,” Section 2.10.1). Normals at nodes defined within a part (or part instance) are defined relative to the part coordinate system. These normals are rotated according to the positioning data given for each instance of the part. Normals can be defined at reference nodes at the assembly level if necessary. Normals defined at the assembly level are defined in the global coordinate system.

For models that are not defined in terms of an assembly of part instances, normals are defined in the global coordinate system.

2.1.5 TRANSFORMED COORDINATE SYSTEMS

Products: Abaqus/Standard Abaqus/Explicit Abaqus/CAE

References

- "Prescribed conditions: overview," Section 34.1.1
- *TRANSFORM
- "Transforming results into a new coordinate system," Section 42.6.8 of the Abaqus/CAE User's Guide, in the HTML version of this guide
- "An overview of the methods for creating a datum coordinate system," Section 62.5.4 of the Abaqus/CAE User's Guide

Overview

A nodal transformation is used to define a local coordinate system for:

- the definition of concentrated forces and moments;
- the definition of displacement and rotation boundary conditions;
- the definition of linear constraint equations; and
- the output of vector-valued quantities.

A nodal transformation cannot be used to specify a local coordinate system for defining:

- nodal coordinates—see "Specifying a local coordinate system in which to define nodes" in "Node definition," Section 2.1.1, or "Specifying a local coordinate system for the nodal coordinates" in "Node definition," Section 2.1.1, instead; or
- material properties or rebars—see "Orientations," Section 2.2.5, instead.

Defining a local coordinate system

Normally displacement and rotation components are associated with the global, rectangular Cartesian axis system. When a transformed coordinate system is associated with a node, all input data for concentrated forces and moments and for displacement and rotation boundary conditions at the node are given in the local system. The following transformations are available:

- Rectangular Cartesian
- Cylindrical
- Spherical

The coordinate transformation defined at a node must be consistent with the degrees of freedom that exist at the node. For example, a transformed coordinate system should not be defined at a node that is connected only to a SPRING1 or SPRING2 element, since these elements have only one active degree of freedom per node.

Input File Usage: You must identify the node set for which the local transformed system is defined.

*TRANSFORM, NSET=*name*

Abaqus/CAE Usage: In Abaqus/CAE you define a local coordinate system independent of its use and then refer to it when you apply a load or boundary condition at a node.

Any module: **Tools→Datum**: **Type**: **CSYS**

Interaction module: load or boundary condition editor: **CSYS: Edit**: select local coordinate system

Defining a local coordinate system in a model that contains an assembly of part instances

In a model defined in terms of an assembly of part instances, you can define a nodal transformation at the part, part instance, or assembly level. A nodal transformation defined at the part or part instance level will be rotated according to the positioning data given for each instance of that part (or for the part instance). See "Defining an assembly," Section 2.10.1. Multiple transformation definitions are not allowed at a node, even if one of them is at the part level and another is at the assembly level.

Large-displacement analysis

The transformed coordinate system is always a set of fixed Cartesian axes at a node (even for cylindrical or spherical transforms). These transformed directions are fixed in space; the directions do not rotate as the node moves. Therefore, even in large-displacement analysis, the displacement components must always be given with respect to these fixed directions in space.

Defining a rectangular Cartesian coordinate transformation

In a rectangular Cartesian transformation the transformed directions are parallel at all nodes of the set. The coordinates of two points must be given, as shown in Figure 2.1.5–1.

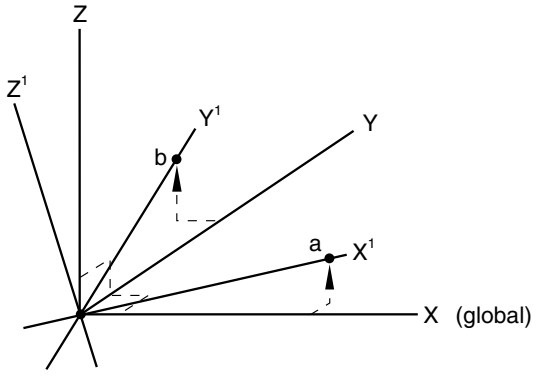


Figure 2.1.5–1 Cartesian transformation.

The first point, *a*, must be on a line through the global origin; this point defines the transformed X^1-direction. The second point, *b*, must be in the plane containing the global origin and the transformed X^1- and Y^1-directions. This second point should be on or near the positive Y^1-axis.

Input File Usage: *TRANSFORM, NSET=*name*, TYPE=R (default)

Abaqus/CAE Usage: Any module: **Tools→Datum**: **Type**: **CSYS**: select any method, and click **OK**: **Rectangular**

Defining a cylindrical coordinate transformation

The radial, tangential, and axial directions must be defined based on the original coordinates of each node in the node set for which the transformation is invoked. The global (X, Y, Z) coordinates of the two points defining the axis of the cylindrical system (points *a* and *b* as shown in Figure 2.1.5–2) must be given.

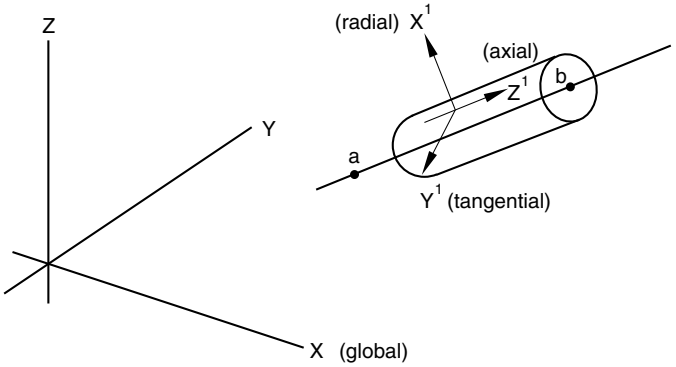


Figure 2.1.5–2 Cylindrical transformation.

The origin of the local coordinate system is at the node of interest. The local X^1-axis is defined by a line through the node, perpendicular to the line through points *a* and *b*. The local Z^1-axis is defined by a line that is parallel to the line through points *a* and *b*. The local Y^1-axis forms a right-handed coordinate system with X^1 and Z^1.

A cylindrical coordinate system cannot be defined for a node that lies along the line joining points *a* and *b*.

Input File Usage: *TRANSFORM, NSET=*name*, TYPE=C

Abaqus/CAE Usage: Any module: **Tools→Datum**: **Type**: **CSYS**: select any method, and click **OK**: **Cylindrical**

Defining a spherical coordinate transformation

The radial, circumferential, and meridional directions must be defined based on the original coordinates of each node in the node set for which the transformation is invoked. The global (X, Y, Z) coordinates

of the center of the spherical system, *a*, and of a point on the polar axis, *b*, must be given as shown in Figure 2.1.5–3.

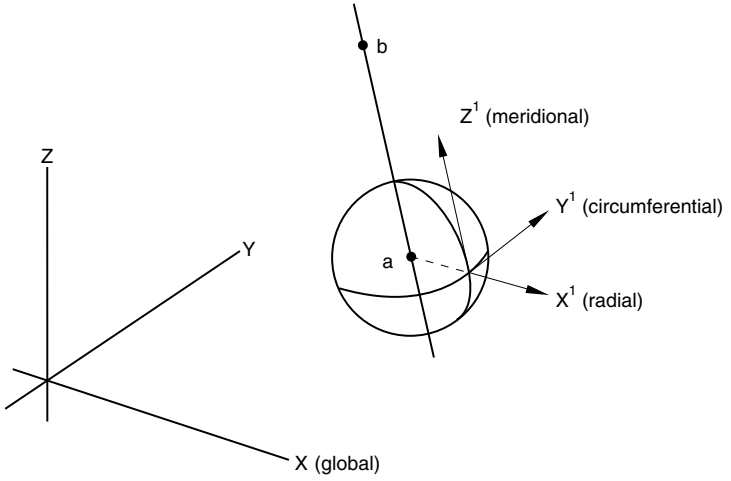


Figure 2.1.5–3 Spherical transformation.

The origin of the local coordinate system is at the node of interest. The local X^1-axis is defined by a line through the node and point *a*. The local Z^1-axis lies in a plane containing the polar axis (the line between points *a* and *b*) and is perpendicular to the local X^1-axis. The local Y^1-axis forms a right-handed coordinate system with X^1 and Z^1.

A spherical coordinate system cannot be defined for a node that lies along the line joining points *a* and *b*.

Input File Usage: *TRANSFORM, NSET=*name*, TYPE=S

Abaqus/CAE Usage: Any module: **Tools→Datum**: **Type**: **CSYS**: select any method, and click **OK**: **Spherical**

Output at a node associated with a coordinate transformation

Printed and file output of vector-valued quantities from Abaqus/Standard at transformed nodes can be in the local or global system (see "Specifying the directions for nodal output" in "Output to the data and results files," Section 4.1.2). By default, the values are written to the data file in the local system, whereas the values are written to the results file in the global system (since this is more convenient for postprocessing). Consequently, reaction forces printed using the default will not appear to equilibrate loads applied in the global system. However, these reaction forces and loads should equilibrate if you output them to the data file in the global system.

File output from Abaqus/Explicit is always in the global system.

Output database output of field vector-valued quantities at transformed nodes is in the global system. The local transformations are also written to the output database. You can apply these transformations to

the results in the Visualization module of Abaqus/CAE to view the vector components in the transformed systems.

Output database output of history vector-valued quantities at transformed nodes can be in the local or global system (see “Output to the output database,” Section 4.1.3). By default, the values are written in the global system (since this is more convenient for postprocessing).

2.1.6 ADJUSTING NODAL COORDINATES

Products: Abaqus/Standard Abaqus/Explicit Abaqus/CAE

References

- *ADJUST
- "Defining adjust points constraints," Section 15.15.5 of the Abaqus/CAE User's Guide

Overview

Nodal adjustment is used for:

- adjusting user-specified nodal coordinates so that the nodes lie on a given surface; and
- specifying the direction along which the nodes are moved.

Adjusting nodal coordinates

In general, user-specified nodal coordinates are not modified during input file processing. However, there are some situations where mesh coordinates are known only in a generic way and it is inconvenient to determine their coordinates for their actual usage. For example, when using fasteners the specified reference node should be positioned at its projection point on the associated surface. Since that location may be known only approximately, you can use nodal adjustment to move the reference node to that location automatically. For typical usage of the nodal adjustment feature, refer to "About assembled fasteners," Section 29.1.3 of the Abaqus/CAE User's Guide.

When using this feature, the nodes are adjusted to lie on the specified surface without regard for shell thickness or shell offsets. Therefore, it is not advisable to use this feature as a way of correcting initial overclosures for contact or for tie constraints. In addition, care should be taken when choosing the nodes to be adjusted because the feature does not respect any constraints relating the relative position of the adjusted node with other nodes (e.g., rigid body definitions).

Input File Usage: Use the following option to identify the nodes to be moved and the surface onto which the nodes are to be moved:

*ADJUST, NODE SET=*name*, SURFACE=*name*

Abaqus/CAE Usage: Use the following option to move the control point of a coupling constraint onto the coupling surface:

Interaction module: **Constraint→Create**: **Coupling**; **Adjust control point to lie on surface**

Use the following option to move any point or points onto any surface:

Interaction module: **Constraint→Create**: **Adjust points**

Specifying the nodal adjustment direction

A node can be moved to the surface using a normal adjustment or a directed adjustment. By default, the node is adjusted to the closest point on the specified surface along the normal to the surface. You can specify an orientation to move the node to the surface along a given direction rather than along the normal to the surface. The vector along the local *Z*-direction from the orientation definition is used to move the node to the surface (see "Orientations," Section 2.2.5). If no projection can be found, the nodal coordinates are left unmodified.

Input File Usage: ∗ADJUST, ORIENTATION=*name*

Abaqus/CAE Usage: The orientation projection option is not supported in Abaqus/CAE.

2.2 Element definition

2.2.1 ELEMENT DEFINITION

Products: Abaqus/Standard Abaqus/Explicit

References

- *ELCOPY
- *ELEMENT
- *ELGEN
- *ELSET

Overview

This section describes the methods for defining elements in an Abaqus input file. In a preprocessor such as Abaqus/CAE, you define the model geometry rather than the nodes and elements; when you mesh the geometry, the preprocessor automatically creates the nodes and elements needed for analysis. Although the concepts discussed in this section apply in general to the element definitions in the input file that is created by Abaqus/CAE, the methods and techniques described here apply only if you are creating the input file manually.

Element definition consists of:

- assigning an element number to the element;
- defining individual elements by specifying their nodes;
- grouping elements into element sets; and
- creating elements from existing elements by generating them incrementally or by copying existing elements.

If any element is specified more than once, the last specification given is used.

Assigning an element number to the element

Each individual element must have a numeric label called the element number, which is assigned when the element is defined. The element number must be a positive integer, and the maximum element number allowed is 999999999 (for information on integer input, see "Input syntax rules," Section 1.2.1). The elements do not need to be numbered continuously.

An Abaqus model can be defined in terms of an assembly of part instances (see "Defining an assembly," Section 2.10.1). In such a model almost all elements must belong to a part or part instance. The only exceptions are mass, rotary inertia, capacitance, connector, spring, and dashpot elements, which can belong to a part or to the assembly. Element numbers must be unique within a part, part instance, or the assembly; but they can be repeated in different parts or part instances.

Defining individual elements by specifying their nodes

You can define individual elements by specifying the element number and the nodes that define the element. In addition, you must specify the element type. The element must be chosen from one of the element types specified in Part VI, "Elements"; or, in Abaqus/Standard, it can be a user-defined element ("User-defined elements," Section 32.15.1) or a substructure ("Using substructures," Section 10.1.1).

Input File Usage: *ELEMENT, TYPE=*name*

For example, the following lines create element number 11, which is of type C3D8R, by defining its nodes (2, 3, 9, 7, 5, 8, 12, 16):

```
*ELEMENT, TYPE=C3D8R
11, 2, 3, 9, 7, 5, 8, 12, 16
```

Using large node numbers with elements that use many nodes

The following rules apply when defining elements:

- The connectivity for each element is considered a logical record, and any number of input lines can be used to specify it. Abaqus will read the first line for an element and consider the next line a continuation line if a comma ends the line and the element definition is not complete.
- Any number of continuation lines can be used.
- For elements such as C3D27 with a variable number of nodes (see "Solid (continuum) elements," Section 28.1.1), the last line should not end with a comma or Abaqus will interpret the next element definition as a continuation of the current element.

For example,

```
*ELEMENT, TYPE=C3D20
100001, 100001, 100002, 100003, 100004, 100005, 100006, 100007,
100008, 100009, 100010, 100011, 100012, 100013, 100014, 100015,
100016, 100017, 100018, 100019, 100020
```

Reading element definitions from a file

Element definitions can be read into Abaqus from an alternate file. The syntax of such file names is described in "Input syntax rules," Section 1.2.1.

Input File Usage: *ELEMENT, INPUT=*file_name*

Reading substructure definitions from a substructure library

Substructure definitions can be read from the substructure library in which the substructure resides ("Using substructures," Section 10.1.1).

Input File Usage: *ELEMENT, FILE=*substructure_library_name*

If the FILE parameter is used without a value, the default substructure library name is used.

Defining axisymmetric elements with asymmetric deformation

You can define a positive offset number that will be used to specify nodes for axisymmetric elements with asymmetric deformation (see "Choosing the element's dimensionality," Section 27.1.2; "Axisymmetric solid elements with nonlinear, asymmetric deformation," Section 28.1.7; and "Axisymmetric shell elements with nonlinear, asymmetric deformation," Section 29.6.10, for more information on axisymmetric elements with asymmetric deformation; they are available only in Abaqus/Standard). The default offset is 100000.

Input File Usage: ∗ELEMENT, OFFSET=*number*

Defining gasket elements

There are several methods for defining gasket elements. (See "Gasket elements: overview," Section 32.6.1; "Including gasket elements in a model," Section 32.6.3; and "Defining the gasket element's initial geometry," Section 32.6.4, for more information on gasket elements; they are available only in Abaqus/Standard.)

In the first method you define individual elements by specifying the element number and the nodes that define the element.

In the second method you specify only the nodes on the bottom surface of the gasket element and a positive offset number that will be used to define the corresponding nodes for the top surface. For the 18-node gasket element you give the first eight nodes followed by the midsurface node; i.e., node 17 in the full element nodal connectivity.

Abaqus/Standard can generate the midface nodes of the 18-node gasket elements automatically if both element faces are part of contact surfaces. To invoke this feature, you enter a blank instead of the actual node numbers in either of the above input methods. Abaqus/Standard will then generate the node numbers and coordinates of the midface nodes automatically.

Input File Usage: Use the following option to specify the element number and the nodes that define the element:

∗ELEMENT, TYPE=*name*

Use the following option to specify the nodes on the bottom surface of the element and a positive offset number for the top surface:

∗ELEMENT, TYPE=*name*, OFFSET=*offset number*

Using solid element connectivity to define gasket elements

The node numbering scheme for gasket elements does not correspond to the node numbering scheme for continuum elements, which can be inconvenient if the mesh generator used does not support gasket elements directly or in thermal-stress analysis where continuum elements are used to model the heat conduction in the gasket. For such cases you can specify that solid element connectivity is used to define the gasket element. By default, it is assumed that the first (S1) face of the solid element coincides with the first (SNEG) face of the gasket element. If the equivalent solid element is oriented differently, specify the face number on the solid element that corresponds to the first face of the gasket element. The

solid element must have the same number of nodes on each face as the corresponding gasket element; any nodes between the faces will be ignored. The 18-node gasket element is an exception. If both element faces are part of contact surfaces, the connectivity of a 20-node brick element can be used, and Abaqus/Standard will generate the node numbers and coordinates of the midface nodes automatically.

Abaqus/Standard will transform the solid element connectivity to the normal gasket element connectivity immediately upon reading the data. Hence, all output to the data (**.dat**), results (**.fil**), and output database (**.odb**) files will use the normal gasket element connectivity.

Input File Usage: Use the following option to specify solid element connectivity for a gasket element in which the first face of the solid element corresponds to the first face of the gasket element:

*ELEMENT, TYPE=*name*, SOLID ELEMENT NUMBERING

Use the following option to specify solid element connectivity for a gasket element and the face of the solid element that corresponds to the first face of the gasket element:

*ELEMENT, TYPE=*name*, SOLID ELEMENT NUMBERING=*face number*

Examples

The following lines create GK3D12M element number 11 that has node numbers 1, 2, 3, 4, 5, 6, 1001, 1002, 1003, 1004, 1005, and 1006:

```
*ELEMENT, TYPE=GK3D12M
11, 1, 2, 3, 4, 5, 6, 1001, 1002, 1003, 1004, 1005, 1006
```

The same element connectivity is also created by the following lines:

```
*ELEMENT, TYPE=GK3D12M, OFFSET=1000
11, 1, 2, 3, 4, 5, 6
```

The equivalent solid element would be C3D15, with the following input:

```
*ELEMENT, TYPE=GK3D12M, SOLID ELEMENT NUMBERING
11, 1, 2, 3, 1001, 1002, 1003, 4, 5, 6, 1004, 1005, 1006,
501, 502, 503
```

where nodes 501, 502, and 503 would not be used.

Defining cohesive elements

There are three methods for defining cohesive elements. (See “Cohesive elements: overview,” Section 32.5.1; “Modeling with cohesive elements,” Section 32.5.3; and “Defining the cohesive element’s initial geometry,” Section 32.5.4, for more information on cohesive elements.)

- In the first method you specify the element number and all of the nodes that define the element.

- In the second method you specify only the nodes on the bottom face of the cohesive element and Abaqus will create the remaining nodes, numbering them according to an offset number that you specify.
- In the third method, which is applicable only to pore pressure cohesive elements, you specify the nodes on the bottom and top faces. Abaqus will create the remaining middle-face nodes according to an offset number that you specify.

Defining a cohesive element by specifying all nodes

With this method you specify all nodes that define the cohesive element. See "Two-dimensional cohesive element library," Section 32.5.8; "Three-dimensional cohesive element library," Section 32.5.9; and "Axisymmetric cohesive element library," Section 32.5.10, for the element node numbering definition.

Input File Usage: Use the following option to specify the element number and the nodes that define the element:

*ELEMENT, TYPE=*name*

For example, the following lines create COH3D8 element number 11 that has node numbers 1, 2, 3, 4, 1001, 1002, 1003, and 1004:

```
*ELEMENT, TYPE=COH3D8
11, 1, 2, 3, 4, 1001, 1002, 1003, 1004
```

Defining a cohesive element by specifying only the bottom face nodes

With this method you specify only the nodes on the bottom face of the cohesive element and a positive offset number. With displacement cohesive elements, the offset number is added to the bottom face node numbers to create the corresponding nodes on the top face. With pore pressure cohesive elements, the offset number first is added to the bottom face node numbers to create the corresponding nodes on the top face, then the offset number is added to the top face node numbers to create the corresponding nodes on the middle face.

Input File Usage: Use the following option to specify the nodes on the bottom face of the element and a positive offset number for nodes on the remaining face or faces:

*ELEMENT, TYPE=*name*, OFFSET=*offset number*

For example, the following lines create COH3D8 element number 11 that has node numbers 1, 2, 3, 4, 1001, 1002, 1003, and 1004:

```
*ELEMENT, TYPE=COH3D8, OFFSET=1000
11, 1, 2, 3, 4
```

and the following lines create pore pressure cohesive element COH3D8P element number 11 that has node numbers 1, 2, 3, 4, 1001, 1002, 1003, 1004, 2001, 2002, 2003, and 2004 (nodes 1, 2, 3, and 4 define the bottom face; nodes 1001, 1002, 1003, and 1004 define the top face; and nodes 2001, 2002, 2003, and 2004 define the middle face):

```
*ELEMENT, TYPE=COH3D8P, OFFSET=1000
11, 1, 2, 3, 4
```

Defining a pore pressure cohesive element by specifying only the bottom and top face nodes

With this method you specify only the nodes on the bottom and top faces of the pore pressure cohesive element and a positive offset number. The offset number is added to the bottom face node numbers to create the corresponding nodes on the middle face.

Input File Usage: Use the following option to specify the nodes on the bottom and top faces of the pore pressure cohesive element and a positive offset number for the remaining middle-face nodes:

*ELEMENT, TYPE=*name*, OFFSET=*offset number*

For example, the following lines create a pore pressure cohesive element COH3D8P element number 11 that has node numbers 1, 2, 3, 4, 1001, 1002, 1003, 1004, 2001, 2002, 2003, and 2004 (nodes 1, 2, 3, and 4 define the bottom face; nodes 1001, 1002, 1003, and 1004 define the top face; and nodes 2001, 2002, 2003, and 2004 define the middle face):

```
*ELEMENT, TYPE=COH3D8P, OFFSET=2000
11, 1, 2, 3, 4, 1001, 1002, 1003, 1004
```

Grouping elements into element sets

Element sets are used as convenient cross-references for defining loads, properties, etc. Element sets are the fundamental references of the model and should be used to assist the input definition. The members of an element set can be individual elements or other element sets. An individual element can belong to several element sets.

Elements can be grouped into element sets when they are created or after they have already been defined. In either case each element set is assigned a name. Element set names can be up to 80 characters long.

The same name can be used for a node set and for an element set.

All elements within an element set will be arranged in ascending order of their element number, and duplicates will be removed.

Once elements are assigned to an element set, additional elements can be added to the same element set; however, elements cannot be removed from an element set.

Assigning elements to an element set as they are created

There are several ways that elements can be assigned to element sets as they are created.

Input File Usage: Use any one of the following options:

*ELEMENT, ELSET=*name*
*ELGEN, ELSET=*name*
*ELCOPY, NEW SET=*name*

Assigning previously defined elements to an element set

You can assign elements that you have defined previously (by specifying their nodes, by generating them incrementally, or by copying existing elements) to an element set by listing the elements forming the set directly or by generating the element set.

Listing the elements that form the set directly

You can list the elements that form the element set directly. Previously defined element sets, as well as individual elements, can be assigned to element sets.

Input File Usage: *ELSET, ELSET=*name*

For example, the following lines add elements 3, 13, and 20 to set **LEFT**:

```
*ELSET, ELSET=LEFT
20
3, 13
```

The following lines add elements 5 and 16 to the existing set **LEFT**:

```
*ELSET, ELSET=LEFT
5, 16
** The above data line is equivalent to
specifying 5, 16, LEFT
```

The following lines add elements 22, 14, and all elements in set **LEFT** to set **B**:

```
*ELSET, ELSET=B
22, 14, LEFT
```

Thus, element set **B** contains the following elements: 3, 5, 13, 14, 16, 20, and 22. Element set **LEFT** can be assigned to element set **B** since the definition of **LEFT** occurs before the definition of **B**.

Generating the element set

To generate an element set, you must specify a first element, e_1; a last element, e_2; and the increment in element numbers between these elements, i. All elements going from e_1 to e_2 in steps of i will be added to the set. Therefore, i must be an integer such that $(e_2 - e_1)/i$ is a whole number (not a fraction). The default is $i = 1$.

Input File Usage: *ELSET, ELSET=*name*, GENERATE

For example, the following lines add elements 1, 3, 5, …, 19, 21 and elements 39, 49, 59, …, 129, 139 to set **UP**:

```
*ELSET, ELSET=UP, GENERATE
1, 21, 2
39, 139, 10
```

Limitation on updating element sets that are used to define other element sets

If an element set is constructed from previously defined element sets, subsequent updates to these sets are not taken into account.

Input File Usage: ∗ELSET, ELSET=*name*

For example, the following lines add elements 1 and 2, but not 3, to the set **SET-AB** while adding elements 1 and 3 to set **SET-A**:

```
*ELSET, ELSET=SET-A
1,
*ELSET, ELSET=SET-B
2,
*ELSET, ELSET=SET-AB
SET-A, SET-B
*ELSET, ELSET=SET-A
3,
```

Defining part and assembly sets

In a model defined in terms of an assembly of part instances, all element sets must be defined within a part, part instance, or the assembly definition. If an element set is defined within a part (or part instance), you can refer to the element numbers directly. To define an assembly-level element set, you must identify the elements to be added to the set by prefixing each element number with the part instance name and a "." (as explained in "Defining an assembly," Section 2.10.1). An assembly-level element set can have the same name as a part-level element set.

Example

The following input defines an element set, **set1**, that belongs to part **PartA** and will be inherited by every instance of **PartA**:

```
*PART, NAME=PartA
   ...
   *ELSET, ELSET=set1
    1,3,26,500
*END PART
```

An element set with the same name is defined at the assembly level as follows:

```
*ASSEMBLY, NAME=Assembly-1
   *INSTANCE, NAME=PartA-1, PART=PartA
    ...
   *END INSTANCE
   *INSTANCE, NAME=PartA-2, PART=PartA
    ...
   *END INSTANCE
```

```
   *ELSET, ELSET=set1
    PartA-1.1, PartA-1.3, PartA-1.26, PartA-1.500
    PartA-2.1, PartA-2.3, PartA-2.26, PartA-2.500
*END ASSEMBLY
```

Assembly-level element set **set1** contains all the elements from element sets **set1** belonging to part instances **PartA-1** and **PartA-2**. Therefore, the elements are assigned to two separate element sets: one at the part instance level and one at the assembly level. An assembly-level element set called **set1** could be created with entirely different elements than those that belong to the part set; part- and assembly-level element sets are independent. However, since in this example the same elements are assigned to both the part- and assembly-level element sets **set1**, the assembly-level set could alternatively be defined by

```
*ASSEMBLY, NAME=Assembly-1
   *INSTANCE, NAME=PartA-1, PART=PartA
    ...
   *END INSTANCE
   *INSTANCE, NAME=PartA-2, PART=PartA
    ...
   *END INSTANCE
   *ELSET, ELSET=set1
    PartA-1.set1, PartA-2.set1
*END ASSEMBLY
```

This element set definition is equivalent to the previous example, where the elements are listed individually.

Alternate method for defining assembly-level element sets

Sometimes it is not convenient to define an assembly-level element set by referring to part-level element sets. In such cases a set definition containing many elements can get quite lengthy. Therefore, an alternate method is provided.

Input File Usage: ∗ELSET, ELSET=*ElsetName*, INSTANCE=*InstanceName*

The following example shows two equivalent ways to define an assembly-level element set; once by prefixing each element number with a part instance name (as shown above) and once using the more compact INSTANCE notation:

```
*ASSEMBLY, NAME=Assembly-1
   *INSTANCE, NAME=PartA-1, PART=PartA
    ...
   *END INSTANCE
   *INSTANCE, NAME=PartA-2, PART=PartA
    ...
   *END INSTANCE
   *ELSET, ELSET=set2
```

```
 PartA-1.11, PartA-1.12, PartA-1.13, PartA-1.14,
 PartA-2.21, PartA-2.22, PartA-2.23, PartA-2.24
*ELSET, ELSET=set3, INSTANCE=PartA-1
 11, 12, 13, 14
*ELSET, ELSET=set3, INSTANCE=PartA-2
 21, 22, 23, 24
*END ASSEMBLY
```

When the *ELSET option is used more than once with the same name, as it is with **set3**, the elements in the second use of *ELSET are appended to the set created by the first use of *ELSET.

Internal element sets created by Abaqus/CAE

In Abaqus/CAE many modeling operations are performed by picking geometry with the mouse. For example, a surface can be created by picking a face on a geometric part instance. Since the *SURFACE option refers to an element set, this "picked" geometry must be translated into an element set in the input file. Such sets are assigned a name by Abaqus/CAE and marked as internal. You can view these internal sets using display groups in the Visualization module of Abaqus/CAE (see Chapter 78, "Using display groups to display subsets of your model," of the Abaqus/CAE User's Guide).

Input File Usage: *ELSET, ELSET=*ElsetName*, INTERNAL

Transferring of element sets

If the results of an Abaqus/Explicit analysis are imported into an Abaqus/Standard analysis (or vice versa) or results from an Abaqus/Standard analysis are imported into another Abaqus/Standard analysis (see "Transferring results between Abaqus analyses: overview," Section 9.2.1), all element set definitions in the original analysis are imported by default. Alternatively, you can import only selected element set definitions; see "Importing element set and node set definitions" in "Transferring results between Abaqus analyses: overview," Section 9.2.1, for details.

If a three-dimensional model is generated from a symmetric model (see "Symmetric model generation," Section 10.4.1), all element sets in the original model will be used (and expanded) in the generated model.

Creating elements from existing elements by generating them incrementally

You can generate elements incrementally from existing elements. The newly created elements are always the same element type as that of the master element.

Abaqus first generates a row of elements by copying the node pattern of a given element with prescribed increments in the node and element numbers. This row can then be repeated to form a layer, which can also be repeated to form a block.

To generate a row of elements, you must specify the following information:

- The master element number. The master element must exist at the time that the generation is specified, although it can be an element that has just been defined in this same element generation.

- The number of elements to be defined in the first row generated, including the master element.
- The increment in node numbers of corresponding nodes from element to element in the row. The default is 1. All element node numbers (except special-purpose nodes, discussed later) will increase by the same value.
- The increment in element numbers in the row. The default is 1.

To copy this newly created master row to create a layer of elements, you must specify the following additional information:

- The number of rows to be defined, including the master row.
- The increment in node numbers of corresponding nodes from row to row.
- The increment in element numbers of corresponding elements from row to row.

To copy this newly created master layer to create a block of elements, you must specify the following additional information:

- The number of layers to be defined, including the master layer.
- The increment in node numbers of corresponding nodes from layer to layer.
- The increment in element numbers of corresponding elements from layer to layer.

Input File Usage: *ELGEN

For example, the elements forming the quarter cylinder shown in Figure 2.2.1–1 can be generated by the following lines:

```
*ELGEN
1, 3, 1, 1, 5, 10, 10, 6, 100, 100
```

Incrementing special-purpose nodes

By default, the following nodes are not incremented:

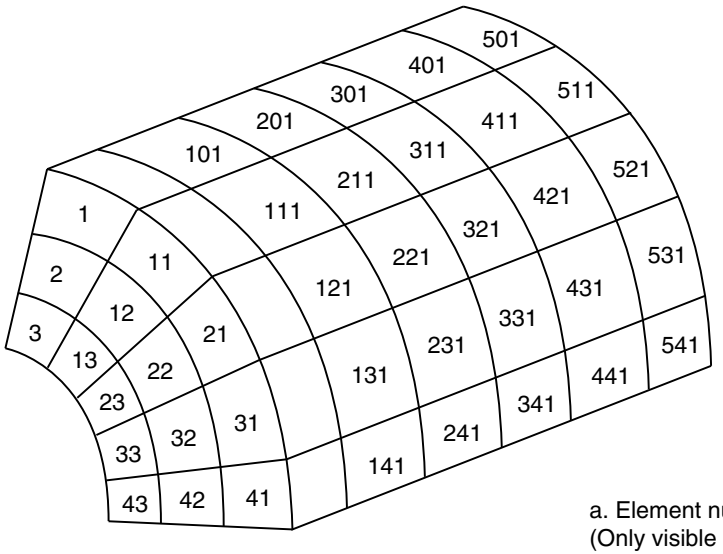
- rigid body reference nodes for IRS-type and drag chain elements; and
- nodes used to define the direction of the first cross-section axis for beams or frames in space.

You can specify that all nodes should be incremented. You define the increment between node numbers as described above. Usually the incrementation of all nodes is needed only for nodes used to define the direction of the first cross-section axis for beams in space.

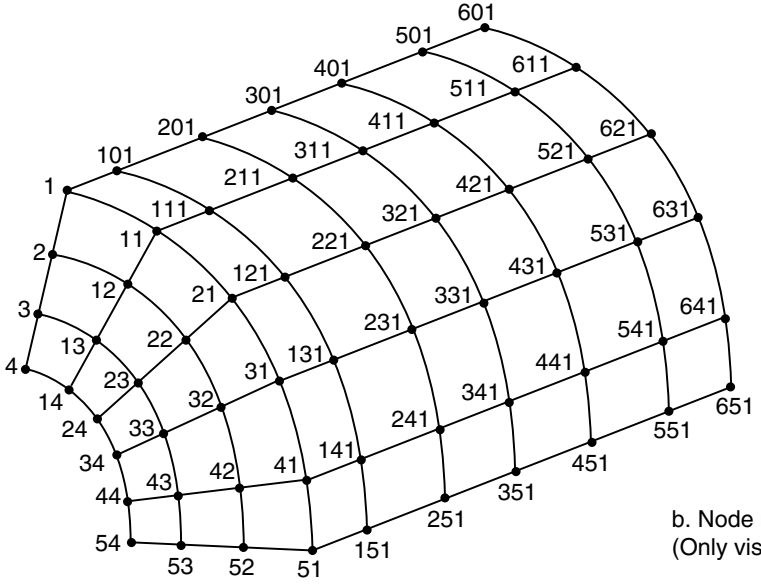
Input File Usage: *ELGEN, ALL NODES

Creating elements by copying existing elements

You can create new elements by copying existing elements. You must identify the existing element set to copy and specify an integer constant that will be added to the node numbers of the existing elements to define the node numbers of the new elements. Likewise, you must specify an integer constant that will be added to the element numbers of existing elements to define element numbers for the elements being created.



a. Element numbers
(Only visible elements shown).



b. Node numbers
(Only visible nodes shown).

Figure 2.2.1–1 Element generation example.

You can assign the newly created elements to an element set. If you do not specify an element set name for the newly created elements, they are not assigned to an element set.

Input File Usage: *ELCOPY, OLD SET=*name*, NEW SET=*new_name*,
SHIFT NODES=*number*, ELEMENT SHIFT=*number*

For example, the following data lines will generate new elements in set **B** that are copies of all elements in set **A** at the time this option is processed, with 1000 added to each element number and to each node number in the definitions of the new elements. The members of set **A** at the time the line is processed are those elements defined to be in set **A** by all element generation and element set definition lines that appear in the input file prior to this *ELCOPY option.

```
*ELCOPY, OLD SET=A, NEW SET=B, ELEMENT SHIFT=1000,
SHIFT NODES=1000
```

Special considerations for continuum elements

When copying existing elements, you can choose to modify the node numbering sequence for the elements being created to avoid creating continuum elements that violate the Abaqus convention for counterclockwise element numbering. This modification is normally required when the nodes have been generated by copying existing nodes ("Creating nodes by copying existing nodes" in "Node definition," Section 2.1.1).

Input File Usage: *ELCOPY, REFLECT

For example, assume element 1 is in element set **A** and is defined by nodes 1, 2, 3, 4. The following data line will generate element number 11, also in set **A**, with nodes 11, 14, 13, and 12:

```
*ELCOPY, OLD SET=A, NEW SET=A, ELEMENT SHIFT=10,
SHIFT NODES=10, REFLECT
```

If the REFLECT parameter is not used, the new element will be defined by the node sequence 11, 12, 13, 14 and will violate the counterclockwise element numbering convention used with continuum elements (see Figure 2.2.1–2).

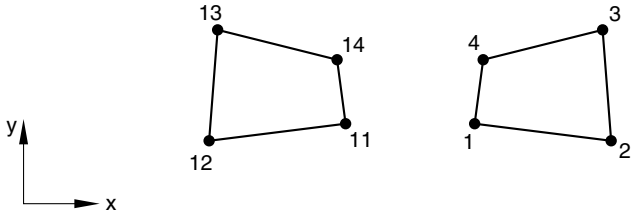


Figure 2.2.1–2 Example of modification of node numbering sequence.

2.2.2 ELEMENT FOUNDATIONS

Products: Abaqus/Standard Abaqus/CAE

References

- *FOUNDATION
- "Defining foundations," Section 15.13.20 of the Abaqus/CAE User's Guide, in the HTML version of this guide

Overview

Elastic element foundations:

- can be defined for stress/displacement elements in Abaqus/Standard according to the load identifiers described in Part VI, "Elements";
- act like springs to ground; and
- are a simple way of including the stiffness effects of a support (such as the soil under a building) without modeling the details of the support.

Defining element foundation behavior

Foundation pressures act normal to the element faces on which they are applied. In large-displacement analysis the direction of action of the foundation is based on the deformed configuration; foundations rotate with the element sides.

Convergence difficulties may arise with large-deformation problems since no corresponding foundation load stiffness terms are included in the element stiffness matrices.

To define the foundation behavior, you specify the foundation stiffness per unit area (per unit length for beams).

Input File Usage: Use the following option in the model definition portion of the input file:

*FOUNDATION

Abaqus/CAE Usage: Interaction module: **Create Interaction**: **Step: Initial**, **Elastic foundation**

2.2.3 DEFINING REINFORCEMENT

Products: Abaqus/Standard Abaqus/Explicit Abaqus/CAE

References

- *EMBEDDED ELEMENT
- *MEMBRANE SECTION
- *PRESTRESS HOLD
- *REBAR
- *REBAR LAYER
- *SHELL SECTION
- *SURFACE SECTION
- "Defining rebar layers," Section 12.13.19 of the Abaqus/CAE User's Guide, in the HTML version of this guide

Overview

Rebar:

- are used to define layers of uniaxial reinforcement in membrane, shell, and surface elements (such layers are treated as a smeared layer with a constant thickness equal to the area of each reinforcing bar divided by the reinforcing bar spacing);
- can be used to add layers of reinforcement in a solid by embedding reinforced surface or membrane elements in the "host" solid elements as described in "Embedded elements," Section 35.4.1;
- can be used to add additional stiffness, volume, and mass to the model;
- can be used to add discrete axial reinforcement in beam elements in Abaqus/Standard;
- can be used in coupled temperature-displacement analysis but do not contribute to the thermal conductivity and specific heat;
- can be used in coupled thermal-electrical-structural analysis but do not contribute to the electrical conductivity, thermal conductivity and specific heat;
- cannot be used in heat transfer or mass diffusion analysis; and
- have material properties that are distinct from those of the underlying or host element.
- do not include the mass or volume of the underlying elements.

Defining a rebar layer

You can specify one or multiple layers of reinforcement in membrane, shell, or surface elements. For each layer you specify the rebar properties including the rebar layer name; the cross-sectional area of each rebar; the rebar spacing in the plane of the membrane, shell, or surface element; the position of

the rebars in the thickness direction (for shell elements only), measured from the midsurface of the shell (positive in the direction of the positive normal to the shell); the rebar material name; the initial angular orientation, in degrees, measured relative to the local 1-direction; and the isoparametric direction from which the rebar angle output will be measured.

You can model rebar layers in solid (continuum) elements by embedding a set of surface or membrane elements with rebar layers defined as discussed above in a set of host continuum elements.

Input File Usage: Use the following options to define one or more rebar layers in membrane elements:

∗MEMBRANE SECTION, ELSET=*memb_set_name*
∗REBAR LAYER

Use the following options to define one or more rebar layers in shell elements:

∗SHELL SECTION, ELSET=*shell_set_name*
∗REBAR LAYER

Use the following options to define one or more rebar layers in surface elements:

∗SURFACE SECTION, ELSET=*surf_set_name*
∗REBAR LAYER

Use the following option to model rebar layers in solid (continuum) elements:

∗EMBEDDED ELEMENT, HOST ELSET=*solid_set_name*
memb_set_name or *surf_set_name*

Abaqus/CAE Usage: Property module: membrane, shell, or surface section editor: **Rebar Layers**

Interaction module: **Create Constraint**: **Embedded region**

Assigning a name to the rebar layer

You must assign each layer of rebar in a particular element or element set a separate name. This name can be used in defining rebar prestress and output requests.

Input File Usage: ∗REBAR LAYER
rebar layer name

Abaqus/CAE Usage: Property module: membrane, shell, or surface section editor: **Rebar Layers**: **Layer Name** *rebar layer name*

Specifying rebar geometry

The rebar geometry is always defined with respect to a local coordinate system. Defining an appropriate local system is described in the next section. The rebar geometry can be constant, vary as a function of radial position in a cylindrical coordinate system, or vary according to the tire "lift" equation. In each case you must specify the spacing, s, and the area, A, which are used to determine the thickness of the equivalent rebar layer, $t = A/s$, as well as the angular orientation, α, of the rebar with respect to this local system.

In addition, for shell elements you must specify the position of the rebars in the shell thickness direction measured from the midsurface of the shell (positive in the direction of the positive normal to

the shell). If the shell's thickness is defined by nodal thicknesses ("Nodal thicknesses," Section 2.1.3), this distance will be scaled by the ratio of the thickness defined by the nodal thickness to the thickness defined by the section definition. If the shell's thickness is defined with a distribution ("Distribution definition," Section 2.8.1), this distance is scaled by the ratio of the element thickness defined by the distribution to the default thickness.

Defining rebar with constant spacing

You can specify the geometry to be constant in the local rebar coordinate system. In this case the spacing, *s*, is specified as a length measure.

Input File Usage: *REBAR LAYER, GEOMETRY=CONSTANT

Abaqus/CAE Usage: Property module: membrane, shell, or surface section editor: **Rebar Layers**: **Rebar geometry: Constant**

Defining rebar spacing as a function of radial position

You can specify the spacing, *s*, in terms of angular spacing in degrees as shown in Figure 2.2.3–1.

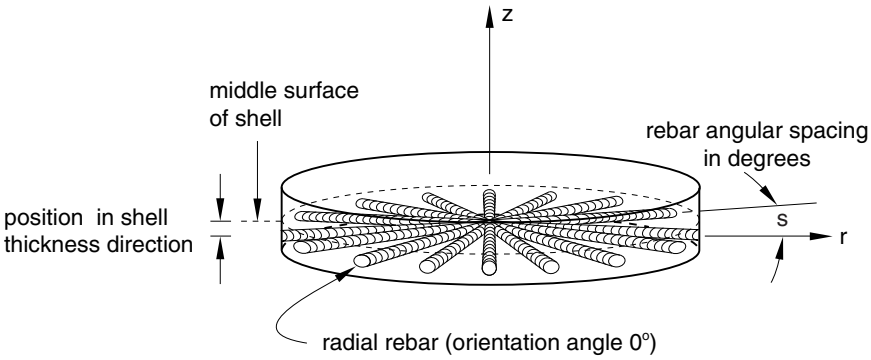


Figure 2.2.3–1 Example of radial rebars in axisymmetric shell elements.

Angular spacing values can also be used for non-radial rebars as well as for rebars having nonzero orientation angles from the meridional plane. In these cases the orientation angles of the rebars do not change. The angular spacing option is used only to compute the spacing between rebars in units of length by multiplying the angular spacing by the radial distance of the concerned point on the rebar from the axis of axisymmetry. A local cylindrical coordinate system must be defined for the rebar if the rebar is associated with three-dimensional elements.

Input File Usage: *REBAR LAYER, GEOMETRY=ANGULAR

Abaqus/CAE Usage: Property module: membrane, shell, or surface section editor: **Rebar Layers**: **Rebar geometry: Angular**

Defining rebar using the tire "lift" equation

Structural tire analysis is often performed using the cured tire geometry as the reference configuration for the finite element model. However, the cord geometry is more conveniently specified with respect to the "green," or uncured, tire configuration. The tire lift equation provides mapping from the uncured geometry to the cured geometry (see Figure 2.2.3–2).

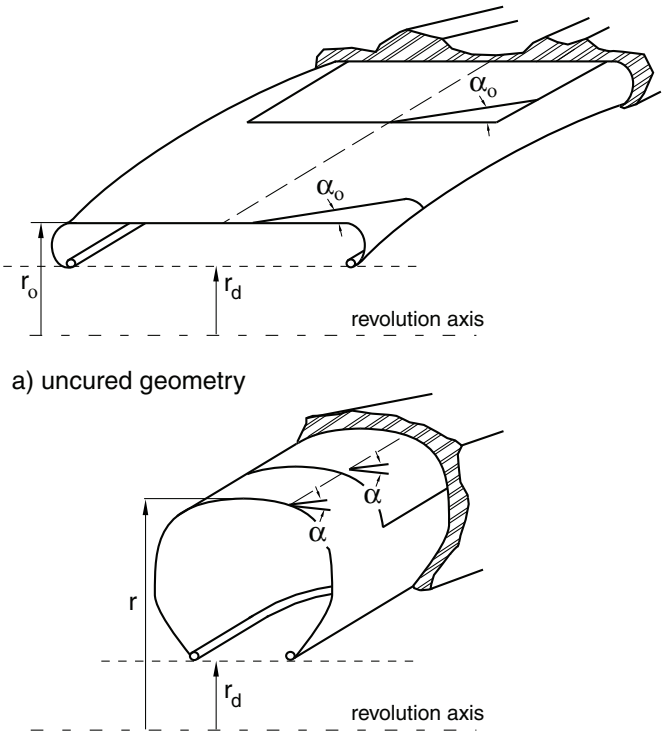


Figure 2.2.3–2 Mapping between uncured and cured tire rebar geometry.

You can specify the spacing and orientation of the rebar cords with respect to the uncured configuration and let Abaqus map these properties to the reference configuration of the cured tire. Using a cylindrical coordinate system, the spacing, s, and angular orientation, α, in the cured tire are obtained from

$$\sin\alpha = \frac{r\sin\alpha_0}{r_0(1+e)} \quad \text{and} \quad s = s_0\frac{r\cos\alpha}{r_0\cos\alpha_0},$$

where r is the position of the rebar along the radial direction in the cured geometry, r_0 is the position of the rebar in the uncured geometry, s_0 is the spacing in the uncured geometry, α_0 is the angle measured

with respect to the projected local 1-direction in the uncured geometry, and e is the cord extension ratio. In a tire e represents the pre-strain that occurs during the curing process; e =1 means a 100% extension. When α_0 is equal to 90°, the rebar is assumed to have a constant spacing of s_0.

A local cylindrical coordinate system must be defined for the rebar if the rebar is associated with three-dimensional elements.

Input File Usage: *REBAR LAYER, GEOMETRY=LIFT EQUATION

Abaqus/CAE Usage: Property module: membrane, shell, or surface section editor: **Rebar Layers**: **Rebar geometry: Lift equation–based**

Local rebar orientation system

The rebar geometry, such as rebar orientation and spacing, is defined with respect to a local orientation system. This local rebar orientation system is entirely independent from the local orientation system used for the underlying assignment.

The rebar angle is always defined with respect to the local 1-direction as shown in Figure 2.2.3–3.

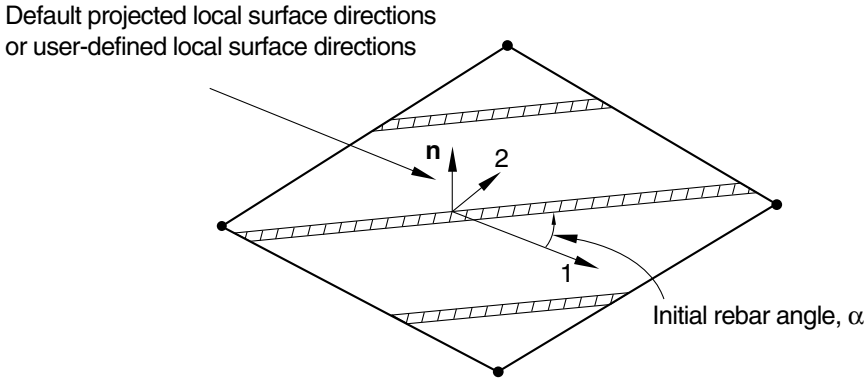


Figure 2.2.3–3 Rebar in a three-dimensional shell, membrane, or surface element.

Rebar defined with either angular spacing or spacing defined by the tire lift equation is specified with respect to a cylindrical orientation system. For axisymmetric analysis the global coordinate system is used as the cylindrical system. For three-dimensional analysis you must provide a user-defined cylindrical orientation definition.

Local orientation system for three-dimensional elements

You can define the local system by referring to a user-defined local coordinate system. See "Orientations," Section 2.2.5, for a description of how the local coordinate system is calculated from the user-defined directions for definition of rebar in shell, membrane, and surface elements.

If you do not specify a user-defined orientation, the local 1-direction is based on the default projected local coordinate system. See "Conventions," Section 1.2.2, for a definition of the default projected local directions on a surface in space.

A positive angle α defines a rotation from local direction 1 to local direction 2 around the element's normal direction or the user-defined normal direction. If the shell, membrane, or surface element is curved in space, the local 1-direction will vary across the element and the initial rebar angular orientation will also vary accordingly. The orientation definition that can optionally be associated with a shell or membrane section definition has no influence on the rebar angular orientation definitions. For example, in a membrane section, shell section, or surface section, the following data would result in the rebar layer definition shown in Figure 2.2.3–4: A=0.01; s=0.1; distance of rebar from the shell midsurface=0.0; α=30.; and the rebar definition refers to a local rectangular orientation defined to have its X-axis go through the point (−0.7071, 0.7071, 0.0), its $X - Y$ plane include the point (−0.7071, −0.7071, 0.0), and an additional rotation of 0.0 degrees about the 3-direction.

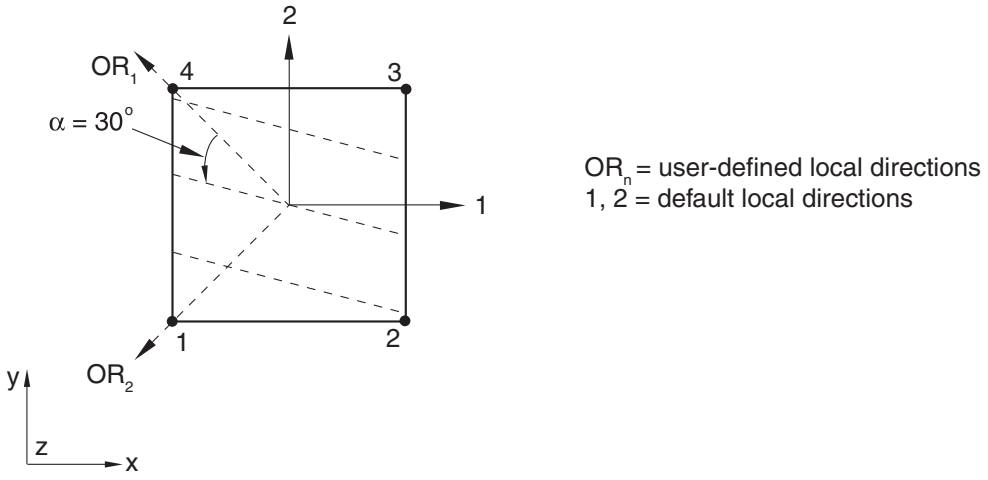


Figure 2.2.3–4 Rebar defined relative to user-defined local coordinate directions.

The following data would result in the rebar layer definition shown in Figure 2.2.3–5: A=0.01, s=0.1, distance of rebar from the shell midsurface=0.0, and α=45.

Input File Usage: Use the following options to define the local 1-direction for a rebar layer:

∗ORIENTATION, NAME=*name*
∗REBAR LAYER, ORIENTATION=*name*

Abaqus/CAE Usage: Property module:
Tools→Datum: **Type**: **CSYS**
Assign→Rebar Reference Orientation

Local orientation system for axisymmetric elements

Rebars in an axisymmetric membrane element or an axisymmetric surface element must lie in the element reference surface, whereas rebars in an axisymmetric shell can lie in the shell reference surface or can be offset from the midsurface. Rebars in axisymmetric membrane, shell, and surface elements can be

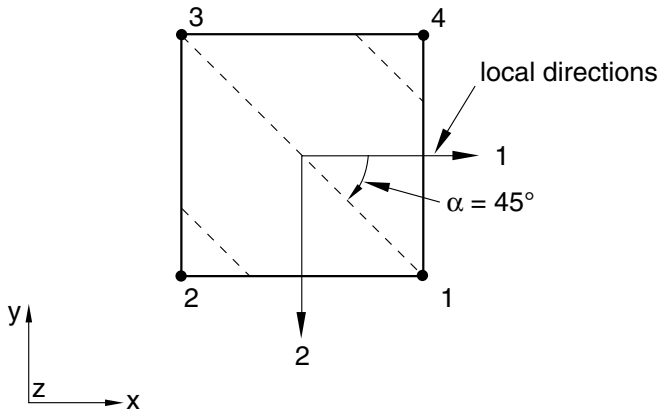


Figure 2.2.3–5 Rebar defined relative to default local coordinate directions.

defined to have any angular orientation with respect to the r–z plane. See Figure 2.2.3–6 for an example of circumferential rebars and Figure 2.2.3–1 for an example of radial rebars in axisymmetric shells.

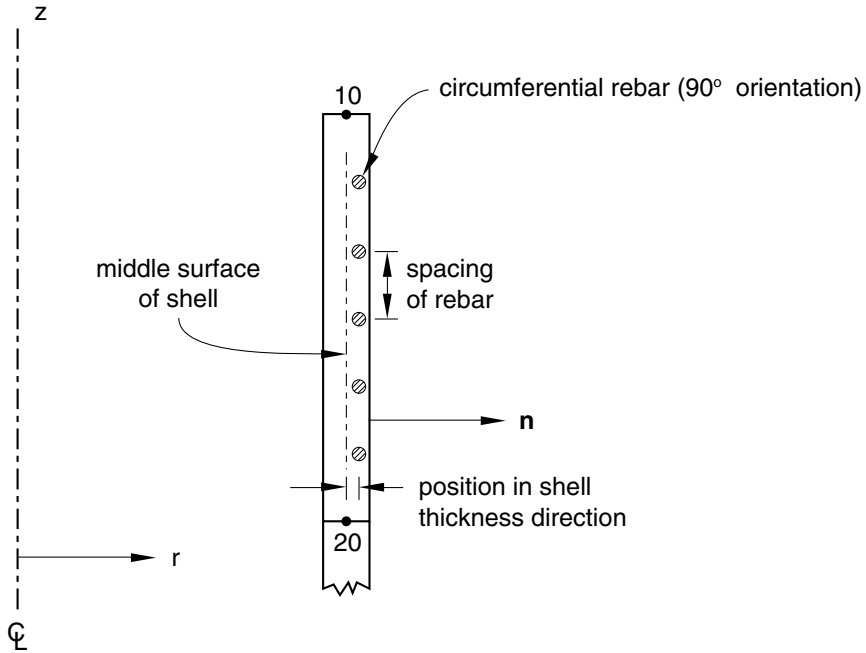


Figure 2.2.3–6 Example of circumferential rebars in axisymmetric shell elements.

You cannot specify a user-defined orientation for rebar layers in axisymmetric membrane, shell, and surface elements. Instead, in the rebar layer definition you specify the angular orientation of the rebar layer, in degrees, with respect to the r–z plane; this orientation is measured positive about the positive normal to the membrane, shell, or surface element.

If you specify an orientation angle other than 0° or 90° for rebar in an axisymmetric membrane without twist, axisymmetric shell, or axisymmetric surface without twist, Abaqus assumes that the rebars are balanced (i.e., half the rebar lie at the specified angle α and the other half at an angle of $-\alpha$) and internal calculations are handled accordingly. Such a rebar definition should not be used with the symmetric model generation capability ("Symmetric model generation," Section 10.4.1). The recommended modeling technique is to define unbalanced rebar in axisymmetric elements with twist. Balanced rebar, on the other hand, can be defined in regular axisymmetric elements or in axisymmetric elements with twist and should be defined by specifying half the rebar at the specified angle α and the other half at an angle of $-\alpha$.

Large-displacement considerations

In geometrically nonlinear analyses as the rebar-reinforced element deforms, the initially defined geometric properties and orientation of the rebar layer can change as a result of finite-strain effects. The deformation of the rebar layer is determined from the deformation gradient of the underlying shell, membrane, or surface element. Rebars rotate with the actual deformation and not with the average rigid body rotation of the material point in the underlying element. See "Rebar modeling in shell, membrane, and surface elements," Section 3.7.3 of the Abaqus Theory Guide, for details.

For example, consider a plate modeled with a first-order element under large pure shear deformation as shown in Figure 2.2.3–7, where rebars are initially aligned with the element isoparametric directions.

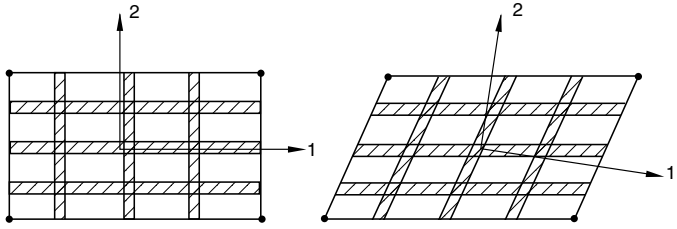


Figure 2.2.3–7 Rebar orientation evolves in a geometrically nonlinear analysis.

As a result of finite-strain effects, rebars rotate but remain aligned with the element isoparametric directions. If the same problem is modeled using anisotropic material properties rather than rebars and the material directions (1 and 2) are initially aligned with the element isoparametric directions, under such large shear deformation the material directions rotate and are no longer aligned with the element isoparametric directions. The material directions in this case are determined based on the average rigid body rotation of the material point. Hence, if the material is not truly a continuum, the anisotropic behavior is better modeled with rebars.

Defining rebar in Abaqus/Standard beam elements

You must use element-based rebar, described in "Defining rebar as an element property," Section 2.2.4, to model discrete rebar in beam elements in Abaqus/Standard. You specify the elements that contain the rebar, the cross-sectional area of each rebar, and the location of each rebar with respect to the local beam section axis (see Figure 2.2.3–8).

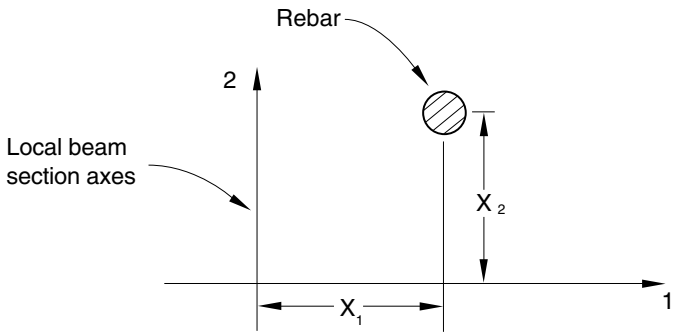


Figure 2.2.3–8 Rebar location in a beam section.

Each individual rebar must be assigned a separate name in a particular element or element set. This name can be used in defining rebar prestress and output requests.

Input File Usage: ∗REBAR, ELEMENT=BEAM, MATERIAL=*mat*, NAME=*name*

Abaqus/CAE Usage: Rebar in Abaqus/Standard beam elements are not supported in Abaqus/CAE.

Defining the rebar material

The material properties of the rebars are distinct from those of the underlying element and are defined by a separate material definition ("Material data definition," Section 21.1.2). You must associate each rebar layer (or, for beam elements in Abaqus/Standard, each rebar definition) with a set of material properties.

The following material behavior cannot be used in Abaqus/Standard to define rebar materials:

- "Porous metal plasticity," Section 23.2.9.

The following material behaviors cannot be used in Abaqus/Explicit to define rebar materials:

- "Defining fully anisotropic elasticity" in "Linear elastic behavior," Section 22.2.1;
- "Defining orthotropic elasticity by specifying the terms in the elastic stiffness matrix" in "Linear elastic behavior," Section 22.2.1;
- "Equation of state," Section 25.2.1;
- "Anisotropic yield/creep," Section 23.2.6;
- "Porous metal plasticity," Section 23.2.9;
- "Extended Drucker-Prager models," Section 23.3.1;

- "Modified Drucker-Prager/Cap model," Section 23.3.2;
- "Crushable foam plasticity models," Section 23.3.5; or
- "Cracking model for concrete," Section 23.6.2.

Although Abaqus/Standard will allow for a rebar material to be defined with orthotropic elasticity ("Defining orthotropic elasticity by specifying the terms in the elastic stiffness matrix" in "Linear elastic behavior," Section 22.2.1) or anisotropic elasticity ("Defining fully anisotropic elasticity" in "Linear elastic behavior," Section 22.2.1), D_{1111} is the only meaningful material constant in these definitions. D_{1111} is used to compute the strain in the rebar direction, ε_{11}, using the corresponding stress component, σ_{11}, as discussed in "Linear elastic behavior," Section 22.2.1; no other strain or stress components exist in rebars.

If a nonzero density is specified for the material in a rebar layer, the mass of the rebar is taken into account for dynamic analysis as well as for gravity, centrifugal, and rotary acceleration distributed loads.

The mass is not taken into account for rebar in beam elements (available only in Abaqus/Standard); you should adapt the density of the beam material to account for the rebar mass.

Input File Usage: *REBAR LAYER
rebar layer name, *A*, *s*, *distance of rebar from shell midsurface*, *rebar material name*

Abaqus/CAE Usage: Property module: membrane, shell, or surface section editor: **Rebar Layers**: **Material** *rebar material name*

Initial conditions

Initial conditions ("Initial conditions in Abaqus/Standard and Abaqus/Explicit," Section 34.2.1) can be used to define prestress or solution-dependent values for rebars.

Defining prestress in rebar

For structures in which reinforcing is defined (such as reinforced concrete structures), you can use initial conditions to define the prestress in the rebars.

In such cases in Abaqus/Standard the structure must be brought to a state of equilibrium before it is actively loaded by means of an initial static analysis step ("Static stress analysis," Section 6.2.2) with no external loads applied (or, perhaps, with the "dead" loads only)—see "Initial conditions in Abaqus/Standard and Abaqus/Explicit," Section 34.2.1.

Input File Usage: *INITIAL CONDITIONS, TYPE=STRESS, REBAR
element number or element set name, rebar name, prestress value

Abaqus/CAE Usage: Rebar prestress is not supported in Abaqus/CAE.

Holding prestress in rebar in Abaqus/Standard

If prestress is defined in the rebars and unless the prestress is held fixed, it will be allowed to change during an equilibrating static analysis step; this is a result of the straining of the structure as the self-equilibrating stress state establishes itself. An example is the pretension type of concrete prestressing in which reinforcing tendons are initially stretched to a desired tension before being covered by concrete.

After the concrete cures and bonds to the rebar, release of the initial rebar tension transfers load to the concrete, introducing compressive stresses in the concrete. The resulting deformation in the concrete reduces the stress in the rebar.

Alternatively, you can keep the initial stress defined in some or all of the rebars constant during this initial equilibrium solution. An example is the post-tension type of concrete prestressing; the rebars are allowed to slide through the concrete (normally they are in conduits), and the prestress loading is maintained by some external source (prestressing jacks). The magnitude of the prestress in the rebar is normally part of the design requirements and must not be reduced as the concrete compresses under the loading of the prestressing. Normally, the prestress is held constant only in the first step of an analysis. This is generally the more common assumption for prestressing.

If the prestress is not held constant in analysis steps following the step in which it is held constant, the stress in the rebar will change due to additional deformation in the concrete. If there is no additional deformation, the stress in the rebar will remain at the level set by the initial conditions. If the loading history is such that no plastic deformation is induced in the concrete or rebar in steps subsequent to the steps in which the prestress is held constant, the stress in the rebar will return to the level set by the initial conditions upon removal of the loading applied in those steps.

Input File Usage: *PRESTRESS HOLD

Abaqus/CAE Usage: Rebar prestress is not supported in Abaqus/CAE.

Defining the initial values of solution-dependent state variables for rebars

You can define the initial values of solution-dependent state variables for rebars within elements. See "Initial conditions in Abaqus/Standard and Abaqus/Explicit," Section 34.2.1, for details.

Input File Usage: *INITIAL CONDITIONS, TYPE=SOLUTION, REBAR

Abaqus/CAE Usage: Initial solution-dependent state variables are not supported in Abaqus/CAE.

Output

Rebar force output is available at the rebar integration locations with output variable RBFOR. The rebar force is equal to the rebar stress times the current rebar cross-sectional area. The current cross-sectional area of the rebar is calculated by assuming the rebar is made of an incompressible material, regardless of the actual material definition. For rebars in membrane, shell, or surface elements output variables RBANG and RBROT identify the current orientation of rebar within the element and the relative rotation of the rebar as a result of finite deformation, respectively. These quantities are measured with respect to the user-specified isoparametric direction in the element, not the default local element system or the orientation-defined system. See "Rebar modeling in shell, membrane, and surface elements," Section 3.7.3 of the Abaqus Theory Guide.

See "Abaqus/Standard output variable identifiers," Section 4.2.1, and "Abaqus/Explicit output variable identifiers," Section 4.2.2, for information on additional output quantities such as stress and strain. For rebars in membrane, shell, or surface elements with multiple integration points, output quantities are available at the integration points and at the centroid of the element.

Specifying the direction for rebar angle output

The output quantities RBANG and RBROT can be measured from either of the isoparametric directions in the plane of the membrane, shell, or surface elements. You can specify the desired isoparametric direction from which the rebar angle will be measured (1 or 2). The rebar angle is measured from the isoparametric direction to the rebar with a positive angle defined as a counterclockwise rotation around the element's normal direction. The default direction is the first isoparametric direction.

In axisymmetric shell, surface, and membrane elements the first isoparametric direction coincides with the meridional direction, and the second isoparametric direction coincides with the hoop direction. In triangular elements Abaqus defines the isoparametric directions as follows: for a 3-node triangle the first isoparametric direction is a straight line going from node 1 to the midpoint of the second element edge, and the second isoparametric direction is a straight line going from the midpoint of the first element edge to the midpoint of the third element edge; for a 6-node triangle the first isoparametric direction is a straight line going from node 1 to node 5, and the second isoparametric direction is a straight line going from node 4 to node 6 (see "Element library: overview," Section 27.1.1, for the element node ordering).

Input File Usage: *REBAR LAYER
rebar layer name, *A*, *s*, *distance of rebar from shell midsurface*,
rebar material name, *angular orientation of rebar*, *isoparametric direction*

Abaqus/CAE Usage: You cannot specify the direction for rebar angle output in Abaqus/CAE; the first isoparametric direction is always used.

Example

As an example, a user-defined local coordinate system is used to define rebar in a shell element ($\alpha = 30°$), and the output value of RBANG is 75°, as illustrated in Figure 2.2.3–9:

```
*REBAR LAYER, ORIENTATION=ORIENT
 Rbname, 0.01, 0.1, 0.0, Rbmat, 30., 2
*ORIENTATION, SYSTEM=RECTANGULAR, NAME=ORIENT
 -0.7071, 0.7071, 0.0, -0.7071, -0.7071, 0.0
 3, 0.0
```

The rebars are located at the midsurface of the shell. Output variable RBANG is measured from the second isoparametric direction to the rebar. If the first isoparametric direction were chosen instead, output variable RBANG would report an angle of 165°.

Visualizing rebar orientation and results in rebar

Abaqus/CAE supports visualization of rebar direction and results in rebar layers. Plots of rebar orientation are available only if you request element output for rebars (see "Element output" in "Output to the output database," Section 4.1.3). Element variables for rebar can be contoured as field output or plotted as history output in the Visualization module. Each rebar layer will have a unique name and represents one additional section point in a membrane, shell, or surface element. You can select a

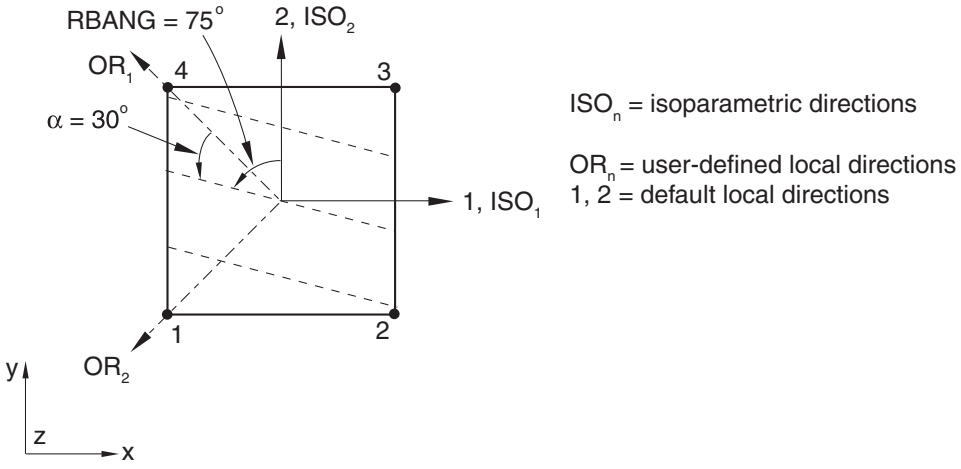


Figure 2.2.3–9 RBANG measurement for rebar defined relative to user-defined local coordinate directions.

named rebar layer in a membrane, shell, or surface element to display its results in the Visualization module. Abaqus/CAE does not yet support rebar in beams.

2.2.4 DEFINING REBAR AS AN ELEMENT PROPERTY

Products: Abaqus/Standard Abaqus/Explicit

References

- *PRESTRESS HOLD
- *REBAR

Overview

The preferred method for defining rebar in shell and membrane elements is defining layers of reinforcement as part of the element section definition (documented in "Defining reinforcement," Section 2.2.3). The preferred method for defining rebar in solids is embedding reinforced surface or membrane elements in "host" solid elements as described in "Embedded elements," Section 35.4.1. This section describes an alternative method of defining rebar in shell, membrane, and continuum elements as an element property. This method is more cumbersome than the method described in "Defining reinforcement," Section 2.2.3, and does not allow visualization of the rebar and rebar results in Abaqus/CAE.

Element-based rebars:

- are used to define uniaxial reinforcement in solid, membrane, and shell elements;
- can be defined as individual reinforcing bars in solid elements;
- can be defined as layers of uniformly spaced reinforcing bars in shell, membrane, and solid elements (such layers are treated as a smeared layer with a constant thickness equal to the area of each reinforcing bar divided by the reinforcing bar spacing);
- can be used with coupled temperature-displacement elements but do not contribute to the thermal conductivity and specific heat;
- can be used with coupled thermal-electrical-structural elements but do not contribute to the electrical conductivity, thermal conductivity and specific heat;
- do not contribute to the mass of the model in Abaqus/Standard;
- cannot be used in elements intended for heat transfer or mass diffusion analysis;
- cannot be used with triangular shell and membrane elements or with triangular, triangular prism, and tetrahedral solid elements; and
- have material properties that are distinct from those of the underlying element.

Assigning a name to the rebar set

You must assign a name to the rebar set. This name can be used in defining rebar prestress and output requests. Each layer of rebar must be assigned a separate name in a particular element or element set.

Input File Usage: *REBAR, ELEMENT=*elem*, MATERIAL=*mat*, NAME=*name*

Defining rebars in three-dimensional shell and membrane elements

Both isoparametric and skew rebars can be defined in three-dimensional shell and membrane elements. Rebars cannot be used with triangular shells or membranes.

If triangular-shaped shells or membranes are needed, collapsed quadrilateral shells or membranes can be used. The resulting rebar directions will depend on the type of rebar (isoparametric or skew) used. The rebar must be defined carefully since the element is distorted. This technique should be used only in regions of the mesh where results are not critical and stress gradients are not high.

The stiffness calculations for the rebars use the same integration points as the calculations for the underlying shell or membrane elements. See "Shell elements: overview," Section 29.6.1, and "Membrane elements," Section 29.1.1, for more information about shell and membrane elements.

Defining isoparametric rebars in three-dimensional shell and membrane elements

Isoparametric rebars are aligned along the mapping of constant isoparametric lines in the element (see Figure 2.2.4–1).

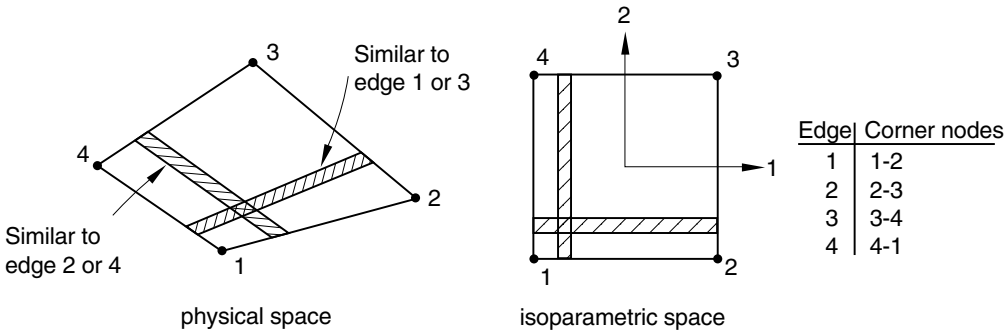


Figure 2.2.4–1 "Isoparametric" rebar in an undistorted three-dimensional shell or membrane element.

If opposite edges of the element containing the rebar are not parallel, the rebar directions will be different at each of the integration points within an element (see Figure 2.2.4–2).

The spacing of the rebar will be fixed in physical space. The spacing, s, and the area of the rebar, A, are used to determine the thickness of the equivalent smeared layer, $t = A/s$. If the edges of the element containing the rebar are not parallel, the number of actual rebar with this spacing passing through one edge will be different than the number passing through the opposite edge (opposite in isoparametric space).

You specify the elements that contain the rebars; the cross-sectional area, A, of each rebar; the rebar spacing in the plane of the shell, s; and the edge number to which the rebars are parallel when plotted in isoparametric space (see Figure 2.2.4–1). In addition, for shell elements you specify the position of the rebars in the shell thickness direction measured from the midsurface of the shell (positive in the direction of the positive normal to the shell). If the shell's thickness is defined by nodal thicknesses

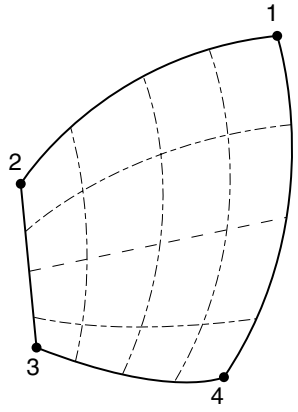


Figure 2.2.4–2 "Isoparametric" rebar directions in a distorted three-dimensional shell or membrane element (dashed lines indicate rebar directions).

("Nodal thicknesses," Section 2.1.3), this distance is scaled by the ratio of the thickness defined by the nodal thickness to the thickness defined by the section definition. If the shell's thickness is defined with a distribution ("Distribution definition," Section 2.8.1), this distance is scaled by the ratio of the element thickness defined by the distribution to the default thickness. If the shell has a composite section whose layer thicknesses are defined with distributions ("Distribution definition," Section 2.8.1), this distance is scaled by the ratio of the sum of the element layer thicknesses defined by the distributions to the sum of the default layer thicknesses.

Input File Usage: Use the following option to define isoparametric rebars in three-dimensional shell elements:

∗REBAR, ELEMENT=SHELL, MATERIAL=*mat*, GEOMETRY=ISOPARAMETRIC

Use the following option to define isoparametric rebars in general membrane elements:

∗REBAR, ELEMENT=MEMBRANE, MATERIAL=*mat*, GEOMETRY=ISOPARAMETRIC

Defining skew rebars in three-dimensional shell and membrane elements

Skew rebars need not be similar to an element edge; they can lie at any prescribed angle from the local 1-axis. The direction of the rebars must be defined in one of two ways, as indicated in Figure 2.2.4–3:

1. The rebars can be defined relative to the default projected local coordinate system (see "Conventions," Section 1.2.2).
2. The rebars can be defined relative to a user-defined local coordinate system (see "Orientations," Section 2.2.5).

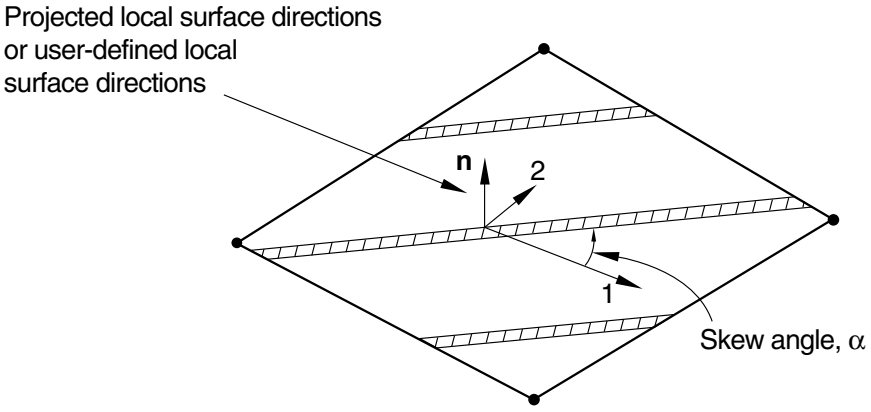


Figure 2.2.4–3 "Skew" rebar in a three-dimensional shell or membrane.

The orientation definition that can optionally be associated with a shell or membrane section definition has no influence on the rebar angular orientation definitions. If the shell or membrane is curved in space, the local 1-direction will vary across the element and the skew rebar will also vary accordingly.

For shell elements the definition of a local coordinate system using distributions ("Distribution definition," Section 2.8.1) has no influence on the rebar angular orientation definitions.

If the rebar cross-sectional area is A, the rebar spacing, s, should be given so that the thickness of the equivalent "smeared" layer of reinforcing is $t = A/s$.

Defining skew rebars relative to the default projected local coordinate system

To define skew rebars relative to the default projected local coordinate system, you specify the elements that contain the rebars; the cross-sectional area, A, of each rebar; the rebar spacing in the plane of the shell, s; the position of the rebars in the thickness direction (for shell elements only), measured from the midsurface of the shell (positive in the direction of the positive normal to the shell); and the angle α, in degrees, between the default local 1-direction and the rebars. See "Conventions," Section 1.2.2, for a definition of the default projected local directions on a surface in space. If the shell's thickness is defined by nodal thicknesses ("Nodal thicknesses," Section 2.1.3), the rebar position in the thickness direction will be scaled by the ratio of the thickness defined by the nodal thickness to the thickness defined by the section definition. If the shell's thickness is defined with a distribution ("Distribution definition," Section 2.8.1), the rebar position in the thickness direction is scaled by the ratio of the element thickness defined by the distribution to the default thickness. A positive angle α defines a rotation from local direction 1 to local direction 2 around the element's normal direction. For example, in a membrane the following data would result in the rebar definition shown in Figure 2.2.4–4: A=0.05, s=0.1, and α=45.

When a user-defined local orientation definition is not used to define the angular orientation of the rebar and the normal to the shell is nearly parallel to the global 1-axis, the local 1-axis may change significantly within an element or from one element to the next (see "Conventions," Section 1.2.2).

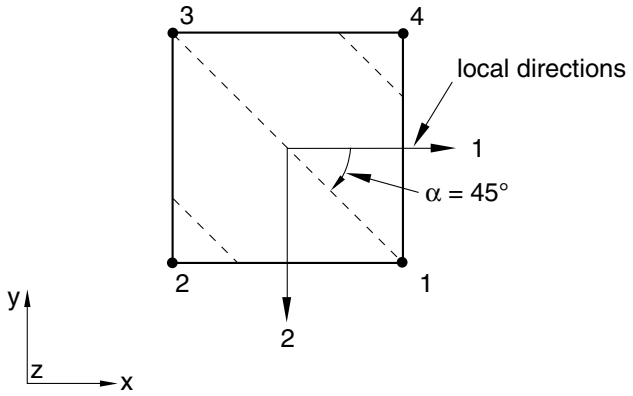


Figure 2.2.4–4 Skew rebar defined relative to default local coordinate directions.

Input File Usage: Use the following option to define skew rebars relative to the default projected local coordinate system in three-dimensional shell elements:

∗REBAR, ELEMENT=SHELL, MATERIAL=*mat*, GEOMETRY=SKEW

Use the following option to define skew rebars relative to the default projected local coordinate system in general membrane elements:

∗REBAR, ELEMENT=MEMBRANE, MATERIAL=*mat*, GEOMETRY=SKEW

Defining skew rebars relative to a user-defined local coordinate system

To define skew rebars relative to a user-defined local coordinate system, you specify the elements that contain the rebars; the cross-sectional area, A, of each rebar; the rebar spacing in the plane, s; the position of the rebars in the thickness direction (for shell elements only), measured from the midsurface of the shell (positive in the direction of the positive normal to the shell); and the angle, α, in degrees, between the user-defined 1-direction and the rebars. See "Orientations," Section 2.2.5, for a description of how the local coordinate system is calculated from the user-defined directions for definition of rebar in shells and membranes. A positive angle α defines a rotation from local direction 1 to local direction 2 around the user-defined normal direction. For example, in a shell the following data would result in the skew rebar definition shown in Figure 2.2.4–5: A=0.01; s=0.1; distance of rebar from the shell midsurface=0.0; α=30.; and the rebar definition refers to a local rectangular orientation defined to have its X-axis go through the point (−0.7071, 0.7071, 0.0), its X–Y plane include the point (−0.7071, −0.7071, 0.0), and an additional rotation of 0.0 degrees about the 3-direction.

Input File Usage: Use the following option to define skew rebars relative to a user-defined local coordinate system in three-dimensional shell elements:

∗REBAR, ELEMENT=SHELL, MATERIAL=*mat*, GEOMETRY=SKEW, ORIENTATION=*name*

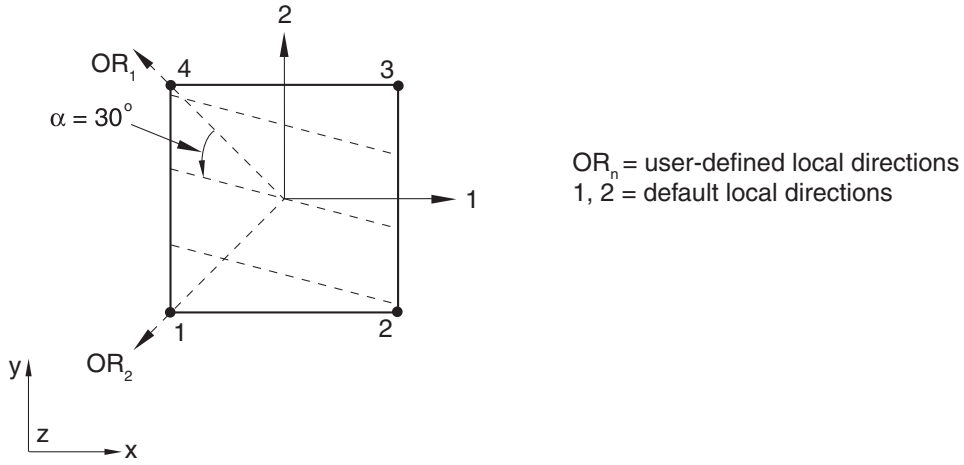


Figure 2.2.4–5 Skew rebar defined relative to user-defined local coordinate directions.

Use the following option to define skew rebars relative to a user-defined local coordinate system in general membrane elements:

∗REBAR, ELEMENT=MEMBRANE, MATERIAL=*mat*, GEOMETRY=SKEW, ORIENTATION=*name*

Defining rebars in axisymmetric shell and membrane elements

Rebars in an axisymmetric membrane must lie in the membrane reference surface, whereas rebars in an axisymmetric shell can lie in the shell reference surface or can be offset from the midsurface. Rebars in axisymmetric shells and membranes can be defined to have any orientation with respect to the *r*–*z* plane. See Figure 2.2.4–6 for an example of circumferential rebars and Figure 2.2.4–7 for an example of radial rebars in axisymmetric shells.

You specify the cross-sectional area, A, of each rebar; the rebar spacing, s; for shell elements the position of the rebars in the shell thickness direction, measured from the midsurface of the shell (positive in the direction of the positive normal to the shell); the angular orientation with respect to the *r*–*z* plane, α, measured in degrees; and the radial position at which the rebar spacing is measured. The angular orientation is measured positive about the positive normal to the shell or membrane element. If the shell's thickness is defined by nodal thicknesses ("Nodal thicknesses," Section 2.1.3), the distance from the midsurface will be scaled by the ratio of the thickness defined by the nodal thickness to the thickness defined by the section definition. If the shell's thickness is defined with a distribution ("Distribution definition," Section 2.8.1) the distance from the midsurface will be scaled by the ratio of the element thickness defined by the distribution to the default thickness.

If an orientation angle other than 0 or 90° is specified for rebar in an axisymmetric shell or membrane without twist, Abaqus assumes that the rebars are balanced (i.e., half the rebar lie at the specified angle α and the other half at an angle of $-\alpha$) and internal calculations are handled accordingly.

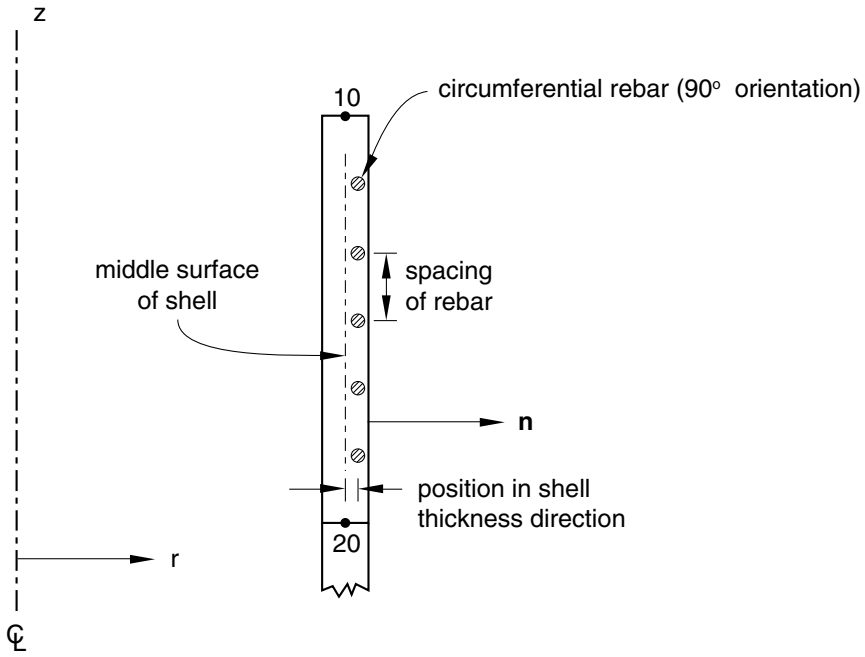


Figure 2.2.4–6 Example of circumferential rebars in axisymmetric shell elements.

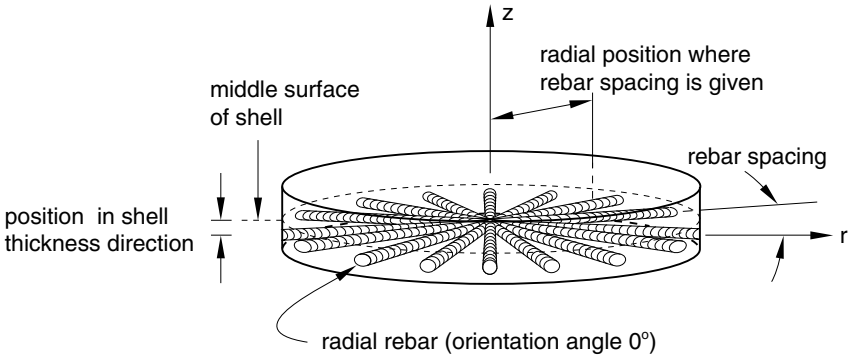


Figure 2.2.4–7 Example of radial rebars in axisymmetric shell elements.

See "Rebar modeling in two dimensions," Section 3.7.1 of the Abaqus Theory Guide, for details. If the symmetric model generation capability ("Symmetric model generation," Section 10.4.1) is used to create a three-dimensional model from an axisymmetric shell or membrane model, only balanced rebars will be translated appropriately. The definition of balanced rebars in the axisymmetric model will result in balanced rebars in the three-dimensional model; such a translation with unbalanced rebars is

not available. Unbalanced rebars in generalized axisymmetric membranes with twist will be translated properly.

If the radial position for the rebar spacing is given, the total cross-sectional area of rebar will remain constant as the radial position changes; this behavior corresponds to the number of rebar in the circumferential direction remaining constant and implies that the thickness of the smeared layer of rebar decreases and that the spacing of the rebars increases as r increases (see Figure 2.2.4–7). If the radial position for the rebar spacing is omitted (or is set to zero), Abaqus assumes that the spacing of the rebar remains constant; the thickness of the corresponding smeared layer is held fixed such that $t = A/s$.

Input File Usage: Use the following option to define rebars in an axisymmetric shell element:

∗REBAR, ELEMENT=AXISHELL, MATERIAL=*mat*

Use the following option to define rebars in an axisymmetric membrane element:

∗REBAR, ELEMENT=AXIMEMBRANE, MATERIAL=*mat*

Defining rebars in continuum elements

Two- or three-dimensional continuum (solid) elements can contain rebars; rebars cannot be defined in triangular, prism, tetrahedral, or infinite elements. If triangular or wedge-shaped elements are needed, collapsed quadrilateral or brick elements can be used. Be careful when collapsing elements that contain rebar. It is important to check that the location and orientation of the rebar are correct.

Rebars are defined as single bars or in layers. In the latter case the layer is a surface in each element; you provide the rebar orientation in the surface.

Defining layers of rebars in planar and axisymmetric continuum elements

By default, the rebars form a layer that lies in a surface that is at right angles to the plane of the model. You define the line where this rebar surface intersects the plane of the model, as described below.

The orientation of the rebars within the rebar surface is defined by giving an angle, in degrees, between the line of intersection in the plane of the model and the rebars. This angle is measured in physical three-dimensional space, not in isoparametric space. See "Rebar modeling in two dimensions," Section 3.7.1 of the Abaqus Theory Guide, for details. The positive direction along the line of intersection is from the lower to the higher numbered element edge that is intersected, and a positive angle indicates rebars oriented down into the plane of the model (where the plane is parallel to the z-axis in plane strain analysis or the θ-axis for axisymmetric analysis), as shown in Figure 2.2.4–8.

If an orientation angle other than 0 or 90° is specified for rebar in an axisymmetric element without twist, it is assumed that the rebar in the element are balanced (i.e., half the rebar lie at the specified angle α and the other half at the angle $-\alpha$).

Defining isoparametric rebars

For isoparametric rebars the intersection of the rebar layer with the plane of the model will lie along the mapping of a constant isoparametric line in the element. You specify the elements that contain the rebars; the cross-sectional area, A, of each rebar; the rebar spacing, s; the rebar orientation, α (as described

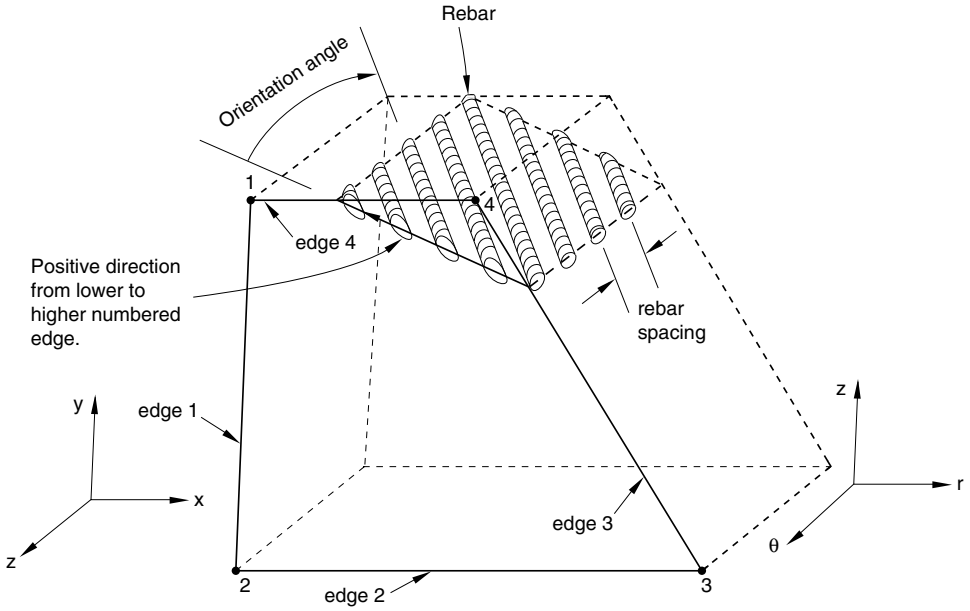


Figure 2.2.4–8 Orientation of rebars in plane and axisymmetric solid elements.

above); the fractional distance *from* the edge, f (the ratio of the distance between the edge and the rebar to the distance across the element); and the edge number from which the rebars are defined. In addition, for axisymmetric elements you specify the radial position at which the rebar spacing is measured.

If the radial position for the rebar spacing is given for rebar in axisymmetric elements, the total cross-sectional area of rebar will remain constant as the radial position changes; this behavior corresponds to the number of rebar remaining constant as r increases; that is, the thickness of the smeared layer of rebar decreases as r increases. If the radial position for the rebar spacing is omitted (or is set to zero), Abaqus assumes that the spacing of the rebar remains constant; the thickness of the corresponding smeared layer is held fixed such that $t = A/s$.

Figure 2.2.4–9 shows an example of isoparametric rebar. In the isoparametric mapping of the element, the line of rebars is parallel to one of the edges of the element. In this figure the line for rebar layer A can be defined using edges 1 or 3 and rebar layer B can be defined by edges 2 or 4. The fractional distance from edge 1 for rebar layer A is the ratio $f_1 = L_{A2}/L_2 = L_{A4}/L_4$; alternatively, layer A can be defined from edge 3, so that $f_3 = 1. - L_{A2}/L_2 = 1. - L_{A4}/L_4$.

Input File Usage: Use the following option to define layers of isoparametric rebars in planar and axisymmetric continuum elements:

∗REBAR, ELEMENT=CONTINUUM, MATERIAL=*mat*,
GEOMETRY=ISOPARAMETRIC

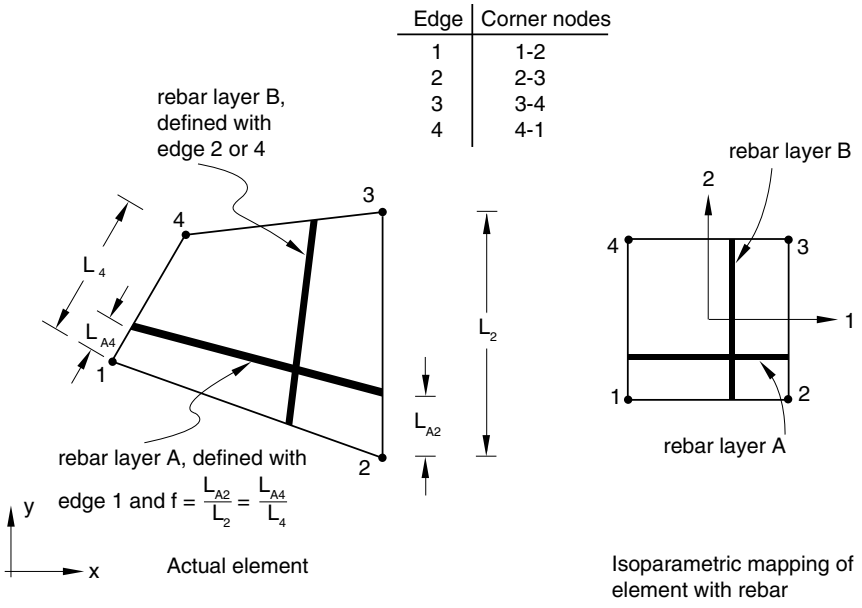


Figure 2.2.4–9 Isoparametric rebar layer definition in solid elements.

Defining skew rebars

For skew rebars the intersection of the rebar layer with the plane of the model can intersect any two edges of an element. You specify the elements that contain the rebars; the cross-sectional area, A, of each rebar; the rebar spacing, s; and the rebar orientation, α (as described above). In addition, for axisymmetric elements you specify the radial position at which the rebar spacing is measured. You also specify the fractional distance *along* the element edge, from the first node of the edge (as listed in Figure 2.2.4–10) to where the rebar layer intersects the edge, for all edges. Only the two values corresponding to the two edges that the rebar intersects can be nonzero.

Figure 2.2.4–10 shows an example of skew rebar. In the isoparametric mapping of the element, the line of rebars intersects two of the element edges. The intersection points are located by defining a fractional distance along each intersected edge. In this figure rebar layer A is defined by the ratio $f_1 = L_{A1}/L_1$ along edge 1 and the ratio $f_2 = L_{A2}/L_2$ along edge 2. Rebar layer B is defined by the ratio $f_3 = L_{B3}/L_3$ along edge 3 and the ratio $f_4 = L_{B4}/L_4$ along edge 4.

Defining skew rebars in continuum elements can increase the run time for an Abaqus/Explicit analysis significantly. The element's stable time increment will, in most cases, be determined by the stable time increment of the rebar, which is proportional to the rebar length. The rebar length is determined by factors including the rebar surface position in the element, the rebar spacing, the rebar area, and the rebar orientation within the rebar surface. If a skew rebar in a continuum element is defined

Edge	Corner nodes
1	1-2
2	2-3
3	3-4
4	4-1

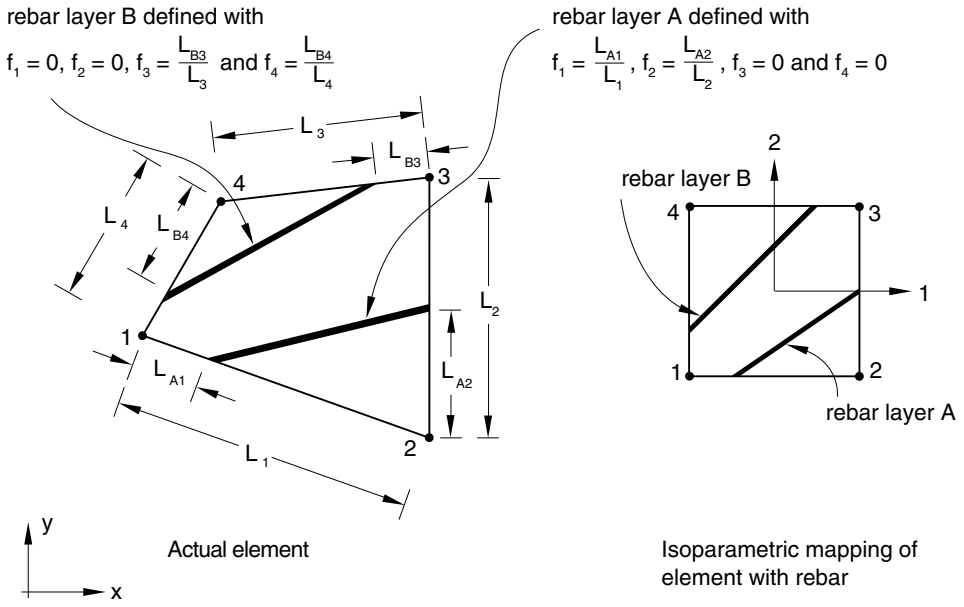


Figure 2.2.4–10 Skew rebar layer definition in solid elements.

such that it intersects two adjacent element edges, the resulting rebar length could be considerably less than the average element edge length, thus resulting in a very small element stable time increment.

Input File Usage: Use the following option to define layers of skew rebars in planar and axisymmetric continuum elements:

*REBAR, ELEMENT=CONTINUUM, MATERIAL=*mat*, GEOMETRY=SKEW

Defining single rebars in two-dimensional axisymmetric and generalized plane strain continuum elements

You can define single rebars in axisymmetric and generalized plane strain continuum elements. In this case the rebar is assumed to be at right angles with the plane of the model—in the thickness direction for generalized plane strain elements or the hoop direction for axisymmetric elements.

The intersection of the rebar with the plane of the model is defined by the fractional distances along edges 1 and 2 of the intersections of constant isoparametric lines that pass through the rebar location (see Figure 2.2.4–11). The fractional distances are measured from the first edge node listed in Figure 2.2.4–11.

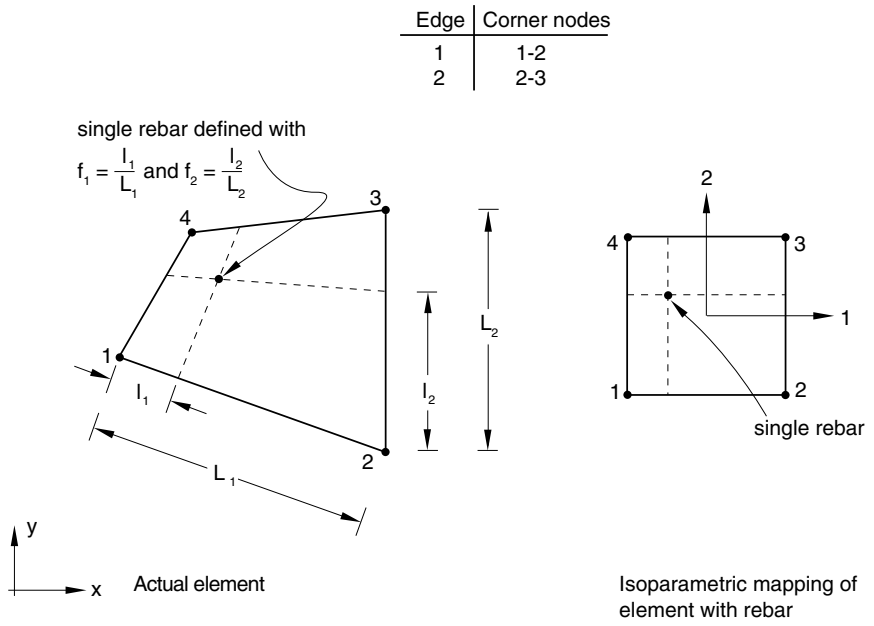


Figure 2.2.4–11 Single rebar in a solid element.

You specify the elements that contain the rebars; the cross-sectional area, A, of each rebar; and the fractional distances locating the rebar's position in the element, f_1 and f_2.

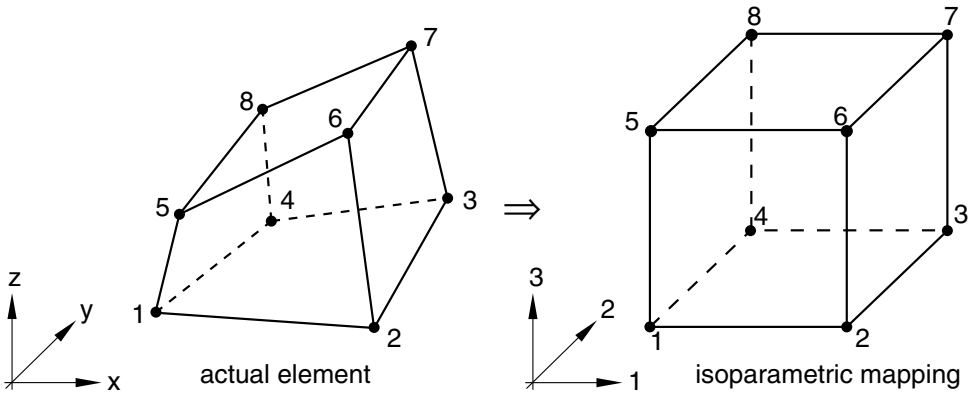
Input File Usage: Use the following option to define single rebars in axisymmetric and generalized plane strain continuum elements:

∗REBAR, ELEMENT=CONTINUUM, MATERIAL=*mat*, SINGLE

Defining layers of rebars in three-dimensional continuum elements

By default, the rebars in three-dimensional continuum elements are defined as layers lying in surfaces. The surfaces are most easily defined with respect to the isoparametric mapped cube of the element. Therefore, you must consider how the rebar will be defined before generating the mesh; if the rebar surfaces are not taken into account in designing the mesh, the rebar definition can be very inefficient.

In the isoparametric mapped cube the rebar surface always has two edges (opposite to one another) that are parallel to an isoparametric direction. The isoparametric directions are defined in Figure 2.2.4–12. You specify this isoparametric direction (1, 2, or 3).



Isoparametric direction: 1 (parallel to the 1-2 edge of the element and intersecting face 1-4-8-5)

Edge	Corner nodes
1	1-4
2	4-8
3	8-5
4	5-1

Isoparametric direction: 2 (parallel to the 1-4 edge of the element and intersecting face 1-5-6-2)

Edge	Corner nodes
1	1-5
2	5-6
3	6-2
4	2-1

Isoparametric direction: 3 (parallel to the 1-5 edge of the element and intersecting face 1-2-3-4)

Edge	Corner nodes
1	1-2
2	2-3
3	3-4
4	4-1

Figure 2.2.4–12 Isoparametric direction and edge definitions for three-dimensional elements.

A particular face of the element, which is perpendicular to this isoparametric direction in the isoparametric mapped cube, is used to define the position of the other two edges of the surface; the faces are defined in Figure 2.2.4–12, where the edges of the faces are also defined.

If isoparametric rebars are defined, the two edges of the rebar surface that are not parallel to the user-specified isoparametric direction will be parallel to one of the other two isoparametric directions; in the isoparametric-mapped cube one isoparametric coordinate is constant on the rebar surface. Figure 2.2.4–13 illustrates this concept with an element containing two layers of isoparametric rebars. The position of each surface is given by the fractional distance *f* from an edge of the face defined in Figure 2.2.4–12 for the isoparametric direction chosen; you must specify the edge from which the fractional distance is measured.

If skew rebars are defined, the two edges of the rebar surface, which are not parallel to the user-specified isoparametric direction, are generally not parallel to one of the other isoparametric directions. The positions of these two edges of the rebar surface are specified by the intersection of the rebar surface with edges of the intersecting face, defined in Figure 2.2.4–12, for the isoparametric direction chosen; the intersections are given by the fractional distance *f* along each edge of the face. (Note that the fractional distance is *along* the edge for skew rebars; for isoparametric rebars the fractional distances are measured *from* an edge.) The fractional distance along an edge is measured from the first node of the edge. All four fractional distances must be given, but only two can be nonzero.

The orientation angle, α, of the rebars within the rebar layer is defined in the isoparametric-mapped cube; it is measured in degrees and is the angle between the line of intersection of the rebar surface with the face for the isoparametric direction chosen and the rebar. The positive direction of the line of intersection is from the lower numbered edge to the higher numbered edge; the positive direction for the rebars points into the elements. An example is shown in Figure 2.2.4–14. The orientation angle is defined in the rebar layer in the isoparametric-mapped cube; therefore, the definition is the same for isoparametric and skew rebar.

If the rebar layer is not flat in physical space, the orientation angle at each integration point may be different. Since it is possible to define only one orientation angle per element, an average value orientation angle for the element must be used; for reasonable meshes this approximation should not affect the results significantly.

Defining isoparametric rebars

You specify the elements that contain the rebars; the cross-sectional area, *A*, of each rebar; the rebar spacing, *s*; the rebar orientation, α (as described above); the fractional distance, *f*, from the edge; the number of the edge from which the fractional distance is measured; and the isoparametric direction of the rebar surface.

Input File Usage: Use the following option to define layers of isoparametric rebars in three-dimensional continuum elements:

∗REBAR, ELEMENT=CONTINUUM, MATERIAL=*mat*,
GEOMETRY=ISOPARAMETRIC

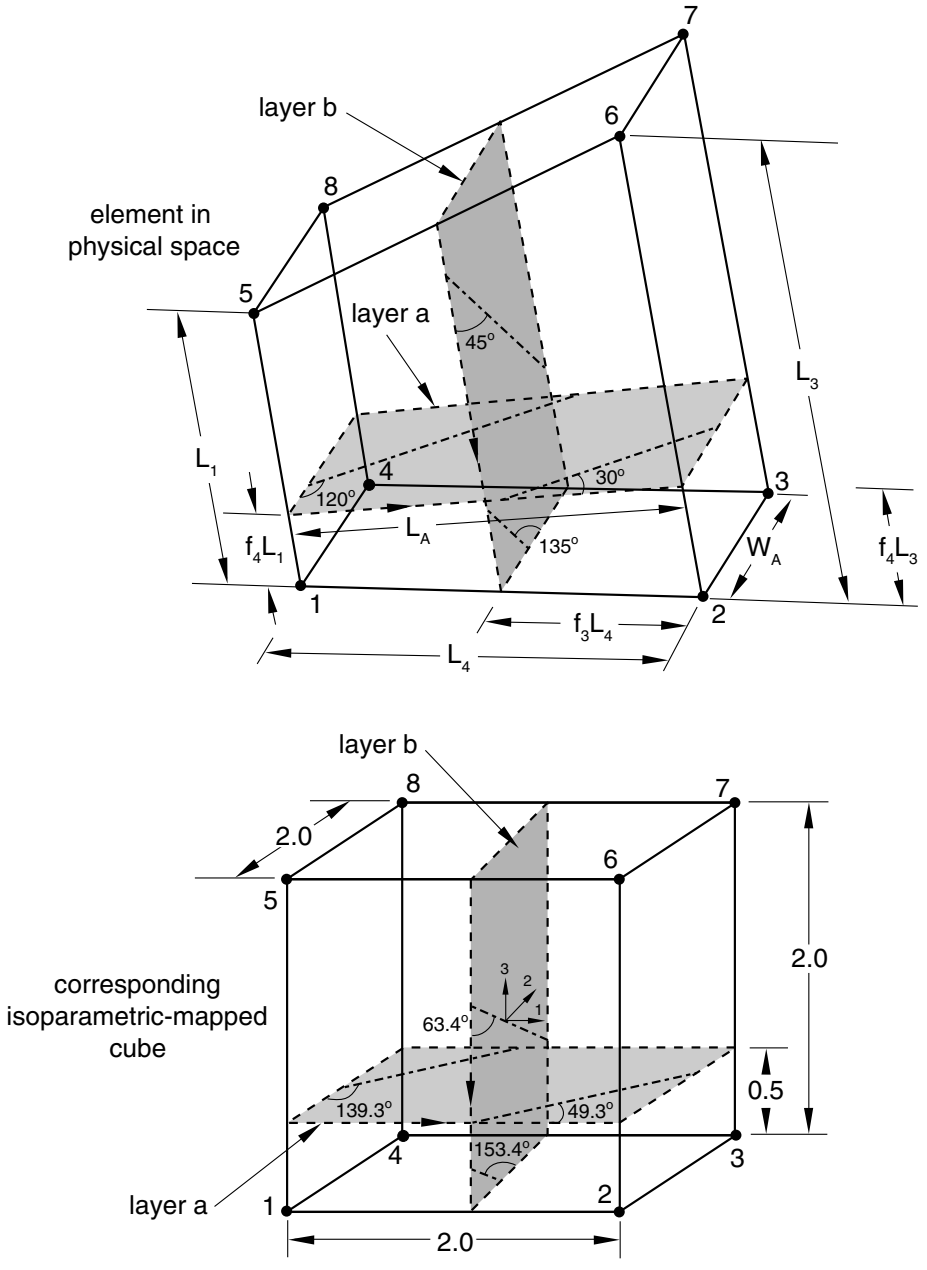


Figure 2.2.4–13 Element with two layers of isoparametric rebar.

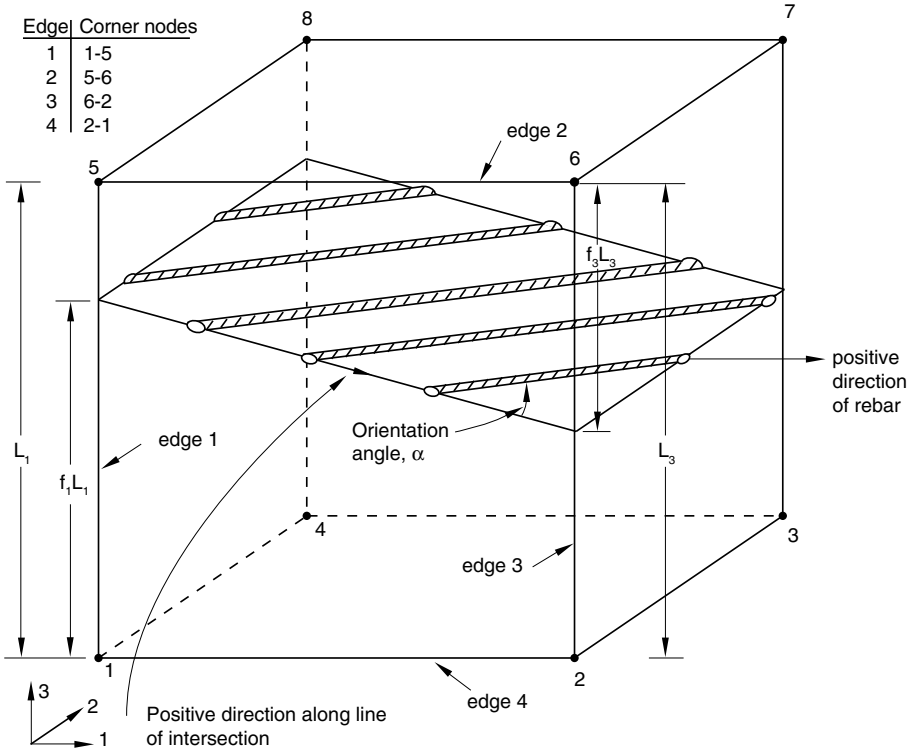


Figure 2.2.4–14 Orientation example for three-dimensional skew rebar modeling, isoparametric direction 2. Shown in the mapped isoparametric element.

Example: isoparametric rebar

For example, the following input defines the isoparametric rebar shown in Figure 2.2.4–13:

```
*HEADING
ISOPARAMETRIC REBAR
*NODE
 1,  0.,  0.
 2, 10.,  0.
 3, 10.,  5.
 4,  0.,  5.
 5,  0.,  0.,  7.5
 6, 10.,  0., 12.5
 7, 10.,  5., 12.5
 8,  0.,  5., 7.5
```

```
*ELEMENT, TYPE=C3D8R, ELSET=ONE
 1,1,2,3,4,5,6,7,8
*REBAR, ELEMENT=CONTINUUM, MATERIAL=STEEL,
 GEOMETRY=ISOPARAMETRIC, NAME=LAYER_A
 ONE,.04,2.5,49.32628,0.25,4,2
*REBAR, ELEMENT=CONTINUUM, MATERIAL=STEEL,
 GEOMETRY=ISOPARAMETRIC, NAME=LAYER_B
 ONE,.04,1.,63.43494,0.5,3,2
*MATERIAL, NAME=STEEL
*ELASTIC
 30.E6,
 ...
```

Rebar layers *A* and *B* are defined using isoparametric direction 2. From Figure 2.2.4–12 the position of the layers must be given with respect to the face with nodes 1-5-6-2.

The fractional distance defining the position of intersection of layer *A* with this face can be measured from edge 4 (edge with nodes 2–1) along edge 3 (edge with nodes 6–2), as shown in Figure 2.2.4–13. For layer *A*, $f_4 = .25$. It could also be given from edge 2 (edge with nodes 5–6), so that $f_2 = 1.0 - f_4 = .75$.

The orientation of rebar for layer *A* in physical space is defined by an angle, β, equal to 30° for layer *A*. This angle must be transformed into the corresponding angle in the isoparametric-mapped cube. This transformation can be done as follows: consider a single rebar that intersects the intersecting line (described above) and an adjacent edge (see Figure 2.2.4–15).

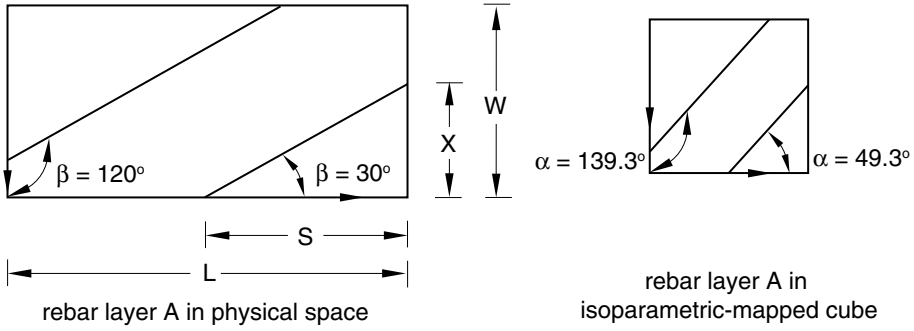


Figure 2.2.4–15 Example defining isoparametric rebar.

From the figure $\tan\beta = X/S$. The length of the rebar layer along the intersecting line is L, and the length of the opposite edge is *W*. Consider the same rebar in the rebar layer in the isoparametric-mapped cube. The orientation angle, α, is given by $\tan\alpha = x/s$, where $x = 2X/W$ and $s = 2S/L$. (The 2 is included because the isoparametric-mapped cube is a 2 × 2 × 2 cube.) This expression can be simplified to give

$$\tan\alpha = \frac{X}{W}\frac{L}{S} = \frac{L}{W}\tan\beta.$$

For layer A, $L = 10.0778$, $W = 5.$, $\beta = 30°$, and $\alpha = 49.33°$, where α is the orientation angle that must be specified.

The fractional distance defining the position of the intersection of layer B with this face can be measured from edge 3 (edge with nodes 6–2); $f_3 = .5$. It could also be measured from edge 1 (edge with nodes 1–5), such that $f_1 = 1.0 - f_3$. The orientation angle for layer B in the rebar layer is 45°. In the isoparametric-mapped cube $L = 10.$, $W = 5.$, $\beta = 45°$, and $\alpha = 63.43°$.

Since an isoparametric rebar layer always lies in two of the isoparametric directions, an alternative but equivalent definition can be given. For example, layer A also lies in isoparametric direction 1, with the intersecting face having nodes 1-4-8-5. The fractional distance for layer A, measured from edge 1 (edge with nodes 1–4), is $f_1 = .25$. The positive sense of the line of intersection is from edge 2 (edge with nodes 4–8) to edge 4 (edge with nodes 5–1); therefore, $\beta = 120°$, $L = 5.$, $W = 10.077$, and $\alpha = 139.32°$.

Layer B also lies in isoparametric direction 3, with the intersecting face having nodes 1-2-3-4. The fractional distance for layer B, measured from edge 2 (edge with nodes 2–3), is $f_2 = .5$. The positive sense of the intersecting line is from edge 1 (edge with nodes 1–2) to edge 3 (edge with nodes 3–4); therefore, the orientation angle of the rebar in physical space is $\beta = 135°$, $L = 5.$, $W = 10.$, and in the isoparametric-mapped cube $\alpha = 153.43°$.

Defining skew rebars

You specify the elements that contain the rebars; the cross-sectional area, A, of each rebar; the rebar spacing, s; the rebar orientation, α (as described above); and the isoparametric direction. In addition, you specify the fractional distance f *along* the element edge for each edge of the intersecting face defined in Figure 2.2.4–12. Only the values corresponding to the two edges that the rebar intersects can be nonzero.

Input File Usage: Use the following option to define layers of skew rebars in three-dimensional continuum elements:

*REBAR, ELEMENT=CONTINUUM, MATERIAL=*mat*, GEOMETRY=SKEW

Example: skew rebar

For example, the following input defines the skew rebar shown in Figure 2.2.4–16:

```
*HEADING
*NODE
 1,  0.,  0.
 2, 10.,  0.
 3, 10.,  5.
 4,  0.,  5.
 5,  0.,  0.,  7.5
 6, 10.,  0., 12.5
 7, 10.,  5., 12.5
 8,  0.,  5., 7.5
```

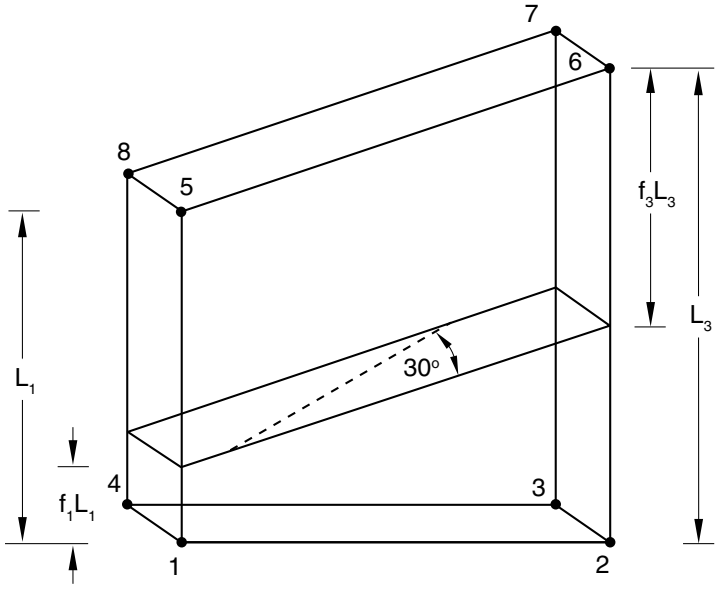


Figure 2.2.4–16 Example defining skew rebar.

```
*ELEMENT, TYPE=C3D8R, ELSET=ONE
 1,1,2,3,4,5,6,7,8
*REBAR, ELEMENT=CONTINUUM, MATERIAL=STEEL, GEOMETRY=SKEW,
 NAME=LAYER_A
 ONE, .04, 2.5, 55.28, , 2
 .2, 0., .4, .0
*MATERIAL, NAME=STEEL
*ELASTIC
 30.E6,
 ...
```

The rebar layer is defined using isoparametric direction 2. The intersecting face is defined in Figure 2.2.4–12 and has nodes 1-5-6-2. The position of the rebar layer is given by its intersection with the edges of this face; the fractional distances, f_1 and f_3, are shown in Figure 2.2.4–16. The orientation angle β of the rebar in physical space is 30°. Following the same procedure for calculating α as was described for isoparametric rebar, $L = 12.5$, $W = 5.$, and the orientation angle in the isoparametric-mapped cube α is 55.28°.

Defining single rebars in three-dimensional continuum elements

You can define single rebars in three-dimensional continuum elements; in this case the rebar is assumed to be placed along one of the element's isoparametric directions. The rebar is then located by its intersection

with the intersecting face (defined in Figure 2.2.4–12). The intersections of constant isoparametric lines with edges 1 and 2 of the intersecting face are given by fractional distances along edges 1 and 2, measured from the first node of each edge, as shown in Figure 2.2.4–11.

You specify the elements that contain the rebars; the cross-sectional area, A, of each rebar; the fractional distances locating the rebar's position in the element, f_1 and f_2; and the isoparametric direction. Give the fractional distances with respect to edge 1 and edge 2 for the isoparametric direction chosen, as defined in Figure 2.2.4–12.

Input File Usage: Use the following option to define single rebars in three-dimensional continuum elements:

∗REBAR, ELEMENT=CONTINUUM, MATERIAL=*mat*, SINGLE

Defining the rebar material

The material properties of the rebars are distinct from those of the underlying element and are defined by a separate material definition ("Material data definition," Section 21.1.2). You must associate each rebar definition with a set of material properties.

The following material behavior cannot be used in Abaqus/Standard to define rebar materials:

- "Porous metal plasticity," Section 23.2.9.

The following material behaviors cannot be used in Abaqus/Explicit to define rebar materials:

- "Defining fully anisotropic elasticity" in "Linear elastic behavior," Section 22.2.1;
- "Defining orthotropic elasticity by specifying the terms in the elastic stiffness matrix" in "Linear elastic behavior," Section 22.2.1;
- "Equation of state," Section 25.2.1;
- "Anisotropic yield/creep," Section 23.2.6;
- "Porous metal plasticity," Section 23.2.9;
- "Extended Drucker-Prager models," Section 23.3.1;
- "Modified Drucker-Prager/Cap model," Section 23.3.2;
- "Crushable foam plasticity models," Section 23.3.5; or
- "Cracking model for concrete," Section 23.6.2.

Although Abaqus/Standard will allow for a rebar material to be defined with orthotropic elasticity ("Defining orthotropic elasticity by specifying the terms in the elastic stiffness matrix" in "Linear elastic behavior," Section 22.2.1) or anisotropic elasticity ("Defining fully anisotropic elasticity" in "Linear elastic behavior," Section 22.2.1), D_{1111} is the only meaningful material constant in these definitions. D_{1111} is used to compute the strain in the rebar direction, ε_{11}, using the corresponding stress component, σ_{11}, as discussed in "Linear elastic behavior," Section 22.2.1; no other strain or stress components exist in rebars.

In Abaqus/Standard density is ignored for the rebar material properties. Hence, the mass of the rebar is neglected in eigenvalue extraction and implicit dynamic procedures and for gravity, centrifugal, and rotary acceleration distributed loads.

Input File Usage: Use the following option to associate a material definition with a rebar definition:

∗REBAR, ELEMENT=*elem*, MATERIAL=*mat*

Initial conditions

Initial conditions (“Initial conditions in Abaqus/Standard and Abaqus/Explicit,” Section 34.2.1) can be used to define rebar prestress or solution-dependent values for rebars.

Defining prestress in rebar

For structures in which reinforcing is defined (such as reinforced concrete structures), you can use initial conditions to define the prestress in the rebars.

In such cases in Abaqus/Standard the structure must be brought to a state of equilibrium before it is actively loaded by means of an initial static analysis step (“Static stress analysis,” Section 6.2.2) with no external loads applied (or, perhaps, with the “dead” loads only)—see “Defining initial stresses” in “Initial conditions in Abaqus/Standard and Abaqus/Explicit,” Section 34.2.1.

Input File Usage: ∗INITIAL CONDITIONS, TYPE=STRESS, REBAR
element number or element set name, rebar name, prestress value

Holding prestress in rebar in Abaqus/Standard

If prestress is defined in the rebars and unless the prestress is held fixed, it will be allowed to change during an equilibrating static analysis step; this is a result of the straining of the structure as the self-equilibrating stress state establishes itself. An example is the pretension type of concrete prestressing in which reinforcing tendons are initially stretched to a desired tension before being covered by concrete. After the concrete cures and bonds to the rebar, release of the initial rebar tension transfers load to the concrete, introducing compressive stresses in the concrete. The resulting deformation in the concrete reduces the stress in the rebar.

Alternatively, you can keep the initial stress defined in some or all of the rebars constant during this initial equilibrium solution. An example is the post-tension type of concrete prestressing; the rebars are allowed to slide through the concrete (normally they are in conduits), and the prestress loading is maintained by some external source (prestressing jacks). The magnitude of the prestress in the rebar is normally part of the design requirements and must not be reduced as the concrete compresses under the loading of the prestressing. Normally, the prestress is held constant only in the first step of an analysis. This is generally the more common assumption for prestressing.

If the prestress is not held constant in analysis steps following the step in which it is held constant, the stress in the rebar will change due to additional deformation in the concrete. If there is no additional deformation, the stress in the rebar will remain at the level set by the initial conditions. If the loading history is such that no plastic deformation is induced in the concrete or rebar in steps subsequent to the steps in which the prestress is held constant, the stress in the rebar will return to the level set by the initial conditions upon removal of the loading applied in those steps.

Input File Usage: ∗PRESTRESS HOLD

Defining the initial values of solution-dependent state variables for rebars

You can define the initial values of solution-dependent state variables for rebars within elements. See "Initial conditions in Abaqus/Standard and Abaqus/Explicit," Section 34.2.1, for details.

Input File Usage: *INITIAL CONDITIONS, TYPE=SOLUTION, REBAR

Output

Rebar force output is available at the rebar integration locations with output variable RBFOR. The rebar force is equal to the rebar stress times the current rebar cross-sectional area. The current cross-sectional area of the rebar is calculated by assuming the rebar is made of an incompressible material, regardless of the actual material definition. For rebars in membrane or shell elements output variables RBANG and RBROT identify the current orientation of isoparametric or skew rebar within the element and the relative rotation of the rebar as a result of finite deformation, respectively. These quantities are measured with respect to the user-specified isoparametric direction in the element, not the default local element system or the orientation-defined system. See "Rebar modeling in shell, membrane, and surface elements," Section 3.7.3 of the Abaqus Theory Guide.

See "Abaqus/Standard output variable identifiers," Section 4.2.1, and "Abaqus/Explicit output variable identifiers," Section 4.2.2, for information on additional output quantities such as stress and strain. For rebars in membrane or shell elements with multiple integration points, output quantities are available at the integration points and at the centroid of the element.

Specifying the direction for rebar angle output in shell and membrane elements

The output quantities RBANG and RBROT can be measured from either of the isoparametric directions in the plane of the shell or the membrane. You can specify the desired isoparametric direction from which the rebar angle will be measured (1 or 2). In axisymmetric shells and membranes the first isoparametric direction coincides with the meridional direction, and the second isoparametric direction coincides with the hoop direction. The rebar angle is measured from the isoparametric direction to the rebar with a positive angle defined as a counterclockwise rotation around the element's normal direction. The default direction is the first isoparametric direction.

Input File Usage: Use any of the following options:

*REBAR, ELEMENT=SHELL, MATERIAL=*mat*, ISODIRECTION=*n*
*REBAR, ELEMENT=AXISHELL, MATERIAL=*mat*, ISODIRECTION=*n*
*REBAR, ELEMENT=MEMBRANE, MATERIAL=*mat*, ISODIRECTION=*n*
*REBAR, ELEMENT=AXIMEMBRANE, MATERIAL=*mat*, ISODIRECTION=*n*

Example

As an example, a user-defined local coordinate system is used to define skewed rebar in a shell element (skew angle $\alpha = 30°$), and the output value of RBANG is 75°, as illustrated in Figure 2.2.4–17:

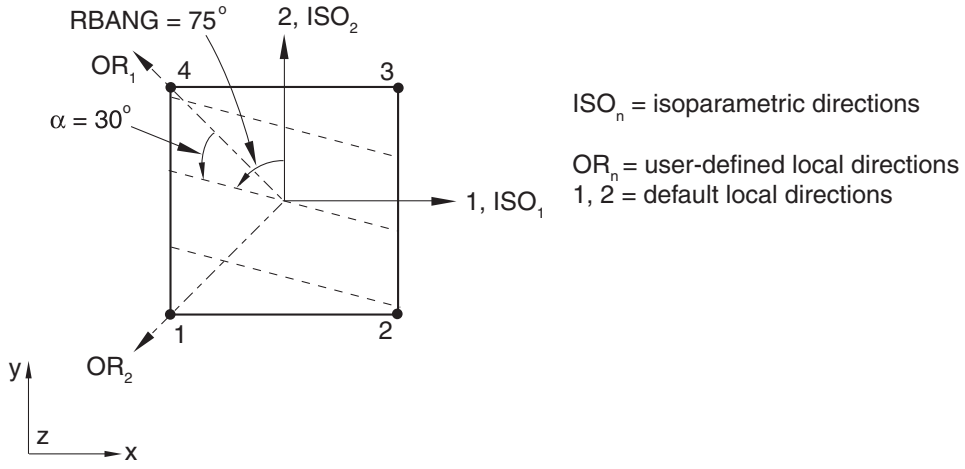


Figure 2.2.4–17 RBANG measurement for skew rebar defined relative to user-defined local coordinate directions.

```
*REBAR, ELEMENT=SHELL, MATERIAL=MAT1, NAME=REBARB,
 GEOMETRY=SKEW, ORIENTATION=ORIENT, ISODIRECTION=2
 ELSET1, 0.01, 0.1, 0.0, 30.
*ORIENTATION, SYSTEM=RECTANGULAR, NAME=ORIENT
 -0.7071, 0.7071, 0.0, -0.7071, -0.7071, 0.0
 3, 0.0
```

The rebars are located at the midsurface of the shell. Output variable RBANG is measured from the second isoparametric direction to the rebar. If the first isoparametric direction were chosen instead, output variable RBANG would report an angle of 165°.

Visualizing rebar orientation and results in rebar

Abaqus/CAE does not support visualization of element-based rebar or rebar results. Abaqus/CAE does support visualization of rebar defined as described in “Defining reinforcement,” Section 2.2.3.

2.2.5 ORIENTATIONS

Products: Abaqus/Standard Abaqus/Explicit Abaqus/CAE

References

- "Distribution definition," Section 2.8.1
- "Material library: overview," Section 21.1.1
- "Material data definition," Section 21.1.2
- "Fabric material behavior," Section 23.4.1
- "Distributed loads," Section 34.4.3
- "Kinematic coupling constraints," Section 35.2.3
- "Coupling constraints," Section 35.3.2
- "Inertia relief," Section 11.1.1
- *ORIENTATION
- "Creating datum coordinate systems," Section 62.9 of the Abaqus/CAE User's Guide, in the HTML version of this guide

Overview

A user-defined orientation is used to define a local coordinate system for:

- definition of material properties—for example, anisotropic materials or jointed materials (a local coordinate system must be defined if anisotropic material properties are defined for solid elements);
- definition of local material directions, such as the in-plane fill and warp yarn directions of a fabric material or the fiber directions of anisotropic hyperelastic materials;
- definition of rebars in shell, membrane, and surface elements;
- definition of rotary inertia and connector elements;
- definition of coupling constraints;
- definition of loading directions for distributed general tractions, shear tractions, and general edge loads;
- definition of local tangent directions for contact in Abaqus/Standard;
- material calculations at integration points;
- output of components of stress, strain, and element section force; and
- definition of a local system of rigid body motion directions for inertia relief in Abaqus/Standard.

A user-defined orientation cannot be used:

- at points where the smeared crack concrete material behavior ("Concrete smeared cracking," Section 23.6.1) is also used in Abaqus/Standard;

- to specify a local coordinate system for defining nodal coordinates—see "Specifying a local coordinate system in which to define nodes" in "Node definition," Section 2.1.1, or "Specifying a local coordinate system for the nodal coordinates" in "Node definition," Section 2.1.1, instead; or
- to specify a local coordinate system for applying loads and boundary conditions—see "Transformed coordinate systems," Section 2.1.5, instead.

Considerable generality is provided in the way the local system can be defined, since this system must often change from point to point because of the shape and construction of the structure being modeled. You can define the local orientation directly. The direct data methods provided in Abaqus are intended to give sufficient generality to model most cases easily: they are particularly useful for regular geometry. Distributions ("Distribution definition," Section 2.8.1) can be used to define spatially varying local coordinate systems for solid continuum, shell, and membrane (in Abaqus/Standard) elements directly for arbitrary geometries.

In Abaqus/Standard you can alternatively define the local orientation in user subroutine **`ORIENT`**.

Assigning a name to an orientation

You must assign a name to each orientation definition. This name is used by various features to refer to the orientation definition.

Input File Usage: *ORIENTATION, NAME=*name*

Abaqus/CAE Usage: Any module: **Tools→Datum**: **Type**: **CSYS**: select any method, and click **OK**: **Name:** *name*

Defining a local coordinate system in a model that contains an assembly of part instances

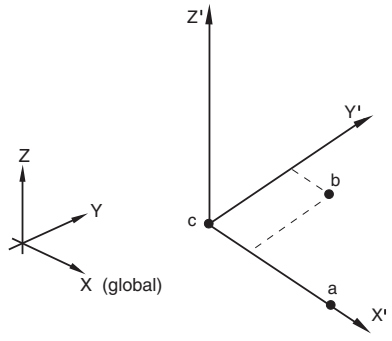
In a model defined in terms of an assembly of part instances, you can define a local orientation at the part, part instance, or assembly level. An orientation defined at the part or part instance level is rotated according to the positioning data given for each instance of that part (or for the part instance). This includes the case when an orientation is defined using a distribution. See "Defining an assembly," Section 2.10.1, and "Distribution definition," Section 2.8.1.

Defining a local coordinate system directly

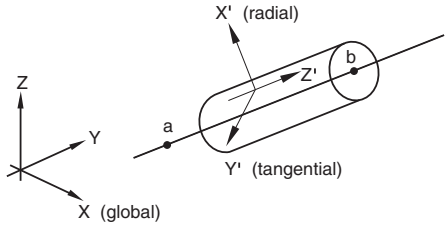
A two-stage process is used to define the local system directly.

1. You define the local coordinate system at the particular location at which it is required. You can select a rectangular, cylindrical, or spherical coordinate system. The coordinate system is defined in terms of points *a*, *b*, and *c*, as shown in Figure 2.2.5–1. You can select the method for defining points *a*, *b*, and *c*, as described below.
2. Optionally, you can specify an additional rotation by identifying one of these local directions (X', Y', or Z') as a rotation axis and giving a rotation, in degrees, about that axis. The local system is then rotated through this angle about the specified axis. This method of defining a local system is required for contact surfaces in Abaqus/Standard, shells, membranes, gasket elements, and when the orientation is associated with a composite solid section. The additional rotation is illustrated in Figure 2.2.5–2.

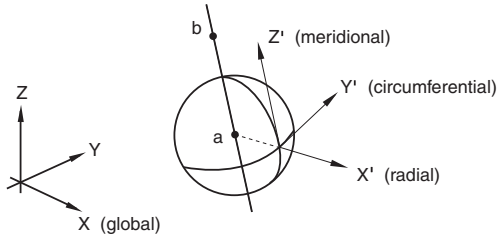
Rectangular system
(a on X'-axis)



Cylindrical system



Spherical system



Rectangular system
(a on Z'-axis)

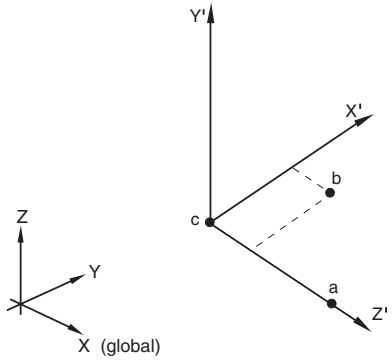


Figure 2.2.5–1 Orientation systems.

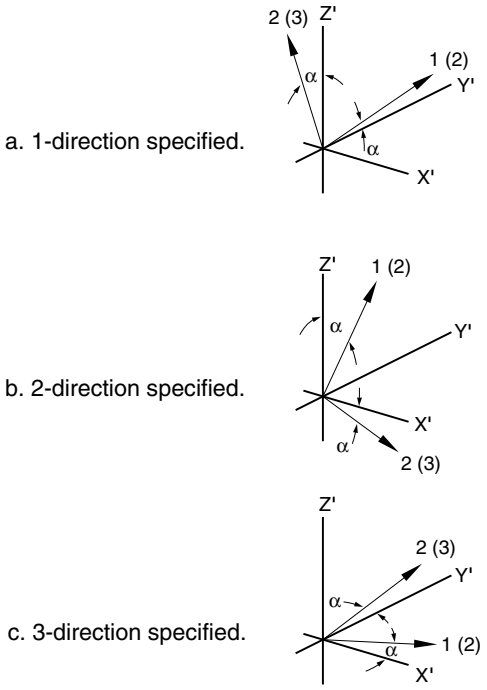


Figure 2.2.5–2 Specifying rotation about a local axis for shell elements, membrane elements, gasket elements (in parentheses), composite solids (in parentheses), and contact surfaces in Abaqus/Standard.

The local coordinate system for composite solids is indicated by X', Y', and Z'. The local coordinate system for other element types is indicated by 1, 2, and 3; the axis labels in parentheses are oriented for gasket elements.

Available coordinate systems

Rectangular, cylindrical, and spherical coordinate systems are available.

Defining a rectangular coordinate system

A rectangular Cartesian coordinate system is shown in Figure 2.2.5–1(a). The rectangular coordinate system is the default. Alternatively, you can define a rectangular Cartesian coordinate system as shown in Figure 2.2.5–1(d).

Input File Usage: ∗ORIENTATION, NAME=*name*, SYSTEM=RECTANGULAR
∗ORIENTATION, NAME=*name*, SYSTEM=Z RECTANGULAR

Abaqus/CAE Usage: Any module: **Tools→Datum**: **Type**: **CSYS**: select any method, and click **OK**: **Rectangular**

Defining a cylindrical coordinate system

A cylindrical coordinate system is shown in Figure 2.2.5–1(b). The local axes are X'=radial, Y'=tangential, Z'=axial.

Input File Usage: *ORIENTATION, NAME=*name*, SYSTEM=CYLINDRICAL

Abaqus/CAE Usage: Any module: **Tools→Datum**: **Type**: **CSYS**: select any method, and click **OK**: **Cylindrical**

Defining a spherical coordinate system

A spherical coordinate system is shown in Figure 2.2.5–1(c). The local axes are X'=radial, Y'=circumferential, Z'=meridional.

Input File Usage: *ORIENTATION, NAME=*name*, SYSTEM=SPHERICAL

Abaqus/CAE Usage: Any module: **Tools→Datum**: **Type**: **CSYS**: select any method, and click **OK**: **Spherical**

Methods for defining a coordinate system

You can define a coordinate system by specifying the locations of points *a*, *b*, and *c* directly; by specifying the locations of points *a*, *b*, and *c* relative to global node numbers; by specifying the locations of points *a*, *b*, and *c* relative to local node numbers; by specifying an offset from another coordinate system; or by specifying two lines in the coordinate system.

Defining a coordinate system by specifying the locations of points a, b, and c directly

You can specify the coordinates of points *a*, *b*, and *c* directly. These coordinates should be appropriate to the system chosen. This method is the default.

You can define a rectangular Cartesian coordinate system (X', Y', Z') by specifying three points (*a*, *b*, and *c*) that lie on the X'-Y' plane, as shown in Figure 2.2.5–1(a). Point *c* is the origin of the system, point *a* must lie on the X'-axis, and point *b* must lie on the X'-Y' plane. Although not necessary, it is intuitive to select point *b* such that it is on or near the local Y'-axis.

Alternatively in Abaqus/Standard you can define a rectangular Cartesian coordinate system (X', Y', Z') by specifying three points (*a*, *b*, and *c*) that lie on the X'-Z' plane, as shown in Figure 2.2.5–1(d). Point *c* is the origin of the system, point *a* must lie on the Z'-axis, and point *b* must lie on the X'-Z' plane. Although not necessary, it is intuitive to select point *b* such that it is on or near the local X'-axis.

For rectangular coordinate systems the default location of the origin (point *c*) is the global origin.

You define a cylindrical coordinate system by giving the two points, *a* and *b*, on the polar axis of the cylindrical system, as shown in Figure 2.2.5–1(b).

You define a spherical coordinate system by giving the center of the sphere, *a*, and point *b* on the polar axis, as shown in Figure 2.2.5–1(c).

To define a spatially varying local coordinate system directly on solid continuum and shell elements, you can specify the coordinates of points *a* and *b* on an element-by-element basis using a distribution.

Using a distribution to define the coordinates of the optional point c is not currently supported. See "Distribution definition," Section 2.8.1.

Input File Usage: *ORIENTATION, NAME=*name*, DEFINITION=COORDINATES

Abaqus/CAE Usage: Any module: **Tools→Datum**: **Type**: **CSYS**, **Method**: **3 points**

Defining a coordinate system by giving global node numbers for points a, b, and c

You can locate points a, b, and c at nodes by specifying three global node numbers. For a rectangular coordinate system the default location of the origin (point c) is the global origin.

Input File Usage: *ORIENTATION, NAME=*name*, DEFINITION=NODES

Abaqus/CAE Usage: You cannot define a coordinate system by giving global node numbers in Abaqus/CAE.

Defining a coordinate system by giving local node numbers for points a, b, and c

You can locate points a, b, and c by specifying the local node numbers of an element. Local node numbers refer to the order in which nodes are specified in the element connectivity. For example, local node number 2 corresponds to the second node specified for the element definition. This definition method allows for variation of the local coordinate system on an element-by-element basis with a single orientation definition. For example, if local node number 2 is given as the location of point c and local node number 3 is given as the location of point a, the local X'-direction is defined to be parallel to the (2, 3) side of the element. By default, the origin (point c) of the local coordinate system is the first node of the element (local node number 1).

Input File Usage: *ORIENTATION, NAME=*name*, DEFINITION=OFFSET TO NODES

Abaqus/CAE Usage: You cannot define a coordinate system by giving local node numbers in Abaqus/CAE.

Defining a coordinate system by giving an offset from another coordinate system

You can define a coordinate system by specifying an offset from an existing coordinate system.

Input File Usage: You cannot define a coordinate system by giving an offset from another coordinate system in the input file.

Abaqus/CAE Usage: Any module: **Tools→Datum**: **Type**: **CSYS**: **Offset from CSYS**

Defining a coordinate system by giving two edges

You can define a coordinate system by specifying two edges. The first edge defines the X- or R-axis, and the X–Y or $R - \theta$ plane passes through the second.

Input File Usage: You cannot define a coordinate system by giving two edges in the input file.

Abaqus/CAE Usage: Any module: **Tools→Datum**: **Type**: **CSYS**: **2 lines**

Defining local material directions for anisotropic hyperelastic materials

When modeling anisotropic hyperelastic materials with an invariant-based formulation ("Invariant-based formulation" in "Anisotropic hyperelastic behavior," Section 22.5.3) you must define the local directions that characterize each family of fibers. These directions need not be orthogonal in the initial configuration. You can specify these local directions with respect to an orthogonal orientation system at a material point. Up to three local directions can be specified as part of the definition of a local orientation system. The local directions can be output as field variables to the output database (see "Output" in "Anisotropic hyperelastic behavior," Section 22.5.3).

Input File Usage: Use the following option to define an orthogonal system and *N* local directions with respect to that system to identify the preferred directions of an anisotropic hyperelastic material:

∗ORIENTATION, LOCAL DIRECTIONS=*N*

Abaqus/CAE Usage: Local material directions cannot be defined in Abaqus/CAE.

Defining yarn directions in the reference configuration for a fabric material

In general, the yarn directions in a fabric material may not be orthogonal to each other in the reference configuration (see "Fabric material behavior," Section 23.4.1). You can specify these local directions with respect to the in-plane axes of an orthogonal orientation system at a material point. Both the local directions and the orthogonal system are defined together as a single orientation definition. If the local directions are not specified, these directions are assumed to match the in-plane axes of the orthogonal system defined. The local direction may not remain orthogonal with deformation. Abaqus updates the local directions with deformation and computes the nominal strains along these directions and the angle between them (the fabric shear strain). The constitutive behavior for the fabric defines the nominal stresses in the local system in terms of the fabric strain. The local directions can be output as field variables to the output database (see "Output" in "Fabric material behavior," Section 23.4.1).

Input File Usage: Use the following option to define an orthogonal system and the local directions with respect to that system to identify the yarn directions in the reference configuration:

∗ORIENTATION, LOCAL DIRECTIONS=2

Abaqus/CAE Usage: Yarn directions for fabric materials cannot be defined in Abaqus/CAE.

Defining a local coordinate system in Abaqus/Standard using a user subroutine

In some cases the simplest way to specify a local system is by means of a user subroutine. User subroutine **ORIENT** is provided in Abaqus/Standard. In this case the user subroutine is called each time that an orientation definition is needed. In a model defined in terms of an assembly of part instances, the local directions defined by user subroutine **ORIENT** must be defined relative to the coordinate system of the assembly.

Input File Usage: ∗ORIENTATION, NAME=*name*, SYSTEM=USER

Abaqus/CAE Usage: You can enter the name of an orientation defined in user subroutine **ORIENT** whenever a user-defined orientation is allowed.

Multiple references to an orientation definition

Because the orientation is independent of the material definition and they can both be referenced in any element property definition, the ability to describe complex structural components (such as laminated composite shells) is quite general and straightforward to use.

An orientation definition can be used as often as needed and with different material or element type definitions; for example, it can be used for different layers of a shell where the orientation is the same.

Large-displacement considerations

In large-displacement analysis a user-defined orientation rotates with the average rigid body motion of the material point, the rigid body when the orientation is used with ROTARYI elements, the first node of the joint in JOINTC elements, the pipeline edge for pipe-soil interaction elements, the appropriate surface for contact in Abaqus/Standard, or the reference node when the orientation is used with coupling constraints. However, when an orientation is defined for spring, dashpot, or gasket elements in Abaqus/Standard, the local directions always remain fixed in space.

Because the material directions rotate with the average rigid body motion at a material point, using anisotropic elasticity to model a material that is not truly a continuum can give significant errors if shear deformation is large. For example, an individual fiber in a reinforcing belt of a tire can shear relatively easily with respect to fibers in other directions. The fibers rotate with the actual deformation of the material point and not with the average rigid body motion. In this case the anisotropic behavior is better modeled with rebars or as a fabric material. The fabric material model in Abaqus/Explicit tracks the current yarn directions as local directions with respect to the orthogonal coordinate system.

Use with two-dimensional solid elements

When a user-defined orientation is used with two-dimensional solid elements such as plane stress, plane strain, or torsionless axisymmetric elements, the orientation must redefine only the X- and Y-directions: the third direction must remain unchanged (Z-direction for plane strain and plane stress elements, θ-direction for axisymmetric elements). When a user-defined orientation is used with axisymmetric elements with twist, all three directions can be redefined. For axisymmetric elements, including the CGAX and CAXA families of elements, the global 1-, 2-, and 3-directions are the radial, axial, and hoop directions, respectively. Cylindrical or spherical orientations may be appropriate for axisymmetric elements only if the local Z'-direction is in the global 3-, or hoop, direction.

Use with shell, membrane, or gasket elements or contact surfaces

When a user-defined orientation is used with shell, membrane, or gasket elements or with contact surfaces, Abaqus first rotates and then projects the orientation system onto the element or contact surface using the algorithm described in this section.

Abaqus first rotates (through the additional rotation angle) the user-defined local coordinate system about the specified rotation axis. If you do not specify a rotation axis or an additional angle, Abaqus will by default use the local 1-axis and a rotation of 0°. After the rotation, Abaqus follows a cyclic permutation (1, 2, 3) of the axes and projects the axis following the axis for additional rotation onto the contact surface or onto the surface of the element to form the local material 1-direction (or the local material 2-direction for gaskets). The remaining material direction is then defined by the cross product of the element normal and the projected direction. Thus, for example:

1. If you choose the user-defined 1-axis as the axis for additional rotation, Abaqus projects the 2-axis onto the element or contact surface. This will be local direction 1 for contact surfaces, shells, and membranes and local direction 2 for gaskets.
2. Abaqus takes the positive element or contact surface normal as the local 3-direction for contact surfaces, shells, and membranes and the local 1-direction for gaskets.
3. Abaqus computes the local 2-direction (3-direction for gaskets) by taking the cross product of the element or contact surface normal and the local 1-direction (2-direction for gaskets), such that the three local axes form an orthonormal, right-handed local coordinate system.

When the axis for additional rotation points in a direction that is opposite to the element or contact surface normal, the local 2-direction (3-direction for gaskets) is reversed with respect to the corresponding user-defined axis; see Figure 2.2.5–3. This does not apply in the case of an orientation used to define rebars; see below.

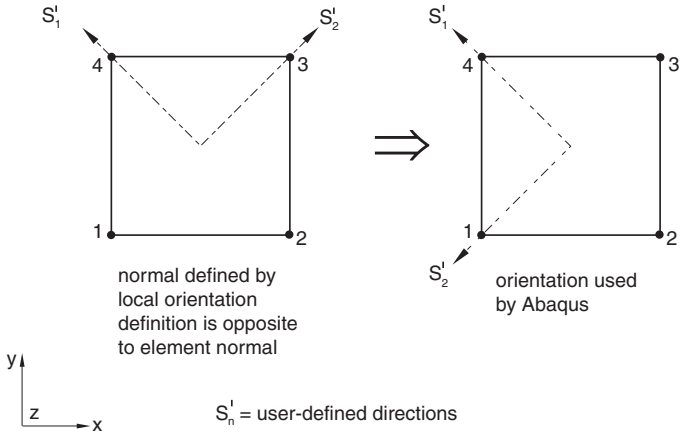


Figure 2.2.5–3 The local 3-direction (1-direction for gaskets) will be in the same direction as the element or contact surface normal.

As an example, the orientation of the spiral-wound layer of the cylindrical shell shown in Figure 2.2.5–4 would be given by defining a cylindrical coordinate system and then specifying the rotation axis as the 1-axis and giving the rotation angle α (in degrees). The local 1- and 2-directions for material property specification and material calculations are then those indicated in the figure.

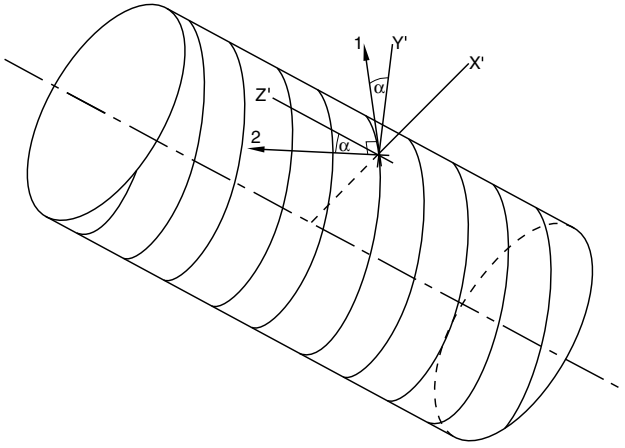


Figure 2.2.5–4 Spiral-wound cylindrical shell layer: material orientation example.

The projected directions are most easily understood when the axis for additional rotation is approximately perpendicular to the element or contact surface.

To define a spatially varying local coordinate system directly on solid continuum and shell elements, as well as membrane elements in Abaqus/Standard, you can specify the additional angle of rotation on an element-by-element basis using a distribution. See "Distribution definition," Section 2.8.1.

Defining rebars in shell, membrane, and surface elements

The orientation of skew rebars in shell, membrane, and surface elements can be defined relative to a user-defined orientation (see "Defining reinforcement," Section 2.2.3). In this case the local coordinate system is calculated as follows:

1. The local 1-direction follows a cyclic permutation of the additional rotation direction; for example, if you choose the user-defined 1-axis as the axis for additional rotation, Abaqus projects the 2-axis onto the element. This will be the local 1-direction.
2. The axis for additional rotation is made orthogonal to the element to create the local 3-direction. This local 3-direction need not be in the same direction as the element normal; in fact it will be in the opposite direction when the dot product of the axis for additional rotation and the element normal is negative.
3. Abaqus computes the local 2-direction by taking the cross product of the local 3-direction and the local 1-direction, such that the three local axes form an orthonormal, right-handed local coordinate system.

Since the local 3-direction may be opposite to the element normal, the definition of rebars is independent of the element connectivity.

Special considerations when defining orientations on contact surfaces in Abaqus/Standard

When a user-defined orientation is used to define the local tangent directions on a surface of a three-dimensional contact pair in Abaqus/Standard (see "Contact formulations in Abaqus/Standard," Section 38.1.1), you cannot define points a and b by giving local node numbers (see Figure 2.2.5–1).

For geometrically nonlinear analysis the local tangent directions of a contact pair rotate with the surface on which the directions were defined initially. These rotated local tangent directions are further rotated to ensure that the normal vector, computed using the cross product of the rotated local tangent directions, corresponds to the normal vector on the master surface when the slave node comes into contact.

Arbitrary local tangent directions can be defined for a "line"-type slave surface defined on three-dimensional beam, truss, or pipe elements. When this surface comes into contact with the master surface during a large-displacement analysis, the local tangent directions are projected onto the master surface.

Use with laminated shells

There are two ways in which a user-defined orientation can be used in the section definition of a laminated shell. In each case the name referenced in the shell section definition is the name of the user-defined orientation.

The first is to associate the user-defined orientation with the entire composite shell section definition. Then each layer's orientation angle can be given relative to this section orientation (or the default shell coordinate directions if no section orientation is used). The angle is given as an additional rotation about the shell normal after the orientation directions have been projected onto the shell surface. Section forces (available only from Abaqus/Standard) are given in the local system specified for the section.

The second is to specify the name of each layer's orientation separately; this method allows different orientation definitions to be referenced for the different layers. Section forces and strains are still reported in the local orientation defined for the entire section (or the default shell coordinate directions if no section orientation is used). The individual layer orientations are used for material calculations and for output of stress and strain.

See "Using a shell section integrated during the analysis to define the section behavior," Section 29.6.5, and "Using a general shell section to define the section behavior," Section 29.6.6, for more information.

Use with laminated three-dimensional solid elements

When a user-defined orientation is used with composite solid elements (available only in Abaqus/Standard), one of the local directions must be identified as the axis for additional rotation. There are two ways in which this orientation can be used with a composite solid section definition to specify the material orientation for individual layers. In each case the name referenced in the solid section definition is the name of the user-defined orientation.

The first is to associate the user-defined orientation with the entire composite solid section definition. Then each layer's orientation angle can be given relative to this section orientation. The angle is given as an additional rotation about the local direction defined as the axis for additional rotation.

The second is to specify the name of each layer's orientation separately; this method allows different orientation definitions to be referenced for the different layers. (In this case any user-defined orientation associated with the entire solid section will be ignored.)

See "Defining the element's section properties" in "Solid (continuum) elements," Section 28.1.1, for more information.

Use with pipe-soil interaction elements

An arbitrary user-defined orientation can be defined for pipe-soil interaction elements (available only in Abaqus/Standard). In a large-displacement analysis the local orientation system rotates with the rigid body motion of the underlying pipeline. In a small-displacement analysis the local system is defined by the initial geometry of the PSI element and remains fixed in space during the analysis.

Use with beam, frame, and truss elements

See "Beam element cross-section orientation," Section 29.3.4, for information on defining local material directions for beams, frames, or trusses.

Use with the fabric material model

The fill and the warp yarn directions in the fabric plane are allowed to rotate with respect to each other under shear deformations ("Fabric material behavior," Section 23.4.1). The current yarn directions are tracked with respect to the orthogonal coordinate system that also rotates with the material.

Use with the jointed material model

When a user-defined orientation is used to define a joint system orientation for the jointed material model available in Abaqus/Standard ("Jointed material model," Section 23.5.1), only the local coordinate system need be defined. It is assumed that the first direction is the direction normal to the plane of the joint and the other directions are in the plane of the joint. An additional axis of rotation cannot be used.

Use with rotary inertia and connector elements

A user-defined orientation must be used to define the local directions for certain connection types used to define connector elements (see "Connection-type library," Section 31.1.5).

A user-defined orientation can be used with SPRING1, SPRING2, DASHPOT1, DASHPOT2, JOINTC, JOINT2D, JOINT3D, and ROTARYI elements to provide a local system for defining the direction of action of such elements. Points a, b, and c (see Figure 2.2.5–1) cannot be defined by giving local node numbers when the orientation is used for these elements. If you do not specify an axis for additional rotation, the local 1-direction with no additional rotation will be chosen as the default.

Use with the kinematic coupling constraint

User-defined orientations can be used in Abaqus/Standard to define the local coordinate systems in which constraint directions are specified for a kinematic coupling constraint (see "Kinematic coupling

constraints," Section 35.2.3). In this case you cannot define points *a*, *b*, and *c* by giving local node numbers (see Figure 2.2.5–1).

Use with surface-based coupling constraints

User-defined orientations can be used to define the local coordinate systems in which surface-based coupling constraint directions are specified (see "Coupling constraints," Section 35.3.2). In this case you cannot define points *a*, *b*, and *c* by giving local node numbers (see Figure 2.2.5–1).

Use with inertia relief

A user-defined orientation can be used in Abaqus/Standard to define a local system of directions along which the inertia relief loads are computed (see "Inertia relief," Section 11.1.1). In this case you cannot define points *a*, *b*, and *c* by giving local node numbers (see Figure 2.2.5–1).

Use with distributed general traction, shear traction, and general edge loads

User-defined orientations can be used in Abaqus to define the local coordinate systems in which the loading directions for distributed general tractions, shear tractions, and general edge loads are specified. See "Distributed loads," Section 34.4.3.

Orientations defined with distributions

Spatially varying local coordinate systems (for material definitions, material calculations, and output) defined with a distribution can be applied only to solid continuum, membrane (in Abaqus/Standard), and shell elements. See "Solid (continuum) elements," Section 28.1.1; "Membrane elements," Section 29.1.1; "Using a shell section integrated during the analysis to define the section behavior," Section 29.6.5; and "Using a general shell section to define the section behavior," Section 29.6.6.

Output

When a user-defined orientation is used in an element section definition, the stress, the strain, and the element section force components are output in the local system.

For a fabric material the output of the regular material point tensors such as stress and strain are given in an orthogonal coordinate system even when the local yarn directions are non-orthogonal. However, the nominal fabric stress SFABRIC and the nominal fabric strain EFABRIC are also available for output (see "Fabric material behavior," Section 23.4.1).

This use of a local system is indicated by a footnote in the printed output tables from Abaqus/Standard. An orientation used with the jointed material model does not affect the output.

When a user-defined orientation is used in Abaqus/Standard with kinematic or distributing coupling constraints, the local system is indicated in the analysis input file processor output tables.

Local coordinate systems are written automatically to the output database with the exception of systems defined by specifying points *a* and *b* relative to local or global node numbers or systems defined through a user subroutine. Any additional rotations specified are ignored.

Material directions are written automatically to the output database. They can also be written to the Abaqus/Standard results file (with at least one output variable specified; see "Output of local directions to the results file" in "Output to the data and results files," Section 4.1.2). The material directions can be visualized in Abaqus/CAE by selecting **Plot→Material Orientations** in the Visualization module.

2.3 Surface definition

2.3.1 SURFACES: OVERVIEW

Products: Abaqus/Standard Abaqus/Explicit Abaqus/CAE

References

- "Element-based surface definition," Section 2.3.2
- "Node-based surface definition," Section 2.3.3
- "Analytical rigid surface definition," Section 2.3.4
- "Eulerian surface definition," Section 2.3.5
- "Operating on surfaces," Section 2.3.6
- "Integrated output section definition," Section 2.5.1
- "Acoustic, shock, and coupled acoustic-structural analysis," Section 6.10.1
- "Distributed loads," Section 34.4.3
- "Prescribed assembly loads," Section 34.5.1
- "Mesh tie constraints," Section 35.3.1
- "Coupling constraints," Section 35.3.2
- "Shell-to-solid coupling," Section 35.3.3
- "Contact interaction analysis: overview," Section 36.1.1
- "Defining tied contact in Abaqus/Standard," Section 36.3.7
- "Cavity radiation," Section 41.1.1

Overview

In Abaqus surfaces:

- can be used to define contact and interactions, including acoustic-structural interactions;
- can define regions used to prescribe distributed surface loads;
- can be used to tie dissimilar meshes together;
- can define cavities used for a cavity radiation analysis in Abaqus/Standard;
- can define pre-tensioned sections used in prescribing assembly loads in Abaqus/Standard;
- can define sections used for tracking the average motion of a surface in Abaqus/Explicit;
- can define sections for output quantities such as the total force transmitted through a surface;
- are geometric entities that have an area associated with them but have zero volume;
- have an identifiable orientation defined by their normals;
- are defined by specifying nodes or node sets, an analytic curve or surface, an Eulerian material instance, or element faces, edges, or ends; and
- can be deformable, rigid, or partially deformable and partially rigid.

This section describes the general rules that apply when creating surfaces in Abaqus.

Why use surfaces?

Surfaces can be used to model the interaction of two or more distinct bodies in a mechanical, acoustic, coupled acoustic-structural, coupled thermal-mechanical, coupled thermal-electrical-structural, thermal, coupled thermal-electrical, or cavity radiation analysis. A rigid surface can be used to represent a body that is much stiffer than the rest of the model in a mechanical or coupled thermal-mechanical analysis, with the limitation that no heat can be transferred to the rigid body. In acoustic-structural analysis, surfaces can be used to define impedance boundary conditions, including first-order conditions for modeling acoustic radiation.

Surfaces can be used to define a region on which a distributed surface load is prescribed; this can facilitate user input of distributed surface loads for complex models. In addition, surfaces can be used to define multi-point or coupling constraints. Surfaces can also define pre-tension sections used in prescribing assembly loads in Abaqus/Standard.

Finally, surfaces can be used to define sections to obtain output of accumulated quantities; this provides a "free body diagram" output, allowing analyses of "force-flow" through a statically indeterminate structure.

The following types of surfaces can be defined in Abaqus:

- Element-based surfaces are defined on the faces, edges, or ends of elements. The elements can be deformable or rigid, leading to a surface that is deformable or rigid. When some of the deformable elements underlying a surface are part of a rigid body, the surface will become partially deformable and partially rigid.

  In Abaqus/Explicit a default element-based surface that includes all bodies in the model is provided for use with the general contact algorithm.
- Node-based surfaces are defined on nodes and, hence, are by definition discontinuous. A user-defined area can be associated with each node on the surface.
- Analytical surfaces are defined directly in geometric terms and are always rigid.
- Eulerian material surfaces are defined on material instances in an Eulerian section. These surfaces are available in Abaqus/Explicit for use with the general contact algorithm.

Element-based surfaces contain more intrinsic information than either node-based surfaces or analytical rigid surfaces. When an element-based surface is used in a mechanical contact analysis, Abaqus can associate a surface area with each node and can calculate the contact stress acting on the surface. In contrast, Abaqus may not be able to calculate accurate contact stresses when a node-based surface ("Node-based surface definition," Section 2.3.3) is used because the actual area associated with each node may not be correct. In addition, when a surface formed by shell, membrane, or rigid elements is used, Abaqus can consider the thickness and possibly the offset of the reference surface of these elements in some applications that refer to surfaces. For example, these thicknesses are accounted for by all contact algorithms available in Abaqus/Explicit and by the surface-to-surface, small-sliding contact formulation in Abaqus/Standard.

Contact between two node-based surfaces or a node-based surface with itself is not allowed; contact between two analytical rigid surfaces is not allowed. Contact between two rigid surfaces defined

using rigid elements is not allowed in Abaqus/Standard and is allowed only with penalty contact in Abaqus/Explicit.

Surface definitions cannot change from step to step; however, new surfaces can be defined upon restart.

Internal surfaces created by Abaqus/CAE

In Abaqus/CAE many modeling operations are performed by picking geometry with the mouse. For example, a contact pair can be defined by picking faces on geometric part instances. Each such face must be translated into a surface in the input file. Such a surface is assigned a name by Abaqus/CAE and is marked as internal. These internal surfaces can be viewed using display groups in the Visualization module of Abaqus/CAE (see Chapter 78, "Using display groups to display subsets of your model," of the Abaqus/CAE User's Guide).

Input File Usage: *SURFACE, NAME=*surface_name*, INTERNAL

Restrictions on surfaces

Refer to the subsequent sections on the different surface types available in Abaqus for details on the general restrictions that apply to all surface definitions of a given type. In addition, some features in Abaqus that use surfaces impose other restrictions on surface characteristics. These limitations are discussed in the following sections:

- "Integrated output section definition," Section 2.5.1
- "Distributed loads," Section 34.4.3
- "Mesh tie constraints," Section 35.3.1
- "Coupling constraints," Section 35.3.2
- "Shell-to-solid coupling," Section 35.3.3
- "Contact interaction analysis: overview," Section 36.1.1
- "Defining contact pairs in Abaqus/Standard," Section 36.3.1
- "Defining general contact interactions in Abaqus/Explicit," Section 36.4.1
- "Defining contact pairs in Abaqus/Explicit," Section 36.5.1

In models that are defined in terms of an assembly of part instances, all surfaces must belong to a part, part instance, or the assembly. All of the general restrictions on surfaces still apply in such models. Additional rules are given in "Defining an assembly," Section 2.10.1.

2.3.2 ELEMENT-BASED SURFACE DEFINITION

Products: Abaqus/Standard Abaqus/Explicit Abaqus/CAE

References

- "Surfaces: overview," Section 2.3.1
- "Integrated output section definition," Section 2.5.1
- "Distributed loads," Section 34.4.3
- "Prescribed assembly loads," Section 34.5.1
- "Mesh tie constraints," Section 35.3.1
- "Coupling constraints," Section 35.3.2
- "Shell-to-solid coupling," Section 35.3.3
- "Contact interaction analysis: overview," Section 36.1.1
- "Cavity radiation," Section 41.1.1
- *SURFACE
- "What is a surface?," Section 73.2.3 of the Abaqus/CAE User's Guide

Overview

An element-based surface:

- can be defined on solid, structural, rigid, surface, gasket, or acoustic elements;
- can be deformable or rigid;
- can be defined on any combination of elements in many cases;
- can be defined on the exterior of any body; and
- can be defined on the interior of any body that is modeled with continuum, shell, membrane, surface, beam, pipe, truss, or rigid elements (e.g., to define a cross-section through a body) either by simply cutting the body with a plane or by identifying the elements and the corresponding interior facets.

For details about defining node-based surfaces, see "Node-based surface definition," Section 2.3.3. For details about defining analytical rigid surfaces, see "Analytical rigid surface definition," Section 2.3.4. For details about defining surfaces using Boolean combinations of existing surfaces, see "Operating on surfaces," Section 2.3.6.

Defining element-based surfaces

You must assign a name to all element-based surfaces; this name can be used with various features to define a contact model, a surface-based load, or a surface-based constraint. In addition, you must specify the region of your model on which the surface is defined. In an input file you can define element-based surfaces on element faces, edges, or ends. In Abaqus/CAE you can define element-based surfaces on

geometric or element faces, edges, or ends. The methods for defining surfaces depend on the underlying element type and are discussed later in this section.

In an input file you need only specify an element number or element set name and all exposed element faces of these elements (or "contact edges" of beam, pipe, and truss elements) will be included in the surface. Optionally(and the only available method in Abaqus/CAE), you can specify individual faces, edges, or ends, which allows you direct control over which faces, edges, or ends are to be included in the surface.

For general contact in Abaqus/Explicit the surface perimeter edges are generated automatically from the surface facets for use in edge-to-edge contact constraints; you can specify that geometric feature edges should be included as well (see "Defining general contact interactions in Abaqus/Explicit," Section 36.4.1, and "Assigning surface properties for general contact in Abaqus/Explicit," Section 36.4.2, for more information).

Input File Usage: *SURFACE, NAME=*surface_name*, TYPE=ELEMENT (default)

An element number or element set name is specified as the first entry of each data line. Optionally, an element face, edge, or end identifier can be specified as the second entry on a data line. The face and edge identifiers used in Abaqus are discussed later in this section.

Multiple data lines can be used to define a surface. For example, **SURF_1** can be specified by the following input:

```
*SURFACE, NAME=SURF_1, TYPE=ELEMENT
ELSET_1,
ELSET_2, S2
```

Abaqus/CAE Usage: Any module except Sketch, Job, and Visualization: **Tools→Surface→Create**: **Name:** *surface_name*

General restrictions on element-based surfaces

Elements defining a single surface must satisfy the following rules, regardless of how the surface is used in Abaqus:

- Two-dimensional, axisymmetric, and three-dimensional elements cannot be mixed in the same surface definition.
- In Abaqus/Standard deformable elements cannot be combined with rigid elements to define a single surface, but can be combined with other deformable elements that are part of a rigid body (see "Rigid body definition," Section 2.4.1).
- The following element types cannot be mixed with other element types in the same surface definition:
  - Coupled thermal-electrical-structural elements
  - Coupled temperature-displacement elements
  - Heat transfer elements
  - Pore pressure elements

  - Coupled thermal-electrical elements
  - Acoustic finite or infinite elements
- The axisymmetric solid Fourier elements with nonlinear, asymmetric deformation (CAXA elements) cannot form element-based surfaces.

Surface discretization

For element-based surfaces Abaqus uses a faceted geometry defined by the finite element mesh as the surface definition. The surface in a coarse finite element model may not be a very good approximation for contact modeling if the physical surface is curved. Therefore, sufficient mesh refinement must be used to ensure that the faceted surface is a reasonable approximation of the curved physical surface. Alternatively, some curved surface geometries may be more effectively modeled with analytical rigid surfaces (see "Analytical rigid surface definition," Section 2.3.4).

Creating surfaces on solid, continuum shell, and cohesive elements

There are three ways to define the facets of an element-based surface on solid, continuum shell, and cohesive elements:

1. by instructing Abaqus to generate the "free surface" from the exposed faces of elements,
2. by specifying the particular faces for each element, and
3. in Abaqus/Explicit by instructing Abaqus to generate an interior surface from element faces that are not exposed (i.e., not part of the "free surface" of the model).

The automatic free surface generation approach is the simplest method of defining exterior surfaces on solid elements. Specifying the element faces gives you exact control over which element faces (any combination of exterior and interior faces) form the surface. Automatic generation of an interior surface is the simplest method of defining interior surfaces on solid elements (interior surfaces can be useful for modeling surface erosion due to element failure).

It is possible to use all three approaches in the same surface definition when creating a single surface.

Generating the free surface automatically

You can define the facets of a surface by specifying a series of elements. The faces of these elements that are on the exterior (free) surface of the model are included in the surface definition.

When the free surface generation method is used to define surfaces, the specified elements can be a mixture of continuum and structural elements.

Multi-point constraints ("General multi-point constraints," Section 35.2.2) involving nodes on exposed surfaces are not taken into account during free surface generation, which can result in faces that are not on the exterior of a body being included in surface definitions. For example, the nodes of the elements in element set **`REFINED`** shown in Figure 2.3.2–1 are used in linear, mesh-refinement constraints. The surfaces generated with and without multi-point constraints are shown in Figure 2.3.2–1.

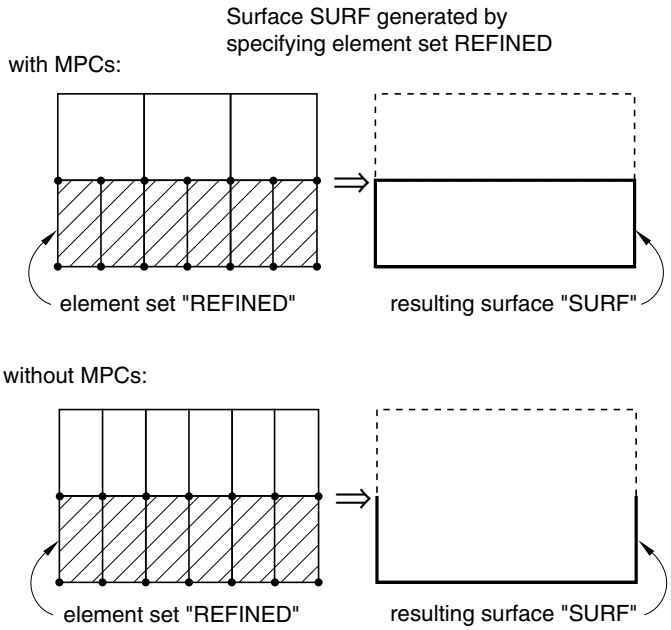


Figure 2.3.2–1 Effect of multi-point constraints on automatic surface generation.

Input File Usage: *SURFACE, NAME=*surface_name*, TYPE=ELEMENT
element number or element set,
For example, if the name of the shaded element set in Figure 2.3.2–2 is **ESETA**, the surface named **ASURF** is specified by

```
*SURFACE, NAME=ASURF, TYPE=ELEMENT
ESETA,
```

Abaqus/CAE Usage: The automatic free surface generation method is not supported in Abaqus/CAE.

Special treatment of cohesive elements for automatic free surface generation

The definition of exposed faces of elements for the purpose of automatic free surface generation has the following unique aspects regarding cohesive elements:

- Faces of non-cohesive elements along an interface of shared nodes with cohesive elements are considered exposed.
- The top and bottom faces of all cohesive elements are considered exposed; side faces of cohesive elements are never considered exposed.

See "Modeling with cohesive elements," Section 32.5.3, for examples of surfaces on or near cohesive elements.

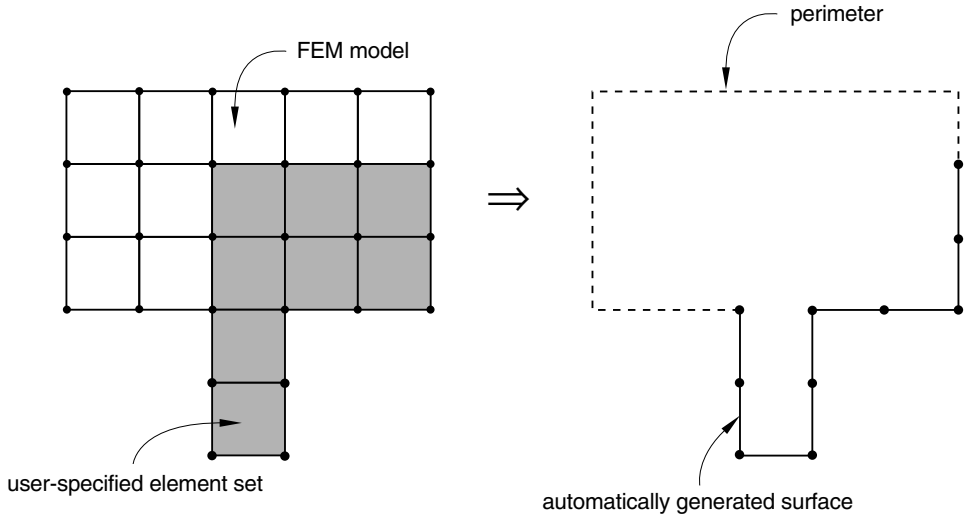


Figure 2.3.2–2 Automatic free surface generation.

Creating surface facets by specifying solid, continuum shell, and cohesive element faces

You can define the facets of a surface by identifying the element faces that should be included in the surface definition.

Input File Usage: ∗SURFACE, NAME=*surface_name*, TYPE=ELEMENT
element number or set, face identifier

Element face numbers are defined in Part VI, "Elements." Table 2.3.2–1 contains a list of valid face identifiers for all solid, continuum shell, and cohesive elements. The face identifier can refer to individual elements or to entire element sets. When you specify the element faces to define surfaces, the specified elements cannot be a mixture of continuum and structural elements; however, each data line of the surface definition can refer to different element types.

Abaqus/CAE Usage: Any module except Sketch, Job, and Visualization: **Tools→Surface→Create**: **Name:** *surface_name*, pick faces in viewport

Generating an interior surface automatically

In Abaqus/Explicit you can define the facets of a surface on the interior of a solid element mesh. The faces of the specified elements that are not on the exterior (free) surface of the model will be included in the surface definition. For example, interior surfaces are used with the general contact algorithm in Abaqus/Explicit for modeling surface erosion due to element failure (see "Defining general contact interactions in Abaqus/Explicit," Section 36.4.1).

Table 2.3.2–1 Surface definition face identifier labels for solid, continuum shell, and cohesive elements.

Elements		Face Labels
DCCAX2(D)		SPOS, SNEG
CPEG3(H)(T) CPS3(T) CPE3(H)(T) CAX3(H)(T) CGAX3(H) AC2D3 ACAX3 DC2D3(E) DCAX3(E)	CPEG6(M)(H)(T) CPS6M(T) CPE6(M)(H)(T) CAX6(M)(H)(T) CGAX6(M)(H)(T) AC2D6 ACAX6 DC2D6(E) DCAX6(E)	S1, S2, S3
CGAX4(R)(H)(T) CPEG4(H)(I)(R)(T) CPS4(I)(R)(T) CPE4(H)(I)(R)(T)(P) CAX4(H)(I)(R)(T)(P) C3D4(H)(T) AC2D4(R) ACAX4(R) AC3D4 DC2D4(E) DCAX4(E) DC3D4(E) DCC2D4(D) COH2D4	CGAX8(R)(H) CPEG8(R)(H)(T) CPS8(R)(T) CPE8(H)(R)(T)(P) CAX8(R)(H)(T)(P) C3D10(M)(H)(I)(T) AC2D8 ACAX8 AC3D10 DC2D8(E) DCAX8(E) DC3D10(E) DCCAX4(D) COHAX4	S1, S2, S3, S4
C3D6(H)(T) AC3D6 CCL9(H) DC3D6(E) SC6R	C3D15(H)(V) AC3D15 CCL18(H) DC3D15(E) COH3D6	S1, S2, S3, S4, S5
C3D8(H)(I)(R)(T)(P) C3D27(R)(H) AC3D8(R) CCL12(H) DC3D8(E) DCC3D8(D) SC8R	C3D20(H)(R)(T)(P) AC3D20 CCL24(R)(H) DC3D20(E) COH3D8	S1, S2, S3, S4, S5, S6

The automatic generation of an interior surface is equivalent to constructing a surface consisting of all faces of the elements and then subtracting the free surfaces of those elements. Shell elements, beam elements, pipe elements, membrane elements, etc. are ignored since they do not have any interior faces by definition.

Multi-point constraints are not taken into account when generating interior surfaces. This can result in faces that are on the interior of a body being excluded from the surface definition.

Input File Usage: *SURFACE, NAME=*surface_name*, TYPE=ELEMENT
element number or element set, INTERIOR

For example, if the name of the shaded element set in Figure 2.3.2–3 is **ESETA**, the surface named **ASURFINTR** (the elements in the figure have been reduced in size to differentiate faces that share the same nodes) is specified by

```
*SURFACE, NAME=ASURFINTR, TYPE=ELEMENT
ESETA, INTERIOR
```

Abaqus/CAE Usage: Any module except Sketch, Job, and Visualization: **Tools→Surface→Create**: **Name:** *surface_name*, **Type**: **Mesh**; pick element faces or edges from an interior surface

You can use the selection tools to select from an interior entity of a model; see "Selecting interior surfaces," Section 6.2.12 of the Abaqus/CAE User's Guide.

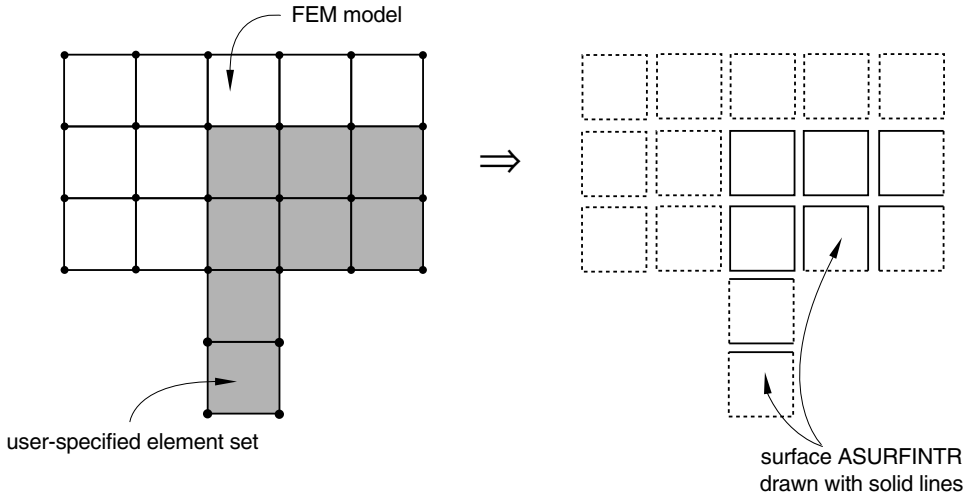


Figure 2.3.2–3 Automatic interior surface generation.

Creating surfaces on structural, surface, and rigid elements

There are five ways to define surfaces on structural, surface, and rigid elements:

1. You can create a single-sided surface with a well-defined orientation by indicating either the top or bottom surface of each specified element.
2. You can create a double-sided surface by specifying only the elements and letting Abaqus generate the "free surface" from the exposed faces.
3. You can create an edge-based surface.
4. You can create a cross-section surface on the ends of beam, pipe, and truss elements.
5. You can create a three-dimensional curve-type surface along the length of beam, pipe, and truss elements by specifying only the elements and letting Abaqus generate the "free surface."

It is possible to use any or all of the above approaches in the same surface definition as long as it makes sense in the use of that surface with other features in Abaqus. Table 2.3.2–2 contains a list of valid face and edge identifiers for structural, surface, and rigid elements.

Table 2.3.2–2 Surface definition face and edge identifier labels for structural, surface, and rigid elements.

Elements		Face and Edge Labels
SAX1 MAX1 MGAX1 M3D6 M3D9(R) MCL9 DS8 DSAX2 SFMAX2 SFMGAX2 SFM3D4(R) SFM3D8(R) SFMCL6	SAX2(T) MAX2 MGAX2 M3D8(R) MCL6 DS4 DSAX1 SFMAX1 SFMGAX1 SFM3D3 SFM3D6 SFMCL9 RAX2	SPOS, SNEG
B21(H) B23(H) PIPE21(H) T2D2(H)(T)	B22(H) (Abaqus/Standard) PIPE22(H) T2D3(H)(T)	END1, END2

Elements		Face and Edge Labels
B22 (Abaqus/Explicit) B32(H)(OS) ELBOW31(B)(C) PIPE31(H) T3D2(H)(T)	B31(H)(OS) B33(H) ELBOW32 PIPE32(H) T3D3(H)(T)	END1, END2; must use node-based surfaces with the contact pair algorithm in Abaqus/Explicit.
STRI3 S3(R)(S) M3D3	STRI65 R3D3	SPOS, SNEG, E1, E2, E3
ACIN2D2 ACINAX2	ACIN2D3 ACINAX3	SPOS E1, E2
S4(R)(S)(W)(5) S9R5 M3D4(R)	S8R5(T) R3D4	SPOS, SNEG, E1, E2, E3, E4
ACIN3D3	ACIN3D6	SPOS E1, E2, E3
ACIN3D4	ACIN3D8	SPOS E1, E2, E3, E4

Defining single-sided surfaces

You can define a single-sided surface on the positive or negative face of structural, surface, or rigid elements. The positive face is defined as the one in the direction of the positive element normal, and the negative face is defined as the one in the direction opposite to the element normal. The definition of the element normal for all elements is given in Part VI, "Elements."

You must ensure that all of the specified elements have their normals oriented consistently. If they are oriented as shown in Figure 2.3.2–4, the surface normals will reverse direction as the surface is traversed and improper results may occur when the surface is used with features requiring an orientation such as distributed surface loads. Further, an error message will be issued and the analysis will terminate if this condition is detected for surfaces used with mesh tie constraints in Abaqus/Standard or with contact pairs. To correct the surface orientations in this figure, two separate element sets with different face identifiers should be used.

Input File Usage: Use the following option to define a surface on the positive face of a structural, surface, or rigid element:

∗SURFACE, NAME=*surface_name*, TYPE=ELEMENT
element number or element set, SPOS

Use the following option to define a surface on the negative face of a structural, surface, or rigid element:

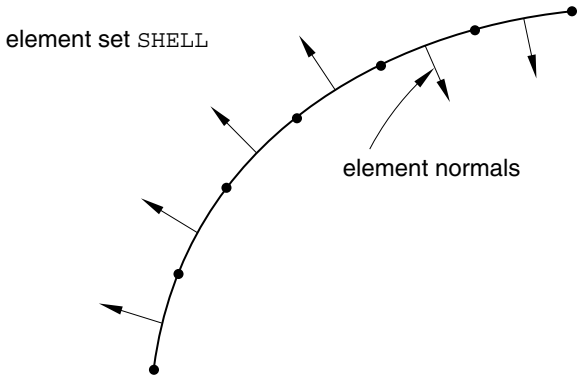


Figure 2.3.2–4 Inconsistent orientation of structural element normals can result in an invalid surface.

∗SURFACE, NAME=*surface_name*, TYPE=ELEMENT
element number or element set, SNEG

For example, single-sided surfaces on the positive faces of the elements in element set **SHELL** can be defined using input similar to

```
*SURFACE, NAME=BSURF, TYPE=ELEMENT
SHELL, SPOS
```

Abaqus/CAE Usage: Any module except Sketch, Job, and Visualization: **Tools→Surface→Create**: **Name:** *surface_name*, pick face in viewport, click mouse button 2, and specify the side of the selected face

Defining double-sided surfaces

You can create double-sided surface facets on three-dimensional shell, membrane, surface, and rigid elements using the automatic surface facet generation approach (i.e., specifying only the element numbers or sets). Some applications that refer to surfaces do not allow the use of double-sided surfaces: examples include contact pairs in Abaqus/Standard and features requiring an oriented surface such as distributed surface loads. When double-sided surfaces can be used, they are often preferred to single-sided surfaces. In some applications, such as when defining the contact domain for general contact, it does not matter whether single- or double-sided surfaces are used.

When double-sided surfaces are used with contact pairs in Abaqus/Explicit, the normals of all the underlying elements do not need to have a consistent positive orientation: Abaqus/Explicit will define the contact surface such that its facets have consistent normals, even if the underlying elements do not have consistent normals. The facet normals will be the same as the element normals if the element normals are all consistent; otherwise, an arbitrary positive orientation is chosen for the surface. The positive orientation is significant only with respect to the sign of the contact pressure output variable for the contact pair algorithm, CPRESS (see "Output" in "Defining contact pairs in Abaqus/Explicit," Section 36.5.1).

Although contact is enforced unconditionally on both sides of a surface when self-contact is used with contact pairs, contact is enforced on both sides of a surface used in two-body contact only when that surface is double-sided (if allowed). The use of single-sided surfaces with contact pairs is sometimes desirable: the resolution of large initial overclosures in contact pairs is more robust with single-sided surfaces than with double-sided surfaces (see "Adjusting initial surface positions and specifying initial clearances for contact pairs in Abaqus/Explicit," Section 36.5.4). However, single-sided contact is generally more limiting than double-sided contact; it may cause an analysis to fail due to excessive element distortion or not enforce the contact conditions realistically if a slave node unexpectedly moves behind a master surface. This condition can occur, for example, when large deformations or rigid-body motions are present or due to complex tool shapes in a forming analysis.

Input File Usage: Use the following option to define a double-sided surface on three-dimensional shell, membrane, surface, or rigid elements in Abaqus/Explicit:

∗SURFACE, NAME=*surface_name*, TYPE=ELEMENT
element number or element set,

For example, double-sided surfaces on the elements in element set **SHELL** can be defined using input similar to

```
*SURFACE, NAME=BSURF, TYPE=ELEMENT
SHELL,
```

Abaqus/CAE Usage: Any module except Sketch, Job, and Visualization: **Tools→Surface→Create**: **Name:** *surface_name*, pick face in viewport, click mouse button 2, and choose **Both sides**

Defining edge-based surfaces

You can define an edge-based surface on three-dimensional shell, membrane, surface, or rigid elements by specifying the individual edges. Alternatively, you can specify that all the edges of the elements that are on the exterior (free) surface of the model are used to form the surface; this method cannot be used to define edge-based surfaces that are in the interior of the model. It is possible to use both methods in the same surface definition when creating a single surface.

Input File Usage: Use the following option to specify the individual edges that form the surface:

∗SURFACE, NAME=*surface_name*, TYPE=ELEMENT
element number or element set, edge identifier

The individual edge identifiers used in Abaqus are listed in Table 2.3.2–2.

Use the following option to specify that all the edges of the elements that are on the exterior (free) surface of the model are used to form the surface:

∗SURFACE, NAME=*surface_name*, TYPE=ELEMENT
element number or element set, EDGE

For example, if the shaded element set in Figure 2.3.2–2 is composed of three-dimensional shell elements and is named **ESETA**, the surface named **ESURF** could be specified by the following input:

```
*SURFACE, NAME=ESURF, TYPE=ELEMENT
ESETA, EDGE
```

Abaqus/CAE Usage: Any module except Sketch, Job, and Visualization: **Tools→Surface→Create**: **Name:** *surface_name*, pick edges in viewport

In Abaqus/CAE you can specify that all the edges of the elements that are on the exterior (free) surface of the model are used to form the surface by directly picking all the free edges in the viewport.

Defining a surface over the cross-section at the ends of beam, pipe, and truss elements

To define a surface over the cross-section of beam, pipe, or truss elements, you must specify the end on which the surface is defined. Surfaces created on the ends of these elements can be used only for integrated output request (see "Integrated output in Abaqus/Explicit" in "Output to the output database," Section 4.1.3) and integrated output section (see "Integrated output section definition," Section 2.5.1) definitions.

Input File Usage: Use the following option to define a surface over the cross-section of a beam, pipe, or truss element:

*SURFACE, NAME=*surface_name*, TYPE=ELEMENT
element number or element set, END1 or END2

Abaqus/CAE Usage: Any module except Sketch, Job, and Visualization: **Tools→Surface→Create**: **Name:** *surface_name*, pick three-dimensional wire region in viewport, click mouse button 2, and choose **End (Magenta)** or **End (Yellow)**

Defining a surface along the length of three-dimensional beam, pipe, and truss elements

You cannot specify the faces to define a surface along the length of three-dimensional beams, pipes, or trusses because their element connectivity cannot define a unique element or surface normal. Instead, you must specify that Abaqus should generate a surface for these elements. Therefore, the use of surfaces along the length of these elements is restricted.

In Abaqus/Standard element-based surfaces created along the length of three-dimensional beam, pipe, or truss elements can be used in tie constraints but can be used only as slave surfaces in contact interactions. However, there are several advantages to using an element-based surface rather than a node-based surface when modeling contact in Abaqus/Standard with three-dimensional beams, pipes, or trusses:

1. The default local tangent directions are parallel and orthogonal to the element axis.
2. Abaqus/Standard calculates the contact results as contact forces per unit length rather than just contact forces.
3. It can be easier to define an element-based surface than a node-based surface.

In Abaqus/Standard a surface definition is not allowed for cases where three or more three-dimensional beams, pipes, or trusses are joined at a common node because of the lack of uniquely defined element tangents.

In Abaqus/Explicit element-based surfaces created along the length of three-dimensional beam, pipe, or truss elements can be used only with the general contact algorithm or tie constraints. To define contact for these elements using the contact pair algorithm, the nodes forming the beam, pipe, or truss elements can be included in a node-based surface definition ("Node-based surface definition," Section 2.3.3) and a contact pair can be defined for this node-based surface and a non-node-based surface.

Surfaces along the length of three-dimensional beam, pipe, or truss elements cannot be used to prescribe a distributed surface load since the loading direction is not unique.

Input File Usage: Use the following option to define a surface along the length of a three-dimensional beam, pipe, or truss element:

*SURFACE, NAME=*surface_name*, TYPE=ELEMENT
element number or element set,

Abaqus/CAE Usage: Any module except Sketch, Job, and Visualization: **Tools→Surface→Create**:
Name: *surface_name*, pick three-dimensional wire region in viewport,
click mouse button 2, and choose **Circumferential**

Surfaces along the length of two-dimensional beam, pipe, and truss elements

Surfaces created along the length of two-dimensional beam, pipe, and truss elements can be used as master surfaces in a contact pair simulation because the underlying elements have unique element normals that lie in the plane of the model. These surfaces can also be used to prescribe distributed surface loads.

Shell, membrane, or rigid element thickness and shell offset

Some applications that refer to surfaces will account for underlying element thicknesses and any offset of the midsurface relative to the reference surface for surfaces based on shell, membrane, or rigid elements. For example, all of the contact algorithms available in Abaqus/Explicit can account for these effects. Of the contact algorithms available in Abaqus/Standard, only the surface-to-surface small-sliding contact formulation can account for these effects. See the following sections for additional details on applications that can account for surface thickness and offset:

- "Mesh tie constraints," Section 35.3.1
- "Contact formulations in Abaqus/Standard," Section 38.1.1
- "Assigning surface properties for general contact in Abaqus/Explicit," Section 36.4.2
- "Assigning surface properties for contact pairs in Abaqus/Explicit," Section 36.5.2

Creating surfaces on gasket elements

When surfaces are defined on gasket elements, automatic surface facet generation cannot be used because only the top and bottom element faces can be used to create surfaces (see "Gasket elements: overview," Section 32.6.1). Abaqus/Standard cannot create surfaces on gasket link elements since the top and bottom surfaces are each reduced to a single node. For other gasket elements you must specify the top and bottom surfaces directly. The positive face of the element is in the thickness direction of the element.

The definition of the thickness direction of all gasket elements is given in "Defining the gasket element's initial geometry," Section 32.6.4. The negative face is defined as the face in the direction opposite to the thickness direction of the element.

Input File Usage: Use the following option to define a surface on the positive face of a gasket element:

∗SURFACE, NAME=*surface_name*, TYPE=ELEMENT
element number or element set, SPOS

Use the following option to define a surface on the negative face of a gasket element:

∗SURFACE, NAME=*surface_name*, TYPE=ELEMENT
element number or element set, SNEG

For example, single-sided surfaces on the positive faces of the elements in element set **GASKET** can be defined using input similar to

```
*SURFACE, NAME=BSURF, TYPE=ELEMENT
GASKET, SPOS
```

Abaqus/CAE Usage: Any module except Sketch, Job, and Visualization: **Tools→Surface→Create**: **Name:** *surface_name*, pick top or bottom faces in viewport

Surfaces on three-dimensional gasket line elements

There are several advantages to using an element-based surface rather than a node-based surface when modeling contact in Abaqus/Standard with three-dimensional gasket line elements:

1. The local tangent directions are parallel and orthogonal to the gasket line element, which is useful for output purposes and for anisotropic friction definition.
2. Abaqus/Standard calculates the contact results as contact forces per unit length rather than just contact forces.

Surfaces created on three-dimensional gasket line elements can be used only as slave surfaces because Abaqus/Standard cannot form unique normals for these surfaces.

Creating interior cross-section surfaces

To study the "force-flow" through various paths in a model, you must create interior surfaces that cut through one or more components (similar to a cross-section) so that you can request integrated output of the total force transmitted across these surfaces (see "Requesting integrated output for "force-flow" studies" in "Output to the output database," Section 4.1.3). Abaqus provides a simple method to create such an interior surface over the element facets, edges, or ends by cutting through a region of the model with a plane. The region can be identified using one or more element sets. If no element sets are specified, the region consists of the whole model. The cutting plane is defined by specifying the coordinates of a point on the plane and a vector normal to the plane. Alternatively, the cutting plane can be defined by specifying the global node numbers of point a on the plane and point b that lies off the cutting plane with the normal determined as the vector from point a to point b. Abaqus then automatically forms a surface

close to the specified cutting plane by selecting the element facets, edges, or ends of the continuum solid, shell, membrane, surface, beam, pipe, truss, or rigid elements in the selected region. The surface generated in this manner is an approximation for the cutting plane.

Multi-point mesh constraints are ignored while generating the interior surface based on the cutting plane; therefore, the result may be a surface that is not continuous if these constraints stitch disjointed meshes together in a region that is cut by the cutting plane. When the cutting plane intersects a beam, pipe, or truss element, the entire element is shown in the Visualization module of Abaqus/CAE as being part of the surface. However, if this surface is used for integrated output, only the element nodal forces from the element end that lies on the positive side as defined by the normal to the cutting plane are included in the integrated output. Point mass and rotary elements, connector elements, spot welds, and spring elements will not be part of the generated surface even if they are cut by the cutting plane.

Input File Usage: Use the following option to define the cutting surface by specifying coordinates of a point on the plane and a vector normal to the plane:

∗SURFACE, NAME=*surface_name*, TYPE=CUTTING SURFACE, DEFINITION=COORDINATES

Use the following option to define the cutting surface by specifying global node numbers of points *a* and *b*:

∗SURFACE, NAME=*surface_name*, TYPE=CUTTING SURFACE, DEFINITION=NODES

Abaqus/CAE Usage: Interior cross-section surfaces are not supported in Abaqus/CAE.

Whole-model free surface in an Abaqus/Explicit input file

In an Abaqus/Explicit input file you can create a surface containing the exposed faces of all elements (and "contact edges" of beam, pipe, and truss elements) in the model except cohesive elements by specifying a blank element set name and a blank face identifier. This "free" surface of the model can be used as the base surface for the cropping and combining operations; without modifications this surface is similar to the default all-inclusive surface commonly used in general contact (see "Defining general contact interactions in Abaqus/Explicit," Section 36.4.1).

Input File Usage: ∗SURFACE, NAME=*surface_name*, TYPE=ELEMENT
,

Abaqus/CAE Usage: The whole-model automatic free surface generation method is not supported in Abaqus/CAE.

Trimming the perimeter of an open surface

An "open" surface is one that has ends in two dimensions or an outside edge in three dimensions. The ends of a two-dimensional surface and the edge of a three-dimensional surface are called the surface's "perimeter." Since Abaqus allows a surface to be defined as only a part of the surface of a body, it may have a perimeter even though it is defined on a closed body. Abaqus automatically performs surface "trimming" on solid element meshes. You can change the default setting when a surface is created, providing some basic control over the extent of surfaces.

Surface trimming:

- is a recursive procedure that removes undesirable convex corners near the perimeter of an open surface (see the example below for details);
- has no effect on closed surfaces (ones with no ends or edges);
- is performed automatically, unless the surface is used as a master surface in a finite-sliding simulation in Abaqus/Standard or the surface is used with the contact pair algorithm in Abaqus/Explicit;
- can be used only for external surfaces on solid element meshes (either specified surfaces or automatically generated free surfaces); and
- has no effect on surfaces used with the contact pair algorithm in Abaqus/Explicit.

Input File Usage: Use the following option to suppress automatic surface trimming:

*SURFACE, TYPE=ELEMENT, NAME=*surface_name*, TRIM=NO

Abaqus/CAE Usage: Automatic surface trimming cannot be suppressed in Abaqus/CAE.

The effect of surface trimming

The effect of surface trimming is best explained by means of an example. Figure 2.3.2–5 illustrates the effect of trimming for two different surfaces defined on the same simple two-dimensional mesh.

In Case I the surface definition consists of a single layer of elements on the perimeter of the model. Using automatic surface facet generation, the resulting default surface (curve) includes the vertical element faces A and B since these faces lie on the perimeter of the model. Trimming the default surface created in Case I eliminates faces A and B since their presence results in the two spurious corners near the perimeter of the curve.

Abaqus uses a special criterion in deciding to remove faces A and B from the original open curve. A face is removed if one of its end nodes is an endpoint and either of the following is true: another face node is a node on an element corner belonging to the curve or the face normal differs by more than 30° from the normal of an adjacent face also belonging to the curve. To be a node on an element corner belonging to the curve means to be a node on two different faces of the same element, both of which are part of the curve. The face removal criterion is applied recursively to the curve definition until all corners on or near the perimeter of the curve have been removed. This procedure is generalized for three-dimensional surface definitions.

In Case II in Figure 2.3.2–5 trimming would not result in the elimination of faces A and B because neither of the endpoints of these two faces meets the criterion described above.

Why Abaqus will, by default, trim most surfaces

Trimming of surfaces used for application of distributed loads is usually desired since loads are normally applied to specific sides of a body. Any surface that is used for application of a distributed load will, by default, be trimmed.

In Abaqus/Standard trimming the slave surface in contact or interaction simulations results in more accurate estimates of the contact pressures, heat fluxes, and electrical current densities along the perimeter of the surface. Any surface that is used as a slave surface in a contact or interaction simulation will, by default, be trimmed. If the slave surface is left untrimmed, the nodes at the corners of the surface will be

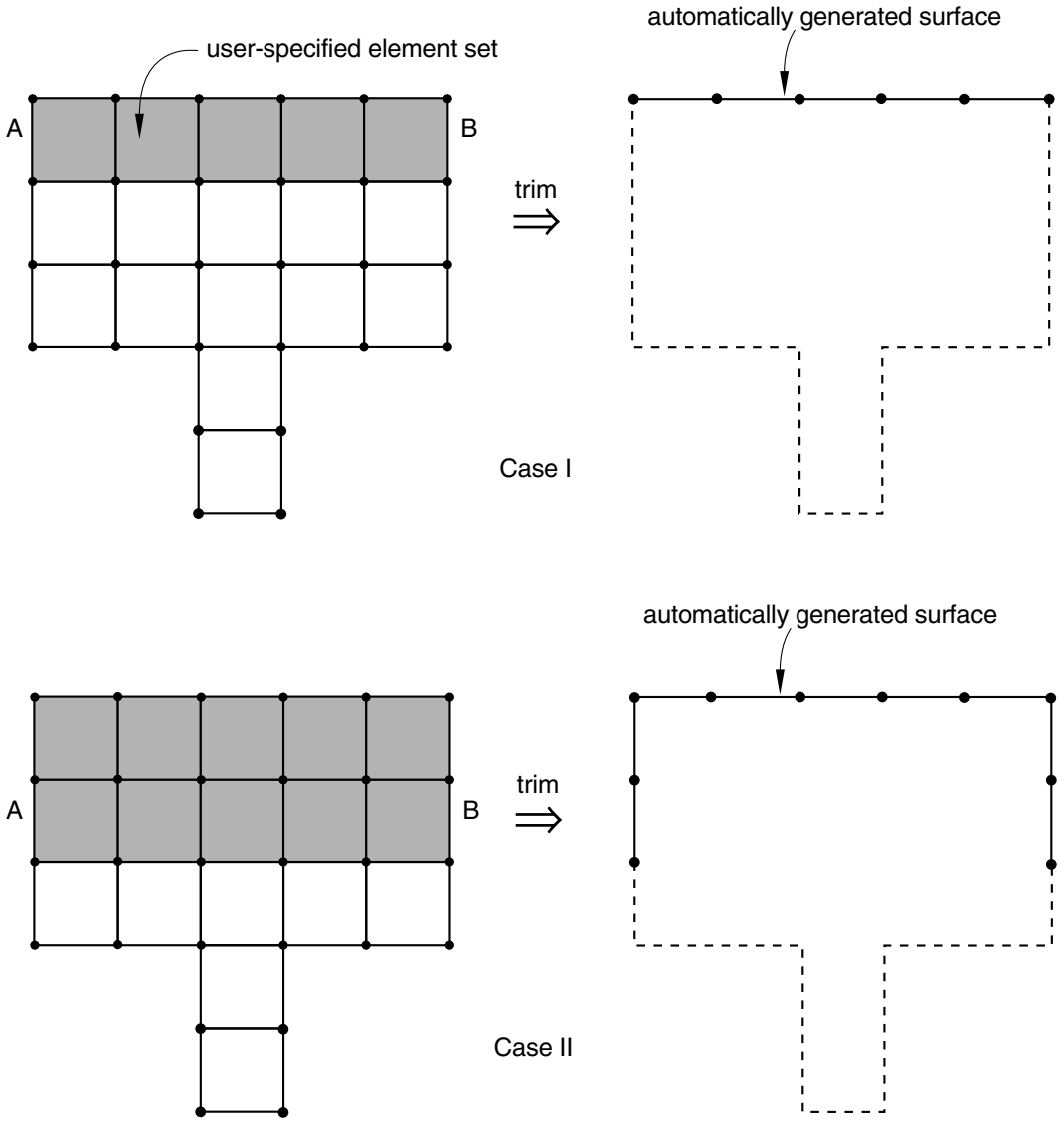


Figure 2.3.2–5 Case I: Faces *A* and *B* are removed when trimming is done since one node of each of the faces is an end node and the other is a corner node. Case II: Faces *A* and *B* are not removed when trimming is done since one node of each of the faces is an end node but the other is not a corner node.

assigned additional contact area from the element faces around the corners that may never be involved in the interaction between the surfaces. This additional contact area introduces errors into the estimates

of the contact output variables at those nodes. Master surfaces in small-sliding simulations will, by default, be trimmed; Abaqus/Standard will normally form a better approximate surface. However, master surfaces in finite-sliding contact simulations will, by default, be left untrimmed, and they should extend far enough away from all expected regions of contact. This practice protects against the possibility of the slave surface nodes sliding off the master surface (see "Common difficulties associated with contact modeling in Abaqus/Standard," Section 39.1.2).

2.3.3 NODE-BASED SURFACE DEFINITION

Products: Abaqus/Standard Abaqus/Explicit

References

- "Surfaces: overview," Section 2.3.1
- "Mesh tie constraints," Section 35.3.1
- "Contact interaction analysis: overview," Section 36.1.1
- *SURFACE

Overview

A node-based "surface":

- can be used only as a "slave surface" in contact calculations;
- can be used as a "slave" or "master surface" in a surface-based tie constraint;
- is convenient in three-dimensional cases where Abaqus cannot construct a unique physical surface on the elements, such as a pipe modeled with pipe elements contacting the ocean floor or cables modeled with trusses contacting the ground after they break;
- should be used with caution or not at all if accurate contact stresses are needed or if heat will be exchanged between the two surfaces;
- can be assigned a nonzero thickness for use with the general contact algorithm in Abaqus/Explicit;
- should not be used to model a shell or membrane surface if the thickness and midsurface offset need to be considered in the problem;
- must either contain nodes that are all part of the same rigid body or not contain any nodes that are part of a rigid body if the node-based surface is to be used in a penalty contact pair in Abaqus/Explicit;
- in Abaqus/Standard does not provide heat conduction between surfaces in fully coupled temperature-displacement analysis or pore fluid flow between surfaces in coupled pore pressure–displacement analysis;
- in Abaqus/Standard does not provide heat conduction and electrical conduction between surfaces in a fully coupled thermal-electrical-structural analysis; and
- does not include circumferential friction when used with axisymmetric elements with twist (CGAX, MGAX elements).

Alternatives to node-based surfaces are element-based surfaces (see "Element-based surface definition," Section 2.3.2) and, in the case of rigid surfaces, analytical rigid surfaces (see "Analytical rigid surface definition," Section 2.3.4). See "Operating on surfaces," Section 2.3.6, for information on defining surfaces using Boolean combinations of existing surfaces.

Creating a node-based surface

You create a node-based surface by specifying the nodes or node sets that form the surface. You must assign a name to the node-based surface; this name will be used when defining contact interactions that involve the surface.

An optional associated area can be defined for each node. If no area is defined for a node and the surface is defined in a contact pair, the area specified as part of the contact property definition is used. If no area is specified as part of the contact property definition, a unit area is used.

In Abaqus/Explicit the area used in contact pair calculations for a node in a node-based surface is always 1.0, regardless of the user-specified value. Therefore, the contact pressure output variable in Abaqus/CAE should be interpreted as the contact force when a node-based surface is used for contact pairs in Abaqus/Explicit.

In models that are defined in terms of an assembly of part instances, all surfaces must belong to a part, part instance, or the assembly. Additional rules are given in "Defining an assembly," Section 2.10.1.

When the nodes of shell and membrane elements are used in a node-based surface, the thickness and midsurface offset of the shell or membrane at each node are not considered. However, a nonzero thickness can be assigned to node-based surfaces when used with the general contact algorithm in Abaqus/Explicit (see "Assigning surface properties for general contact in Abaqus/Explicit," Section 36.4.2, for more information).

Input File Usage: ∗SURFACE, NAME=*name*, TYPE=NODE
node number or node set, area

2.3.4 ANALYTICAL RIGID SURFACE DEFINITION

Products: Abaqus/Standard Abaqus/Explicit Abaqus/CAE

References

- "Surfaces: overview," Section 2.3.1
- "Contact interaction analysis: overview," Section 36.1.1
- "RSURFU," Section 1.1.16 of the Abaqus User Subroutines Reference Guide
- *RIGID BODY
- *SURFACE

Overview

An analytical rigid surface:

- can be two-dimensional or three-dimensional;
- must be defined as model data;
- can be used with the infinitesimal-sliding, small-sliding, or finite-sliding mechanical contact formulations;
- should be oriented such that the analytical rigid surface's outward normal points toward any body it may contact; and
- is associated with a node, known as the rigid body reference node, whose motion governs the motion of the surface.

What are analytical rigid surfaces and why use them?

Analytical rigid surfaces are geometric surfaces with profiles that can be described with straight and curved line segments. These profiles can be swept along a generator vector or rotated about an axis to form a three-dimensional surface. An analytical rigid surface is associated with a rigid body reference node, whose motion governs the motion of the surface. An analytical rigid surface does not contribute to the rigid body's mass or inertia properties (see "Rigid body definition," Section 2.4.1). The degrees of freedom of the rigid body reference node become active only when the analytical surface is used in a contact interaction or when an element (such as a spring element or a mass element) is connected to the rigid body reference node.

Analytical rigid surfaces are always single-sided with their orientation specified through their definition. Therefore, contact interaction is recognized only on the outer boundary of an analytical rigid surface. To model contact on both sides of a thin structure, use an analytical rigid surface that wraps around the boundary of the thin structure.

Advantages

Using analytical rigid surfaces instead of defining element-based rigid surfaces provides two important advantages in contact modeling.

- Many curved geometries can be modeled exactly with analytical rigid surfaces because of the ability to parameterize the surface with curved line segments. The result is a smoother surface description, which can reduce contact noise and provide a better approximation to the physical contact constraint.
- Using analytical rigid surfaces instead of rigid surfaces formed by element faces may result in decreased computational cost incurred by the contact algorithm.

  The use of curved line segments instead of many linear facets will decrease the time spent in contact tracking operations. Additional computational savings may be realized in three dimensions because of the intrinsic two-dimensional descriptions of the analytical surfaces.

Disadvantages

There are also some disadvantages to using analytical rigid surfaces for contact modeling.

- An analytical rigid surface must always act as a master surface in a contact interaction. Therefore, contact cannot be modeled between two analytical rigid surfaces.
- Contact forces and pressures cannot be contoured on an analytical rigid surface. However, contact forces and pressures can be plotted on the slave surface.
- The use of a very large number (thousands) of segments to define an analytical rigid surface can degrade performance. In most cases it is not necessary to use a large number of segments to define an analytical rigid surface, because curved segment types are allowed. In rare cases in which a very large number of segments would be necessary, the analysis may be more efficient if an element-based rigid surface is used instead (see "Element-based surface definition," Section 2.3.2).
- An analytical rigid surface does not contribute to the mass and rotary inertia properties of the rigid body with which it is associated. Therefore, if the mass distribution on an analytical rigid surface needs to be accounted for, equivalent mass and rotary inertia properties must be defined for the rigid body by using MASS and ROTARYI elements, or a finite element discretization of the surface should be used instead of an analytical rigid surface (see "Rigid body definition," Section 2.4.1).
- In Abaqus/Explicit reaction force output for a rigid body containing an analytical rigid surface is calculated only for constraints that are active at the reference node (e.g., constraints specified as boundary conditions). If the net contact force on the rigid body corresponding to an unconstrained degree of freedom is desired, it must be calculated from the rigid body's acceleration and mass.

Creating an analytical rigid surface

You can define the following types of simple, two- or three-dimensional, geometric analytical surfaces:

- planar (two-dimensional) surfaces,
- three-dimensional cylindrical (swept) surfaces, and
- three-dimensional surfaces of revolution.

In Abaqus/Standard if none of these surfaces is adequate, you can define a more general analytical surface with user subroutine **RSURFU**.

Analytical rigid surfaces are useful when the cross-sections of the surfaces can be represented by straight and curved line segments. The curved segments can be either circular or parabolic arcs. In two-dimensional simulations the line segments are defined in the global coordinate system of the deformable model. In three-dimensional simulations a local, two-dimensional coordinate system must be created, and the line segments are then defined in that system. The two standard types of three-dimensional analytical rigid surfaces available are shown in Figure 2.3.4–1.

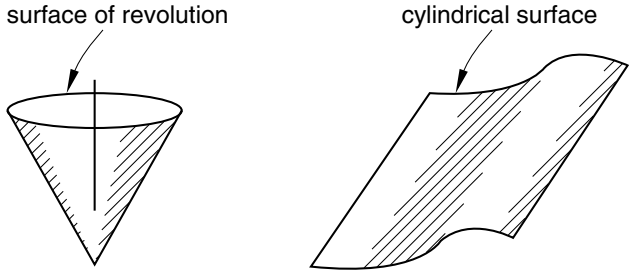


Figure 2.3.4–1 Examples of three-dimensional rigid surfaces.

You must indicate which type of analytical surface (planar, cylindrical, or revolution) is being created and assign a name to the surface. In addition, you must define the analytical surface as part of a rigid body by specifying the name of the analytical surface and the rigid body reference node that will control the motion of the surface in a rigid body definition.

An Abaqus model can be defined in terms of an assembly of part instances (see "Defining an assembly," Section 2.10.1). A part can contain only one analytical surface. A part containing an analytical surface definition cannot also contain elements.

Input File Usage: Use both of the following options to create an analytical rigid surface:

∗SURFACE, TYPE=*analytical_surface_type*, NAME=*name*
∗RIGID BODY, ANALYTICAL SURFACE=*name*, REF NODE=*n*

Abaqus/CAE Usage: Part module: **Create Part**: **Name:** *analytical_rigid_part*: select **Analytical rigid** as the **Type**

Then do one of the following:

Any module except Sketch, Job, and Visualization: **Tools→Surface→Create**: select *analytical_rigid_part*

Interaction module: **Create Constraint**: **Rigid body**: **Analytical Surface**: **Edit**: select *analytical_rigid_part*

Interaction module: **Create Interaction**: *any valid type*: select *analytical_rigid_part* as one of the regions involved in contact

Defining a surface profile

The surface profile is the collection of line segments defining the cross-section of the surface. The surface type determines whether the profile is swept (cylindrical surfaces), revolved (surfaces of revolution), or, in the two-dimensional case, used as is (planar surfaces).

You construct a profile by providing the endpoint of each line segment in the profile; the starting point is always the endpoint of the previous segment, or, in the case of the first segment, the point specified as the starting point. The center points of circular arcs must be given. Abaqus can define only arcs that are less than 179.74°; thus, it will use the shorter arc defined by the data provided (use two adjacent arcs to define a longer arc). For parabolic arcs you must give a third point that lies on the parabola and within the arc.

Two-dimensional rigid surfaces

To define a planar rigid surface, specify the line segments forming the rigid surface's profile in the global coordinate system. If the analytical surface is being defined inside a part, specify the line segments in the local part coordinate system.

Input File Usage: ∗SURFACE, TYPE=SEGMENTS, NAME=*name*
data lines to define the line segments forming the surface

For example, the definition of the two-dimensional rigid surface depicted in Figure 2.3.4–2 is

∗SURFACE, TYPE=SEGMENTS, NAME=BSURF
START, x_a**,** y_a
CIRCL, x_b**,** y_b**,** x_c**,** y_c
LINE, x_d**,** y_d
CIRCL, x_e**,** y_e**,** x_f**,** y_f
∗RIGID BODY, ANALYTICAL SURFACE=BSURF, REF NODE=101

where x_i and y_i are the global coordinates of the points shown in Figure 2.3.4–2.

Abaqus/CAE Usage: Part module: **Create Part**: **Name:** *analytical_rigid_part*: select **2D Planar** or **Axisymmetric** as the **Modeling Space** and **Analytical rigid** as the **Type**

Three-dimensional cylindrical rigid surfaces

To define a cylindrical rigid surface in a model that is not defined in terms of an assembly of part instances, specify the points *a*, *b*, and *c* shown in Figure 2.3.4–3 that define the local coordinate system. Give the coordinates of these points—(X_a, Y_a, Z_a), (X_b, Y_b, Z_b), and (X_c, Y_c, Z_c)—in the default global coordinate system. As shown in Figure 2.3.4–3, point *a* defines the origin of the local system; point *b* defines the local *x*-axis; and point *c* defines the generator vector, which is the *negative* local *z*-axis. If the segment ac is not perpendicular to ab, Abaqus will automatically adjust point *c* within the plane defined by points *a*, *b*, and *c*, such that they become perpendicular. The line segments forming the profile of the rigid surface are defined in the local *x*–*y* plane. The three-dimensional surface is formed by sweeping this profile along the generator vector. The resulting surface extends to infinity in both the positive and negative directions of the generator vector.

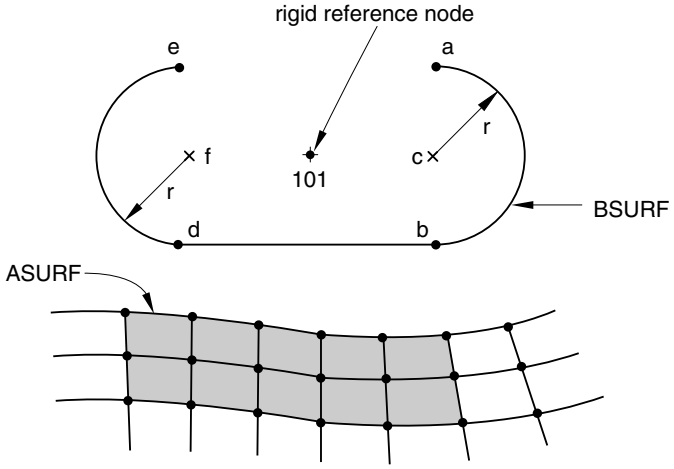


Figure 2.3.4–2 Two-dimensional analytical rigid surface contacting a deformable body.

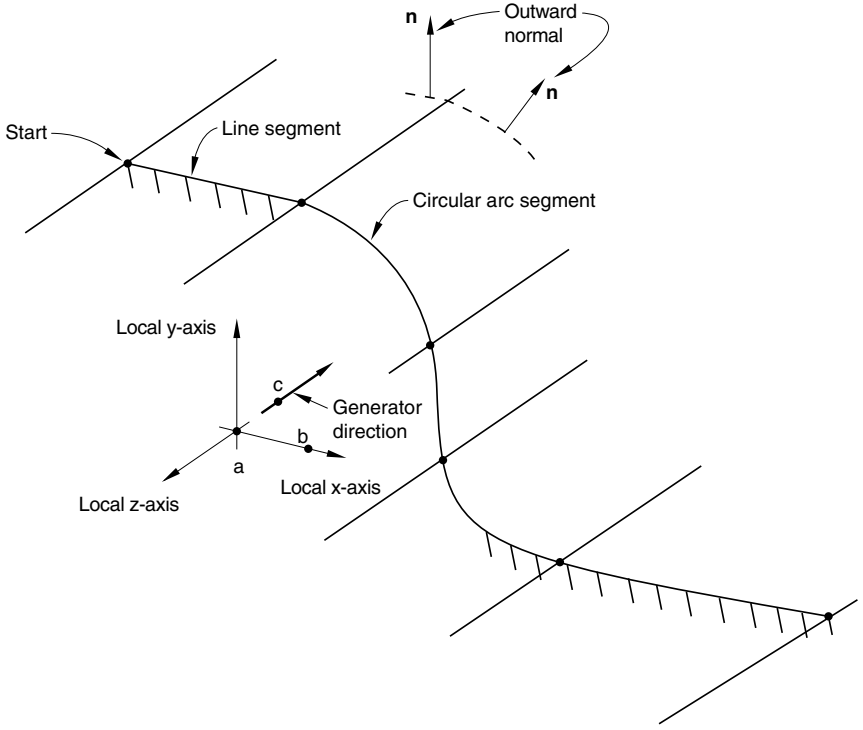


Figure 2.3.4–3 Cylindrical rigid surface.

To define a cylindrical rigid surface within a part, specify the line segments forming the profile of the rigid surface in the part coordinate system. For an analytical surface defined within a part (or part instance), point *a* is located at the origin of the part coordinate system, point *b* is located on the part *x*-axis, and point *c* is located on the negative part *z*-axis. If the segment ac is not perpendicular to ab, Abaqus will automatically adjust point *c* within the plane defined by points *a*, *b*, and *c*, such that they become perpendicular. You cannot redefine this analytical surface coordinate system; instead, you can position the surface in the model by giving positioning data when you instance the part (see "Defining an assembly," Section 2.10.1).

Input File Usage: ∗SURFACE, TYPE=CYLINDER, NAME=*name*
$X_a, Y_a, Z_a, X_b, Y_b, Z_b$
X_c, Y_c, Z_c
data lines to define the line segments forming the surface

For example, the following input, where x_i and y_i are points in the local coordinate system, would define the rigid surface shown in Figure 2.3.4–3 in a model that is not defined in terms of an assembly of part instances (the reference node is not shown in the figure):

∗SURFACE, TYPE=CYLINDER, NAME=CSURF
X_a, Y_a, Z_a, X_b, Y_b, Z_b
X_c, Y_c, Z_c
START, x_s, y_s
LINE, x_1, y_1
CIRCL, …
…
∗RIGID BODY, ANALYTICAL SURFACE=CSURF, REF NODE=*n*

Leave the first two data lines blank to define a cylindrical rigid surface within a part.

Abaqus/CAE Usage: Part module: **Create Part**: **Name:** *analytical_rigid_part*: select **3D** as the **Modeling Space**, **Analytical rigid** as the **Type**, and **Extruded shell** as the **Base Feature**

Three-dimensional surfaces of revolution

To define a rigid surface of revolution in a model that is not defined in terms of an assembly of part instances, specify the two points *a* and *b* shown in Figure 2.3.4–4 that define the local coordinate system. Give the coordinates of these points—(X_a, Y_a, Z_a) and (X_b, Y_b, Z_b)—in the default global coordinate system. As shown in Figure 2.3.4–4, point *a* defines the origin of the local system, and the vector from *a* to *b* defines the local *z*-axis, which is the axis of a cylindrical coordinate system. The line segments forming the profile of the surface of revolution are defined in the local *r*–*z* plane, where the local *r*-axis aligns with the radial axis of the cylindrical coordinate system. The three-dimensional surface is formed by revolving this profile about the axis of the cylindrical system, the local *z*-axis.

To define a rigid surface of revolution within a part, specify the line segments forming the cross-section of the rigid surface in the local part coordinate system. For an analytical surface defined within a

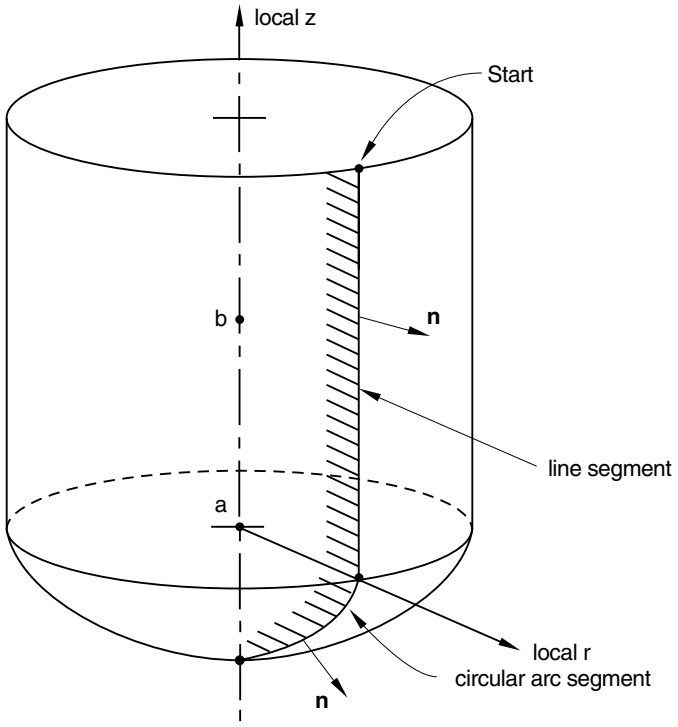


Figure 2.3.4–4 Rigid surface of revolution.

part (or part instance), point *a* is located at the origin of the part coordinate system, the part *x*-axis aligns with the radial axis of the cylindrical coordinate system, and point *b* is located on the part *y*-axis. You cannot redefine this local axis; instead, you can position the surface in the model by giving positioning data when you instance the part (see "Defining an assembly," Section 2.10.1).

Input File Usage: ∗SURFACE, TYPE=REVOLUTION, NAME=*name*
$X_a, Y_a, Z_a, X_b, Y_b, Z_b$
data lines to define the line segments forming the surface

For example, the following input would define the rigid surface shown in Figure 2.3.4–4 (the reference node is not shown in the figure):

***SURFACE, TYPE=REVOLUTION, NAME=REVSURF**
X_a, Y_a, Z_a, X_b, Y_b, Z_b
START, x_s, y_s
LINE, …
CIRCL, …
…

***RIGID BODY, ANALYTICAL SURFACE=REVSURF, REF NODE=999**

Leave the first data line blank to define a rigid surface of revolution within a part.

Abaqus/CAE Usage: Part module: **Create Part**: **Name:** *analytical_rigid_part*: select **3D** as the **Modeling Space**, **Analytical rigid** as the **Type**, and **Revolved shell** as the **Base Feature**

Defining the surface normals

The outward surface normal for analytical rigid surfaces is determined by the direction of the line segments forming the profile of the surface. The sequence of line segments defines a vector $\mathbf{s}$ along the rigid surface from the starting point of the first segment to the ending point of the last segment. The outward surface normal is created by taking the cross product of the vector $\mathbf{e}_3$, the unit normal to the plane in which the surface is defined, and the vector $\mathbf{s}$, the tangent to the surface: $\mathbf{n} = \mathbf{e}_3 \times \mathbf{s}$. Figure 2.3.4–5 shows the vector $\mathbf{s}$ in the definition plane of an analytical rigid surface.

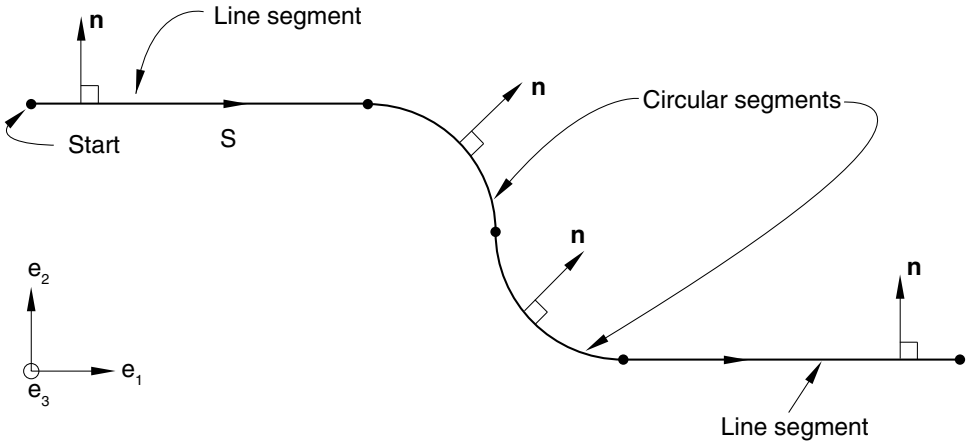


Figure 2.3.4–5 Orientation of surface normals for a rigid surface.

The unit vector $\mathbf{e}_3$ is defined such that $\mathbf{e}_1$, $\mathbf{e}_2$, and $\mathbf{e}_3$ form a right-handed orthonormal coordinate system. In-plane coordinate directions $\mathbf{e}_1$ and $\mathbf{e}_2$ depend on the type of analytical rigid surface being defined. For two-dimensional analytical rigid surfaces they correspond to the global X- and Y-axes in planar models and the r- and z-axes in axisymmetric models. For cylindrical rigid surfaces they correspond to the local x- and y-axes, and for rigid surfaces of revolution they correspond to the local r- and z-axes. The outward normals for a cylindrical rigid surface and rigid surface of revolution are shown in Figure 2.3.4–3 and Figure 2.3.4–4, respectively.

If the line segments are specified in the wrong order, the surface normals of a rigid surface will appear in exactly the opposite direction to what was intended. Such a mistake can be corrected only by specifying the line segments in the opposite sequence.

Smoothing analytical rigid surfaces

In many cases it can be beneficial to smooth surfaces to more accurately represent the surface geometry. In particular, it can be very difficult to obtain a converged solution in a finite-sliding Abaqus/Standard simulation if the master surface does not have continuous normal and surface tangent vectors (see "Contact formulations in Abaqus/Standard," Section 38.1.1); therefore, it is important to smooth any sharp corners on the master surface so that discontinuities in these vectors are eliminated.

By default, Abaqus does not smooth master surfaces that are analytical rigid surfaces. Smooth transitions between adjacent line segments can always be created by manually inserting additional curved line segments. Alternatively, smooth surfaces can be generated automatically by Abaqus. You specify the radius of curvature, r, in the units of length used in the model, that Abaqus will use to construct a smooth transition between any discontinuous line segments forming the rigid surface. The default value of zero provides no smoothing of the surface.

The effect of a fillet radius on adjoining line segments and on adjoining line and circular arc segments is illustrated in Figure 2.3.4–6.

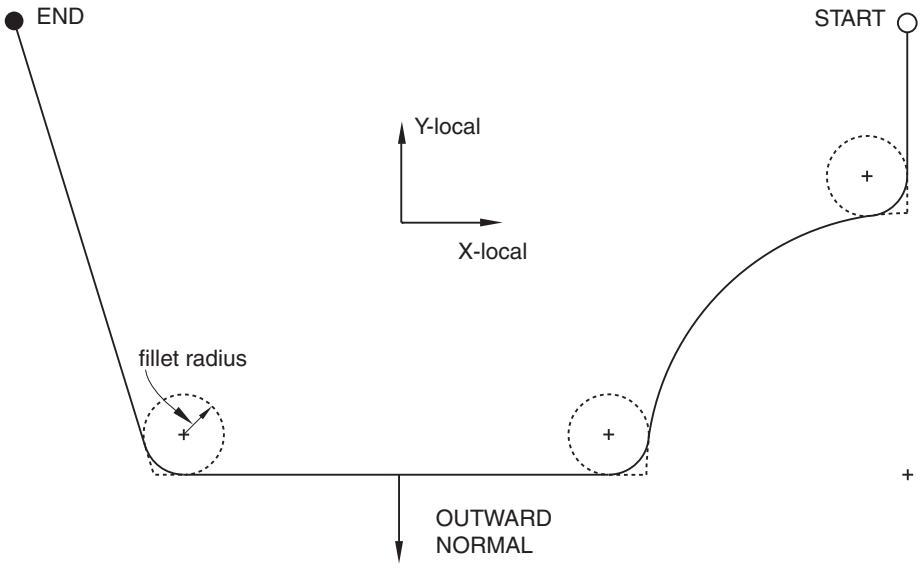


Figure 2.3.4–6 Effect of fillet radius on an analytical rigid surface.

The sharp corners have been smoothed using the fillet radius so that the normal and tangent surface vectors are continuous along the entire master surface. Any value r can be used in a model. However, if

r is greater than the length of either of the two adjacent segments, no smoothing will occur. Therefore, a practical limit on the size of r is the length of the smallest line segment forming the surface.

Input File Usage: *SURFACE, TYPE=*analytical_surface_type*, NAME=*name*, FILLET RADIUS=*r*

Abaqus/CAE Usage: When you create an analytical rigid part in Abaqus/CAE, you can create a fillet radius between segments or join the segments using arcs. See "Sketching simple objects," Section 20.10 of the Abaqus/CAE User's Guide, in the HTML version of this guide.

Surface tangent conventions

Abaqus forms analytical rigid surfaces such that the first surface tangent, $\mathbf{t}_1$, is always along the direction of the line segments forming the surface $\mathbf{s}$. The second surface tangent, $\mathbf{t}_2$, is defined such that the outward surface normal and the two surface tangents form a right-handed orthonormal system, as shown in Figure 2.3.4–7.

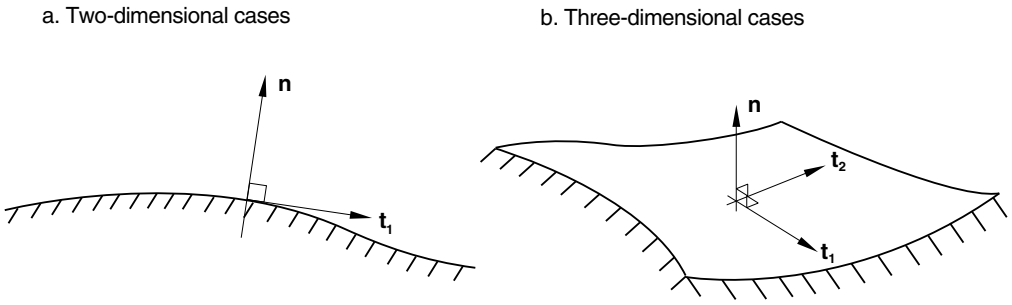


Figure 2.3.4–7 Surface tangent and outward normal definitions for analytical rigid surfaces.

Creating an analytical rigid surface in a user subroutine

More complicated analytical rigid surfaces can be defined in Abaqus/Standard by user subroutine **RSURFU**. Writing subroutine **RSURFU** to create a smooth surface is usually difficult, and convergence problems are often caused by inadequate surface definition in this subroutine. When using **RSURFU**, ensure that the outward surface normal and the two surface tangents form a right-handed orthonormal system. In two-dimensional cases the second surface tangent is always (0, 0, −1). You must also ensure that the surface is smooth in finite-sliding simulations and that the orientation of the rigid surface relative to the deformable surface is reasonable (i.e., the rigid surface cannot be inside the deformable surface).

Input File Usage: *SURFACE, TYPE=USER, NAME=*name*

Abaqus/CAE Usage: User subroutine **RSURFU** is not supported in Abaqus/CAE.

Defining analytical rigid surfaces when drag chain or rigid surface elements are used

An alternative method of defining analytical rigid surfaces must be used to define the surface of the seabed when three-dimensional drag chain elements (available only in Abaqus/Standard) are used. This alternative method must also be used when rigid surface elements are used; these elements are required only when CAXA or SAXA elements contact a rigid surface. For this method the rigid surface must be flat and parallel to the x–y plane.

In a model defined in terms of an assembly of part instances, the rigid surface definition must appear inside the same part definition as the drag chain or rigid surface elements.

You must indicate which type of analytical surface (planar, cylindrical, or user-defined) is being created. Cylindrical rigid surfaces are not valid for use with CAXA or SAXA elements. In addition, you must assign a name to the surface and identify the rigid body reference node that will control the motion of the surface.

Input File Usage: *RIGID SURFACE, TYPE=*surface_type*, NAME=*name*, REF NODE=*n*

Abaqus/CAE Usage: Drag chain and rigid surface elements are not supported in Abaqus/CAE.

Two-dimensional rigid surfaces

To define a planar rigid surface, define the line segments forming the rigid surface's cross-section in the global coordinate system. You must provide the endpoint of each line segment; the starting point is always the endpoint of the previous segment, or, in the case of the first segment, the point specified as the starting point. The centers of the circular arcs, points *c* and *f* in Figure 2.3.4–2, must be given. Abaqus can define only arcs that are less than, but not equal to, 179.74°; thus, it will use the shorter arc defined by the data provided (use two adjacent arcs to define a longer arc). For parabolic arcs you must give a third point that lies on the parabola and within the arc.

Input File Usage: *RIGID SURFACE, TYPE=SEGMENTS, NAME=*name*, REF NODE=*n*
START, *starting point X- or r-coordinate, starting point Y- or z-coordinate*
data lines to define the endpoints of the line segments forming the surface, beginning with the word LINE (for straight line segments), CIRCL (for circular arc segments), or PARAB (for parabolic arc segments)

Abaqus/CAE Usage: Drag chain and rigid surface elements are not supported in Abaqus/CAE.

Three-dimensional cylindrical rigid surfaces

To define a cylindrical rigid surface, specify the points *a*, *b*, and *c* shown in Figure 2.3.4–3 that define the local coordinate system. Give the coordinates of these points—(X_a, Y_a, Z_a), (X_b, Y_b, Z_b), and (X_c, Y_c, Z_c)—in the default global coordinate system. As shown in Figure 2.3.4–3, point *a* defines the origin of the local system; point *b* defines the local x-axis; and point *c* defines the generator vector, which is the *negative* local z-axis. The line segments forming the cross-section of the rigid surface are defined in the local x–y plane. The three-dimensional surface is formed by sweeping this cross-section along the generator vector. The resulting surface extends to infinity in both the positive and negative directions of the generator vector.

Input File Usage: *RIGID SURFACE, TYPE=CYLINDER, NAME=*name*, REF NODE=*n*
$X_a, Y_a, Z_a, X_b, Y_b, Z_b$
X_c, Y_c, Z_c
START, *starting point x-coordinate, starting point y-coordinate*
data lines to define the endpoints of the line segments forming the surface, beginning with the word LINE (for straight line segments), CIRCL (for circular arc segments), or PARAB (for parabolic arc segments)

Abaqus/CAE Usage: Drag chain and rigid surface elements are not supported in Abaqus/CAE.

2.3.5 EULERIAN SURFACE DEFINITION

Product: Abaqus/Explicit

References

- "Surfaces: overview," Section 2.3.1
- "Eulerian analysis," Section 14.1.1
- "Contact interaction analysis: overview," Section 36.1.1
- *EULERIAN SECTION
- *SURFACE

Overview

An Eulerian surface:

- must be three-dimensional;
- must be defined as model data;
- can be used with the general contact algorithm in Abaqus/Explicit; and
- is created by specifying the name of an Eulerian material instance.

What are Eulerian surfaces and why use them?

An Eulerian surface represents the exterior surface of a particular Eulerian material instance in an Abaqus/Explicit analysis. Since Eulerian materials flow through the Eulerian mesh, their surfaces cannot be defined by a simple list of element faces. Instead, these surfaces often lie within Eulerian elements and must be computed in each time increment using element volume fraction data.

You can use Eulerian surfaces to define specific interactions with Lagrangian surfaces in Abaqus/Explicit's general contact algorithm. Once defined, you can reference Eulerian surfaces in inclusions, exclusions, and interaction definitions. You cannot combine or crop Eulerian surfaces.

Eulerian surface definitions are not required for the use of Eulerian-Lagrangian contact. If you specify "automatic" contact for the entire model, the exterior surface of all Eulerian materials will automatically be considered for contact.

Advantages of creating Eulerian surfaces

You can use Eulerian surfaces to:

- Assign contact properties for contact interactions involving a particular Eulerian material instance.
- Exclude interactions between Eulerian materials and Lagrangian bodies that are unlikely to make contact, simplifying the contact problem and reducing computational cost.

Creating an Eulerian surface

To create an Eulerian surface, you must specify the name of a material instance that is present in the model. The material instance names are defined as part of the Eulerian section (see "Eulerian elements," Section 32.14.1). Abaqus/Explicit calculates the exterior boundary of the specified material instance and defines a surface corresponding to that boundary. The surface is recalculated in each time increment as the material deforms.

Input File Usage: *SURFACE, TYPE=EULERIAN MATERIAL, NAME=*name*
material instance name,

2.3.6 OPERATING ON SURFACES

Products: Abaqus/Standard Abaqus/Explicit

References

- "Surfaces: overview," Section 2.3.1
- "Coupling constraints," Section 35.3.2
- "Mesh-independent fasteners," Section 35.3.4
- "Defining general contact interactions in Abaqus/Explicit," Section 36.4.1
- *SURFACE

Overview

Combined surfaces:

- are created by performing a Boolean operation (union, intersection, or difference) on existing surfaces;
- can be formed from element-based or node-based surfaces;
- cannot be formed from Eulerian surfaces;
- can be used in the same way as other element-based or mode-based surfaces in Abaqus/Standard; and
- cannot be used with contact pairs in Abaqus/Explicit (but can be used with general contact in Abaqus/Explicit).

Cropped surfaces:

- are created by cropping an existing surface and keeping only that part of the surface that is enclosed in a specified rectangular box;
- can be formed from element-based or node-based surfaces;
- cannot be formed from Eulerian surfaces;
- can be used in the same way as other element-based or mode-based surfaces in Abaqus/Standard; and
- cannot be used with contact pairs in Abaqus/Explicit (but can be used with general contact in Abaqus/Explicit).

Creating a combined surface

You must assign a name to the combined surface; this name can be used with other features that refer to surfaces.

In models that are defined in terms of an assembly of part instances, all surfaces must belong to a part, part instance, or the assembly. Surfaces can be created at the part level and combined at the assembly level. Additional rules are given in "Defining an assembly," Section 2.10.1.

The surfaces being combined must be the same type; i.e., an element-based surface can be combined with another element-based surface but not with a node-based surface. Combined surfaces can be used to create another combined surface.

Union of existing surfaces

Any number of existing surfaces can be combined to create a new surface. If the surfaces being combined are element-based surfaces, the new surface will also be an element-based surface and any overlap among the surfaces will be merged. Similarly, if the surfaces being combined are node-based surfaces, the new surface will be a node-based surface and any overlap among the surfaces will be merged.

Input File Usage: *SURFACE, NAME=*name*, COMBINE=UNION
list of surface names

Intersection or difference of existing surfaces

The intersection or difference of two existing surfaces can be used to create a new surface. The difference operation subtracts the second surface from the first surface. When the intersection or difference operations are performed on element-based surfaces, they act only on the facets. A warning message is issued if the intersection operation results in an empty surface.

Input File Usage: Use the following option to create a new surface based on the intersection of two existing surfaces:

*SURFACE, NAME=*name*, COMBINE=INTERSECTION
first surface name, second surface name

Use the following option to create a new surface based on the difference of two existing surfaces:

*SURFACE, NAME=*name*, COMBINE=DIFFERENCE
first surface name, second surface name

Creating a cropped surface

You can create a new surface that will contain only those faces of an existing surface that have nodes inside a specified cropping box. For a node-based surface the new surface will contain only those nodes that are enclosed inside the cropping box. If the face has at least one node inside the box, the entire face is accepted as valid. You must assign a name to the new surface and specify the name of the existing surface from which the new surface is to be generated. Only one surface can be specified.

To define the location of the box, specify the coordinates of the lower corner of the box (X_{min}, Y_{min}, Z_{min}) and the coordinates of the opposite (upper) corner of the box (X_{max}, Y_{max}, Z_{max}). The cutting box can be rotated about the lower corner (X_{min}, Y_{min}, Z_{min}) if an optional rotation is defined. The coordinates of the two points, a and b, that define the rotation are given in the unrotated system.

These points should be defined such that point *a* lies on the rotated *X*-axis and point *b* lies on the *X*–*Y* plane and close to the *Y*-axis.

Input File Usage:

∗SURFACE, NAME=*name*, CROP
old_surface_name
X_{min}, Y_{min}, Z_{min}, X_{max}, Y_{max}, Z_{max}
X_a, Y_a, Z_a, X_b, Y_b, Z_b

For example, to crop the surface that contains all exposed faces in the model, use the following input:

SURFACE, TYPE=ELEMENT, NAME=*entire_surface
,
***SURFACE, NAME=*name*, CROP**
entire_surface
X_{min}, Y_{min}, Z_{min}, X_{max}, Y_{max}, Z_{max}
X_a, Y_a, Z_a, X_b, Y_b, Z_b

2.4 Rigid body definition

- “Rigid body definition,” Section 2.4.1

2.4.1 RIGID BODY DEFINITION

Products: Abaqus/Standard Abaqus/Explicit Abaqus/CAE

References

- "Surfaces: overview," Section 2.3.1
- "Element-based surface definition," Section 2.3.2
- "Analytical rigid surface definition," Section 2.3.4
- "Rigid elements," Section 30.3.1
- *RIGID BODY
- "Defining rigid body constraints," Section 15.15.2 of the Abaqus/CAE User's Guide, in the HTML version of this guide

Overview

A rigid body:

- can be two-dimensional planar, axisymmetric, or three-dimensional;
- is associated with a node, called the rigid body reference node, whose motion governs the motion of the entire rigid body;
- can consist of nodes, elements, and surfaces;
- can act as a method of constraint;
- can be used with connector elements in multibody dynamic simulations;
- can be used to prescribe the motion of a rigid surface for contact modeling;
- can be computationally efficient and, in Abaqus/Explicit, does not affect the global time increment; and
- can have temperature gradients or be isothermal in a fully coupled temperature-displacement analysis where thermal interactions are considered.

What is a rigid body?

A rigid body is a collection of nodes, elements, and/or surfaces whose motion is governed by the motion of a single node, called the rigid body reference node. The relative positions of the nodes and elements that are part of the rigid body remain constant throughout a simulation. Therefore, the constituent elements do not deform but can undergo large rigid body motions. The mass and inertia of a rigid body can be calculated based on contributions from its elements or can be assigned specifically. Analytical surfaces can also be made part of the rigid body, whereas any surfaces based on the nodes or elements of a rigid body are associated automatically with the rigid body.

The motion of a rigid body can be prescribed by applying boundary conditions at the rigid body reference node. Loads on a rigid body are generated from concentrated loads applied to nodes and

from distributed loads applied to elements that are part of the rigid body. Rigid bodies interact with the remainder of the model in several ways. Rigid bodies can connect at the nodes to deformable elements, and surfaces defined on rigid bodies can continue on these deformable elements, provided that compatible element types are used. Rigid bodies can also be connected to other rigid bodies by connector elements (see "Connectors: overview," Section 31.1.1). Surfaces defined on rigid bodies can contact surfaces defined on other bodies in the model.

Determining when to use a rigid body

Rigid bodies can be used to model very stiff components, either fixed or undergoing large motions. For example, rigid bodies are ideally suited for modeling tooling (i.e., punch, die, drawbead, blank holder, roller, etc.). They can also be used to model constraints between deformable components, and they provide a convenient method of specifying certain contact interactions. Rigid bodies can be used with connector elements to model a wide variety of multibody dynamic problems.

It may be useful to make parts of a model rigid for model verification purposes. For example, in complex models elements far away from the particular region of interest could be included as part of a rigid body, resulting in faster run times at the model development stage. When you are satisfied with the model, you can remove the rigid body definitions and incorporate an accurate deformable finite element representation throughout.

In multibody dynamic simulations rigid bodies are useful for many reasons. Although the motion of the rigid body is governed by the six degrees of freedom at the reference node, rigid bodies allow accurate representation of the geometry, mass, and rotary inertia of the rigid body. Furthermore, rigid bodies provide accurate visualization and postprocessing of the model.

The principal advantage to representing portions of a model with rigid bodies rather than deformable finite elements is computational efficiency. Element-level calculations are not performed for elements that are part of a rigid body. Although some computational effort is required to update the motion of the nodes of the rigid body and to assemble concentrated and distributed loads, the motion of the rigid body is determined completely by a maximum of six degrees of freedom at the reference node.

Rigid bodies are particularly effective for modeling relatively stiff parts of a model in Abaqus/Explicit for which tracking waves and stress distributions are not important. Element stable time increment estimates in the stiff region can result in a very small global time increment. Since rigid bodies and elements that are part of a rigid body do not affect the global time increment, using a rigid body instead of a deformable finite element representation in a stiff region can result in a much larger global time increment, without significantly affecting the overall accuracy of the solution.

Creating a rigid body

You must assign a rigid body reference node to the rigid body.

Input File Usage: *RIGID BODY, REF NODE=*n*

Abaqus/CAE Usage: Interaction module:
Tools→Reference Point: select a point to act as a reference point
Create Constraint: **Rigid body**: **Point: Edit**: select reference point region

The rigid body reference node

A rigid body reference node has both translational and rotational degrees of freedom and must be defined for every rigid body. If the reference node has not been assigned coordinates, Abaqus will assign it the coordinates of the global origin by default. Alternatively, you can specify that the reference node should be placed at the center of mass of the rigid body. In fully coupled temperature-displacement analysis where a rigid body is considered as isothermal, a single temperature degree of freedom describing the temperature of the rigid body exists at the rigid body reference node. The rigid body reference node:

- can be connected to mass, rotary inertia, capacitance, or deformable elements;
- cannot be a rigid body reference node for another rigid body; and
- can have a temperature degree of freedom if the body is an isothermal rigid body.

Positioning the reference node at the center of mass

The specific location of the rigid body reference node relative to the rest of the rigid body or to its center of mass is important if nonzero boundary conditions are to be applied to the rigid body or concentrated loads are to be applied at the reference node. In many problems of rigid body dynamics, it may be desirable to apply loads and boundary conditions to the rigid body at its center of mass. In addition, it may be useful to monitor the configuration of the rigid body at its center of mass for output purposes. However, it may be difficult to locate the center of mass a priori when the rigid body mass and inertia properties (discussed below) contain contributions from a finite element discretization or a complex arrangement of MASS and ROTARYI elements.

By default, the rigid body reference node will not be repositioned. You can specify that it should be repositioned at the calculated center of mass. In this case if a MASS element is defined at the rigid body reference node, the calculated center of mass used for repositioning includes all mass contributions except the mass at the reference node. The MASS element is then repositioned at the center of mass and included in the mass properties of the rigid body. If the only mass contribution to the rigid body is from a MASS element defined at the rigid body reference node, the reference node will not be repositioned.

Input File Usage: Use the following option to indicate that the reference node should not be repositioned (the default):

∗RIGID BODY, REF NODE=*n*, POSITION=INPUT

Use the following option to specify that the rigid body reference node should be repositioned at the calculated center of mass:

∗RIGID BODY, REF NODE=*n*, POSITION=CENTER OF MASS

Abaqus/CAE Usage: Interaction module: **Create Constraint**: **Rigid body**: toggle **Adjust point to center of mass at start of analysis**

The collection of nodes that constitute the rigid body

In addition to the rigid body reference node, rigid bodies consist of a collection of nodes that is generated by assigning elements and nodes to the rigid body. These nodes provide a connection to other elements. Nodes that are part of a rigid body are one of two types:

- pin nodes, which have only translational degrees of freedom associated with the rigid body, or
- tie nodes, which have both translational and rotational degrees of freedom associated with the rigid body.

The rigid body node type is determined by the type of elements on the rigid body to which the node is attached. You can also specify the node type when you assign nodes directly to a rigid body. For pin nodes only the translational degrees of freedom are part of the rigid body, and the motion of these degrees of freedom is constrained by the motion of the rigid body reference node. For tie nodes both the translational and rotational degrees of freedom are part of the rigid body and are constrained by the motion of the rigid body reference node.

The node type has important implications when the node is connected to rotary inertia elements, deformable structural elements, or connector elements or when the node has concentrated moments or follower loads applied to it. Rotary inertia elements and applied concentrated moments affect the rigid body only when associated with a tie node. Rigid body connections to deformable elements always involve the translational degrees of freedom; rigid body connections to deformable shell, beam, pipe, and connector elements also involve the rotational degrees of freedom if the connection is at a tie node. The behavior of the two types of connections is illustrated in Figure 2.4.1–1, which shows an octagonal rigid body connected to two deformable shell elements through nodes at opposite ends subjected to an applied rotational velocity.

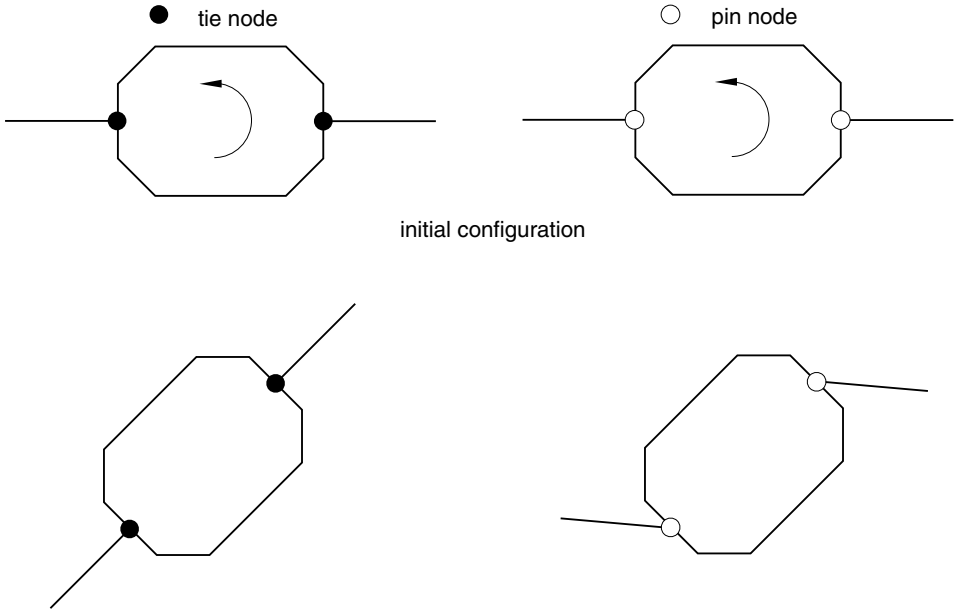


Figure 2.4.1–1 Rigid body with tie node and pin node connections.

The shell elements are assumed to be stiff (negligible bending is shown in the figure). When the nodes common to the rigid body and the shell elements are tie nodes, the rotation applied to the rigid body is transmitted directly to the shell elements. When the common nodes are pin nodes, the rigid body rotation is not transmitted directly to the shell elements, which can result in large relative motions between the rigid body and the adjacent shell structure.

Assigning elements to a rigid body

To include elements in the rigid body definition, you specify the region of your model containing all of the elements that are part of the rigid body. Elements in this region or nodes connected to the elements in this region cannot be part of any other rigid body. Table 2.4.1–1 lists the continuum, structural, and rigid element types that can be included in a rigid body and the respective node types generated in the rigid body.

Table 2.4.1–1 List of valid elements that can be included in a rigid body (* indicates all elements beginning with the preceding label).

Rigid Body Geometry	Elements		Nodal Degrees of Freedom	
	Generate Pin Nodes	Generate Tie Nodes	Pin Nodes	Tie Nodes
Planar	CPE3*, CPE4*, CPE6*, CPE8*, CPS3, CPS4*, CPS6*, CPS8*, GK2D2, GKPS*, GKPE*, R2D2, T2D2*	B21*, B22*, B23*, FRAME2D, PIPE2*, RB2D2	u_x, u_y	u_x, u_y, ϕ_z
Axisymmetric	CAX3, CAX4*, CAX6*, CAX8*, GKAX*, MAX*, RAX2	CGAX*, MGAX*, SAX1, SAX2*	u_r, u_z	u_r, u_z, ϕ
Three-dimensional	C3D4*, C3D6*, C3D8*, C3D10*, C3D15*, C3D20*, C3D27*, GK3D*, M3D3, M3D4*, M3D6, M3D8*, M3D9*, SFM3D*, SFMAX*, SFMGAX*, R3D3, R3D4, T3D2*, CCL*, MCL*, SFMCL*	B31*, B32*, B33*, FRAME3D, PIPE*, RB3D2, S3*, S4*, S8*, S9*	u_x, u_y, u_z	$u_x, u_y, u_z, \phi_x, \phi_y, \phi_z$

When connector elements are included in the rigid body, the type of generated nodes depends on whether the rotational degrees of freedom are active for their connection type. If connector elements that activate material flow degree of freedom at nodes are included in the rigid body, the material and flow through the rigid body as that degree of freedom is constrained to the motion of the rigid body.

The following elements cannot be declared as rigid:

- Acoustic elements
- Axisymmetric-asymmetric continuum and shell elements
- Coupled thermal-electrical elements
- Diffusive heat transfer/mass diffusion elements and forced convection/diffusion elements
- Eulerian elements
- Generalized plane strain elements
- Gasket elements with thickness-direction behavior
- Heat capacitance elements
- Inertial elements (mass and rotary inertia)
- Infinite elements
- Piezoelectric elements
- Special-purpose elements
- Substructures
- Thermal-electrical-structural elements
- User-defined elements

If elements of more than one type or section definition are part of a rigid body, the specified region will contain elements with different section definitions. When continuum or structural elements are assigned to a rigid body, they are no longer deformable and their motion is governed by the motion of the rigid body reference node. Element stiffness calculations are not performed for these elements, and they do not affect the global time increment in Abaqus/Explicit. However, the mass and inertia of the rigid body includes contributions from these elements as calculated from their section and material density definitions (see Part VI, “Elements”). Mass and rotary inertia elements, as well as point heat capacitance elements, should not be included in the specified region. Contributions to a rigid body from mass, rotary inertia, and heat capacitance elements are accounted for automatically when these elements are connected to nodes that are part of the rigid body.

A list of nodes that are part of a rigid body is generated automatically when you assign elements to a rigid body. The node list is constructed as a unique list including all the nodes that are connected to elements in the specified region. Nodes in this list cannot be part of any other rigid body. The type of each node, pin or tie, is determined by the type of elements on the rigid body to which it is connected. Shell, beam, pipe, and rigid beam elements generate tie nodes; solid, membrane, truss, and rigid (other than beam) elements generate pin nodes (see Table 2.4.1–1). For nodes that are connected to both elements that generate pin nodes and elements that generate tie nodes, the common node is defined as the tie type.

All elements that are part of a rigid body must be of like geometry. Therefore, elements contained in the specified region must be either planar, axisymmetric, or three-dimensional. The geometry of the elements determines the geometry of the rigid body as shown in Table 2.4.1–1.

Input File Usage: Use the following option to assign elements to a rigid body:

*RIGID BODY, REF NODE=*n*, ELSET=*name*

Abaqus/CAE Usage: Interaction module: **Create Constraint**: **Rigid body**: **Body (elements)**: **Edit**: select body regions

Assigning nodes to a rigid body

To assign nodes directly to a rigid body, you specify all the desired pin nodes and all the tie nodes separately. These nodes become part of the rigid body in addition to any nodes that have been generated from elements assigned to the rigid body. The following rules apply when assigning nodes directly to a rigid body:

- The rigid body reference node cannot be contained in either the set of pin nodes or the set of tie nodes.
- Nodes that are part of the set of pin nodes cannot also be contained in the set of tie nodes.
- Nodes that are contained in the set of pin nodes or the set of tie nodes cannot be part of any other rigid body definition.
- Nodes that are generated automatically from elements assigned to the rigid body that are also contained in the set of pin nodes are classified as pin nodes, regardless of their element connections.
- Nodes that are generated automatically from elements assigned to the rigid body that are also contained in the set of tie nodes are classified as tie nodes, regardless of their element connections.

The types of nodes generated by elements included in a rigid body can, therefore, be overridden by assigning the nodes directly to the rigid body, thereby allowing you greater flexibility to define a constraint with a rigid body by easily specifying the type of connection the rigid body makes with its attached deformable finite elements.

Input File Usage: Use the following option to assign nodes to a rigid body:

*RIGID BODY, REF NODE=*n*, PIN NSET=*name*, TIE NSET=*name*

Abaqus/CAE Usage: Interaction module: **Create Constraint**: **Rigid body**: **Pin (nodes)**: **Edit**: select pin regions, and **Tie (nodes)**: **Edit**: select tie regions

Assigning analytical surfaces to a rigid body

You can assign an analytical surface to a rigid body. The procedure for creating and naming an analytical rigid surface is described in "Analytical rigid surface definition," Section 2.3.4. Only one analytical surface can be defined as part of the rigid body definition.

Input File Usage: Use the following option to assign an analytical rigid surface to a rigid body:

*RIGID BODY, REF NODE=*n* or *name*, ANALYTICAL SURFACE=*name*

Abaqus/CAE Usage: Interaction module: **Create Constraint**: **Rigid body**: **Analytical Surface**: **Edit**: select analytical surface regions

Defining a rigid body in a model that is defined in terms of an assembly of part instances

An Abaqus model can be defined in terms of an assembly of part instances (see "Defining an assembly," Section 2.10.1). A rigid body in such a model can be created from deformable elements at either the part level or the assembly level. In either case all node and element definitions must belong to one or more parts. If all nodes making up the rigid body belong to the same part, create a rigid part by defining the rigid body at the part level.

Multiple deformable part instances can be combined into a single rigid body by creating an assembly-level node or element set that spans the part instances, then defining the rigid body at the assembly level to refer to that set. The rigid body reference node can also be defined at the assembly level, if necessary.

Rigid body mass and inertial properties

When a rigid body is not constrained fully, the mass and inertia properties of the rigid body are important to its dynamic response. In Abaqus/Explicit an error message will be issued if there is no mass (or rotary inertia) corresponding to an unconstrained degree of freedom. Abaqus automatically calculates the mass, center of mass, and rotary inertia of each rigid body and prints the results to the data (`.dat`) file if model definition data are requested (see "Controlling the amount of analysis input file processor information written to the data file" in "Output," Section 4.1.1). The following rules are used to determine the mass and inertia of a rigid body:

- The mass of each continuum, structural, and rigid element that is part of the rigid body contributes to the rigid body's mass, center of mass, and rotary inertia properties.
- Point mass elements that are connected to any node that is part of a rigid body or to the rigid body reference node contribute to the rigid body's mass, center of mass, and rotary inertia properties.
- Rotary inertia elements that are connected to any tie node or to the rigid body reference node contribute to the rigid body's rotary inertia properties.

Since the rotational degrees of freedom at a pin node are not part of a rigid body, rotary inertia elements connected to a pin node do not contribute to the rigid body inertia but are rather associated with the independent rotation of the node.

Defining mass and inertia properties by discretization

In many cases it is desirable to model rigid components for which the mass, center of mass, and rotary inertia are not readily available. In Abaqus it is not necessary to define the mass and inertia properties of the rigid body directly. Instead, a finite element discretization can be used to model the rigid components, and Abaqus will automatically calculate the properties from the discretization. Rigid structures with one-dimensional rod or beam geometries can be modeled with beam or truss elements, structures containing two-dimensional surface geometries can be modeled with shell or membrane elements, and solid geometries can be modeled with solid elements. The mass contributions to the rigid

body for each of these elements are based on that element's section properties (see Part VI, "Elements") and the material density (see "Density," Section 21.2.1). Although both shell and membrane elements in a rigid body can yield similar mass contributions given similar section and density definitions, they will generate different node types (tie nodes for shells and pin nodes for membranes), which may affect the overall results. The same holds true for beam and truss elements.

In situations where one portion of a rigid component can be modeled with a finite element discretization but it is not convenient to do so for other portions, point mass and rotary inertia elements can be used to represent the mass distribution of these other portions. The mass, center of mass, and rotary inertia for the rigid body will then include the contributions from both the finite elements and the point mass and rotary inertia elements.

Abaqus uses the lumped mass formulation for low-order elements. As a consequence, the second mass moments of inertia can deviate from the theoretical values, especially for coarse meshes. This inaccuracy can be circumvented by adding point mass and rotary inertia elements with the correct inertia properties and eliminating the mass contribution from the solid elements. Alternatively, second-order elements could be used in Abaqus/Standard.

Defining mass and inertia properties directly

When the mass, center of mass, and rotary inertia properties of the actual rigid component are known or can be approximated, it is not necessary to use a finite element discretization or to use an array of point masses to generate the rigid body properties. You can assign these properties directly by locating the rigid body reference node at the center of mass (see "Positioning the reference node at the center of mass") and by specifying the rigid body mass and rotary inertia at the reference node (see "Point masses," Section 30.1.1, and "Rotary inertia," Section 30.2.1).

It may also be desirable to input mass properties directly at the center of mass but to specify boundary conditions at a location other than the center of mass. In this case you should place the rigid body reference node at the desired boundary condition location. In addition, you must define a tie node at the center of mass of the rigid body by correctly specifying its coordinates to coincide with the coordinates of the center of mass of the rigid body and then assigning it to a tie node set in the rigid body definition. You can then define the rigid body mass and rotary inertia at the tie node.

For most applications where mass properties are input directly, it may be necessary to assign additional elements or nodes to a rigid body so that the rigid body can interact with the rest of the model. For example, contact pair definitions could require rigid surfaces formed with element faces on the rigid body and additional pin or tie nodes may be necessary to provide the desired constraints with deformable elements attached to the rigid body. Abaqus will account for the mass and rotary inertia contributions from all elements on a rigid body; therefore, if you want to assign the rigid body mass properties directly, you should take care to ensure that contributions from other element types that are part of the rigid body do not affect the desired input mass properties. If rigid elements are part of the rigid body definition, you can set their mass contribution to zero by not specifying a density for these elements in the rigid body definition. If other element types are used to define the rigid body, you should set their density to zero.

Kinematics of a rigid body

The motion of a rigid body is defined entirely by the motion of its reference node. The active degrees of freedom at the reference node depend on the geometry of the rigid body (see "Conventions," Section 1.2.2). The geometry of a rigid body is planar, axisymmetric, or three-dimensional and is determined by the type of elements that are assigned to the rigid body. In the case where no elements are assigned to a rigid body, the geometry of the rigid body is assumed to be three-dimensional.

The calculated mass and rotary inertia properties for each of the active degrees of freedom for all rigid bodies are printed to the data (`.dat`) file if model definition data are requested (see "Controlling the amount of analysis input file processor information written to the data file" in "Output," Section 4.1.1). These properties include the contributions from elements that are part of the rigid body, as well as point mass and rotary inertia elements at the nodes of the rigid body.

Although this calculated mass represents the true mass of the rigid body, Abaqus/Explicit actually uses an augmented mass in the integration of the equation of motion, which is conceptually similar to an added mass formulation. Essentially, the calculated mass and rotary inertia of the rigid body is augmented with the mass contributions of all of its attached deformable elements to create a larger, augmented mass and rotary inertia. Rotary inertia contributions from adjacent deformable elements are also included in the augmented rotary inertia if the nodal connection is at a tie node.

Rigid body motions

A rigid body can undergo free rigid body motion in each of its active translational degrees of freedom, as well as each of its active rotational degrees of freedom.

Boundary conditions

Boundary conditions for rigid bodies should be defined as described in "Boundary conditions in Abaqus/Standard and Abaqus/Explicit," Section 34.3.1, at the rigid body reference node. Reaction forces and moments can be recovered for all degrees of freedom that are constrained at the reference node. If a nodal transformation is defined at the rigid body reference node, boundary conditions are applied in the local system (see "Transformed coordinate systems," Section 2.1.5).

In Abaqus/Standard, if boundary conditions are applied to any nodes on a rigid body other than the rigid body reference node, Abaqus will attempt to transfer these boundary conditions to the reference node. If successful, you are warned that this transfer has taken place. Otherwise, an error message is produced (see "Overconstraint checks," Section 35.6.1, for more details).

In Abaqus/Explicit, if boundary conditions are applied to any nodes on a rigid body other than the rigid body reference node, these boundary conditions are ignored with the exception of the symmetry-type boundary conditions that can affect the contact logic at the perimeter of a surface in the Abaqus/Explicit contact pair algorithm (see "Contact formulations for contact pairs in Abaqus/Explicit," Section 38.2.2, and "Common difficulties associated with contact modeling using contact pairs in Abaqus/Explicit," Section 39.2.2).

Constraints

In Abaqus/Standard nodes on a rigid body, excluding the rigid body reference node, cannot be used in a multi-point constraint or linear constraint equation definition.

In Abaqus/Explicit a multi-point constraint or linear constraint equation can be defined for any node on a rigid body, including the reference node.

Connector elements

Connector elements can be used at any node of a rigid body, including the reference node, to define a connection between rigid bodies, between a rigid body and a deformable body, or from a rigid body to ground. Connector elements are convenient for providing multiple points of attachment on rigid bodies; modeling complex nonlinear kinematic constraints; specifying zero or nonzero boundary conditions at a point on a rigid body that is not the rigid body reference node; applying force actuation; and modeling discrete interactions, such as spring, dashpot, node-to-node contact, friction, locking mechanisms, and failure joints. Unlike multi-point constraints or linear constraint equations, connector elements retain degrees of freedom in the connection, thereby allowing output of information related to the connection (such as constraint forces and moments, relative displacements, velocities, accelerations, etc.). See "Connector elements," Section 31.1.2, for a detailed description of connector elements.

Planar rigid body

A rigid body with a planar geometry has three active degrees of freedom: 1, 2, and 6 (u_x, u_y, and ϕ_z). Here, the x- and y-directions coincide with the global X- and Y-directions, respectively. If a nodal transformation is defined at the rigid body reference node, the x- and y-directions coincide with the user-defined local directions. The coordinate transformation defined at the reference node must be consistent with the geometry; the local directions must remain in the global X–Y plane. All nodes and elements that are part of a planar rigid body should lie in the global X–Y plane.

Planar rigid bodies should be connected only to planar deformable elements. To model the connection of a rigid component with a planar geometry to three-dimensional deformable elements, model the planar rigid component as a three-dimensional rigid body consisting of the appropriate three-dimensional elements.

Axisymmetric rigid body

A rigid body with an axisymmetric geometry has three active degrees of freedom in Abaqus: 1, 2, and 6 (u_r, u_z, ϕ). Classical axisymmetric theory admits only one rigid body mode, which is displacement in the z-direction. To maximize the flexibility of using rigid bodies for axisymmetric analysis, Abaqus allows for three active degrees of freedom, although only the axial displacement is a rigid body mode.

The r- and z-directions coincide with the global X- and Y-directions, respectively. If a nodal transformation is defined at the rigid body reference node, the r- and z-directions coincide with the user-defined local directions. The coordinate transformation defined at the reference node must be consistent with the geometry; the local directions must remain in the global X–Y plane. All nodes and elements that are part of an axisymmetric rigid body should lie in the global X–Y plane.

Translation in the r-direction is associated with a radial mode, and rotation in the r–z plane is associated with a rotary mode (see Figure 2.4.1–2). For an axisymmetric rigid body in Abaqus each of these modes develop no hoop stress, but mass and inertia computed for these degrees of freedom represent the modal mass associated with their modal motion. The mass properties for an axisymmetric rigid body are, therefore, calculated based on the initial configuration assuming the following:

- Point masses defined on nodes of the rigid body (see "Point masses," Section 30.1.1) are assumed to account for the entire mass around the circumference of the body.
- Mass contributions from axisymmetric elements assigned to the rigid body include the integrated value around the circumference.
- The center of mass of the rigid body is located at the center of mass of the circumferential slice, as shown in Figure 2.4.1–2.

If the rigid body reference node is positioned at the center of mass, the reference node for an axisymmetric rigid body will, thus, be repositioned at the center of mass of the circumferential slice.

These assumptions are consistent with the manner in which Abaqus handles other axisymmetric features but are noted here because of the deviation from classical rigid body theory.

Axisymmetric rigid bodies should be connected only to axisymmetric deformable elements. To model the connection of a rigid component with an axisymmetric geometry to three-dimensional deformable elements, model the axisymmetric rigid component as a three-dimensional rigid body consisting of the appropriate three-dimensional elements.

Three-dimensional rigid body

A rigid body with a three-dimensional geometry has six active degrees of freedom: 1, 2, 3, 4, 5, and 6 (u_x, u_y, u_z, ϕ_x, ϕ_y, ϕ_z). Here, the x-, y-, and z-directions coincide with the global X-, Y- and Z-directions, respectively. If a nodal transformation is defined at the rigid body reference node, the x-, y-, and z-directions coincide with the user-defined local directions.

In general, three-dimensional rigid bodies will possess a full, nonisotropic inertia tensor and can behave in a nonintuitive manner when they are spun about an axis that is not one of the principal inertia axes. Classical phenomena of rigid body dynamics (e.g., precession, gyroscopic moments, etc.) can be simulated using three-dimensional rigid bodies in Abaqus.

In most cases three-dimensional rigid bodies should be connected only to three-dimensional deformable elements. If it is physically relevant, a three-dimensional rigid body can be connected to two-dimensional plane stress, plane strain, or axisymmetric elements; however, you should always constrain the z-displacement, x-axis rotation, and y-axis rotation of the rigid body. The above procedure is useful when incorporating a two-dimensional plane strain approximation in one region of a model and a three-dimensional discretization in another. Rigid bodies can be used to constrain the two finite element geometries at their interface as shown in Figure 2.4.1–3. A unique rigid body should be used at each node in the plane along the interface to handle the constraint properly.

Defining loads on rigid bodies

Loads on a rigid body are assembled from contributions of all of the loads on nodes and elements that are part of the rigid body. Loads are defined on nodes and elements that are part of a rigid body in the

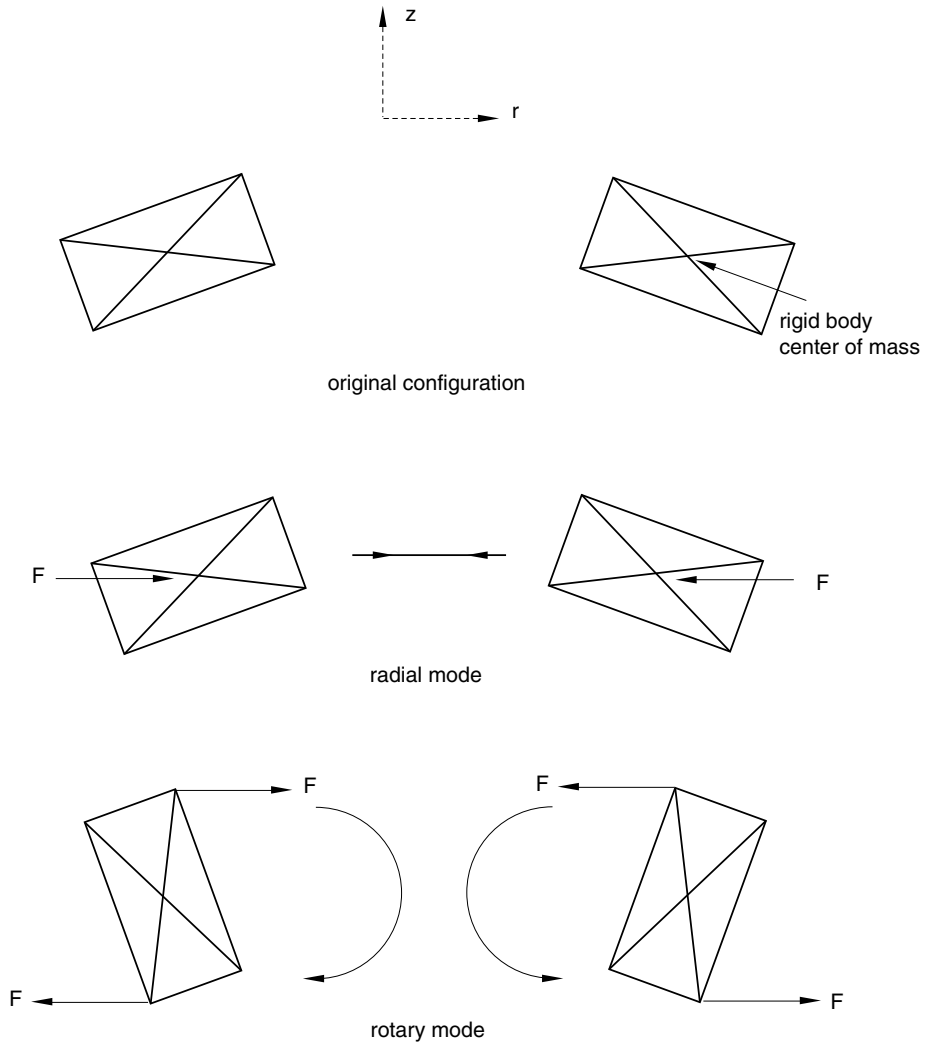


Figure 2.4.1–2 Axisymmetric rigid body modes.

same manner that they are specified if the nodes and elements are not part of a rigid body. Contributions include:

- applied concentrated forces on pin nodes, tie nodes, and the rigid body reference node;
- applied concentrated moments on tie nodes and the rigid body reference node; and
- applied distributed loads on all elements and surfaces that are part of the rigid body.

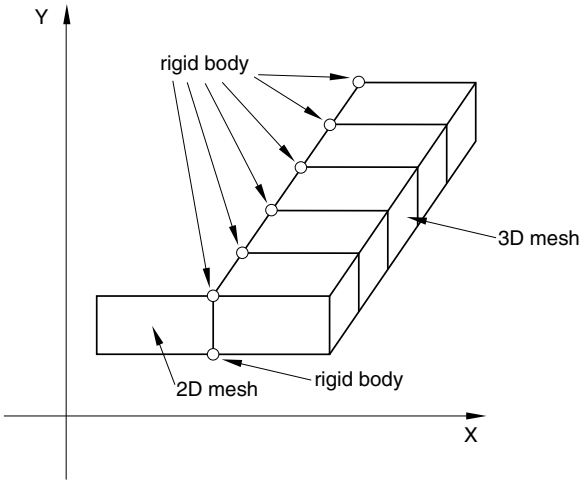


Figure 2.4.1–3 Rigid body nodes used to connect a two-dimensional and three-dimensional mesh.

Unless the point of action is through the rigid body center of mass, each of these loads will create both a force at and a torque about the center of mass, which will tend to rotate an unconstrained rigid body. If a nodal transformation is defined at any rigid body nodes, concentrated loads defined at these nodes are interpreted in the local system. The local system defined by the nodal transformation does not rotate with the rigid body.

Concentrated moments defined on rigid body pin nodes do not contribute load to the rigid body but are rather associated with the independent rotation of that node. Independent rotation of a pin node exists only if it is connected to a deformable element with rotational degrees of freedom or a rotary inertia element. Follower forces (see "Specifying concentrated follower forces" in "Concentrated loads," Section 34.4.2) can be defined at pin nodes if the independent rotation exists. However, the results may be nonintuitive since the direction of the force is determined by the independent rotation even though the follower force acts on the rigid body.

Rigid bodies with temperature degrees of freedom

Only rigid bodies that contain coupled temperature-displacement elements have temperature degrees of freedom. If it is reasonable to assume that a rigid body used in a fully coupled temperature-displacement analysis has a uniform temperature, you can define the rigid body as isothermal. A transient heat transfer process involving an isothermal rigid body assumes that the internal resistance of the body to heat is negligible in comparison with the external resistance. Thus, the body temperature can be a function of time but cannot be a function of position. The temperature degree of freedom that is created at the rigid body reference node describes the temperature of the body.

Thermal interactions for rigid bodies with analytical rigid surfaces are available only in Abaqus/Explicit and are activated by specifying that the rigid body is isothermal.

By default, rigid bodies are not considered isothermal and all nodes on a rigid body connected to coupled temperature-displacement elements will have independent temperature degrees of freedom. The fact that the nodes are part of a rigid body does not affect the ability of the coupled elements to conduct heat within the rigid body. However, the mechanical response will be rigid.

The lumped heat capacitance associated with the rigid body reference node of an isothermal body is calculated automatically if the rigid body is composed of coupled temperature-displacement elements for which a specific heat and a density property are defined. Otherwise, you should specify a point heat capacitance for the rigid body (see "Point capacitance," Section 30.4.1). An error message will be issued in Abaqus/Explicit if no heat capacitance is associated with an isothermal rigid body for which temperature is not prescribed at the reference node.

- The capacitance of each coupled temperature-displacement element that is part of the rigid body contributes to the isothermal rigid body's capacitance. For an axisymmetric isothermal rigid body, capacitance contributions from axisymmetric elements assigned to the rigid body include the integrated value around the circumference.
- HEATCAP elements that are connected to any node that is part of a rigid body or the rigid body reference node contribute to the isothermal rigid body's capacitance. For an axisymmetric isothermal rigid body the point capacitances defined on nodes of the rigid body are assumed to account for the capacitance integrated around the circumference of the body.

Thermal loads acting on the reference node of an isothermal body are assembled from contributions of all the thermal loads on nodes and elements that are part of the rigid body. Heat transfer between a deformable body and an isothermal rigid body can occur during contact, as well as when the bodies are not in contact if gap conductance and gap radiation are defined (see "Thermal contact properties," Section 37.2.1). Heat transfer between two isothermal rigid bodies can occur only via gap conduction and gap radiation.

Input File Usage: *RIGID BODY, ISOTHERMAL=YES

Abaqus/CAE Usage: Interaction module: **Create Constraint**: **Rigid body**: toggle on **Constrain selected regions to be isothermal**

Modeling contact with a rigid body

Contact with a rigid body is modeled by specifying a contact interaction formed with a rigid surface and with a surface defined on another body (see "Defining contact pairs in Abaqus/Standard," Section 36.3.1; "Defining general contact interactions in Abaqus/Explicit," Section 36.4.1; or "Defining contact pairs in Abaqus/Explicit," Section 36.5.1). A rigid surface can be formed by nodes, element faces, or an analytical surface (see "Node-based surface definition," Section 2.3.3; "Element-based surface definition," Section 2.3.2; and "Analytical rigid surface definition," Section 2.3.4).

Contact modeling can be a primary factor when choosing the appropriate rigid body geometry. Contact interactions should be formed with surfaces of like geometry. For example, a planar rigid body should be used to model contact either with deformable surfaces formed by two-dimensional plane stress or plane strain elements or via node-based surfaces with two-dimensional beam, pipe, or truss elements. Similarly, an axisymmetric rigid body should be used to model contact with surfaces formed by

axisymmetric elements, and a three-dimensional rigid body should be used to model contact either with surfaces formed by three-dimensional element faces or via node-based surfaces with three-dimensional beam, pipe, or truss elements.

A rigid body must contain only two-dimensional or only three-dimensional elements. Nodes cannot be shared between two rigid bodies. Contact between two analytical rigid surfaces or between an analytical rigid surface and itself cannot be modeled.

Limitations in Abaqus/Standard

Contact between rigid bodies is allowed if the slave surface belongs to an elastic body that has been declared as rigid. In this case softened contact should be prescribed to avoid possible overconstraints.

Contact between two rigid surfaces defined using rigid elements is not allowed.

Rigid beams and trusses cannot be included in a contact pair definition because surfaces from beams and trusses can be node-based surfaces only. A node-based surface must be a slave surface, and elements that are part of a rigid body should be part of the master surface in a contact pair.

Limitations in Abaqus/Explicit

Contact between two rigid surfaces can be modeled in Abaqus/Explicit only if the penalty contact pair algorithm or the general contact algorithm is used; kinematic contact pairs cannot be used for rigid-to-rigid contact. Therefore, when converting two deformable regions of a model to two distinct rigid bodies for the purpose of model development, any contact interaction definitions between these rigid bodies must use penalty contact pairs or general contact.

For rigid-to-rigid contact involving analytical rigid surfaces, at least one of the rigid surfaces must be formed by element faces since contact between two analytical rigid surfaces cannot be modeled in Abaqus.

The penalty contact pair algorithm, which introduces numerical softening to the contact enforcement through the use of penalty springs, or the general contact algorithm must be used for all contact interactions involving a rigid body if an equation constraint, a multi-point constraint, a tie constraint, or a connector element is defined for a node on the rigid body.

Rigid beams and trusses cannot be included in a kinematic contact pair definition because surfaces from beams and trusses can be node-based surfaces only. A node-based surface must be a slave surface, and elements that are part of a rigid body must be part of the master surface in a kinematic contact pair.

When a rigid surface acts as a slave surface in a penalty contact pair or in general contact, initial penetrations of the rigid slave nodes into the master surface will not be corrected with strain-free corrections (see “Adjusting initial surface positions and specifying initial clearances for contact pairs in Abaqus/Explicit,” Section 36.5.4, and “Controlling initial contact status for general contact in Abaqus/Explicit,” Section 36.4.4). For contact pairs any initial penetrations of this type may cause artificially large contact forces in the initial increments. For general contact these initial penetrations are stored as contact offsets.

Using rigid bodies in geometrically linear Abaqus/Standard analysis

If rigid bodies are used in a geometrically linear Abaqus/Standard analysis (see "General and linear perturbation procedures," Section 6.1.3), the rigid body constraints are linearized. Consequently, except for analytical rigid surfaces, the distance between any two nodes belonging to the rigid body may not remain constant during the analysis if the magnitudes of the rotations are not small.

2.5 Integrated output section definition

- “Integrated output section definition,” Section 2.5.1

2.5.1 INTEGRATED OUTPUT SECTION DEFINITION

Products: Abaqus/Explicit Abaqus/CAE

References

- "Output to the output database," Section 4.1.3
- *INTEGRATED OUTPUT SECTION
- *INTEGRATED OUTPUT
- *SURFACE
- "Defining integrated output sections," Section 14.13.1 of the Abaqus/CAE User's Guide, in the HTML version of this guide

Overview

An integrated output section:

- can be two-dimensional or three-dimensional;
- can be used to track the average motion of a surface;
- can be used in association with integrated output requests to study the "force-flow" in the model; and
- does not impose any constraint on the motion of the surface.

Introduction

An integrated output section is a way to associate a surface with a coordinate system and/or a reference node for one or both of the following purposes:

- tracking the average motion of the surface; and/or
- expressing the force and the moment transmitted through the surface in a local coordinate system, with the moment taken about a point that moves with the surface.

The average motion of a surface can be obtained as the displacement and/or rotation history at the reference node on an integrated output section definition. You must define a reference node that is not connected to any other part of the finite element model and select whether the reference node follows only the average translation of the surface or both the translation and the rotation. Since the reference node is not connected to the rest of the model, an integrated output section definition used to track the average surface motion does not form a constraint on the motion of any nodes in the model.

The "force-flow" in a complicated model can be studied using integrated output sections defined over a number of interior cross-section-like surfaces cutting through various parts of the model. It can be equally useful to sum forces over an exterior surface in contact or to sum forces transmitted through a tie constraint between surfaces, which is done by associating an integrated output section definition with an integrated output request. The vector output quantities can be expressed in a coordinate system

of choice by specifying an orientation on an integrated output section definition. This coordinate system can rotate by an amount given by the rotational degrees of freedom at the reference node. In addition, the output of the integrated moment across the surface can be taken about a location that can translate by an amount given by the translational degrees of freedom at the reference node. Integrated output over a given surface can be requested with different coordinate systems and reference nodes by employing multiple integrated output section definitions over the same surface.

Creating an integrated output section

You must assign a name to each integrated output section. This name is used to associate the section with an integrated output request. In addition, you must identify the surface over which the section is being defined (see "Element-based surface definition," Section 2.3.2).

Input File Usage: *INTEGRATED OUTPUT SECTION, NAME=*section_name*, SURFACE=*surface_name*

Abaqus/CAE Usage: Step module: **Output→Integrated Output Sections→Create**: **Name:** *section_name*: select surface region

Creating interior cross-section surfaces

To study the "force-flow" through various paths in a model, you must create interior surfaces that cut through one or more regions (similar to a cross-section) so that you can request integrated output of the total force and moment transmitted across these surfaces. You can create such interior surfaces over the element facets, edges, or ends by simply cutting through one or more regions of the model with a plane; see "Creating interior cross-section surfaces" in "Element-based surface definition," Section 2.3.2, for more information.

The integrated output section reference node

A reference node can be associated with an integrated output section for one or both of the following purposes:

- tracking the average motion of the surface; and/or
- computing the variables from an integrated output request in a coordinate system that moves with the motion of the reference node.

If the average surface motion must be tracked, you must define a reference node that is not connected to any other part of the finite element model and select whether the reference node follows only the average translation of the surface or both the translation and the rotation. The rotational degrees of freedom will be activated in addition to the translational degrees of freedom at the reference node if it is selected to follow the average rotation of the surface. Further, the initial position of the reference node may be adjusted to lie at the center of the surface automatically.

When an integrated output section with a reference node is associated with an integrated output request, the total moment transmitted through the section is computed with respect to the current location of the reference node. If the reference node has active rotational degrees of freedom, the coordinate system used to express the integrated output variables rotates with the rotation of the reference node.

Positioning the reference node at the center of the surface

The reference node can be repositioned automatically at the center of the surface in the initial configuration when the reference node is not connected to the rest of the model.

The default is to leave the reference node in its specified position.

Input File Usage: Use the following option to position the reference node at the center of the surface:

*INTEGRATED OUTPUT SECTION, REF NODE=*n*, POSITION=CENTER

Abaqus/CAE Usage: Step module: integrated output section editor: **Anchor at reference point: Edit**: select reference point: **Move point to center of surface**

Setting the reference node to track the average motion of the surface

It is often meaningful to obtain integrated output over a surface using a coordinate system and a point that moves with the average surface motion. When the reference node is not connected to the rest of the model, it can be specified to translate with the average translation of the surface without any rotation or to both translate and rotate with the average motion of the surface. The average motion is based on the mass weighted motion of the individual nodes that are on the surface and are not part of any rigid body.

By default, the reference node does not track the average motion of the surface.

Input File Usage: Use the following option if the reference node must translate with the average translation of the surface:

*INTEGRATED OUTPUT SECTION, REF NODE=*n*,
REF NODE MOTION=AVERAGE TRANSLATION

Use the following option if the reference node must both translate and rotate with the average translation of the surface:

*INTEGRATED OUTPUT SECTION, REF NODE=*n*,
REF NODE MOTION=AVERAGE

Abaqus/CAE Usage: Step module: integrated output section editor: **Anchor at reference point: Edit**: select reference point: **Point motion: Average translation and rotation** or **Average translation**

The integrated output section local coordinate system

You can define a local coordinate system on an integrated output section and associate the section with an integrated output request to express the integrated output variables in the local coordinate system. You can specify an orientation as the local coordinate system and, possibly, further project it onto the surface. Alternatively, you can form a local coordinate system by projecting the global coordinate system onto the surface following the Abaqus conventions (see "Conventions," Section 1.2.2). If a local system is not defined explicitly, the local system is initialized to the global coordinate system.

The initial coordinate system, whether explicitly defined or initialized to the global coordinate system, will rotate with the deformation if a reference node is specified and that reference node has active rotational degrees of freedom. If the reference node is not connected to the rest of the model

and its motion is based on both the average translation and rotation of the surface, the rotational and translational degrees of freedom are activated at the reference node.

Input File Usage: Use the following option to define the initial coordinate system for the section:

∗INTEGRATED OUTPUT SECTION, ORIENTATION=*orientation_name*

Abaqus/CAE Usage: Step module: integrated output section editor: **CSYS: Edit**: select orientation

Projecting the coordinate system onto the section surface

Either the coordinate system defined by the specified orientation or the global coordinate system can be projected onto the section surface to obtain a local coordinate system. Projection onto the surface is based on the average normal of the surface; the local 1-direction is formed perpendicular to the surface (see Figure 2.5.1–1).

Input File Usage: Use the following option to project the coordinate system onto the section surface:

∗INTEGRATED OUTPUT SECTION, PROJECT ORIENTATION=YES

Abaqus/CAE Usage: Step module: integrated output section editor: **Project orientation onto surface**

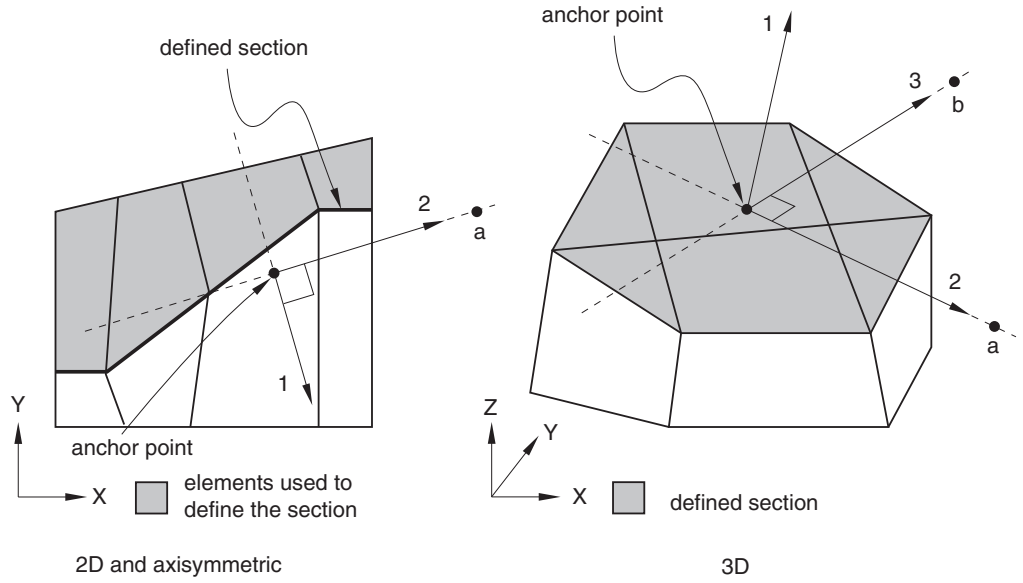


Figure 2.5.1–1 User-defined local coordinate system.

Associating an integrated output section with an integrated output request

An integrated output request is used to obtain history output of variables such as total force transmitted across a surface (see "Integrated output in Abaqus/Explicit" in "Output to the output database," Section 4.1.3). Such a request may refer to an integrated output section definition to identify the surface where output is needed and to provide a local coordinate system and/or a reference node as a point about which the total moment across the surface is computed.

Input File Usage: Use both of the following options to associate an integrated output section with an integrated output request:

∗INTEGRATED OUTPUT SECTION, NAME=*section_name*
∗INTEGRATED OUTPUT, SECTION=*section_name*

Abaqus/CAE Usage: Step module:

Output→Integrated Output Sections→Create: **Name:** *section_name*

History output request editor: **Domain: Integrated output section:** *section_name*

Limitations

Integrated output sections are subject to the following limitations:

- The surface associated with an integrated output section cannot be an analytical rigid surface.
- The surface associated with an integrated output section can contain facets over rigid or axisymmetric elements. However, such an integrated output section cannot be associated with an integrated output request (see "Output to the output database," Section 4.1.3).

2.6 Mass adjustment

- “Adjust and/or redistribute mass of an element set,” Section 2.6.1

2.6.1 ADJUST AND/OR REDISTRIBUTE MASS OF AN ELEMENT SET

Product: Abaqus/Explicit

References

- "Density," Section 21.2.1
- "Point masses," Section 30.1.1
- "Nonstructural mass definition," Section 2.7.1
- "Mass scaling," Section 11.6.1
- *MASS ADJUST

Overview

Mass adjustment:

- is useful to set the net mass of one or more components in the model to a known value;
- is useful to account for any errors in mass due to modeling approximations;
- is useful to account for mass from nonstructural features otherwise omitted from the model, such as paint;
- can be applied over all element types that have mass;
- adjusts the mass of the individual elements in an element set in proportion to their pre-adjusted mass including any nonstructural mass, so as to meet the specified target value for the set;
- can be used to redistribute mass among elements in the set to raise the minimum stable time increment to a target value;
- can be specified only once in an Abaqus/Explicit analysis during the model definition; and
- can be applied in a hierarchical fashion to adjust the mass for individual parts first and then for an assembly of these parts.

Adjusting the total mass of an element set to a known value

The mass of a component in a numerical model may differ from its actual value for a number of reasons including modeling approximations and omission of minor features from the model. You can specify mass adjustment in the numerical model for such components by identifying the element sets defining these components and their respective total mass values. For a given element set, the mass is adjusted at the start of the analysis such that the adjustment in each element in that set is in proportion to the pre-adjusted mass of that element, thus preserving the center of mass and the principal directions of the rotary inertia. The pre-adjusted mass of an element includes the mass due to any associated material density; any mass directly specified on the section definition as in the case of beam, pipe, shell, membrane, rigid, and surface elements; and any nonstructural mass applied directly to that element. "Knee bolster impact

with general contact," Section 2.1.9 of the Abaqus Example Problems Guide, is an example of setting the total mass of an element set using mass adjustment.

When mass is adjusted for an element with active rotational degrees of freedom, the rotary inertia contribution from that element is also modified proportionally to correspond with the scaling in the element mass from mass adjustment, thus preserving the principal directions of the rotary inertia. The adjusted mass value is considered when calculating the stable time increment of an element. Loads such as mass proportional damping (see "Material damping," Section 26.1.1) and gravity take the adjusted mass into account.

Mass adjustment can be applied in a hierarchical fashion to adjust the mass for individual parts first and then for an assembly of these parts. In this scenario, the mass adjustment defined over the assembly may further modify the adjusted mass of the individual parts. You must associate all of the mass-adjusted element sets in the desired order with a single mass adjustment definition.

Abaqus/Explicit automatically calculates the mass, center of mass, and rotary inertia of each element set and prints the results to the data (**.dat**) file if model definition data are requested (see "Controlling the amount of analysis input file processor information written to the data file" in "Output," Section 4.1.1). The contributions from mass adjustment are also listed in these tables. Element output variable MASSADJUST can be requested as output to the output database (**.odb**) file, and it will indicate how the mass of the set is adjusted or redistributed to each element included in the set (see "Abaqus/Explicit output variable identifiers," Section 4.2.2). This output variable is available as field output (contour plots) in the first output frame of the first analysis step.

Redistribution of mass to raise the minimum stable time increment to a target value

You can increase the minimum stable time increment in the initial configuration for an element set to a specified target value by redistributing mass among the elements in that set. The redistribution of mass to affect the stable time increment and adjustment of mass to achieve a target total mass can be requested independently of each other. If both options are requested for a given element set, the mass is first adjusted to meet the target total mass for the set and then redistributed among the elements to achieve the target time increment.

You can set a default target time increment that is applicable for all of the mass-adjusted element sets as well as specific targets for any of the individual element sets. Within each set, the mass is transferred to the elements with time increments below the target value from the remaining elements. Abaqus/Explicit prints the amount of mass available for redistribution along with the percentage of this amount that is redistributed to the data (**.dat**) file if model definition data are requested (see "Controlling the amount of analysis input file processor information written to the data file" in "Output," Section 4.1.1). If a sufficient amount of mass is not available to meet the specified target time increment, the analysis terminates with an error message. "Impact of a water-filled bottle," Section 2.3.2 of the Abaqus Example Problems Guide, is an example of maintaining the target stable time increment of an element set using mass adjustment.

When compared to the fixed mass scaling functionality, the redistribution feature above does not alter the total mass of the set. However, both features affect the center of mass and the principal directions of rotary inertia. The redistribution feature is performed only in the initial configuration at the start of the analysis; whereas the fixed mass scaling is performed in the configuration at the start of the step

requesting that mass scaling. When you specify mass adjustment and mass scaling, the mass scaling adds mass as necessary on top of the adjusted mass.

Defining mass adjustment

To adjust the total mass of one or more components in the model, you first identify the corresponding element sets. If you specify multiple elements sets, the mass is adjusted in the order in which the element sets are specified. For element sets that share elements, you must determine the order in which to specify the element sets to obtain the desired results.

Defining total mass for an element set without altering its center of mass

You must specify the total mass for each mass-adjusted element set.

Input File Usage: ∗MASS ADJUST
element_set_name, element_set_mass

Defining mass redistribution to raise the time increment

You can redistribute the mass of an element set to achieve a target time increment and specify the total mass for each mass-adjusted element set, or you can redistribute the mass without changing the existing total mass of the element set. You can set a default target time increment that is applicable for all of the mass-adjusted sets as well as specific targets for any of the individual sets. When both a default target and a specific target are specified, the specific target is used for that set.

Input File Usage: Use the following option to raise the time increment and specify the total mass:

∗MASS ADJUST, TARGET DT=*min_stable_time_increment*
element_set_name, element_set_mass,
element_set_min_stable_time_increment

Use the following option to raise the time increment without altering the total mass:

∗MASS ADJUST, TARGET DT=*min_stable_time_increment*
element_set_name, CURRENT, *element_set_min_stable_time_increment*

2.7 Nonstructural mass definition

- "Nonstructural mass definition," Section 2.7.1

2.7.1 NONSTRUCTURAL MASS DEFINITION

Products: Abaqus/Standard Abaqus/Explicit Abaqus/CAE

References

- "Point masses," Section 30.1.1
- "Density," Section 21.2.1
- "Adjust and/or redistribute mass of an element set," Section 2.6.1
- *NONSTRUCTURAL MASS
- "Defining nonstructural mass," Section 33.4 of the Abaqus/CAE User's Guide, in the HTML version of this guide

Overview

A nonstructural mass:

- is a contribution to the model mass from features that have negligible structural stiffness (such as paint on sheet metal panels in a car);
- can be used to bring the net mass of one or more components in the model up to a known value;
- can be positive to add mass to the model and negative to remove mass from the model, with the corresponding increase or decrease in the element stable time increment in an Abaqus/Explicit analysis;
- can be specified in the form of a total mass of the nonstructural features to be distributed over one or more components in the model;
- can be specified in the form of an increase in density over the smeared region;
- can be specified in the form of mass per unit area to be applied over a smeared region consisting of shells, membranes, and/or surface elements; and
- can be specified in the form of mass per unit length to be applied over a smeared region consisting of beam, pipe, and/or truss elements.

Nonstructural mass

The mass contribution from nonstructural features can be included in the model even if the features themselves are omitted. The nonstructural mass is smeared over an element set that is typically adjacent to the nonstructural feature. This element set can contain solid, shell, membrane, surface, beam, pipe, or truss elements. The nonstructural mass can be specified in the following forms:

- a total mass value,
- a mass per unit volume,

- a mass per unit area (for element sets that contain conventional shell, membrane, and/or surface elements), or
- a mass per unit length (for element sets that contain beam, pipe, and/or truss elements).

When a total mass is spread over an element set region, it can be distributed either in proportion to the underlying element "structural" mass or in proportion to the element volume in the initial configuration.

A "structural" mass is defined as the sum of all the mass contributions to an element outside of the nonstructural features. This may include the mass due to any material definitions associated with the element; any "mass per unit area" given on the section definition for shell, membrane, and surface elements; mass from any rebars included in shell, membrane, and surface elements; and any additional inertia given on the section definition of beam/pipe elements. A nonstructural mass contribution to an element is not allowed if that element has no structural mass.

A given element in the model can have contributions from multiple nonstructural mass specifications. The nonstructural mass in a given element will participate in any mass proportional distributed loads, such as gravity loading, defined on that element. When a nonstructural mass is added to a shell, beam, or pipe element with active rotational degrees of freedom, the nonstructural contribution affects both the element mass and the element rotary inertia. The element stable time increment increases with a positive nonstructural mass and decreases with a negative nonstructural mass. In general, it is easier to use a nonstructural mass definition to bring an additional mass into the model than to do the same with a group of point masses. It is also more beneficial in an Abaqus/Explicit analysis due to a possibly higher time increment.

Any mass proportional damping specified as part of the material definition (see "Material damping," Section 26.1.1) will also apply to the nonstructural mass contribution assigned to the element or element set using that material definition.

Defining nonstructural mass

To define a nonstructural mass contribution to the model mass, you must first identify the region over which the contribution must be added. You then specify the value of the nonstructural mass using the appropriate units and, if the total mass from the nonstructural features is known, determine how the nonstructural mass is distributed over the region.

Input File Usage: *NONSTRUCTURAL MASS, ELSET=*element_set_name*

Abaqus/CAE Usage: Property or Interaction module: **Special→Inertia→Create**: **Nonstructural mass**: select region

Specifying the units of the nonstructural mass

The nonstructural mass can be specified in different types of units, depending on the types of elements contained in the specified region.

Specifying units of mass

A total nonstructural mass with units of "mass" can be spread over a region containing solid, shell, membrane, beam, pipe, and/or truss elements.

Input File Usage: *NONSTRUCTURAL MASS, UNITS=TOTAL MASS
total mass of the nonstructural feature

Abaqus/CAE Usage: Property or Interaction module: **Special→Inertia→Create**: **Nonstructural mass**: select region: **Units: Total Mass**: **Magnitude:** *total mass of the nonstructural feature*

Specifying units of mass per unit volume

A nonstructural mass with units of "mass per unit volume" can be spread over a region containing solid, shell, membrane, beam, pipe, and/or truss elements.

Input File Usage: *NONSTRUCTURAL MASS, UNITS=MASS PER VOLUME
added density due to the nonstructural feature

Abaqus/CAE Usage: Property or Interaction module: **Special→Inertia→Create**: **Nonstructural mass**: select region: **Units: Mass per Volume**: **Magnitude:** *added density due to the nonstructural feature*

Specifying units of mass per unit area

A nonstructural mass with units of "mass per unit area" can be spread over a region containing conventional shells, membranes, and/or surface elements.

Input File Usage: *NONSTRUCTURAL MASS, UNITS=MASS PER AREA
added mass per unit area due to the nonstructural feature

Abaqus/CAE Usage: Property or Interaction module: **Special→Inertia→Create**: **Nonstructural mass**: select region: **Units: Mass per Area**: **Magnitude:** *added mass per unit area due to the nonstructural feature*

Specifying units of mass per unit length

A nonstructural mass with units of "mass per unit length" can be spread over a region containing beam, pipe, and/or truss elements.

Input File Usage: *NONSTRUCTURAL MASS, UNITS=MASS PER LENGTH
added mass per unit length due to the nonstructural feature

Abaqus/CAE Usage: Property or Interaction module: **Special→Inertia→Create**: **Nonstructural mass**: select region: **Units: Mass per Length**: **Magnitude:** *added mass per unit length due to the nonstructural feature*

Controlling the distribution of the total mass from nonstructural features

There are two methods available for distributing the nonstructural mass over the region when the total mass from the nonstructural features is known.

Distributing the nonstructural mass in proportion to the element structural mass

If you do not want to change the center of mass for the region, distribute the nonstructural mass in proportion to the element structural mass. This method results in a uniform scaling of the structural density of the region. Abaqus uses mass proportional distribution by default.

The element structural mass in shell, membrane, and surface elements includes any mass contribution from rebar provided that the rebar are defined as a rebar layer (see "Defining reinforcement," Section 2.2.3).

Input File Usage: *NONSTRUCTURAL MASS, UNITS=TOTAL MASS, DISTRIBUTION=MASS PROPORTIONAL
total mass of the nonstructural feature

Abaqus/CAE Usage: Property or Interaction module: **Special→Inertia→Create**: **Nonstructural mass**: select region: **Units: Total Mass**: **Magnitude:** *total mass of the nonstructural feature*: **Distribution: Mass Proportional**

Distributing the nonstructural mass in proportion to the element volume

Alternatively, you can distribute the nonstructural mass in proportion to the element volume in the initial configuration. This method results in a uniform value added to the underlying structural density over the region. Therefore, the center of mass for the region may be altered if the region has nonuniform structural density.

Input File Usage: *NONSTRUCTURAL MASS, UNITS=TOTAL MASS, DISTRIBUTION=VOLUME PROPORTIONAL
total mass of the nonstructural feature

Abaqus/CAE Usage: Property or Interaction module: **Special→Inertia→Create**: **Nonstructural mass**: select region: **Units: Total Mass**: **Magnitude:** *total mass of the nonstructural feature*: **Distribution: Volume Proportional**

2.8 Distribution definition

- “Distribution definition,” Section 2.8.1

2.8.1 DISTRIBUTION DEFINITION

Products: Abaqus/Standard Abaqus/Explicit Abaqus/CFD Abaqus/CAE

References

- "Orientations," Section 2.2.5
- "Material library: overview," Section 21.1.1
- "Material data definition," Section 21.1.2
- "Combining material behaviors," Section 21.1.3
- "Density," Section 21.2.1
- "Linear elastic behavior," Section 22.2.1
- "Thermal expansion," Section 26.1.2
- "Solid (continuum) elements," Section 28.1.1
- "Membrane elements," Section 29.1.1
- "Using a shell section integrated during the analysis to define the section behavior," Section 29.6.5
- "Using a general shell section to define the section behavior," Section 29.6.6
- "Connectors: overview," Section 31.1.1
- "Controlling initial contact status for general contact in Abaqus/Explicit," Section 36.4.4
- "Boundary conditions in Abaqus/CFD," Section 34.3.2
- *DISTRIBUTION
- *DISTRIBUTION TABLE
- Chapter 63, "The Discrete Field toolset," of the Abaqus/CAE User's Guide

Overview

A distribution:

- is a spatially varying field defined over elements or nodes in an Abaqus model;
- can be used to define shell thicknesses on an element-by-element basis;
- can be used to define shell stiffness on an element-by-element basis;
- can be used to define local coordinate systems on solid continuum and shell elements on an element-by-element basis;
- can be used to define orientation angles on the layers of composite shell elements;
- can be used to define orientation angles for connector elements;
- can be used to define thicknesses on the layers of conventional composite shell elements;
- can be used to specify initial contact clearances;

- can be used to specify pressure that varies with the total volume of fluid crossing a surface in an Abaqus/CFD analysis; and
- in an Abaqus/Standard analysis can be used to define mass density, linear elastic material behavior, and thermal expansion for solid continuum elements; shell offsets; orientation angles on the layers of composite solid continuum elements; local coordinate systems on membrane elements; and membrane thickness on an element-by-element basis.

Distributions

A distribution is a spatial analogy of an amplitude definition (see "Amplitude curves," Section 34.1.2). Amplitude definitions are used to provide arbitrary time variations of loads, displacements, and other prescribed variables. Distributions are used to specify arbitrary spatial variations of selected element properties, material properties, local coordinate systems, and spatial variations of initial contact clearances.

The two main components of a distribution are its *location* and *field data*. The location identifies where the distribution is defined, either on elements or nodes. Field data are a specified number of floating point values defined for each element or node in the distribution.

To define a distribution, you must assign it a unique name. You must also specify the number and physical dimension of each data value in the distribution by referring to a distribution table.

Input File Usage: *DISTRIBUTION, NAME=*name*, TABLE=*distribution table name*

Abaqus/CAE Usage: Abaqus/CAE supports distributions using discrete fields.

Property, Interaction, or Load module: **Tools→Discrete Field→Create**

Specifying the location of a distribution

You can define a distribution on elements or nodes. Currently distributions on nodes are supported only for defining initial contact clearances as described in "Controlling initial contact status for general contact in Abaqus/Explicit," Section 36.4.4. For a distribution used with fluid boundary definitions in Abaqus/CFD, you specify that no location is required. All other applications of distributions require distributions defined on elements.

There is no limit on the number of distributions to which a given element or node may belong. Elements and nodes cannot be combined within the same distribution definition.

Defining a distribution on elements

Defining a distribution on elements requires you to specify field data for each element or element set included in the distribution definition. All distributions on elements require that default data be defined. Default data are used for all elements that are not specifically assigned a value in the distribution.

Input File Usage: *DISTRIBUTION, LOCATION=ELEMENT
blank space, *field data*
element set or element number, *field data*

Default data are defined by using a blank space instead of an element number or element set for the first data item on the first data line of a distribution definition.

Only one set of default data can be defined for a distribution. If you specify only default data, all elements that reference that distribution use the default values.

If an element is specified more than once in a given distribution definition, the last specification given is used.

Abaqus/CAE Usage: Property, Interaction, or Load module: **Tools→Discrete Field→Create**: **Definition**: **Elements**

Defining a distribution on nodes

Defining a distribution on nodes requires you to specify field data for each node or node set included in the distribution definition.

Input File Usage: *DISTRIBUTION, LOCATION=NODE
node set or node number, *field data*

If a node is specified more than once in a given distribution definition, the last specification given is used.

Abaqus/CAE Usage: Defining a distribution on nodes for initial contact clearances is not supported in Abaqus/CAE.

Defining a distribution used in Abaqus/CFD

For a distribution used to define fluid boundary conditions for pressure that varies with the total volume of fluid crossing a surface, you specify field data and that no location is required.

Input File Usage: *DISTRIBUTION, LOCATION=NONE
field data, *field data*

Abaqus/CAE Usage: Defining a distribution used in Abaqus/CFD is not supported in Abaqus/CAE.

Defining a distribution table

Every distribution definition must refer to a distribution table. A distribution table defines the number of field data items needed for each element or node in a distribution. The distribution table also defines the physical dimension of each data value in a distribution. A distribution table can be referred to as many times as needed by different distributions. The distribution table consists of a list of predefined labels shown in Table 2.8.1–1 and Table 2.8.1–2. The combination of labels needed for a given distribution is determined by how the distribution is applied.

Input File Usage: Use the following option to define a distribution table:

*DISTRIBUTION TABLE, NAME=*distribution table name*
list of distribution table labels

Abaqus/CAE Usage: Abaqus/CAE creates a distribution table when you specify a distribution by selecting a discrete field.

Defining a distribution table used in Abaqus/CFD is not supported in Abaqus/CAE.

Table 2.8.1–1 Distribution table labels—Abaqus/Standard and Abaqus/Explicit.

Data label	Physical dimension	Number of data items per label
ANGLE	angle in degrees	1
COORD3D	(L, L, L)	3
DENSITY	ML^{-3}	1
EXPANSION	θ^{-1}	1
LENGTH	L	1
MODULUS	FL^{-2}	1
RATIO	dimensionless	1
SHELLSTIFF1	FL^{-1}	1
SHELLSTIFF2	F	1
SHELLSTIFF3	FL	1

Table 2.8.1–2 Distribution table labels—Abaqus/CFD.

Data label	Physical dimension	Number of data items per label
PRESSURE	FL^{-2}	1
VOLUME	L^3	1

Applying distributions

The data defined in a distribution are not used in an Abaqus analysis unless the distribution is referred to by name by a feature that supports distributions, and the distribution is applied only to the elements or nodes that are associated with the referenced feature. In addition, a distribution definition can be referenced more than one time in a given model. These points are illustrated in the examples below.

If an element in an Abaqus/Standard or Abaqus/Explicit analysis is declared rigid (see "Rigid body definition," Section 2.4.1) any distributions used to define element properties, material properties (with the exception of density), or local coordinate systems are ignored.

Examples

The simple examples below illustrate how distributions are defined. A large number of illustrative example problems using distributions can be found in "Spatially varying element properties," Section 5.1.4 of the Abaqus Verification Guide.

Example 1

A distribution for shell thickness is defined and applied to two different shell section definitions through the SHELL THICKNESS parameter—as noted above the distribution **dist0** would not be used if it is not referred to by a feature that supports distributions. See "Using a shell section integrated during the analysis to define the section behavior," Section 29.6.5, for more details. The distribution table defines both the number of data values (one) and the physical dimension (LENGTH) of the thickness data. The thicknesses defined in distribution **dist0** are assigned only to shell elements that belong to the element set **elset1** or **elset2**. The default thickness (t_0) defined in the first data line of **dist0** will be assigned to all elements in **elset1** and **elset2** that are not explicitly assigned a thickness in **dist0**.

```
*DISTRIBUTION TABLE, NAME=tab0
 LENGTH
*DISTRIBUTION, NAME=dist0, LOCATION=element, TABLE=tab0
                        , t0
 element set or number, t1
 element set or number, t2
 ...
*SHELL SECTION, ELSET=elset1, SHELL THICKNESS=dist0
*SHELL SECTION, ELSET=elset2, SHELL THICKNESS=dist0
```

Example 2

A distribution for spatially varying isotropic elastic material behavior is defined and applied to a material definition ("Linear elastic behavior," Section 22.2.1). This material is then referred to by a solid section definition. This is important because like any material definition, a material defined by a distribution is not used unless it is referred to by a section definition, and then it is applied only to the elements associated with the section definition. The distribution table defines both the number of data values (two) and the physical dimensions (MODULUS and RATIO) of the isotropic elastic data. Other material behaviors (in this case plasticity) can also be included in the material definition. The default elastic constants (E_0, ν_0) in distribution **dist1** will be assigned to all elements in **elset3** that are not explicitly assigned elastic constants in **dist1**.

```
*DISTRIBUTION TABLE, NAME=tab1
 MODULUS, RATIO
*DISTRIBUTION, NAME=dist1, LOCATION=element, TABLE=tab1
                       , E0, ν0
 element set or number, E1, ν1
 element set or number, E2, ν2
 ...
*MATERIAL, NAME=MAT
*ELASTIC
 dist1
```

```
*PLASTIC
 ...
*SOLID SECTION, ELSET=elset3, MATERIAL=MAT
```

Example 3

A spatially varying local coordinate system (“Orientations,” Section 2.2.5) is defined by specifying both spatially varying coordinates for points a and b as well as a spatially varying additional rotation angle. This orientation is then referred to by a general shell section definition. This is important because like any orientation definition, an orientation defined by a distribution is not used unless it is referred to by a section definition, and then it is applied only to the elements associated with the section definition. The distribution table for the coordinates specifies COORD3D twice to indicate that data for two three-dimensional coordinates points must be specified for each element in the distribution.

```
*DISTRIBUTION TABLE, NAME=tab2
 COORD3D, COORD3D
*DISTRIBUTION, NAME=dist2, LOCATION=element, TABLE=tab2
                       , aX0 ,aY0 ,aZ0 ,bX0 ,bY0 ,bZ0
 element set or number, aX1 ,aY1 ,aZ1 ,bX1 ,bY1 ,bZ1
 element set or number, aX2 ,aY2 ,aZ2 ,bX2 ,bY2 ,bZ2
 ...
*DISTRIBUTION TABLE, NAME=tab3
 ANGLE
*DISTRIBUTION, NAME=dist3, LOCATION=element, TABLE=tab3
                       , θ0
 element set or number, θ1
 element set or number, θ2
 ...
*ORIENTATION, NAME=ORI, DEFINITION=COORDINATES
 dist2
 3, dist3
*SHELL GENERAL SECTION, ELSET=elset4, ORIENTATION=ORI
```

Example 4

Spatially varying thicknesses and orientation angles are defined on the layers of a composite shell element. The distribution table for the thicknesses specifies LENGTH, and the distribution table for the orientation angles specifies ANGLE. A distribution of thicknesses is used on layers 1 and 3, while a distribution of angles is used on layers 2 and 3.

```
*DISTRIBUTION TABLE, NAME=tableThick
 LENGTH
*DISTRIBUTION, NAME=thickPly1, LOCATION=element, TABLE=tableThick
                       , t0
 element set or number, t1
```

```
 element set or number, t2
 …
*DISTRIBUTION, NAME=thickPly3, LOCATION=element, TABLE=tableThick
                       , t0
 element set or number, t1
 element set or number, t2
 …
*DISTRIBUTION TABLE, NAME=tableOriAngle
 ANGLE
*DISTRIBUTION, NAME=oriAnglePly2, LOCATION=element,
TABLE=tableOriAngle
                       , φ0
 element set or number, φ1
 element set or number, φ2
 …
*DISTRIBUTION, NAME=oriAnglePly3, LOCATION=element,
TABLE=tableOriAngle
                       , φ0
 element set or number, φ1
 element set or number, φ2
 …
*SHELL SECTION, ELSET=elset1, COMPOSITE
 thickPly1, 3, mat1, 0.
        1., 3, mat2, oriAnglePly2
 thickPly3, 3, mat3, oriAnglePly3
```

2.9 Display body definition

- “Display body definition,” Section 2.9.1

2.9.1 DISPLAY BODY DEFINITION

Products: Abaqus/Standard Abaqus/Explicit Abaqus/CAE

References

- *DISPLAY BODY
- "Defining display body constraints," Section 15.15.3 of the Abaqus/CAE User's Guide, in the HTML version of this guide

Overview

A display body:

- can be two-dimensional planar, axisymmetric, or three-dimensional;
- is associated with a part instance and up to three reference nodes, such that the motion of the part instance is governed by the motion of the reference nodes;
- is used for display purposes only and does not take part in the analysis;
- can be used to make the analysis more efficient while improving visualization of analysis results; and
- is especially useful for mechanism or multibody dynamic analyses.

What is a display body?

A display body is a part instance that is used for display only. None of the nodes or elements of the instance take part in the analysis, but they are still available during postprocessing. The motion of the display body is governed by the motion of the associated reference nodes, if any. It behaves like a rigid body since the relative positions of the nodes and elements of the part instance remain constant throughout a simulation. The nodes and elements of the part instance cannot be used to define prescribed conditions, interactions, constraints, etc. Section properties do not have to be assigned to the elements.

A display body is useful in cases where the physical model is different from the idealized model used for the analysis. An idealized model may be difficult to visualize; it may help to include more details in the model for realistic postprocessing purposes. Display bodies allow this without increasing the analysis time.

Display bodies are especially useful in mechanism or multibody dynamics problems where rigid parts interact with each other via connectors. In such cases a part can be represented by a very simple rigid body and a more complex display body. In this case, the rigid body can be as simple as just a node, along with mass and rotary inertia elements attached to that node.

Display bodies can also be used to model stationary objects that are not involved in the analysis but aid in visualization.

Creating a display body

You must specify the part instance to be made a display body.

Input File Usage: *DISPLAY BODY, INSTANCE=*name*

Abaqus/CAE Usage: Interaction module: **Create Constraint**: **Display body**: select part instance

The reference nodes

If the display body is not associated with any reference nodes, it will remain fixed in space during the analysis. However, you can specify that the motion of the display body should be governed by the motion of selected reference nodes. These nodes must belong to another part instance in the assembly. They cannot belong to another display body definition. If you specify only one reference node, the display body will translate and rotate based on the translations and rotations of that node during the analysis. If the reference node has no rotational degrees of freedom, the display body will not rotate during the analysis.

If you specify three reference nodes, the display body will translate and rotate based on the translations of all three nodes. The new position of the part instance at any time will be calculated from the new position and orientation of the coordinate system defined by the three reference nodes: the first node will be the origin, the second will be a point in the x-direction, and the third node will be a point in the X–Y plane. Care should be taken when specifying the three nodes so that they do not become colinear at any stage of the analysis. If this occurs, the position of the part instance may change abruptly through that increment.

Input File Usage: *DISPLAY BODY, INSTANCE=*name*
first reference node number, second reference node number, third reference node number

Abaqus/CAE Usage: Interaction module: **Create Constraint**: **Display body**: select part instance, choose **Follow single point** or **Follow three points**, click **Edit**, and select the reference points

Using display bodies with connectors

Display bodies can be used effectively in models containing rigid part instances that interact with each other using connector elements. Such models need both rigid bodies and display bodies. The rigid body should contain any nodes used by connectors, used to define mass and inertia properties, and used to apply loads or boundary conditions. The display body should contain the nodes and elements representing the physical part. Care should be taken to ensure that the nodes in the rigid body are not part of the display body. The reference node of the display body will typically be the same as the rigid body reference node.

Figure 2.9.1–1(a) illustrates a model containing rigid bodies and a display body. Part instance A is included in a display body definition. Figure 2.9.1–1(b) shows the same model without the display body. This model will actually be involved in the analysis. The connector node and reference node form a rigid body that represents the analysis version of part instance A. Both these nodes are assembly-level nodes and are not included in the display body.

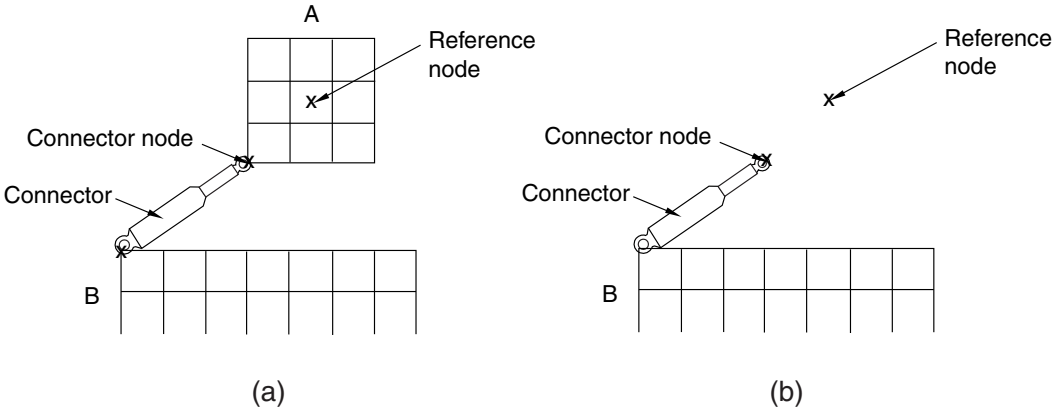


Figure 2.9.1–1 Example of a display body.

Input file template

The following input shows how display bodies can be used in a model with rigid part instances and connectors:

```
*ASSEMBLY
...
*INSTANCE, NAME=INST1
...
*END INSTANCE
*NODE, NSET=INST1-REFNODE
1001, -10, 0, 0
*NODE, NSET=INST1-CONNECTOR-NODE
1002, -5, -5, 0
*RIGID BODY, TIE NSET=INST1-CONNECTOR-NODE,
REF NODE=INST1-REFNODE
*DISPLAY BODY, INSTANCE=INST1
1001
...
*END ASSEMBLY
```

2.10 Assembly definition

- “Defining an assembly,” Section 2.10.1

2.10.1 DEFINING AN ASSEMBLY

Products: Abaqus/Standard Abaqus/Explicit

References

- *ASSEMBLY
- *INSTANCE
- *PART

Overview

A finite element model in Abaqus can be defined as an assembly of part instances. The organization of such a model:

- is consistent with models generated by Abaqus/CAE and displayed in the Visualization module (Abaqus/Viewer); and
- allows reuse of part definitions, which is valuable for creating large, complex models.

By default, input files written by Abaqus/CAE are written in terms of an assembly of part instances. For input files not written by Abaqus/CAE, the use of part and assembly definitions in the input file is currently optional. However, since the Visualization module displays results in terms of an assembly of part instances, an assembly and at least one part instance will be created automatically by the analysis input file processor if they are not defined in the input file.

Introduction

A physical model is typically created by assembling various components. The assembly interface in Abaqus allows analysts to create a finite element mesh using an organizational scheme that parallels the physical assembly. In Abaqus the components that are assembled together are called *part instances*. This section explains how to organize an Abaqus finite element model in terms of an assembly of part instances.

The mesh is created by defining parts, then assembling instances of each part. Each part can be used (instanced) one or more times, and each part instance has its own position within the assembly. This organization of the model definition matches the way models are created in Abaqus/CAE, where the assembly can be created interactively or imported from an input file (see the Abaqus/CAE User's Guide).

Terminology

Assembly

An assembly is a collection of positioned part instances. An analysis is conducted by defining boundary conditions, constraints, interactions, and a loading history for the assembly.

Part

A part is a finite element idealization of an object. Parts are the building blocks of an assembly and can be either rigid or deformable. Parts are reusable; they can be instanced multiple times in the assembly. Parts are not analyzed directly; a part is like a blueprint for its instances.

Part instance

A part instance is a usage of a part within the assembly. All characteristics (such as mesh and section definitions) defined for a part become characteristics for each instance of that part—they are *inherited* by the part instances. Each part instance is positioned independently within the assembly.

Example

A hinge can be modeled using two flanges and a pin, as shown in Figure 2.10.1–1. The flange geometry is defined by creating a part, which is instanced twice inside the hinge assembly. Another part, the pin, is created and instanced once. The pin is modeled as a rigid body created from an analytical surface (see "Analytical rigid surface definition," Section 2.3.4).

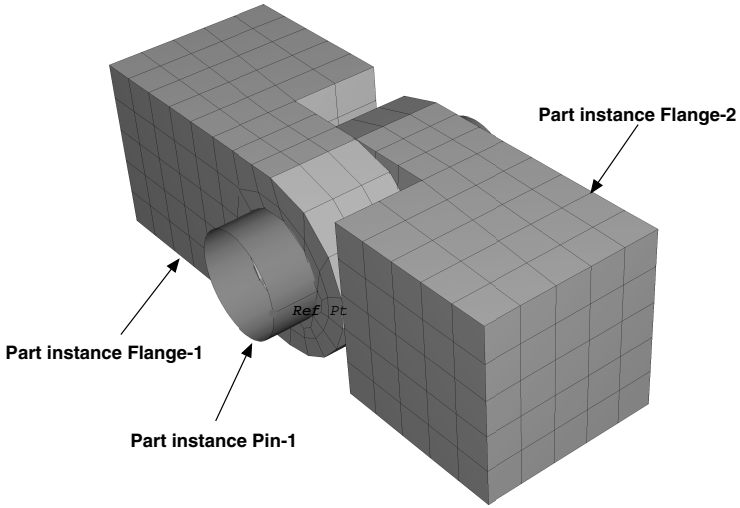


Figure 2.10.1–1 The hinge assembly.

This hinge example is used throughout this section to illustrate the keyword interface for parts and assemblies. This example is also used to illustrate the interactive assembly process (see Getting Started with Abaqus: Interactive Edition).

Defining parts, part instances, and the assembly

Everything defined within a part, instance, or the assembly is local to that part, instance, or the assembly. This means that node/element identifiers and names (like set and surface names) need not be unique throughout a model; they need only be unique within the part, instance, or assembly where they are being defined (see "Viewing part and assembly information in the data file" in "Output," Section 4.1.1). Names should not use an underscore to join part instance names to element set, node set, orientation names, or distribution names because the names may conflict with internal names used by Abaqus.

For example, consider Figure 2.10.1–2. In this model the assembly (**Hinge**) contains three part instances (**Flange-1**, **Flange-2**, and **Pin-1**). Multiple sets named **top** can be defined: in this case one is defined within the assembly and one is defined within each of the **Flange** part instances. The set name **top** can be reused, and each set named **top** is independent from the others.

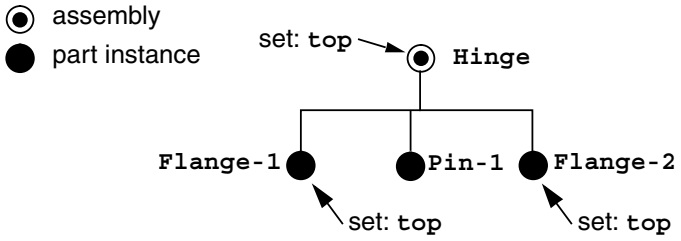


Figure 2.10.1–2 The organization of the **Hinge** assembly.

Input File Usage: Use the following options to begin and end each part, instance, and assembly definition:

*PART/*END PART
*INSTANCE/*END INSTANCE
*ASSEMBLY/*END ASSEMBLY

If any one of these options appears in an input file, they must all appear except when you import a part instance from a previous analysis; in this case *PART and *END PART are not required. The model must be consistently defined as an assembly of part instances.

Defining a part

A part definition must appear outside the assembly definition. Multiple parts can be defined in a model; each part must have a unique name.

Input File Usage: Use the following options to define a part:

*PART, NAME=*PartName*
Node, element, section, set, and surface definitions
*END PART

Defining part instances

A part instance definition must appear within the assembly definition. If the part instance is not imported from a previous analysis, each part instance must have a unique name and refer to a part name. A part instance name of **Assembly** is not allowed. In addition, you can specify data that are used to position the instance within the assembly. Give a translation and rotation for the part instance relative to the origin of the assembly (global) coordinate system.

If the part instance is to be imported from a previous analysis, each part instance must specify the name of the instance to be imported. For more information on defining part instances for use with the import capability, see "Transferring results between Abaqus analyses: overview," Section 9.2.1.

Additional sets and surfaces can be defined at the instance level, as explained later in this section.

Input File Usage: Use the following options to instance a part that is not imported from a previous analysis:

```
*INSTANCE, NAME=InstanceName, PART=PartName
 <positioning data>
 Additional set and surface definitions (optional)
*END INSTANCE
```

Repeat these options, each time referring to the same part name, to instance a part multiple times.

Use the following options to import a part instance from a previous analysis:

```
*INSTANCE, INSTANCE=instance-name
 Additional set and surface definitions (optional)
*IMPORT
*END INSTANCE
```

Defining the assembly

Only one assembly can be defined in a model. All part instance definitions must appear within the assembly definition.

Sets and surfaces can be defined at the assembly level by including the appropriate definitions within the assembly definition.

Input File Usage: Use the following options to create an assembly:

```
*ASSEMBLY, NAME=name
 Part instance definitions
 Set and surface definitions
 Connector and constraint definitions
 Rigid body definitions
*END ASSEMBLY
```

Example

The hinge assembly shown in Figure 2.10.1–1 can be defined using the following syntax in the input file:

```
*PART, NAME=Flange
   *NODE, NSET=Flange
    1, ...
    2, ...
    ...
    360, ...
   *ELEMENT, ELSET=Flange
    1, ...
    2, ...
    ...
    200, ...
   *SOLID SECTION, ELSET=Flange, MATERIAL=Steel
   *ELSET, ELSET=Flat, GENERATE
    176, 200, 1
   *SURFACE, NAME=Flat
    Flat, S1
*END PART
*PART, NAME=Pin
   *NODE, NSET=RefPt
    1, ...
   *SURFACE, TYPE=REVOLUTION, NAME=Pin
    ...
   *RIGID BODY, REF NODE=1, ANALYTICAL SURFACE=Pin
*END PART
*ASSEMBLY, NAME=Hinge
   *INSTANCE, NAME=Flange-1, PART=Flange
    <positioning data>
   *END INSTANCE
   *INSTANCE, NAME=Flange-2, PART=Flange
    <positioning data>
   *END INSTANCE
   *INSTANCE, NAME=Pin-1, PART=Pin
    <positioning data>
   *END INSTANCE
   *ELSET, ELSET=Top
    ...
   *NSET, NSET=Output
    ...
*END ASSEMBLY
*MATERIAL, NAME=Steel
 ...
```

Notes

- All of the nodes and elements that describe the **Flange** part are defined between the *PART and *END PART options. The section definition (*SOLID SECTION) must also appear within the part definition.
- At least one element set must be defined within the **Flange** part so that the section definition can refer to it. Additional node and element sets can also be defined in the part.
- The **Flange** part is instanced twice in the **Hinge** assembly. Therefore, the model contains two element sets named **Flat**: one belongs to part instance **Flange-1**, and the other belongs to part instance **Flange-2**.
- When a meshed part is instanced, the node and element numbers are repeated in each part instance.
- The **Pin** part is instanced once. It is a rigid body created from an analytical surface (see "Analytical rigid surface definition," Section 2.3.4).
- Keywords can be indented to help clarify the definition of each part, part instance, and assembly.

Organizing the model definition

In a traditional Abaqus model without an assembly definition, the components of the model fall into one of two categories: model data (step independent) and history data (step dependent). In an Abaqus model that is organized into an assembly of part instances, all components are further categorized and must fall within the proper level: part, assembly, instance, step, or model. Step-level components correspond to history data; all step-dependent component definitions must appear within a step definition (see "Defining an analysis," Section 6.1.2). Model-level data include everything that does not fall into part-, assembly-, instance-, or step-level data (for example, material definitions; see Figure 2.10.1–3). The proper level within which a keyword option must appear in the input file is indicated at the top of each section in the Abaqus Keywords Reference Guide.

Rules for defining an assembly

The organization shown in Figure 2.10.1–3 is achieved by following a few basic rules.

Referring to items between levels

When creating a model, it is often necessary to refer to something outside of the current level; for example, a section definition within a part must refer to a material, which is defined at the model level. Loads defined within a step must refer to sets within the assembly. But some references between levels are not allowed; for example, a set in one part instance cannot refer to nodes in another part instance. The following references are allowed:

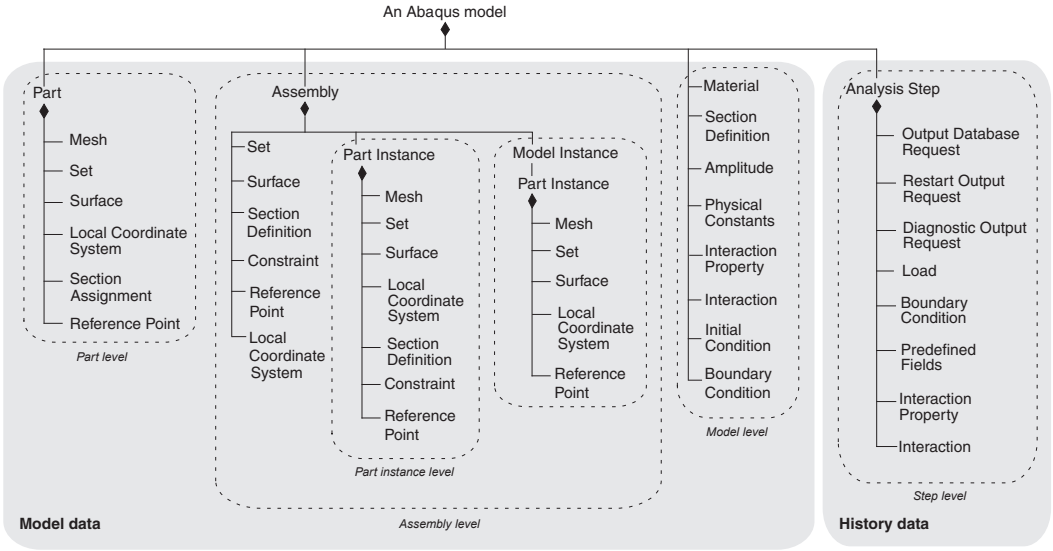


Figure 2.10.1–3 Organization of a model defined in terms of an assembly of part instances.

A definition within:	Can refer to items within:
the assembly	an instance
	the model
an instance	the model
a part	the model
a step	the assembly
	an instance
	the model

These rules are illustrated in Figure 2.10.1–4.

Naming conventions

The Abaqus naming conventions allow for a model that contains an assembly. When something is defined within a part, instance, or the assembly and is referred to from outside its level, the complete name must be used to identify it (set **`Flat`** of instance **`Flange-2`** in assembly **`Hinge`**, for example). A complete name is given in the input file using "dot" notation: each name in the hierarchy is separated by a "." (period). For example, some complete names in the **`Hinge`** assembly are

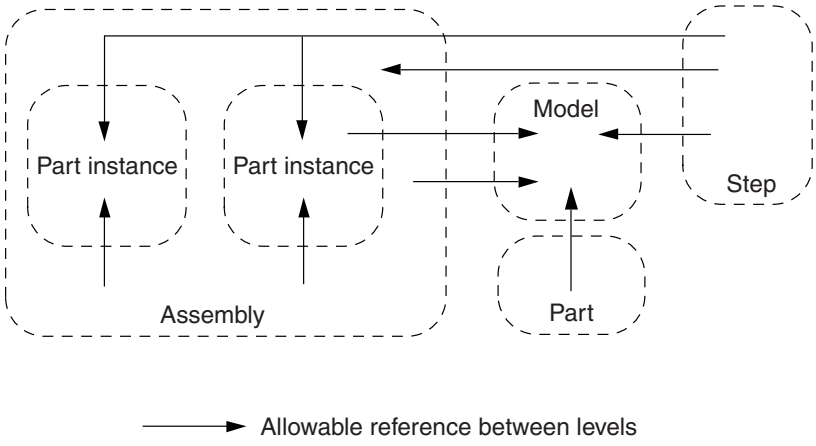


Figure 2.10.1–4 Allowable references between levels.

`Hinge.Flange-2.Flat`	An element set that belongs to part instance **`Flange-2`**.
`Hinge.Output`	A node set that belongs to assembly **`Hinge`**.

Such names would be used to refer to the sets from outside the assembly. The same syntax is used to refer to individual nodes or elements.

`Hinge.Flange-1.3`	A node or element that belongs to part instance **`Flange-1`**.
`Hinge.Flange-2.11`	A node or element that belongs to part instance **`Flange-2`**.

As always, the context determines whether a node or element is being referred to. The "." has special meaning; it is used to separate the individual names in a complete name. Therefore, the "." cannot be used in labels such as set and surface names. For example,

`*ELSET, ELSET=Set.1`	Error
`*ELSET, ELSET=Set1`	OK

Complete names are limited to 80 characters, including the periods.

However, when referring to a name in an input file that is not defined in terms of an assembly of part instances, the "." in the name should be replaced by underscores. Such a situation can occur, for example, when an element set from a previous analysis is referred to by the current analysis but the current input file is not defined in terms of an assembly of part instances.

Quoted labels

Labels for set and surface names can be defined by enclosing the label in quotation marks (see “Input syntax rules,” Section 1.2.1). Any subsequent use of the label in a complete name must be enclosed in quotation marks as well. For example,

```
*PART, NAME=Flange
 ...
*ELSET, ELSET="Set 1"
 ...
*END PART
 ...
*ELEMENT OUTPUT, ELSET=Hinge.Flange-1."Set 1"
```

Example

An assembly node set **Top** can be defined by the following syntax:

```
*ASSEMBLY, NAME=Hinge
   ...
   *NSET, NSET=Top
    Flange-1.2, Flange-1.5, ...
    Flange-2.1, Flange-2.4, ...
*END ASSEMBLY
```

Since the node set is defined within the assembly level, **Hinge.** is not part of the complete names given on the data lines. However, the prefix **Hinge.** would be required to request output for this node set, since the output request exists within the step definition, which is outside the assembly level.

```
*STEP
     ...
     *NODE OUTPUT, NSET=Hinge.Top
*END STEP
```

Similarly, a boundary condition could be applied to a set defined for part instance **Flange-2**.

```
*STEP
     ...
     *BOUNDARY
      Hinge.Flange-2.FixedEnd, 1, 3
*END STEP
```

The mesh (nodes and elements)

- The mesh can be defined either on a part or on an instance of that part (not both). Typically, parts are meshed and instances inherit that mesh, but it is not required. If, for example, you want to use fully integrated elements for one part instance and reduced-integration elements for another, or if

you want to define a more refined mesh on one part instance than on another, you must mesh the instances separately.

  - If the mesh is defined on a part, it is inherited by every instance of that part.
  - If the mesh is defined on a part, it cannot be redefined (overridden) on an instance of that part. In other words, if the node and element definitions appear within the part definition, they cannot appear within the instance definition for that part.
  - If a mesh is not defined on a part, it must be defined on every instance of that part.

- A part definition is required even if no mesh is defined on it. In such cases the empty part definition is used only to relate various instances to each other via the instance definitions. This allows the Visualization module to group information by part.
- Rebar must be defined within a part along with the elements that are being reinforced.
- Reference nodes can be created at the assembly level.
- Only mass, rotary inertia, capacitance, connector, spring, and dashpot elements can be created at the part or the assembly level. All other element types must be defined within a part (or part instance). To define assembly-level elements that refer to part-level nodes, include the part instance name when defining the element connectivity. For example:

```
*ELEMENT, TYPE=MASS
1, Instance-1.10
```

Section definitions

- Sections must be assigned where the mesh is defined (either within a part definition or within each instance of the part).
- If a part is meshed, all instances of that part have the same element types and are made of the same materials.
- The set referred to by a section definition must be created at the same level as the mesh and section definition.
- If the part is meshed, the section assignment cannot be overridden at the instance level.

Sets and surfaces

- Sets and surfaces (rigid or deformable) can be created within a part, part instance, or the assembly.
  - Sets and surfaces can be created on a part if a mesh is defined on the part.
  - Sets and surfaces defined on a part are inherited by each instance of that part.
  - Assembly-level sets and, in Abaqus/Standard, slave surfaces can span part instances.
- If an element set or node set definition with the same name appears more than once at the same level, the new members are appended to the set.
- A surface definition cannot appear more than once with the same surface name within the same level.

- New sets and surfaces can be created on a part instance. If a set or surface is defined on a part instance and a set or surface with that name was not defined on the part, the set or surface is added to the instance.
- Sets and surfaces cannot be redefined on a part instance. If a set or surface is defined on a part instance and a set or surface with that name was also defined on the part, an error will be generated.
- Sets and surfaces are not step dependent. All sets and surfaces must be defined within a part, part instance, or the assembly.

Defining assembly-level sets

You can refer to a part instance from an element set or node set definition as a shortcut to using the complete name when defining assembly-level sets. Specify the name of the instance that contains the specified elements or nodes. To add elements or nodes from more than one instance to the set, repeat the element set or node set definition (see "Node definition," Section 2.1.1, and "Element definition," Section 2.2.1, for more details).

Input File Usage: Use the following options to define assembly-level sets:

∗NSET, NSET=*NsetName*, INSTANCE=*InstanceName*
∗ELSET, ELSET=*ElsetName*, INSTANCE=*InstanceName*

Adding sets and surfaces on restart

- Existing sets and surfaces cannot be redefined on restart.
- Analytical surfaces cannot be created on restart.
- New sets and surfaces (excluding analytical surfaces) can be added to part instances or the assembly on restart. To add a set or surface, give the complete name. As in the original analysis, you can refer to the part instance name from the element set or node set definition to define an assembly-level set in the restart analysis. For example,

```
*HEADING
*RESTART, READ, STEP=1
** Add element set "Bottom" to assembly "Hinge":
*ELSET, ELSET=Hinge.Bottom
 Flange-1.40, Flange-2.99
** Add node set "Top" to assembly "Hinge":
*NSET, NSET=Hinge.Top, Instance=Flange-1
 21, 22, 23, 24, 26, 28, 31
*NSET, NSET=Hinge.Top, Instance=Flange-2
 21, 22, 23, 24, 26, 28, 31
**
** Add element set "Right" to part instance "Flange-2":
*ELSET, ELSET=Hinge.Flange-2.Right
 16, 18, 20, 29
**
```

```
** Add surface "surfR" to part instance "Flange-2":
*SURFACE, TYPE=ELEMENT, NAME=Hinge.Flange-2.surfR
Right, S1
**
*STEP
 ...
*END STEP
```

Rigid bodies

Rigid bodies can be defined at the part or assembly level.

- To define a rigid body at the part level, include the rigid body and rigid body reference node definitions within the part definition.
  - Rigid elements, deformable elements, and analytical surfaces cannot be combined within a part.
  - If a rigid body is defined within a part, all deformable, rigid, or connector elements in the part must belong to the rigid body.
  - Mass, rotary inertia, spring, dashpot, and heat capacitance elements can be included in a part that contains a rigid body definition, but these elements cannot belong to the rigid body.
  - To create a part-level rigid body from an analytical surface, include the surface definition within the part definition. Only one analytical surface is allowed per part.
- To define a rigid body at the assembly level, include the rigid body and reference node definitions within the assembly definition.
  - A rigid body can be created at the assembly level from any combination of rigid elements, deformable elements, and up to one analytical surface.
  - The rigid body definition can refer to assembly-level or part-level sets.
  - A part that contains a rigid body definition cannot be included in an assembly-level rigid body.
- You can define a discrete surface at the part or assembly level independent from the rigid body definition.
- An analytical surface definition can appear only within a part definition, even if the rigid body is defined at the assembly level.

Materials

- Materials are defined at the model level so that they can be reused. The material definition cannot appear within a part, part instance, or the assembly.
- All materials in a model must have unique names.

Interactions

An interaction is a relationship between surfaces or between a surface and its environment. Interactions in Abaqus include contact, radiation, film conditions, and element foundations.

- Interactions are defined at the model level in Abaqus/Standard and at the model level or within steps in Abaqus/Explicit; they cannot be defined within a part, assembly, or instance.

Constraints

Constraints are inflexible coupling mechanisms such as MPCs and equations (see "Kinematic constraints: overview," Section 35.1.1).

- Constraints can be defined within a part or the assembly. They can be defined within a part instance if the mesh is defined within the part instance. Constraints should be defined at the assembly level if they constrain the motion of one part instance relative to another.
- Constraints are translated and rotated according to the positioning data given for a part instance.

Distributions

Distributions are used to specify arbitrary spatial variations of selected element properties, material properties, local coordinate systems, and spatial variations of initial contact clearances (see "Distribution definition," Section 2.8.1).

- Distributions should be defined at the level at which they are used. For example, if a distribution is used to define shell thicknesses, the distribution should be defined at the same level as the section definition that refers to it. If a distribution is used to define a material property, it should be defined at the model level with the material definition.

Examples

In the following examples most parameters and data lines are omitted for clarity.

Example 1		Notes
*PART, NAME=PartA		
*NODE ...		The mesh is defined on the part.
*ELEMENT ...		
*SOLID SECTION, ELSET=setA, MATERIAL=Mat1		Section assignment must appear within the part level if the mesh is defined on the part.
*SURFACE, NAME=surf1	*error*	Element set **setB** is not defined at the part level.
setB, ...		
*ELSET, ELSET=setA		Sets and surfaces can be defined on the part since the mesh is defined on the part.
*NSET, NSET=setA		
*SURFACE, NAME=surf2		
setA, ...		
*END PART		
*ASSEMBLY, NAME=Assembly-1		
*INSTANCE, NAME=I1, PART=PartA		

Example 1		Notes
*NODE	*error*	Mesh and section assignment cannot be defined on the instance if they are defined on the part.
*ELEMENT	*error*	
*SOLID SECTION	*error*	
*ELSET, ELSET=setA	*error*	Sets and surfaces cannot be redefined on the instance.
*NSET, NSET=setA	*error*	
*SURFACE, NAME=surf2	*error*	
*ELSET, ELSET=setB		New sets and surfaces can be defined on the instance.
*NSET, NSET=setB		
*SURFACE, NAME=surf3 setA, ...		Set and surface definitions can refer to inherited sets.
*END INSTANCE		
*END ASSEMBLY		

In the second example the instances are meshed.

Example 2		Notes
*PART, NAME=PartB *END PART		The *PART and *END PART options are required, even when the instance is meshed.
*PART, NAME=PartC *SOLID SECTION, ... *END PART	*error*	Section cannot be defined on the part if mesh is not defined on the part.
*ASSEMBLY, NAME=Assembly-1		
*INSTANCE, NAME=I1, PART=PartB		
*NODE ...		The mesh is defined on the part instance.
*ELEMENT ...		
*SOLID SECTION, ELSET=setA, MATERIAL=Mat1		Section assignment must appear within the same level as the mesh definition.
*ELSET, ELSET=setA		Sets and surfaces are defined on the instance since the mesh is defined on the instance.
*NSET, NSET=setA		
*SURFACE, NAME=surf2 setA, ...		
*END INSTANCE		

Example 2	Notes
*INSTANCE, NAME=I3, PART=PartC *error* *<positioning data>* *END INSTANCE *END ASSEMBLY	The mesh and section must be defined for each instance since the part is not meshed.

Coordinate system definitions

Abaqus provides several methods for defining local coordinate systems.

Nodal coordinate systems

You can define nodal coordinates in a local coordinate system (see "Specifying a local coordinate system in which to define nodes" in "Node definition," Section 2.1.1). The coordinate system can be defined within a part definition to define the nodes in that part. The nodal coordinate system definition remains in effect until another nodal coordinate system is defined within the same level or until the level ends.

Nodal transformations

A nodal transformation is used for applying loads and boundary conditions (see "Transformed coordinate systems," Section 2.1.5). It can be defined at the part or assembly level to define a local coordinate system for application of loads and boundary conditions or for the definition of linear constraint equations.

User-defined orientations

A user-defined orientation is used for defining material properties, coupling, connectors, and rebar (see "Orientations," Section 2.2.5). It can be defined at the part level for reference from a section, connector, rebar, or coupling definition. An orientation definition can also be used at the assembly level for reference from a connector or coupling definition.

Distributions

Distributions can be used to specify arbitrary spatial variations of local coordinate systems for continuum and shell elements (see "Orientations," Section 2.2.5). A distribution used by an orientation should be defined at the level in which the orientation is defined.

Normal definitions at nodes

Normals can be defined at nodes as part of the node definition for beam, pipe, and shell elements or with a user-specified normal definition (see "Normal definitions at nodes," Section 2.1.4). These normals can be defined at the part or assembly level.

A local coordinate system defined for a part using any of these methods is inherited by all instances of the part.

Translating and rotating a part instance

The assembly's coordinate system is the global coordinate system. You can position part instances within the assembly by giving a translation and/or rotation relative to the global origin. Specify a translation by giving a translation vector. Specify a rotation by giving two points, *a* and *b*, to define a rotation axis plus a right-handed angular rotation around that axis.

Local coordinate systems defined within a part or part instance will be translated and rotated according to the specified positioning data, as shown in Figure 2.10.1–5. (In this figure details such as element and section definitions are omitted for clarity.) Results given in a local coordinate system are output in the transformed local system. Equations will also be translated and rotated according to the positioning data for an instance. All data within a part (or part instance) definition are defined relative to the part's local coordinate system; positioning data are applied to a part instance after everything within that instance is defined.

Limitations

The following capabilities are not supported in a model defined in terms of an assembly of part instances:

- "Mapping a set of nodes from one coordinate system to another" in "Node definition," Section 2.1.1
- "Using auxiliary analyses to generate shape variations" in "Parametric shape variation," Section 2.1.2
- "Symmetric model generation," Section 10.4.1
- "Transferring results from a symmetric mesh or a partial three-dimensional mesh to a full three-dimensional mesh," Section 10.4.2
- "Reading the element matrices from an Abaqus/Standard results file" in "User-defined elements," Section 32.15.1

The substructure library is not organized in terms of an assembly of part instances, so substructures cannot be generated from models that have an assembly defined. None of the substructure options are supported in models that have an assembly defined.

Input file template

This template shows an input file that is written in terms of parts and assemblies with the part instances defined in this analysis. For templates that show how to import a part instance from a previous analysis to transfer model data and results, see "Transferring results between Abaqus/Explicit and Abaqus/Standard," Section 9.2.2, and "Transferring results from one Abaqus/Standard analysis to another," Section 9.2.3.

```
*HEADING
*PART, NAME=Part-1
    Node, element, section, set, and surface definitions
    Connector and constraint definitions
*END PART
*PART, NAME=Part-2
```

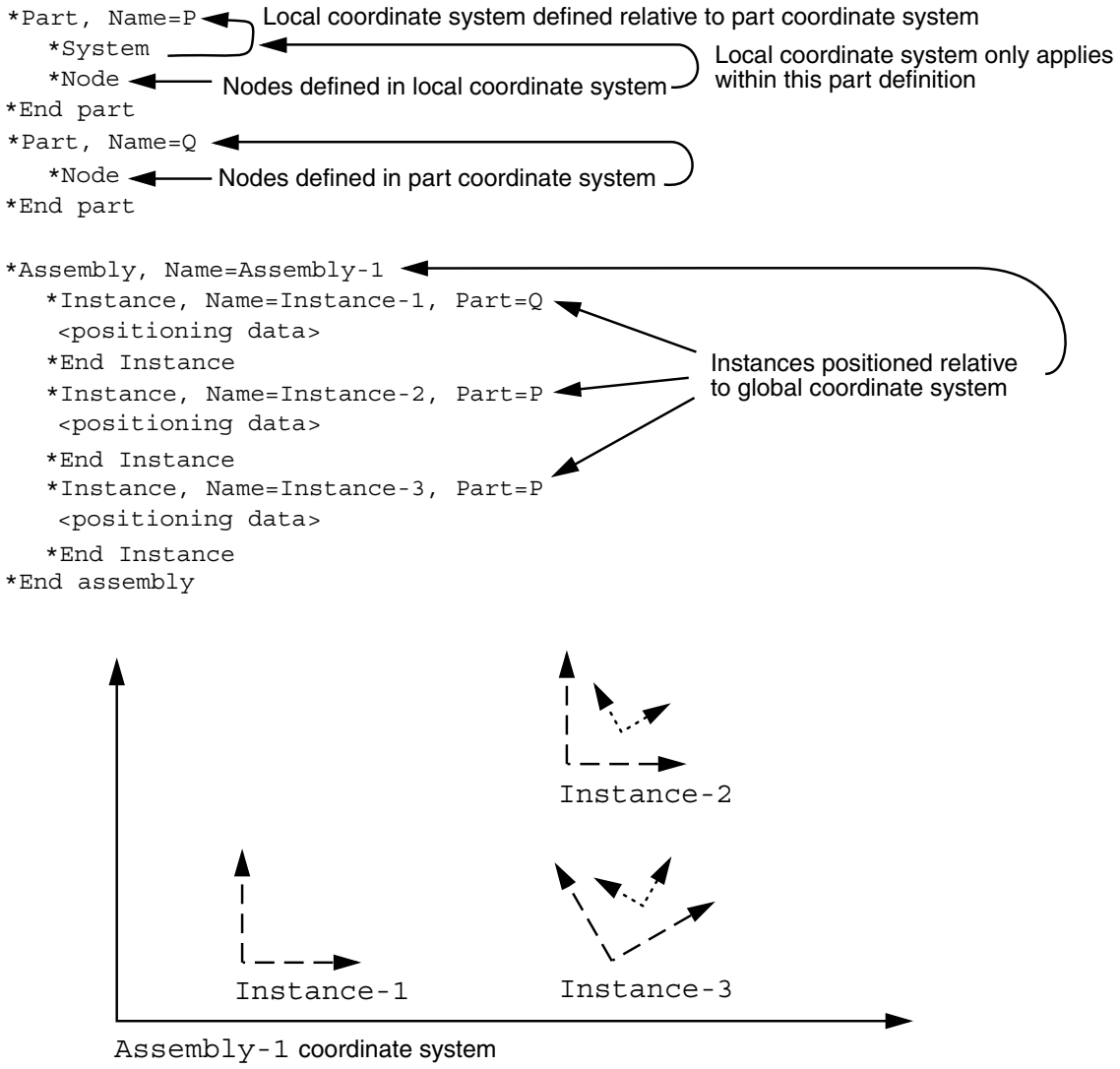


Figure 2.10.1–5 Defining local coordinate systems.

```
   **The instance is meshed, so the part definition is empty
*END PART
*MATERIAL, NAME=mat1
   Suboptions and data lines to define this material
*ASSEMBLY, NAME=Assembly-1
   *INSTANCE, NAME=i1, PART=Part-1
    <positioning data>
      Additional set and surface definitions (optional)
   *END INSTANCE
   *INSTANCE, NAME=i2, PART=Part-2
    <positioning data>
      Node, element, section, set, and surface definitions
      Connector and constraint definitions
   *END INSTANCE
   Assembly-level set and surface definitions
   Assembly-level connectors and constraints
   Assembly-level reference node definitions
   Assembly-level rigid body definitions
*END ASSEMBLY
*MATERIAL, NAME=mat2
   Suboptions and data lines to define this material
*AMPLITUDE
*INITIAL CONDITIONS
*BOUNDARY
   Zero-valued boundary conditions
*PHYSICAL CONSTANTS
*CONNECTOR BEHAVIOR
   Suboptions and data lines to define this connector behavior
Interaction and interaction property definitions in Abaqus/Standard or Abaqus/Explicit
*STEP
   Loads and boundary conditions
   Predefined field definitions
   Output requests
   Contact interaction definitions in Abaqus/Explicit
*END STEP
```

2.11 Matrix definition

- “Defining matrices,” Section 2.11.1

2.11.1 DEFINING MATRICES

Product: Abaqus/Standard

References

- "Generating structural matrices," Section 10.3.1
- *MATRIX ASSEMBLE
- *MATRIX GENERATE
- *MATRIX INPUT
- *MATRIX OUTPUT

Overview

A matrix:

- can be used to represent stiffness, mass, viscous damping, or structural damping for a part of the model or for the entire model;
- is defined by giving it a unique name and by specifying matrix data, which may be scaled;
- can be symmetric or unsymmetric;
- can be given in text format in lower triangular, upper triangular, or square form or read from binary **`.sim`** files generated by the matrix generation procedure;
- can be used to provide linear elastic response with large translations but not large rotations;
- can be used in static and natural frequency extraction procedures;
- can be used in matrix generation and substructure generation procedures;
- can be used in transient modal dynamics, mode-based steady-state dynamics, subspace-based steady-state dynamics, random response, response spectrum, and complex eigenvalue extraction procedures that use the SIM architecture;
- can have loads, boundary conditions, and constraints applied directly to any matrix nodal degrees of freedom;
- can be used in submodeling analysis; and
- cannot be used in direct steady-state dynamic or mode-based analyses that do not use the SIM architecture.

What is a matrix in Abaqus/Standard?

Designing complex models of structures like automobiles typically involves subcontracting the work on various parts. When the entire model has to be put together, information about the parts needs to be exchanged between different vendors. Often, to avoid the exchange of proprietary information, this information is exchanged in terms of matrices representing the stiffness, mass, and damping for each

part. During an analysis these matrices are added to the corresponding global finite element matrices to complete the assembly of the entire model.

Abaqus/Standard provides the capability to input stiffness, mass, viscous damping, and structural damping matrices directly. You can define as many different matrices as are necessary to build the model.

Including matrices in a model

You must assign a name to the matrix to include it in the matrix usage model.

Input File Usage: *MATRIX INPUT, NAME=*name*

Specifying a matrix type

For matrices given in text format, you can specify the matrix type as symmetric (default) or unsymmetric. If symmetric, it can be entered as a lower triangular, upper triangular, or square matrix.

For matrices read from a **.sim** file, the matrix type is automatically set according to the matrix data stored on the SIM database.

Input File Usage: Use one of the following options to specify the type for matrices given in text format:

*MATRIX INPUT, NAME=*name*, TYPE=SYMMETRIC

*MATRIX INPUT, NAME=*name*, TYPE=UNSYMMETRIC

Scaling the matrix data

You can define a multiplication scale factor for all matrix entries.

Input File Usage: *MATRIX INPUT, NAME=*name*, SCALE FACTOR=*sval*

Providing matrix data directly

You can specify data directly to define a symmetric matrix in lower triangular, upper triangular, or square format. For a square matrix to be symmetric, corresponding entries above and below the diagonal must have exactly the same values. You can specify data directly to define an unsymmetric matrix by providing data for each matrix entry.

Input File Usage: *MATRIX INPUT
row node label, *degree of freedom for row node*, *column node label*, *degree of freedom for column node*, *matrix entry*

Repeat this data line to specify data for each matrix entry.

Reading the matrix data in text format from an alternate file

Matrix data in text format can be contained in an alternate file. Typically, an alternate file is used for large matrices. To ensure acceptable performance, the data lines in the alternate file are read without extensive checking for data format. You should make sure that the data entries are specified in the proper format without any comments or blank lines. Matrix data output in text format can be generated in the matrix generation procedure (see "Output" in "Generating structural matrices," Section 10.3.1).

Input File Usage: *MATRIX INPUT, NAME=*name*, INPUT=*input_file_name*

Reading the matrix data from the SIM database

Matrix data in binary format can be read from the **.sim** file generated by the matrix generation procedure (see "Introduction" in "Generating structural matrices," Section 10.3.1). The **.sim** file can contain stiffness, mass, viscous damping, and structural damping matrices. You specify each matrix to be read from the **.sim** file.

Input File Usage: Use the following options:

∗MATRIX INPUT, NAME=*stif_name*, INPUT=*sim_file_name*, MATRIX=STIFFNESS

∗MATRIX INPUT, NAME=*mass_name*, INPUT=*sim_file_name*, MATRIX=MASS

∗MATRIX INPUT, NAME=*dmpv_name*, INPUT=*sim_file_name*, MATRIX=VISCOUS DAMPING

∗MATRIX INPUT, NAME=*dmps_name*, INPUT=*sim_file_name*, MATRIX=STRUCTURAL DAMPING

Defining the stiffness, mass, and damping with matrices included in a model

You can assemble the stiffness, mass, viscous damping, and structural damping matrices that you have specified into the corresponding global finite element matrices for the model. Many matrices with different names can be defined and assembled.

Input File Usage: Use the following option to assemble matrices generated from the same original model:

∗MATRIX ASSEMBLE, STIFFNESS=*stif_name*, MASS=*mass_name*, VISCOUS DAMPING=*dmpv_name*, STRUCTURAL DAMPING=*dmps_name*

To assemble matrices generated from different original models, repeat the ∗MATRIX ASSEMBLE option for each model.

Connecting a part of a model represented by matrices

A part of the model represented by user-defined matrices is connected to other parts and finite elements through shared nodes. You must define these nodes directly in the model (see "Node definition," Section 2.1.1). In addition, there may be nodes that are used only by matrices but that are not shared. You do not need to define nodes that are not shared and have no loads, boundary conditions, or constraints associated with them; these nodes will be defined for you and placed at the origin of the global coordinate system.

Input File Usage: Use the following option to define the shared nodes directly:

∗NODE

Remapping user-defined nodes in assembled matrices

The nodes defined in the assembled matrices can be remapped (renamed) to different node labels in the matrix usage model. You must define all the new node labels in the matrix usage model, create a node set from them, and specify this node set when assembling the matrices. The size of the node set and the order of the nodes in the set must fully correspond to the combined set of nodes of all the matrices that are assembled. The matrix nodes are assumed to be sorted in ascending order of their original labels that were defined at generation or specified in the matrix data.

Input File Usage: Use the following option to create a node set for the matrix nodes:

∗NSET, NSET=*nset_name*, UNSORTED

Use the following option to assemble matrices with node remapping:

∗MATRIX ASSEMBLE, STIFFNESS=*stif_name*, MASS=*mass_name*,
VISCOUS DAMPING=*dmpv_name*,
STRUCTURAL DAMPING=*dmps_name*, NSET=*nset_name*

Multiple instantiation of matrices

With the node remapping feature, the same matrix can be used multiple times in the matrix usage model. You define the matrix once and assemble it several times, specifying the relevant node sets for remapping.

Input File Usage:
∗MATRIX INPUT, NAME=*name*
∗MATRIX ASSEMBLE, STIFFNESS=*name*
∗MATRIX ASSEMBLE, STIFFNESS=*name*, NSET=*nset1_name*
∗MATRIX ASSEMBLE, STIFFNESS=*name*, NSET=*nset2_name*

Internal nodes in matrix data

Internal nodes are nodes with internal degrees of freedom associated with them (for example, Lagrange multipliers and generalized displacements) that are created internally by Abaqus/Standard. By definition, user-defined nodes have positive node labels, and internal nodes have negative node labels. You can use the matrix generation procedure to designate some of the user-defined nodes as internal nodes to hide them in the matrix usage model (see “Introduction” in “Generating structural matrices,” Section 10.3.1).

When using matrix data that contains internal nodes, these nodes are remapped automatically to unique internal node labels in the matrix usage model. For assembled matrices that originate from the same model, the internal nodes are shared. For assembled matrices that originate from different models, the internal nodes are mapped to different internal nodes in the matrix usage model, even if they have the same negative node labels.

Using matrices in nonlinear analyses

When you use matrices in a nonlinear analysis procedure, nonlinearities are not accounted for. Since the matrix data remain unchanged during the analysis, only linear elastic material behavior can be represented and only large translations can be modeled correctly in a geometrically nonlinear analysis.

Changes to the matrix due to large rotations or load stiffness are not computed in a geometrically nonlinear analysis.

Using matrices in linear perturbation analyses

Matrices can be used in a static perturbation analysis as well as in a natural frequency extraction analysis using the Lanczos or AMS eigensolver. For certain quantities (such as participation factors and global inertia properties) to be computed properly, the coordinates of the nodes associated with the matrices should be defined in the model using matrices. Matrices can also be used in modal analysis procedures using the high-performance SIM architecture; namely, steady-state dynamic, modal dynamic, random response, response spectrum, and complex frequency extraction analyses. Matrices can be used in the substructure generation and matrix generation procedures as well.

Matrices cannot be used in the direct-solution steady-state dynamic analysis procedure and in modal procedures that are not based on the high-performance SIM architecture.

Constraints and transformations

Kinematic constraints (for example, coupling constraints, linear constraint equations, multi-point constraints, or surface-based tie constraints) can be applied to any nodes in a model containing matrices. Since kinematic constraints in Abaqus/Standard are usually imposed by eliminating degrees of freedom at the dependent nodes, matrix nodes should not be used as dependent nodes.

To apply contact constraints on matrix nodes, a node-based surface must be defined on these nodes and this surface should be used as the slave surface in the contact pair definition.

Nodal transformations defined at nodes that appear in the matrix do not affect the matrix. The matrix entries corresponding to these nodes are assumed to be in the local coordinates defined by the nodal transformations.

Initial conditions

Initial conditions can be specified as usual; however, only node-based initial conditions can be applied to nodes that appear in matrices. See “Initial conditions in Abaqus/Standard and Abaqus/Explicit,” Section 34.2.1.

Boundary conditions

Boundary conditions can be specified as usual. See “Boundary conditions in Abaqus/Standard and Abaqus/Explicit,” Section 34.3.1. Matrix nodes can be defined as driven nodes in a submodel analysis (see “Submodeling: overview,” Section 10.2.1); they cannot be defined as driving nodes in a global model. For shell-to-solid submodeling, matrix nodes that are defined as driven nodes are treated as lying within the center zone no matter how far they are from the shell reference surface.

Loads

Concentrated nodal forces can be applied at displacement degrees of freedom (1–6) of any node as usual. Distributed pressure forces can be applied to surface elements defined over matrix nodes (see “Surface

elements," Section 32.7.1). Body forces cannot be applied to parts of the model represented by matrices. User-defined loads can be applied with the same restrictions as above for distributed pressure forces and body forces.

Predefined fields can be applied at any nodes as usual (see "Predefined field variables" in "Predefined fields," Section 34.6.1, and "Predefined temperature" in "Predefined fields," Section 34.6.1); however, matrix data are not affected by predefined fields. For example, if temperatures are specified as a predefined field on nodes that appear on a matrix, only the elements that share these nodes with the matrix experience thermal strains if thermal expansion is specified for those elements. The matrix does not experience any thermal strains, but it may experience linear elastic forces due to displacements at shared nodes.

Elements

All elements that can be used in static stress analysis are available (see "Choosing the appropriate element for an analysis type," Section 27.1.3).

Output

All nodal output variables that apply to static analysis are available (see "Abaqus/Standard output variable identifiers," Section 4.2.1).

Limitations

The following are known limitations to using matrices:

- Matrices cannot be used in a model containing parts and assemblies.
- Matrices containing acoustic pressure and mechanical degrees of freedom will disable the coupled acoustic structural eigenvalue extraction.
- By default, using the matrix data containing internal nodes in text format is not supported. Usage of such matrices in text format can be allowed for some special cases. This feature should be used with caution.
- In an Abaqus/Standard analysis using matrix input data for the mass matrix, inertia quantities for the global model that are reported in the data (**.dat**) file, including coordinates of the center of mass and moments of inertia, may be calculated incorrectly.
- Matrices cannot be used in analyses with inertia relief loads.
- Matrices cannot be used in direct steady-state dynamic analysis or in mode-based analyses that do not use the SIM-based architecture.

Input file template

```
*HEADING
...
*NODE
Data lines to specify nodes
```

NSET, NSET=NSET1***, UNSORTED**
Data lines to specify a node set with the nodes in a particular order
...
***BOUNDARY**
Data lines to specify zero-valued boundary conditions
MATRIX INPUT, NAME=MAT1***, SCALE FACTOR=***sval*
Data lines to specify a stiffness matrix
MATRIX INPUT, NAME=MAT2***, SCALE FACTOR=***sval*
Data lines to specify a mass matrix
MATRIX INPUT, NAME=MAT3***, SCALE FACTOR=***sval*
Data lines to specify a viscous damping matrix
MATRIX INPUT, NAME=MAT4***, INPUT=***input_file_name*
MATRIX INPUT, NAME=MAT5***, INPUT=***input_file_name*
MATRIX INPUT, NAME=MAT6***, INPUT=***sim_file_name***, MATRIX=STIFFNESS**
MATRIX ASSEMBLE, STIFFNESS=MAT1***, MASS=***MAT2***,**
VISCOUS DAMPING=*MAT3***, STRUCTURAL DAMPING=***MAT4*
MATRIX ASSEMBLE, STIFFNESS=MAT6***, MASS=***MAT5*
MATRIX ASSEMBLE, STIFFNESS=MAT6***, MASS=***MAT5***, NSET=***NSET1*
***STEP(,NLGEOM)(,PERTURBATION)**
Use NLGEOM to include nonlinear geometric effects; it will remain active in all subsequent steps.
***STATIC**
***BOUNDARY**
Data lines to prescribe zero-valued or nonzero boundary conditions
***CLOAD and/or *DLOAD**
Data lines to specify loads
***END STEP**
***STEP**
***FREQUENCY**
***BOUNDARY**
Data lines to prescribe zero-valued or nonzero boundary conditions
***END STEP**
***STEP**
***STEADY STATE DYNAMICS**
***CLOAD and/or *DLOAD**
Data lines to specify loads
***END STEP**

3. Job Execution

3.1 Execution procedures: overview

- “Execution procedure for Abaqus: overview,” Section 3.1.1

3.1.1 EXECUTION PROCEDURE FOR Abaqus: OVERVIEW

Overview

Abaqus is executed by using the Abaqus execution procedure. In the following discussion the command to run the execution procedure is assumed to be **abaqus**. However, you can customize the execution procedure to run Abaqus using any alias you choose. (See the Abaqus Installation and Licensing Guide for details.)

The **abaqus** command is described in "Execution procedures," Section 3.2. The following sections contain further information about running Abaqus jobs:

- "Using the Abaqus environment settings," Section 3.3.1
- "Managing memory and disk use in Abaqus," Section 3.4.1
- "Parallel execution," Section 3.5
- "File extensions used by Abaqus," Section 3.6.1
- "FORTRAN unit numbers used by Abaqus," Section 3.7.1

Conventions

The following conventions are used in these sections:

- Each discussion includes a "Command summary" section that provides the syntax for the command in the left column and the syntax for its options in the right column. The full command must appear first, followed by the options. In some cases the command has multiple words, such as **abaqus cae**; you must enter all words of the command before issuing any option statements.
- Options are presented in **boldface**. They can appear in any order and can be abbreviated.
- Default options are underlined (__).
- Items enclosed in square brackets ([ ]) are optional.
- Items appearing in a list separated by bars (|) are mutually exclusive.
- One value must be selected from a list of values enclosed by curly brackets ({ }).
- You must supply values in *italics*.
- Blanks are used as separators between options and must not precede nor follow an equal sign.
- An alternate syntax of **-option** *value* can be used instead of the **option**=*value* format.

The **abaqus** procedure will prompt for any information required that is not provided on the command line. If **abaqus** is typed with no options, prompts are issued for all options.

Environment settings

The Abaqus execution procedure uses "environment" settings to customize the execution of a job. These settings can be changed using the Abaqus environment file, **`abaqus_v6.env`**. The execution procedure looks for this file in two places other than the installation location when running a job. The first place it looks is in your home directory. If it exists, the settings in this file will be applied to all jobs that you run. The second place the execution procedure looks is in the current directory. If the file exists, the settings defined there will be applied to all jobs run from that directory.

If the same job parameter is defined in more than one environment file or is defined more than once within the same environment file, the last definition encountered will be used. Some exceptions to this rule are noted in "Using the Abaqus environment settings," Section 3.3.1. These environment files can be used to customize the behavior of Abaqus, including modification of the default options. See "Using the Abaqus environment settings," Section 3.3.1, for further information on the environment files.

Selecting TCP/UDP port numbers

Several of the execution procedure command line options, such as **port** and **listenerport**, require that you specify a port number. TCP/UDP port numbers can range from 0 to 65535.

Port numbers 0 to 1023 are well-known ports used by system processes (such as FTP, SSH, SMTP, etc.) and should never be used. Port numbers 1024 to 49151 are registered ports with the Internet Assigned Number Authority (IANA) by software vendors. These ports can be used, but you should be careful that you are not conflicting with any software installed on your system that may be using this port. Port numbers 49152 to 65535 are unreserved and can be used freely, as long as no other application uses them.

Ports may be blocked by a firewall. Contact your system administrator to ensure that the ports that you want to specify are not blocked.

You can use the **`netstat`** command to obtain information on TCP/UDP network connections.

3.2 Execution procedures

- “Obtaining information,” Section 3.2.1
- “Abaqus/Standard, Abaqus/Explicit, and Abaqus/CFD execution,” Section 3.2.2
- “SIMULIA Co-Simulation Engine director execution,” Section 3.2.3
- “Abaqus/Standard, Abaqus/Explicit, and Abaqus/CFD co-simulation execution,” Section 3.2.4
- “Dymola model execution,” Section 3.2.5
- “Abaqus/CAE execution,” Section 3.2.6
- “Abaqus/Viewer execution,” Section 3.2.7
- “Python execution,” Section 3.2.8
- “Parametric studies,” Section 3.2.9
- “Abaqus documentation,” Section 3.2.10
- “Licensing utilities,” Section 3.2.11
- “ASCII translation of results (`.fil`) files,” Section 3.2.12
- “Joining results (`.fil`) files,” Section 3.2.13
- “Querying the keyword/problem database,” Section 3.2.14
- “Fetching sample input files,” Section 3.2.15
- “Making user-defined executables and subroutines,” Section 3.2.16
- “Input file and output database upgrade utility,” Section 3.2.17
- “Generating output database reports,” Section 3.2.18
- “Joining output database (`.odb`) files from restarted analyses,” Section 3.2.19
- “Combining output from substructures,” Section 3.2.20
- “Combining data from multiple output databases,” Section 3.2.21
- “Network output database file connector,” Section 3.2.22
- “Mapping thermal and magnetic loads,” Section 3.2.23
- “Element matrix assembly utility,” Section 3.2.24
- “Fixed format conversion utility,” Section 3.2.25
- “Translating Nastran bulk data files to Abaqus input files,” Section 3.2.26
- “Translating Abaqus files to Nastran bulk data files,” Section 3.2.27
- “Translating ANSYS input files to Abaqus input files,” Section 3.2.28
- “Translating PAM-CRASH input files to partial Abaqus input files,” Section 3.2.29
- “Translating RADIOSS input files to partial Abaqus input files,” Section 3.2.30
- “Translating Abaqus output database files to Nastran Output2 results files,” Section 3.2.31
- “Translating LS-DYNA data files to Abaqus input files,” Section 3.2.32

- “Exchanging Abaqus data with ZAERO,” Section 3.2.33
- “Translating Abaqus data to msc.adams modal neutral files,” Section 3.2.34
- “Encrypting and decrypting Abaqus input data,” Section 3.2.35
- “Job execution control,” Section 3.2.36

3.2.1 OBTAINING INFORMATION

Products: Abaqus/Standard Abaqus/Explicit

Reference

- "Execution procedure for Abaqus: overview," Section 3.1.1

Overview

The Abaqus execution procedure can be used to obtain help regarding command syntax or information about the installation and computing environment.

Command summary

abaqus {**help** | **information**={**environment** | **local** | **memory** | **release** | **support** | **system** | **all**} [**job**=*job-name*] | **whereami**}

Command line options

help

This option prints a summary of the **abaqus** command syntax.

information

This option writes information about the installation and the environment that is in effect to the screen. The following information is output for all information requests: the current release, the directory in which Abaqus is located, and the directory in which the information files are located.

If **information**=**environment**, the current settings of the environment file options are displayed.

If **information**=**local**, the local installation notes are output.

If **information**=**memory**, some suggestions for setting memory parameters for analysis jobs are output.

If **information**=**release**, information is provided about where to locate the current release notes.

If **information**=**support**, information on diagnosing hardware-related issues is provided. Please send this information to systems support when requesting assistance.

If **information**=**system**, information is provided about system software and hardware resources (operating system level, compiler levels, processor type, graphics board, memory, etc).

If **information**=**all**, information on all of the above information topics is output.

job

If a *job-name* is specified, the information text is written to the file *job-name*`.log`.

whereami

This option prints the location of the Abaqus release directory.

Examples

Use the following command to display the local installation notes:

```
abaqus information=local
```

The following command will write the local installation notes to the file **support.log**:

```
abaqus information=local job=support
```

3.2.2 Abaqus/Standard, Abaqus/Explicit, AND Abaqus/CFD EXECUTION

Products: Abaqus/Standard Abaqus/Explicit Abaqus/CFD

Reference

- "Execution procedure for Abaqus: overview," Section 3.1.1

Overview

Abaqus/Standard, Abaqus/Explicit, and Abaqus/CFD are executed by running the Abaqus execution procedure. Several parameters can be set either on the command line or in the environment file (see "Using the Abaqus environment settings," Section 3.3.1). Alternatively, you can use the convenient Abaqus/CAE user interface to submit an Abaqus analysis from an input file and set the analysis parameters; see "Understanding analysis jobs," Section 19.2 of the Abaqus/CAE User's Guide.

Abaqus enforces a character limit on file names. For any command line reference to a file, the total length of the file name, including the path description, cannot exceed 256 characters.

Command summary

abaqus

job=*job-name*
[**analysis** | **datacheck** | **parametercheck** | **continue** |
convert={**select** | **odb** | **state** | **all**} |
recover | **syntaxcheck** | **information**={**environment** | **local** |
memory | **release** | **support** | **system** | **all**}]
[**input**=*input-file*] [**user**={*source-file* | *object-file*}]
[**oldjob**=*oldjob-name*] [**fil**={**append** | **new**}]
[**globalmodel**={*results file-name* | *output database file-name*}]
[**cpus**=*number-of-cpus*] [**parallel**={**domain** | **loop**}]
[**domains**=*number-of-domains*]
[**dynamic_load_balancing**]
[**mp_mode**={**mpi** | **threads**}]
[**standard_parallel**={**all** | **solver**}]
[**gpus**=*number-of-gpgpus*] [**memory**=*memory-size*]
[**interactive** | **background** | **queue**=[*queue-name*] [**after**=*time*]]
[**double**={**explicit** | **both** | **off** | **constraint**}]
[**scratch**=*scratch-dir*]
[**output_precision**={**single** | **full**}]
[**field**={**odb** | **exodus** | **nemesis**}]
[**history**={**odb** | **csv**}]
[**port**=*co-simulation port-number*] [**host**=*co-simulation hostname*]

[**csedirector**=*Co-Simulation Engine director host:port-number*]
[**timeout**=*co-simulation timeout value in seconds*]
[**unconnected_regions**={**yes** | **no**}]

Command line options

Required option

job

The value of this option specifies the name of all files generated during the run and the name of files that are read in the **continue**, **convert**, and **recover** phases.

If this option is omitted from the command line, you will be prompted for its value (except when only the informational options described in "Obtaining information," Section 3.2.1, are used). If the **input** option is not supplied, the procedure will look for an input file called *job-name*`.inp` in the current directory.

Mutually exclusive options that determine which phases of an analysis are performed

All options are order independent. If none of these options is present, the **analysis** option is assumed. The **convert** option is an exception to the mutual exclusion rule: **convert** can appear with any option except **datacheck**, **parametercheck**, **syntaxcheck**, and **information**. The **convert** and **parametercheck** options are not available for Abaqus/CFD.

analysis

This option indicates that a complete Abaqus analysis (or a restart of an Abaqus analysis) is to be performed.

datacheck

This option indicates that the run is for data checking only. No analysis will be performed. If this option is used, all files necessary to continue the analysis are saved.

parametercheck

This option indicates that the run is for input parameter checking only (parameter definitions must have been used; see "Parametric input," Section 1.4.1). No analysis or data checking will be performed. This option is not applicable for Abaqus/CFD.

continue

This option indicates that the run is to begin at the point at which a previous data check run ended.

convert

The value of this parameter indicates which files will be postprocessed. This option is not applicable for Abaqus/CFD.

Results can be converted either immediately following an analysis run, as a separate run subsequent to an analysis run, or while an analysis is running as follows:

1. To run an analysis including a subsequent conversion of the results, use the **convert** option in conjunction with the **job** and **analysis** options.
2. To convert the results of a previously run analysis, use the **convert** option in conjunction with the **job** option.
3. To convert results from a job that is currently running, use the **convert** option in conjunction with the **oldjob** option (to name the running job) and the **job** option (to supply a new name for the files generated by the **convert** option).

If **convert**=**`select`**, the Abaqus/Explicit selected results file (*job-name*`.sel`) will be converted into a standard Abaqus results file (*job-name*`.fil`). If the analysis is run in parallel with **parallel**=**`domain`**, the separate selected results files (*job-name*`.sel.`*n*) will be converted into a single selected results file (*job-name*`.sel`) prior to being converted into a standard Abaqus results file.

If **convert**=**`odb`**, the output database (*job-name*`.odb`) will be converted using the postprocessing calculator (see "The postprocessing calculator," Section 4.3.1). This conversion is necessary only if the types of output listed in "The postprocessing calculator," Section 4.3.1, are requested.

If **convert**=**`state`**, the separate Abaqus/Explicit state files (*job-name*`.abq.`*n*) will be converted into a single Abaqus/Explicit state file (*job-name*`.abq`) if the analysis is run in parallel with **parallel**=**`domain`**.

If **convert**=**`all`**, all of the applicable convert options will be executed.

recover

This option applies only to Abaqus/Explicit. It indicates that an analysis is to be restarted at the last available step and increment in the state file. This capability is available to restart after a catastrophic failure, such as exceeding a CPU limit or a disk quota (see "Restarting an analysis," Section 9.1.1). If the original analysis was run in parallel with **parallel**=**`domain`**, it must be restarted with **parallel**=**`domain`** and the same number of processors.

syntaxcheck

This option indicates that the run is for checking the syntax of the input file only. This option does not use any license tokens. No analysis will be performed, and the **continue** option cannot be used to continue with an analysis. Only the data (`.dat`) and output database (`.odb`) files are generated for viewing. In an Abaqus/Explicit analysis, the model data in the output database may not be complete.

information

This option writes information about the installation and the environment that is in effect to the screen or to the file *job-name*`.log`. For output information for each value of this option, see "Obtaining information," Section 3.2.1. If the **information** option is used in conjunction with the **analysis** option, the job must be run in the background to write the information text to the log file.

Additional options available for the analysis module

input

This option is used to specify the input file name, which may be given with or without the **`.inp`** extension (if the extension is not supplied, Abaqus will append it automatically). If this option is not supplied, the procedure will look for an input file called *job-name*`.inp` in the current directory. If *job-name*`.inp` cannot be found, the procedure will prompt for the input file name.

user

This option specifies the name of a source or object file that contains any user subroutines to be used in the analysis. The name of the user routine may contain a path name and may be given with or without a file extension. Abaqus/Standard and Abaqus/Explicit only accept user subroutines written in FORTRAN. Abaqus/CFD accepts user subroutines written in C or C++.

If an extension is given, the program will take the appropriate action based on the file type. If the file name has no extension, the program will search for a FORTRAN, C, or C++ source file depending on the analysis type. If the source file does not exist, an object file will be searched for instead. The execution procedure creates a shared library using the user subroutine file that is used by the analysis during execution.

If the same user subroutine will be needed often, consider setting the **usub_lib_dir** environment file parameter and using the **abaqus make** execution procedure to create a shared library containing the user subroutine. This will avoid the need to recompile and/or relink the user subroutine each time it is needed. The **user** option is not required if the user subroutine called by the analysis is contained in the user library. User libraries contained in the directory given by the **usub_lib_dir** environment file parameter will not be used if the **user** option is specified.

The **user** option cannot be used to specify an object file when the **double** option is used to run an Abaqus/Explicit analysis because Abaqus/Explicit double precision runs need both single precision and double precision objects. In this case you must set the **usub_lib_dir** environment file parameter and place the single and double precision object files in the specified directory; alternatively, you can supply the user subroutine source.

oldjob

This option specifies the name of the files from a previous run from which a restart or postprocessing (Abaqus/Standard only; see "Recovering additional results output from restart data in Abaqus/Standard" in "Output," Section 4.1.1) run is to be started or from which results are to be imported. A path or file extension is not allowed. This option is required when a restart, postprocessing, symmetric model generation, or import analysis reads data from the restart or the results file. The *oldjob-name* must be different from the current *job-name*.

fil

This option specifies whether the data from the old results file specified in a restart run are included at the beginning of the new results file (default). If **fil**=**`new`** is used, the new results file will contain only the data from the point in the analysis where the restart occurred. This feature is used for Abaqus/Standard

runs to join the output from restarted analyses into a single, continuous results file. Non-restart jobs cannot use this feature to append results file output to an old results file; the **abaqus append** execution procedure must be used for this purpose. Setting **fil**=**`new`** is not allowed for Abaqus/Explicit runs. This option is not applicable for Abaqus/CFD.

globalmodel

This option specifies the name of the global model's results file or output database file from which the results are to be interpolated to drive a submodel analysis. This option is required whenever a submodel analysis or submodel boundary condition reads data from the global model's results. The file extension is optional. If both a results file and an output database file exist for the global model and no extension is given, the results file will be used. This option is not applicable for Abaqus/CFD.

cpus

This option specifies the number of processors to use during an analysis run if parallel processing is available. The default value for this parameter is 1 and can be changed in the environment file (see "Using the Abaqus environment settings," Section 3.3.1).

parallel

This option specifies the method to use for thread-based parallel processing in Abaqus/Explicit. The possible values are **`domain`** and **`loop`**. If **parallel**=**`domain`**, the domain-level method is used to break the model into geometric domains. If **parallel**=**`loop`**, the loop-level method is used to parallelize low-level loops. See "Parallel execution in Abaqus/Explicit," Section 3.5.3, for more information on these methods. The default value is **`domain`**, which can be changed in the environment file (see "Using the Abaqus environment settings," Section 3.3.1).

domains

This option specifies the number of parallel domains in Abaqus/Explicit. If the value is greater than 1, the domain decomposition will be performed regardless of the values of the **parallel** and **cpus** options. However, if **parallel**=**`domain`**, the value of **cpus** must be evenly divisible into the value of **domains**. The default value is set equal to the number of processors used during the analysis run if **parallel**=**`domain`** and 1 if **parallel**=**`loop`**. The default value can be changed in the environment file (see"Using the Abaqus environment settings," Section 3.3.1). A restart analysis uses the same number of parallel domains as the original analysis, and the value specified with this option will be ignored.

dynamic_load_balancing

For domain-parallel execution in Abaqus/Explicit (**parallel**=**`domain`**) where the number of domains is larger than the number of cpus, this option activates the dynamic load balancing scheme. Abaqus/Explicit will attempt to improve computational efficiency by periodically reassigning domains to processors in a way that minimizes load imbalance (see "Parallel execution in Abaqus/Explicit," Section 3.5.3).

mp_mode

If this option is set equal to **`mpi`**, the MPI-based parallelization method will be used when applicable. Set **mp_mode**=**`threads`** to use the thread-based parallelization method. The default value is **`mpi`** on

Windows platforms if MPI components are installed; otherwise, thread-based parallel execution is the default behavior. On all other platforms, the default value is **mpi**. The default setting can be changed in the environment file (see "Using the Abaqus environment settings," Section 3.3.1). For Abaqus/CFD only **mp_mode**=**mpi** can be used.

standard_parallel

This option specifies the parallel execution mode in Abaqus/Standard. The possible values are **all** and **solver**. If **standard_parallel**=**all**, both the element operations and the solver will run in parallel. If **standard_parallel**=**solver**, only the solver will run in parallel. The default value is **standard_parallel**=**all** on platforms where MPI-based parallelization is supported.

The parallel execution mode can also be set in the environment file (see "Using the Abaqus environment settings," Section 3.3.1).

gpus

This option specifies acceleration of the Abaqus/Standard direct solver. This option is meaningful only on computers equipped with appropriate GPGPU hardware. By default, GPGPU solver acceleration is not activated. The value of this parameter is the number of GPGPUs to use in an Abaqus/Standard analysis.

GPGPU-based solver acceleration can also be set in the environment file (see "Using the Abaqus environment settings," Section 3.3.1).

memory

Maximum amount of memory or maximum percentage of the physical memory that can be allocated during the input file preprocessing and during the Abaqus/Standard analysis phase (see "Managing memory and disk use in Abaqus," Section 3.4.1). The default values can be changed in the environment file (see "Using the Abaqus environment settings," Section 3.3.1). This option is not applicable for Abaqus/CFD.

interactive

This option will cause the job to run interactively. For Abaqus/Standard and Abaqus/CFD the log file will be output to the screen; for Abaqus/Explicit the status file and the log file will be output to the screen. The default **run_mode** can be set in the environment file (see "Using the Abaqus environment settings," Section 3.3.1).

background

This option will submit the job to run in the background, which is the default. Log file output will be saved in the file *job-name*`.log` in the current directory. The default method for submitting the job can be set in the environment file by using the **run_mode** parameter (see "Using the Abaqus environment settings," Section 3.3.1).

queue

This option will submit the job to a batch queue. If the option appears with no value, the job will be submitted to the system default queue. Quoted strings are allowed. The available queues are

site specific. Contact your site administrator to find out more about local queuing capabilities. Use **information**=**`local`** to see what local queuing capabilities have been installed. The default method for submitting the job can be set in the environment file by using the **run_mode** parameter (see "Using the Abaqus environment settings," Section 3.3.1).

after

This option is used in conjunction with the **queue** option to specify the time at which the job will start in the selected batch queue. This capability is supported for each individual site through the Abaqus environment file. (See the Abaqus Installation and Licensing Guide for details.)

double

This option is used to specify that the double precision executable is to be used for Abaqus/Explicit. The possible values are **`both`**, **`constraint`**, **`explicit`**, and **`off`**. This capability is also supported through the Abaqus environment file with the environment variable **double_precision** (see "Using the Abaqus environment settings," Section 3.3.1).

If **double**=**`both`**, both the Abaqus/Explicit packager and analysis will run in double precision.

If **double**=**`constraint`**, the constraint packaging and constraint solver in Abaqus/Explicit will run in double precision, while the Abaqus/Explicit packager and Abaqus/Explicit analysis continue to run in single precision.

If **double**=**`explicit`**, the Abaqus/Explicit analysis will run in double precision, while the packager will still run in single precision. The default value is **`explicit`**.

If **double**=**`off`**, the environment file setting is overridden if necessary to invoke both the Abaqus/Explicit packager and Abaqus/Explicit analysis in single precision. For a discussion of when to use the double precision executable, see "Defining an analysis," Section 6.1.2.

scratch

This option is used to specify the name of the directory used for scratch files. On UNIX platforms the default value is the value of the **`$TMPDIR`** environment variable or **`/tmp`** if **`$TMPDIR`** is not defined. On Windows platforms the default value is the value of the **`%TEMP%`** environment variable or **`\TEMP`** if this variable is not defined. During the analysis a subdirectory will be created under this directory to hold the analysis scratch files. The default value for this parameter can be set in the environment file (see "Using the Abaqus environment settings," Section 3.3.1).

output_precision

This option specifies the precision of the nodal field output written to the output database file (*job-name*`.odb`). Using **output_precision**=**`full`** results in double precision field output for Abaqus/Standard analyses. To obtain double precision field output for Abaqus/Explicit analyses, use the **double** option in addition to using **output_precision**=**`full`**. Nodal history output is available only in single precision. This option cannot be used with the **recover** option.

field

This option specifies the format of field output for Abaqus/CFD. If **field**=**`odb`**, field output is written to the output database file. If **field**=**`exodus`**, the field output is written to files in EXODUS-II format, one

file per processor. To obtain a single file for parallel execution, use **field**=**nemesis**; the file is written in EXODUS-II format using the NEMESIS library. The default value is **odb**. For more information, see "Alternate output formats in Abaqus/CFD" in "Output," Section 4.1.1.

history

This option specifies the format of history output for Abaqus/CFD. If **history**=**odb**, history output is written to the output database file. If **history**=**csv**, history output is written to a file in comma-separated values format.

The default value depends on the setting for the **field** option. When **field**=**odb**, the default is **history**=**odb**. When **field**=**exodus** or **nemesis**, the default is **history**=**csv**. For more information, see "Alternate output formats in Abaqus/CFD" in "Output," Section 4.1.1.

port

This option is used to specify the TCP/UDP port number for co-simulation between solvers using the direct coupling interface, which includes co-simulation between Abaqus and certain third-party analysis programs. Set **port** equal to the port number used for the connection. The default value is **48000**. The default port number that Abaqus uses to initiate communication can be set with the **cosimulation_port** parameter in the environment file (see "Using the Abaqus environment settings," Section 3.3.1). This option is used in conjunction with the **host** option. For more information, see "Selecting TCP/UDP port numbers" in "Execution procedure for Abaqus: overview," Section 3.1.1.

host

This option is used to specify the host name for co-simulation between solvers using the direct coupling interface, which includes co-simulation between Abaqus and certain third-party analysis programs. This option specifies the name of the machine that is hosting the connection. Refer to the third-party program documentation to determine if the **host** option is required. This option is used in conjunction with the **port** option.

csedirector

This option is used to specify the connection (e.g., host:port) for the SIMULIA Co-Simulation Engine director process when performing a co-simulation using the SIMULIA Co-Simulation Engine. The **csedirector** entry identifies the host name and the TCP/UDP port number for the listening port of the SIMULIA Co-Simulation Engine director process.

timeout

This option is used to specify a timeout value in seconds for establishing the co-simulation connection using the direct coupling interface or the SIMULIA Co-Simulation Engine. Abaqus terminates if it does not receive any communication from the coupled analysis program during the time specified. The default value is 3600 seconds. The default timeout value that Abaqus uses can be set with the **cosimulation_timeout** parameter in the environment file when using the direct coupling interface (see "Using the Abaqus environment settings," Section 3.3.1).

Additional option available for the datacheck module

unconnected_regions

This option is used to request that Abaqus/Standard create element and node sets for unconnected regions in the analysis output database. Set **unconnected_regions**=**yes** to create element and node sets that are named MESH COMPONENT *N*, where *N* is the component number.

Examples

The following examples illustrate the different functions and capabilities of the **abaqus** execution procedure.

Running analyses in Abaqus/Standard

Use the following command to run a heat transfer analysis called "c8" in the background:

```
abaqus analysis job=c8 background
```

The following command will run the job c8 in the background and output the current environment settings to the log file:

```
abaqus analysis job=c8 information=environment background
```

The follow-up analysis to the heat transfer analysis c8 is "c10," which is a static analysis that uses temperature data from c8 as input. The temperature data are read in from the c8 results file as predefined fields. The execution procedure scans the Abaqus/Standard input file for file dependencies of this sort. In this example the procedure will look for the c8 results file in the current directory with the extension **.fil**. The results file identifier can include a path name (see "Input syntax rules," Section 1.2.1), and the execution procedure will then look in the directory specified. In either case an error message will be issued if the file does not exist. The following command is used to run the job c10 in the "long" queue:

```
abaqus analysis job=c10 queue=long
```

This job is next restarted as "c11," using the final results from c10 as the starting point for a creep analysis. The following command is used to run this job in the default queue:

```
abaqus analysis job=c11 oldjob=c10 queue=
```

The following command is used to run an Abaqus/Standard analysis called "draw_imp" that imports the results from a previously run Abaqus/Explicit analysis called "draw_exp":

```
abaqus analysis job=draw_imp oldjob=draw_exp
```

Running analyses in Abaqus/Explicit

Use the following command to submit an Abaqus/Explicit analysis called "beam" to the default queue:

```
abaqus analysis job=beam convert=all queue=
```

Equivalent results would be obtained from the following series of commands:

```
abaqus datacheck job=beam interactive
abaqus continue job=beam queue=
abaqus convert=all job=beam interactive
```

Note that the CPU-intensive analysis option is run in batch, while the other options are run interactively.

Running analyses in Abaqus/CFD

Use the following command to submit an Abaqus/CFD analysis called “cylinder” using 128 cores in parallel:

```
abaqus analysis job=cylinder cpus=128
```

Running different phases of an analysis

Use the following command to perform a parameter check run on an input file called “parmodel”:

```
abaqus job=parmodel parametercheck
```

Use the following command to perform a data check run on an input file called “parmodel” (the parameter check is done again if this job is run after the previous one):

```
abaqus job=parmodel datacheck
```

The following command will continue the previous **datacheck** job to execute the analysis:

```
abaqus job=parmodel continue
```

3.2.3 SIMULIA Co-Simulation Engine DIRECTOR EXECUTION

Products: Abaqus/Standard Abaqus/Explicit Abaqus/CFD

Reference

- "Execution procedure for Abaqus: overview," Section 3.1.1

Overview

Co-simulation between Abaqus/Standard, Abaqus/Explicit, and Abaqus/CFD is governed by an additional process, the SIMULIA Co-Simulation Engine (CSE) director. Typically, you are not required to invoke the CSE director process; it is invoked automatically when you run the Abaqus co-simulation procedure ("Abaqus/Standard, Abaqus/Explicit, and Abaqus/CFD co-simulation execution," Section 3.2.4) or if you submit the co-simulation from Abaqus/CAE.

If you are unable to use the Abaqus co-simulation procedure or Abaqus/CAE and are required to submit the co-simulation analyses separately using the Abaqus execution procedure ("Abaqus/Standard, Abaqus/Explicit, and Abaqus/CFD execution," Section 3.2.2), you must invoke the CSE director as described in this section.

Command summary

abaqus cse

job=*cosim-job-name*
configure=*configuration file-name*
listenerport=*listener port-number*
[**datacheck**]
[**interactive**]
[**timeout**=*timeout value in seconds*]

Command line options

job

The value of this option specifies the name of the co-simulation summary log file generated during the run. If this option is omitted from the command line, you will be prompted for its value.

configure

This option specifies the name of the SIMULIA Co-Simulation Engine configuration file that governs the co-simulation. For more information, see "Defining the coupling and rendezvousing scheme with the SIMULIA Co-Simulation Engine configuration file" in "Preparing an Abaqus analysis for co-simulation," Section 17.2.1.

listenerport

This option is used to specify the TCP/UDP port number for co-simulation inbound messages to the director. Set **listenerport** equal to the port number used for the connection.

datacheck

This option causes the director to check the correctness of the configuration file only.

interactive

This option causes the director to run interactively.

timeout

This option is used to specify a timeout value in seconds for the co-simulation director connection. The director terminates if it does not receive any communication from the coupled analysis program during the time specified. The default value is 3600 seconds.

Example

The following example illustrates the different functions and capabilities of the co-simulation director execution procedure when you are required to submit the co-simulation analyses separately.

Running an Abaqus/Standard to Abaqus/Explicit co-simulation

Use the following command for the first Abaqus analysis, running on machine "earth," to connect to the co-simulation director, running on machine "mercury" and listening on port 44444:

```
abaqus job=explicit csedirector=mercury:44444
```

Use the following command for the second Abaqus analysis, running on machine "venus," to connect to the co-simulation director, running on machine "mercury" and listening on port 44444:

```
abaqus job=standard csedirector=mercury:44444
```

Use the following command for the co-simulation director, running on machine "mercury," to operate according to the co-simulation configuration defined in the file **explicit_standard_config.xml** and to receive communication via port 44444:

```
abaqus cse job=cosim listenerport=44444
   configure=explicit_standard_config.xml
```

3.2.4 Abaqus/Standard, Abaqus/Explicit, AND Abaqus/CFD CO-SIMULATION EXECUTION

Products: Abaqus/Standard Abaqus/Explicit Abaqus/CFD

Reference

- "Execution procedure for Abaqus: overview," Section 3.1.1

Overview

Co-simulation between Abaqus/Standard, Abaqus/Explicit, and Abaqus/CFD can be executed by running the Abaqus co-simulation procedure. Several parameters can be set either on the command line or in the environment file (see "Using the Abaqus environment settings," Section 3.3.1).

A co-simulation analysis executes two "child" analyses and directs the communication of the two processes using a co-simulation configuration file. The co-simulation execution procedure allows you to enter a single command to run the co-simulation and should be used whenever possible (see "Limitations" below). If you are unable to use the Abaqus co-simulation procedure, you are required to submit the co-simulation analyses separately using the Abaqus execution procedure ("Abaqus/Standard, Abaqus/Explicit, and Abaqus/CFD execution," Section 3.2.2) and to invoke the SIMULIA Co-Simulation Engine (CSE) director ("SIMULIA Co-Simulation Engine director execution," Section 3.2.3).

The co-simulation execution procedure supports a subset of the options that are available for the Abaqus execution procedure; these options are included in the command summary below.

Allocating CPUs for parallel processing

Three methods are available for allocating CPUs to child analysis jobs for parallel processing: specifying the number of CPUs for each job, distributing CPUs between analysis jobs, and distributing CPUs between analysis products.

Specifying the number of CPUs for each job

The most direct method of allocating CPUs is to specify the number of CPUs to be used for each child analysis. You provide a comma-separated pair of values using the **cpus** parameter.

Distributing CPUs between analysis jobs

You can specify the total number of CPUs to be used for your co-simulation analysis and weighting factors that determine the distribution of the CPUs between the two child analyses. This method enables you to specify a CPU count that relates directly to your resource limits and to describe the relative computational needs of the two child analyses. You provide one value for the number of CPUs to allocate for the co-simulation using the **cpus** parameter, and you define weight factors using the **cpuratio** parameter.

Weight factors are floating point numbers and are considered in a normalized sense. For example, if you wish to specify that the CPU allocation for the first child job is four times that of the second job, you can provide any of the following pairings:

```
cpuratio=4.0,1.0
cpuratio=16,4
cpuratio=0.8,0.2
```

Distributing CPUs between analysis products

You can specify the total number of CPUs to be used for your co-simulation analysis and weighting factors that determine the distribution of the CPUs between the analysis products involved in the co-simulation. This method enables you to specify a CPU count that relates directly to your resource limits and to describe the relative computational needs of the two child analyses based on the analysis product used (Abaqus/Standard, Abaqus/Explicit, or Abaqus/CFD). You provide one value for the number of CPUs to allocate for the co-simulation using the **cpus** parameter, and you define weight factors in the environment file using the **cpus_weight_std**, **cpus_weight_xpl**, and **cpus_weight_cfd** environment variable parameters (see "Co-simulation parameters" in "Using the Abaqus environment settings," Section 3.3.1).

Weight factors are interpreted in a normalized sense. For example, if you wish to specify that the CPU allocation for the Abaqus/CFD analysis is twice that of the Abaqus/Explicit analysis, you define the parameters in the environment file as follows:

```
cpus_weight_xpl=1
cpus_weight_cfd=2
```

Rounding considerations for distributing CPUs

In cases where the distribution of the CPUs between analysis jobs or analysis products does not result in whole numbers, Abaqus rounds down the CPU allocation for the first job listed in the **job** parameter and rounds up the allocation for the second job listed. For example, if 8 CPUs are allocated and the CPU allocation for the Abaqus/CFD analysis is twice that of the Abaqus/Explicit analysis, the distribution between Abaqus/Explicit and Abaqus/CFD is 2/6 if the Abaqus/Explicit job is listed first and is 3/5 if the Abaqus/CFD job is listed first.

Specifying options for child analyses

Command line options that pertain to the child analyses require you to enter a comma-separated pair of values. The order of entries in the pairing must be consistent for all child analysis options to obtain the desired co-simulation execution behavior. For example, in an Abaqus/Standard to Abaqus/Explicit co-simulation, if you specify the job name for the Abaqus/Standard analysis as the first entry for the job parameter, the first entry for the remainder of the child analysis options will apply to the Abaqus/Standard analysis.

If an option is relevant for only one of the child analyses, you can enter a value of **NONE** for the analysis in which the option is not relevant. In cases where you wish to use the default settings for an

option for both child analyses or wish to use environment settings to control the behavior, you need not provide that option in the command line.

Performing a co-simulation with input files that specify co-simulation controls

With releases prior to Abaqus 6.13, all co-simulation parameters and co-simulation controls were specified in the input files and a configuration file was not required. To support re-use of these input files with Abaqus 6.13 and later, an automated configuration file creation capability is provided. In a limited number of cases, you can generate a configuration file automatically; namely, if the following conditions are met:

- Both of your input files contain *CO-SIMULATION CONTROLS options that are valid for co-simulation with Abaqus 6.12.
- These controls conform to the recommended uses of co-simulation parameters, as described in the Abaqus 6.12 Analysis User's Manual.

If you omit the **configure** option for the co-simulation execution procedure, Abaqus attempts to automatically generate a configuration file and, if successful, the generated configuration file will be used in the analysis directly. The contents of the automatically generated configuration file are determined from the *CO-SIMULATION CONTROLS options, the analysis procedure types, and the duration of the co-simulation step.

Limitations

The following limitations apply to the co-simulation execution procedure:

- Only co-simulation between two analyses is supported.
- The analyses can be run only on a single machine or a compute cluster where the head node can be shared by both child analysis jobs.
- Co-simulation with third-party applications is not supported with this execution procedure; for information on Abaqus job execution for co-simulation with third-party applications, consult the third-party program documentation.

Command summary

abaqus cosimulation

cosimjob=*cosim-job-name*
configure=*co-simulation configuration file name*
job=*comma-separated pair of job names*
[**cpus**={*number-of-cpus* | *comma-separated pair of number-of-cpus*}]
[**cpuratio**=*comma-separated pair of weight factors specifying cpu allocation to child analyses*]
[**interactive** | **background** | **queue**=[*queue-name*] [**after**=*time*]]
[**timeout**=*co-simulation timeout value in seconds*]
[**portpool**=*colon-separated pair of socket port numbers*]
[**input**=*comma-separated pair of input-file names*]

[**user**=*comma-separated pair of* {*source-file* | *object-file*} *names*]
[**globalmodel**=*comma-separated pair of* {*results file* | *output database file*} *names*]
[**memory**=*comma-separated pair of memory-sizes*]
[**oldjob**=*comma-separated pair of oldjob-names*]
[**double**=*comma-separated pair of double precision executable settings*]
[**scratch**=*comma-separated pair of scratch-dir names*]
[**output_precision**=*comma-separated pair of* {**single** | **full**}]
[**field**=*comma-separated pair of field output format settings*]
[**history**=*comma-separated pair of history output format settings*]

Command line options

Required global options

cosimjob

This option specifies the name of the co-simulation summary log file generated during the run. If this option is omitted from the command line, you will be prompted for its value.

configure

This option specifies the name of the co-simulation configuration file. If this option is omitted from the command line, an attempt is made to automatically generate a configuration file based on the co-simulation controls specified in the input files for the child analyses. If successful, the generated configuration file is used in the co-simulation; if unsuccessful, you will be prompted for a value. For more information, see "Performing a co-simulation with input files that specify co-simulation controls."

Required option for child analyses

job

The comma-separated values of this option specify the names of all child analysis files generated during the run. If this option is omitted from the command line, you will be prompted for its value.

Parallel processing options

cpus

This option is used to specify how CPUs are allocated for the co-simulation during parallel processing. The default value for this parameter is **2** and can be changed to a value greater than 2 in the environment file (see "Using the Abaqus environment settings," Section 3.3.1).

If this option is set equal to a single value, that value specifies the total number of processors allocated for the co-simulation, which can be distributed between child analyses or between analysis products. The distribution of the CPUs between child analyses is split evenly by default and may be further controlled either by using the **cpuratio** parameter or by defining the distribution of the CPUs

between analysis products by setting the **cpus_weight_std**, **cpus_weight_xpl**, and **cpus_weight_cfd** environment file parameters (see "Co-simulation parameters" in "Using the Abaqus environment settings," Section 3.3.1).

If this option is set equal to a comma-separated pair of values, these values specify the number of processors to be used for each child analysis.

cpuratio

The comma-separated values of this option specify the relative weighting of the distribution of processors allocated to each child analysis. This option is valid only when the **cpus** option is set to a single value.

Additional global options available

interactive

This option causes the co-simulation job to run interactively. A summary log file will be output to the screen, and the child analysis summary output will be written to their separate log files.

background

This option submits the co-simulation job to run in the background, which is the default. Log file output is saved for the co-simulation job in the file *cosim-job-name*`.log` and in the child analysis files *job-name*`.log` in the current directory.

queue

This option submits the co-simulation job to a batch queue. If the option appears with no value, the job is submitted to the system default queue. Quoted strings are allowed. The available queues are site specific. Contact your site administrator to find out more about local queuing capabilities.

after

This option is used in conjunction with the **queue** option to specify the time at which the job will start in the selected batch queue. This capability is supported for each individual site through the Abaqus environment file. (See the Abaqus Installation and Licensing Guide for details.)

timeout

This option is used to specify a timeout value in seconds for the co-simulation connection. Abaqus terminates if it does not receive any communication between the child analysis processes during the time specified. The default value is 3600 seconds. The default timeout value that Abaqus uses can be set with the **cosimulation_timeout** parameter in the environment file (see "Using the Abaqus environment settings," Section 3.3.1).

portpool

This option is used to specify a colon-separated pair of TCP/UDP port numbers that represent the start and end value of port numbers to be used when establishing connections between the child processes. The default range is `51000:52000`. The default range that Abaqus uses can be set with the **portpool** parameter in the environment file (see "Using the Abaqus environment settings," Section 3.3.1).

Additional options for child analyses

input

The comma-separated values of this option specify the child analysis input file names, which may be given with or without the **.inp** extension (if the extension is not supplied, Abaqus appends it automatically). For each child analysis, if this option is not supplied, the procedure looks for an input file called *job-name*.**inp** in the current directory. If *job-name*.**inp** cannot be found, the procedure prompts for the input file name.

user

The comma-separated values of this option specify the names of FORTRAN source or object files that contain any user subroutines to be used in the analysis. The names of the user routines may contain a path name and may be given with or without a file extension. This option is not applicable for Abaqus/CFD.

globalmodel

The comma-separated values of this option specify the names of the global model's results (**.fil**) file or output database (**.odb**) file from which the results are to be interpolated to drive a submodel analysis. This option is required whenever a submodel analysis or submodel boundary condition reads data from the global model's results. The file extension is optional. If both a results file and an output database file exist for the global model and no extension is given, the results file is used. This option is not applicable for Abaqus/CFD.

memory

The comma-separated values of this option specify the maximum amount of memory or maximum percentage of the physical memory that can be allocated during the input file preprocessing and during the Abaqus/Standard analysis phase (see "Managing memory and disk use in Abaqus," Section 3.4.1). This option is not applicable for Abaqus/CFD.

oldjob

The comma-separated values of this option specify the names of the files from a previous run from which a restart run is to be started or from which results are to be imported. A path or file extension is not allowed. This option is required when a restart or import analysis reads data from the restart file. The *oldjob-names* must be different from the current *job-names*.

double

This option is applicable only for an Abaqus/Explicit analysis.

The comma-separated values of this option specify the double precision executable settings to be used; the value for the Abaqus/Standard or Abaqus/CFD analysis is always **NONE**. The possible values for the Abaqus/Explicit analysis are **both**, **constraint**, **explicit**, and **off**. This capability is also supported through the Abaqus environment file with the environment variable **double_precision** (see "Using the Abaqus environment settings," Section 3.3.1).

If the **double** option is omitted for an Abaqus/Standard to Abaqus/Explicit co-simulation, the Abaqus/Explicit packager and analysis will be run in double precision. If the **double** option is omitted

for an Abaqus/CFD to Abaqus/Explicit co-simulation, the Abaqus/Explicit packager and analysis will be run in single precision.

If **double**=**both**, both the Abaqus/Explicit packager and analysis will run in double precision.

If **double**=**constraint**, the constraint packaging and constraint solver in Abaqus/Explicit will run in double precision, while the Abaqus/Explicit packager and Abaqus/Explicit analysis continue to run in single precision.

If **double**=**explicit** or the **double** option is specified without a value, the Abaqus/Explicit analysis will run in double precision, while the packager will still run in single precision.

If **double**=**off**, the environment file setting is overridden if necessary to invoke both the Abaqus/Explicit packager and Abaqus/Explicit analysis in single precision. For a discussion of when to use the double precision executable, see "Defining an analysis," Section 6.1.2.

scratch

The comma-separated values of this option specify the names of the directories used for scratch files. On UNIX platforms the default value is the value of the **$TMPDIR** environment variable or **/tmp** if **$TMPDIR** is not defined. On Windows platforms the default value is the value of the **%TEMP%** environment variable or **\TEMP** if this variable is not defined. During the analysis a subdirectory will be created under this directory to hold the analysis scratch files.

output_precision

The comma-separated values of this option specify the precision of the nodal field output written to the output database files (*job-name*.**odb**). Using **output_precision**=**full** results in double precision field output for Abaqus/Standard analyses. To obtain double precision field output for Abaqus/Explicit analyses, use the **double** option in addition to using **output_precision**=**full**. Nodal history output is available only in single precision. This option is not applicable for Abaqus/CFD.

field

This option is applicable only for an Abaqus/CFD analysis.

The comma-separated values of this option specify the format of the field output; the value for the Abaqus/Standard or Abaqus/Explicit analysis is always **NONE**. The possible values for the Abaqus/CFD analysis are **odb**, **exodus**, and **nemesis**.

If **field**=**odb**, field output is written to the output database file. If **field**=**exodus**, the field output is written to files in EXODUS-II format, one file per processor. To obtain a single file for parallel execution, use **field**=**nemesis**; the file is written in EXODUS-II format using the NEMESIS library. The default value is **odb**. For more information, see "Alternate output formats in Abaqus/CFD" in "Output," Section 4.1.1.

history

This option is applicable only for an Abaqus/CFD analysis.

The comma-separated values of this option specify the format of the history output; the value for the Abaqus/Standard or Abaqus/Explicit analysis is always **NONE**. The possible values for the Abaqus/CFD analysis are **odb** and **csv**.

If **history**=**odb**, history output is written to the output database file. If **history**=**csv**, history output is written to a file in comma-separated values format.

The default value depends on the setting for the **field** option. When **field**=**odb**, the default is **history**=**odb**. When **field**=**exodus** or **nemesis**, the default is **history**=**csv**. For more information, see "Alternate output formats in Abaqus/CFD" in "Output," Section 4.1.1.

Examples

The following examples illustrate the different functions and capabilities of the **abaqus cosimulation** execution procedure.

Running an Abaqus/Standard to Abaqus/CFD co-simulation interactively

Use the following command to run a co-simulation between a heat transfer analysis called "solid_heat" and a fluids analysis called "fluid," interactively:

```
abaqus cosimulation cosimjob=cosim_cht
   job=solid_heat,fluid configure=cosim_cht_config interactive
```

Allocating CPUs in an Abaqus/Explicit to Abaqus/CFD co-simulation

Use the following command to run a co-simulation between an Abaqus/Explicit analysis called "beam" and an Abaqus/CFD analysis called "fluid" and to allocate 8 cores to the Abaqus/Explicit job and 16 cores to the Abaqus/CFD job:

```
abaqus cosimulation cosimjob=beam_fluid job=beam,fluid cpus=8,16
   configure=beam_fluid_config
```

Equivalent results would be obtained using the following command:

```
abaqus cosimulation cosimjob=beam_fluid job=beam,fluid
   cpus=24 cpuratio=1,2 configure=beam_fluid_config
```

Alternatively, you can specify settings for co-simulation environment variable parameters in the environment file and run the co-simulation execution procedure. Use the following combination of environment file settings:

```
ask_delete=OFF
# The following parameters set the CPU
# allocation by analysis product
cpus_weight_xpl=1
cpus_weight_std=1
cpus_weight_cfd=2
```

Use the following command:

```
abaqus cosimulation cosimjob=beam_fluid configure=beam_fluid_config
job=beam,fluid cpus=24
```

Submitting an Abaqus/Standard to Abaqus/Explicit co-simulation to a batch queue

Use the following command to submit a co-simulation for an Abaqus/Explicit analysis called “beam” and an Abaqus/Standard analysis called “beam2” to a batch queue named “long” and to allocate 8 cores to the Abaqus/Explicit analysis and 4 cores to the Abaqus/Standard analysis:

```
abaqus cosimulation cosimjob=beam job=beam,beam2
   configure=beam_config cpus=8,4 queue=long
```

3.2.5 Dymola MODEL EXECUTION

Products: Abaqus/Standard Abaqus/Explicit

References

- "Execution procedure for Abaqus: overview," Section 3.1.1
- "SIMULIA Co-Simulation Engine director execution," Section 3.2.3

Overview

You can perform a co-simulation between an Abaqus/Standard or Abaqus/Explicit model and a model exported from Dymola. This procedure requires that you have the following two files available in your current working directory: **`dymosim.dll`**, which contains the Dymola export of your model details, and **`libdsdll.dll`**, which contains a basic collection of Dymola libraries. See "Structural-to-logical co-simulation," Section 17.4.1, for details on creating or obtaining these files.

Command summary

abaqus dymola **input**=*Dymola map file name*
port=*co-simulation port number*
host=*co-simulation host name*

Command line options

input

This option is used to specify the map file name. The map file has a **`.sgn`** file extension.

port

This option is used to specify the TCP/UDP port number for co-simulation between solvers using the direct coupling interface, which includes co-simulation between Abaqus and certain third-party analysis programs. Set **port** equal to the port number used for the connection. The default value is **`48000`**. The default port number that Abaqus uses to initiate communication can be set with the **cosimulation_port** parameter in the environment file (see "Using the Abaqus environment settings," Section 3.3.1). This option is used in conjunction with the **host** option. For more information, see "Selecting TCP/UDP port numbers" in "Execution procedure for Abaqus: overview," Section 3.1.1.

host

This option is used to specify the host name for co-simulation between solvers using the direct coupling interface, which includes co-simulation between Abaqus and certain third-party analysis programs. This option specifies the name of the machine that is hosting the connection. Refer to the third-party program

documentation to determine if the **host** option is required. This option is used in conjunction with the **port** option.

Example

The following example illustrates use of the Dymola execution procedure in a co-simulation involving Abaqus/Explicit and an exported Dymola model.

Running the Dymola simulation

Use the following command to start the Dymola simulation, which will listen on port 44444 for a connection from Abaqus/Explicit:

```
abaqus dymola input=inverted_pend_map port=44444
```

Running the Abaqus/Explicit simulation

Use the following command for the Abaqus/Explicit analysis, which will connect to the Dymola simulation on machine “mecury,” via port 44444:

```
abaqus job=inverted_pend_xpl host=mercury port=44444
```

3.2.6 Abaqus/CAE EXECUTION

Product: Abaqus/CAE

Reference

- "Execution procedure for Abaqus: overview," Section 3.1.1

Overview

Abaqus/CAE, an interactive environment for creating, submitting, monitoring, and evaluating results from Abaqus simulations, is executed by running the Abaqus execution procedure and specifying the **cae** parameter.

Command summary

abaqus cae [**database**=*database-file*] [**replay**=*replay-file*] [**recover**=*journal-file*] [**startup**=*startup-file*] [**script**=*script-file*] [**noGUI**=[*noGUI-file*]] [**noenvstartup**] [**noSavedOptions**] [**noSavedGuiOptions**] [**noStartupDialog**] [**custom**=*script-file*] [**guiTester**=[*GUI-script*]] [**guiRecord**] [**guiNoRecord**]

Command line options

database

This option specifies the name of the model database file or output database file to open. To specify a model database file, include either the **`.cae`** file extension or no file extension in the file name. To specify an output database file, include the **`.odb`** file extension in the file name.

replay

This option specifies the name of the file from which Abaqus/CAE commands are to be replayed. The commands in *replay-file* will execute immediately upon startup of Abaqus/CAE. If no file extension is given, the default extension is **`.rpy`**. You cannot use the **`replay`** option to execute a script with control flow statements.

recover

This option specifies the name of the file from which a model database is to be rebuilt. The commands in *journal-file* will execute immediately upon startup of Abaqus/CAE. If no file extension is given, the default extension is **`.jnl`**.

startup

This option specifies the name of the file containing Python configuration commands to be run at application startup. Commands in this file are run after any configuration commands that have been

set in the environment file. Abaqus/CAE does not echo the commands to the replay file when they are executed.

script

This option specifies the name of the file containing Python configuration commands to be run at application startup. Commands in this file are run after any configuration commands that have been set in the environment file.

Arguments can be passed into the file by entering `--` on the command line, followed by the arguments separated by one or more spaces. These arguments will be ignored by the Abaqus/CAE execution procedure, but they will be accessible within the script.

noGUI

This option specifies that Abaqus/CAE is to be run without the graphical user interface (GUI). If no file name is specified, an Abaqus/CAE license is checked out and the Python interpreter is initialized to allow interactive entry of Python or Abaqus Scripting Interface commands.

If a file name is specified, Abaqus/CAE runs the commands in the file and exits upon their completion. If no file extension is given, the default extension is **`.py`**. This option is useful for automating pre- or post-analysis processing tasks without the added expense of running a display. Since no interface is provided, the scripts cannot include any user interaction. If you use the **`noGUI`** option, Abaqus/CAE ignores any other command line options that you provide.

Arguments can be passed into the file by entering `--` on the command line, followed by the arguments separated by one or more spaces. These arguments will be ignored by the Abaqus/CAE execution procedure, but they will be accessible within the Python script. If you are using the **`noGUI`** option, you can use an argument to pass in a variable that would otherwise be provided by a command line option. For example, you can pass in the name of a file that would otherwise be specified by the **`script`** option.

noenvstartup

This option specifies that all configuration commands in the environment files should not be run at application startup. This option can be used in conjunction with the **script** command to suppress all configuration commands except those in the **script** file.

noSavedOptions

This option specifies that Abaqus/CAE should not apply the display options settings stored in **`abaqus_v6.13.gpr`** (for example, the render style and the display of datum planes). For more information, see “Saving your display options settings,” Section 76.16 of the Abaqus/CAE User’s Guide.

noSavedGuiOptions

This option specifies that Abaqus/CAE should not apply the GUI settings stored in **`abaqus_v6.13.gpr`** (for example, the size and location of the Abaqus/CAE main window or its dialog boxes).

noStartupDialog

This option specifies that the **Start Session** dialog box for Abaqus/CAE should not be displayed.

custom

This option specifies the name of the file containing Abaqus GUI Toolkit commands. This option executes an application that is a customized version of Abaqus/CAE. For more information, see Chapter 1, "Introduction," of the Abaqus GUI Toolkit User's Guide.

guiTester

This option starts a separate user interface containing the Abaqus Python development environment along with Abaqus/CAE. The Abaqus Python development environment allows you to create, edit, step through, and debug Python scripts. For more information, see Part III, "The Abaqus Python development environment," of the Abaqus Scripting User's Guide.

You can specify a script as the argument for this option, which prompts Abaqus/CAE to run a GUI script. Abaqus/CAE closes when the end of the script is reached.

guiRecord

This option enables you to record your actions in the Abaqus/CAE user interface in a file named **`abaqus.guiLog`**. You can also set this option at startup by using the environment variable **`ABQ_CAE_GUIRECORD`**. The **guiRecord** option cannot be used with the **guiTester** option.

guiNoRecord

This option enables you to disable user interface recording when the environment variable **`ABQ_CAE_GUIRECORD`** is set.

Examples

The following examples illustrate the command line options of the **cae** execution procedure and how arguments are passed to Abaqus/CAE.

Opening a model database

The following command will execute Abaqus/CAE and load the model database file called "beam":

```
abaqus cae database=beam
```

Passing arguments to a script

The following command will run the Python script in a file named "try.py" at application startup and pass "argument1" to the script:

```
abaqus cae script=try.py -- argument1
```

The above command will print **`argument1`** if "try.py" is defined as

```
import sys
print sys.argv[-1]
```

Running Abaqus/CAE without the graphical user interface

The following command will run the Python script in a file named “checkPartValidity.py” and pass arguments to the script specifying the model database, the model, and the part. The script is executed by Abaqus/CAE; however, the graphical user interface is never displayed.

```
abaqus cae noGui=checkPartValidity.py -- test.cae Model-1 Part-1
```

The above command will print **`Part-1 is valid`** if “checkPartValidity.py” is defined as

```
import sys
import os

myMdb= sys.argv[-3]
myModel = sys.argv[-2]
myPart = sys.argv[-1]

mdb = openMdb(myMdb)
model = mdb.models[myModel]
part = model.parts[myPart]

if part.geometryValidity:
    sys.__stderr__.write('%s is valid\n' % myPart)
else:
    sys.__stderr__.write('%s is invalid\n' % myPart)
```

3.2.7 Abaqus/Viewer EXECUTION

Product: Abaqus/Viewer

Reference

- "Execution procedure for Abaqus: overview," Section 3.1.1

Overview

Abaqus/Viewer, a subset of Abaqus/CAE that contains only the postprocessing capabilities of the Visualization module, is executed by running the Abaqus execution procedure and specifying the **viewer** parameter.

Command summary

abaqus viewer [**database**=*database-file*] [**replay**=*replay-file*] [**startup**=*startup-file*] [**script**=*script-file*] [**noGUI**=[*noGUI-file*]] [**noenvstartup**] [**noSavedOptions**] [**noSavedGuiOptions**] [**noStartupDialog**] [**custom**=*script-file*] [**guiTester**=[*GUI-script*]] [**guiRecord**] [**guiNoRecord**]

Command line options

database

This option specifies the name of the output database file to use if it is different from *job-name*. The procedure searches for *database-file* as entered on the command line with the **`.odb`** file extension.

replay

This option specifies the name of the file from which Abaqus/Viewer commands are read. The commands in *replay-file* will execute immediately upon startup of Abaqus/Viewer. If no file extension is given, the default extension is **`.rpy`**. You cannot use the **`replay`** option to execute a script with control flow statements.

startup

This option specifies the name of the file containing the Python configuration commands to be run at application startup. Commands in this file are run after any configuration commands that have been set in the environment file. Abaqus/Viewer does not echo the commands to the replay file when they are executed.

script

This option specifies the name of the file containing Python configuration commands to be run at application startup. Commands in this file are run after any configuration commands that have been set in the environment file.

noGUI

This option specifies that Abaqus/Viewer is to be run without the graphical user interface (GUI). If no file name is specified, an Abaqus/Viewer license is checked out and the Python interpreter is initialized to allow interactive entry of Python or Abaqus Scripting Interface commands.

If a file name is specified, Abaqus/Viewer runs the commands in the file and exits upon their completion. If no file extension is given, the default extension is **`.py`**. This option is useful for automating post-analysis processing tasks without the added expense of running a display. Since no interface is provided, the scripts cannot include any user interaction.

noenvstartup

This option specifies that all configuration commands in the environment files should not be run at application startup. This option can be used in conjunction with the **script** command to suppress all configuration commands except those in the **script** file.

noSavedOptions

This option specifies that Abaqus/Viewer should not apply the display options settings stored in **`abaqus_v6.13.gpr`** (for example, the render style and the display of boundary conditions). For more information, see "Saving your display options settings," Section 76.16 of the Abaqus/CAE User's Guide.

noSavedGuiOptions

This option specifies that Abaqus/Viewer should not apply the GUI settings stored in **`abaqus_v6.13.gpr`** (for example, the size and location of the Abaqus/CAE main window or its dialog boxes).

noStartupDialog

This option specifies that the **Start Session** dialog box for Abaqus/Viewer should not be displayed.

custom

This option specifies the name of the file containing Abaqus GUI Toolkit commands. This option executes an application that is a customized version of Abaqus/Viewer. For more information, see Chapter 1, "Introduction," of the Abaqus GUI Toolkit User's Guide.

guiTester

This option starts a separate user interface containing the Python development environment along with Abaqus/Viewer. The Python development environment allows you to create, edit, step through, and debug Python scripts. For more information, see Part III, "The Abaqus Python development environment," of the Abaqus Scripting User's Guide.

You can specify a script as the argument for this option, which prompts Abaqus/Viewer to run a GUI script. Abaqus/Viewer closes when the end of the script is reached.

guiRecord

This option enables you to record your actions in the Abaqus/Viewer user interface in a file named **`abaqus.guiLog`**. You can also set this option at startup by using the environment variable **`ABQ_CAE_GUIRECORD`**. The **guiRecord** option cannot be used with the **guiTester** option.

guiNoRecord

This option enables you to disable user interface recording when the environment variable **`ABQ_CAE_GUIRECORD`** is set.

3.2.8 Python EXECUTION

Products: Abaqus/Standard Abaqus/Explicit

Reference

- "Execution procedure for Abaqus: overview," Section 3.1.1

Overview

The Python language is used throughout Abaqus: in the Abaqus Scripting Interface, in the Abaqus environment file (**`abaqus_v6.env`**), and to perform parametric studies. The **abaqus python** facility is used to access the Python interpreter.

Command summary

abaqus python [*script-file*]

Command line option

script-file

The Python interpreter executes the instructions in the specified *script-file*. If this option is omitted from the command line, the Python interpreter is started in interactive mode.

3.2.9 PARAMETRIC STUDIES

Products: Abaqus/Standard Abaqus/Explicit

References

- "Execution procedure for Abaqus: overview," Section 3.1.1
- "Abaqus/Standard, Abaqus/Explicit, and Abaqus/CFD execution," Section 3.2.2

Overview

The **abaqus script** facility indicates that a parametric study is to be done (see "Scripting parametric studies," Section 20.1.1). Each analysis involved in the design can be executed using the **execute** command (see "Execute the analysis of parametric study designs.," Section 20.2.4). You can add any necessary Abaqus execution options (refer to "Abaqus/Standard, Abaqus/Explicit, and Abaqus/CFD execution," Section 3.2.2) to the execution command for each of the analyses by specifying them on the **execOptions** option of the **execute** command. If the script file contains references to other input files, these files must be located in the same directory as the script file. The files created by the execution of the script file are placed in the directory from which the Abaqus execution procedure is run.

Command summary

abaqus script [=*script-file*]
[**startup**=*startup file-name*]
[**noenvstartup**]

Command line options

script-file

When a script file name is specified, the parametric study module is imported and the instructions in the parametric study script file are executed. If the script file name is omitted from the command line, the Python interpreter is initialized by importing the parametric study module.

startup

This option specifies the name of the file containing Python configuration commands to be run at application startup. Commands in this file are run after any configuration commands that have been set in the environment file.

noenvstartup

This option specifies that all configuration commands in the environment files should not be run at application startup. This option can be used in conjunction with the **startup** command to suppress all configuration commands except those in the **startup** file.

Examples

Use the following command to execute the Python script in a file named “parstudy.psf”:

```
abaqus script=parstudy
```

The following command will initiate a Python scripting session:

```
abaqus script
```

In a Python scripting session the following command will execute the Python script in a file named “scriptfile”:

```
script("scriptfile")
```

3.2.10 Abaqus DOCUMENTATION

Products: Abaqus/Standard Abaqus/Explicit Abaqus/CAE

References

- "Execution procedure for Abaqus: overview," Section 3.1.1
- "Getting help," Section 2.6 of the Abaqus/CAE User's Guide

Overview

Abaqus documentation is installed separately from the product and is viewed through a web browser or PDF reader. See Chapter 2, "Installing Abaqus," of the Abaqus Installation and Licensing Guide, for information on installing the Abaqus documentation.

The documentation consists of the following books:

- Abaqus Analysis User's Guide
- Abaqus/CAE User's Guide
- Abaqus Keywords Reference Guide
- Abaqus Theory Guide
- Abaqus User Subroutines Reference Guide
- Abaqus Glossary
- Abaqus Example Problems Guide
- Abaqus Benchmarks Guide
- Abaqus Verification Guide
- Abaqus Release Notes
- Abaqus Installation and Licensing Guide
- Getting Started with Abaqus: Interactive Edition
- Getting Started with Abaqus: Keywords Edition
- Abaqus Scripting User's Guide
- Abaqus Scripting Reference Guide
- Abaqus GUI Toolkit User's Guide
- Abaqus GUI Toolkit Reference Guide
- Abaqus Interface for Moldflow User's Guide
- Using Abaqus Online Documentation

Using Abaqus documentation

To view the documentation:

1. Type **abaqus doc**.

   The documentation collection page (**`index.html`** or **`index.pdf`** file) opens in either a web browser or Adobe Acrobat Reader, depending on which formats of documentation were installed and configured by your system administrator. See "Information to enter during product installation," Section 2.4.2 of the Abaqus Installation and Licensing Guide, and "Configuration of documentation application" below. The documentation collection page lists the book titles grouped by category.

2. Click the title of a book to display it.

   In the HTML documentation, each book opens in a new browser window or tab. The book window contains four HTML frames: the navigation frame (top frame), the expand/collapse frame (upper left frame), the table of contents frame (lower left frame), and the text frame (right frame).

3. Navigate and search the book's content.
   - In the HTML documentation, use any of the following methods:
     - Use the buttons in the expand/collapse frame to vary the level of detail displayed in the table of contents frame.
     - Use the back and forward arrows in the text frame to navigate sequentially through the text. You can also use the web browser functions to return to recently viewed pages.
     - Expand the topic headings in the table of contents by clicking the book icon to the left of the heading. To jump directly to a section whose title is displayed in the table of contents, click that title.
     - Use the search panel located in the navigation frame to search for specific words or phrases.
   - In the PDF documentation, use the standard controls in Adobe Acrobat Reader to navigate and search the books.

For more detailed information on viewing and searching the HTML or PDF documentation, refer to Using Abaqus Online Documentation.

Configuration of documentation application

The **abaqus doc** command locates a web browser executable or the Adobe Acrobat Reader executable depending on which documentation format was installed and configured by your system administrator.

Configuration of web browser

If the HTML documentation was installed and configured by your system administrator, the **abaqus doc** command will locate a web browser executable as follows:

- **Windows platforms:** The **abaqus doc** command uses your default web browser.

- **UNIX and Linux platforms:** The **abaqus doc** command searches the system path for Firefox. If the help system cannot find Firefox, an error is displayed.

  The **browser_type** and **browser_path** variables can be set in the Abaqus environment file to modify the behavior of this command. For more information, see "System customization parameters," Section 4.1.4 of the Abaqus Installation and Licensing Guide.

Configuration of PDF reader executable

If the PDF documentation was installed and configured by your system administrator, the **abaqus doc** command will locate the Adobe Acrobat Reader executable as follows:

- **Windows platforms:** The **abaqus doc** command uses the default installed Acrobat Reader.
- **UNIX and Linux platforms:** The **abaqus doc** command searches the system path for the **`acroread`** executable. You can also set the **doc_resource** variable (in the Abaqus environment file) to the path of the **`acroread`** executable. For more information, see "System customization parameters," Section 4.1.4 of the Abaqus Installation and Licensing Guide.

Command summary

abaqus doc

3.2.11 LICENSING UTILITIES

Products: Abaqus/Standard Abaqus/Explicit Abaqus/CFD

Reference

- "Execution procedure for Abaqus: overview," Section 3.1.1

Overview

The **abaqus licensing** utilities provide management and monitoring tools for both types of Abaqus licensing: FLEXnet and Dassault Systèmes licensing. Executing the **abaqus licensing** command without additional arguments displays a command usage summary of all available utilities.

For a detailed description of all of the FLEXnet Licensing utilities, refer to the FLEXnet Licensing End User Guide Version 11.6.1. You can download this document from the **Licensing** section of the **Support** page at www.3ds.com/simulia. Several of the most useful licensing utilities are listed in the command summary below.

For more information, see Chapter 3, "Abaqus licensing," of the Abaqus Installation and Licensing Guide.

Command summary

abaqus licensing **[lmstat | lmdiag | lmpath | lmtools | dslsstat | reporttool]**

Command line options

lmstat

This option displays information about the location and features served by the FLEXnet Licensing servers used to serve the Abaqus license. Additional arguments may be used with this command to generate more license usage information.

lmdiag

This option displays information relating to the various FLEXnet Licensing features and indicates whether or not the feature may be checked out.

lmpath

This option can be used to control where Abaqus looks for licenses. Additional arguments are used to print, set, or add license location information. Running the command without arguments will display the command summary for each action.

lmtools

This option starts the FLEXnet Licensing toolchest on Windows platforms. This application can be used to invoke most FLEXnet Licensing administration tool functions.

dslsstat

This option displays information about the location and features served by the Dassault Systèmes license server (DSLS). See "Using the **`dslsstat`** utility for a Dassault Systèmes license server," Section 3.9 of the Abaqus Installation and Licensing Guide, for more information.

reporttool

This option is used to generate reports from license usage history. See "Using the **`reporttool`** utility," Section 3.10 of the Abaqus Installation and Licensing Guide, for more information.

3.2.12 ASCII TRANSLATION OF RESULTS (`.fil`) FILES

Products: Abaqus/Standard Abaqus/Explicit

Reference

- "Execution procedure for Abaqus: overview," Section 3.1.1

Overview

The **abaqus ascfil** translation facility:

- is provided to convert results (**`.fil`**) files (produced by an Abaqus analysis) to ASCII format for porting between dissimilar operating systems;
- permits the movement of results data to a different system for postprocessing; and
- can also be used to convert a results file in ASCII format to binary format to save disk space.

Command summary

abaqus ascfil	**job**=*job-name* [**input**=*input-file*]

Command line options

job

This option specifies the input and output file names to use during results file translation. The *job-name* value is used as the default input file name. The translated output file will have the name *job-name***`.fin`**.

If the input file is in binary format (default), this utility will create the *job-name***`.fin`** file in ASCII format. To transfer the results file back to binary format after porting to a dissimilar operating system, rename the *job-name***`.fin`** file to *job-name***`.fil`**, and use this utility again; the resulting *job-name***`.fin`** file will be in binary format.

If this option is omitted from the command line, you will be prompted for this value.

input

This option specifies the name of the input file if it is different from *job-name*.

Example

To convert the results file **`c4.fil`** from binary to ASCII format, use the following command:

```
abaqus ascfil job=c4
```

The translated file will have the name **`c4.fin`**.

3.2.13 JOINING RESULTS (`.fil`) FILES

Products: Abaqus/Standard Abaqus/Explicit

Reference

- "Execution procedure for Abaqus: overview," Section 3.1.1

Overview

The **abaqus append** postprocessing facility:

- is provided to join results (`.fil`) files into a single file;
- permits two results files that may be either ASCII or binary files, or a combination of ASCII and binary, to be joined for further postprocessing; and
- will write a results file in the same format as the file specified with the **oldjob** option.

A similar utility, **abaqus restartjoin**, is used to join output database (`.odb`) files. See "Joining output database (`.odb`) files from restarted analyses," Section 3.2.19, for details.

Command summary

abaqus append **job**=*job-name*
oldjob=*oldjob-name*
input=*input-file*

Command line options

job

This option specifies the output file name to use during execution. The *job-name* value is used as the output file name. The joined output file will have the name *job-name*`.fil`.

If this option is omitted from the command line, you will be prompted for this value.

oldjob

This option specifies the name of the first results file to use during execution. The *oldjob-name* value is used as the results file name.

If this option is omitted from the command line, you will be prompted for this value.

input

This option specifies the name of the second results file to use during execution. The *input-file* results file will be appended to the *oldjob-name* results file.

If this option is omitted from the command line, you will be prompted for this value.

Example

The following command will append the history contents of the **fjoin003.fil** results file to the end of the **fjoin002.fil** results file and create the file **fjoin001.fil**:

```
abaqus append job=fjoin001 oldjob=fjoin002 input=fjoin003
```

3.2.14 QUERYING THE KEYWORD/PROBLEM DATABASE

Products: Abaqus/Standard Abaqus/Explicit Abaqus/CFD

Reference

- "Execution procedure for Abaqus: overview," Section 3.1.1

Overview

The **abaqus findkeyword** utility queries a keyword/problem database that contains information on Abaqus/Standard, Abaqus/Explicit, and Abaqus/CFD example problems, verification problems, problems used in training seminars, problems shown in the Abaqus technology briefs, benchmark timing problems, and those in the tutorial book Getting Started with Abaqus: Keywords Edition. You specify which keywords, parameters, and values are of interest; and this utility will list the input files that contain those keywords, parameters, and values. You can specify multiple keywords, which causes the **findkeyword** utility to list those input files that contain all of the specified keywords. You can then use the **abaqus fetch** utility to fetch the input files (see "Fetching sample input files," Section 3.2.15). The output is grouped into problem sets; e.g., Abaqus Example Problems or Abaqus/Standard Technology Brief Problems.

Command summary

abaqus findkeyword [**job**=*job-name*]
[**maximum**=*maximum-output*]

keyword data lines

Command line options

job

This option is used to specify the output file name for the output listing. If this option is omitted from the command line, the output will be printed to the standard output device.

maximum

This option is used to limit the number of sample problems that are listed for each set. If this option is omitted, a maximum of 100 sample problems are listed for each set.

keyword data lines

The *keyword data lines* specify which Abaqus keywords, parameters, and values are of interest to the user. The names of sample problems that contain the specified keywords, parameters, and values are printed to the standard output device or to the file indicated by the **job** command line parameter. The keyword is required, but parameters and values are optional. If a keyword is specified without a parameter or a

value, all sample problems that use that keyword (with or without parameters and values) will be listed. If a parameter is specified without a value, all sample problems that use that parameter with any value will be listed. Parameter values that are user-specified data (e.g., numeric data, set names, orientation names, etc.) are ignored. The end of the keyword data lines is indicated by an empty line or an end of file.

Examples

The following examples illustrate the different types of search criteria utilized by the **findkeyword** execution procedure.

Querying for keywords and parameters

To list the sample problems that use the *RESTART option with the WRITE parameter, type the following command and data lines:

```
abaqus findkeyword
*RESTART,WRITE
```

To generate a list of sample problems that contain two keyword lines in the same file, both keywords are included as data lines. For example,

```
abaqus findkeyword
*RESTART,WRITE
*NGEN
```

To list all sample problems that use a keyword and parameter with a value, the value must be included on the data line. For example,

```
abaqus findkeyword job=beam
*BEAM SECTION,SECTION=ARBITRARY
```

The output is written to the file **beam.dat**.

Querying for user-specified parameter values

User-specified parameter values (e.g., numeric data, set names, orientation names, etc.) are ignored. The following two examples are equivalent because the value **MYSET** is an element set name.

```
abaqus findkeyword
*ELSET,ELSET=MYSET
```

```
abaqus findkeyword
*ELSET,ELSET
```

3.2.15 FETCHING SAMPLE INPUT FILES

Products: Abaqus/Standard Abaqus/Explicit

Reference

- "Execution procedure for Abaqus: overview," Section 3.1.1

Overview

The **abaqus fetch** utility is used to extract sample Abaqus input files, user subroutine files, journal files, parametric study script files, or postprocessing programs from the compressed archive files provided with the release (for problems in the Abaqus Example Problems Guide, the Abaqus Benchmarks Guide, and the Abaqus Verification Guide). File names are specified in the guides. If no file extension is specified, all files corresponding to the name given will be extracted.

Wildcard expressions can be used when specifying the file names and include the following:

- An asterisk (*) matches a sequence of zero or more characters.
- A question mark (?) matches exactly one character.
- A bracketed item [...] matches any single character found inside the brackets; ranges are specified by a beginning character, a hyphen, and an ending character. If an exclamation point (!) or a caret (^) follow the left bracket, the range of characters within the brackets is complemented; that is, anything except the characters inside the brackets is considered a match.

Any character that might otherwise be interpreted or modified by the operating system, particularly on UNIX platforms, should be placed inside quotation marks. If no matches are found using the wildcard expressions, the **abaqus fetch** utility attempts to extract a file with the name specified.

Command summary

abaqus fetch **job**=*job-name*
[**input**=*input-file*]

Command line options

job

This option is used to specify the output file name for the fetched input file or files. It is also the default name of the input file to fetch.

If this option is omitted from the command line, you will be prompted for this value.

input

This option is used to specify the name of the input file or files to fetch if it is different from the *job-name*.

Examples

To fetch the example input file **c2.inp** from the archive files, use the following command:

```
abaqus fetch job=c2.inp
```

To fetch all files associated with job **c8** from the archive files, do not specify a file extension. The following command will extract both the input file (**c8.inp**) and the user subroutine file (**c8.f**):

```
abaqus fetch job=c8
```

To fetch the sample parametric study scripting file **parstudy.psf** from the archive files, use the following command:

```
abaqus fetch job=parstudy.psf
```

3.2.16 MAKING USER-DEFINED EXECUTABLES AND SUBROUTINES

Products: Abaqus/Standard Abaqus/Explicit

Reference

- "Execution procedure for Abaqus: overview," Section 3.1.1

Overview

The **abaqus make** utility is used to create user postprocessing executables and user-defined libraries of Abaqus user subroutines. The commands used to compile and link a user-supplied program or user subroutine source file can be changed using the appropriate Abaqus environment file parameters; i.e., **compile_cpp**, **compile_fortran**, **link_exe**, and **link_sl**. You can skip the compilation step by providing a precompiled object as input for postprocessing programs.

Postprocessing executables created using this procedure must be run using the Abaqus execution procedure. This is necessary to set the operating system environment variables for finding the Abaqus utility libraries. To run a user postprocessing program, use the following command:

abaqus *job-name*

User subroutine shared libraries created using this procedure are used by specifying the **usub_lib_dir** variable in the Abaqus environment file. The advantage of doing this is that an analysis using user subroutines can execute without having to compile or link the user subroutine.

Command summary

abaqus make {**job**=*job-name* | **library**=*source-file*}
[**user**={*source-file* | *object-file*}]
[**directory**=*library-dir*]
[**object_type**={**fortran** | **c** | **cpp**}]

Command line options

job

This option is used to create a user-supplied postprocessing program. The value of the option specifies the name of the executable created by this procedure. It is also used as the default source file name.

If no option is given on the command line, you will be prompted for this value.

library

This option is used to create user subroutine object files and shared libraries. The value of the option specifies the name of the user subroutine source file to be compiled and linked. The resulting object and shared library files are placed in the directory given by the command line **directory** option. If the **directory** option is not used, the files are placed in the current working directory.

The object file or files created have a suffix indicating if the user subroutine is for Abaqus/Standard or Abaqus/Explicit. The Abaqus/Standard object file suffix is **–std**. Abaqus/Explicit has single and double precision object files; the object file suffixes are **–xpl** and **–xplD**. The Abaqus/Standard user subroutine shared library that is created is called **standardU**, and the Abaqus/Explicit shared libraries are called **explicitU** and **explicitU-D**. If the **directory** option is used and it contains object files with the appropriate suffix for the shared library that is being created, those files are linked to the shared library.

user

This option is valid only when used in conjunction with the **job** option. It is used to specify the name of the source or object file containing your program if it is different from *job-name*. If a file extension is not provided, the option value with a FORTRAN source file extension is sought. If a file by this name is not found, the option value with an object file extension is sought.

directory

This option is valid only when used in conjunction with the **library** option. It is used to specify the destination of the user subroutine object and shared library files that will be created by the procedure. It is also used to specify the location of additional object files that are to be linked to the shared library or libraries being created. If the option is omitted, the files created by the procedure are placed in the current working directory.

object_type

This option is valid only when used in conjunction with the **job** option. It is used to specify the type of object file, either FORTRAN, C, or C++, given by the **job** or **user** option.

Example

To create an executable called “pprocess” given a FORTRAN source file of the same name, use the following command:

```
abaqus make job=pprocess
```

This program can then be run using the command

```
abaqus pprocess
```

3.2.17 INPUT FILE AND OUTPUT DATABASE UPGRADE UTILITY

Products: Abaqus/Standard Abaqus/Explicit

References

- "Execution procedure for Abaqus: overview," Section 3.1.1
- "Fixed format conversion utility," Section 3.2.25

Overview

The **abaqus upgrade** utility will convert an input file or output database file from earlier releases of Abaqus to the current release. Input files based on the syntax of Abaqus 5.8 or later can be upgraded; output database files from Abaqus 6.1 or later can be upgraded. The **abaqus upgrade** utility will generate a log file (*job-name*`.log`) that contains error, warning, diagnostic, and informational messages. You should carefully review the conversion log file to ensure that changes made to the older release input file or output database file are appropriate. If no conversions are necessary, a message will be issued to the log file as well as to the screen.

Abaqus does not allow the use of dots (".") in set, surface, or rebar names in an input file except as delimiters between a part instance name and a set, surface, or rebar name. The **abaqus upgrade** utility will change dots to underscores ("_") for dots not used as delimiters. Manual conversion of dots to underscores will improve performance for very large input or include files.

The **abaqus upgrade** utility expects input files to be in free format; you can use the **abaqus free** utility to convert fixed format data to free format. See "Fixed format conversion utility," Section 3.2.25.

Command summary

abaqus upgrade **job**=*job-name*
[**input**=*old-input-file-name* | **odb**=*old-odb-file-name*]
[**fromversion**=*release*] [**previousdefaults**]

Command line options

Required option

job

This option is used to specify the name of the upgraded input file or output database file to be output by the utility.

Mutually exclusive options

input

This option is used to specify the name of the input file to be upgraded.

odb

This option is used to specify the name of the output database file to be upgraded.

Additional options

fromversion

This option is relevant for input file upgrades only. By default, the upgrade utility converts the input file from Abaqus 6.12 to the current release. This option is used to upgrade an input file from an earlier release. For the release number, specify the general release number (two numbers separated by a period, such as `6.8`).

previousdefaults

This option is relevant for input file upgrades only. This option is used to minimize modeling differences between the old input file and the upgraded input file.

3.2.18 GENERATING OUTPUT DATABASE REPORTS

Products: Abaqus/Standard Abaqus/Explicit

References

- "Execution procedure for Abaqus: overview," Section 3.1.1
- "Object model for the output database," Section 10.5 of the Abaqus Scripting User's Guide

Overview

The output database report utility prints information from an Abaqus output database (**`.odb`**) file to a formatted report. By default, the report is printed in plain text format; however, you can also create reports in HTML and CSV (comma-separated values) formats.

Output database structure

Every output database consists of two main sections: model data and results data. The database is further broken down into a hierarchical structure of containers, as indicated in Figure 3.2.18–1.

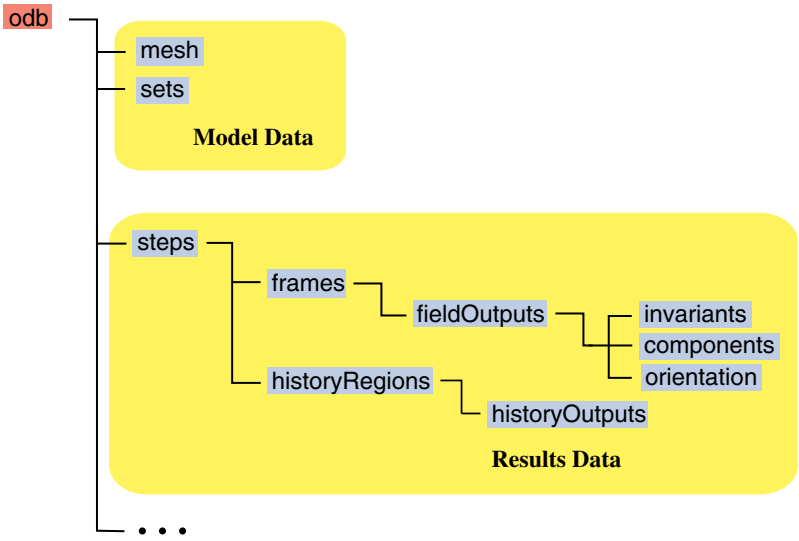


Figure 3.2.18–1 Structure of an output database

The data that can appear in a report reside in the containers at the far right of each branch. These containers can be used to classify the four main branches of the output database:

- The **mesh** branch terminates in a container holding nodal coordinates and element connectivity information for the model.
- The **sets** branch terminates in a container holding the names and node or element labels of the sets and surfaces in the model.
- The **fieldOutputs** branch terminates in a container holding the values of field output variables from the analysis. These values are further broken down into their vector or tensor attributes: **invariants**, **components**, and **orientation**.
- The **historyOutputs** branch terminates in a container holding the values of history output variables from the analysis.

The containers in the model data section of the tree are singular containers: each model has one container for mesh information and one container for sets information. The containers in the results section of the tree, however, represent aggregates of multiple containers. For a multistep analysis, the output database will have a separate **step** container for each step of the analysis. Within each **step** container will be multiple **frames** and **historyRegions** containers. Within each individual **frames** container will be multiple **fieldOutputs** containers, and so on. The output database assigns names or values to these individual containers to help distinguish and identify them.

For a more detailed discussion of the output database structure, see "Object model for the output database," Section 10.5 of the Abaqus Scripting User's Guide.

Generating summary reports

If you generate a report using only the required and file formatting command line options, the report will be a brief summary of the output database. This summary contains a listing of the following information:

- Part instance names
- Number of nodes and elements in the model
- Names of sets and surfaces
- Names of steps and load cases
- Numbers of frames in the steps
- Names of field and history output variables

The information contained in this summary can help you determine the names and values of containers in the output database.

Adding information to a report

You can create more comprehensive reports using additional command line options. Most of these options correspond to a container in the output database structure outlined in Figure 3.2.18–1. Using these options to specify the name or value of a container instructs the utility to extract the data found in that container and to add it to the generated report. Container names and values are not always unique, and may appear more than once in an output database. For example, a container corresponding to frame 1 will likely appear in every individual step container for a multistep analysis; similarly, a container holding

a specific field output variable usually appears inside every frame of the step. The utility will add all instances of these containers to the report.

To refine the container selection, you can combine options. When more than one container from the same branch is indicated on the command line, the utility only reports the data that are common to both containers. For example, if two options specify the container for Step 1 and the container for frame 3, the utility will add results data only from the third frame of the first step to the report. If you specify containers from different branches, the data from each container are added to the report. For example, if the two options specify the sets container and a history region container, both sets data and history output data are added to the report.

You identify specific containers by setting the associated option equal to the name or value of that container. To include multiple containers of the same type, set the option equal to a comma-separated list. The names are case-sensitive. If the names include spaces, you must enclose the entire value in double quotation marks (`"`*container name*`"`).

Additional options

The output database report utility offers some additional options for controlling the organization and details of a report. These options will have no effect unless they are invoked in conjunction with other "container" options.

Command summary

abaqus odbreport [**job**=*job-name*] [**odb**=*output-database-file*] [**mode**={**HTML** | **CSV**}]
[**all**] [**mesh**] [**sets**] [**results**] [**step**={*step-name* | **_LAST_**}]
[**frame**={*number* | *load-case-name* | *description* | **_LAST_**}]
[**framevalue**={*time* | *mode* | *frequency*}]
[**field**=[*field-variable*]] [**components**] [**invariants**] [**orientation**]
[**histregion**=*region-name*] [**history**=[*history-variable*]]
[**instance**={*instance-name* | **_NONE_**}] [**blocked**] [**extrema**]

Command line options

Required options

You must include at least one of the following options when executing **abaqus odbreport**. They tell the utility where to find the output database and where to print the report. Use both options together to make the report's file name unique from the output database name.

job

This option is used to specify the file name of the generated report. If you omit this option, the utility prints the report to the standard output device.

odb

This option is used to specify the output database (**.odb**) file from which the report is generated. If you omit this option, the utility looks for an output database called *job-name***.odb** in the current directory.

File formatting option

mode

This option specifies the file format of the generated report. If you omit this option, the report is in plain text format with the file extension **.rep**. If **mode**=**HTML**, the report is in HTML format with the file extension **.htm**. If **mode**=**CSV**, the report is in comma-separated values format with the file extension **.csv**.

Option to generate a full output database report

all

This option is used to report all available model information and results information from every step in the analysis; data from the base state of each step (frame zero) is not included in the report. The report will be very long for large output databases.

Options to report model data

The following options extract information from the model data section of the output database.

mesh

This option is used to report the nodal coordinates and element connectivity associated with the model's mesh.

sets

This option is used to report the names and contents of all sets and surfaces associated with the model.

Options to report results data

The following options extract information from the results data section of the output database.

results

This option is used to report all field and history output variable values from the output database. If you include any other options corresponding to specific results containers, this option is ignored.

step

This option is used to report the field and history output variable values for the specified steps. When invoking this option, you must set it equal to at least one step name. If **step**=**_LAST_**, the report includes results from only the last step of the analysis.

The **steps** container is common to both the **fieldOutputs** and **historyOutputs** branches of the output database. If you combine the **step** option with a field output variable option, only field output

variable data appear in the report. Similarly, if you combine the **step** option with a history output variable option, only history output variable data appear in the report. If you combine the **step** option with both field and history output variable options, both types of variable data appear in the report.

Options to report field output variables

The following options extract information from containers in the **fieldOutputs** branch of the output database.

frame

This option is used to report field output variable values for the specified frames. When invoking this option, you must set it equal to at least one frame number, load case name, or frame description. The initial (or "zero increment") frame can be identified only by setting **frame**=`0`. If **frame**=`_LAST_`, the report includes results from only the last frame of each included step.

framevalue

This option is used to report field output variable values for the specified frame values. Each frame can be identified by a frame value that may be unique from the frame number. The frame value is either the time, eigenmode number, or frequency point associated with a frame.

This option can be used as an alternative or complement to the **frame** option. When invoking this option, you must set it equal to at least one frame value. The values you provide do not need to be exact; the utility will find the frame with the closest frame value.

field

This option is used to report the specified field output variable values. If you invoke this option without setting it equal to any variable names, all field variable containers are included in the report.

Options to report different field variable attributes

If none of the following options is invoked, the utility automatically reports components and (if applicable) orientations for each field variable. Otherwise, the utility reports only the attributes specified by these options. These options will have an effect only if used in conjunction with other field output variable options. Invariants and orientations are not available for all field variables.

components

This option is used to report components for all field output variables.

invariants

This option is used to report invariant values for all field output variables.

orientation

This option is used to report the local coordinate system for each field output variable.

Options to report history output variables

The following options extract information from containers in the **historyOutputs** branch of the output database.

histregion

This option is used to report history output variable values for the specified history region. When invoking this option, you must set it equal to at least one history region name.

history

This option is used to report the specified history output variable values. If you invoke this option without setting it equal to any variable names, all history variable containers are included in the report.

Additional options

The following options add an additional level of control and detail to a report. They are not associated directly with the output database structure and will not add database information to a report. They must be used in conjunction with the previously described options.

instance

This option is used to limit reported model and results data to a specific part or assembly instance in the model. It is not directly associated with any output database containers and will not add any data to a report.

When invoking this option, you must set it equal to at least one instance name. If **instance**=**_NONE_**, the report includes data for the whole assembly and model.

blocked

This option is used to subdivide tables of field output variables into blocks according to part instance, element type, and section point. It is useful if you are interested in separating output from different areas of a large model. By default, the tables are organized according to variable name and frame.

This option instructs the report utility to access the output database using the field bulk data API. For details about how the field bulk data API operates, see "Using bulk data access to an output database," Section 10.10.7 of the Abaqus Scripting User's Guide. An additional benefit of this option is enhanced performance of the utility when dealing with large volumes of field variables, leading to faster report generation. The option has no effect if there are no field output variables in a report, or when the **invariants** option is also specified.

extrema

This option is used to report maximum and minimum values at the end of each table of nodal coordinates and field output variables. By default, these extrema do not appear in a report. The option will have no effect if there are no nodal coordinates or field output variables in a report.

Examples

The following examples illustrate the capabilities of the **odbreport** execution procedure and the effects of different option combinations.

File naming and formatting

The following command generates a brief summary of the output database **beam.odb** in a plain text file named **beam.rep**:

```
abaqus odbreport job=beam
```

To create the same report in HTML format and with the name **beamreport.htm**, execute the following command:

```
abaqus odbreport job=beamreport odb=beam mode=html
```

Adding information to a report

Use additional command line options to add data from specified containers to a report. The following command creates a report listing nodal coordinates and element connectivity from the model and all output variable values associated with the step named **Apply weight**:

```
abaqus odbreport job=beam mesh step="Apply weight"
```

You can refine the results data listed by using combinations of options. In the following example, the utility reports only history output variable values that were output from the history region named **Node350** in the **Apply weight** step:

```
abaqus odbreport job=beam step="Apply weight"
   histregion=Node350
```

If a container is identified by a name or value that is not unique, the generated report will include all occurrences of that container. The following command creates a report listing the values for field variable RF that were output in the third frame of every individual step:

```
abaqus odbreport job=beam frame=3 field=RF
```

To report the magnitude of RF instead of its components, use the **invariants** option:

```
abaqus odbreport job=beam frame=3 field=RF invariants
```

To add multiple containers of the same type to a report, you can set an option equal to a comma-separated list. The following command reports all values of field output variables U and S that were output during the steps **Apply weight** and **Side load**:

```
abaqus odbreport job=beam step="Apply weight","Side load"
   field=U,S
```

Additional options

Use the **instance** option to limit reported information to a particular section of your model. The following command reports set names and nodes, and values of S in the last frame of every step from the database **motor.odb**. However, only information related to part instance **pistonA** appears in the report:

```
abaqus odbreport job=motor sets frame=_LAST_ field=S
   instance=pistonA
```

Selecting frames

The **frame** and **framevalue** options can accept a wide variety of value types, making them powerful report-building options. Because of this variety, it is sometimes necessary to invoke both options to specify a particular frame. For example, consider the output database **plate.odb**, the results of a steady-state dynamic analysis. The analysis investigated the response of a plate over a range of 20 different frequencies under three different load cases. The output database, therefore, includes results for the three different load cases at each frequency. You are interested in the response at 45 Hz under the load case named **lc2**. Setting **frame**=**lc2** will report field variables for load case **lc2** at every frequency (a total of 20 frames). Setting **framevalue**=**45** will report field variables for every load case associated with the 45 Hz frequency (a total of three frames). To limit the report to the single frame of interest, you must invoke both options together:

```
abaqus odbreport job=plate frame=lc2 framevalue=45
```

3.2.19 JOINING OUTPUT DATABASE (.odb) FILES FROM RESTARTED ANALYSES

Products: Abaqus/Standard Abaqus/Explicit

References

- "Execution procedure for Abaqus: overview," Section 3.1.1
- "Continuation of output upon restart" in "Restarting an analysis," Section 9.1.1

Overview

The **abaqus restartjoin** utility appends an output database (**.odb**) file produced by a restart analysis of a model to the output database produced by the original analysis of that model. Combining the original and restart output database files into a single file enables you to examine all of the output data for the analysis in Abaqus/CAE.

A similar utility, **abaqus append**, is used to join results (**.fil**) files. See "Joining results (**.fil**) files," Section 3.2.13, for details.

Appending data when the analysis restarts between steps versus midstep

You can append output database files from analyses that restart between steps and from analyses that restart in the middle of a step. While the required syntax is the same for these two types of analyses, Abaqus appends data differently, as follows:

- For an analysis that stops and restarts between steps, Abaqus simply appends the output from the new steps to the output from the existing steps of the original analysis.
- For an analysis that stops and restarts in the middle of a step, the original and restart analyses overlap because the restart analysis resumes at the beginning of the interrupted step. In this case the **abaqus restartjoin** utility retains the results for any completed steps in the original analysis but replaces the results for the interrupted step with the output data produced by the restart analysis.

Customizing the combined output database file

By default, Abaqus appends the output data produced by the restart analysis directly to the original output database file. If you prefer to retain the original output database file, you can create a copy of it and append the restart analysis output data to the copy instead. Abaqus names this copy using the format **Restart_***original-odb-filename*; for example, a copy of the original output database file **job-1.odb** would be named **Restart_job-1.odb**.

Abaqus omits history data when you combine original and restart output databases; however, you can override this default. You can also control whether Abaqus compresses the combined output database file.

Command summary

abaqus restartjoin **originalodb**=*odb-file-name*
restartodb=*odb-file-name*
[**copyoriginal**] [**history**] [**compressresult**]

Command line options

originalodb

This option specifies the output database file produced by the original analysis. If you omit the **copyoriginal** option, Abaqus appends the output data from the restart output database file directly to the original output database file.

If you omit this option from the command line, Abaqus will prompt you for its value.

restartodb

This option specifies the output database file produced by the restart analysis. You can specify only one restart analysis output database file at a time.

If you omit this option from the command line, Abaqus will prompt you for its value.

copyoriginal

If this option is specified, Abaqus creates a copy of the output database file specified by the **originalodb** option and appends the contents of the **restartodb** output database file to that copy instead of to the original file. When this option is omitted, Abaqus appends the output data from the restart analysis directly to the original output database file.

Abaqus names the copied output database file by adding the prefix **`Restart_`** to the name of the original output database file; for example, a copy of the original output database file **`original.odb`** would be named **`Restart_original.odb`**.

history

If this option is specified, Abaqus copies history data from the restart output database to the original output database or its copy. Abaqus omits history data in the joined output database file unless you specify this option.

compressresult

If this option is specified, Abaqus compresses the resulting output database file.

Examples

If your model produced an initial output database file named **`Job-1.odb`** and a restart output database file named **`Job-1_res.odb`**, issue the following command to append the contents of the restart database to the initial output database file:

```
abaqus restartjoin originalodb=Job-1.odb restartodb=Job-1_res.odb
```

If you prefer to retain the original output database file, you can create a copy of this original file and append the contents of the restart output database file to the copy instead. Abaqus creates the name of the copied output database file by adding the prefix **Restart_** to the name of the original file; in the preceding example the copy of the original file **Job-1.odb** would be named **Restart_Job-1.odb**. To perform the restart join operation using a copy of the original file, issue the following command:

```
abaqus restartjoin originalodb=Job-1.odb restartodb=Job-1_res.odb
   copyoriginal
```

By default, Abaqus does not copy history data to the combined output database. To include history data, issue the following command:

```
abaqus restartjoin originalodb=Job-1.odb restartodb=Job-1_res.odb
   history
```

3.2.20 COMBINING OUTPUT FROM SUBSTRUCTURES

Products: Abaqus/Standard Abaqus/Explicit

References

- "Execution procedure for Abaqus: overview," Section 3.1.1
- "Obtaining output of results within a substructure" in "Using substructures," Section 10.1.1

Overview

The **abaqus substructurecombine** utility combines the model and results data produced by two of a model's substructures into a single output database (**.odb**) file. By combining all of a model's substructure analysis output database files, you can display all of the data produced by a substructure analysis in Abaqus/CAE.

Abaqus combines output data by adding the contents of the second file you specify (the copy output database) directly into the first file you specify (the base output database). Because this process changes the base output database, consider backing up your data before using this utility.

Combining data for models with more than two substructures

Because the **abaqus substructurecombine** utility combines data from only two output databases at a time, you must run the utility multiple times to create a single output database from an analysis with more than two substructures. Combine data from two of the substructures first, then repeat the operation to combine the resulting output database file with data from each remaining substructure.

Customizing the combined output database

You can customize the substructure combine operation by adding only a subset of the data from the copy output database into the base output database. Abaqus enables you to add output data to the base output database from a single step or frame in the copy output database. You can also include only output data from the copy output database that relates to a particular variable; for example, you can copy output data related to Mises stress.

Command summary

abaqus substructurecombine **baseodb**=*odb-file-name*
copyodb=*odb-file-name*
[**all**] [**step**=*step-name*]
[**frame**=*frame-number*] [**variable**=*variable-key*]

Command line options

baseodb

This option specifies the name of the base output database, to which Abaqus adds the contents of the copy output database.

If you omit this option from the command line, Abaqus will prompt you for its value.

copyodb

This option specifies the name of the copy output database, which Abaqus adds to the contents of the base output database. You can specify only one file at a time for this option.

If you omit this option from the command line, Abaqus will prompt you for its value.

all

This option indicates that data for all variables within all steps and frames of output should be copied to the combined output database. When you specify this option, Abaqus ignores the **step**, **frame**, and **variable** options.

step

This option indicates the name of the step from which Abaqus will copy results data. You can specify only one step; if you omit this option, Abaqus copies data from the last step in the output database.

Abaqus ignores this option if you specify the **all** option.

frame

This option indicates the number of the frame from which Abaqus will copy results data. You can specify only one frame; if you omit this option, Abaqus uses the last frame in the step specified by the **step** option.

Abaqus ignores this option if you specify the **all** option.

variable

This option indicates the variable key for the variable from which Abaqus will copy results data. If you omit this option, Abaqus copies data for all variables in the output database. Abaqus ignores this option if you specify the **all** option.

Only output variable keys that are valid for output database file output are available for use with **abaqus substructurecombine**. In general, if a key corresponds to a collective output variable, rather than an individual component, it can be used with this execution procedure. The collective output variable keys are distinguished from their individual components by the fact that they have a bullet (•) in one of the **.odb** columns in the tables in "Abaqus/Standard output variable identifiers," Section 4.2.1.

Examples

The following examples illustrate different methods of combining substructures using the **abaqus substructurecombine** execution procedure.

Combining two substructures

If your model contains two substructures that produce output database files named **subst1.odb** and **subst2.odb**, issue the following command to overwrite **subst1.odb** with the combined contents of the two files:

```
abaqus substructureCombine baseodb=subst1.odb copyodb=subst2.odb
```

Combining more than two substructures

If your model contains more than two substructures, you must first combine the output database files from two of the substructures, then combine the combined output database with each of the other substructures' output databases in turn. In this example the substructure analysis produces four output database files named **subst1.odb**, **subst2.odb**, **subst3.odb** and **subst4.odb**, so you must issue the **abaqus substructure** command a total of three times to combine all four files into a single output database, as shown in the following example:

```
abaqus substructureCombine baseodb=subst1.odb copyodb=subst2.odb
abaqus substructureCombine baseodb=subst1.odb copyodb=subst3.odb
abaqus substructureCombine baseodb=subst1.odb copyodb=subst4.odb
```

Combining specific elements of the substructures

If you want to include only the output data from the step **Step-1** in the combined output database, issue the following command:

```
abaqus substructureCombine baseodb=subst1.odb copyodb=subst2.odb
   step="Step-1"
```

If you want to include only the output data from the **Mises** variable in the combined output database, issue the following command:

```
abaqus substructureCombine baseodb=subst1.odb copyodb=subst2.odb
   variable="Mises"
```

3.2.21 COMBINING DATA FROM MULTIPLE OUTPUT DATABASES

Products: Abaqus/Standard Abaqus/Explicit Abaqus/CFD

References

- "Execution procedure for Abaqus: overview," Section 3.1.1
- "Joining output database (**.odb**) files from restarted analyses," Section 3.2.19
- "Combining data from multiple output databases," Section 82.13 of the Abaqus/CAE User's Guide, in the HTML version of this guide

Overview

The **abaqus odbcombine** utility combines the results data in two or more Abaqus output database files (**.odb**) into a single output database (**.odb**) file. The **abaqus odbcombine** utility is intended for the combination of output databases containing different results. If you want to combine output databases from the same analysis before and after a restart, use the **abaqus restartjoin** execution procedure instead. For more information, see "Joining output database (**.odb**) files from restarted analyses," Section 3.2.19.

Abaqus includes all model data from the selected output databases in the combined output database; however, for results data you can choose to include a subset of the data from the output databases that you specify. Abaqus/CAE determines which results data are included in the combined output database based on two factors: the filtering options you specify and your selection of master output database.

Filters

You can filter the data that the utility includes in the combined output database to include results only from selected steps or frames, from selected output variables, or from a combination of these options. For example, a filter can enable you to include results data only from the last step and the last frame of the specified output databases, and the same filter can dictate that only Mises stress results are included in the combined output database. You can also establish multiple filters if you want to set up different filtering conditions for the first step than in the second step.

The **abaqus odbcombine** utility also provides two levels of filtering: output database–specific filters, which filter results from only a single output database; and default filters, which apply to the entire job. The output database–specific filters take precedence over the default filters, so Abaqus/CAE employs the settings in the default filters only when the default filter you define does not conflict with filters for one of the individual output databases.

The filtering syntax is flexible enough to allow you to specify multiple steps, frame, or output variable values. You can specify multiple step names in a comma-separated list, such as **`Step-1, Step-2, Step-4`**. For frames you can include ranges or individual values; for example, entering **`1, 3, 5, 7:9`** returns frames 1, 3, 5, 7, 8, and 9 to the combined output database.

You can also use the symbolic constants **'ALL'**, **'FIRST'**, and **'LAST'** as shortcuts to specify the data you want to include. These options enable you to include results data from all steps or frames and data from all output variables rather than one or more selected variables.

Master output database

One output database in every combine operation is designated as the master output database. The utility first transfers all field output data, subject to filtering selections, from the master output database to the combined output database. The utility then locates results data from matching steps and frames in the subsequent output databases and copies only those data into the combined output database. This strategy provides a more coherent structure for the combined results data.

Configuration file usage

The **abaqus odbcombine** utility uses data in configuration files to determine which output databases to combine, the file to designate as the master output database, and the filtering options to enforce by default and for each output database. The configuration file must be in **.xml** format, and it can have three types of elements in the following order:

- The **<DefaultFilters>** element specifies one or more default filtering definitions. This section is optional, but you must include it if you want to set up default filtering for your combine operation.
- The **<MasterOdb>** element specifies the location of the master output database and, if desired, one or more filtering definitions for the data in that output database. This section is required.
- One **<Odb>** element is required for each additional output database that you want to include in the combine operation.

You can then specify default filters for output database–specific filters by embedding **<Filter>** elements within the **<DefaultFilters>** element or within one of the output database elements.

Configuration file template

The following example illustrates the structure of the configuration file for the **abaqus odbcombine** utility.

```
<?xml version='1.0' encoding='UTF-8'>
```
Your XML file declaration may differ from this one.

```
<OdbInput>
   <DefaultFilters>
```
The default filtering element is optional. If you include this element in the configuration file, you must include at least one <Filter> element within this section. Filter elements can use the Steps or Frames attributes to refer to symbolic constants or the StepName or FrameIndex attributes to refer to individual steps or frames, as shown in the following examples:

```
      <Filter Steps='step names or symbolic constants'
          Frames='frame numbers or symbolic constants'
```

```
            VariableName='variable' />
        <Filter StepName='full step name'
            FrameIndex='individual frame number'
            VariableName='variable' />
    </DefaultFilters>

    <MasterOdb Name='path to master output database'>
    Filtering elements for the master output database are optional. If you want to filter
    the data from this output database, include a <Filter> element within this section
    for each filtering option you want to define.
    </MasterOdb>

    <Odb Name='path to output database'>
    Filtering elements for the output database are optional. If you want to filter
    the data from this output database, include a <Filter> element within this section
    for each filtering option you want to define.
    </Odb>

    Append an <Odb> element for each additional output database you want to include.

</OdbInput>
```

Data not included in combined output databases

The following types of output data are not included when you combine output database files:

- History output.
- Surface data.
- Data from analytical rigid part instances.
- Local coordinate systems associated with field output data.

Command summary

abaqus odbcombine {**job**=*job-name*}
[**input**=*configuration-file-name*] [**verbose**=*level*]

Command line options

job

This option specifies the name of the resulting combined output database and the name of the log file. Abaqus also searches for a configuration file by this name.

If you omit this option from the command line, Abaqus will prompt you for its value.

input

This option specifies the name of the configuration file that specifies the output databases you want to combine and the steps, frames, and output variables to be included in the combination. The configuration file must be in **`.xml`** format.

verbose

This option specifies the level of detail for the messages that Abaqus writes to the log file. Possible values are **`1`** or **`2`**. If you specify **`1`**, Abaqus writes only errors and warnings to the log file; if you specify **`2`**, Abaqus also records the filtering options you select and lists the model data and field output data that were successfully copied to the combined output database.

3.2.22 NETWORK OUTPUT DATABASE FILE CONNECTOR

Products: Abaqus/CAE Abaqus/Viewer

References

- "Execution procedure for Abaqus: overview," Section 3.1.1
- "Accessing an output database on a remote computer," Section 9.3 of the Abaqus/CAE User's Guide

Overview

A network ODB connector creates a connection to a network ODB server that can be used to access a remote output database. The **abaqus networkDBConnector** command is used to start the network ODB server. A network ODB connector can be created from any platform—Windows, UNIX, or Linux; however, the network ODB server must reside on a UNIX or Linux platform.

Abaqus uses password files to authenticate the connection between the client and the server. The password on the network ODB server must be stored in a file called **`.abaqus_net_passwd`** in your home directory on the remote system. You must update this file after 30 days, and the password must be at least 8 characters long.

In addition, your home directory on the local client machine can contain either of the following:

- A file called **`.abaqus_`***hostname***`_passwd`**. This file allows you to connect to the remote server on the machine called *hostname*.
- A file called **`.abaqus_net_passwd`**. This file allows you to connect to the network ODB server on any machine.

The contents of the password file on both the server and the client must be identical. In addition, Abaqus checks that you are the only user with permission to read from or to write to the password files. If neither file exists, Abaqus tries to use remote and secure shell commands to read the password from the network ODB server. However, the security configuration at your site may prevent Abaqus from reading the password.

Command summary

abaqus networkDBConnector **port**={*serverPortNumber* | **`auto_assigned`**}
[**timeout**=*time out value in seconds*]
[**host**=*hostname*]
[**stop**]
[**ping**]

Command line options

port

This option specifies the port number on the network ODB server. If **port**=**`auto_assigned`**, Abaqus automatically assigns the port number.

timeout

This option specifies the timeout period in seconds for the network ODB server. The server exits if it does not receive any communication from the client during the time specified. A timeout value of zero indicates that the server will run until it is terminated explicitly using the **stop** option.

host

This option specifies the name of the machine that is hosting the network ODB server. This option is used with the **stop** and **ping** options. If this option is not provided, Abaqus uses the name of the machine from which the execution procedure was issued.

stop

This option specifies that Abaqus should stop the network ODB server that was established using the specified host name and port number.

ping

This option queries the network ODB file server that was established using the specified host name and port number. Use this option to confirm that the network ODB server exists and that communications have been established.

3.2.23 MAPPING THERMAL AND MAGNETIC LOADS

Product: Abaqus/Standard

References

- "Execution procedure for Abaqus: overview," Section 3.1.1
- "Eddy current analysis," Section 6.7.5
- "Predefined loads for sequential coupling," Section 16.1.3
- *CFLUX
- *CLOAD

Overview

The **abaqus emloads** utility converts results output from a time-harmonic eddy current analysis for use as loads in a subsequent heat transfer, coupled temperature-displacement, or stress/displacement analysis. For example, magnetic body force intensity output is converted to point loads. You specify the names of the time-harmonic eddy current analysis results output database (**.odb**) file and the input file for the subsequent analysis on the command line. The utility creates an output database file containing a mesh that matches the mesh in your subsequent analysis and steady-state concentrated nodal fields consistent with the time-harmonic eddy current analysis results. Your time-harmonic eddy current and subsequent analysis meshes can be dissimilar, and results transfer ensures global conservation of the flux quantities when your model domains match; i.e., the model boundaries are the same. You can then use this new output database file to apply concentrated loads and concentrated heat fluxes in the subsequent analysis.

Results conversion

The utility converts whole element output quantities from a time-harmonic eddy current analysis to nodal results. You use the options listed in Table 3.2.23–1 in the subsequent analysis to specify the output database file (and optionally the step and increment) from which the data are to be read.

Utility execution

The utility executes in two phases. Abaqus writes progress information and, if appropriate, error messages to the screen during each phase.

In the first phase a datacheck analysis is performed on your subsequent analysis input file to create an output database representation of a "target" mesh. This phase requires that your input file be sufficiently complete to successfully run **abaqus datacheck**, with the exception that you can have *CFLUX and *CLOAD options that include the FILE parameter to refer to files that are not available. If this phase is successful, the utility proceeds to the second phase; otherwise, an error message is issued.

In the second phase time-harmonic eddy current analysis load data are mapped from the source to the target output database. In this phase all steps and increments found in the original analysis are defined

Table 3.2.23–1 Supported results conversion.

Electromagnetic analysis output variable	Converted output variable	Input file option
Rate of Joule heat dissipation EMJH	Concentrated heat flux CFL11	*CFLUX, FILE=*odb-name*, STEP=*step-number*, INC=*inc*
Magnetic body force intensity EMBF	Point load components CF	*CLOAD, FILE=*odb-name*, STEP=*step-number*, INC=*inc*

in the target output database. This phase requires that your target model domain lie within the source model domain. If it does not, an appropriate error message is issued.

Command summary

abaqus emloads **job**=*target-odb-name*
input=*subsequent analysis input-file-name*
sourceodb=*time-harmonic eddy current analysis odb-file-name*

Command line options

job

This option specifies the name of the resulting "target" output database file.

input

This option specifies the name of the subsequent analysis Abaqus input file. This file must be sufficiently complete to successfully run, as described above.

sourceodb

This option specifies the name of the time-harmonic eddy current analysis output database file.

3.2.24 ELEMENT MATRIX ASSEMBLY UTILITY

Product: Abaqus/Standard

Reference

- "Generating matrices," Section 10.3

Overview

The **abaqus mtxasm** utility assembles element matrices contained in a SIM document and, optionally, writes the assembled matrices to text files. If assembled matrices are already available in a SIM document, you can use this utility to write them to text files.

Command summary

abaqus mtxasm **job**=*name-of-assembled-mtx-sim-doc*
[**oldjob**=*name-of-element-mtx-sim-doc*] [**text**]

Command line options

job

This option is used to specify the name of the SIM document containing assembled matrices or to which assembled matrices will be written, depending on the mode of operation.

oldjob

This option is used to specify the name of the SIM document containing element matrices to be assembled. If this option is not used, the SIM document specified using the **job** option must already exist and contain assembled matrices.

text

This option is used to write assembled matrices to text files in the matrix input format. Each matrix is written to a file that follows the naming convention *jobname_matrixN*.**mtx**, where *jobname* is the name specified using the **job** option, *matrix* is a four-letter identifier (**STIF**, **MASS**, **DMPV**, **DMPS**, or **LOAD**) indicating the matrix type relevant for structural or thermal matrices, and *N* is the increment number.

3.2.25 FIXED FORMAT CONVERSION UTILITY

Products: Abaqus/Standard Abaqus/Explicit

Reference

- "Execution procedure for Abaqus: overview," Section 3.1.1

Overview

The **abaqus free** utility will convert the fixed format input files used with Abaqus 5.8 to the free format input files used with subsequent Abaqus releases.

Command summary

abaqus free **job**=*job-name*
input=*input-file*

Command line options

job

This option is used to specify the name of the free format input file to be output by the utility.

input

This option is used to specify the name of the fixed format input file to be converted.

3.2.26 TRANSLATING NASTRAN BULK DATA FILES TO Abaqus INPUT FILES

Products: Abaqus/Standard Abaqus/Explicit

References

- "Execution procedure for Abaqus: overview," Section 3.1.1
- "Translating Abaqus files to Nastran bulk data files," Section 3.2.27
- "Importing a model from a Nastran input file," Section 10.5.4 of the Abaqus/CAE User's Guide

Overview

The translator from Nastran to Abaqus converts certain entities in a Nastran input file into their equivalent in Abaqus.

Using the translator

The Nastran data must be in a file with the extension **`.bdf`**, **`.dat`**, **`.nas`**, **`.nastran`**, **`.blk`**, or **`.bulk`**. The Nastran data entries that are translated are listed in the tables below. Other valid Nastran data are skipped over and noted in the log file.

The translator is designed to translate a complete Nastran input file. If only bulk data are present, the first two lines in the file should be the terminators for the executive control and case control sections, namely:

```
CEND
BEGIN BULK
```

For normal termination, end the Nastran input data with the line

```
ENDDATA
```

Nastran solution sequences are translated to the Abaqus procedures listed in Table 3.2.26–1. The translator attempts to create a history section based on the contents of the case control data in the Nastran file.

Summary of Nastran entities translated

Table 3.2.26–1 Executive control data.

Nastran Statement	Abaqus Equivalent
SOL	

Nastran Statement	Abaqus Equivalent
1 (STATICS1) 24 (STATICS) 101 (SESTATIC) 106 (NLSTATIC)	*STATIC
3 (MODES) 25 (OLDMODES) 103 (SEMODES)	*FREQUENCY
5 (BUCKLING) 105 (SEBUCKL)	*BUCKLE
26 (DFREQ) 108 (SEDFREQ)	*STEADY STATE DYNAMICS, DIRECT
27 (DTRAN) 109 (SEDTRAN)	*DYNAMIC
107 (SEDCEIG) 110 (SEMCEIG)	*COMPLEX FREQUENCY
30 (DFREQ) 111 (SEMFREQ)	*FREQUENCY and *STEADY STATE DYNAMICS
31 (MTRAN) 112 (SEMTRAN)	*FREQUENCY and *MODAL DYNAMIC

Table 3.2.26–2 Case control data.

Nastran Command	Comment
SPC	Selects SPC sets alone or in combinations
LOAD	Selects individual loads and load combinations
METHOD	Selects EIGRL, EIGR, or EIGB from bulk data for eigenfrequency extraction and eigenvalue buckling prediction procedures
SUBCASE	Delimiter for steps or load cases; optional if there is only one step

Nastran Command	Comment
TITLE	Echoed as comment at top of input file and for each step
SUBTITLE	Echoed as comment for the step to which it applies
LABEL	Used as text following the *STEP option
DLOAD LOADSET	Selects dynamic loads from bulk data
FREQUENCY	Selects forcing frequencies from bulk data
MPC	Selects MPCADD and MPC from bulk data if referenced in the first SUBCASE
SUPORT1	Selects SUPORT1 from bulk data
TSTEP	Selects TSTEP from bulk data
K2GG K2PP M2GG M2PP B2GG B2PP K42GG	Selects DMIG from bulk data using the matrix name from the first SUBCASE
TEMPERATURE	Selects nodal temperatures from bulk data
SET DISPLACEMENT VELOCITY ACCELERATION SPCFORCES PRESSURE	Selects nodal quantities for output

Table 3.2.26–3 Bulk data.

Nastran Data Entry	Comment
PARAM	Ignored except for: 1. WTMASS, which can be used to modify density, mass, and rotary inertia values if the **wtmass_fixup** command line parameter is used 2. INREL, which if equal to −1 or −2 will create inertia relief loads 3. G, which is translated to *GLOBAL DAMPING, STRUCTURAL, FIELD=MECHANICAL 4. GFL, which is translated to *GLOBAL DAMPING, STRUCTURAL, FIELD=ACOUSTIC
CDAMP1 CDAMP2 PDAMP PDAMPT	DASHPOT1/DASHPOT2 and *DASHPOT
CELAS1 CELAS2 PELAS PELAST	SPRING1/SPRING2 and *SPRING (CELAS2 at SPOINTs are translated to *MATRIX INPUT, stiffness, and/or structural damping terms.)
CMASS2	*MATRIX INPUT mass terms
CBUSH PBUSH PBUSHT	CONN3D2 and *CONNECTOR SECTION
CWELD PWELD	*FASTENER and *FASTENER PROPERTY
CONM1	MASS and/or ROTARY INERTIA and/or UEL
CONM2	MASS and/or ROTARY INERTIA

Nastran Data Entry	Comment
CHEXA CPENTA CTETRA PSOLID PLSOLID	C3D8I/C3D20R/C3D6/C3D15/C3D4/C3D10 and *SOLID SECTION
CQUAD4 CTRIA3 CQUAD8 CTRIA6 CQUADR CTRIAR PSHELL PCOMP PCOMPG	S4/S3R/S8R/STRI65, and *SHELL SECTION, *SHELL GENERAL SECTION, or *MEMBRANE SECTION.
CSHEAR PSHEAR	*USER ELEMENT, LINEAR and *MATRIX, TYPE=STIFFNESS and TYPE=MASS
CBAR CBEAM PBAR PBARL PBEAM PBEAML	B31 and *BEAM SECTION or *BEAM GENERAL SECTION
CROD CONROD PROD	T3D2 and *SOLID SECTION
CGAP PGAP	GAPUNI and *GAP
RBAR	*COUPLING or *MPC, type BEAM

Nastran Data Entry	Comment
MAT1	*ELASTIC, TYPE=ISO; *EXPANSION, TYPE=ISO; *DENSITY; and *DAMPING (G is used only for *BEAM GENERAL SECTION)
MAT2	When used alone in a PSHELL, MAT2 is translated to *ELASTIC, TYPE=LAMINA or *ELASTIC, TYPE=ANISOTROPIC. When used in combination with other materials, the coefficients relating midsurface strains and curvatures to section forces and moments are computed and entered following the *SHELL GENERAL SECTION option.
MAT8	*ELASTIC, TYPE=LAMINA; *EXPANSION, TYPE=ORTHO; *DENSITY; and *DAMPING
MAT9	*ELASTIC, TYPE=ANISOTROPIC unless the data are found to be orthotropic, in which case the data are analyzed to create *ELASTIC, TYPE=ENGINEERING CONSTANTS. Also *DENSITY; *EXPANSION, TYPE=ANISO or ORTHO; and *DAMPING.
MAT10	*ACOUSTIC MEDIUM and *DENSITY
ACMODL	*TIE between a *SURFACE, TYPE=ELEMENT defining the exterior surfaces of all acoustic solid elements and a *SURFACE, TYPE=NODE defined by the SET1 referenced by the SSID.
NSM NSM1 NSML NSML1 NSMADD	*NONSTRUCTURAL MASS
GRID	*NODE and *SYSTEM

Nastran Data Entry	Comment
CORD1R CORD1C CORD1S CORD2R CORD2C CORD2S	*SYSTEM for nodes; *TRANSFORM if referred to on GRID; *ORIENTATION for some elements
RBE2	*COUPLING and *KINEMATIC; or *KINEMATIC COUPLING (If the RBE2 has only two nodes and neither node has rotational stiffness, the RBE2 is translated to *MPC, type LINK)
RBE3	*COUPLING and *DISTRIBUTING; or DCOUP3D and *DISTRIBUTING COUPLING
SPCADD	Used to combine SPC/SPC1/SPCD data into a new set
SPC SPC1 SPCD	*BOUNDARY
LOAD	Used to combine FORCE, MOMENT, etc. data into a new set
FORCE FORCE1 FORCE2 MOMENT MOMENT1 MOMENT2	*CLOAD
PLOAD PLOAD1 PLOAD2 PLOAD4 RFORCE	*DLOAD

Nastran Data Entry	Comment
DLOAD DAREA LSEQ RLOAD1 RLOAD2 TLOAD1 TABLED1 TABLED2 TABLED4 DELAY DPHASE	Dynamic loads as functions of time or frequency
TEMP TEMPD	*INITIAL CONDITIONS, TYPE=TEMPERATURE and *TEMPERATURE
TSTEP	Time step size for dynamic and modal dynamic procedures
EIGB	*BUCKLE
EIGR EIGRL	*FREQUENCY
EIGC	*COMPLEX FREQUENCY
TABDMP1	*MODAL DAMPING
FREQ FREQ1 FREQ2 FREQ3 FREQ4 FREQ5	Forcing frequencies for steady-state dynamic procedures
MPCADD MPC	*EQUATION

Nastran Data Entry	Comment
SUPORT SUPORT1	*INERTIA RELIEF and *BOUNDARY
DMIG	*MATRIX INPUT and *MATRIX ASSEMBLE
GENEL	*USER ELEMENT, LINEAR and *MATRIX, TYPE=STIFFNESS
PLOTEL	Ignored unless the command line option **plotel**=**ON**.

Command summary

abaqus fromnastran **job**=*job-name* [**input**=*input-file*]
[**wtmass_fixup**={**OFF** | **ON**}] [**loadcases**={**OFF** | **ON**}]
[**pbar_zero_reset**=[*small-real-number*]]
[**distribution**={**OFF** | **preservePID** | **ON**}]
[**surface_based_coupling**={**OFF** | **ON**}]
[**beam_offset_coupling**={**OFF** | **ON**}]
[**beam_orientation_vector**={**OFF** | **ON**}]
[**cbar**=*2-node-beam-element*] [**cquad4**=*4-node-shell-element*]
[**chexa**=*8-node-brick-element*]
[**ctetra**=*10-node-tetrahedron-element*]
[**plotel**={**OFF** | **ON**}] [**cdh_weld**={**OFF** | **RIGID** | **COMPLIANT**}]

Command line options

job

This option is used to specify the name of the Abaqus input file to be output by the translator. It is also the default name of the file containing the Nastran data. Diagnostics created by the translator will be written to a file named *job-name*`.log`.

input

This option is used to specify the name of the file containing the Nastran data if it is different from *job-name*.

wtmass_fixup

If **wtmass_fixup**=**ON**, the value on the Nastran data line **PARAM, WTMASS, *value*** is used as a multiplier for all density, mass, and rotary inertia values created in the Abaqus input file.

This option can be defined in the Abaqus environment file as follows:

```
fromnastran_wtmass_fixup={OFF | ON}
```

loadcases

By default, each **SUBCASE** is translated to a *STEP option in Abaqus. If **loadcases**=**ON**, this behavior is altered for linear static analyses: each **SUBCASE** is translated to a *LOAD CASE option, and all such *LOAD CASE options are grouped in a single *STEP option.

This option can be defined in the Abaqus environment file as follows:

```
fromnastran_loadcases={OFF | ON}
```

pbar_zero_reset

Nastran allows beams to have zero values for cross-sectional area or moments of inertia; Abaqus does not. Set this option equal to a small real number to reset any zero values for A, I_1, I_2, or J to the specified small real number. If this option is omitted or present without a value, the default value of 1.0×10^{-20} is used in place of the zeros. To retain the zeros in the translated Abaqus input file, set **pbar_zero_reset**=**0**.

This option can be defined in the Abaqus environment file as follows:

```
fromnastran_pbar_zero_reset=small-real-number
```

distribution

This option determines how shell and membrane sections in Nastran data are translated to Abaqus. If **distribution**=**OFF**, a separate section is created for each combination of orientation, material offset, and/or thickness. If **distribution**=**preservePID** or **ON**, element orientations and offsets are written using the *DISTRIBUTION option. If **distribution**=**preservePID**, an Abaqus section is created corresponding to each PSHELL or PCOMP property ID. If **distribution**=**ON**, a single Abaqus section is created for all homogeneous elements referencing the same material.

This option can be defined in the Abaqus environment file as follows:

```
fromnastran_distribution={OFF | preservePID | ON}
```

surface_based_coupling

Certain Nastran rigid elements have more than one equivalent in Abaqus. If **surface_based_coupling**=**ON**, RBE2 and RBE3 elements translate to *COUPLING with the appropriate parameters. Otherwise, RBE2 elements translate to *KINEMATIC COUPLING and RBE3 elements translate to *DISTRIBUTING COUPLING. This translation behavior also applies to "implied" RBE2-type rigid elements used for offsets on CBAR, CBEAM, and CONM2 elements.

For input files created with **surface_based_coupling**=**ON**, the translated elements can be visualized and manipulated in Abaqus/CAE. However, large numbers of these elements may cause slower performance.

This option can be defined in the Abaqus environment file as follows:

```
fromnastran_surface_based_coupling={OFF | ON}
```

beam_offset_coupling

If **beam_offset_coupling**=**ON**, beam element offsets are translated by creating new nodes at the offset locations, changing the beam connectivity to the new nodes, and rigidly coupling the new and original nodes.

If **beam_offset_coupling**=**OFF**, beam element offsets are translated to the *CENTROID and *SHEAR CENTER options, which are suboptions of the *BEAM GENERAL SECTION option.

The setting for this parameter is ignored if the beam element references a PBARL or PBEAML property or if the beam offset has a significant component in the direction of the beam axis. In these situations the beam offsets are always translated as if **beam_offset_coupling**=**ON**.

This option can be defined in the Abaqus environment file as follows:

```
fromnastran_beam_offset_coupling={OFF | ON}
```

beam_orientation_vector

If **beam_orientation_vector**=**OFF**, beam cross-section orientations are translated by creating new nodes at the tips of vectors defining the first principal direction of the cross-section and changing the beam connectivity to the new nodes.

If **beam_orientation_vector**=**ON**, beam cross-sections are translated by defining vectors on the *BEAM SECTION and *BEAM GENERAL SECTION options.

This option can be defined in the Abaqus environment file as follows:

```
fromnastran_beam_orientation_vector={OFF | ON}
```

cbar

This option is used to define the 2-node beam that is created from CBAR and CBEAM elements. The default is B31.

This option can be defined in the Abaqus environment file as follows:

fromnastran_cbar=*2-node-beam-element*

cquad4

This option is used to define the 4-node shell that is created from CQUAD4 elements. The default is S4R. If a reduced-integration element is chosen, the enhanced hourglass formulation is applied automatically.

This option can be defined in the Abaqus environment file as follows:

fromnastran_cquad4=*4-node-shell-element*

chexa

This option is used to define the 8-node brick that is created from CHEXA elements. The default is C3D8I. If a reduced-integration element is chosen, the enhanced hourglass formulation is applied automatically.

This option can be defined in the Abaqus environment file as follows:

fromnastran_chexa=*8-node-brick-element*

ctetra

This option is used to define the 10-node tetrahedron that is created from CTETRA elements. The default is C3D10.

This option can be defined in the Abaqus environment file as follows:

`fromnastran_ctetra=`*10-node-tetrahedron-element*

plotel

By default, PLOTEL elements are not translated. If **plotel**=**`ON`**, PLOTEL elements are translated to T3D2 truss elements in an element set named PLOTEL_TRUSSES. The cross-sectional area of the trusses is the value entered for **pbar_zero_reset**, and the material has a Young's modulus, *E*, equal to 1.0.

cdh_weld

By default, CHEXA elements with RBE3 elements at all eight corner nodes are translated to the type of 8-node element specified in the **chexa** parameter. If **cdh_weld**=**`RIGID`**, CHEXA elements with RBE3 elements at all eight corner nodes are translated to rigid fasteners in Abaqus. If **cdh_weld**=**`COMPLIANT`**, CHEXA elements with RBE3 elements at all eight corner nodes are translated to compliant fasteners in Abaqus.

3.2.27 TRANSLATING Abaqus FILES TO NASTRAN BULK DATA FILES

Products: Abaqus/Standard Abaqus/Explicit

References

- "Execution procedure for Abaqus: overview," Section 3.1.1
- "Translating Nastran bulk data files to Abaqus input files," Section 3.2.26

Overview

The translator from Abaqus to Nastran converts certain entities in an Abaqus file into equivalent entities in Nastran. Only "flat" Abaqus files can be translated; i.e., the Abaqus file cannot contain parts and assemblies.

Using the translator

The Abaqus input data must be in a file with the extension **`.inp`** or **`.sim`**. If you specify an **`.inp`** file, the execution procedure translates selected keywords and creates a Nastran bulk data file with the extension **`.bdf`**. If you use the **substructure** option and specify a substructure **`.sim`** file, the execution procedure translates the substructure data to Nastran DMIG coefficients and creates a Nastran bulk data file with the extension **`.bdf`**.

Summary of Abaqus keywords translated

In the *ELEMENT usages listed below, an italicized *x* indicates that all Abaqus elements beginning with the preceding label will be mapped to the Nastran entity shown. For example, the statement *ELEMENT, C3D4*x* indicates that the selected Abaqus-to-Nastran translation applies to the Abaqus elements C3D4, C3D4H, and C3D4T.

Table 3.2.27–1 Abaqus keyword–to–Nastran mapping.

Abaqus Keyword	Nastran Complement
*BEAM GENERAL SECTION, SECTION=GENERAL	PBAR
*BOUNDARY	SPC
*CLOAD	FORCE
*COUPLING, DISTRIBUTING	RBE3
*COUPLING, KINEMATIC	RBE2

Abaqus Keyword	Nastran Complement
*ELEMENT, B31	CBAR (for *BEAM GENERAL SECTION, SECTION=GENERAL)
*ELEMENT, B33	CBAR (for *BEAM GENERAL SECTION, SECTION=GENERAL)
*ELEMENT, C3D4*x*	CTETRA
*ELEMENT, C3D10*x*	CTETRA
*ELEMENT, C3D6*x*	CPENTA
*ELEMENT, C3D15*x*	CPENTA
*ELEMENT, C3D8*x*	CHEXA
*ELEMENT, C3D20*x*	CHEXA
*ELEMENT, MASS	CONM2
*ELEMENT, ROTARYI	CONM2
*ELEMENT, S3*x*	CTRIA3
*ELEMENT, S4*x*	CQUAD4
*ELEMENT, S8*x*	CQUAD8
*ELEMENT, SPRING1 or SPRING2	CELAS
*ELEMENT, SPRINGA	CROD
*ELEMENT, STRI65	CTRIA6
*ELEMENT, T3D2	CROD
*FREQUENCY	SOL 103
*HEADING	TITLE
*MATERIAL, DENSITY	MAT1
*MATERIAL, ELASTIC, TYPE=ISO	MAT1
*MATERIAL, ELASTIC, TYPE=LAMINA	MAT8
*MATERIAL, EXPANSION, TYPE=ISO	MAT1
*MATERIAL, EXPANSION, TYPE=ORTHO	MAT8
*NODE	GRID
*ORIENTATION, DEFINITION=COORDINATES	CORD2R, CORD2C, or CORD2S

Abaqus Keyword	Nastran Complement
*SHELL GENERAL SECTION (Non-composite)	PSHELL
*SHELL SECTION (Non-composite)	
*SHELL SECTION (Composite)	PCOMP
*SHELL GENERAL SECTION (Composite)	
*SOLID SECTION	PSOLID
*SOLID SECTION (Trusses)	PROD
*STATIC	SOL 101
*SYSTEM	CORD2R, CORD2C, or CORD2S
*TRANSFORM	

Command summary

abaqus tonastran **job**=*job-name* [**input**=*input-file*] [**substructure**] [**complex**={**YES** | **NO**}]

Command line options

job

This option is used to specify the name of the Nastran bulk data file to be output by the translator. It is also the default name of the Abaqus file. Diagnostics created by the translator are written to a file named *job-name*`.log`.

input

This option is used to specify the name of the file containing the Abaqus data if it is different from *job-name*.

substructure

This option is used to translate a substructure within an Abaqus `.sim` file into Nastran bulk data file (`.bdf`) format.

complex

This option is used to determine how structural damping terms are represented. If **complex**=**YES** (default), structural damping terms are written as the imaginary part of the stiffness matrix; if **complex**=**NO**, structural damping terms are written as a separate real matrix.

3.2.28 TRANSLATING ANSYS INPUT FILES TO Abaqus INPUT FILES

Products: Abaqus/Standard Abaqus/Explicit

Reference

- "Execution procedure for Abaqus: overview," Section 3.1.1

Overview

The translator from ANSYS to Abaqus converts certain entities in an ANSYS blocked coded database file into their equivalent in an Abaqus input file.

Using the translator

The **abaqus fromansys** translator can convert ANSYS blocked coded database files (**.cdb**) into a "flat" Abaqus input file; that is, an Abaqus input file that is not written in terms of parts and assemblies. The **.cdb** file must be created in ANSYS using the following command:

```
CDWRITE , , <jobname>, cdb
```

The second field of the **CDWRITE** command may contain **ALL** or **DB**. The eighth field may contain **BLOCKED**. Any other use of the **CDWRITE** command will create problems for the translator.

Summary of ANSYS entities translated

The translator from ANSYS to Abaqus supports the mappings shown in the tables below.

Table 3.2.28–1 Nodal data mapping for ANSYS commands.

ANSYS command	Abaqus equivalent
NBLOCK	*NODE *TRANSFORM

Table 3.2.28–2 Element data mapping for ANSYS structural lines.

ANSYS command	Abaqus equivalent
LINK1	*ELEMENT, TYPE=T2D2
LINK8	*ELEMENT, TYPE=T3D2
LINK10	*ELEMENT, TYPE=T3D2

ANSYS command	Abaqus equivalent
LINK11	*ELEMENT, TYPE=T3D2
LINK180	*ELEMENT, TYPE=T3D2

Table 3.2.28–3 Element data mapping for ANSYS structural beams.

ANSYS command	Abaqus equivalent
BEAM3	*ELEMENT, TYPE=B21
BEAM4	*ELEMENT, TYPE=B31
BEAM23	*ELEMENT, TYPE=B21
BEAM24	*ELEMENT, TYPE=B31
BEAM188	*ELEMENT, TYPE=B31 or B32
BEAM189	*ELEMENT, TYPE=B32

Table 3.2.28–4 Element data mapping for ANSYS structural shells.

ANSYS command	Abaqus equivalent
SHELL43	*ELEMENT, TYPE=S4 or S3
SHELL63	*ELEMENT, TYPE=S4, S3, M3D4, or M3D3
SHELL93	*ELEMENT, TYPE=S8R or STRI65
SHELL181	*ELEMENT, TYPE=S4R or S3R

Table 3.2.28–5 Element data mapping for ANSYS structural pipes.

ANSYS command	Abaqus equivalent
PIPE16	*ELEMENT, TYPE=PIPE32
PIPE20	*ELEMENT, TYPE=PIPE31
PIPE59	*ELEMENT, TYPE=PIPE31

Table 3.2.28–6 Element data mapping for ANSYS planar elements.

ANSYS command	Abaqus equivalent
PLANE42 PLANE82 PLANE182 PLANE183	*ELEMENT, TYPE=CPS*n*, CAX*n*, or CPE*n*

Table 3.2.28–7 Element data mapping for ANSYS solid elements.

ANSYS command	Abaqus equivalent
SOLID45	*ELEMENT, TYPE=C3D8I, C3D4, or C3D6
SOLID65	*ELEMENT, TYPE=C3D8I, C3D4, or C3D6
SOLID92	*ELEMENT, TYPE=C3D10
SOLID95	*ELEMENT, TYPE=C3D20, C3D10, or C3D15
SOLID147	*ELEMENT, TYPE=C3D20, C3D10, or C3D15
SOLID148	*ELEMENT, TYPE=C3D10
SOLID185	*ELEMENT, TYPE=C3D8, C3D4, or C3D6
SOLID186	*ELEMENT, TYPE=C3D20R, C3D10, or C3D15
SOLID187	*ELEMENT, TYPE=C3D10

Table 3.2.28–8 Load and boundary condition data mapping.

ANSYS command	Abaqus equivalent
SFE, *ELEM*, *LKEY*, PRES, *KVAL*, *VAL1*, *VAL2*, *VAL3*, *VAL4*, where *VAL1=VAL2=VAL3=VAL4=n*	*SURFACE and *DSLOAD
SFE, *ELEM*, *LKEY*, HFLU, *KVAL*, *VAL1*, *VAL2*, *VAL3*, *VAL4*, where *VAL1=VAL2=VAL3=VAL4=n*	*SURFACE and *DSFLUX
BF, *NODE*, TEMP, *VAL1*, *VAL2*, *VAL3*, *VAL4*	*TEMPERATURE and *CFLUX

ANSYS command	Abaqus equivalent
BFE, *NODE*, HGEN, *STLOCVAL1*, *VAL2*, *VAL3*, *VAL4*	*DFLUX
ACEL, *1-component*, *2-component*, *3-component*	*DLOAD
F, *NODE*, *Lab*, *VALUE*, *VALUE2*, *NEND*, *NINC*, where *Lab*=FX, FY, or FZ	*CLOAD
D, *NODE*, *Lab*, *VALUE*, *VALUE2*, *NEND*, *NINC*, where *Lab*=UX ,UY, UZ, ROTX, ROTY, or ROTZ	*BOUNDARY

Table 3.2.28–9 Material data mapping.

ANSYS command	Abaqus equivalent
MPTEMP, … MPDATA, … , EX MPDATA, … , NUXY or PRXY	*MATERIAL and *ELASTIC Minor Poisson's ratios (such as NUXY), if present, are automatically converted to major Poisson's ratios (such as PRXY).
MPTEMP, …. MPDATA, … , EX MPDATA, … , EY MPDATA, … , EZ MPDATA, … , NUXY or PRXY MPDATA, … , NUXZ or PRXZ MPDATA, … , NUYZ or PRYZ MPDATA, … , GXY MPDATA, … , GXZ MPDATA, … , GYZ	*MATERIAL and *ELASTIC, TYPE=ENGINEERING CONSTANTS Minor Poisson's ratios (such as NUXY), if present, are automatically converted to major Poisson's ratios (such as PRXY).
MPTEMP, … MPDATA, … , KXX	*MATERIAL and *CONDUCTIVITY
MPTEMP, … MPDATA, … , DENS	*DENSITY
MPTEMP, … MPDATA, … , C	*SPECIFIC HEAT
MPTEMP, … MPDATA, … , CTEX or ALPX	*EXPANSION

Command summary

abaqus fromansys **job**=*job-name* [**input**=*input-file*]

Command line options

job

This option is used to specify the name of the Abaqus input file to be output by the translator. It is also the default name of the input file containing the ANSYS data. Diagnostics created by the translator will be written to a file named *job-name*`.log`.

input

This option is used to specify the name of the file containing the ANSYS data if it is different from *job-name*.

3.2.29 TRANSLATING PAM-CRASH INPUT FILES TO PARTIAL Abaqus INPUT FILES

Product: Abaqus/Explicit

Reference

- "Execution procedure for Abaqus: overview," Section 3.1.1

Overview

The translator from PAM-CRASH to Abaqus converts certain keywords in a PAM-CRASH input file into their equivalent in Abaqus/Explicit.

Using the translator

The translator requires an input file created by PAM-CRASH Version 2002 or later. The input file can have any name and extension.

The PAM-CRASH data entries that are translated are listed in the tables below. Other PAM-CRASH keywords and data are skipped over and noted in the log file.

The translator creates a partial Abaqus input file that contains only the model data. You must provide history data (including output data) to complete the input.

Element numbering and grouping

All elements must have unique element numbers. Elements that are assigned the same PART identification number are grouped together in an element set.

Except for connector elements that result from the translation of SPRING and KJOIN, section properties need to be entered in the PART section rather than individually in the element section. Elements that have different material or section properties should be given different PART identification numbers; that is, the same material and section properties must be applicable to all elements grouped in the same element set.

If elements that result from the translation of SPRING and KJOIN have different element data (such as frame numbers used to define local directions), and they are assigned the same PART identification number, the translator automatically separates them into different element sets.

Material models

The translator supports only the material models shown in Table 3.2.29–3. All unsupported material models between Types 1 and 99 are translated as bilinear elastic-plastic, and all other material types are translated as linear elastic if a stress-strain law definition is required. In these cases the translator provides nominal values for the material properties.

History section data

The translator creates a history section based partially on keywords (except TITLE) from the control section of the PAM-CRASH file as shown in Table 3.2.29–1. Other control data are unsupported.

Summary of PAM-CRASH entities translated

Table 3.2.29–1 Control section data.

PAM-CRASH keyword	Abaqus equivalent
TITLE	*HEADING
RUNEND	*DYNAMIC, EXPLICIT time period
TCTRL / DYNA_MASS_SCALE	*VARIABLE MASS SCALING
ECTRL / RATEFILTER	*MATERIAL, SRATE FACTOR

Table 3.2.29–2 Part section data.

PAM-CRASH keyword	Abaqus equivalent
PART / BAR	Truss element properties and grouping data
PART / BEAM	Beam element properties and grouping data
PART / SPRING	Connector behavior and grouping data
PART / KJOIN	Connector type, behavior, and grouping data
PART / SOLID	Solid element properties and grouping data
PART / SHELL	Shell element properties and grouping data
PART / MEMBR	Membrane element properties and grouping data
PART / TIED	Mesh tie constraint data and parameters
PART / PLINK	Mesh-independent fastener data and parameters

Table 3.2.29–3 Material section data.

PAM-CRASH keyword	Abaqus equivalent
MATER / Types 1, 16, 41, 99	C3D4/C3D6/C3D8R; solid material model data
MATER / Types 100, 101, 102, 103, 105	S3RS/S4RS; shell material model data
MATER / Types 150, 151	M3D3/M3D4/M3D4R and *USER MATERIAL
MATER / Types 200, 201, 202	T3D2/B31; beam and truss material model data

PAM-CRASH keyword	Abaqus equivalent
MATER / Types 203, 204, 205, 230	CONN3D2; connector behavior data
MATER / Types 212, 213	B31; beam material model data
MATER / Type 302[1]	CONN3D2; connector behavior data
[1] Material type 302 supports the use of a rupture model (see RUPMO in Table 3.2.29–10).	

Table 3.2.29–4 Node section data.

PAM-CRASH keyword	Abaqus equivalent
FRAME	*ORIENTATION and *TRANSFORM
NODE	*NODE
MASS	*MASS and *ROTARY INERTIA
NSMAS	*NONSTRUCTURAL MASS
INVEL	*INITIAL CONDITIONS, TYPE=VELOCITY or ROTATING VELOCITY
BOUNC	*BOUNDARY
DIS3D	*BOUNDARY and *AMPLITUDE
VEL3D	*BOUNDARY and *AMPLITUDE
DAMP	*DLOAD and *AMPLITUDE
TRSFM	*NODE with transformed coordinates

Table 3.2.29–5 Element section data.

PAM-CRASH keyword	Abaqus equivalent
SOLID	C3D4/C3D6/C3D8R and *SOLID SECTION
TETR4	C3D4 and *SOLID SECTION
SHELL	S3RS/S4RS and *SHELL SECTION
MEMBR	M3D3/M3D4R and *MEMBRANE SECTION
BEAM	B31 and *BEAM SECTION, SECTION=CIRC
BAR	For MATER / Types 203 and 204: CONN3D2 and *CONNECTOR SECTION [AXIAL] For all other MATER / Types: T3D2 and *SOLID SECTION

PAM-CRASH keyword	Abaqus equivalent
SPRING	CONN3D2 and *CONNECTOR SECTION [CARTESIAN + CARDAN]
KJOIN	CONN3D2 and *CONNECTOR SECTION
PLINK	*FASTENER and *FASTENER PROPERTY; CONN3D2 and *CONNECTOR SECTION

Table 3.2.29–6 Constraint section data.

PAM-CRASH keyword	Abaqus equivalent
RWALL (Stationary, segmented finite rigid wall) Velocity flag=0 Wall description=20	*RIGID BODY and *CONTACT
RBODY Types 0, 3	*RIGID BODY and/or *MPC (type BEAM) To define a group of elements as a rigid body, enter the part identification number of that element group as the PART entity[1]. To define an element as a rigid body, enter the element number as the ELE entity or enter all the element node numbers as the NOD entity[2].
RBODY Type 1	CONN3D2, *CONNECTOR SECTION [PROJECTION CARTESIAN + PROJECTION FLEXION-TORSION], *CONNECTOR DAMAGE INITIATION, and *CONNECTOR DAMAGE EVOLUTION
CNTAC Sliding interface types: 33, 34, 36, 37, 46	*CONTACT, *CONTACT INCLUSIONS, *CONTACT EXCLUSIONS, *CONTACT PROPERTY ASSIGNMENT, *CONTACT FORMULATION, *SURFACE INTERACTION, and *SURFACE PROPERTY ASSIGNMENT
TIED	*TIE

[1] If PART entities are used to define a rigid body, RBODY is translated as *RIGID BODY.

[2] If the ELE and NOD entities constitute all elements in a part, RBODY is translated as *RIGID BODY. If the ELE and NOD entities do not constitute all elements in a part (i.e., if the part consists of both rigid and deformable elements), RBODY is translated as *MPC (MPC type BEAM), a beam-type multi-point constraint for the set of nodes that consists of all input NOD entities and nodes extracted from all ELE entities.

Table 3.2.29–7 Nodes/faces/elements entity selection data.

PAM-CRASH keyword	Abaqus equivalent
ELE	*ELSET; data for elements to be grouped in a set using *ELSET
PART	Data for selecting element sets (*ELSET) already defined
NOD	Data for nodes to be grouped in a set using *NSET
ELE>NOD	Same procedure as ELE
PART>NOD	Same procedure as PART
DELELE	*ELSET and *NSET
DELPART	*ELSET and *NSET
DELNOD	*ELSET and *NSET
GRP	Named set of entities defined in GROUP

Table 3.2.29–8 Airbag data.

PAM-CRASH keyword	Abaqus equivalent
GASPEC	*FLUID BEHAVIOR, *MOLECULAR WEIGHT, and *CAPACITY
BAGIN	*PHYSICAL CONSTANTS and *FLUID CAVITY
GEN_INI_COND	*INITIAL CONDITIONS
GAS	*FLUID CAVITY, BEHAVIOR or MIXTURE
CHAMBER	*NODE, NSET=*ref_node_name*; *SURFACE, TYPE=ELEMENT; and *FLUID CAVITY
EXT_SKIN	M3D3/M3D4 and *SURFACE, TYPE=ELEMENT
WALL_OPENING	*FLUID EXCHANGE, *FLUID EXCHANGE ACTIVATION, and *FLUID EXCHANGE PROPERTY
WALL_FABRIC	*FLUID EXCHANGE, *FLUID EXCHANGE ACTIVATION, and *FLUID EXCHANGE PROPERTY
LEAKAGE	*FLUID EXCHANGE, *FLUID EXCHANGE ACTIVATION, and *FLUID EXCHANGE PROPERTY

PAM-CRASH keyword	Abaqus equivalent
INI_COND	*INITIAL CONDITIONS
INFLATOR	*FLUID INFLATOR, *FLUID INFLATOR ACTIVATION, *FLUID INFLATOR MIXTURE, and *FLUID INFLATOR PROPERTY

Table 3.2.29–9 Seat belt data.

PAM-CRASH keyword	Abaqus equivalent
SLIPR	*ELEMENT, TYPE=CONN3D2; *CONNECTOR SECTION; and *BOUNDARY
RETRA	*ELEMENT, TYPE=CONN3D2; *CONNECTOR SECTION; and *BOUNDARY

Table 3.2.29–10 Miscellaneous data.

PAM-CRASH keyword	Abaqus equivalent
GROUP	Convert entities to Abaqus equivalents
METRIC	*INITIAL CONDITIONS, TYPE=REF COORDINATE
SENSOR	Type-1: use activation time in *AMPLITUDE Type-4: use belt feed rate in *CONNECTOR LOCK
FUNCT	Data for material properties and time-dependent parameters, such as *AMPLITUDE, *CONNECTOR ELASTICITY, *PLASTIC, and *FLUID EXCHANGE PROPERTY
RUPMO	Data for connector behavior, such as *CONNECTOR DAMAGE INITIATION, *CONNECTOR DAMAGE EVOLUTION, *CONNECTOR POTENTIAL, and *CONNECTOR HARDENING
THELE	Element sets defined as *ELSET; output quantities are not specified for the element set
THNOD	Node sets defined as *NSET; output quantities are not specified for the node set

Command summary

abaqus frompamcrash **job**=*job-name*
input=*input-file*
[**pLinkConnectors**={**OFF** | **ON**}]
[**splitAirbagElements**={**OFF** | **ON**}]
[**autoKJoinStops**={**OFF** | **ON**}]

Command line options

job

This option is used to specify the name of the Abaqus input file to be output by the translator. The name of the Abaqus input file must be given without the **.inp** extension. Diagnostics created by the translator are written to a file named *job-name***_frompam.log**.

input

This option is used to specify the name of the file containing the PAM-CRASH data. The name of the file must be given with the file extension.

pLinkConnectors

This option is used to specify the inclusion of connector elements in the PLINK translation. The default value is **ON**.

splitAirbagElements

This option is used to specify the splitting of 4-node airbag membrane elements into two 3-node airbag membrane elements. The default value is **ON**. Airbag membrane elements result from the translation of MEMBR and MATER / Types 150 and 151. This option is valid only if the keyword BAGIN is specified in the PAM-CRASH input file.

autoKJoinStops

This option is used to add connector stops to the behavior of all KJOIN connector elements. If the stiffness interpolated at an endpoint on the force-displacement curve exceeds the stiffness interpolated at an adjacent point by a factor of 10, a connector stop is defined at the point adjacent to the endpoint. The default value is **OFF**.

3.2.30 TRANSLATING RADIOSS INPUT FILES TO PARTIAL Abaqus INPUT FILES

Product: Abaqus/Explicit

Reference

- "Execution procedure for Abaqus: overview," Section 3.1.1

Overview

The translator from RADIOSS to Abaqus converts certain keywords in a RADIOSS input file into their equivalent in Abaqus/Explicit.

Using the translator

The translator requires an input file in block format created by RADIOSS Version 4.4 or 5.1. The input file can have any name and an optional extension.

The RADIOSS data entries that are translated are listed in the tables below. Other RADIOSS keywords and data are skipped over and noted in the log file.

The translator creates a partial Abaqus input file that contains only the model data and time history output data. You can provide additional output data to complete the input.

Element numbering and grouping

All elements in the generated Abaqus input file will have unique element numbers. New element numbers will be assigned automatically to elements with non-unique element numbers in the RADIOSS input. Elements that are assigned the same PART identification number are grouped together in an element set.

Elements that have different material or properties must be given different PART identification numbers; that is, the same material and properties must be applicable to all elements grouped in the same element set.

If elements that result from the translation of SPRING have different element properties (such as skew systems used to define local directions) and are assigned the same PART identification number, the translator automatically separates them into different element sets.

Material models

The translator supports only the material models shown in Table 3.2.30–1. All unsupported material models are translated as linear elastic if a stress-strain law definition is required. In these cases the translator provides nominal values for the material properties.

Summary of RADIOSS entities translated

Table 3.2.30–1 Material data.

RADIOSS keyword	Abaqus equivalent
MAT / LAW01 (ELAST)	*ELASTIC
MAT / LAW02 (PLAS_JOHN)	*PLASTIC, HARDENING=JOHNSON COOK
MAT / LAW03 (HYDPLA)	*EOS, *TENSILE FAILURE, *DAMAGE INITIATION, and *DAMAGE EVOLUTION
MAT / LAW19 (FABRI)	*USER MATERIAL
MAT / LAW22 (DAMA)	*PLASTIC, HARDENING=JOHNSON COOK; *RATE DEPENDENT, TYPE=JOHNSON COOK; *DAMAGE INITIATION; and *DAMAGE EVOLUTION
MAT / LAW35 (FOAM_VISC)	*HYPERFOAM and *VISCOELASTIC
MAT / LAW36 (PLAS_TAB)	*PLASTIC, HARDENING=ISOTROPIC

Table 3.2.30–2 Property data.

RADIOSS keyword	Abaqus equivalent
PROP / TRUS	Truss element properties and grouping data
PROP / BEAM	Beam element properties and grouping data
PROP / SPRING	Connector behavior and grouping data
PROP / SPR_BEAM	Connector behavior and grouping data
PROP / SPR_GENE	Connector behavior and grouping data
PROP / SOLID	Solid element properties and grouping data
PROP / SOL_ORTH	Solid element properties and grouping data
PROP / SHELL	Shell element properties and grouping data
PROP / SH_ORTH	Shell element properties and grouping data

Table 3.2.30–3 Nodal data.

RADIOSS keyword	Abaqus equivalent
NODE	*NODE
ADMAS	*MASS and *ROTARY INERTIA

RADIOSS keyword	Abaqus equivalent
BCS	*BOUNDARY
IMPDISP	*BOUNDARY and *AMPLITUDE
IMPVEL	*BOUNDARY and *AMPLITUDE
INIVEL	*INITIAL CONDITIONS, TYPE=VELOCITY or ROTATING VELOCITY
CLOAD	*CLOAD and *AMPLITUDE
GRAV	*DLOAD and *AMPLITUDE
SKEW	*ORIENTATION and *TRANSFORM
FRAME	*ORIENTATION and *TRANSFORM

Table 3.2.30–4 Element data.

RADIOSS keyword	Abaqus equivalent
BRICK	C3D4/C3D6/C3D8R and *SOLID SECTION
SHELL[1]	S3RS/S4RS and *SHELL SECTION; or M3D3/M3D4/M3D4R and *MEMBRANE SECTION
SH3N[1]	S3RS and *SHELL SECTION; or M3D3 and *MEMBRANE SECTION
BEAM	B31 and *BEAM SECTION, SECTION=CIRC
TRUSS	T3D2 and *SOLID SECTION
SPRING	CONN3D2 and *CONNECTOR SECTION
[1] Shell elements with one integration point through the thickness are translated as membrane elements.	

Table 3.2.30–5 Constraint data.

RADIOSS keyword	Abaqus equivalent
RWALL	*RIGID BODY and *CONTACT
RBODY	*RIGID BODY and/or *MPC (type BEAM) To define an element as a rigid body, enter all the element node numbers in the node group associated with the rigid body.

RADIOSS keyword	Abaqus equivalent
INTER / Type 2	*TIE and *FASTENER
INTER / Types 7, 10, 11	*CONTACT, *CONTACT CONTROLS ASSIGNMENT, *CONTACT FORMULATION, *CONTACT INCLUSIONS, *CONTACT EXCLUSIONS, *CONTACT PROPERTY ASSIGNMENT, *SURFACE INTERACTION, and *SURFACE PROPERTY ASSIGNMENT
CYL_JOINT	CONN3D2 and *CONNECTOR SECTION

Table 3.2.30–6 Group data.

RADIOSS keyword	Abaqus equivalent
SUBSET	*ELSET; data for elements to be grouped in a set using *ELSET
PART	*ELSET; data for elements to be grouped in a set using *ELSET
MAT	*ELSET; data for elements to be grouped in a set using *ELSET
PROP	*ELSET; data for elements to be grouped in a set using *ELSET
NODE	*NSET; data for elements to be grouped in a set using *NSET
SH3N	*ELSET; data for elements to be grouped in a set using *ELSET
SHEL	*ELSET; data for elements to be grouped in a set using *ELSET
GRNOD	*NSET; data for elements to be grouped in a set using *NSET
GRSH3N	*ELSET; data for elements to be grouped in a set using *ELSET
GRSHEL	*ELSET; data for elements to be grouped in a set using *ELSET
GRSPRI	*ELSET; data for elements to be grouped in a set using *ELSET
GENE	*NSET; data for elements to be grouped in a set using *NSET

RADIOSS keyword	Abaqus equivalent
SEG	*ELSET; data for elements to be grouped in a set using *ELSET
SURF	*ELSET and *NSET

Table 3.2.30–7 Monitored volume and seat belt data.

RADIOSS keyword	Abaqus equivalent
MONVOL / GAS MONVOL / AIRBAG	*FLUID BEHAVIOR, *FLUID CAVITY, *FLUID EXCHANGE, *FLUID EXCHANGE ACTIVATION, *FLUID EXCHANGE PROPERTY, *FLUID INFLATOR, *FLUID INFLATOR ACTIVATION, *FLUID INFLATOR MIXTURE, *FLUID INFLATOR PROPERTY, *MOLECULAR WEIGHT, *CAPACITY, and *PHYSICAL CONSTANTS
SPRING with property SPR_PUL	*ELEMENT, TYPE=CONN3D2; *CONNECTOR SECTION; and *BOUNDARY

Table 3.2.30–8 Miscellaneous data.

RADIOSS keyword	Abaqus equivalent
TITLE	*HEADING
ACCEL	CONN3D2 and connector type ACCELEROMETER
FUNCT	Data for material properties and time-dependent parameters, such as *AMPLITUDE, *CONNECTOR ELASTICITY, *PLASTIC, and *FLUID EXCHANGE PROPERTY
SECT	*INTEGRATED OUTPUT SECTION
SENSOR / Type 0	Use activation time in *AMPLITUDE
TH	Data for time history output, such as *OUTPUT, HISTORY; *NODE OUTPUT; *ELEMENT OUTPUT; and *ENERGY OUTPUT

Command summary

abaqus fromradioss **job**=*job-name* **input**=*input-file*
[**splitAirbagElements**={**OFF** | **ON**}]
[**readAbaqusDat**=*data-file*] [**userDefaultMass**=*real-number*]
[**userDefaultInertia**=*real-number*] [**userHistoryTime**=*real-number*]

Command line options

job

This option is used to specify the name of the Abaqus input file to be output by the translator. The name of the Abaqus input file must be given without the **.inp** extension. Diagnostics created by the translator are written to a file named *job-name***_fromradioss.log**.

input

This option is used to specify the name of the file containing the RADIOSS data. The file extension is optional.

splitAirbagElements

This option is used to specify the splitting of 4-node airbag membrane elements into two 3-node airbag membrane elements. The default value is **ON**. Airbag membrane elements result from the translation of SHELL or SH3N with one integration point through the thickness. This option is valid only if the keyword MONVOL/AIRBAG is specified in the RADIOSS input file.

readAbaqusDat

This option enables the use of an Abaqus data (**.dat**) file from a previous Abaqus analysis to reformulate spot weld definitions. The data file should identify spot welds that could not be formed. Using this option, the attachment points for the identified spot welds are translated using distributed coupling constraints.

userDefaultMass

This option is used to specify the nodal mass that is assigned to additional nodes generated during the translation that require nonzero mass. This value should be small (typically 10^{-6} times the mass for the entire model). If this option is omitted, the default mass is set to 10^{-4}.

userDefaultInertia

This option is used to specify the rotary inertia that is assigned to additional nodes generated during the translation that require nonzero rotary inertia. This value should be small (typically 10^{-6} times the inertia for the entire model). If this option is omitted, the default rotary inertia is set to 10^{-3}.

userHistoryTime

This option is used to specify the time interval used for time history output. If this option is omitted, the time history interval is set to 10^{-5}.

3.2.31 TRANSLATING Abaqus OUTPUT DATABASE FILES TO NASTRAN OUTPUT2 RESULTS FILES

Product: Abaqus/Standard

Reference

- "Execution procedure for Abaqus: overview," Section 3.1.1

Overview

The translator converts certain results from an Abaqus output database **(.odb)** file to the Nastran Output2 file format.

Using the translator

The toOutput2 translator can only be used to translate Abaqus output database of a *STATIC or *FREQUENCY procedure. Results from an Abaqus analysis are written to the Abaqus output database by using the *OUTPUT option. The following options should be included in the Abaqus input file to ensure that the results to be translated are available in the Abaqus output database:

```
*OUTPUT, FIELD
*NODE OUTPUT
U,
RF,
CF,
*ELEMENT OUTPUT
S,
E,
SF,
NFORC,
```

Results in the Abaqus output database other than those specified above are skipped during translation. Only results from spring elements and three-dimensional continuum, shell, membrane, beam, and truss elements are translated.

For shell elements, the translator treats stresses and strains at the lowest numbered section point as being at the bottom surface and stresses and strains at the highest numbered section point as being at the top surface. Midsurface stresses and strains translated to the Output2 file are computed as the averages of the stresses and strains at the bottom and top surfaces.

Nodal results are always in global coordinates. Element tensor results are in the Abaqus element coordinate system.

Model data from the output database (nodal coordinates, element topology, material properties, and element properties) are written to the Output2 file when applicable records exist.

Command summary

abaqus toOutput2 **job**=*job-name*
[**odb**=*odb-name*] [**step**=*step-number*]
[**increment**=*increment-number*] [**slim**] [**quad4corner**]

Command line options

job

This option specifies the name of the Nastran Output2 file to be created by the translator. It is also the default name for the Abaqus output database.

odb

This option specifies the name of the Abaqus output database if it is different from *job-name*.

step

This option specifies the step number of the Abaqus output database for the translator to translate. If the specified step contains multiple load cases, all of the load cases are translated. The default value is the last step of the analysis.

increment

This option is valid only when used in conjunction with the **step** option. It is used to specify the increment number of the step in the Abaqus output database for the translator to translate. The default value is the last increment of the specified step.

slim

This option is used to include data blocks required for postprocessing in the SLIM/VISION software (available from Third Millennium Productions, Inc.) in the Output2 file.

quad4corner

This option is used to request shell output at corner nodes instead of at the centroid. This option is relevant for stress, strain, and section force output.

3.2.32 TRANSLATING LS-DYNA DATA FILES TO Abaqus INPUT FILES

Product: Abaqus/Explicit

Reference

- "Execution procedure for Abaqus: overview," Section 3.1.1

Overview

The translator from LS-DYNA to Abaqus converts a set of supported keywords in an LS-DYNA input file into their equivalent in Abaqus.

Using the translator

The translator supports translation of input files created by LS-DYNA Version 971 Rev 5 or earlier. The input file can have any name and an optional extension.

The LS-DYNA keywords that are supported are listed in the tables below. Other LS-DYNA keywords and data are skipped over and noted in the log file.

The translator creates an Abaqus input file that contains both the model data and history data. However, the translator does not create exact Abaqus equivalents for specific output quantities for nodal output, element output, and contact output; it uses preselected variables instead. You can provide additional output entities to complete the requests.

Element numbering and grouping

All elements in the generated Abaqus input file have unique element numbers. New element numbers are assigned automatically to elements with non-unique element numbers in the LS-DYNA input; all element number reassignments are noted in the log file.

Elements that are assigned the same PART identification number are grouped together in an element set. Elements that have different material or properties must be given different PART identification numbers; that is, the same material and properties must be applicable to all elements grouped in the same element set.

When a PART references a rigid material, the part is considered rigid. The element set that corresponds to the part is used in the rigid body definition.

Material models

The translator supports only the material models shown in Table 3.2.32–1. All unsupported material models are translated as linear elastic if a stress-strain law definition is required. In these cases the translator provides nominal values for the material properties.

Mapping LS-DYNA elements that end in _ID or _TITLE

Many LS-DYNA keywords include the options _ID, _TITLE, or both of these options. Unless the LS-DYNA keyword with _ID or _TITLE is specified in the mapping tables in this document, the translator maps data from these options to the same Abaqus keywords specified for the main LS-DYNA keyword.

Summary of LS-DYNA entities translated

The translator from LS-DYNA to Abaqus supports the mappings shown in the tables below.

Table 3.2.32–1 Material data.

LS-DYNA Keyword	Abaqus Equivalent
*MAT_BLATZ-KO_RUBBER	*HYPERELASTIC, NEO HOOKE
*MAT_CABLE_DISCRETE_BEAM	*ELASTIC
*MAT_DAMPER_NONLINEAR _VISCOUS	*CONNECTOR DAMPING, NONLINEAR
*MAT_DAMPER_VISCOUS	*CONNECTOR DAMPING
*MAT_ELASTIC	*ELASTIC
*MAT_ELASTIC_PLASTIC _THERMAL	*ELASTIC *PLASTIC *EXPANSION
*MAT_FU_CHANG_FOAM	*LOW DENSITY FOAM and *UNIAXIAL TEST DATA
*MAT_HONEYCOMB	Built-in **VUMAT** user material model ABQ_HONEYCOMB[1]
*MAT_JOHNSON_COOK	*PLASTIC, HARDENING=JOHNSON COOK *RATE DEPENDENT, TYPE=JOHNSON COOK *SHEAR FAILURE, TYPE=JOHNSON COOK *TENSILE FAILURE, TYPE=JOHNSON COOK
*MAT_LINEAR_ELASTIC _DISCRETE_BEAM	*CONNECTOR ELASTICITY and *CONNECTOR DAMPING
*MAT_LOW_DENSITY_FOAM	*HYPERFOAM and *UNIAXIAL TEST DATA

LS-DYNA Keyword	Abaqus Equivalent
*MAT_NULL	*ELASTIC Shell elements that reference a null material are translated as surface elements
*MAT_OGDEN_RUBBER	*HYPERELASTIC, OGDEN
*MAT_PIECEWISE_LINEAR _PLASTICITY	*PLASTIC
*MAT_PLASTIC_KINEMATIC	*PLASTIC, HARDENING=KINEMATIC
*MAT_RIGID	*ELASTIC *RIGID BODY (for LS-DYNA parts that refer to a rigid material)
*MAT_SEATBELT	*CONNECTOR ELASTICITY, NONLINEAR
*MAT_SPOTWELD	*CONNECTOR ELASTICITY, RIGID
*MAT_SPRING_ELASTIC	*CONNECTOR ELASTICITY
*MAT_SPRING_NONLINEAR _ELASTIC	*CONNECTOR ELASTICITY, NONLINEAR
*MAT_VISCOELASTIC	*VISCOELASTIC, TIME=PRONY
[1] For more information about using **ABQ_HONEYCOMB**, refer to "Abaqus/Explicit honeycomb material model," which is available in the Dassault Systèmes Knowledge Base at www.3ds.com/support/knowledge-base.	

Table 3.2.32–2 Part data.

LS-DYNA Keyword	Abaqus Equivalent
*PART *PART_PRINT	*ELSET and the corresponding type of element section
*PART_CONTACT	*SURFACE INTERACTION properties
*PART_INERTIA	*ELEMENT, TYPE=MASS *ELEMENT, TYPE=ROTARYI

Table 3.2.32–3 Auxiliary data.

LS-DYNA Keyword	Abaqus Equivalent
*DEFINE_COORDINATE_NODES	*ORIENTATION, DEFINITION=NODES
*DEFINE_COORDINATE _SYSTEM	*ORIENTATION, DEFINITION=COORDINATES
*DEFINE_COORDINATE _VECTOR	*ORIENTATION, DEFINITION=COORDINATES
*DEFINE_CURVE	Data from a single curve used in the following keywords: *AMPLITUDE *CONNECTOR DAMPING (nonlinear) *CONNECTOR ELASTICITY (nonlinear) *SURFACE BEHAVIOR *UNIAXIAL TEST DATA
*DEFINE_SD_ORIENTATION	*ORIENTATION
*DEFINE_TABLE	Multi-curve data used in conjunction with *PLASTIC and *LOW DENSITY FOAM in which the stress-strain relationship is defined for various strain rates

Table 3.2.32–4 Section data.

LS-DYNA Keyword	Abaqus Equivalent
*SECTION_BEAM	Beam elements: *BEAM SECTION or *BEAM GENERAL SECTION Truss elements: *SOLID SECTION
*SECTION_DISCRETE	*CONNECTOR SECTION
*SECTION_SEATBELT	*CONNECTOR SECTION
*SECTION_SHELL	Shell elements: *SHELL SECTION Membrane elements: *MEMBRANE SECTION Surface elements: *SURFACE SECTION

LS-DYNA Keyword	Abaqus Equivalent
*SECTION_SOLID	*SOLID SECTION
*SECTION_TSHELL	*SHELL SECTION

Table 3.2.32–5 Nodal data.

LS-DYNA Keyword	Abaqus Equivalent
*NODE	*NODE

Table 3.2.32–6 Output options data.

LS-DYNA Keyword	Abaqus Equivalent
*DATABASE_BINARY_D3PLOT	*OUTPUT, FIELD and *ELEMENT OUTPUT
*DATABASE_BINARY_D3THDT	*OUTPUT, FIELD and *ELEMENT OUTPUT
*DATABASE_DEFORC	*OUTPUT, FIELD and *ELEMENT OUTPUT
*DATABASE_ELOUT	*OUTPUT, FIELD and *ELEMENT OUTPUT
*DATABASE_NODOUT	*OUTPUT, FIELD and *NODE OUTPUT
*DATABASE_HISTORY_BEAM *DATABASE_HISTORY_BEAM_ID *DATABASE_HISTORY_BEAM_SET	*OUTPUT, HISTORY and *ENERGY OUTPUT
*DATABASE_HISTORY_NODE *DATABASE_HISTORY_NODE_ID *DATABASE_HISTORY_NODE_SET	*OUTPUT, HISTORY and *ENERGY OUTPUT
*DATABASE_HISTORY_SHELL *DATABASE_HISTORY_SHELL_ID *DATABASE_HISTORY_SHELL_SET	*OUTPUT, HISTORY and *ENERGY OUTPUT
*DATABASE_HISTORY_SOLID *DATABASE_HISTORY_SOLID_ID *DATABASE_HISTORY_SOLID_SET	*OUTPUT, HISTORY and *ENERGY OUTPUT

Table 3.2.32–7 Element data.

LS-DYNA Keyword	Abaqus Equivalent
*ELEMENT_BEAM	Beam elements: *ELEMENT, TYPE=B31 Truss elements: *ELEMENT, TYPE=T3D2
*ELEMENT_BEAM_PID	*ELEMENT, TYPE=CONN3D2 and *FASTENER
*ELEMENT_DISCRETE	*ELEMENT, TYPE=CONN3D2
*ELEMENT_MASS	*ELEMENT, TYPE=MASS and *MASS
*ELEMENT_SEATBELT	*ELEMENT, TYPE=CONN3D2
*ELEMENT_SHELL	Shell elements: *ELEMENT, TYPE=S3R or S4R Membrane elements: *ELEMENT, TYPE=M3D3 or M3D4R Surface elements (with *MAT_NULL): *ELEMENT, TYPE=SFM3D3 or SFM3D4R
*ELEMENT_SOLID	*ELEMENT, TYPE=C3D4, C3D6, C3D8R, or C3D10M
*ELEMENT_TSHELL	*ELEMENT, TYPE=SC6R or SC8R

Table 3.2.32–8 Prescribed conditions data.

LS-DYNA Keyword	Abaqus Equivalent
*BOUNDARY_PRESCRIBED _MOTION_NODE	*BOUNDARY, TYPE=DISPLACEMENT, VELOCITY, or ACCELERATION
*BOUNDARY_PRESCRIBED _MOTION_SET	*BOUNDARY, TYPE=DISPLACEMENT, VELOCITY, or ACCELERATION
*BOUNDARY_PRESCRIBED _MOTION_RIGID	*BOUNDARY for reference node of rigid body
*BOUNDARY_PRESCRIBED _MOTION_RIGID_LOCAL	*BOUNDARY for reference node of rigid body
*BOUNDARY_SPC_NODE	*BOUNDARY
*BOUNDARY_SPC_SET	*BOUNDARY

LS-DYNA Keyword	Abaqus Equivalent
*INITIAL_VELOCITY _GENERATION	*INITIAL CONDITIONS, TYPE=ROTATING VELOCITY
*INITIAL_VELOCITY_NODE	*INITIAL CONDITIONS, TYPE=VELOCITY

Table 3.2.32–9 Miscellaneous constraints data.

LS-DYNA Keyword	Abaqus Equivalent
*CONSTRAINED_NODE_SET	*EQUATION
*CONSTRAINED_NODAL_RIGID _BODY	*MPC type BEAM
*CONSTRAINED_EXTRA_NODES _NODE	Node set used as TIE NSET in the definition of *RIGID BODY
*CONSTRAINED_EXTRA_NODES _SET	Node set used as TIE NSET in the definition of *RIGID BODY
*CONSTRAINED_JOINT _CYLINDRICAL	*ELEMENT, TYPE=CONN3D2
*CONSTRAINED_JOINT _REVOLUTE	*ELEMENT, TYPE=CONN3D2
*CONSTRAINED_JOINT _SPHERICAL	*ELEMENT, TYPE=CONN3D2
*CONSTRAINED_JOINT _STIFFNESS_GENERALIZED	*ELEMENT, TYPE=CONN3D2 *CONNECTOR SECTION, BEHAVIOR
*CONSTRAINED_JOINT _TRANSLATIONAL	*ELEMENT, TYPE=CONN3D2
*CONSTRAINED_JOINT _UNIVERSAL	*ELEMENT, TYPE=CONN3D2
*CONSTRAINED_RIGID_BODIES	Merged element set used in the definition of *RIGID BODY
*CONSTRAINED_SPOTWELD	*MPC type BEAM

Table 3.2.32–10 Load data.

LS-DYNA Keyword	Abaqus Equivalent
*LOAD_BODY_PARTS	*ELSET for *DLOAD
*LOAD_BODY_X	*DLOAD
*LOAD_BODY_Y	*DLOAD
*LOAD_BODY_Z	*DLOAD
*LOAD_NODE_POINT	*CLOAD with node data
*LOAD_NODE_SET	*CLOAD with node set data

Table 3.2.32–11 Set data.

LS-DYNA Keyword	Abaqus Equivalent
*SET_NODE_LIST	*NSET with node data
*SET_NODE_LIST_GENERATE	*NSET with node data
*SET_PART	*ELSET with element set data
*SET_PART_LIST	*ELSET with element set data
*SET_PART_LIST_GENERATE	*ELSET with element set data
*SET_SEGMENT	*ELSET with element data
*SET_SHELL_LIST	*ELSET with element data
*SET_SHELL_LIST_GENERATE	*ELSET with element data
*SET_SOLID_LIST	*ELSET with element data

Table 3.2.32–12 Contact data.

LS-DYNA Keyword	Abaqus Equivalent
*CONTACT_AUTOMATIC_GENERAL	*CONTACT *CONTACT INCLUSIONS *CONTACT PROPERTY ASSIGNMENT *SURFACE INTERACTION *SURFACE PROPERTY ASSIGNMENT

LS-DYNA Keyword	Abaqus Equivalent
*CONTACT_AUTOMATIC _NODES_TO_SURFACE	*CONTACT *CONTACT INCLUSIONS *CONTACT PROPERTY ASSIGNMENT *SURFACE INTERACTION *SURFACE PROPERTY ASSIGNMENT
*CONTACT_AUTOMATIC _SINGLE_SURFACE	*CONTACT *CONTACT INCLUSIONS *CONTACT PROPERTY ASSIGNMENT *SURFACE INTERACTION *SURFACE PROPERTY ASSIGNMENT
*CONTACT_AUTOMATIC _SURFACE_TO_SURFACE	*CONTACT *CONTACT INCLUSIONS *CONTACT PROPERTY ASSIGNMENT *SURFACE INTERACTION *SURFACE PROPERTY ASSIGNMENT
*CONTACT_NODES_TO_SURFACE	*CONTACT *CONTACT INCLUSIONS *CONTACT PROPERTY ASSIGNMENT *SURFACE INTERACTION *SURFACE PROPERTY ASSIGNMENT
*CONTACT_RIGID_NODES_TO _RIGID_BODY	*CONTACT *CONTACT INCLUSIONS *CONTACT PROPERTY ASSIGNMENT *SURFACE INTERACTION *SURFACE PROPERTY ASSIGNMENT
*CONTACT_SINGLE_SURFACE	*CONTACT *CONTACT INCLUSIONS *CONTACT PROPERTY ASSIGNMENT *SURFACE INTERACTION *SURFACE PROPERTY ASSIGNMENT

LS-DYNA Keyword	Abaqus Equivalent
*CONTACT_SURFACE_TO_SURFACE	*CONTACT *CONTACT INCLUSIONS *CONTACT PROPERTY ASSIGNMENT *SURFACE INTERACTION *SURFACE PROPERTY ASSIGNMENT
*CONTACT_TIED_NODES _TO_SURFACE	*TIE
*CONTACT_TIED_SURFACE _TO_SURFACE	*TIE

Table 3.2.32–13 Miscellaneous data.

LS-DYNA Keyword	Abaqus Equivalent
*CONTROL _TERMINATION	Time period entered in *DYNAMIC, EXPLICIT
*END STEP	*END STEP
*KEYWORD	None
*TITLE	*HEADING
*INCLUDE	Process multiple LS-DYNA files

Command summary

abaqus fromdyna **job**=*job-name*
input=*dyna-input-file*
[**splitFile**={**OFF** | **ON**}]

Command line options

job

This option is used to specify the name of the Abaqus input file to be output by the translator. The name of the Abaqus input file must be given without the **.inp** extension. Diagnostics created by the translator are written to a file named *job-name*.**log**.

input

This option is used to specify the name of the file containing the LS-DYNA keyword data. The LS-DYNA input file can have an extension.

splitFile

This option specifies whether the Abaqus input file is to be split into multiple files. If **splitFile**=**ON**, the following files are output:

- **job-name_nodes.inc**: include file that contains the nodal data
- **job-name_elements.inc**: include file that contains the element data
- **job-name_model.inc**: include file that contains the remaining model data
- **job-name.inp**: Abaqus input file that includes all of the above include files and the history data

3.2.33 EXCHANGING Abaqus DATA WITH ZAERO

Product: Abaqus/Standard

Reference

- "Execution procedure for Abaqus: overview," Section 3.1.1

Overview

The **abaqus tozaero** interface enables you to exchange aeroelastic data between the Abaqus and ZAERO analysis products. By using this interface between the applications, you can perform structural modal analysis on a model in Abaqus, transfer the model to ZAERO for aeroelastic analysis, then transfer it back to Abaqus for stress analysis.

Universal file

The universal file is the means of data exchange between Abaqus and ZAERO. It consists of four data sets: 2411, which describes node and coordinate data; 2414, which describes mass-normalized mode shapes; 2420, which describes the global coordinate system; and 2453, which describes the mass matrix in text format, or 2453b, which describes the mass matrix in binary format.

You can specify the universal file's output format by using the **mode** parameter. Choosing text format enables you to modify the universal file in a text editor but increases the file size to over twice that of similar files in binary format. Text is the default format and the only format supported by ZAERO. Table 3.2.33–1 and Table 3.2.33–2 describe the mass matrix data set text format and binary format, respectively.

Table 3.2.33–1 Format for data set 2453 (text).

Record	Field	Description	Format
1	1	Matrix Identifier 1: DOF 131: Mass 139: Stiffness 147: Back-expansion	(I10)

Record	Field	Description	Format
2	1	Matrix Data Type 1: Integer 2: Real 4: Double Precision 5: Complex 6: Complex Double Precision	(6I10)
	2	Matrix Form 3: General Rectangular	
	3	Number of rows	
	4	Number of columns	
	5	Storage Key 1: Row 2: Column 11: Sparse (not supported for IMAT=1)	
	6	Matrix Size Parameter For IMAT=1 this is the number of dynamic modes. For sparse this is the number of matrix entries. Otherwise, 0.	
3 for storage keys 1 and 2	N/A	Matrix Data	For data type 1: (8 I10) For data type 2: (4 E20.12) For data type 4: (4 D20.12) For data type 5: (2 (2 E20.12)) For data type 6: (2 (2 D20.12))

Record	Field	Description	Format
3 for storage key 11	1	Row	For data type 1: (2 (2I10 1I10)) For data type 2: (2 (2I10 1E20.12)) For data type 4: (2 (2I10 1D20.12)) For data type 5: (1 (2I10 2E20.12)) For data type 6: (1 (2I10 2D20.12))
	2	Column	
	3	Value at cell	

Table 3.2.33–2 Format for data set 2453b (binary).

Record	Field	Description	Format
Header	1	2453	(I6)
	2	Lowercase b	(IA1)
	3	Byte Ordering Method 1: Little Endian (Windows and DOS) 2: Big Endian (most UNIX)	(I6)
	4	Floating Point Format 1: DEC VMS 2: IEEE 754 (UNIX) 3: IBM 5/370	(I6)
	5	Number of ASCII lines following 2 for data set 2453b	(I12)
	6	Number of bytes following ASCII lines	(I12)
	7–10	Not used (fill with zeros)	
1	1	Matrix Identifier 1: DOF 131: Mass 139: Stiffness 147: Back-expansion	(I10)

Record	Field	Description	Format
2	1	Matrix Data Type 1: Integer 2: Real 4: Double Precision 5: Complex 6: Complex Double Precision	(6I10)
	2	Matrix Form 3: General Rectangular	
	3	Number of rows	
	4	Number of columns	
	5	Storage Key 1: Row 2: Column 11: Sparse (not supported for IMAT=1)	
	6	Matrix Size Parameter For IMAT=1 this is the number of dynamic modes. For sparse this is the number of matrix entries. Otherwise, 0.	
3 (Binary Matrix Data)	1 (4 bytes)	Row	For data type 1: (2 Int32 1 Int32) For data type 2: (2 Int32 1 Flt32) For data type 4: (2 Int32 1 Dbl64) For data type 5: (2 Int32 2 Flt32) For data type 6: (2 Int32 2 Dbl64)
	2 (4 bytes)	Column	
	3	Value at cell	

Preparing the Abaqus analysis input file

Before the interface can create the universal file, you must make the following additions to your Abaqus input (**`.inp`**) file, then run Abaqus:

- Normalize the eigenvectors in the eigenfrequency extraction analysis with respect to the structure's mass matrix. This normalization is necessary because the translator assumes the mode shapes are mass normalized; if you skip this step before the Abaqus run, the modes translated will be incorrect and will give incorrect results with no warnings or errors. For more information, see "Natural frequency extraction," Section 6.3.5.
- Include the following line in the analysis step:

  `*ELEMENT MATRIX OUTPUT, ELSET=allelements, MASS=YES,`
  `OUTPUT FILE=USER DEFINED, FILE NAME=`*mtx-file-name*

  where **`allelements`** is a defined element set containing all the elements that should be included in the global mass matrix. The matrix output will be placed into the file *mtx-file-name*`.mtx`; you should not specify the **`.mtx`** extension since Abaqus adds it automatically.

Workflow

This section describes the input and output of the three main steps in the workflow between Abaqus and ZAERO.

Modal analysis in Abaqus

The Abaqus modal analysis uses an Abaqus input file and outputs the following data to an output database (**`.odb`**) file and matrix (**`.mtx`**) file: structural model nodes, coordinate systems, mode frequencies, generalized mass, mode shapes, and the mass matrix.

Aeroelastic analysis in ZAERO

Aeroelastic analysis requires a ZAERO input file and the universal file created by toZAERO. ZAERO outputs force and moment data on structural nodes due to aeroelastic forces to the universal file.

Stress analysis in Abaqus

The forces and moments output from ZAERO can then be used in a static (linear or nonlinear) Abaqus analysis to calculate deflections, stresses, and loads.

Command summary

abaqus tozaero

job=*job-name*
[**unvfile**=*unv-file-name*]
[**odbfile**=*odb-file-name*]
[**mtxfile**=*mtx-file-name*]
[**step**=*step-number*]
[**mode**={**`text`** | **`binary`**}]

Command line options

job

This option is used to specify the name of the Abaqus input file. It is also the default name for the universal output database and mass matrix files.

unvfile

This option is used to specify the name of the universal file if it is different from *job-name*. If the **`.unv`** extension is not supplied, Abaqus adds it automatically.

odbname

This option is used to specify the name of the Abaqus output database file if it is different from *job-name*. If the **`.odb`** extension is not supplied, Abaqus adds it automatically.

mtxfile

This option is used to specify the file containing the element mass matrices generated by Abaqus. If the **`.mtx`** extension is not supplied, Abaqus adds it automatically.

step

This option specifies the step number containing the eigenfrequency extraction results from Abaqus. The default value is 1.

Note: You must normalize the eigenvectors in the eigenfrequency extraction analysis with respect to the structure's mass matrix. For more information, see "Natural frequency extraction," Section 6.3.5.

mode

This option specifies the output format of the universal file. If this option is set equal to **`binary`**, Abaqus writes a portion of the universal file in binary format to save space. If this option is set equal to **`text`**, Abaqus writes the entire file in all text format. The default value is **`text`**, which is the only mode currently supported by ZAERO.

3.2.34 TRANSLATING Abaqus DATA TO MSC.ADAMS MODAL NEUTRAL FILES

Product: Abaqus/Standard

References

- "Execution procedure for Abaqus: overview," Section 3.1.1
- "Translating Abaqus data to modal neutral file format for analysis in MSC.ADAMS," Section 15.1.7 of the Abaqus Example Problems Guide

Overview

The ADAMS/Flex product from MSC.Software Corporation can be used to account for flexibility in a component when performing a dynamic analysis in MSC.ADAMS. ADAMS/Flex relies on a finite element analysis code such as Abaqus to provide the component's flexibility information in a form that is usable by MSC.ADAMS. The **abaqus adams** translator can be used to create Abaqus models of MSC.ADAMS components and to convert the Abaqus results into an MSC.ADAMS modal neutral (**`.mnf`**) file, the format required by ADAMS/Flex.

The **abaqus adams** translator requires a SIM file created by the current version of Abaqus.

Using the translator

The following procedure summarizes the typical usage of the **abaqus adams** translator:

1. Create an Abaqus model for each flexible component of the MSC.ADAMS model. Each component is modeled as an Abaqus substructure.
2. Run the Abaqus analysis. For more information, see "Preparing the substructure SIM database file."
3. Run the **abaqus adams** translator to read the substructure SIM database produced by the analysis and to create the modal neutral (**`.mnf`**) file for MSC.ADAMS.
4. Read the modal neutral file into MSC.ADAMS. A separate modal neutral file must be created for each flexible part in MSC.ADAMS.

Contents of the modal neutral file

The **abaqus adams** execution procedure translates data from a substructure SIM database (**`.sim`**) and creates an MSC.ADAMS modal neutral (**`.mnf`**) file. Depending on the contents of the results in the substructure SIM database and the translation parameters, the translator creates a modal neutral file containing the data blocks shown in Table 3.2.34–1.

Table 3.2.34–1 Modal neutral file contents.

Block Number	Contents	Created by the Translator
1	Version code	Yes
2	Header	Yes
3	Content summary	Yes
4	Nodal coordinates	Yes
5	<Not used>	N/A
6	Global mass properties	Yes
7	Eigenvalues	Yes
8	Mode shapes	Yes
9	Nodal masses	Yes
10	Nodal inertias	Yes
11	Units	Yes
12	Generalized stiffness matrix	Yes
13	Generalized mass matrix	Yes
14	Element faces	Yes
15	Generalized damping	Yes
16	Mode shape transformation	Yes
17	Interface nodes	Yes
18	Modal stress	Optional
19 to 26	Inertia invariants	Yes
27	Modal preload	No
28	Modal loads	Yes
29	Modal strain	Optional

Preparing the substructure SIM database file

This section describes the preparation of a substructure SIM database that will produce the results quantities required by ADAMS/Flex.

The Abaqus substructure model

The first step in accounting for a component's flexibility in MSC.ADAMS is to model that component as an Abaqus substructure. This process involves creating an Abaqus finite element model of the component. General guidelines for building Abaqus models with substructures are described in "Using substructures," Section 10.1.1.

Setting up the Abaqus model to create a modal neutral file

When you create a substructure to be translated to MSC.ADAMS, the substructure generation step must specify that you are working with a flexible body. In addition, if you want stress and/or strain to be translated to Adams, you must add the following data to the substructure generation step:

```
*ELEMENT RECOVERY MATRIX, POSITION=AVERAGED AT NODES
S,
E,
```

Units

The MSC.ADAMS programs require that you define the units used in the component model, while Abaqus does not. Therefore, during the creation of the modal neutral file you must declare the units used in the model explicitly. The approach to doing this in the **abaqus adams** execution procedure is very similar to the way it is done in the ADAMS/View **Units Settings** dialog box. A predefined units system can be specified by using the **units** option on the **abaqus adams** execution procedure. Alternatively, the individual length, mass, force, and time units can be specified by using the **length**, **mass**, **force**, and **time** options on the **abaqus adams** execution procedure. Any individual units that are specified override the corresponding units in the units system. The default units system is **mks**. The valid units systems for the **units** option are listed in Table 3.2.34–2.

Table 3.2.34–2 Valid units systems.

Units System	Length Units	Mass Units	Force Units	Time Units
mks	meters	kilograms	newtons	seconds
mmks	millimeters	kilograms	newtons	seconds
cgs	centimeters	grams	dyne	seconds
ips	inches	pound-mass	pound-force	seconds

The valid options for each of the **length**, **mass**, **force**, and **time** options are as follows:

Length units

Valid options for the length units are

- **meters**
- **millimeters**, **mm**

- **centimeters**, **cm**
- **kilometers**, **km**
- **inches**, **inch**, **in**
- **feet**, **foot**, **ft**
- **mile**

Mass units

Valid options for the mass units are

- **kilograms**, **kg**
- **megagram**, **tonne**
- **gram**, **g**
- **pound_mass**, **lbm**, **pound**
- **slug**
- **kpound_mass**
- **ounce_mass**

Force units

Valid options for the force units are

- **newtons**, **N**
- **knewton**, **kN**
- **kilogram_force**, **kgf**
- **dyne**
- **ounce_force**
- **pound_force**, **lbf**, **pound**
- **kpound_force**

Time units

Valid options for the time units are

- **seconds**, **sec**
- **milliseconds**, **ms**
- **minutes**, **min**
- **hours**

Default values for the units options can be defined in the Abaqus environment file (**abaqus_v6.env**). The default for the **units** option can be defined with the **adams_units_family** parameter. The defaults for the **length**, **mass**, **time**, and **force** options can be defined with the **adams_length_units**, **adams_mass_units**, **adams_time_units**, and **adams_force_units** parameters, respectively.

Translating modes with negative eigenvalues

Typically, for a non-prestressed, unrestrained substructure in three dimensions, you expect to find six rigid body modes with associated zero eigenvalues. The situation is, in general, different for prestressed substructures, which may have fewer than six modes with zero eigenvalues. Prestressing may change the expected zeroes into values that are significantly positive or negative, depending on the sign of the prestress.

By default, the translator deletes modes with negative eigenvalues and reorthogonalizes the reduced basis. If you want to retain modes with negative eigenvalues, define the environment variable **`MDI_MNFWRITE_OPTIONS`**.

- On UNIX platforms type the following command:

```
setenv MDI_MNFWRITE_OPTIONS negative_roots_OK
```

- On Windows platforms type the following command:

```
set MDI_MNFWRITE_OPTIONS=negative_roots_OK
```

In this case the translator will treat modes with negative eigenvalues in the same manner as all other modes.

To determine if a model will have negative eigenvalues when translated by the translator, you can add an eigenfrequency extraction step with no boundary conditions to the input file.

Command summary

abaqus adams **job**=*job-name*
[**substructure_sim**=*filename*]
[**model_odb**=*filename*]
[**units**=**`mmks`** | **`mks`** | **`cgs`** | **`ips`**]
[**length**=*length-units-name*]
[**mass**=*mass-units-name*]
[**time**=*time-units-name*]
[**force**=*force-units-name*]

Command line options

job

This option specifies the input and output file names to use during results translation. The *job-name* value is used to construct the default SIM database file name, *job-name*`.sim`. The output modal neutral file is given the name *job-name*`.mnf`.

If this option is omitted from the command line, the user will be prompted for this value.

substructure_sim

This option specifies the name of the substructure SIM database (**.sim**) file if it is different from *job-name*.**sim**. The file will usually be named *job-name*_**Z***nn*.**sim**.

model_odb

This option specifies the name of the model output database (**.odb**) file if it is different from *job-name*.**odb**.

units

This option specifies the units system for the model. The possible values are **mmks**, **mks**, **cgs**, or **ips**, which correspond to the ADAMS/View options with the same names. The default value is **mks**.

This option can be defined in the Abaqus environment file as follows:

adams_unit_family=*unit-family*

length

This option specifies the length units for the model. If this option is specified, it overrides the length units of the specified units system.

This option can be defined in the Abaqus environment file as follows:

adams_length_units=*length-unit*

mass

This option specifies the mass units for the model. If this option is specified, it overrides the mass units of the specified units system.

This option can be defined in the Abaqus environment file as follows:

adams_mass_units=*mass-unit*

time

This option specifies the time units for the model. If this option is specified, it overrides the time units of the specified units system.

This option can be defined in the Abaqus environment file as follows:

adams_time_units=*time-unit*

force

This option specifies the force units for the model. If this option is specified, it overrides the force units of the specified units system.

This option can be defined in the Abaqus environment file as follows:

adams_force_units=*force-unit*

3.2.35 ENCRYPTING AND DECRYPTING Abaqus INPUT DATA

Products: Abaqus/Standard Abaqus/Explicit

References

- "Execution procedure for Abaqus: overview," Section 3.1.1
- "Including an encrypted data file" in "Defining a model in Abaqus," Section 1.3.1
- *INCLUDE

Overview

You can use the **abaqus encrypt** utility to prevent the unauthorized use of Abaqus input data. The utility converts a data file into an encrypted, password-protected format that only authorized Abaqus input parties can access. The utility is intended for the encryption of data that you include by reference in input (`.inp`) files or in other data files. For example, you could encrypt a file that contains all of the proprietary material data for your model, then include the encrypted data file by reference in an unencrypted Abaqus input file. See "Including an encrypted data file" in "Defining a model in Abaqus," Section 1.3.1, for information on how to include an encrypted data file in an Abaqus input file.

You can encrypt any input file. However, Abaqus cannot run an encrypted Abaqus input file directly; the encrypted file must be included in an unencrypted file.

Specifying additional access levels and controls

You can customize your encryption so that only users with a license for a particular Abaqus feature or from a particular site can include or decrypt the file. For example, you can specify that only Abaqus/Standard users can access the file. You can also prevent decryption of an encrypted file by any user, regardless of their license and site; end users can still use the encrypted data in an analysis by including it by reference in an unencrypted Abaqus input file, provided that the users know the encrypted file's password.

Security and support considerations

The primary intent of the Abaqus encryption implementation is to prevent unauthorized use of encrypted input data, not to prevent disclosure of encrypted data to authorized users. Running an Abaqus analysis input using encrypted data may produce output files that are not encrypted. Only material and connector behavior information contained within an encrypted input file is prevented from being visible in the output. This approach means that recipients of encrypted data who satisfy the access criteria, such as the password, license feature, or SiteID, will be able to reconstruct some input in an unencrypted form. Providers of encrypted data should consider establishing contractual agreements to protect proprietary data. Users of encrypted data must accept responsibility for security of files produced from encrypted input and should consider restricting access to resulting analysis files.

Abaqus technical support cannot retrieve lost passwords for encrypted data files. Users receiving encrypted data should contact the data provider for any technical support issues.

Adding comments to the header of an encrypted file

When you encrypt a file, Abaqus adds the following unencrypted comment line to the beginning of the file:

```
** encrypted input
```

Do not modify or delete this header comment. You can, however, insert additional comment lines between this header comment and the first line of encrypted data. These post-encryption comment lines can describe the encrypted file's contents, provide release numbers, or display copyright and legal information about the encrypted data. For more information about comment line syntax, see "Input syntax rules," Section 1.2.1.

You should not, however, add post-encryption comment lines within the lines of encrypted data. If you want to edit or amend the comment lines within the data itself, you must first decrypt the data.

Command summary

abaqus {encrypt | decrypt} **input**=*input-file-name*
output=*output-file-name*
password=*password*
[**license**=*feature_list*] [**siteid**=*site-id_list*] [**include_only**]
[**expiration**=*expiration_date*]

Command line options

input

This option specifies the name of the data file that you want to encrypt or decrypt.

If you omit this option from the command line, Abaqus will prompt you for its value.

output

This option specifies the name of the data file after encryption or decryption.

If you omit this option from the command line, Abaqus will prompt you for its value.

password

This option specifies the password for this encryption or decryption. Passwords are case-sensitive.

If you omit this option from the command line while encrypting data, Abaqus will prompt you for its value. If you enter the password incorrectly or omit it from the command line while decrypting data, Abaqus reports that the input file is either corrupted or the password is incorrect.

license

This option applies only to file encryption.

This option specifies the Abaqus feature or features for which end users must be licensed if they want to include or decrypt this encrypted data file. You can use a comma-separated list to allow access to the file by licensees of any one of a series of Abaqus features.

Any feature name that appears in an Abaqus license file is valid. These might include the following features: **foundation**, **standard**, **explicit**, **design**, **aqua**, **ams**, **cae**, **viewer**, **cae_nogui**, **cmold**, **moldflow**, **safe**, **cadporter_catia**, **cadporter_catiav5**, **cadporter_ideas**, **cadporter_parasolid**, **cadporter_proe**, **afcv5_structural**, and **afcv5_thermal**.

siteid

This option applies only to file encryption.

This option specifies the Abaqus Site ID or IDs where end users can include or decrypt this encrypted data file. You can use a comma-separated list to allow multiple sites access to the file. You can use this option only when you also use the **license** option.

To determine your Abaqus Site ID, run **abaqus whereami** from a command prompt.

include_only

This option applies only to file encryption.

This option specifies that encrypted input data cannot be decrypted using the **abaqus decrypt** execution procedure; such data can only be included in an Abaqus input file.

If you attempt to decrypt a file that was encrypted with the **include_only** option, Abaqus issues an error message stating that the input file can be included in an analysis but is not eligible for decryption.

expiration

This option applies only to file encryption.

This option specifies the date after which the end users can no longer decrypt or include the encrypted data file. The date must be provided in the formYYYY-MM-DD.

Examples

The following examples illustrate the different encryption methods that are possible using the **encrypt** execution procedure.

Creating encrypted files

In the simplest encryption scenario an Abaqus user creates an encrypted copy of a file named **material_data.inp**, which contains all of the material data for a model, before sending the encrypted version to an authorized end user. Encryption prevents unauthorized users from accessing the encrypted file during its transmission. To create an encrypted copy of **material_data.inp** named **material_data_enc.inp**, issue the following command:

```
abaqus encrypt input=material_data.inp
   output=material_data_enc.inp password=e1No9c2z
```

Upon receiving the file, the end user can run the **abaqus decrypt** execution procedure to create a copy of the original, non-encrypted material data file. Because of the encryption options selected in this example,

the end user requires only the encrypted file's password to decrypt it. To decrypt the encrypted data file **material_data_enc.inp**, producing the non-encrypted file **material_data.inp**, issue the following command:

```
abaqus decrypt input=material_data_enc.inp
   output=material_data.inp password=e1No9c2z
```

Alternatively, the end user can skip the decryption and run an analysis that includes the encrypted data by reference. To include the encrypted file by reference in an Abaqus input file, add the following statement to the input file:

```
*INCLUDE, INPUT=material_data_enc.inp, PASSWORD=e1No9c2z
```

Limiting access to decrypted files by license feature or site ID

You can specify that end users cannot access the file unless they have a valid license for a particular Abaqus feature, run Abaqus at a particular site, or satisfy both of these criteria. To encrypt a data file that can be accessed only by users who have an Abaqus/Explicit license and who run the software at site **09YYY**, issue the following command:

```
abaqus encrypt input=material_data.inp
   output=material_data_enc.inp password=e1No9c2z
   license=explicit siteid=09YYY
```

An end user can attempt to access the file **material_data_enc.inp** using the same decryption or inclusion syntax specified in the previous example. For this encrypted file, Abaqus would validate that the end user has an Abaqus/Explicit license and is running Abaqus at site **09YYY** before providing access to the file. If the end user's license or site settings do not match those specified during encryption, Abaqus issues an error message that lists the licenses or sites that are required to access the file.

Creating encrypted files that must be included to be used by Abaqus

You can use the **include_only** option to prevent end users from decrypting the file directly using **abaqus decrypt**. Authorized users can access a file encrypted with the **include_only** option by including the file by reference in an Abaqus input file. Material and connector behavior definitions within an encrypted input file are not written to the output database. In addition, all material and connector behavior definitions output to the data file are suppressed if an encrypted file is used as input for any portion of the model. To create an encrypted file that is available only for inclusion by reference in other input files, issue the following command:

```
abaqus encrypt input=material_data.inp
   output=material_data_enc.inp password=e1No9c2z include_only
```

The resulting encrypted file can be included by reference in an Abaqus input file using the same syntax as in the previous example. If you attempt to decrypt a file that was encrypted with the **include_only** option, Abaqus returns an error message.

3.2.36 JOB EXECUTION CONTROL

Products: Abaqus/Standard Abaqus/Explicit

Reference

- "Execution procedure for Abaqus: overview," Section 3.1.1

Overview

The execution procedures for job execution control include **abaqus suspend**, **abaqus resume**, and **abaqus terminate**. These utilities are used to suspend, resume, and terminate Abaqus analysis jobs. Suspending an analysis job will stop its execution and release its license tokens to the free-token pool. Resuming an analysis will reactivate a suspended job and check out license tokens for that job if they are available. The job will be placed in the license queue if license tokens are not available. Terminating an analysis job will stop the executable for the analysis and release its license tokens. A terminated analysis job cannot be resumed.

Command summary

abaqus {suspend | resume | terminate} job=*job-name*

Command line options

Required option

job

This option is used to specify the name of the analysis job to suspend, resume, or terminate.

3.3 Environment file settings

- “Using the Abaqus environment settings,” Section 3.3.1

3.3.1 USING THE Abaqus ENVIRONMENT SETTINGS

Products: Abaqus/Standard Abaqus/Explicit

Reference

- "Execution procedure for Abaqus: overview," Section 3.1.1

Overview

The Abaqus environment settings allow you to control various aspects of an Abaqus job's execution. For example, you can

- "Tune" Abaqus to improve its performance by changing memory-related parameters.
- Control where and how scratch files are written.
- Provide default values for job parameters that would otherwise have to be given on the command line.

Many other aspects of a job's execution can be configured through the environment settings. Some of these are discussed in this section; others, which are mainly of interest to the Abaqus site manager, are discussed in detail in the Abaqus Installation and Licensing Guide.

Environment settings hierarchy

Abaqus environment settings are processed in the following order:

1. The host-level environment settings. These settings are applied to all Abaqus jobs run on the designated computer.
2. The user-level environment settings. These settings are applied to all Abaqus jobs run in your account.

   For Abaqus to locate the environment file in your home directory on Windows platforms, the full path to your home directory must be specified using the **`HOME`** environment variable or a combination of the **`HOMEDRIVE`** and **`HOMEPATH`** environment variables.
3. The job-level environment settings. These settings are applied to only the designated Abaqus job.

Environment settings can be specified more than once. The last value processed will be the one used for the setting if it is defined at more than one level or if it is given twice at the same level.

Abaqus environment settings are set using special files in specific directories. The host-level settings are set in the **`site`** directory in the **`abaqus`** account directory. You can change these settings by creating an environment file, **`abaqus_v6.env`**, in your home directory and/or the current directory. Settings in the home directory file will be applied to all jobs that you run. Settings in the current directory file will be applied only to jobs run from the current directory.

Syntax

The entries given in the environment file must be given using Python language syntax. Entries take the form:

```
parameter=value
```

The following is a brief overview of the Python syntax rules:

- The parameter must always have a value. The value can be any valid Python constant or expression.
- A string value must be enclosed in a pair of double or single quotes.
- Comments are preceded by a number sign (#). All characters following a number sign on a line are ignored. Number signs within a quoted string are part of the string, not the beginning of a comment.
- Blank lines are ignored.
- Embedded single quotes do not require special handling if they are placed within a double quoted string. For example, `"my value's"` is translated as `my value's`. The same holds true for double quotes embedded in a single quoted string. Quotes of the same type as the enclosing quotes can be embedded if they are prefixed by the backslash (\) character.
- Triple quoted (""") strings can span more than one line, and no special treatment of quotes within the string is necessary. Entries take the form:

  ```
  parameter="""
  multi-line
  value
  """
  ```

- Lists must be enclosed in parentheses (( )) or square brackets ([ ]). Individual items in the list are separated by commas. If the list is enclosed in parentheses and contains only one value, a comma has to follow the value. String list items must be enclosed in quotes. Entries take the form:

  ```
  parameter=(value1, value2, value3)
  ```

Troubleshooting

Problems caused by faulty environment settings can be diagnosed by using the command

```
abaqus information=environment
```

This command prints all of the current environment settings.

Command line default parameters

The following parameters provide default values for various settings that would otherwise have to be specified on the command line (see "Abaqus/Standard, Abaqus/Explicit, and Abaqus/CFD execution," Section 3.2.2, and "Abaqus/Standard, Abaqus/Explicit, and Abaqus/CFD co-simulation execution," Section 3.2.4). Values given on the command line override values specified in the environment files.

cpus

Number of processors to use if parallel processing is available. The default is **2** for the co-simulation execution procedure; otherwise, the default is **1**.

domains

The number of parallel domains in Abaqus/Explicit. If the value is greater than 1, the domain decomposition will be performed regardless of the values of the **parallel** and **cpus** parameters. However, if **parallel**=**domain**, the value of **cpus** must be evenly divisible into the value of **domains**. If this parameter is not set, the number of domains defaults to the number of processors used during the analysis run if **parallel**=**domain** or to 1 if **parallel**=**loop**.

double_precision

The default precision version of Abaqus/Explicit to run if you do not specify the precision version on the **abaqus** command line. Possible values are **EXPLICIT** (only the Abaqus/Explicit analysis is run in double precision), **BOTH** (both the Abaqus/Explicit packager and analysis are run in double precision), **CONSTRAINT** (the constraint packager and constraint solver in Abaqus/Explicit are run in double precision, while the Abaqus/Explicit packager and analysis continue to run in single precision), or **OFF** (both the Abaqus/Explicit packager and analysis are run in single precision). The default is **OFF**.

parallel

The default parallel method in Abaqus/Explicit if you do not specify the parallel method on the **abaqus** command line. Possible values are **DOMAIN** or **LOOP**; the default value is **DOMAIN**.

run_mode

Default run mode (interactive, background, or batch) if you do not specify the run mode on the **abaqus** command line. The default for **abaqus analysis** is **"background"**, while the default for **abaqus viewer** is **"interactive"**.

scratch

Directory to be used for scratch files. This directory must exist (i.e., it will not be created by Abaqus) and must have write permission assigned. On UNIX platforms the default value is the value of the **$TMPDIR** environment variable or **/tmp** if **$TMPDIR** is not defined. On Windows platforms the default value is the value of the **%TEMP%** environment variable or **\TEMP** if this variable is not defined. During the analysis a subdirectory will be created under this directory to hold the analysis scratch files. The name of the subdirectory is constructed from your user name, the job id, and the job's process identifier. The subdirectory and its contents are deleted upon completion of the analysis.

standard_parallel

The default parallel execution mode in Abaqus/Standard if you do not specify the parallel mode on the **abaqus** command line. If this parameter is set equal to **ALL**, both the element operations and

the solver will run in parallel. If this parameter is set equal to **SOLVER**, only the solver will run in parallel. The default parallel execution mode is **ALL**.

gpus

The GPGPU direct solver acceleration setting in Abaqus/Standard if you do not specify the GPGPU solver acceleration option on the **abaqus** command line. By default, GPGPU solver acceleration is not activated. The value of this parameter is the number of GPGPUs to be used in an Abaqus/Standard analysis. In an MPI-based analysis, this is the number of GPGPUs to be used on each host.

unconnected_regions

If this variable is set to **ON**, Abaqus/Standard will create element and node sets in the output database for unconnected regions in the model during a **datacheck** analysis. Element and node sets created with this option are named **MESH COMPONENT *N***, where *N* is the component number. The default value is **OFF**.

order_parallel

The ordering mode for the direct sparse solver in Abaqus/Standard if you do not specify the ordering mode on the **abaqus** command line. If this parameter is set equal to **OFF**, the ordering procedure will not run in parallel. If this parameter is set equal to **ON**, the ordering procedure will run in parallel. The default ordering mode is **ON**.

System resource parameters

The following environment file variable can be set after the code has been installed to change the resources used by Abaqus and, therefore, to improve system performance. By default, Abaqus detects the physical memory on a machine (or on each compute node in a cluster) and allocates a percentage of the available memory based on the machine platform (for details, refer to the Dassault Systèmes Knowledge Base at www.3ds.com/support/knowledge-base). You can override the default percentage by specifying a number followed by the percentage sign. The variable can also be defined as the number of megabytes or the number of gigabytes. More detailed information about changing the system resources used by Abaqus is given in "Managing memory and disk use in Abaqus," Section 3.4.1.

memory

Maximum amount of memory or maximum percentage of the physical memory that can be allocated during the input file preprocessing and during the Abaqus/Standard analysis phase. For parallel execution on computer clusters, this memory limit specifies the maximum amount of memory that can be allocated on each process.

System customization parameters

The following is a discussion of some additional environment file parameters that are commonly used. A complete listing of parameters can be found in the Abaqus Installation and Licensing Guide.

ask_delete

If this parameter is set equal to **OFF**, you will not be asked whether old job files of the same file name should be deleted; the files will be deleted automatically. The default value is **ON**.

auto_calculate

If this parameter is set equal to **ON**, the postprocessing calculator will be launched automatically at the end of an analysis if the execution procedure detects that output database file conversion is necessary. If this parameter is set to **OFF**, the postprocessing calculator will not run at the end of an analysis even if the execution procedure detects that it is necessary. The default value is **ON**.

auto_convert

If this parameter is set equal to **ON** and an Abaqus/Explicit analysis is run in parallel with **parallel**=**domain**, the **convert**=**select**, **convert**=**state**, and **convert**=**odb** options will be run automatically at the end of the analysis. The default value is **ON**.

average_by_section

This parameter is used only for an Abaqus/Standard analysis. If this parameter is set equal to **OFF**, the averaging regions for output written to the data (**.dat**) file and results (**.fil**) file are based on the structure of the elements. If this parameter is set equal to **ON**, the averaging regions also take into account underlying values of element properties and material constants. In problems with many section and/or material definitions the default value of **OFF** will, in general, give much better performance than the nondefault value of **ON**. See "Output to the data and results files," Section 4.1.2, for further details on the averaging scheme.

mp_host_list

List of host machine names to be used for an MPI-based parallel Abaqus analysis, including the number of processors to be used on each machine; for example,

```
mp_host_list=[['maple',1],['pine',1],['oak',2]]
```

indicates that, if the number of **cpus** specified for the analysis is 4, the analysis will use one processor on a machine called **maple**, one processor on a machine called **pine**, and two processors on a machine called **oak**. The total number of processors defined in the host list has to be greater than or equal to the number of **cpus** specified for the analysis. If the host list is not defined, Abaqus will run on the local system. When using a supported queuing system, this parameter does not need to be defined. If it is defined, it will get overridden by the queuing environment.

mp_mode

Set this variable equal to **MPI** to indicate that the MPI components are available on the system. Set **mp_mode**=**THREADS** to use the thread-based parallelization method. The default value is **MPI** where applicable.

odb_output_by_default

If this parameter is set equal to **ON**, output database output will be generated automatically. If this parameter is set equal to **OFF**, output database request keywords must be placed in an input file to obtain output database output. The default value is **ON**.

onCaeStartup

Optional function to be executed before Abaqus/CAE begins. See "Customizing Abaqus/CAE startup," Section 4.3.3 of the Abaqus Installation and Licensing Guide, for examples of this function.

Co-simulation parameters

The following environment file variables provide default settings for co-simulation between solvers using the direct coupling interface. This includes Abaqus/Standard to Abaqus/Explicit co-simulation and co-simulation between Abaqus and certain third-party analysis programs.

cosimulation_port

Set **cosimulation_port** equal to the port number used for the connection. The default value is **48000**.

cosimulation_timeout

Set **cosimulation_timeout** equal to the timeout period in seconds. Abaqus terminates if it does not receive any communication from the coupled analysis program during the time specified. The default value is **3600** seconds.

The following environment file variables provide settings that allow you to allocate CPUs for co-simulation jobs submitted using the co-simulation execution procedure. This includes Abaqus/Standard to Abaqus/Explicit, Abaqus/Standard to Abaqus/CFD, and Abaqus/CFD to Abaqus/Explicit co-simulation (see "Abaqus/Standard, Abaqus/Explicit, and Abaqus/CFD co-simulation execution," Section 3.2.4).

cpus_weight_std

This option controls the allocation of CPUs to Abaqus/Standard analyses. The actual CPU allocation for Abaqus/Standard analyses is made in proportion to this value and considering the settings of **cpus_weight_xpl**, **cpus_weight_cfd**, and **cpus**.

cpus_weight_xpl

This option controls the allocation of CPUs to Abaqus/Explicit analyses. The actual CPU allocation for Abaqus/Explicit analyses is made in proportion to this value and considering the settings of **cpus_weight_std**, **cpus_weight_cfd**, and **cpus**.

cpus_weight_cfd

This option controls the allocation of CPUs to Abaqus/CFD analyses. The actual CPU allocation for Abaqus/CFD analyses is made in proportion to this value and considering the settings of **cpus_weight_std**, **cpus_weight_xpl**, and **cpus**.

portpool

Set this variable equal to a colon-separated pair of TCP/UDP port numbers that represents the start and end value of port numbers to be used by the co-simulation execution procedure when establishing connections between the child processes.

Environment file examples

Example environment files that use some of the previously discussed parameters are shown below. A sample environment file, named **abaqusinc.env**, is included in the **site** subdirectory of the release to show the options used at SIMULIA.

UNIX environment file:

```
ask_delete=OFF
# The following parameter causes the scratch files to
# be written to /tmp.
scratch="/tmp"
```

Windows environment file:

```
ask_delete=OFF
# The following parameter causes the scratch files to
# be written to the tmp directory on c:.
scratch="c:/tmp"
```

3.4 Managing memory and disk resources

- “Managing memory and disk use in Abaqus,” Section 3.4.1

3.4.1 MANAGING MEMORY AND DISK USE IN Abaqus

Products: Abaqus/Standard Abaqus/Explicit

References

- "Execution procedure for Abaqus: overview," Section 3.1.1
- "Using the Abaqus environment settings," Section 3.3.1

Overview

For small analyses management of computer resources is generally of secondary concern, but with large models intelligent use of disk and memory resources is a critical part of the analysis process. For moderate to large analyses you will find it necessary to modify resource management settings.

Understanding resource use

For Abaqus disk and memory are effectively two similar means of storing data. Data that will be required after an analysis completes must eventually be written to disk; but during an analysis, disk and memory provide functionally equivalent storage mechanisms. Typically disk is a more abundant resource, while memory provides faster access to stored data. Management of Abaqus resources hinges on this simple trade-off.

Abaqus data

There are effectively two types of data generated by an Abaqus analysis. The first is "output" data that must persist after an analysis is complete. Output data are typically either results that you require for postprocessing or data that are necessary to restart an analysis. As mentioned above, these data must be stored on disk before an analysis completes.

In addition, an analysis generates a considerable amount of "scratch" or temporary data. These are data that are needed only while an analysis is running. The scratch data can be subdivided into two groups: performance-critical data and generic data. The performance-critical data are always stored in memory, while the generic data can be stored either in memory or on disk.

Requirements and considerations

To run an analysis, the following requirements must be satisfied:

- There must be sufficient disk space available to hold the requested output data.
- There must be sufficient memory available to hold all performance-critical data.
- There must be sufficient disk space or memory resource available to hold all generic scratch data.

If the above requirements are satisfied, an analysis can be completed; however, for Abaqus/Standard you may find that allowing Abaqus to use additional memory will often improve performance. With the increased availability of computer clusters, dedicated shared memory computers, and most importantly

job queuing systems that allocate processors and memory for analyses, it makes most sense to be able to use all the memory resources to improve performance.

Typically Abaqus/Standard allocates a large portion of the available system memory on a machine during the analysis phase, but you can manually specify a limit for memory usage with the **memory** parameter (see "Resource management parameters" below). No scratch data are written to disk during the Abaqus/Explicit analysis phase, since the majority of scratch data are performance critical.

Resource management parameters

Abaqus resource management parameters fall into two classes: memory management and disk management. Each can be adjusted through one environment file parameter. The following sections explain how to best make use of this parameter. For information about the environment file, see "Using the Abaqus environment settings," Section 3.3.1.

Memory management parameters

The **memory** parameter is used to limit the amount of memory that can be used during the analysis phase of Abaqus/Standard and during the input file processing phase, which is executed before both Abaqus/Standard and Abaqus/Explicit analyses.

If you do not define the **memory** parameter, Abaqus automatically detects the physical memory on the machine and allocates a percentage of this available memory. The default percentages are platform specific, but they typically represent a large portion of the available physical memory. For details on the default memory allocation settings, refer to the Dassault Systèmes Knowledge Base at www.3ds.com/support/knowledge-base.

You can override the default memory allocation by specifying the percent of physical memory or by specifying an absolute limit in units of megabytes or gigabytes. Percentages are indicated by a "%" sign following the specified limit. Units of megabytes and gigabytes are indicated by "mb" or "gb" following the specified limit. If no units are specified, megabytes are assumed. For example, with any of the following settings:

```
memory="2048 mb"
memory="2 gb"
memory="25 %"
```

Abaqus uses up to 2 gigabytes of memory on a machine with 8 gigabytes physical memory. The memory setting value must be surrounded by quotes. The values specified for **memory** must be reasonable for the machine being used. Abaqus/Standard does not check the validity of the numerical values. To be consistent with operating system memory measurement tools, a megabyte is defined by Abaqus to be 1,048,576 bytes, not 1,000,000 bytes. A similar rule applies to the unit of gigabyte.

There are no memory management parameters for the Abaqus/Explicit analysis phase, since no scratch data are written to disk during this phase.

Environment file parameters can be set for a host, for a user, or for a particular job (see "Using the Abaqus environment settings," Section 3.3.1, for further discussion). Because a default memory setting

that works well for one machine with a large amount of memory may not be ideal for another machine that has less memory, it may be useful to vary the default memory settings by machine.

Disk management parameters

Management of output data is discussed in detail in "Output," Section 4.1.1. Output data are written to files in the directory from which you launched the job.

Abaqus/Standard scratch files are written to a separate scratch directory. You can control the directory used to hold the scratch files with the **scratch** environment file parameter. Due to the frequent access of the scratch data throughout the analysis phase, ensuring high I/O speed of the scratch disks is essential to the analysis performance.

As explained above, no scratch data are written to disk for Abaqus/Explicit, so you have to be concerned only with proper management of output data.

Input file processing and data check

In general, the amount of memory required during input file processing is not large. The amount of memory and disk space needed for the analysis phase of a job is more likely to be a concern. It is not possible for Abaqus to estimate the amount of memory that will be required to complete input file processing. A data check run can be performed by using the **datacheck** parameter in the command for running Abaqus (see "Abaqus/Standard, Abaqus/Explicit, and Abaqus/CFD execution," Section 3.2.2) to obtain an estimate of the required memory for completing the analysis phase. General guidelines for setting the **memory** parameter for performing the data check (which includes the input file processing phase) are given below.

Guidelines for memory settings

You will usually not have to change the default memory setting. If a job fails as a result of insufficient memory with the default setting, you will need to find a machine with more memory to run the job. If you need to override the default behavior by specifying a value for the **memory** environment file parameter, Table 3.4.1–1 lists some typical data check memory settings for problems of various sizes. The actual values required for **memory** may vary considerably from problem to problem depending on the features used in a model.

Table 3.4.1–1 Typical **memory** settings for performing the data check analysis.

Degrees of freedom	Memory
250,000	250 megabytes
1 million	750 megabytes
2.5 million	1200 megabytes
5 million	2000 megabytes

Abaqus/Standard analysis

Depending on the execution environment and typical job sizes run on the machine, **memory** can be set by machine or by job. More detailed guidelines are provided in the following section. When setting **memory** by job is needed, you are advised to run a data check analysis and set **memory** based on the memory estimates. These estimates are written to the printed output (`.dat`) file in a table under the heading "MEMORY ESTIMATE." Two columns in this table are relevant to memory use. The first relevant column is labeled "MINIMUM MEMORY REQUIRED" and specifies the **memory** setting that is needed to hold critical scratch data in memory. An attempt to run the analysis with **memory** set below this value will result in a warning, and the job is not likely to run to completion due to the insufficient memory. The second relevant column is labeled "MEMORY TO MINIMIZE I/O" and specifies the **memory** that is required to hold all scratch data, both critical and generic, in memory. If the memory specified by **memory** is larger than the "MINIMUM MEMORY REQUIRED," Abaqus/Standard automatically uses the additional memory up to the memory limit to improve speed of access to generic scratch data that would otherwise be written to disk. When the **memory** is not enough to hold all the generic scratch data in memory, Abaqus/Standard decides which data should be written to disk and which should be kept in memory based on their relative importance with respect to their effect on the analysis performance. Therefore, the actual disk space used by the scratch data can vary from very close to zero to the "MEMORY TO MINIMIZE I/O" depending on the **memory** setting. The **memory** setting can be changed in an analysis continued from a data check without the need of rerunning the analysis input file processor.

Guidelines for memory settings

The **memory** parameter allows you to specify the memory limit that can be used by Abaqus during the input file processing and analysis phases. You can specify the setting that should generally be available to Abaqus on a particular machine in the host environment file. Settings can be modified as necessary for individual jobs in job-specific environment files. Reasonable settings for a particular machine depend on the size of the problems being run and how the machine is being used in addition to the physical memory available on the machine. You should be aware of the difference between physical and virtual memory. When virtual memory is used, a machine's operating system simply uses disk for additional memory. While this can be useful, memory access may require I/O operations that add a considerable performance penalty. Therefore, the guidelines below for managing memory in Abaqus/Standard are always given relative to the physical memory on a machine. Virtual memory should be used only when necessary and with awareness of the associated performance penalty.

Setting **memory** on single-user machines

For a single-user machine that is dedicated to running Abaqus/Standard, using the default setting of **memory** is sensible. If the estimates indicate that the job requires more than this value, the job is too large to run efficiently on this machine. At this point you are urged to move the analysis to another machine with more memory resources.

For a single-user machine that is used to run both Abaqus/Standard and other applications simultaneously, setting a lower **memory** limit makes sense. If an analysis requires more than the specified value, you can decide to increase **memory** and continue the job. However, Abaqus/Standard will have to contend with the other applications for memory, which will impair the efficiency of both Abaqus/Standard and the other applications. If the other applications are interactive, the performance degradation could be problematic. In such a case you might decide to delay continuing the analysis until the machine can be dedicated to running Abaqus/Standard alone.

Setting **memory** on multi-user machines

The guidelines for setting **memory** on a multi-user machine are very similar to those for single-user machines, except that a judgement must be made as to the amount of memory that each user on the machine can expect to have for a single analysis. A reasonable approach might be to divide the machine's physical memory by the number of expected simultaneous jobs. Another sensible approach is to divide the machine's physical memory by the total number of CPUs and then multiply by the number of CPUs used for the current job. If the memory requirement among the simultaneous jobs is not even, you might want to divide the machine's physical memory in an uneven way accordingly. In general, to ensure acceptable performance, users on multi-user machines need to coordinate with each other to properly set the memory limit.

Setting **memory** when using queues

Often queues have an associated memory limit, and determining the appropriate queue for a job requires some judgement. You are advised to run a data check analysis and select a queue based on the estimates provided in the printed output file. However, for large analyses even a data check analysis can require a large amount of memory. Choosing an appropriate queue for a data check analysis requires some experience with particular classes of problems. You may want to submit data check runs initially to queues with very large memory limits to get the necessary estimates. An appropriate queue can then be chosen to actually run the job. If the jobs are to be submitted to shared memory machines, it makes sense to set **memory** to about 90% of the memory limit for the queue. If the jobs are to be submitted to computer clusters, it is reasonable to use the default memory setting.

3.5 Parallel execution

3.5.1 PARALLEL EXECUTION: OVERVIEW

Products: Abaqus/Standard Abaqus/Explicit Abaqus/CFD

References

- "Obtaining information," Section 3.2.1
- "Using the Abaqus environment settings," Section 3.3.1
- "Parallel execution in Abaqus/Standard," Section 3.5.2
- "Parallel execution in Abaqus/Explicit," Section 3.5.3
- "Parallel execution in Abaqus/CFD," Section 3.5.4

Overview

Parallel execution of Abaqus is implemented using two different schemes: threads and message passing. Threads are lightweight processes that can perform different tasks simultaneously within the same application. Threads can communicate relatively easily by sharing the same memory pool. Thread-based parallelization is readily available on all shared memory platforms.

Parallelization with message passing uses multiple analysis processes that communicate with each other via the Message Passing Interface (MPI). This requires MPI components to be installed. On the command line you can set **mp_mode=mpi** to indicate that MPI components are available on the system. Alternatively, set **mp_mode=MPI** in the environment file (see "Using the Abaqus environment settings," Section 3.3.1). The MPI-based implementation is the default on all platforms where it is supported.

Abaqus/CFD is implemented using only the MPI mode and does not support threads. The parallel linear solvers used in Abaqus/CFD require that MPI components be installed even for single-processor calculations.

Output the local installation notes for your system to learn about local multiprocessing capabilities (see "Obtaining information," Section 3.2.1). From the **Support** page at www.3ds.com/simulia, refer to the **System Information** page for the current release of Abaqus for complete information about parallel processing support on various platforms, including information about MPI requirements and availability.

Parallel processing support for Abaqus features

The following Abaqus/Standard features can be executed in parallel: the direct sparse solver, the iterative solver, and element operations. The analysis input preprocessing is not executed in parallel. For Abaqus/Explicit all of the computations other than those involving the analysis input preprocessor and the packager can be executed in parallel. Each of the features that are available for parallel execution has certain limitations, which are documented in detail; see "Parallel execution in Abaqus/Standard," Section 3.5.2, and "Parallel execution in Abaqus/Explicit," Section 3.5.3. All features in Abaqus/CFD are available for parallel execution without restrictions.

Parallel execution on shared memory computers

Abaqus/Standard and Abaqus/Explicit can be executed in parallel on shared memory computers by using threads or the MPI. When the MPI is available, Abaqus runs all available parallel features with MPI-based parallelization and activates thread-based parallel implementations for cases where an equivalent MPI-based implementation does not exist (e.g., direct sparse solver). Abaqus/CFD can also be executed on shared memory computers but only with the MPI.

Parallel execution on computer clusters

Abaqus can be executed in parallel on computer clusters by using MPI-based parallelization. For parallel execution on computer clusters, the list of machines or hosts is given with the **mp_host_list** environment file parameter. This parameter also defines the number of processors to be used on each host.

Parallel execution using GPGPU hardware

The direct solver in Abaqus/Standard can be executed in parallel on computers equipped with compute-capable GPGPU cards.

Use with user subroutines

User subroutines can be used when running jobs in parallel. However, user subroutines and any subroutines called by them must be thread safe. This precludes the use of common blocks, data statements, and save statements. Calling subroutines that are not thread safe will result in unpredictable behavior of the executable.

3.5.2 PARALLEL EXECUTION IN Abaqus/Standard

Products: Abaqus/Standard Abaqus/CAE

References

- "Obtaining information," Section 3.2.1
- "Using the Abaqus environment settings," Section 3.3.1
- "Controlling job parallel execution," Section 19.8.8 of the Abaqus/CAE User's Guide, in the HTML version of this guide

Overview

Parallel execution in Abaqus/Standard:

- reduces run time for large analyses;
- is available for shared memory computers and computer clusters for the element operations, direct sparse solver, and iterative linear equation solver; and
- can use compute-capable GPGPU hardware on shared memory computers for the direct sparse solver.

Parallel equation solution with the default direct sparse solver

The direct sparse solver ("Direct linear equation solver," Section 6.1.5) supports both shared memory computers and computer clusters for parallelization. On shared memory computers or a single node of a computer cluster, thread-based parallelization is used for the direct sparse solver, and high-end graphics cards that support general processing (GPGPUs) can be used to accelerate the solution. On multiple compute nodes of a computer cluster, a hybrid MPI and thread-based parallelization is used.

The direct sparse solver cannot be used on multiple compute nodes of a computer cluster if:

- the analysis also includes an eigenvalue extraction procedure, or
- the analysis requires features for which MPI-based parallel execution of element operations is not supported.

In addition, the direct sparse solver cannot be used on multiple nodes of a computer cluster for analyses that include any of the following:

- multiple load cases with changing boundary conditions ("Multiple load case analysis," Section 6.1.4), and
- the quasi-Newton nonlinear solution technique ("Convergence criteria for nonlinear problems," Section 7.2.3).

To execute the parallel direct sparse solver on computer clusters, the environment variable **mp_host_list** must be set to a list of host machines (see "Using the Abaqus environment settings," Section 3.3.1). MPI-based parallelization is used between the machines in the host list. Thread-based

parallelization is used within a host machine if more than one processor is available on that machine in the host list and if the model does not contain cavity radiation using parallel decomposition (see "Decomposing large cavities in parallel" in "Cavity radiation," Section 41.1.1). For example, if the environment file has the following:

```
cpus=8
mp_host_list=[['maple',4],['pine',4]]
```

Abaqus/Standard will use four processors on each host through thread-based parallelization. A total of two MPI processes (equal to the number of hosts) will be run across the host machines so that all eight processors are used by the parallel direct sparse solver.

Models containing parallel cavity decomposition use only MPI-based parallelization. Therefore, MPI is used on both shared memory parallel computers and distributed memory compute clusters. The number of processes is equal to the number of CPUs requested during job submission. Element operations are executed in parallel using MPI-based parallelization when parallel cavity decomposition is enabled.

Input File Usage: Use the following option in conjunction with the command line input to execute the parallel direct sparse solver:

∗STEP

Enter the following input on the command line:

abaqus job=*job-name* **cpus**=*n*

For example, the following input will run the job "beam" on two processors:

```
abaqus job=beam cpus=2
```

Abaqus/CAE Usage: Step module: step editor: **Other**: **Method: Direct**

Job module: job editor: **Parallelization**: toggle on **Use multiple processors**, and specify the number of processors, *n*

GPGPU acceleration of the direct sparse solver

The direct sparse solver supports GPGPU acceleration.

Input File Usage: Enter the following input on the command line to activate GPGPU direct sparse solver acceleration:

abaqus job=*job-name* **gpus**=*n*

Abaqus/CAE Usage: Step module: step editor: **Other**: **Method: Direct**

Job module: job editor: **Parallelization**: toggle on **Use GPGPU acceleration**, and specify the number GPGPUs

Memory requirements for the parallel direct sparse solver

The parallel direct sparse solver processes multiple fronts in parallel in addition to parallelizing the solution of individual fronts. Therefore, the direct parallel solver requires more memory than the serial

solver. The memory requirements are not predictable exactly in advance since it is not determined *a priori* which fronts will actually be processed simultaneously.

Equation ordering for minimum solve time

Direct sparse solvers require the system of equations to be ordered for minimum floating point operation count. The ordering procedure is performed in parallel when multiple host machines are used on a computer cluster. In a shared memory configuration the ordering procedure is not performed in parallel. The parallel ordering procedure will compute different orders when run on different number of host machines, which will affect the floating point operation count for the direct solver. Parallel ordering can offer performance improvements, particularly for large models using many host machines by significantly reducing the time to compute the order. Parallel ordering may cause performance degradation if the order determined results in a higher floating point operation count for the direct solver.

The serial ordering procedure can be used in cases where the variability in the ordering inherent in the parallel ordering procedure is not acceptable. You can deactivate parallel solver ordering from the command line or by using the **order_parallel** environment file parameter (see "Command line default parameters" in "Using the Abaqus environment settings," Section 3.3.1).

Input File Usage: Enter the following input on the command line to deactivate parallel solver ordering:

abaqus job=*job-name* **order_parallel**=**OFF**

Abaqus/CAE Usage: Deactivation of parallel solver ordering is not supported in Abaqus/CAE.

Parallel equation solution with the iterative solver

The iterative solver ("Iterative linear equation solver," Section 6.1.6) uses only MPI-based parallelization. Therefore, MPI is used on both shared memory parallel computers and distributed memory compute clusters. To execute the parallel iterative solver, specify the number of CPUs for the job. The number of processes is equal to the number of CPUs requested during job submission. Element operations are executed in parallel using MPI-based parallelization when the parallel iterative solver is used.

Input File Usage: Use the following option in conjunction with the command line input to execute the parallel iterative solver:

*STEP, SOLVER=ITERATIVE

Enter the following input on the command line:

abaqus job=*job-name* **cpus**=*n*

For example, the following input will run the job "cube" on four processors with the iterative solver:

```
abaqus job=cube cpus=4
```

Abaqus/CAE Usage: Step module: step editor: **Other**: **Method: Iterative**

Job module: job editor: **Parallelization**: toggle on **Use multiple processors**, and specify the number of processors, *n*

Parallel execution of the element operations in Abaqus/Standard

Parallel execution of the element operations is the default on all supported platforms. The command line and environment variable **standard_parallel** can be used to control the parallel execution of the element operations (see "Using the Abaqus environment settings," Section 3.3.1, and "Abaqus/Standard, Abaqus/Explicit, and Abaqus/CFD execution," Section 3.2.2). If parallel execution of the element operations is used, the solvers also run in parallel automatically. For analysis using the direct sparse solver and not containing parallel cavity decomposition, thread-based parallelization of the element operations is used on shared memory computers and a hybrid MPI and thread parallel scheme is used on computer clusters. For analyses using the iterative solver or if parallel cavity decomposition is enabled, only MPI-based parallelization of element operations is supported.

When MPI-based parallelization of element operations is used, element sets are created for each domain and can be inspected in Abaqus/CAE. The sets are named **`STD_PARTITION_`***n*, where *n* is the domain number.

Parallel execution of the element operations (thread or MPI-based parallelization) is not supported for the following procedures:

- eigenvalue buckling prediction ("Eigenvalue buckling prediction," Section 6.2.3),
- natural frequency extraction ("Natural frequency extraction," Section 6.3.5) that does not use the SIM architecture,
- response spectrum analysis ("Response spectrum analysis," Section 6.3.10),
- random response analysis ("Random response analysis," Section 6.3.11), and
- mode-based linear dynamics ("Transient modal dynamic analysis," Section 6.3.7; "Mode-based steady-state dynamic analysis," Section 6.3.8; "Subspace-based steady-state dynamic analysis," Section 6.3.9; and "Complex eigenvalue extraction," Section 6.3.6) that do not use the SIM architecture.

Parallel execution of element operations is available only through MPI-based parallelization for analyses that include any of the following:

- static linear perturbation ("General and linear perturbation procedures," Section 6.1.3),
- direct cyclic analysis ("Direct cyclic analysis," Section 6.2.6),
- direct-solution steady-state dynamics ("Direct-solution steady-state dynamic analysis," Section 6.3.4),
- steady-state transport ("Steady-state transport analysis," Section 6.4.1),
- coupled temperature-displacement ("Fully coupled thermal-stress analysis," Section 6.5.3),
- coupled thermal-electrical-structural ("Fully coupled thermal-electrical-structural analysis," Section 6.7.4),
- coupled pore fluid diffusion and stress ("Coupled pore fluid diffusion and stress analysis," Section 6.8.1),
- crack propagation analysis ("Crack propagation analysis," Section 11.4.3),
- pressure penetration loading ("Pressure penetration loading," Section 37.1.7), and

- static, implicit dynamic, or direct-solution steady-state dynamic analyses for models using substructures, if recovering results within substructures is not requested ("Static stress analysis," Section 6.2.2; "Implicit dynamic analysis using direct integration," Section 6.3.2; "Direct-solution steady-state dynamic analysis," Section 6.3.4; "Substructuring," Section 10.1).

Analyses using the direct sparse solver and any of the procedures above that support only MPI-based parallelization of element operations can be run on computer clusters. However, only one processor per compute node is used for the element operations since thread-based parallelization is not supported.

Parallel execution of element operations is available only through thread-based parallelization for:

- cavity radiation analyses where parallel decomposition of the cavity is not allowed and writing of restart data is requested ("Cavity radiation," Section 41.1.1),
- heat transfer analyses where average-temperature radiation conditions are specified ("Thermal loads," Section 34.4.4),
- natural frequency extraction ("Natural frequency extraction," Section 6.3.5) that uses the SIM architecture,
- mode-based linear dynamics ("Transient modal dynamic analysis," Section 6.3.7; "Mode-based steady-state dynamic analysis," Section 6.3.8; "Subspace-based steady-state dynamic analysis," Section 6.3.9; and "Complex eigenvalue extraction," Section 6.3.6) that use the SIM architecture,
- substructure generation("Defining substructures," Section 10.1.2), and
- matrix generation ("Introduction" in "Generating thermal matrices," Section 10.3.2).

Finally, parallel execution of the element operations is not supported for analyses that include any of the following:

- element matrix output requests ("Element matrix output in Abaqus/Standard" in "Output," Section 4.1.1),
- alternative solution techniques except for the quasi-Newton method ("Approximate implementation" in "Fully coupled thermal-stress analysis," Section 6.5.3; "Approximate implementation" in "Coupled thermal-electrical analysis," Section 6.7.3; and "Specifying the separated method" in "Convergence criteria for nonlinear problems," Section 7.2.3),
- continuation of output upon restart ("Continuation of output upon restart" in "Restarting an analysis," Section 9.1.1),
- import from Abaqus/Explicit ("Transferring results between Abaqus analyses: overview," Section 9.2.1),
- substructures, if recovering results within substructures is requested ("Substructuring," Section 10.1), and
- adaptive meshing ("Defining ALE adaptive mesh domains in Abaqus/Standard," Section 12.2.6).

Input File Usage: Enter the following input on the command line:

abaqus job=*job-name* **standard_parallel**=**all** **cpus**=*n*

Abaqus/CAE Usage: Control of the parallel execution of the element operations is not supported in Abaqus/CAE.

Memory management with parallel execution of the element operations

When running parallel execution of the element operations in Abaqus/Standard, specifying the upper limit of the memory that can be used (see "Abaqus/Standard analysis" in "Managing memory and disk use in Abaqus," Section 3.4.1) specifies the maximum amount of memory that can be allocated *by each process*.

Transverse shear stress output for stacked continuum shells

The output variables CTSHR13 and CTSHR23 are currently not available when running parallel execution of the element operations in Abaqus/Standard. See "Continuum shell element library," Section 29.6.8.

Consistency of results

Some physical systems (systems that, for example, undergo buckling, material failure, or delamination) can be highly sensitive to small perturbations. For example, it is well known that the experimentally measured buckling loads and final configurations of a set of seemingly identical cylindrical shells can show significant scatter due to small differences in boundary conditions, loads, initial geometries, etc. When simulating such systems, the physical sensitivities seen in an experiment can be manifested as sensitivities to small numerical differences caused by finite precision effects. Finite precision effects can lead to small numerical differences when running jobs on different numbers of processors. Therefore, when simulating physically sensitive systems, you may see differences in the numerical results (reflecting the differences seen in experiments) between jobs run on different numbers of processors. To obtain consistent simulation results from run to run, the number of processors should be constant.

3.5.3 PARALLEL EXECUTION IN Abaqus/Explicit

Products: Abaqus/Explicit Abaqus/CAE

References

- "Obtaining information," Section 3.2.1
- "Using the Abaqus environment settings," Section 3.3.1
- "Controlling job parallel execution," Section 19.8.8 of the Abaqus/CAE User's Guide, in the HTML version of this guide

Overview

Parallel execution in Abaqus/Explicit:

- reduces run time for analyses that require a large number of increments;
- reduces run time for analyses that contain a large number of nodes and elements;
- produces analysis results that are independent of the number of processors used for the analysis;
- is available for shared memory computers using a thread-based loop level or thread-based domain decomposition implementation; and
- is available for both shared memory computers and computer clusters using an MPI-based domain decomposition parallel implementation.

Invoking parallel processing

Parallelization in Abaqus/Explicit is implemented in two ways: domain level and loop level. The domain-level method breaks the model up into topological domains and assigns each domain to a processor. The domain-level method is the default. The loop-level method parallelizes low-level loops that are responsible for most of the computational cost. The element, node, and contact pair operations account for the majority of the low-level parallelized routines.

Parallelization can be invoked by specifying the number of processors to be used.

Input File Usage: Enter the following input on the command line:

abaqus job=*job-name* **cpus**=*n*

For example, the following input will run the job "beam" on two processors:

```
abaqus job=beam cpus=2
```

Abaqus/CAE Usage: Job module: job editor: **Parallelization**: toggle on **Use multiple processors**, and specify the number of processors, *n*

Domain-level parallelization

The domain-level method splits the model into a number of topological domains. These domains are referred to as parallel domains to distinguish them from other domains associated with the analysis. The domains are distributed evenly among the available processors. The analysis is then carried out independently in each domain. However, information must be passed between the domains in each increment because the domains share common boundaries. Both MPI and thread-based parallelization modes are supported with the domain-level method.

During initialization, the domain-level method divides the model so that the resulting domains take approximately the same amount of computational expense. The load balance is defined as the ratio of the computational expense of all domains in the most expensive process to that of all domains in the least expensive process. For cases exhibiting significant load imbalance, either because the initial load balancing is not adequate (static imbalance) or because imbalance develops over time (dynamic imbalance), the dynamic load balancing technique may be applied (see "Abaqus/Standard, Abaqus/Explicit, and Abaqus/CFD execution," Section 3.2.2). Dynamic load balancing is based on over-decomposition: the user selects a number of domains that is a multiple of the number of processors. During the calculation, Abaqus/Explicit will regularly measure the computational expense and redistribute the domains over the processors so as to minimize the load imbalance. The following functionality is not supported with dynamic load balancing:

- Selective subcycling ("Selective subcycling," Section 11.7.1)
- Co-simulation ("Co-simulation," Section 17.1)
- Predefined fields using a results file ("Predefined fields," Section 34.6.1)

The efficiency of the dynamic load balancing scheme depends on the load imbalance inherent to the problem, on the degree of overdecomposition, and on the efficiency of the hardware. Most imbalanced problems will see optimal performance improvement when the number of domains is two to four times the number of processors. The efficiency may be significantly reduced on systems with a slow interconnect, such as Gigabit Ethernet clusters. Best results are obtained when an external interconnect is not needed, such as within a multicore node of a cluster, or on a shared-memory system. Applications most likely to benefit from dynamic load balancing are problems with a strongly time-dependent and/or spatially varying computational load. Examples are models containing airbags, where contact-impact activity is highly localized and time dependent; and coupled Lagrangean-Eulerian problems, where constitutive activity follows the material as it moves through empty space.

Element and node sets are created for each domain and can be inspected in Abaqus/CAE. The sets are named **`domain_`***n*, where *n* is the domain number.

During the analysis, separate state (*job-name*`.abq`) and selected results (*job-name*`.sel`) files are created. There will be one state and one selected results file for each processor. The naming convention is to append the processor number to the file name. For example, the state files are named *job-name*`.abq.`*n*, where *n* is the processor number. At the completion of the analysis the individual files are merged automatically into a single file (for example, *job-name*`.abq`), and the individual files are deleted.

Input File Usage: Enter the following input on the command line:

abaqus job=*job-name* **cpus**=*n* **parallel**=**domain domains**=*m* **dynamic_load_balancing**

For example, the following input will run the job "beam" on two processors with the domain-level parallelization method:

```
abaqus job=beam cpus=2 parallel=domain domains=2
```

The domain-level parallelization method can also be set in the environment file using the environment file parameters **parallel**=**DOMAIN** and **domains**.

Abaqus/CAE Usage: Job module: job editor: **Parallelization**: toggle on **Use multiple processors** and specify the number of processors, *n*; **Number of domains:** *m*; toggle on **Activate dynamic load balancing**; **Parallelization method**: **Domain**

You can activate dynamic load balancing when the number of domains is a multiple of the number of processors.

Consistency of results

The analysis results are independent of the number of processors used for the analysis. However, the results do depend on the number of parallel domains used during the domain decomposition. Except for cases in which the single- and multiple-domain models are different due to features that are not yet available with multiple parallel domains (discussed below), these differences should be triggered only by finite precision effects. For example, the order of the nodal force assembly may depend on the number of parallel domains, which can result in differences in trailing digits in the computed force. Some physical systems are highly sensitive to small perturbations, so a tiny difference in the force applied in one increment can result in noticeable differences in results in subsequent increments. Simulations involving buckling and other bifurcations tend to be sensitive to small perturbations.

To obtain consistent analysis results from run to run, the number of domains used in the domain decomposition should be constant. Increasing the number of domains increases the computational cost slightly; therefore, unless dynamic load balancing is being applied, it is recommended that the number of domains be set equal to the maximum number of processors used for analysis execution for optimal performance. If you do not specify the number of domains, the number defaults to the number of processors.

Features that do not allow domain-level parallelization

The use of the domain-level parallelization method is not allowed with the following features:

- Extreme value output.
- Steady-state detection.

If these features are included, an error message will be issued.

Features that cannot be split across domains

Certain features cannot be split across domains. The domain decomposition algorithm automatically takes this into account and forces these features to be contained entirely within one domain. If fewer domains than requested processors are created, Abaqus/Explicit issues an error message. Even if the algorithm succeeds in creating the requested number of domains, the load may be balanced unevenly. If this behavior is not acceptable, the job should be run with the loop-level parallelization method.

Adaptive smoothing domains cannot span parallel domain boundaries. The nodes on the boundary between an adaptive smoothing domain and a nonadaptive domain as well as the adaptive nodes on the surface of the adaptive smoothing domain cannot be shared with another parallel domain. To enforce this in a consistent manner when parallel domains are specified, all nodes shared by adjacent adaptive smoothing domains will be set as nonadaptive. In this case the analysis results may be significantly different from that of a serial run with no parallel domains. Set the number of parallel domains to 1, and switch to the loop-level parallelization method if this behavior is undesirable. See "Defining ALE adaptive mesh domains in Abaqus/Explicit," Section 12.2.2, for details.

A contact pair cannot be split across parallel domains, but separate contact pairs are not restricted to be in the same parallel domain. A contact pair that uses the kinematic contact algorithm requires that all of the nodes associated with the involved surfaces be within a single parallel domain and not be shared with any other parallel domains. A contact pair that uses the penalty contact algorithm requires that the associated nodes be part of a single parallel domain, but these nodes may also be part of other parallel domains. Analyses in which a large percentage of nodes are involved in contact may not scale well if contact pairs are used, especially with kinematic enforcement of contact constraints. General contact does not limit the domain decomposition boundaries.

Nodes involved in kinematic constraints ("Kinematic constraints: overview," Section 35.1.1) will be within a single parallel domain, and they will not be shared with another parallel domain. However, two kinematic constraints that do not share nodes can be placed within different parallel domains.

In some cases beam elements that share a node may be forced into the same parallel domain. This happens only for beams whose center of mass does not coincide with the location of the beam node or for beams with additional inertia (see "Adding inertia to the beam section behavior for Timoshenko beams" in "Beam section behavior," Section 29.3.5).

Restart

There are certain restrictions for restart when using domain-level parallelization. To ensure that optimal parallel speedup is achieved, the number of processors used for the restart analysis must be chosen so that the number of parallel domains used during the original analysis can be distributed evenly among the processors. Because the domain decomposition is based only on the features specified in the original analysis and steps defined therein, features that affect domain decomposition are restricted from being defined in restart steps only if they would invalidate the original domain decomposition. Because the newly added features will be added to existing domains, there is a potential for load imbalance and a corresponding degradation of parallel performance.

The restart analysis requires that the separate state and selected results files created during the original analysis be converted into single files, as described in "Abaqus/Standard, Abaqus/Explicit, and

Abaqus/CFD execution," Section 3.2.2. This should be done automatically at the conclusion of the original analysis. If the original analysis fails to complete successfully, you must convert the state and selected results files prior to restart. An Abaqus/Explicit analysis packaged to run with a domain-level parallelization technique cannot be restarted or continued with a loop-level parallelization technique.

Co-simulation

The co-simulation technique ("Co-simulation: overview," Section 17.1.1) for run-time coupling of Abaqus/Explicit to Abaqus/Standard or to third-party analysis programs can be used with Abaqus/Explicit running either in serial or parallel.

Loop-level parallelization

The loop-level method parallelizes low-level loops in the code that are responsible for most of the computational cost. The speedup factor using loop-level parallelization may be significantly less than what can be achieved with domain-level parallelization. The speedup factor will vary depending on the features included in the analysis since not all features utilize parallel loops. Examples are the general contact algorithm and kinematic constraints. The loop-level method may scale poorly for more than four processors depending on the analysis. Using multiple parallel domains with this method will degrade parallel performance and, hence, is not recommended. The loop-level method is not supported on the Windows platform.

Analysis results for this method do not depend on the number of processors used.

Input File Usage: Enter the following input on the command line:

abaqus job=*job-name* **cpus**=*n* **parallel**=`loop`

The loop-level parallelization method can also be set in the environment file using the environment file parameter **parallel**=`LOOP`.

Abaqus/CAE Usage: Job module: job editor: **Parallelization**: toggle on **Use multiple processors**, and specify the number of processors, *n*; **Parallelization method: Loop**

Restart

There are no restrictions on features that can be included in steps defined in a restart analysis when using loop-level parallelization. For performance reasons the number of processors used when restarting must be a factor of the number of processors used in the original analysis. The most common case would be restarting with the same number of processors as used in the original analysis. An Abaqus/Explicit analysis packaged to run with a loop-level parallelization technique cannot be restarted or continued with a domain-level parallelization technique.

Measuring parallel performance

Parallel performance is measured by comparing the total time required to run on a single processor (serial run) to the total time required to run on multiple processors (parallel run). This ratio is referred to as the speedup factor. The speedup factor will equal the number of processors used for the parallel run in the case of perfect parallelization. Scaling refers to the behavior of the speedup factor as the

number of processors is increased. Perfect scaling indicates that the speedup factor increases linearly with the number of processors. For both parallelization methods the speedup factors and scaling behavior are heavily problem dependent. In general, the domain-level method will scale to a larger number of processors and offer the higher speedup factor.

Output

There are no output restrictions.

3.5.4 PARALLEL EXECUTION IN Abaqus/CFD

Products: Abaqus/CFD Abaqus/CAE

References

- "Obtaining information," Section 3.2.1
- "Using the Abaqus environment settings," Section 3.3.1
- "Controlling job parallel execution," Section 19.8.8 of the Abaqus/CAE User's Guide, in the HTML version of this guide

Overview

Parallel execution in Abaqus/CFD:

- reduces run time for analyses that require a large number of increments;
- reduces run time for analyses that contain a large number of nodes and elements;
- produces analysis results that are independent of the number of processors used for the analysis; and
- is available for both shared memory computers and computer clusters using an MPI-based domain decomposition parallel implementation.

Invoking parallel processing

Abaqus/CFD uses domain-based parallelism implemented with explicit message passing for both shared memory and distributed memory computers. All procedures provided by Abaqus/CFD and their associated features are fully parallel ("Parallel execution: overview," Section 3.5.1). Parallel execution is invoked by specifying the number of processors to be used.

Input File Usage: Enter the following input on the command line:

abaqus job=*job-name* **cpus**=*n*

For example, the following input will run the job "manifold" on two processors:

```
abaqus job=manifold cpus=2
```

Abaqus/CAE Usage: Job module: job editor: **Parallelization**: toggle on **Use multiple processors**, and specify the number of processors, *n*

Domain-based parallelism

Abaqus/CFD uses a domain-decomposition message passing paradigm for its parallel implementation. An element-based decomposition strategy is used that minimizes the number of communications required between subdomains while providing a nearly uniform computational work distribution among the processors. The number of domains maps exactly to the number of user-specified processors for a given calculation. The load-balancing procedures are implemented in parallel as well, so that

you can avoid time consuming serial load-balancing procedures at the start of a calculation. Every attempt has been made to ensure that Abaqus/CFD provides scalable parallel solutions for a broad range of applications. All procedures and features in Abaqus/CFD are provided with a fully parallel implementation. All output is serialized automatically for the user so that there is no translation between parallel domains and the original user input. In addition, this permits Abaqus/CFD to restart seamlessly on any number of processors, regardless of how many were used for the original computation.

Co-simulation

The co-simulation technique ("Co-simulation: overview," Section 17.1.1) for run-time coupling of Abaqus/CFD to Abaqus/Standard or to Abaqus/Explicit can be used with Abaqus/CFD running either in serial or parallel.

Restart

There are no restrictions on features that can be included in steps defined in a restart analysis. The number of processors used for the restart analysis is not required to be the same as the number of processors used in the original analysis.

Output

There are no output restrictions.

3.6 File extension definitions

- “File extensions used by Abaqus,” Section 3.6.1

3.6.1 FILE EXTENSIONS USED BY Abaqus

Products: Abaqus/Standard Abaqus/Explicit Abaqus/CFD

Reference

- "Execution procedure for Abaqus: overview," Section 3.1.1

Overview

The **abaqus** procedure generates several files. Some of these files contain analysis, postprocessing, and translation results and are retained for use by other analysis options, restarting, or postprocessing. This section describes the files that are created and retained by Abaqus.

Other files exist only while Abaqus is executing and are deleted when a run completes. These temporary files are generated in the scratch directory. The number and types of temporary files generated depend on the analysis procedures, memory management parameters, and environment settings.

Certain file extensions used by Abaqus are also used by other software applications. You must handle any file extension conflicts with other applications.

File extensions

`abq`

State file, only used by Abaqus/Explicit. It is written by the **analysis**, **continue**, and **recover** options. It is read by the **convert** and **recover** options. This file is required for restart.

`axi`

Symmetric model data file, only used by Abaqus/Standard. It is written during symmetric model generation by the **datacheck** and **analysis** options.

`bsp`

Text file containing beam cross-section properties for meshed section profiles. It is written by Abaqus/Standard during meshed beam cross-section generation.

`c`

User subroutine or other special-purpose C file.

`c++`

User subroutine or other special-purpose C++ file.

`cpp`

User subroutine or other special-purpose C++ file.

cid

Auto-release file, which contains information needed for license recovery and suspension.

com

Command file, created by the Abaqus execution procedure.

dat

Printed output file. It is written by the **analysis**, **datacheck**, **parametercheck**, and **continue** options. Abaqus/Explicit and Abaqus/CFD do not write analysis results to this file.

f

User subroutine or other special-purpose FORTRAN file.

fil

Results file. It is written by the **analysis** and **continue** options in Abaqus/Standard and by the **convert**=**select** and **convert**=**all** options in Abaqus/Explicit.

fin

Results file created when changing the format of the **.fil** file using the **abaqus ascfil** command. It can be in either ASCII or binary format. (See "ASCII translation of results (**.fil**) files," Section 3.2.12.) The ASCII format is convenient for data transfer between machines that do not have compatible binary data formats.

inp

Analysis input file. It is read when the **analysis**, **datacheck**, and **parametercheck** options are selected.

ipm

Interprocess message file. It is written when an analysis is run from Abaqus/CAE, and it contains a log of all messages sent from Abaqus/Standard, Abaqus/Explicit, or Abaqus/CFD to Abaqus/CAE.

lck

Lock file for the output database. This file is written whenever an output database file is opened with write access; it prevents you from having simultaneous write permission to the output database from multiple sources. It is deleted automatically when the output database file is closed or when the analysis that creates it ends. The **ask_delete** environment file parameter setting will not affect the lock file.

log

Log file, which contains start and end times for modules run by the current Abaqus execution procedure.

mdl

Model file, used by Abaqus/Standard and Abaqus/Explicit. It is written by the **datacheck** option. It is read and can be written by the **analysis** and **continue** options in Abaqus/Standard. It is read by the **analysis** and **continue** options in Abaqus/Explicit. Multiple model files may exist if the element operations are executed in parallel in an Abaqus/Standard analysis. In such a case a process identifier is attached to the file name. This file is required for restart.

msg

Message file. It is written by the **analysis**, **datacheck**, and **continue** options in Abaqus/Standard and Abaqus/Explicit. Multiple message files may exist if the element operations are executed in parallel in an Abaqus/Standard analysis. In such a case a process identifier is attached to the file name.

nck

Nickname file used by Abaqus/Standard. It stores a set of internal identifiers for the degrees of freedom in a model.

odb

Output database. It is written by the **analysis** and **continue** options in Abaqus/Standard, Abaqus/Explicit, and Abaqus/CFD. It is read by the Visualization module in Abaqus/CAE (Abaqus/Viewer) and by the **convert**=**odb** option. This file is required for restart.

pac

Package file, which contains model information and is used by Abaqus/Explicit only. It is written by the **analysis** and **datacheck** options. It is read by the **analysis**, **continue**, and **recover** options. This file is required for restart.

par

Modified version of original parametrized input file showing input parameters and their values.

pes

Modified version of original parametrized input file showing input free of parameter information (after input parameter evaluation and substitution has been performed).

pmg

Parameter evaluation and substitution message file. It is written when the input file is parametrized.

prt

Part file, used by Abaqus/Standard and Abaqus/Explicit. This file is used to store part and assembly information and is created even if the input file does not contain an assembly definition. The part file is required for restart, import, sequentially coupled thermal-stress analysis, symmetric model generation, and underwater shock analysis, even if the model is not defined in terms of an assembly of part instances. This file may also be needed for submodeling analysis.

psf

Python scripting file. You must create this type of file to define a parametric study.

res

Restart file, which contains information necessary to continue a previous analysis and is used by Abaqus/Standard and Abaqus/Explicit. The restart file is written by the **analysis**, **datacheck**, and **continue** options. It is read by any restarted analysis.

sel

Selected results file, used by Abaqus/Explicit. It is written by the **analysis**, **continue**, and **recover** options and is read by the **convert**=**select** option. This file is required for restart.

sim

Linear dynamics data file, used by Abaqus/Standard. It is written during the frequency extraction procedure in SIM-based linear dynamics analyses (see "Using the SIM architecture for modal superposition dynamic analyses" in "Dynamic analysis procedures: overview," Section 6.3.1, for details) and is used to store eigenvectors, substructure matrices, and other modal system information. This file is required for restart.

Model file, used by Abaqus/CFD. It is written by the **datacheck** option. It is read and can be written by the **analysis** and **continue** options. This file is required for restart.

sta

Status file. Abaqus writes increment summaries to this file in the **analysis**, **continue**, and **recover** options.

stt

State file. It is written by the **datacheck** option in Abaqus/Standard and Abaqus/Explicit. It is read and can be written by the **analysis** and **continue** options in Abaqus/Standard. It is read by the **analysis** and **continue** options in Abaqus/Explicit. Multiple state files may exist if the element operations are executed in parallel in an Abaqus/Standard analysis. In such a case a process identifier is attached to the file name. This file is required for restart.

sup

Substructure file, used by Abaqus/Standard.

var

File containing information about the input file variations generated by a parametric study.

023

Communications file, used by Abaqus/Standard and Abaqus/Explicit. It is written by the **analysis** and **datacheck** options and is read by the **analysis** and **continue** options.

3.7 FORTRAN unit numbers

- “FORTRAN unit numbers used by Abaqus,” Section 3.7.1

3.7.1 FORTRAN UNIT NUMBERS USED BY Abaqus

Products: Abaqus/Standard Abaqus/Explicit

Reference

- "Execution procedure for Abaqus: overview," Section 3.1.1

Overview

Abaqus uses the FORTRAN unit numbers outlined in the table below. Unless noted otherwise, you should not try to write to these FORTRAN units from user subroutines.

For Abaqus/Standard, you should specify unit numbers 15–18 or unit numbers greater than 100 .

For Abaqus/Explicit, specify units 16–18 or unit numbers greater than 100 ending in 5 to 9, e.g. 105, 268, etc. You cannot write to the **.sta** file.

FORTRAN unit numbers

Code	Unit Number	Description
Abaqus/Standard	1	Internal database
	2	Solver file
	6	Printed output (**.dat**) file (You can write output to this file.)
	7	Message (**.msg**) file (You can write output to this file.)
	8	Results (**.fil**) file
	10	Internal database
	12	Restart (**.res**) file
	19–30	Internal databases (scratch files). Unit numbers 21 and 22 are always written to disk.
	73	Text file containing meshed beam cross-section properties (**.bsp**)

Code	Unit Number	Description
Abaqus/Explicit	6	Printed output (**.log**) .
	12	Restart (**.res**) file
	13	Old restart (**.res**) file, if applicable
	15	Analysis Preprocessor (**.dat** or **.pre**) file
	23	Communications (**.023**) file
	60	Global package (**.pac**) file
	61	Global state (**.abq**) file
	62	Temporary file
	63	Global selected results (**.sel**) file
	64	Message (**.msg**) file
	65	Output database (**.odb**) file
	67	Old package (**.pac**) file, if import from Abaqus/Explicit
	68	Old state (**.abq**) file, if import from Abaqus/Explicit
	69	Internal database; temporary file
If domain-parallel	70	Local package (**.pac.1**) file for CPU #1
	71	Local state (**.abq.1**) file for CPU #1
	73	Local selected results (**.sel.1**) file for CPU #1
	80	Local package (**.pac.2**) file for CPU #2
	81	Local state (**.abq.2**) file for CPU #2
	83	Local selected results (**.sel.2**) file for CPU #2
	...	Add three files, incrementing units by 10, for each additional CPU

Part II: Output

- Chapter 4, “Output”
- Chapter 5, “File Output Format”

4. Output

4.1 Output

4.1.1 OUTPUT

Products: Abaqus/Standard Abaqus/Explicit Abaqus/CFD Abaqus/CAE

References

- "Output to the data and results files," Section 4.1.2
- "Output to the output database," Section 4.1.3
- "Abaqus/Standard output variable identifiers," Section 4.2.1
- "Abaqus/Explicit output variable identifiers," Section 4.2.2
- "Abaqus/CFD output variable identifiers," Section 4.2.3
- "Diagnostic printing," Section 14.5.3 of the Abaqus/CAE User's Guide
- "Degree of freedom monitor requests," Section 14.5.4 of the Abaqus/CAE User's Guide

Overview

Abaqus can create the following output files during an analysis:

- a data file containing printed output of the model and history definition generated by the analysis input file processor and, in Abaqus/Standard, printed output of results written during the analysis run;
- an output database file containing results for postprocessing with the Visualization module of Abaqus/CAE (Abaqus/Viewer) and, in Abaqus/Standard, diagnostic information;
- a selected results file in Abaqus/Explicit;
- a results file containing results for postprocessing with external software in Abaqus/Standard and Abaqus/Explicit (in Abaqus/Explicit this file is generated by converting the selected results file);
- a message file containing diagnostic messages about the solution in Abaqus/Standard and Abaqus/Explicit;
- a status file containing information about the status of the analysis and, in Abaqus/Explicit, diagnostic messages and information about the stable time increment; and
- output files in Abaqus/CFD using alternate file formats.

Abaqus can create files for restarting an analysis—see "Restarting an analysis," Section 9.1.1. In Abaqus/Standard these files can also be used to extract results output not requested during an analysis.

The data file

The data file (*job-name*`.dat`) is a text file that contains information about the model definition (generated by the analysis input file processor) and, in Abaqus/Standard, tabular output of results. The analysis input file processor information includes the model definition, the history definition, and messages identifying any error and warning conditions that were detected while processing the input data.

Controlling the amount of analysis input file processor information written to the data file

You can control the amount of information written to the data file by the analysis input file processor in Abaqus/Standard and Abaqus/Explicit.

Input File Usage: Use the following option in the model definition section of the input file:

*PREPRINT

Abaqus/CAE Usage: Job module: job editor: **General**: **Preprocessor Printout**

Input file echo

By default, the input file will not be echoed to the data file. You can choose to activate this printout. If the input file is defined in terms of an assembly of part instances, the echo to the data file will be that of the flattened input file (i.e., one that does not use parts and assemblies).

Input File Usage: *PREPRINT, ECHO=YES *or* NO

Abaqus/CAE Usage: Job module: job editor: **General**: **Preprocessor Printout**: **Print an echo of the input data**

Input parameter information

For parametrized input files, information about input parameters and their values can be printed in the data file. By default, the modified version of the original input file showing this information will not be printed in the data file. You can choose to activate this printout.

Input File Usage: *PREPRINT, PARVALUES=YES *or* NO

Abaqus/CAE Usage: Parametrized input files are not supported in Abaqus/CAE.

Parameter-free input file information

For parametrized input files, a parameter-free version (after parameter evaluation and substitution) of the original input file can be printed in the data file. By default, this modified version of the input file will not be printed in the data file. You can choose to activate this printout.

Input File Usage: *PREPRINT, PARSUBSTITUTION=YES *or* NO

Abaqus/CAE Usage: Parametrized input files are not supported in Abaqus/CAE.

Model and history definition summaries

By default, the options defining the model and history data will not be summarized in the data file. You can choose to activate this printout.

For an Abaqus/Explicit analysis the model summary data, when requested, includes the mass, center of mass, and the rotary inertia information for the element sets in the model and for the whole model. However, for two-dimensional models the reported rotary inertia includes the I_{33} component corresponding to the only active rotation degree of freedom; the remaining components are not included.

Input File Usage: *PREPRINT, MODEL=YES *or* NO, HISTORY=YES *or* NO

Abaqus/CAE Usage: Job module: job editor: **General**: **Preprocessor Printout**: **Print model definition data** and **Print history data**

Contact constraint information

In Abaqus/Standard you can choose to activate printout of detailed information about the contact constraints generated by the contact pair definition data.

Input File Usage: *PREPRINT, CONTACT=YES *or* NO

Abaqus/CAE Usage: Job module: job editor: **General**: **Preprocessor Printout**: **Print contact constraint data**

Mass information

In Abaqus/Explicit you can choose to activate printout of detailed information about the mass property of each user-defined element set.

Input File Usage: *PREPRINT, MASS PROPERTY=YES *or* NO

Abaqus/CAE Usage: This parameter is not supported by Abaqus/CAE.

Requesting printed results

In Abaqus/Standard the values of output variables can be printed to the data file in tabular format throughout the analysis. You can control the following types of printed output during the analysis run: element output, node output, contact surface output, energy output, fastener interaction output, modal output, section output, and radiation output—see "Output to the data and results files," Section 4.1.2, and "Cavity radiation," Section 41.1.1. You specify the variables to be printed in each output table and, for element variables, the locations at which they are to be printed (at the integration points, at the element centroid, at the nodes, or averaged at the nodes). Nodal variables at nodes with transformations can be written in either the global or the local coordinate system (see "Transformed coordinate systems," Section 2.1.5). The list of available variables is given in "Abaqus/Standard output variable identifiers," Section 4.2.1. Output of results to the data file is requested as part of a step definition.

Viewing part and assembly information in the data file

An Abaqus model can be defined in terms of an assembly of part instances (see "Defining an assembly," Section 2.10.1). In such a model node and element numbers can be repeated within the definitions of different parts. These local numbers are converted internally by Abaqus to unique global numbers, and the output written to the data file is given in terms of those internal numbers. A map between user-defined numbers and internal numbers is printed to the data file (after the step data) if any output that includes node and element numbers is requested in the data file.

Set and surface names that appear in the data file are prefixed by the assembly and part instance names, separated by underscores (**`Assembly_Part1-1_setname`**, for example).

Local coordinate systems defined within a part or part instance are translated and rotated according to the positioning data given in the part instance definition.

The output database

The Abaqus output database (*job-name*`.odb`) is a neutral binary file used to store model information and analysis results in terms of an assembly of part instances. The Visualization module of Abaqus/CAE (Abaqus/Viewer) uses the output database for postprocessing analysis results and viewing diagnostic information.

Requesting output to the output database

You choose the variables to be written to the output database from the lists in "Abaqus/Standard output variable identifiers," Section 4.2.1, "Abaqus/Explicit output variable identifiers," Section 4.2.2, and "Abaqus/CFD output variable identifiers," Section 4.2.3. The following types of output are available: element output, node output, contact surface output, energy output, integrated output, time incrementation output, fastener interaction output, modal output, and radiation output. In addition, a subset of the diagnostic information that is written to the message file in Abaqus/Standard and Abaqus/Explicit (see "The message file in Abaqus/Standard and Abaqus/Explicit") and to the Abaqus/Explicit status file (see "The status file") is included in the output database. See "Output to the output database," Section 4.1.3, for a detailed explanation of how to generate output database requests.

Three types of information are stored in the output database: "field" output, "history" output, and diagnostic information. Field output is intended to be relatively infrequent output for a large portion of the model. Abaqus/CAE uses field output to generate contour plots, displaced shape plots, symbol plots, and *X*–*Y* plots in the Visualization module. History output is intended to be output for a small portion of the model requested at a fairly high frequency. Abaqus/CAE uses history output to generate *X*–*Y* plots in the Visualization module. See "Output to the output database," Section 4.1.3, for detailed descriptions of field and history output. Diagnostic information is intended to provide convergence information for use in Abaqus/CAE; for more information, see Chapter 41, "Viewing diagnostic output," of the Abaqus/CAE User's Guide.

Format of the output database

The output database is a neutral binary, platform-independent file. Unlike the restart or binary results files, it can be copied directly from one computing platform to another without translation.

By default, floating point data are written to the output database file in single precision. You can choose to write floating point nodal field output data to the output database file in double precision; see "Abaqus/Standard, Abaqus/Explicit, and Abaqus/CFD execution," Section 3.2.2, for details.

You can open an output database file from an older release of Abaqus in Abaqus/CAE, with the exception that Abaqus 5.8 output database files cannot be opened in Version 6. Output database files from previous releases of Abaqus must be converted to the current release when they are opened. If you are using an older release of Abaqus/CAE, you cannot open an output database file created from a newer release of Abaqus.

The selected results file

The Abaqus/Explicit selected results file (*job-name*`.sel`) stores user-selected results, which are converted into the results file (*job-name*`.fil`) for postprocessing by other commercial postprocessing packages.

Element output, node output, and energy output can be requested (see "Output to the data and results files," Section 4.1.2, for details); the variables available for output are listed in "Abaqus/Explicit output variable identifiers," Section 4.2.2. You can write a user-selected subset of the results for a given node set or element set at more frequent intervals than the restart intervals. You specify the output requests within a step definition, which allows you to be selective about the amount of data written to the selected results file to avoid using excessive disk storage. For example, when dealing with a very large model, you may choose to write only the current displacements and the equivalent plastic strain for the entire model 20 times in the step and to write the acceleration history at one node 200 times in the step.

The results file

The Abaqus results file in Abaqus/Standard and Abaqus/Explicit (*job-name*`.fil`) can be read by external postprocessors to produce *X–Y* plots or printed tabular output. Most commercial finite element results-display packages provide translators that use the Abaqus results file as their input. The results file can also be used as a convenient medium for importing analysis results into your own postprocessing program. "Accessing the results file information," Section 5.1.3, provides details on how to read this file.

Results file output of temperature from a heat transfer, thermal-electrical, or thermal-electrical-structural analysis can be used as input to a stress analysis of the same mesh (see "Sequentially coupled thermal-stress analysis," Section 16.1.2).

Obtaining results file output in Abaqus/Standard

In Abaqus/Standard you choose the variables to be written to the results file from the lists in "Abaqus/Standard output variable identifiers," Section 4.2.1, in a manner similar to that for output printed to the data file. You must specifically request that values be written to the results file or none will be provided. Element output, node output, contact surface output, energy output, modal output, and radiation output are available—see "Output to the data and results files," Section 4.1.2, and "Cavity radiation," Section 41.1.1, for details.

Obtaining results at the beginning of a step

You can request that the solution state at the beginning of a step (the zero increment) be written to the Abaqus/Standard results file. Zero-increment file output is available only for steps in which the concept of time governs the incrementation scheme of the selected procedure and, hence, the following procedures are excluded:

- Linear static perturbation analysis ("Static stress analysis," Section 6.2.2)
- "Eigenvalue buckling prediction," Section 6.2.3

- "Natural frequency extraction," Section 6.3.5
- "Mode-based steady-state dynamic analysis," Section 6.3.8
- "Response spectrum analysis," Section 6.3.10
- "Random response analysis," Section 6.3.11

If you request zero-increment results file output, it will be generated for all valid procedures in a given analysis.

You must request zero-increment results file output to generate a zero-increment results file in a data check analysis (see "Abaqus/Standard, Abaqus/Explicit, and Abaqus/CFD execution," Section 3.2.2). It is strongly recommended that you request zero-increment results file output if the results file is used to drive a submodel; see "Node-based submodeling," Section 10.2.2, for further discussion.

Input File Usage: *FILE FORMAT, ZERO INCREMENT

The *FILE FORMAT option can be given as model data or as history data, but it can appear only once in the input file.

Abaqus/CAE Usage: Results file output cannot be requested in Abaqus/CAE.

Obtaining results file output in Abaqus/Explicit

The Abaqus/Explicit results file is a sequential access file generated from the selected results file (see "Abaqus/Standard, Abaqus/Explicit, and Abaqus/CFD execution," Section 3.2.2). The results file contains the requested results in the format described in "Results file output format," Section 5.1.2.

Input File Usage: Use either of the following command line options to convert a selected results file to a results file:

abaqus job=*job-name* **convert**=**`select`**

abaqus job=*job-name* **convert**=**`all`**

Abaqus/CAE Usage: The selected results file cannot be converted in Abaqus/CAE.

Part and assembly information

An Abaqus model can be defined in terms of an assembly of part instances (see "Defining an assembly," Section 2.10.1). However, the results file does not contain part and assembly records.

In a model defined in terms of an assembly of part instances, node and element numbers can be repeated within the definitions of different parts. These local numbers are converted internally by Abaqus to unique global numbers, and the output written to the results file is given in terms of the global (internal) numbers. A map between user-defined numbers and internal numbers is printed to the data file if any results file output that includes node and element numbers is requested.

Set and surface names that appear in the results file are prefixed by the assembly and part instance names, separated by underscores (**`Assembly_Part1-1_setname`**, for example).

Local coordinate systems defined within a part or part instance are translated and rotated according to the positioning data given in the part instance definition.

Format of the results file

The Abaqus results file in Abaqus/Standard or Abaqus/Explicit is organized as a sequential file, in binary or in ASCII format. ASCII format is necessary if the file is to be read on a computer system that is different from the one on which the file was written. ASCII format allows the results file to be transferred between different computer systems without having to translate binary data. ASCII format is not needed if the file will always be used on the same system or on systems that use the same binary format. If the results file output will always reside on the same computer, the default binary format is usually the most efficient way of storing the file. For large problems a file in ASCII format will be significantly larger than the same file in binary format.

Controlling the format of the results file in Abaqus/Standard

Abaqus/Standard can write the results file in either binary or ASCII format. The default format is binary.

The results file output must be written in the same format for the entire analysis. The format cannot be changed upon restarting the problem.

The format of the Abaqus/Standard results file can also be controlled in the Abaqus/Standard environment file (see "Using the Abaqus environment settings," Section 3.3.1). The format specified in an analysis supersedes the value defined in the enviroment file.

In addition, the **ascfil** facility in the Abaqus execution procedure ("ASCII translation of results (`.fil`) files," Section 3.2.12) can be used to convert a binary Abaqus/Standard results file (*job-name*`.fil`) to ASCII format (*job-name*`.fin`) after the analysis completes.

Input File Usage: ∗FILE FORMAT, ASCII

The ∗FILE FORMAT option can be given as model data or as history data, but it can appear only once in the input file.

Abaqus/CAE Usage: Results file output cannot be requested in Abaqus/CAE.

Controlling the format of the results file in Abaqus/Explicit

Abaqus/Explicit always writes the results file output in binary format during file conversion, but the binary Abaqus/Explicit results file can be converted to ASCII format using the **ascfil** facility ("ASCII translation of results (`.fil`) files," Section 3.2.12).

ASCII format

"Results file output format," Section 5.1.2, defines the contents of the records that are written to the results file; these descriptions also hold if the results file is written in ASCII format. All the data items in these files are either integers, floating point numbers, or character strings. When ASCII format is requested, each data item is translated into an equivalent character string before it is written to the file. These strings are written in 80-character logical records in the order described in the record definitions.

Each 80-character logical record is completely filled before the next one is started, so that any data item can be split, with some of the characters that define the item in one logical record and the remainder in the next. Each data item usually follows immediately behind its predecessor. The exception is that for results file record key 2001 Abaqus will fill out the logical record with blank characters, so that the

record can be written immediately to the physical storage medium. Abaqus then inserts a logical record consisting of 80 blanks, which allows the end-of-file to be handled correctly.

The beginning of each "record" is indicated by an asterisk (*). Each floating point number begins with the character D, followed by the number in the format E22.15 or D22.15, depending on whether the release of Abaqus that wrote the results file used single precision or double precision. Each character string begins with the character A, followed by eight characters (if the character string has fewer than eight characters, the right part of the string is blank; character strings longer than eight characters are written eight characters at a time). Each integer begins with the character I, followed by a two digit integer giving the number of decimal digits in the integer, followed by the integer itself (written as decimal digits).

For example, record key 1900 for an S4R element with element number 5 and nodes 195, 198, 205, and 204 would be written

```
*I 18I 41900I 15AS4R     I 3195I 3198I 3205I 3204
```

and record key 101 for node 135 and 6 degrees of freedom would be written

```
*I 19I 3101I 3135D1.280271914214298E-10D1.500000000000036E+00
D-1.074629835784448E-46D 6.983222716550941E-12
D-4.084928798492785E-13D-1.072688441364597E-10
```

Precision of floating point data in the results file

The precision of floating point data written to the results file depends on the precision of the executable that generates the data. Abaqus/Standard always uses double precision; thus, floating point data are always written to the Abaqus/Standard results file in double precision. Abaqus/Explicit can be run in single or double precision on most machines; see "Defining an analysis," Section 6.1.2, for details on the precision level of the Abaqus/Explicit executable. If the double precision executable for Abaqus/Explicit is used, floating point data are written to the Abaqus/Explicit results file in double precision; likewise, if the single precision executable for Abaqus/Explicit is used, floating point data are written to the Abaqus/Explicit results file in single precision.

Maximizing the efficiency of the results file

In Abaqus/Standard each element output request (a collection of identifying keys entered on a single line) is preceded by an "element header" record (see "Results file output format," Section 5.1.2). Hence, the size of the results file can be minimized by entering all element output variables of the same "type" (element integration point variable, element section variable, whole element variable, etc.) on a single line. (See "Output to the data and results files," Section 4.1.2, for an explanation of the output variable types.) Consolidating output variable entries is encouraged, since it will reduce the size of the results file.

Example

For example, the following output requests can be used to request output of element variables in the results file in a stress/displacement analysis:

```
*EL FILE
 S, SINV, E, PE, CE, EE, ENER, TEMP, FV, COORD
 SF, SE
 LOADS, ELEN, EVOL
*EL FILE, REBAR
 S, SINV, E, PE, CE, EE, RBFOR, RBANG
 SF, SE
 LOADS, ELEN
```

(The output requests for rebar quantities need not be the same as the underlying element output requests.)

The message file in Abaqus/Standard and Abaqus/Explicit

The message file (*job-name*`.msg`) is a text file that contains diagnostic messages about the progress of the solution.

The Abaqus/Standard message file

In Abaqus/Standard the message file contains diagnostic or informative messages about the progress of the solution. If any of these messages describe errors or warnings, the number of such errors or warnings is also given at the end of the data file. The message file is written automatically during an Abaqus/Standard analysis.

The Abaqus/Standard message file contains information about the increment number, step time, fraction of a step completed, equilibrium iterations, severe discontinuity (contact) iterations, plasticity algorithms, adaptive mesh smoothing, the load proportionality factor in a Riks analysis, etc. A portion of the diagnostic information in the message file is also written to the output database for use in Abaqus/CAE (for more information, see "Requesting diagnostic information in Abaqus/Standard and Abaqus/Explicit" in "Output to the output database," Section 4.1.3).

You can control the amount of information written to the message file for each step. This feature is sometimes helpful in difficult analyses since it allows detailed diagnostic information to be written about certain events (such as contact) during a nonlinear solution; this information can often be useful in developing a strategy for the solution of highly nonlinear problems.

Input File Usage: *PRINT

The *PRINT option can appear only once within a step definition.

Abaqus/CAE Usage: Step module: **Output→Diagnostic Print**

Controlling the frequency of output to the message file

You can control the frequency at which information is printed to the message file by specifying the desired output frequency in increments. The default output frequency is 1 (or 10 in a direct cyclic or a low-cycle fatigue analysis). The output will always be printed at the last increment of each step unless you specify a frequency of zero to suppress the output.

Input File Usage: *PRINT, FREQUENCY=*N*

Abaqus/CAE Usage: Step module: **Output→Diagnostic Print**: **Frequency** *N*

Requesting detailed contact printout

You can obtain a detailed printout of contact conditions during iteration. This information about which points are contacting or separating in interface and gap problems is useful in tracking the development of the solution in difficult contact problems. The details are written for every severe discontinuity iteration. By default, the detailed contact output is suppressed.

Input File Usage: *PRINT, CONTACT=YES *or* NO

Abaqus/CAE Usage: Step module: **Output→Diagnostic Print**: toggle on **Contact**

Requesting detailed model change printout

You can obtain a detailed printout of model change operations (removal and reactivation) at the start of a step. This information includes the new original coordinates and normals of elements being reactivated strain free in a large-displacement analysis. By default, the detailed model change output is suppressed. See "Element and contact pair removal and reactivation," Section 11.2.1, for details on model change operations.

Input File Usage: *PRINT, MODEL CHANGE=YES *or* NO

Abaqus/CAE Usage: Step module: **Output→Diagnostic Print**: toggle on **Model Change**

Requesting detailed printout of problems with the plasticity algorithms

You can activate printout of element and integration point numbers for which the plasticity algorithms have failed to converge during an iteration. This information is useful for finding the place in the mesh and/or the plasticity model at which Abaqus is encountering material model difficulties. Modeling problems and material parameter specification problems can be identified using this detailed printout. By default, this printout is suppressed.

Input File Usage: *PRINT, PLASTICITY=YES *or* NO

Abaqus/CAE Usage: Step module: **Output→Diagnostic Print**: toggle on **Plasticity**

Requesting output of equilibrium residuals

By default, equilibrium residuals during equilibrium iterations are output. You can choose to suppress this output entirely, but it is not recommended; without the output of equilibrium residuals, you cannot see the accuracy of the iteration process.

Input File Usage: *PRINT, RESIDUAL=YES *or* NO

Abaqus/CAE Usage: Step module: **Output→Diagnostic Print**: toggle on **Residual**

Requesting solver information

By default, information about the number of equations being solved and the required memory for each iteration is output. You can request that output be suppressed.

Input File Usage: *PRINT, SOLVE=YES *or* NO

Abaqus/CAE Usage: Step module: **Output→Diagnostic Print**: toggle on **Solve**

Requesting detailed adaptive mesh smoothing printout

You can activate detailed printout of adaptive mesh smoothing in Abaqus/Standard. The output includes information about the magnitude of the maximum displacement and the node and degree of freedom where the maximum displacement increment occurs during each mesh sweep. It also provides the node numbers at which geometric feature changes occur. By default, only a summary is output.

Input File Usage: ∗PRINT, ADAPTIVE MESH=YES *or* NO

Abaqus/CAE Usage: Adaptive mesh output to the message file is not supported in Abaqus/CAE.

Monitoring a degree of freedom in the message file

You can write the current value of a specified point and degree of freedom to the message file. This information can be used to monitor the progress of the solution. The information will also be written in the status file (see below). You can control the frequency at which the value is printed in the message file. The default frequency is 1 (or 10 in a direct cyclic analysis).

Degree of freedom monitoring does not apply to eigenvalue buckling prediction, eigenfrequency extraction, or response spectrum procedures. For other linear perturbation procedures output for the monitored degree of freedom is the base state value.

Input File Usage: ∗MONITOR, NODE=*node_number*, DOF=*dof*, FREQUENCY=*N*

The node and degree of freedom being monitored can be changed from step to step by repeating the ∗MONITOR option. The node and degree of freedom specified in the last occurrence of this option in a step will be used for that step.

Abaqus/CAE Usage: Step module: **Output→DOF Monitor**: **Monitor a degree of freedom throughout the analysis**, click **Edit** to select the point, **Degree of freedom:** *dof*, **Print to the message file every *N* increments**

In Abaqus/CAE only one point and degree of freedom can be monitored for an analysis; you cannot change the monitor request from step to step.

The Abaqus/Explicit message file

In Abaqus/Explicit the message file contains messages if potential problems are detected during an analysis. You can control the output of diagnostic messages for each step (see "Explicit dynamic analysis," Section 6.3.3, and "Contact diagnostics in an Abaqus/Explicit analysis," Section 39.2.1). A portion of the diagnostic information in the message file is also written to the output database for use in Abaqus/CAE (for more information, see "Requesting diagnostic information in Abaqus/Standard and Abaqus/Explicit" in "Output to the output database," Section 4.1.3).

The status file

The status file (*job-name*`.sta`) is a text file that contains information about the progress of an analysis.

The Abaqus/Standard or Abaqus/CFD status file

The Abaqus/Standard or Abaqus/CFD status file contains a single 80-character record for each increment and is updated upon completion of each increment of an analysis. This record is written directly to secondary storage immediately at the completion of the increment. Therefore, the status file can be examined as the analysis job is executing, thus providing a monitor of the progress of the analysis. Other than specifying that a degree-of-freedom variable be monitored in the status file in Abaqus/Standard (as described below), the information written to the Abaqus/Standard or Abaqus/CFD status file cannot be controlled.

The Abaqus/Explicit status file

In Abaqus/Explicit the status file (*job-name*`.sta`) contains, by default, mass and inertial properties for the model, initial stable time increment information, a synopsis of the progress of the analysis including total accumulated CPU usage and the current time increment size, and an estimate of the memory required to process each step. You can control additional output including the total kinetic energy, the energy balance, the identifiers of the elements with the smallest stable time increments, and the percent change in total mass of the model due to mass scaling.

The frequency at which summary increments are written to the Abaqus/Explicit status file depends on the duration of the analysis in CPU minutes and the amount of output specified in the analysis. The following list provides general guidelines for when a summary increment will be written to the status file.

Summary information will generally be written:

- Each time restart information, field output to the output database, or results file output is written.
- Once per increment if the problem requires fewer than 20 increments.
- 20 times during the step for a short analysis (less than 40 CPU minutes).
- Every 2 CPU minutes for an analysis longer than 40 CPU minutes.

A degree-of-freedom variable can be monitored in the status file while the analysis is running. You can also write additional diagnostic information to the status file (see "Explicit dynamic analysis," Section 6.3.3, and "Contact diagnostics in an Abaqus/Explicit analysis," Section 39.2.1, for details). A portion of the diagnostic information in the status file, including information for each summary increment, is also written to the output database for use in Abaqus/CAE (for more information, see "Requesting diagnostic information in Abaqus/Standard and Abaqus/Explicit" in "Output to the output database," Section 4.1.3).

Errors that can be detected only while packaging the data for Abaqus/Explicit or during analysis are also written to the status file.

Input File Usage: *PRINT

The *PRINT option can appear only once within a step definition.

Abaqus/CAE Usage: Step module: **Output→Diagnostic Print**

Requesting kinetic energy output

By default, the kinetic energy for the model is written to the status file. This output is written periodically throughout the step. You can choose to include or exclude the kinetic energy output for each step.

Input File Usage: *PRINT, ALLKE=YES *or* NO

Abaqus/CAE Usage: Step module: **Output→Diagnostic Print**: toggle on **Allke**

Requesting total energy output

By default, the energy balance is written periodically throughout the step. You can choose to include or exclude the energy balance output for each step.

Input File Usage: *PRINT, ETOTAL=YES *or* NO

Abaqus/CAE Usage: Step module: **Output→Diagnostic Print**: toggle on **Etotal**

Requesting output of the critical element

By default, the number of the element with the current minimum stable time increment and its value are output to the status file. This output is written periodically throughout the step. You can choose to include or exclude the critical element output for each step.

Input File Usage: *PRINT, CRITICAL ELEMENT=YES *or* NO

Abaqus/CAE Usage: Step module: **Output→Diagnostic Print**: toggle on **Crit. Elem.**

Requesting output of the change in the total mass

You can write the percent change in total mass of the model due to mass scaling to the status file for each step. This output is written periodically throughout the step. The percent change in total mass is printed by default only if mass scaling is present in the model.

Input File Usage: *PRINT, DMASS=YES *or* NO

Abaqus/CAE Usage: Step module: **Output→Diagnostic Print**: toggle on **Dmass**

Monitoring a degree of freedom in the status file

You can write the current value of a specified point and degree of freedom to the Abaqus/Standard status file. The value of the point and degree of freedom being monitored will appear in the status file for every increment written during the analysis.

When a degree of freedom is monitored in the Abaqus/Standard status file, the same information is written to the message file (see above), but the specified frequency has no effect on the output to the status file.

Degree of freedom monitoring does not apply to eigenvalue buckling prediction, eigenfrequency extraction, or response spectrum procedures. For other linear perturbation procedures output for the monitored degree of freedom is the base state value.

Input File Usage: *MONITOR, NODE=*node_number*, DOF=*dof*

The node and degree of freedom being monitored can be changed from step to step by repeating the *MONITOR option. The node and degree of freedom specified in the last occurrence of this option in a step will be used for that step.

Abaqus/CAE Usage: Step module: **Output→DOF Monitor**: **Monitor a degree of freedom throughout the analysis**, click **Edit** to select the point, **Degree of freedom:** *dof*

In Abaqus/CAE only one point and degree of freedom can be monitored for an analysis; you cannot change the monitor request from step to step.

Alternate output formats in Abaqus/CFD

By default, when you request output in Abaqus/CFD, the output is sent to the output database file. However, you have the option of selecting alternate file formats for field and history output. Field output can be sent to files in EXODUS-II format; history output can be sent to files in comma-separated values (CSV) format.

You request the field and history output in the same manner as described in "Requesting output to the output database." To select an alternate output format, you set the **field** and **history** options on the command line when you run an Abaqus/CFD analysis. For more information, see "Abaqus/Standard, Abaqus/Explicit, and Abaqus/CFD execution," Section 3.2.2.

Field output in EXODUS-II format

The EXODUS-II format is widely supported by third-party postprocessors for both computational solid mechanics and computational fluid dynamics. This format is binary, machine independent, and well suited for transient simulation results on unstructured grids.

The EXODUS-II format and associated EXODUS-II/NEMESIS programming API for reading and writing were developed at Sandia National Laboratories. This open source software is available under the BSD License. The source code and documentation can be found at http://sourceforge.net/projects/exodusii.

The EXODUS-II format cannot natively represent all of the Abaqus/CFD output features. The features listed in Table 4.1.1–1 cannot be represented directly and are either omitted or modified.

Table 4.1.1–1 Abaqus/CFD output feature representation in EXODUS-II format.

Feature	Comment
Parts and assemblies	Node and element numbers do not include the part instance name and are numbered sequentially (see "Naming conventions" in "Defining an assembly," Section 2.10.1)
Element sets	General element sets are not supported and are omitted
Amplitudes	Not supported

The EXODUS-II format uses file extension **exo**. For parallel processing of an analysis run, EXODUS-II output is directed to multiple files (one file per processor is created), which is useful for some third-party postprocessors. The files are named *job*`.exo.`*rank*, where *rank* is a number ranging from 0 to one less than the number of CPUs. In contrast, you can write field output for parallel execution to a single file (*job*`.exo`); the file is written in EXODUS-II format using the NEMESIS library.

Input File Usage: Use the following command line option in Abaqus/CFD to write field output in EXODUS-II format to one file per processor:

abaqus job=*job-name* **field**=`exodus`

Use the following command line option in Abaqus/CFD to write field output in EXODUS-II format to a single file for parallel execution:

abaqus job=*job-name* **field**=`nemesis`

Abaqus/CAE Usage: You cannot select an alternate format for field output in Abaqus/CAE.

History output in CSV format

The comma-separated values (CSV) format is a text-based output format. The format of the CSV text file consists of one or more comment lines followed by one line of comma-separated data per history output frame. Comments in the CSV file begin with the character **#**. Each column in the CSV file has a comment that describes the mesh location, the part instance, and the output request label. Possible values for mesh locations are node, element, or surface. Vector output requests also include the component; i.e., 1, 2, or 3.

This format uses file extension **csv**. History output in the CSV format creates one file per output request label per step. Additional files are created if the job is run in parallel and the set associated with the history output request is split between processors due to the domain decomposition. In this case there will be one file per processor on which the set is present. The files are named *job_output-request_rank_step-number*`.csv`, where *rank* is a number ranging from 0 to one less than the number of CPUs.

Input File Usage: Use the following command line option to write history output to an alternate file format in Abaqus/CFD:

abaqus job=*job-name* **history**=`csv`

Abaqus/CAE Usage: You cannot select an alternate format for history output in Abaqus/CAE.

Requesting output in multiple steps

In general, output requests apply to the step in which they are given and to all subsequent steps until they are respecified. However, output specifications for linear perturbation steps (available only in Abaqus/Standard; see below and "General and linear perturbation procedures," Section 6.1.3) are treated independently of output requests for general analysis steps and apply only to a continuous sequence of linear perturbation steps.

Database output, printed output, and results file output are independent output modes in Abaqus; therefore, changing the specification for one form of output does not affect the other forms.

General analysis steps

The default output requests are used in the first general analysis step of an analysis unless you redefine them. For subsequent general analysis steps, the definition of each form of output from the previous general step is maintained unless you redefine it.

Linear perturbation steps

The default output requests are used in the first of any sequence of linear perturbation steps unless they are redefined in that step. If a subsequent linear perturbation step is defined without an intermediate general analysis step, the definition of each mode of output from the previous perturbation step is maintained unless you redefine it. If an intermediate general step is defined, the default output requests are again used in the linear perturbation step unless they are redefined in that step.

Element matrix output in Abaqus/Standard

In Abaqus/Standard you can write element stiffness matrices and, if available, mass matrices for each step to a file. For heat transfer elements the operator matrices are written if stiffness matrix output is requested.

Element matrix output is available only for elements without internal nodes (unless those nodes have no active degrees of freedom) and with no acoustic or internal degrees of freedom. Examples of elements for which element matrix output is prohibited include acoustic, pipe, elbow, frame, gap, and interface elements as well as axisymmetric elements with Fourier modes. Element matrix output is not available for elements with coupled fields such as coupled temperature-displacement elements and pore pressure elements. For incompatible mode and hybrid elements, stiffness matrix output is prohibited while mass matrix output is available. A substructure matrix output request is used to write a substructure's reduced stiffness matrix, mass matrix, and load case vectors to a file (see "Defining substructures," Section 10.1.2).

Element matrix output cannot be requested in a mode-based dynamic analysis (response spectrum, steady-state dynamic, modal dynamic, or random response). However, it can be requested in the eigenfrequency extraction analysis that precedes the mode-based dynamic analysis to output the mass and stiffness matrices.

The element matrices are written without the effects of nodal conditions; therefore, boundary conditions, concentrated loads, and the effects of multi-point constraints are not included in this output. The degrees of freedom are always in the global directions, even if a local coordinate system ("Transformed coordinate systems," Section 2.1.5) has been defined at nodes associated with the element.

You must select the element set for which output is requested. For models defined in terms of an assembly of part instances ("Defining an assembly," Section 2.10.1), element numbers written with element matrix output are internal numbers generated by Abaqus/Standard. A map between internal numbers and the original element numbers and part instance names is provided in the data file.

Writing the element matrices to the results file

By default, element matrix output records are written to the Abaqus/Standard results file. The record formats for the results file are described in "Results file output format," Section 5.1.2. The file can be written in binary or ASCII format based on the file format you specify (see "Controlling the format of the results file in Abaqus/Standard" above).

Input File Usage: *ELEMENT MATRIX OUTPUT, ELSET=*element_set*,
OUTPUT FILE=RESULTS FILE

Abaqus/CAE Usage: Element matrix output is not supported in Abaqus/CAE.

Writing the element matrices to a user-defined file

You can write the element matrices to a user-defined file. The file name should not include an extension; the extension **`.mtx`** will be added. (See "Input syntax rules," Section 1.2.1, for the syntax of user-specified file names.)

The format of the output file is compatible with the linear user element (see "User-defined elements," Section 32.15.1).

Input File Usage: *ELEMENT MATRIX OUTPUT, ELSET=*elset*,
OUTPUT FILE=USER DEFINED, FILE NAME=*output_file_name*

Abaqus/CAE Usage: Element matrix output is not supported in Abaqus/CAE.

Writing the element matrices to the data file

You can write the element matrix records to the Abaqus/Standard data file.

Input File Usage: *ELEMENT MATRIX OUTPUT, ELSET=*elset*,
OUTPUT FILE=USER DEFINED

Abaqus/CAE Usage: Element matrix output is not supported in Abaqus/CAE.

Including distributed loads

You can choose to write the load vector from distributed loads on the elements. By default, the load vector is not written.

Input File Usage: *ELEMENT MATRIX OUTPUT, ELSET=*elset*, DLOAD=YES *or* NO

Abaqus/CAE Usage: Element matrix output is not supported in Abaqus/CAE.

Controlling the frequency of element matrix output

You can control the frequency at which element matrix output will be written by specifying an output frequency in increments. By default, the element matrices will be output every increment (equivalent to an output frequency of 1). Specify an output frequency of 0 to suppress output of the element matrices. Unless the output is suppressed, the matrices will always be written at the last increment of a step.

Input File Usage: *ELEMENT MATRIX OUTPUT, ELSET=*elset*, FREQUENCY=*N*

Abaqus/CAE Usage: Element matrix output is not supported in Abaqus/CAE.

Writing the stiffness or operator matrix

You can choose to output the stiffness matrix (or operator matrix in heat transfer elements). By default, the stiffness (operator) matrix is not output.

Input File Usage: *ELEMENT MATRIX OUTPUT, ELSET=*elset*, STIFFNESS=YES *or* NO

Abaqus/CAE Usage: Element matrix output is not supported in Abaqus/CAE.

Writing the mass matrix

You can choose to output the mass matrix. By default, element mass matrices are not output.

Input File Usage: *ELEMENT MATRIX OUTPUT, ELSET=*elset*, MASS=YES *or* NO

Abaqus/CAE Usage: Element matrix output is not supported in Abaqus/CAE.

User-defined output variables in Abaqus/Standard

In Abaqus/Standard output quantities can be defined as functions of any element integration point variable listed in "Abaqus/Standard output variable identifiers," Section 4.2.1, by using user subroutine **UVARM**. Then, output variable UVARM*n* can be requested for output to the data file, the results file, or the output database.

User-defined state variables in Abaqus/Standard

In Abaqus/Standard you can allocate solution-dependent state variables and define them in user subroutines defining material behavior, as well as user subroutines **FRIC**, **UEL**, and **UINTER** (see "User subroutines: overview," Section 18.1.1). Output variable SDV*n* can be requested for output of these state variables to the data file, the results file, or the output database. For user-defined elements output variable SDV*n* cannot be requested for output to the output database.

Postprocessing with Abaqus/CAE

Abaqus/CAE provides interactive graphical postprocessing from the Abaqus output database file in the Visualization module (also licensed separately as Abaqus/Viewer). Capabilities include model and deformed shape plotting, contour plotting, vector plotting, X–Y plotting, and animation.

Recovering additional results output from restart data in Abaqus/Standard

Data needed for restart in Abaqus/Standard are contained in several files that are generated when you request that restart data be written for an analysis: the restart (**.res**), analysis database (**.mdl** and **.stt**), part (**.prt**), and output database (**.odb**) files. "Restarting an analysis," Section 9.1.1, describes the writing of restart data in more detail.

In Abaqus/Standard you can extract output from the restart data and write it to new data (**.dat**), results (**.fil**), and output database (**.odb**) files using a postprocessing analysis procedure. If the original analysis included user subroutines, the postprocessing analysis procedure requires the specification of the user subroutines. The data, results, and output database file output requests are

defined as described in "Output to the data and results files," Section 4.1.2, and "Output to the output database," Section 4.1.3. The output requests should be defined exactly as they would be in an analysis, except that:

1. The output frequency specification has no meaning and is, therefore, ignored (unless you are recovering additional output from a previous direct cyclic or low-cycle fatigue analysis). Instead, you specify each increment at which output is to be generated in the postprocessing procedure definition.
2. No default output is provided to the output database. Furthermore, model information, such as boundary conditions, is not written to the output database.
3. Element set energy information cannot be recovered since it is not written to the restart file.
4. Output is not available for procedures that do not support restart; for example, linear perturbation procedures.

The element sets and node sets that are defined for the analysis can be used for defining output sets during the postprocessing procedure. Additional sets can also be defined for the postprocessing procedure. You specify the step number in the restart file from which output is required. You cannot obtain results at the beginning of a step (see below).

Input File Usage: *POST OUTPUT, STEP=*step_number*

When the *POST OUTPUT option is used, it must appear as the first option in the input file. No data lines from the analysis input file are required. This option can be repeated as often as necessary to obtain further output. Since *POST OUTPUT is a purely postprocessing procedure, analysis options must not appear in the input file.

Abaqus/CAE Usage: Postprocessing of restart data is not supported in Abaqus/CAE.

Recovering additional output from a direct cyclic analysis

If you use this postprocessing technique to recover additional output from a previous direct cyclic analysis (see "Direct cyclic analysis," Section 6.2.6), you must specify the iteration number in the restart file from which output is required instead of the increment. If temperatures (or predefined field variables) are read from a results (`.fil`) file in the original direct cyclic analysis, the same temperatures (or predefined field variables) must be read into the postprocessing analysis. This specification is needed to recover thermal strains at each time increment in the original direct cyclic analysis since the results file is not stored in the restart analysis database.

Input File Usage: *POST OUTPUT, STEP=*step_number*, ITERATION=*iteration_number*

There are no data lines associated with this option if the ITERATION parameter is specified.

Abaqus/CAE Usage: Postprocessing of restart data is not supported in Abaqus/CAE.

Recovering additional output from a low-cycle fatigue analysis

If you use this postprocessing technique to recover additional output from a previous low-cycle fatigue analysis (see "Low-cycle fatigue analysis using the direct cyclic approach," Section 6.2.7), you must specify the cycle number in the restart file from which output is required instead of the increment. If temperatures (or predefined field variables) are read from a results (**.fil**) file in the original low-cycle fatigue analysis, the same temperatures (or predefined field variables) must be read into the postprocessing analysis. This specification is needed to recover thermal strains at each time increment in the original low-cycle fatigue analysis since the results file is not stored in the restart analysis database.

Input File Usage: *POST OUTPUT, STEP=*step_number*, CYCLE=*cycle_number*

There are no data lines associated with this option if the CYCLE parameter is specified.

Abaqus/CAE Usage: Postprocessing of restart data is not supported in Abaqus/CAE.

Example

A job can be submitted using the following input file. The analysis for which restart data were written must be specified when you submit the job (using the **oldjob** parameter of the Abaqus execution procedure). This example creates a new data (**.dat**) file containing tabular data. The first two tables will contain data from increments 5 and 10 of Step 1 and will give the reaction forces of the nodes in the set **CLAMP**, which was defined when the analysis was run. The next table will contain data from increment 3 of Step 2 and will give displacements from the new node set **TIP** that is defined in this postprocessing analysis.

```
*HEADING
*POST OUTPUT, STEP=1
 5, 10
*NODE PRINT, NSET=CLAMP
 RF,
*POST OUTPUT, STEP=2
 3,
*NSET, NSET=TIP
 1200, 1203, 1205
*NODE PRINT, NSET=TIP
 U,
```

The following example input file recovers additional output from a previous direct cyclic analysis and creates a new output database (**.odb**) file, which contains the stress and strain for the elements in the set **ELIST** from each increment in Iteration 5 of Step 1, followed by data from each increment in Iteration 10 of Step 1:

```
*HEADING
*POST OUTPUT, STEP=1, ITERATION=5
*OUTPUT, HISTORY
```

```
*ELEMENT OUTPUT, ELSET=ELIST
 S,E
*POST OUTPUT, STEP=1, ITERATION=10
*OUTPUT, HISTORY
*ELEMENT OUTPUT, ELSET=ELIST
 S,E
```

The following example input file recovers additional output from a previous low-cycle fatigue analysis and creates a new output database (**.odb**) file, which contains the stress and strain for the elements in the set **ELIST** from each increment in Cycle 5 of Step 1, followed by data from each increment in Cycle 10 of Step 1:

```
*HEADING
*POST OUTPUT, STEP=1, CYCLE=5
*OUTPUT, HISTORY
*ELEMENT OUTPUT, ELSET=ELIST
 S,E
*POST OUTPUT, STEP=1, CYCLE=10
*OUTPUT, HISTORY
*ELEMENT OUTPUT, ELSET=ELIST
 S,E
```

4.1.2 OUTPUT TO THE DATA AND RESULTS FILES

Products: Abaqus/Standard Abaqus/Explicit

References

- "Output," Section 4.1.1
- *CONTACT FILE
- *CONTACT PRINT
- *EL FILE
- *EL PRINT
- *ENERGY FILE
- *ENERGY PRINT
- *FILE OUTPUT
- *MODAL FILE
- *MODAL PRINT
- *NODE FILE
- *NODE PRINT
- *RADIATION FILE
- *RADIATION PRINT
- *SECTION PRINT
- *SECTION FILE

Overview

Output variables are available for:

- element integration points, element section points, whole elements, and element sets;
- nodes;
- the whole model;
- modes in mode-based dynamics procedures;
- surfaces in Abaqus/Standard; and
- sections in Abaqus/Standard.

All of the output variables are defined in "Abaqus/Standard output variable identifiers," Section 4.2.1, and "Abaqus/Explicit output variable identifiers," Section 4.2.2. Output quantities from the elements, nodes, and whole model can be written to the data and results files in Abaqus/Standard and to the selected results file in Abaqus/Explicit. In Abaqus/Standard output quantities from eigenmodes, surfaces, and sections can also be written to the data and results files.

For Abaqus models defined in terms of an assembly of part instances (see "Defining an assembly," Section 2.10.1), output in the data and results files is given in terms of node, element, set, and surface labels generated internally by Abaqus. See "Output," Section 4.1.1, for details on how to relate the internally generated numbers and names to those you specified.

Requesting output to the data and results files

The following sections discuss the input file syntax for requesting output to the data and results files. Abaqus/CAE automatically requests that a data file containing the default printed output for the current analysis procedure at the end of each step be generated; you cannot control the contents of the data file from within Abaqus/CAE. An analysis from Abaqus/CAE does not create a results file.

Output to the Abaqus/Standard data file

Abaqus/Standard analysis results can be written to the data (**.dat**) file. Element output, nodal output, contact surface output, energy output, modal output, and section output are available.

Input File Usage: Use any of the following options to request output to the Abaqus/Standard data file:

*CONTACT PRINT
*EL PRINT
*ENERGY PRINT
*MODAL PRINT
*NODE PRINT
*SECTION PRINT

These options are discussed in detail below.

Output to the Abaqus/Standard results file

Abaqus/Standard analysis results can be written to the results (**.fil**) file. Element output, nodal output, contact surface output, energy output, modal output, and section output are available.

Input File Usage: Use any of the following options to request output to the Abaqus/Standard results file:

*CONTACT FILE
*EL FILE
*ENERGY FILE
*MODAL FILE
*NODE FILE
*SECTION FILE

These options are discussed in detail below.

Output to the Abaqus/Explicit results file

You can write Abaqus/Explicit analysis results to the selected results (**.sel**) file by specifying a results file output request in conjunction with element output, nodal output, and/or energy output requests, as

explained below. A results file output request can appear only once per step but remains in effect in subsequent steps unless it is redefined.

You can convert the selected results file (*job-name*`.sel`) into the results (*job-name*`.fil`) file using the **convert** utility described in "Obtaining results file output in Abaqus/Explicit" in "Output," Section 4.1.1, and "Abaqus/Standard, Abaqus/Explicit, and Abaqus/CFD execution," Section 3.2.2.

Input File Usage: Use the first option in conjunction with one or more of the subsequent options to request output to the Abaqus/Explicit selected results file:

```
*FILE OUTPUT
*EL FILE
*ENERGY FILE
*NODE FILE
```

Output frequency

You can control the frequency of all Abaqus/Explicit results file output for a particular step by specifying the number of intervals during the step at which file output will be written, *n*. The data are always written at the start and end of each step in which a results file output request is active. The times at which the results are written are referred to as time marks.

If the specified number of intervals is 10, Abaqus/Explicit will write results 11 times: the values at the beginning of the step and at the end of 10 equal time intervals throughout the step. The specified number of intervals must be a positive integer.

By default, results will be written at the increment ending immediately after each time mark. Alternatively, you can choose to have the time increment size adjusted so that an increment will end exactly at each of the time marks calculated by dividing the step into *n* equal intervals.

Input File Usage: Use the following option to request results at the increments ending immediately after each time interval:

```
*FILE OUTPUT, NUMBER INTERVAL=n, TIME MARKS=NO
```

Use the following option to request results at the exact time intervals:

```
*FILE OUTPUT, NUMBER INTERVAL=n, TIME MARKS=YES
```

Requesting output in multiple steps

Output requests apply to the step in which they are defined and to all subsequent steps until they are respecified.

One exception occurs when the step type changes from general to linear perturbation (available only in Abaqus/Standard). Output requests defined in general steps apply only to subsequent general steps; output requests defined in linear perturbation steps apply only to subsequent consecutive linear perturbation steps. In other words, output defined in a general step is independent of output defined in a linear perturbation step. Propagation between linear perturbation steps occurs only for consecutive linear perturbation steps. If a general analysis step occurs between perturbation steps, output defined in the first perturbation step will not propagate to the next perturbation step. In addition, section output requests are not propagated among linear perturbation steps in Abaqus/Standard.

Element output

You can output element variables (stresses, strains, section forces, element energies, etc.) for a particular step to the Abaqus/Standard data (**.dat**) file, the Abaqus/Standard results (**.fil**) file, or the Abaqus/Explicit selected results (**.sel**) file. The output requests can be repeated as often as necessary within a step to define output for different types of element variables, different element sets, etc. The same element (or element set) can appear in several output requests.

In general, element output requests remain in effect for subsequent steps unless they are redefined; the appearance of a single element output request in a step removes all element output requests from a previous step. See "Output," Section 4.1.1, for a discussion of requesting output in multiple general analysis steps or linear perturbation steps.

In Abaqus/Explicit the element output is written to the selected results (**.sel**) file, which must be converted to the results (**.fil**) file as explained above.

Input File Usage: Use the following option to output element variables to the Abaqus/Standard data file:

*EL PRINT

Use the following option to output element variables to the Abaqus/Standard results file or the Abaqus/Explicit selected results file:

*EL FILE

Selecting the element output variables

The following types of element variables are recognized for the purpose of defining output:

- "Element integration point" variables are associated with the integration points at which the material calculations are performed (for example, components of stress and strain). For beams and pipes defined in Abaqus/Standard with a general beam section, integration point variables are available only if the output section points were specified for the section (see "Using a general beam section to define the section behavior," Section 29.3.7). For first-order heat transfer elements the integration points are located at the corners of the element in heat capacitance calculations.
- "Element section point" variables are associated with the cross-section of a beam, pipe, or a shell (for example, bending moments and membrane forces on the section).
- "Whole element" variables are attributes of an entire element (for example, the total energy content of the element).
- "Whole element set" variables are attributes of an entire element set (for example, the current coordinates of the center of mass); these variables are available only in Abaqus/Standard.

The element variables that can be written to the data and results files are defined in "Abaqus/Standard output variable identifiers," Section 4.2.1, and "Abaqus/Explicit output variable identifiers," Section 4.2.2.

Abaqus/Standard allows only complete sets of basic variables (for example, all of the stress or strain components) to be written to the results file. Individual variables (such as a particular stress component) cannot be selected and must be obtained by postprocessing. Abaqus/Standard element variables can be

written to the data and results files at the integration points, at the centroid, averaged at the nodes, or extrapolated to the nodes.

In Abaqus/Explicit the complete stress or strain tensors can be written to the selected results file, or individual scalar variables such as equivalent plastic strain can be written. Abaqus/Explicit writes element variables to the results file only at the integration points where they are calculated.

Selecting the elements for which output is required

You can specify the element set for which output is being requested. If you do not specify an element set, the output will be printed for all elements and, in Abaqus/Explicit, for all rebars in the model. In Abaqus/Standard output requests for rebars are governed separately, as discussed below.

Input File Usage: Use either of the following options:

∗EL PRINT, ELSET=*element_set_name*
∗EL FILE, ELSET=*element_set_name*

Specifying the section point in beams, pipes, shells, and layered solid elements

For beams, pipes, shells, or layered solid elements in Abaqus/Standard output is provided at the default section points listed in Part VI, “Elements.” You can specify nondefault output points.

In Abaqus/Explicit output is always provided at all section points for beam, pipe, and shell element output requests.

Input File Usage: Use either of the following options in Abaqus/Standard:

∗EL PRINT
list of output points
∗EL FILE
list of output points

Requesting output for rebars in a reinforced model

In Abaqus/Standard you can request output for rebars (“Defining reinforcement,” Section 2.2.3). If you do not explicitly request rebar output in an Abaqus/Standard model with rebars, the element output requests govern the output for the matrix material only (except for section forces, where the forces in the rebar are included in the force calculation). You can request output for a particular rebar. If you do not specify the name of a rebar, output will be given for all rebars in the specified element set (or in the whole model, if you have not specified an element set).

In beam and continuum elements in Abaqus/Standard rebar output can be obtained at the integration points only. In shell, membrane, and surface elements rebar output is available at the integration points and at the element’s centroid.

In Abaqus/Explicit output for the rebars in the specified element set (or the whole model, if you have not specified an element set) is always included for element output requests.

Input File Usage: Use either of the following options in Abaqus/Standard:

∗EL PRINT, REBAR=*rebar_name*
∗EL FILE, REBAR=*rebar_name*

Selecting the position of element integration and section point output in Abaqus/Standard

In Abaqus/Standard integration point variables and section variables can be written to the data and results files in four different positions. By default, output is provided at the integration points.

Obtaining element output at the integration points

By default, the variables are output at the integration points where they are calculated. (You can obtain the position of the integration points by using output variable COORD—see "Abaqus/Standard output variable identifiers," Section 4.2.1.)

Input File Usage: Use either of the following options:

```
*EL PRINT, POSITION=INTEGRATION POINTS
*EL FILE, POSITION=INTEGRATION POINTS
```

Obtaining element output at the centroid of each element

You can choose to output the variables at the centroid of each element (the centroid of the reference surface of a shell element or the midpoint between the end nodes of a beam or a pipe element). Centroidal values are obtained by interpolation of the integration point values if the integration scheme for the element does not include a centroidal integration point.

Input File Usage: Use either of the following options:

```
*EL PRINT, POSITION=CENTROIDAL
*EL FILE, POSITION=CENTROIDAL
```

Obtaining element output averaged at the nodes

You can choose to extrapolate the variables to the nodes, then average them over all of the elements in the set that contribute to each node. For derived variables, such as the principal stress, Abaqus/Standard will first average the extrapolated tensor components over all of the elements connected to the node to obtain unique components at each node, then calculate the derived value based on the averaged components.

By default, Abaqus/Standard partitions the elements in the model into averaging regions. The partitioning is based upon the structure of the elements: element type, number of section points, type of material, single layer or composite, etc. Partitioning is not based upon the values of element properties (such as thickness), material orientations, or material constants. Averaging will occur only over elements that contribute to a node and belong to the same averaging region.

In some situations you may want the averaging regions to take into account the values of element properties. For example, since variables may be discontinuous between elements with different material constants, you may not want elements with different property definitions included in the same averaging region. In such cases you can force Abaqus/Standard to take into account values of element properties by setting the Abaqus environment parameter **average_by_section** to **`ON`**. However, in problems with many section and/or material definitions the default value of **`OFF`** will, in general, give much better performance than the nondefault value of **`ON`**.

Input File Usage: Use either of the following options:

*EL PRINT, POSITION=AVERAGED AT NODES
*EL FILE, POSITION=AVERAGED AT NODES

Obtaining element output extrapolated to the nodes

You can choose to extrapolate the element integration point variables to the nodes of each element independently, without averaging the results from adjoining elements.

Input File Usage: Use either of the following options:

*EL PRINT, POSITION=NODES
*EL FILE, POSITION=NODES

Extrapolation and interpolation of element output variables

The shape functions of the element are used for purposes of extrapolation and interpolation of output variables. Extrapolated values are generally not as accurate as the values calculated at the integration points in the areas of high stress gradients, particularly in the case of modified triangles and tetrahedra. Therefore, adequately detailed meshing is necessary around nodes where accurate nodal values of such element results are needed. If a cylindrical or spherical coordinate system is defined for the element (see "Orientations," Section 2.2.5), the orientation at each integration point may be different. When the values at the integration points are extrapolated to the nodes, the difference in the orientation is not taken into account; therefore, if the orientation varies significantly over the elements connected to a node, the extrapolated values will not be very accurate. If the material orientation undergoes significant spatial variation in a region of the model where the material behavior is truly anisotropic, a finer mesh is required to obtain accurate results even at the integration points. In that situation once the overall solution has converged with respect to the mesh density, the interpolation or extrapolation away from the integration points can also be assumed to be reasonably accurate. Element output for second-order elements with one collapsed side in two dimensions or one collapsed face in three dimensions should not be extrapolated to the nodes.

In a coupled temperature-displacement and a coupled thermal-electrical-structural analysis nodal temperatures (variable NT11) are more accurate than temperatures at the integration point (variable TEMP) extrapolated to the nodes.

For derived variables, such as the Mises equivalent stress, the components are first extrapolated or interpolated, then the derived value is calculated from the extrapolated or interpolated components. However, in linear mode-based dynamic analysis procedures where values are obtained as nonlinear combinations of modal response magnitudes ("Random response analysis," Section 6.3.11, and "Response spectrum analysis," Section 6.3.10), the nonlinear combinations are first calculated at the integration points. These derived values are extrapolated to the nodes or interpolated to the centroid.

Requesting summaries in the Abaqus/Standard data file

By default in Abaqus/Standard, summaries of element variables are printed in the data file. A summary of the maximum and minimum values is printed at the end of each column in an output table. The locations of the maximum and minimum values are also printed. You can choose to suppress this summary.

Input File Usage: *EL PRINT, SUMMARY=YES *or* NO

Requesting totals in the Abaqus/Standard data file

In Abaqus/Standard you can print the sum (total) of each column in an output table to the data file. Totals can be used, for example, to obtain a sum of all the energies in a set of elements. By default, these totals are suppressed.

Input File Usage: *EL PRINT, TOTALS=YES *or* NO

Controlling the frequency of output

In Abaqus/Standard you can control the frequency of element output by specifying the output frequency in increments. Unless a frequency of zero is specified to suppress output, the variables will always be output at the last increment of the step.

In Abaqus/Explicit the frequency of element output is controlled as described in "Output frequency" above.

Input File Usage: Use either of the following options in Abaqus/Standard:

*EL PRINT, FREQUENCY=*n*
*EL FILE, FREQUENCY=*n*

Specifying the directions for element output

For components of stress, strain, and similar material variables, 1, 2, and 3 refer to the directions in an orthogonal coordinate system. If a local orientation is not defined for the element, the stress/strain components are in the default directions defined by the convention given in "Conventions," Section 1.2.2: global directions for solid elements; surface directions for shell, membrane, and gasket elements; and axial and transverse directions for beam and pipe elements.

If a local orientation is associated with the element, the element output variable components are in the local directions defined by the orientation (see "Orientations," Section 2.2.5). In Abaqus/Standard you can request that the local directions be written to the results file if component output is requested for any variable (see "Output of local directions to the results file" below). In Abaqus/Explicit the local directions will always be written to the results file when tensor output is requested for any element variable. The local directions are written automatically to the output database file from both Abaqus/Standard and Abaqus/Explicit.

In large-displacement problems the local directions defined in the reference configuration are rotated into the current configuration by the average material rotation. See "State storage," Section 1.5.4 of the Abaqus Theory Guide, for details.

Controlling the output during eigenvalue extraction

You can control element output during natural frequency extraction ("Natural frequency extraction," Section 6.3.5), complex eigenvalue extraction ("Complex eigenvalue extraction," Section 6.3.6), and eigenvalue buckling analysis ("Eigenvalue buckling prediction," Section 6.2.3) by specifying the first and last mode numbers for which output is required. By default, the first mode number is 1 and the last mode number is N, where N is the number of modes extracted. If you specify the first mode number, the default value for the last mode number is M, where M is the value specified for the first mode number.

Input File Usage: Use either of the following options:

*EL PRINT, MODE=*m*, LAST MODE=*n*
*EL FILE, MODE=*m*, LAST MODE=*n*

Abaqus/Standard data file format

In Abaqus/Standard the printed output of variables is arranged in tables in the data file. For element variables, each row of a table corresponds to a particular location: an element, a node, a section point within an element, or an integration point. The rows that will appear in a particular table are defined by choosing an element set and, possibly, locations within each element in the set.

Each table is defined by a data line of the element output request, which specifies the variables to appear in that table. There is no limit to the number of tables that can be defined. The first columns of a table define the location—the element or node number, integration point number, etc. You choose which data will appear in the remaining columns; up to 9 variables (columns) can appear in a table. For example, output variables S and E cannot be requested on the same data line in a three-dimensional analysis because that would produce 12 columns of output. If all of the entries in a row are zero, the row is not printed.

Each table can contain only one type of output variable (whole element, section, or integration point); one type of element; and only one type of section definition. If an element output request to the data file includes more than one type of output variable, element, or section definition, Abaqus/Standard will split the output automatically into the necessary number of individual tables. All of the tables defined by the first data line of the output request will be printed, then all of the tables defined by the second data line, etc.

Results file format

An element header record (the type 1 record described in "Results file output format," Section 5.1.2) is created for each line of requests for each integration point and section point in an element. In addition to the element header record, a direction record (record type 85) can be written in Abaqus/Standard when complete stress or strain tensor output is requested (see below). In Abaqus/Explicit a direction record is always written when complete stress or strain tensor output is requested.

For Abaqus/Standard file output requests with multiple variables, it is advantageous to specify as many variables as possible on each data line of the element output request (up to 16). By keeping the number of lines of requests to a minimum, extra type 1 and type 85 records are avoided and the size of the results file may be reduced substantially. This is not an issue in Abaqus/Explicit. Element variables must be of the same "type" (element integration point variable; element section variable; whole element variable; etc.) to be entered on a single line—see "Output," Section 4.1.1. In Abaqus/Standard if all results in a file output record are zero, the record is not written to the results file.

Output of local directions to the results file

By default, in Abaqus/Standard the local coordinate directions are not written to the results file. If component output is requested, you can write the local coordinate directions to the results file. A direction record of type 85 will be written following the type 1 record.

In Abaqus/Explicit the local coordinate directions are always written to the selected results file as a direction record of type 85 when complete stress or strain tensor output is requested.

Tensor component output is given in the local coordinate system, which may be inherent to the element (as is the case in shells and membranes) or user-defined ("Orientations," Section 2.2.5).

For shell elements a direction record is written for every material point in the section for which component output is requested, and a separate direction record is written for section forces and section strains. For geometrically nonlinear analysis in Abaqus/Standard the record contains the current, updated directions, except for small-strain shells and gasket elements, for which the original directions are given. For three-dimensional beams, direction output is written only if section output has been requested.

Direction output is not provided for trusses, two-dimensional beams, two-dimensional gasket elements, axisymmetric shells, axisymmetric membranes, axisymmetric gasket elements, or for values averaged at nodes. In addition, it is not provided for GK*xx*N-type gasket elements, which have no membrane or transverse shear deformation.

Input File Usage: Use the following option in Abaqus/Standard:

*EL FILE, DIRECTIONS=YES

Default element output

If you do not specify an element output request to the results file in a step (or in any previous step of the analysis), no element output will be written to the results file; similarly, if you do not specify an element output request to the data file (available only in Abaqus/Standard) in a step (or in any previous step of the analysis), no element output will be written to the data file.

Node output

You can output nodal variables (displacements, reaction forces, etc.) for a particular step to the Abaqus/Standard data (**`.dat`**) file, the Abaqus/Standard results (**`.fil`**) file, or the Abaqus/Explicit selected results (**`.sel`**) file. The output requests can be repeated as often as necessary within a step to define output for different node sets. The same node (or node set) can appear in several output requests.

In general, nodal output requests remain in effect for subsequent steps unless they are redefined; the appearance of a single nodal output request in a step removes all nodal output requests from a previous step. See "Output," Section 4.1.1, for a discussion of requesting output in multiple general analysis steps or linear perturbation steps.

In Abaqus/Explicit the nodal output is written to the selected results (**`.sel`**) file, which must be converted to the results (**`.fil`**) file as explained above.

Input File Usage: Use the following option to output nodal variables to the Abaqus/Standard data file:

*NODE PRINT

Use the following option to output nodal variables to the Abaqus/Standard results file or the Abaqus/Explicit selected results file:

*NODE FILE

Selecting the nodal output variables

The nodal variables that can be written to the data and results files are defined in the "Nodal variables" portion of "Abaqus/Standard output variable identifiers," Section 4.2.1, and "Abaqus/Explicit output variable identifiers," Section 4.2.2.

Abaqus allows only complete sets of basic variables (for example, all of the displacement components) to be written to the results file. Individual variables (such as a particular displacement component) cannot be selected and must be obtained by postprocessing.

Selecting the nodes for which output is required

You can specify the node set for which output is being requested. If you do not specify a node set, the output will be printed for all nodes in the model.

Input File Usage: Use either of the following options:

*NODE PRINT, NSET=*node_set_name*
*NODE FILE, NSET=*node_set_name*

Requesting summaries in the Abaqus/Standard data file

By default in Abaqus/Standard, summaries of nodal variables are printed in the data file. A summary of the maximum and minimum values is printed at the end of each column in an output table. The locations of the maximum and minimum values are also printed. You can choose to suppress this summary.

Input File Usage: *NODE PRINT, SUMMARY=YES *or* NO

Requesting totals in the Abaqus/Standard data file

In Abaqus/Standard you can print the sum (total) of each column in an output table to the data file. Totals can be used, for example, to sum reaction forces at the nodes. By default, these totals are suppressed.

Input File Usage: *NODE PRINT, TOTALS=YES *or* NO

Controlling the frequency of output

In Abaqus/Standard you can control the frequency of nodal output by specifying the output frequency in increments. Unless a frequency of zero is specified to suppress output, the variables will always be output at the last increment of the step.

In Abaqus/Explicit the frequency of nodal output is controlled as described in "Output frequency" above.

Input File Usage: Use either of the following options in Abaqus/Standard:

*NODE PRINT, FREQUENCY=*n*
*NODE FILE, FREQUENCY=*n*

Specifying the directions for nodal output

For nodal variables 1, 2, and 3 refer to the global directions *X*, *Y*, and *Z*, respectively. For axisymmetric elements 1 and 2 refer to the global directions *r* and *z*.

In Abaqus/Standard components of nodal variables such as reaction forces are output in the global directions unless a local coordinate system has been defined at a node (see "Transformed coordinate systems," Section 2.1.5). In this case you can specify whether output is desired in global or local directions. The local directions defined by the nodal transformation cannot be written to the results file.

The data in the Abaqus/Explicit selected results file are always output in the global directions, even if a local coordinate system has been defined at a node.

Obtaining nodal output in the global directions

In Abaqus/Standard you can request vector-valued nodal variables in the global directions, which is the default for nodal output requests to the results file since most postprocessors assume that components are given in the global system.

Input File Usage: Use either of the following options:

```
*NODE PRINT, GLOBAL=YES
*NODE FILE, GLOBAL=YES
```

Obtaining nodal output in the local directions defined by nodal transformations

In Abaqus/Standard you can request vector-valued nodal variables in the local directions defined by nodal transformations, which is the default for nodal output requests to the data file.

Input File Usage: Use either of the following options:

```
*NODE PRINT, GLOBAL=NO
*NODE FILE, GLOBAL=NO
```

Controlling the output during eigenvalue extraction

You can control nodal output during natural frequency extraction, complex eigenvalue extraction, and eigenvalue buckling analysis by specifying the first and last mode numbers for which output is required, as described above for element output.

Input File Usage: Use either of the following options:

```
*NODE PRINT, MODE=m, LAST MODE=n
*NODE FILE, MODE=m, LAST MODE=n
```

Abaqus/Standard data file format

In Abaqus/Standard the printed output of variables is arranged in tables by node set in the data file. For nodal variables each row of a table corresponds to an individual node.

Each table is defined by a data line of the nodal output request, which specifies the variables to appear in that table. There is no limit to the number of tables that can be defined. The first column of each table is the node number. You choose the variables to appear in the remaining columns; up to nine variables (columns) can appear in a table. If all of the entries in a row are zero, the row is not printed. Displacement, velocity, and acceleration components less than a relative tolerance (equal to 100 times the machine precision times the current maximum value in the model) are treated as zero.

Results file format

There is no header or direction record for nodes, so it makes little difference whether items are requested on a single line or multiple lines. In Abaqus/Standard if all results in a record are zero, the record is not written to the results file.

Default nodal output

If you do not specify a nodal output request to the results file in a step (or in any previous step of the analysis), no nodal output will be written to the results file; similarly if you do not specify a nodal output request to the data file (available only in Abaqus/Standard) in a step (or in any previous step of the analysis), no nodal output will be written to the data file.

Total energy output

You can output summaries of the energy content of the model to the Abaqus/Standard data (**.dat**) file, the Abaqus/Standard results (**.fil**) file, or the Abaqus/Explicit selected results (**.sel**) file. Energy output requests are not available for the following procedures:

- "Eigenvalue buckling prediction," Section 6.2.3
- "Natural frequency extraction," Section 6.3.5
- "Complex eigenvalue extraction," Section 6.3.6

Energy output requests remain in effect for subsequent steps. Detailed energy density output is available by using element output requests (see "Element output").

In Abaqus/Explicit the energy output is written to the selected results (**.sel**) file, which must be converted to the results (**.fil**) file as explained above.

Input File Usage: Use the following option to output summaries of the energy content to the Abaqus/Standard data file:

*ENERGY PRINT

Use the following option to output summaries of the energy content to the Abaqus/Standard results file or the Abaqus/Explicit selected results file:

*ENERGY FILE

External work calculation due to concentrated follower forces

Abaqus/Standard may generate inaccurate external work (ALLWK) in the presence of a concentrated follower load that rotates with time (see "Specifying concentrated follower forces" in "Concentrated loads," Section 34.4.2). This problem may occur in both static and implicit dynamic analyses and may result in an inaccurate total energy (ETOTAL) history output. Other results (displacements, stresses, strains, etc.) are not affected. The inaccuracy is due to the fact that the increment of work is calculated using the direction of the concentrated load at the end of the increment instead of using an average load over the increment.

Selecting the energy output variables

When energy output is requested, all of the total energy quantities listed in "Abaqus/Standard output variable identifiers," Section 4.2.1, or "Abaqus/Explicit output variable identifiers," Section 4.2.2, are output; the variables cannot be selected individually.

Selecting the element set for which total energy output is required

In Abaqus/Standard you can specify the element set for which total energy output is being requested. In this case the energies are summed for all the elements in the specified set. You cannot specify an element set for the following procedures:

- "Transient modal dynamic analysis," Section 6.3.7
- "Mode-based steady-state dynamic analysis," Section 6.3.8
- "Response spectrum analysis," Section 6.3.10
- "Random response analysis," Section 6.3.11

If you do not specify an element set, the total energies for the whole model will be output. If total energy output for both the whole model and for different element sets is desired, the energy output requests must be repeated; once without a specified element set to request energy output for the whole model and once for each specified element set.

In Abaqus/Explicit you cannot specify selected element sets for an energy output request; the total energies for the whole model will always be output.

Input File Usage: Use one of the following options in Abaqus/Standard:

*ENERGY PRINT, ELSET=*element_set_name*
*ENERGY FILE, ELSET=*element_set_name*

Controlling the frequency of output

In Abaqus/Standard you can control the frequency of energy output by specifying the output frequency in increments. Unless a frequency of zero is specified to suppress output, the variables will always be output at the last increment of the step.

In Abaqus/Explicit the frequency of energy output is controlled as described in "Output frequency" above.

Input File Usage: Use either of the following options in Abaqus/Standard:

*ENERGY PRINT, FREQUENCY=*n*
*ENERGY FILE, FREQUENCY=*n*

Default energy output

Energy output requests must be included for total energy output to be written to the data and results files; no default output is provided.

Modal output from Abaqus/Standard

You can output generalized coordinate (modal amplitude and phase) values during modal dynamic procedures (see "Dynamic analysis procedures: overview," Section 6.3.1, for an overview of the modal dynamic procedures available in Abaqus/Standard) to the data (**.dat**) file or results (**.fil**) file.

You can also request that eigenvalues be written to the results file during "Eigenvalue buckling prediction," Section 6.2.3, or "Natural frequency extraction," Section 6.3.5. The eigenvalues are always written to the results file when element or nodal output to the results file is requested; however, modal output requests allow you to write the eigenvalues to the results file without requesting any additional output.

Input File Usage: Use the following option to output modal variables to the Abaqus/Standard data file:

*MODAL PRINT

Use the following option to output modal variables to the Abaqus/Standard results file:

*MODAL FILE

Selecting the modal output variables

The modal variables that can be written to the data and results files are defined in the "Modal variables" portion of "Abaqus/Standard output variable identifiers," Section 4.2.1.

Controlling the frequency of output

You can control the frequency of modal output by specifying the output frequency in increments. Unless a frequency of zero is specified to suppress output, the variables will always be output at the last increment of the step.

Input File Usage: Use either of the following options:

*MODAL PRINT, FREQUENCY=*n*
*MODAL FILE, FREQUENCY=*n*

Default modal output

Modal output requests must be included for modal results to be written to the data and results files; no default output is provided.

Surface output from Abaqus/Standard

In Abaqus/Standard you can write variables associated with surfaces in contact, coupled temperature-displacement, coupled thermal-electrical-structural, coupled thermal-electrical, and crack propagation problems to the data and results files. The output requests can be repeated as often as necessary within a step to define output for different contact pairs and different types of surface variables.

See “Cavity radiation,” Section 41.1.1, for information on requesting output of surface variables associated with cavity radiation.

Use element output requests (see “Element output”) to obtain data and results file output for contact elements (such as slide line elements; see “Slide line contact elements,” Section 40.4.1).

Selecting the surface output variables

The following types of surface variables are recognized for the purpose of defining output:

- “Slave node” variables are associated with the integration points at which the material calculations are performed (for example, the contact stress).
- “Whole surface” variables are attributes of an entire slave surface (for example, the total force due to contact pressure).

The surface variables that can be written to the data and results files are listed in the “Surface variables” portion of “Abaqus/Standard output variable identifiers,” Section 4.2.1.

Selecting the contact pairs for which output is required

You can select the master and slave surfaces for which output is required, and you can specify a subset of slave nodes for output in addition to the master and slave surfaces or independently. If no surfaces or slave nodes are specified, surface variables are written for all the contact pairs in the model. If you specify the slave surface but not the master surface, output is given for all contact pairs that involve the specified slave surface.

Input File Usage: Use either of the following options:

∗CONTACT PRINT, MASTER=*master*, SLAVE=*slave*, NSET=*node_set*
∗CONTACT FILE, MASTER=*master*, SLAVE=*slave*, NSET=*node_set*

Requesting summaries in the data file

By default, summaries of surface variables are printed in the data file. A summary of the maximum and minimum values is printed at the end of each column in an output table. The locations of the maximum and minimum values are also printed. You can choose to suppress this summary.

Input File Usage: ∗CONTACT PRINT, SUMMARY=YES *or* NO

Requesting totals in the data file

You can print the sum (total) of each column in an output table to the data file. By default, these totals are suppressed.

Input File Usage: ∗CONTACT PRINT, TOTALS=YES *or* NO

Controlling the frequency of output

You can control the frequency of surface output by specifying the output frequency in increments. Unless a frequency of zero is specified to suppress output, the variables will always be output at the last increment of the step.

Input File Usage: Use either of the following options:

*CONTACT PRINT, FREQUENCY=*n*
*CONTACT FILE, FREQUENCY=*n*

Default surface output

Surface output requests must be included for surface variables associated with contact pairs to be written to the data and results files; no default output is provided.

If a surface output request is defined without any specified output variables, the following variables will be written to the data and results files by default:

- For contact analysis, contact pressure (CPRESS), frictional shear stresses (CSHEAR), contact opening (COPEN), and relative tangential motions (CSLIP); see "Defining contact pairs in Abaqus/Standard," Section 36.3.1.
- For heat transfer analysis, heat flux per unit area (HFL), heat flux (HFLA), time integrated HFL (HTL), and time integrated HFLA (HTLA); see "Thermal contact properties," Section 37.2.1.
- For coupled thermal-electrical analysis, HFL, HFLA, HTL, HTLA, electrical current per unit area (ECD), electrical current (ECDA), time integrated ECD (ECDT), and time integrated ECDA (ECDTA); see "Electrical contact properties," Section 37.3.1.
- For coupled pore fluid-mechanical analysis, CPRESS, CSHEAR, COPEN, CSLIP, pore fluid volume flux per unit area (PFL), pore fluid volume flux (PFLA), time integrated PFL (PTL), and time integrated PFLA (PTLA); see "Pore fluid contact properties," Section 37.4.1.
- For crack propagation analysis, there are no default output quantities; bond failure quantities must be requested explicitly; see "Crack propagation analysis," Section 11.4.3.

Data file format

Printed output of variables is arranged in tables. Each table is defined by a data line of the surface output request, which specifies the variables to appear in that table. Each table can contain only one type of output variable (slave node or whole surface). For example, output variables CSTRESS and CFN cannot be requested on the same data line. For the slave node type of output, each row of a table corresponds to a node on the slave surface. The rows that will appear in a particular table will be limited to the node set specified in the output request. The first column of each table defines the location (the node number). The remaining columns contain variables such as contact pressure, frictional shear stresses, contact opening, and relative tangential (slip) motions. For the whole surface type of output, each row of a table corresponds to an entire slave surface. If all of the variables in a row of a table are zero, the row is not printed.

If a contact output request refers to more than one contact pair, a separate table will be generated for each contact pair. All of the tables defined by the first data line of the output request will be printed, then all of the tables defined by the second line, etc.

Results file format

A contact output request record (the type 1503 record described in "Results file output format," Section 5.1.2) is created for each output request. For the slave node type of output, this record is

followed by several node header records, each of which contains a node on the slave surface. Each node header record is followed by records that contain output variables. The output will be limited to the node set specified in the output request. For the whole surface type of output, the type 1503 record is followed by only one type 1504 node header record with a node number zero. The node header record is followed by records containing the requested output variables.

If a contact output request refers to more than one contact pair, a separate contact output request record is generated for each contact pair.

Section output from Abaqus/Standard

In Abaqus/Standard you can output accumulated quantities associated with user-defined sections (see "Abaqus/Standard output variable identifiers," Section 4.2.1) for a particular step to the data or results file. This facility provides "free body diagram" output, allowing analyses of force flow through a redundant structure. The output requests can be repeated as often as necessary within a step to define output for different sections and different section output variables. You can assign a label to each output request that will be used to identify the output for the section. Section output is not available for eigenfrequency extraction, eigenvalue buckling prediction, complex eigenfrequency extraction, or linear dynamics procedures or in procedures using multiple load cases.

Defining the surface section

Section output requests are available only for sections defined using element-based surfaces (see "Element-based surface definition," Section 2.3.2). Consequently, the sections must be defined using faces of continuum elements although other types of elements (beams, membranes, shells, springs, dashpots, etc.) can be attached to the section.

Calculation of accumulated quantities on the section (such as the total force) involves nodal quantities associated with elements on one side of the section only. Therefore, the surface definition should use elements only from one side of the section (the "base elements," as defined in "Prescribed assembly loads," Section 34.5.1), thus precisely identifying the side from which accumulated quantities are computed.

Since the section usually cuts through the mesh in a typical section output request, automatic generation of the surface cannot be used. Specifying the element faces gives exact control over which element faces form the surface, which is essential when defining a cross-section through a solid body.

You must specify the name of the surface for which output is being requested.

Surfaces that are defined in a restart analysis can be used only for section output requests. The newly defined surface cannot be used for any other purpose (such as a contact pair or pre-tension section definition).

Input File Usage: Use either of the following options:

∗SECTION PRINT, NAME=*section_name*, SURFACE=*surface_name*
∗SECTION FILE, NAME=*section_name*, SURFACE=*surface_name*

Example

For example, the following input illustrates a typical section output request to the data file:

```
*HEADING
Section print example
...
*SURFACE, NAME=surface_name
Data lines that specify the elements and their associated faces to define the
surface section
...
*STEP
...
*SECTION PRINT, NAME=section_name,
SURFACE=surface_name, ...
...
*END STEP
```

Alternatively, if additional section output requests are needed after the analysis is completed, a restart analysis can be performed to request more output as shown in the following input:

```
*RESTART, READ, ...
...
*SURFACE, NAME=surface_name
Data lines that specify the elements and their associated faces to define the
surface section
...
*STEP
...
*SECTION PRINT, NAME=section_name,
SURFACE=surface_name, ...
...
*END STEP
```

Selecting the coordinate system in which output is desired

You can specify the choice of coordinate system in which the section output is desired. By default, the components of vector quantities associated with the section are obtained with respect to the global system of coordinates. Alternatively, you can specify that output is desired in a local system as defined below.

Input File Usage: Use either of the following options:

*SECTION PRINT, NAME=*section_name*, SURFACE=*surface_name*, AXES=GLOBAL or LOCAL
*SECTION FILE, NAME=*section_name*, SURFACE=*surface_name*, AXES=GLOBAL or LOCAL

Defining a coordinate system local to the surface section

You can allow Abaqus/Standard to define the local system, or you can specify it directly.

Default local system

The default local system is particularly useful when the section is flat or almost flat. While it can also be used in the case when the defined surface is curved, the default local system may be irrelevant for such problems.

The default system is defined by a straight line in two-dimensional and axisymmetric cases or by a plane in three-dimensional cases, fitted (in a least square sense) through the nodes belonging to the section. The anchor point (origin) of the local system is the centroid of the projection of the surface on the fitted line or plane. The local directions are given by the normal (1-direction) and the tangent direction (the 2-direction in two-dimensional and axisymmetric cases) or the tangent directions (the 2- and 3-directions in three-dimensional cases) to the fitted line or plane. When several straight lines or planes can be fit equally well between the nodes defining the section (for example, a closed circular or spherical surface), the original local directions will be parallel to the global axes.

The positive local 1-direction is selected such that it will form an acute angle with the average normal direction to the section, computed by averaging the positive normals to the element faces defining the section. If the average normal direction is zero (a closed surface), the 1-direction will form an acute angle with the global x-axis. If in two-dimensional or axisymmetric cases the 1-direction is within 0.1° of being normal to the global x-axis, it will form an acute angle with the global y-axis. In three-dimensional cases if the 1-direction is within 0.1° of being normal to the global X–Y plane, it will form an acute angle with the global z-axis.

In two-dimensional and axisymmetric cases the local 2-direction is obtained by rotating the local 1-direction counterclockwise by 90° about the anchor point. For three-dimensional situations the tangent directions of the surface are defined using the Abaqus conventions for local directions on surfaces in space (see "Conventions," Section 1.2.2).

Input File Usage: Use either of the following options to use the default local coordinate system:

*SECTION PRINT, NAME=*section_name*, SURFACE=*surface_name*, AXES=LOCAL
*SECTION FILE, NAME=*section_name*, SURFACE=*surface_name*, AXES=LOCAL

User-specified local system

A user-specified local system is defined by specifying the origin and the directions of the axes. You can specify the origin (anchor point) by giving a node number or by specifying the coordinates of the anchor point.

In two-dimensional and axisymmetric cases the local 2-direction is defined by specifying either a predefined node number or the coordinates of a point (point a) on the local 2-direction. The local 1-direction is then obtained by rotating the local 2-axis clockwise by 90° about the anchor point (see Figure 4.1.2–1). If node numbers are used to define the anchor point or the local directions, they must be connected to the mesh.

In three-dimensional cases either two predefined nodes or the coordinates of two points can be used to specify the local directions. A rectangular Cartesian coordinate system is then defined by its origin (the anchor point) and these two points. The first point (point a) must lie on the local 2-direction, and

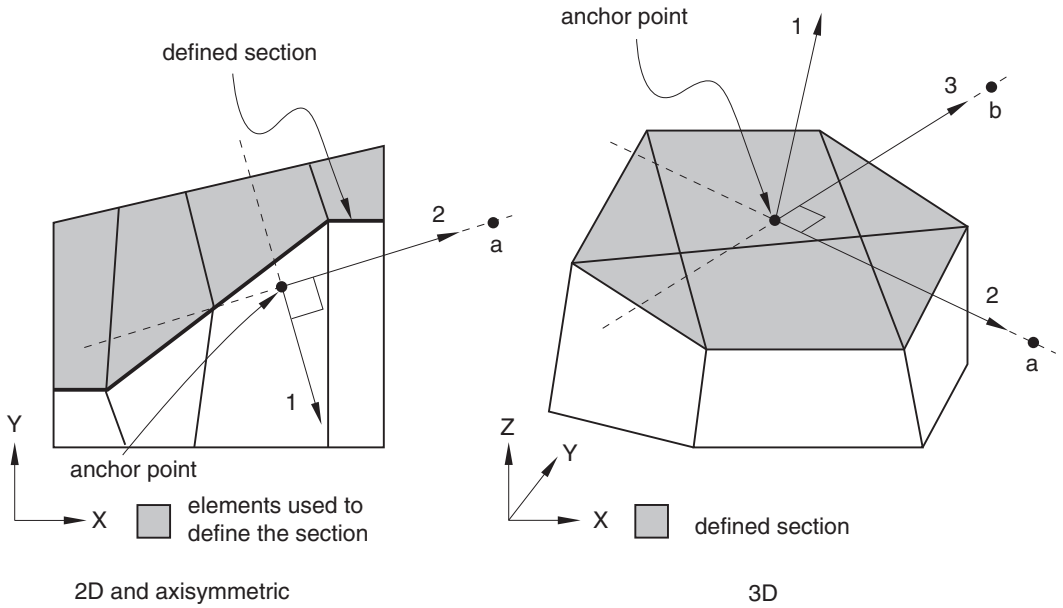


Figure 4.1.2–1 User-defined local coordinate system.

the second (point *b*) must be in the local 2–3 plane on the side of the local 3-direction. Although it is not necessary, it is intuitive to select the second point such that it is on or near the local 3-direction (see Figure 4.1.2–1).

If you do not specify the anchor point of the local system, it is taken to be the centroid of the projection of the surface on the fitted line or plane. If you do not specify the directions of the axes, the local system will be anchored at the specified anchor point and its axes will be parallel to the default axes of the projected surface. If neither the anchor point nor the directions are defined, the default local system will be used.

In large-deformation analyses the surface section may rotate significantly during the deformation. By default, when output is requested in a local coordinate system, the system rotates with the average rigid body motion of the elements used to define the surface section (i.e., the local system and the output are updated during the analysis). The anchor point and local directions must then be specified relative to the undeformed configuration. You can choose to obtain vector output in the original local coordinate system instead. This choice is irrelevant in steps in which geometric nonlinearities are not considered.

Input File Usage: Use either of the following options to specify the local coordinate system directly:

∗SECTION PRINT, NAME=*section_name*, SURFACE=*surface_name*, AXES=LOCAL, UPDATE=YES or NO
anchor point definition
axes definition

∗SECTION FILE, NAME=*section_name*, SURFACE=*surface_name*,
AXES=LOCAL, UPDATE=YES or NO
anchor point definition
axes definition

Controlling the frequency of output

You can control the frequency of section output by specifying the output frequency in increments. Unless a frequency of zero is specified to suppress output, the variables will always be output at the last increment of the step.

Input File Usage: Use either of the following options:

∗SECTION PRINT, NAME=*section_name*, SURFACE=*surface_name*,
FREQUENCY=*n*
∗SECTION FILE, NAME=*section_name*, SURFACE=*surface_name*,
FREQUENCY=*n*

Data file format

Printed output is arranged in tables. The first line of the table contains the name of the requested output variable (see "Abaqus/Standard output variable identifiers," Section 4.2.1), and the second line contains the corresponding value. If a section output request is defined without any specified output variables, all appropriate variables associated with the current analysis type are output.

If several section output requests to the data file are encountered in one particular step, separate tables will be created for each request. Each table has a header denoting the name of the section and the name of the surface used. In addition, if the output is requested in a local coordinate system, the global coordinates of the anchor point and the cosine directions of the local axes are output.

Results file format

Several section output records (record numbers 1580–1591 in "Results file output format," Section 5.1.2) are output for each section output request to the results file. The actual collection of records to be written to the results file depends on the number of valid output requests. If a section output request is defined without any specified output variables, all records relevant to the current analysis type are stored in the results file.

Vector output in the section

Vector output associated with section output requests consists of the total force (SOF), the total moment (SOM), and the center of forces (SOCF). Output variable SOF is computed as a vector sum of the stress-based (internal) nodal forces of the nodes in the surface.

Output variable SOM is computed with respect to the origin of the coordinate system considered. Thus, if the output is requested in the global coordinate system, the total moment is computed about the global origin; if the output is requested in a local coordinate system, the moment is computed about the current anchor point of the local system. The coordinates of the current anchor point may change during the analysis if the local coordinate system is updated. Output variables SOF and SOM are both reported in the coordinate system considered.

The center of forces SOCF is computed as the closest point to the centroid of the section through which the total force SOF acts. SOCF is always reported in the global coordinate system. If the total force vector is equal to zero, the centroid of the section is reported as the center of forces SOCF.

The total moment vector, SOM, will not necessarily equal the cross product of the center of force vector, SOCF, and total force vector, SOF. Forces acting on two different points of the section may have components acting in opposite directions, such that these force components generate a net moment but not a net force; therefore, the total moment may not arise entirely from the resultant force.

Scalar output in the section

Scalar output associated with a section output request consists of the area of the defined section (SOAREA), the total heat flux (SOH) in heat transfer analysis, the total current (SOE) in electrical analysis, the total mass flow (SOD) in mass diffusion analysis, and the total pore fluid volume flux (SOP) in couple pore fluid diffusion-stress analysis. These output variables are computed as the algebraic sum of the scalar internal nodal fluxes (work-conjugate to the associated primary solution variables) of the nodes in the surface. For example, in heat transfer analysis the total heat flux (SOH) is the sum of the NFLUX values at the nodes on the surfaces.

Limitations when using section output requests

Section output requests are subject to the following limitations:

- Section output requests are available only for sections defined by an element-based surface. Thus, they can be used only for sections along faces of continuum elements.
- When defining the section, elements on only one side of the section must be used. Abaqus/Standard identifies all elements attached to the surface on this side and computes the section output variables as in a free-body diagram.
- The defined section must cut completely through the mesh, form a closed surface, or be on the exterior of the body. Figure 4.1.2–2 presents some typical cases of valid surfaces. If the section cuts only partially through the mesh, a valid free-body diagram cannot be isolated (see Figure 4.1.2–3) and incorrect answers may be computed. Abaqus/Standard will attempt to identify the invalid cases and will issue error or warning messages.
- Elements attached to the section can be on either side of the surface but must not cross the defined section. Figure 4.1.2–3 presents a few invalid cases. In most cases Abaqus/Standard will successfully identify elements that cross the surface, and warning messages will be issued. The elements will then not be considered in the calculation of the section variables.
- For section output purposes, Abaqus/Standard will ignore the elements attached to the section for which it cannot establish whether they belong to one side or the other of the section (e.g., SPRING1 elements).
- Section output requests cannot be specified within a substructure.
- Section output requests cannot be specified in random response analyses.
- The total force and the total moment in the section are computed based only on the stresses (internal forces) in the identified elements. Thus, inaccurate results may be obtained if distributed body

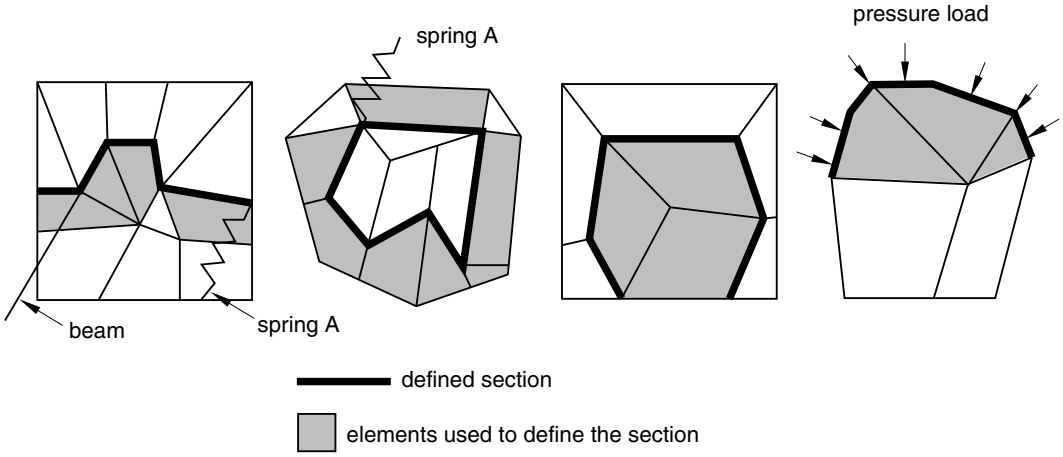


Figure 4.1.2–2 Valid section definitions.

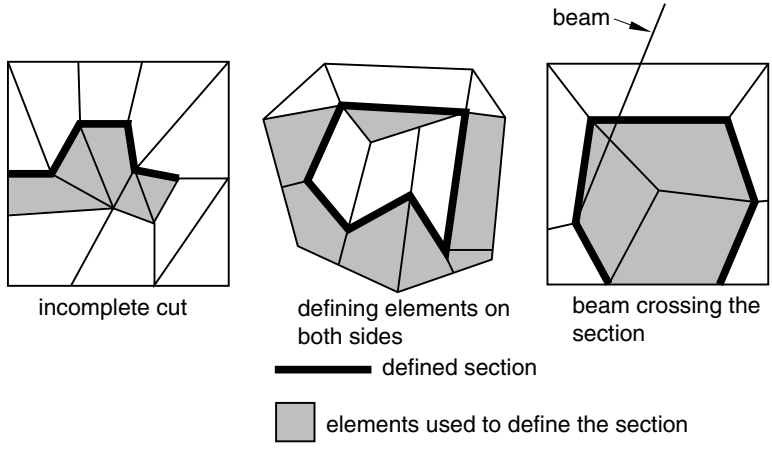


Figure 4.1.2–3 Invalid section definitions.

loads are present in these elements since their effect on the total force in the section is not included. Common examples are the inertial loading in dynamic analyses, gravity loads, distributed body forces, and centrifugal loads. In these cases the total force in the section may depend on the choice of elements used to define the section as illustrated in Figure 4.1.2–4(a). Assuming that gravity loading is the only active load, the element stresses will be different in the two elements. Hence, if the same section is defined first using element 1 and then using element 2, different answers for the total force will be obtained. In a similar way the effects of any distributed body fluxes (heat, electrical, etc.) prescribed in the identified elements are not included.

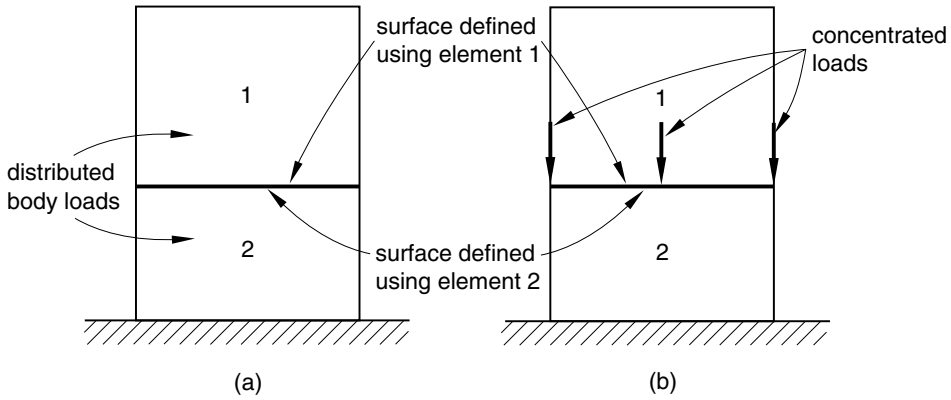


Figure 4.1.2–4 Total force in the section.

- Depending on which side of the surface is used to define the section, different answers will be obtained in analyses similar to the case illustrated in Figure 4.1.2–4(b). Assuming a static analysis with the concentrated loads shown in the figure being the only active loads, a zero total force is reported if the section is defined using element 1 and a nonzero force equal to the sum of the concentrated loads is obtained if the section is defined using element 2.

4.1.3 OUTPUT TO THE OUTPUT DATABASE

Products: Abaqus/Standard Abaqus/Explicit Abaqus/CFD Abaqus/CAE

References

- "Element-based surface definition," Section 2.3.2
- "Integrated output section definition," Section 2.5.1
- "Output," Section 4.1.1
- "The postprocessing calculator," Section 4.3.1
- *OUTPUT
- *FILTER
- *CONTACT OUTPUT
- *ELEMENT OUTPUT
- *ENERGY OUTPUT
- *INTEGRATED OUTPUT
- *INCREMENTATION OUTPUT
- *MODAL OUTPUT
- *NODE OUTPUT
- *RADIATION OUTPUT
- *SURFACE OUTPUT
- "Understanding output requests," Section 14.4 of the Abaqus/CAE User's Guide

Overview

Output variables are available for:

- element integration points, element section points, whole elements, and element sets;
- surfaces in Abaqus/Explicit and Abaqus/CFD;
- integrated output sections in Abaqus/Explicit;
- nodes; and
- the whole model.

All the output variables are defined in "Abaqus/Standard output variable identifiers," Section 4.2.1, "Abaqus/Explicit output variable identifiers," Section 4.2.2, and "Abaqus/CFD output variable identifiers," Section 4.2.3.

Model information and analysis results are stored in terms of an assembly of part instances (see "Defining an assembly," Section 2.10.1).

See the Abaqus Scripting User's Guide for a description of how to use the Abaqus Scripting Interface or C++ to access an output database.

Requesting output to the output database

Three types of information are stored in the output database in Abaqus/Standard and Abaqus/Explicit: "field" output, "history" output, and diagnostic information. In Abaqus/CFD four types of information are stored in the output database: nodal field output, surface field output, element history output, and surface history output. Field output and history output are controlled by output database requests as described in this section. A subset of the diagnostic information that is written to the message file for Abaqus/Standard analyses and to the status and message files for Abaqus/Explicit analyses is included in the output database.

- Field output is intended for infrequent requests for a large portion of the model and can be used to generate contour plots, animations, symbol plots, *X–Y* plots, and displaced shape plots in Abaqus/CAE. Only complete sets of basic variables (for example, all the stress or strain components) can be requested as field output.
- History output is intended for relatively frequent output requests for small portions of the model and is displayed in *X–Y* data plots in Abaqus/CAE. Individual variables (such as a particular stress component) can be requested.
- Diagnostic information in Abaqus/Standard and Abaqus/Explicit is intended to provide analysis warning and/or error information as well as convergence information for use in Abaqus/CAE.

Output database requests can be repeated as often as necessary within a step to produce both field and history output at multiple frequencies.

Requesting field output

Contact surface output, element output, nodal output, and radiation output are available as field output in Abaqus/Standard and Abaqus/Explicit. Nodal, element, and surface output are available as field output in Abaqus/CFD.

Input File Usage: Use the first option in conjunction with one or more of the subsequent options to request field output to the output database:

```
*OUTPUT, FIELD
*CONTACT OUTPUT
*ELEMENT OUTPUT
*NODE OUTPUT
*RADIATION OUTPUT
*SURFACE OUTPUT
```

These options are discussed in detail below.

Abaqus/CAE Usage: Step module: field output request editor

Requesting history output

Contact surface output, element output, energy output, integrated output, time incrementation output, modal output, nodal output, and radiation output are available as history output in Abaqus/Standard and Abaqus/Explicit. Both element output and surface output are available as history output in Abaqus/CFD.

Requesting large amounts of history output (more than 1000 output requests) may cause performance to degrade in Abaqus/Standard and will cause performance to degrade in Abaqus/Explicit and Abaqus/CFD. For vector- or tensor-valued output variables each component is considered to be a single request. In the case of element variables history output will be generated at each integration point. For example, requesting history output of the tensor variable S (stress) for a C3D10M element will generate 24 history output requests: (6 components) × (4 integration points). When requesting history output of vector- and tensor-valued variables, it is recommended that individual components be selected where available.

Input File Usage: Use the first option in conjunction with one or more of the subsequent options to request history output to the output database:

*OUTPUT, HISTORY
*CONTACT OUTPUT
*ELEMENT OUTPUT
*ENERGY OUTPUT
*INTEGRATED OUTPUT
*INCREMENTATION OUTPUT
*MODAL OUTPUT
*NODE OUTPUT
*RADIATION OUTPUT
*SURFACE OUTPUT

These options are discussed in detail below.

Abaqus/CAE Usage: Step module: history output request editor

Requesting diagnostic information in Abaqus/Standard and Abaqus/Explicit

By default, a subset of the diagnostic information that is written to the message file for Abaqus/Standard analyses and to the status and message files for Abaqus/Explicit analyses is also written to the output database. You can use the Visualization module of Abaqus/CAE to view this diagnostic information interactively, highlighting problematic areas on a view of the model and using them to resolve errors and warnings in the analysis. For more information, see "The message file in Abaqus/Standard and Abaqus/Explicit" in "Output," Section 4.1.1, and Chapter 41, "Viewing diagnostic output," of the Abaqus/CAE User's Guide.

Input File Usage: Use the following option to write diagnostic information to the output database:

*OUTPUT, DIAGNOSTICS=YES

Use the following option to exclude diagnostic information:

*OUTPUT, DIAGNOSTICS=NO

Abaqus/CAE Usage: You cannot exclude diagnostic information from the output database from within Abaqus/CAE. Use the following option to view the saved diagnostic information:

Visualization module: **Tools→Job Diagnostics**

Controlling the output frequency

The frequency of output to the output database is controlled differently in Abaqus/Standard, Abaqus/Explicit, and Abaqus/CFD. Control of the output frequency in Abaqus/Explicit depends upon whether field or history output was selected.

Controlling the output frequency in Abaqus/Standard

Abaqus/Standard provides several options for controlling the output frequency, depending on whether the analysis is in the time domain (e.g., general statics), frequency domain (e.g., steady state dynamics), or mode domain (e.g., natural frequency extraction). These options can be used to reduce the amount of output written and hence improve performance and disk space use as compared to the default output.

History output in Abaqus/Standard is buffered and is written to disk only after every 10 increments of history data output or when a step has completed. Therefore, history results may not be available immediately for postprocessing.

Default output frequency

If you do not specify the output frequency, field and history output will be written at every increment of the analysis for all procedure types except dynamic and modal dynamic analyses for which output will be written every 10 increments.

Controlling output frequency in a frequency domain analysis

In frequency domain procedures, you only can control the frequency of output by specifying the frequency of output in increments. The data will be written at this frequency as well as at the end of each step of the analysis. Specify an output frequency of zero to suppress output.

Input File Usage: *OUTPUT, FREQUENCY=*n*

Abaqus/CAE Usage: Step module: field or history output request editor: **Frequency**: **Every *n* increments**: *n*

Controlling output frequency in a mode domain analysis

In an eigenvalue extraction or eigenvalue buckling analysis, you can select the modes at which output is desired. If you do not specify a list of modes, output is produced for all of the modes.

Input File Usage: *OUTPUT, FIELD, MODE LIST

Abaqus/CAE Usage: Step module: field output request editor: **Frequency**: **Specify modes**: *list of modes*

Controlling output frequency in a time domain analysis

In time domain analyses, you can control the frequency of output by specifying the output frequency in terms of increments, the number of intervals during the step, the size of regular time intervals throughout the step, or time points throughout the step. The different options are described in more detail below.

Whichever option is chosen, the output will always be written at the zero-increment and last increment of the analysis and, for a low-cycle fatigue analysis, at the end of each cycle. The zero-increment output represents the initial conditions for the current analysis step and is essential for sequential thermal-stress analyses and analyses involving submodeling, for which a complete solution history (including the solution state at the beginning of the step) is needed to ensure proper interpolation in time. The zero-increment state is written at the beginning of the step, before the solution of the incremental nonlinear finite-element equations for the step commences, and is therefore in general not an equilibrium solution. Particular examples where the solution is not in equilibrium include the first step of an analysis in which an initial stress state is defined and when loads or boundary condition changes are discontinuous between steps.

Usually, the zero-increment output in any step corresponds to the base state, which is the state of the model at the end of the last general step. The exception to this is modal transient dynamic analysis, where the zero-increment output represents the linear perturbation response at time zero.

Time domain analysis: specifying output frequency in increments

You can specify how frequently you want output in terms of increments. Specify an output frequency of zero to suppress output.

Input File Usage: *OUTPUT, FREQUENCY=*n*

Abaqus/CAE Usage: Step module: field or history output request editor: **Frequency**: **Every *n* increments**: *n*

Time domain analysis: specifying output frequency in number of intervals

You can specify the output frequency in number of intervals, *n*. The specified number of intervals must be a positive integer.

By default, Abaqus/Standard adjusts the time increment (in some cases Abaqus/Standard might violate the minimum time increment specified) to ensure that data are written at the exact times calculated by dividing the step into *n* equal intervals. Alternatively, you can specify that the data be written immediately after each time mark. In this case no adjustment of the time increment is necessary.

Input File Usage: Use the following option to request results at the exact time intervals:

*OUTPUT, NUMBER INTERVAL=*n*, TIME MARKS=YES

Use the following option to request results at the increments ending immediately after each time interval:

*OUTPUT, NUMBER INTERVAL=*n*, TIME MARKS=NO

Abaqus/CAE Usage: Use the following option to request results at the exact time intervals:

Step module: field or history output request editor: **Frequency**: **Evenly spaced time intervals**, **Interval**: *n*, **Timing**: **Output at exact times**

Use the following option to request results at the increments ending immediately after each time interval:

Step module: field or history output request editor: **Frequency**: **Evenly spaced time intervals**, **Interval**: *n*, **Timing**: **Output at approximate times**

Time domain analysis: specifying output frequency in regular time interval size

You can write the results at specified regular intervals throughout the step as well as at the end of the step.

By default, Abaqus/Standard will adjust the time increment (in some cases Abaqus/Standard might violate the minimum time increment specified) to ensure that data will be written at the exact times, as defined by multiples of the time interval, *t*. Alternatively, the data can be written immediately after each time mark. In this case no adjustment of the time increment is necessary.

Input File Usage: Use the following option to request results at the exact time intervals:

∗OUTPUT, TIME INTERVAL=*t* , TIME MARKS=YES

Use the following option to request results at the increments ending immediately after each time interval:

∗OUTPUT, TIME INTERVAL=*t* , TIME MARKS=NO

Abaqus/CAE Usage: Use the following option to request results at the exact time intervals:

Step module: field or history output request editor: **Frequency**: **Every *x* units of time**: *t*, **Timing**: **Output at exact times**

Use the following option to request results at the increments ending immediately after each time interval:

Step module: field or history output request editor: **Frequency**: **Every *x* units of time**: *t*, **Timing**: **Output at approximate times**

Time domain analysis: specifying output frequency in time points

You can write the results at specified time points throughout the step.

By default, Abaqus/Standard adjusts the time increment (in some cases Abaqus/Standard might violate the minimum time increment specified) to ensure that data are written at the exact time points specified. Alternatively, you can specify that the data be written immediately after each time point. In this case no adjustment of the time increment is necessary.

Input File Usage: Use the following options to request results at the exact time points:

∗TIME POINTS, NAME=*time points name*
∗OUTPUT, TIME POINTS=*time points name*, TIME MARKS=YES

Use the following options to request results at the increments ending immediately after each time point:

∗TIME POINTS, NAME=*time points name*
∗OUTPUT, TIME POINTS=*time points name*, TIME MARKS=NO

Abaqus/CAE Usage: Use the following option to request results at the exact time points:

Step module: field or history output request editor: **From time points**, **Name**: *time points name*, **Timing**: **Output at exact times**

Use the following option to request results at the increments ending immediately after each time point:

Step module: field or history output request editor: **From time points**, **Name**: *time points name*, **Timing**: **Output at approximate times**

Time domain analysis: time incrementation

If the output frequency is specified at exact times and in terms of the number of intervals, in regular time intervals, or in time points, Abaqus/Standard adjusts the time increments to ensure that data are written at the exact time points. In some cases Abaqus may use a time increment smaller than the minimum time increment allowed in the step in the increment directly before a time point. However, Abaqus will not violate the minimum time increment allowed for consolidation, transient mass diffusion, transient heat transfer, transient couple thermal-electrical, transient coupled temperature-displacement, and transient coupled thermal-electrical-structural analyses. For these procedures if a time increment smaller than the minimum time increment is required, Abaqus will use the minimum time increment allowed in the step and will write output data at the first increment after the time point.

When the output frequency is specified at exact times and in terms of the number of intervals, in regular time intervals, or in time points, the number of increments necessary to complete the analysis might increase, which might adversely affect performance.

Controlling the output frequency for field output in Abaqus/Explicit

Field output data are always written at the start and end of each step in which the output request is active. In addition, you can specify the output frequency in terms of the number of intervals during the step, the size of regular time intervals throughout the step, or time points throughout the step. The times at which the results are written are referred to as time marks.

Specifying field output frequency in number of intervals

You can specify the output frequency in number of intervals, n. The specified number of intervals must be a positive integer. For example, if the specified number of intervals is 10, Abaqus/Explicit will write field data 11 times: the values at the beginning of the step and at the end of 10 equal time intervals throughout the step.

By default, field data will be written at the increment ending immediately after each time mark. Alternatively, when you specify the output frequency in number of intervals, you can choose to have the time increment size adjusted so that an increment will end exactly at each of the time marks calculated by dividing the step into n equal intervals.

Input File Usage: Use the following option to request results at the increments ending immediately after each time interval:

*OUTPUT, FIELD, NUMBER INTERVAL=*n*, TIME MARKS=NO

Use the following option to request results at the exact time intervals:

*OUTPUT, FIELD, NUMBER INTERVAL=*n*, TIME MARKS=YES

Abaqus/CAE Usage: Use the following option to request results at the increments ending immediately after each time interval:

Step module: field output request editor: **Frequency**: **Evenly spaced time intervals**, **Interval**: *n*, **Timing**: **Output at approximate times**

Use the following option to request results at the exact time intervals:

Step module: field output request editor: **Frequency**: **Evenly spaced time intervals**, **Interval**: *n*, **Timing**: **Output at exact times**

Specifying field output frequency in regular time interval size

Alternatively, you can write the results at specified regular intervals throughout the step as well as at the beginning and end of the step. The time increment size will not be adjusted to meet the specified time marks; results will be written at the increment ending immediately after each time mark, as defined by multiples of the time interval, *t*.

Input File Usage: *OUTPUT, FIELD, TIME INTERVAL=*t*

Abaqus/CAE Usage: Step module: field output request editor: **Frequency**: **Every *x* units of time**: *t*

Specifying field output frequency in time points

You can write the results at specified time points throughout the step. Regular time intervals between time points are not required; you can specify any desired time points at which the field output is to be written.

Input File Usage: Use the following option to request results at the exact time points:

*TIME POINTS, NAME=*time points name*
*OUTPUT, FIELD, TIME POINTS=*time points name*, TIME MARKS=YES

Use the following option to request results at the increments ending immediately after each time point:

*TIME POINTS, NAME=*time points name*
*OUTPUT, FIELD, TIME POINTS=*time points name*, TIME MARKS=NO

Abaqus/CAE Usage: Use the following option to request results at the exact time points:

Step module: field output request editor: **Frequency**: **From time points**, **Name**: *time points name*, **Timing**: **Output at exact times**

Use the following option to request results at the increments ending immediately after each time point:

Step module: field output request editor: **Frequency**: **From time points**, **Name**: *time points name*, **Timing**: **Output at approximate times**

Default field output

If you do not specify the output frequency (in either number of intervals, time interval size, or time points), field output will be written at 20 equally spaced intervals throughout the step.

Controlling the output frequency for history output in Abaqus/Explicit

If history output is selected, you can specify the output frequency in terms of either increments or regular intervals throughout the step.

Specifying history output frequency in increments

You can specify the output frequency in increments. The data will be written at this frequency as well as at the end of each step of the analysis.

Input File Usage: *OUTPUT, HISTORY, FREQUENCY=*n*

Abaqus/CAE Usage: Step module: history output request editor: **Frequency**: **Every *n* time increments**: *n*

Specifying history output frequency in regular time interval size

Alternatively, you can write the results at specified regular intervals throughout the step as well as at the end of the step. The time increment size will not be adjusted to meet the specified time marks; results will be written at the increment ending immediately after each time mark, as defined by multiples of the time interval, *t*.

Input File Usage: *OUTPUT, HISTORY, TIME INTERVAL=*t*

Abaqus/CAE Usage: Step module: history output request editor: **Frequency**: **Every *x* units of time**: *t*

Default history output

If you do not specify the output frequency (in either increments or time interval size), history output will be written at 200 equally spaced intervals throughout the step.

Controlling the output frequency for field output in Abaqus/CFD

Field output data are always written at the start and end of each step in which the output request is active. In addition, you can specify the output frequency in terms of increments, the number of intervals during the step, or the size of regular time intervals throughout the step. By default, field output will be written at 20 equally spaced intervals throughout the step.

Specifying field output frequency in increments

You can specify the output frequency in increments. The data will be written at this frequency as well as at the beginning and end of each step of the analysis.

Input File Usage: *OUTPUT, FIELD, FREQUENCY=*n*

Abaqus/CAE Usage: Step module: field output request editor: **Frequency**: **Every *n* time increments**: *n*

Specifying field output frequency in number of intervals

You can specify the output frequency in number of intervals, *n*. The specified number of intervals must be a positive integer. For example, if the specified number of intervals is 10, Abaqus/CFD will write field data 11 times: the values at the beginning of the step and at the end of 10 equal time intervals throughout the step.

Input File Usage: *OUTPUT, FIELD, NUMBER INTERVAL=*n*

Abaqus/CAE Usage: Step module: field output request editor: **Frequency**: **Evenly spaced time intervals**, **Interval**: *n*

Specifying field output frequency in regular time interval size

Alternatively, you can write the results at specified regular intervals throughout the step as well as at the beginning and end of the step. The time increment size will not be adjusted to meet the specified time marks; results will be written at the increment ending immediately after each time mark, as defined by multiples of the time interval, *t*.

Input File Usage: *OUTPUT, FIELD, TIME INTERVAL=*t*

Abaqus/CAE Usage: Step module: field output request editor: **Frequency**: **Every *x* units of time**: *t*

Controlling the output frequency for history output in Abaqus/CFD

You can specify the output frequency in terms of increments, the number of intervals during the step, or regular intervals throughout the step. By default, no history output is automatically written to the output database.

Specifying history output frequency in increments

You can specify the output frequency in increments. The data will be written at this frequency as well as at the beginning and end of each step of the analysis.

Input File Usage: *OUTPUT, HISTORY, FREQUENCY=*n*

Abaqus/CAE Usage: Step module: history output request editor: **Frequency**: **Every *n* time increments**: *n*

Specifying history output frequency in number of intervals

You can specify the output frequency in number of intervals, *n*. The specified number of intervals must be a positive integer. For example, if the specified number of intervals is 10, Abaqus/CFD will write history data 11 times: the values at the beginning of the step and at the end of 10 equal time intervals throughout the step.

Input File Usage: *OUTPUT, HISTORY, NUMBER INTERVAL=*n*

Abaqus/CAE Usage: Step module: history output request editor: **Frequency**: **Evenly spaced time intervals**, **Interval**: *n*

Specifying history output frequency in regular time interval size

Alternatively, you can write the results at specified regular intervals throughout the step as well as at the end of the step. The time increment size will not be adjusted to meet the specified time marks; results will be written at the increment ending immediately after each time mark, as defined by multiples of the time interval, t.

Input File Usage: *OUTPUT, HISTORY, TIME INTERVAL=n

Abaqus/CAE Usage: Step module: history output request editor: **Frequency**: **Every *x* units of time**: t

Requesting output in multiple steps

Output requests apply to the step in which they are defined and to all subsequent steps until they are respecified.

The only exception occurs when the step type changes from general to linear perturbation (available only in Abaqus/Standard). Output requests defined in general steps apply only to subsequent general steps; output requests defined in linear perturbation steps apply only to subsequent consecutive linear perturbation steps. In other words, output defined in a general step is independent of output defined in a linear perturbation step. Propagation between linear perturbation steps occurs only for consecutive linear perturbation steps. If a general analysis step occurs between perturbation steps, output defined in the first perturbation step will not propagate to the next perturbation step.

In any given step you can add or selectively replace the output requests that are continued from previous steps. Alternatively, you can discontinue all requests from previous steps and request a completely new set of output. The preselected field variables and preselected history output variables (see "Preselected output requests" below) are requested by default for the first step of an analysis; you can modify this request as in any other step.

Specifying new output requests

By default, all output requests defined in previous steps are removed when new requests are defined, regardless of the type of output request being defined. In other words, a new field output request in a step removes all field and history output requests defined in previous steps.

Because all existing output requests are removed when a new request is defined in a step, all output requests within the same step are treated as new (i.e., additional output requests or replacement output requests are treated as equivalent to new output requests).

Input File Usage: Use one of the following options to remove all existing output requests and to specify new requests:

*OUTPUT, FIELD, OP=NEW
*OUTPUT, HISTORY, OP=NEW

Abaqus/CAE Usage: Step module: **Create Field Output Request** or **Create History Output Request**

Abaqus/CAE automatically respecifies all previously defined output requests when you create a new request.

Specifying additional output requests

Alternatively, you can specify additional output requests without removing all default and previously defined output requests.

Input File Usage: Use one of the following options to specify additional output requests without removing all default and previously defined output requests:

*OUTPUT, FIELD, OP=ADD
*OUTPUT, HISTORY, OP=ADD

Abaqus/CAE Usage: Step module: **Create Field Output Request** or **Create History Output Request**

Abaqus/CAE automatically respecifies all previously defined output requests when you create a new request.

Replacing or removing an output request

You can replace an output request of the same type (e.g., field or history) and frequency with a new request. No other previously defined requests will be affected.

You cannot replace an output request to change its frequency. If no matching request is found, the request specified is simply added to the step.

To remove a previously defined request, you can replace the output request without specifying any new output variables.

Input File Usage: Use one of the following options to replace an output request with a new request:

*OUTPUT, FIELD, OP=REPLACE
*OUTPUT, HISTORY, OP=REPLACE

Abaqus/CAE Usage: Step module: **Field Output Requests Manager** or **History Output Requests Manager**: **Edit** or **Delete**

Suppressing output requests defined in previous steps

To suppress completely all output requests that have been defined in previous steps, you can specify an output frequency of 0.

Preselected output requests

There are two ways to define output variable requests quickly and easily. Both methods are available for field and history output requests and for the individual output requests used for requesting specific variable types (e.g., nodal, element). There are no preselected output variables for surface output requests in Abaqus/CFD. The use of these methods with individual output requests for specific variable types is explained in detail later in this section.

Requesting procedure-specific preselected output requests

You can activate a procedure-specific set of commonly requested output variables. See Table 4.1.3–1 for a list of procedure types and their accompanying preselected variables. The variables written to the output database may change if the procedure type changes between steps.

If you request preselected field or history output and request additional output variables using individual output requests for specific variable types, the variables requested will be appended to the variables contained in the preselected list.

For geometrically nonlinear analysis in Abaqus/Standard, E is not available for output and LE is output by default. For linear perturbation analyses and geometrically linear analyses in Abaqus/Standard, LE and NE strain output requests yield the same output as E. For geometrically linear analysis in Abaqus/Explicit, LE is output.

Abaqus may omit some preselected variables from the analysis results. Abaqus omits preselected output variables if they are not applicable for the element type used to mesh the model or if other factors make the variables unsuitable for the analysis. No preselected variables are available for surface output in an Abaqus/CFD analysis.

Input File Usage: Use one of the following options:

*OUTPUT, FIELD, VARIABLE=PRESELECT
*OUTPUT, HISTORY, VARIABLE=PRESELECT

Abaqus/CAE Usage: Step module: field or history output request editor: **Preselected defaults**

Table 4.1.3–1 List of preselected variables for various procedure types.

Procedure type	Preselected element variables (field; history for Abaqus/CFD)	Preselected nodal and surface variables (field)	Preselected energy variables (history)
Annealing	none	none	none
Complex frequency extraction	none	U	none
Coupled pore fluid diffusion/stress	S, E, VOIDR, SAT, POR	U, RF, CF, PFL, PFLA, PTL, PTLA, TPFL, TPTL	ALLAE, ALLCD, ALLFD, ALLIE, ALLKE, ALLPD, ALLSE, ALLVD, ALLDMD, ALLWK, ALLKL, ALLQB, ALLEE, ALLJD, ALLSD, ETOTAL

Procedure type	Preselected element variables (field; history for Abaqus/CFD)	Preselected nodal and surface variables (field)	Preselected energy variables (history)
Coupled thermal-electric	HFL, EPG	NT, RFL, EPOT	ALLAE, ALLCD, ALLFD, ALLIE, ALLKE, ALLPD, ALLSE, ALLVD, ALLDMD, ALLWK, ALLKL, ALLQB, ALLEE, ALLJD, ALLSD, ETOTAL
Direct cyclic	S, E, PE, PEEQ, PEMAG	U, RF, CF	ALLAE, ALLCD, ALLFD, ALLIE, ALLKE, ALLPD, ALLSE, ALLVD, ALLDMD, ALLWK, ALLKL, ALLQB, ALLEE, ALLJD, ALLSD, ETOTAL
Direct-integration implicit dynamic (with an output frequency of 10)	S, E, PE, PEEQ, PEMAG	U, V, A, RF, CF, CSTRESS, CDISP	ALLAE, ALLCD, ALLFD, ALLIE, ALLKE, ALLPD, ALLSE, ALLVD, ALLDMD, ALLWK, ALLKL, ALLQB, ALLEE, ALLJD, ALLSD, ETOTAL
Direct-solution steady-state dynamic	S, E	U, V, A, RF, CF	ALLKE, ALLSE, ALLVD, ALLWK
Eigenfrequency extraction	none	U	none
Eigenvalue buckling prediction	none	U	none

Procedure type	Preselected element variables (field; history for Abaqus/CFD)	Preselected nodal and surface variables (field)	Preselected energy variables (history)
Explicit dynamic	S, LE, PE, PEEQ, EVF, SVAVG, PEVAVG, PEEQVAVG	U, V, A, RF, CSTRESS	ALLKE, ALLSE, ALLWK, ALLPD, ALLCD, ALLVD, ALLDMD, ALLAE, ALLIE, ALLFD, ETOTAL
Fully coupled thermal-electrical-structural in Abaqus/Standard	S, E, PE, PEEQ, PEMAG, HFL, EPG	U, RF, CF, NT, RFL, CSTRESS, CDISP, EPOT	ALLAE, ALLCD, ALLFD, ALLIE, ALLKE, ALLPD, ALLSE, ALLVD, ALLDMD, ALLWK, ALLKL, ALLQB, ALLEE, ALLJD, ALLSD, ETOTAL
Fully coupled thermal-stress in Abaqus/Standard	S, E, PE, PEEQ, PEMAG, HFL	U, RF, CF, NT, RFL, CSTRESS, CDISP	ALLAE, ALLCD, ALLFD, ALLIE, ALLKE, ALLPD, ALLSE, ALLVD, ALLDMD, ALLWK, ALLKL, ALLQB, ALLEE, ALLJD, ALLSD, ETOTAL
Fully coupled thermal-stress in Abaqus/Explicit	S, LE, PE, PEEQ, HFL	U, V, A, RF, CSTRESS, NT, RFL	ALLKE, ALLSE, ALLWK, ALLPD, ALLCD, ALLVD, ALLDMD, ALLAE, ALLIE, ALLFD, ALLIHE, ALLHF, ETOTAL

Procedure type	Preselected element variables (field; history for Abaqus/CFD)	Preselected nodal and surface variables (field)	Preselected energy variables (history)
Geostatic stress field	S, E, POR, SAT, VOIDR	U, RF, CF, CSTRESS, CDISP	ALLAE, ALLCD, ALLFD, ALLIE, ALLKE, ALLPD, ALLSE, ALLVD, ALLDMD, ALLWK, ALLKL, ALLQB, ALLEE, ALLJD, ALLSD, ETOTAL
Heat transfer	HFL	NT, RFL	none
Incompressible fluid dynamics in Abaqus/CFD	V, PRESSURE, TEMP, TURBNU	U, V, PRESSURE, TEMP, TURBNU	none
Linear static perturbation	S, E	U, RF, CF	ALLAE, ALLCD, ALLFD, ALLIE, ALLKE, ALLPD, ALLSE, ALLVD, ALLDMD, ALLWK, ALLKL, ALLQB, ALLEE, ALLJD, ALLSD, ETOTAL
Mass diffusion	CONC, MFL	NNC, RFL	none
Modal dynamic (with an output frequency of 10)	S, E	U, V, A, RF, CF	ALLAE, ALLCD, ALLFD, ALLIE, ALLKE, ALLPD, ALLSE, ALLVD, ALLDMD, ALLWK, ALLKL, ALLQB, ALLEE, ALLJD, ALLSD, ETOTAL
SIM-based modal dynamic	none	none	none

Procedure type	Preselected element variables (field; history for Abaqus/CFD)	Preselected nodal and surface variables (field)	Preselected energy variables (history)
Quasi-static	S, E, PE, PEEQ, PEMAG, CE, CEEQ, CEMAG	U, RF, CF, CSTRESS, CDISP	ALLAE, ALLCD, ALLFD, ALLIE, ALLKE, ALLPD, ALLSE, ALLVD, ALLDMD, ALLWK, ALLKL, ALLQB, ALLEE, ALLJD, ALLSD, ETOTAL
Random response	S, E	U, V, A	none
Response spectrum	S, E	U, RF, CF	ALLKE, ALLSE, ALLWK
Static	S, E, PE, PEEQ, PEMAG	U, RF, CF, CSTRESS, CDISP	ALLAE, ALLCD, ALLFD, ALLIE, ALLKE, ALLPD, ALLSE, ALLVD, ALLDMD, ALLWK, ALLKL, ALLQB, ALLEE, ALLJD, ALLSD, ETOTAL
Steady-state dynamic	S, E	U, V, A, RF, CF	ALLKE, ALLSE, ALLWK
SIM-based steady-state dynamic	none	none	none
Steady-state transport	S, E	U, RF, CF, CSTRESS, CDISP	ALLAE, ALLCD, ALLFD, ALLIE, ALLKE, ALLPD, ALLSE, ALLVD, ALLDMD, ALLWK, ALLKL, ALLQB, ALLEE, ALLJD, ALLSD, ETOTAL
Subspace-based steady-state dynamic	S, E	U, V, A, RF, CF	ALLKE, ALLSE, ALLVD, ALLWK

Requesting all variables applicable to the current procedure and material type in Abaqus/Standard and Abaqus/Explicit

You can request all variables applicable to the current procedure and material type. Any individual output requests for specific variable types are ignored in this case.

Input File Usage: Use one of the following options:

*OUTPUT, FIELD, VARIABLE=ALL
*OUTPUT, HISTORY, VARIABLE=ALL

Abaqus/CAE Usage: Step module: field or history output request editor: **All**

Default output

In Abaqus/Standard and Abaqus/Explicit, if no output database requests are specified, the preselected field and history output variables are written automatically to the output database. In Abaqus/Standard the default variables are written at every increment for both field and history output for all procedure types except dynamic and modal dynamic analyses; the default frequency for field and history output for these procedure types is every 10 increments. In Abaqus/Explicit the default variables are written at 20 intervals for field output and 200 intervals for history output. In Abaqus/CFD the default variables are written at 20 intervals for field output.

You can turn these defaults off for an analysis in Abaqus/Standard and Abaqus/Explicit by using the **odb_output_by_default** environment file parameter; see "Using the Abaqus environment settings," Section 3.3.1, for details. Furthermore, specifying new output database requests in a step (see "Specifying new output requests") overrides the default field and history output requests for that step. For large models the default output to the output database may increase the solution time and required disk space considerably. In such cases you are encouraged to review carefully the relevance of the default output variables for the proposed analysis. A C++ program is available that creates a smaller copy of a large output database by copying data from only selected frames; for more information, see "Decreasing the amount of data in an output database by retaining data at specific frames," Section 10.15.4 of the Abaqus Scripting User's Guide.

The **odb_output_by_default** environment file parameter is ignored in a restart analysis. If no output requests are defined in a restart analysis, the output requests are those that propagate from the original analysis.

Abaqus/Explicit output as a result of analysis termination

When an Abaqus/Explicit analysis encounters a fatal error in an increment, the preselected variables applicable to the current procedure are written automatically to the output database as field data. The analysis will go through an additional increment with a zero time increment size before writing these data.

Element output

You can request that element variables (stresses, strains, section forces, element energies, etc.) be written to the output database. The output request can be repeated as often as necessary to define output for different types of element variables, different element sets, etc. The same element (or element set) can appear in several output requests. Element output to the output database is not supported for user elements.

Selecting the element output variables

The following types of element variables are recognized for the purpose of defining output:

- "Element integration point" variables are associated with the integration points at which material calculations are performed (for example, components of stress and strain).
- "Element section point" variables are associated with the cross-section of a beam, pipe, or a shell (for example, bending moments and membrane forces on the section); these variables are not available in Abaqus/CFD.
- "Element face" variables are associated with the faces of a shell or a solid (for example, uniformly distributed pressure load on the face).
- "Whole element" variables are attributes of an entire element (for example, the total energy content of the element).
- "Whole element set" variables are attributes of an entire element set (for example, the current coordinates of the center of mass); these variables are available in Abaqus/Standard and Abaqus/Explicit.

The element variables that can be written to the output database are defined in "Abaqus/Standard output variable identifiers," Section 4.2.1, "Abaqus/Explicit output variable identifiers," Section 4.2.2, and "Abaqus/CFD output variable identifiers," Section 4.2.3.

Input File Usage: *ELEMENT OUTPUT
list of output variables

Abaqus/CAE Usage: Step module: field or history output request editor: **Select from list below**

Selecting elements for which output is required

For history output you must specify the element set (or, in Abaqus/Explicit, the tracer set) for which output is being requested. For field output specifying the element set or tracer set is optional; if you do not specify an element set or tracer set, the output will be written for all the elements in the model.

Input File Usage: *ELEMENT OUTPUT, ELSET=*element_set_name*

Abaqus/CAE Usage: Step module: field or history output request editor: **Domain: Set:** *set_name*

Requesting field output for the exterior elements in the model in Abaqus/Standard and Abaqus/Explicit

You can select output on the element set consisting of all the exterior three-dimensional elements in the model. This element set is generated internally by Abaqus.

Input File Usage: *ELEMENT OUTPUT, EXTERIOR

Abaqus/CAE Usage: Step module: field output request editor: **Domain**: **Whole model**; toggle on **Exterior only**

Specifying the section point in beam, pipe, shell, and layered solid elements in Abaqus/Standard and Abaqus/Explicit

For beams, pipes, shells, or layered solids output is provided at the default section points. You can specify nondefault output points.

Input File Usage: *ELEMENT OUTPUT
list of output points
list of output variables

Abaqus/CAE Usage: Step module: field or history output request editor: **Output at shell, beam, and layered section points: Specify:** *list of output points*

Requesting output for rebars in a reinforced model in Abaqus/Standard and Abaqus/Explicit

You can request output for rebars ("Defining reinforcement," Section 2.2.3). If you do not explicitly request rebar output in a model with rebars, the element output requests govern the output for the matrix material only (except for section forces, where the forces in the rebar are included in the force calculation). You can request output for a particular rebar. If you do not specify the name of a rebar, output will be given for all rebars in the specified element set (or in the whole model, if you have not specified an element set).

Rebar output is available only in membrane, shell, or surface elements at the integration points and at the centroid of the element.

Input File Usage: Use the following options:

*OUTPUT, FIELD
*ELEMENT OUTPUT, REBAR=*rebar_name*, ELSET=*element_set_name*
*OUTPUT, HISTORY
*ELEMENT OUTPUT, REBAR=*rebar_name*, ELSET=*element_set_name*

Abaqus/CAE Usage: Use the following option to request output for rebar in addition to output for the matrix material:

Step module: field or history output request editor: **Output for rebar: Include**

Use the following option to request output only for rebar:

Step module: field or history output request editor: **Output for rebar: Only**

You cannot request output for a particular rebar in Abaqus/CAE; if you request rebar output, it is given for all rebars in the specified output domain.

Selecting the position of element integration point and section point output

Integration point variables and section variables in Abaqus/Standard and Abaqus/Explicit can be written as field output to the output database in three different positions: the integration points, the centroid, or the nodes. By default, output is provided at the integration points.

In most cases Abaqus writes only integration point data to the output database. Transferring of results from the integration points to the user-specified position in Abaqus/Standard and Abaqus/Explicit is done by the postprocessing calculator. See "The postprocessing calculator," Section 4.3.1, for details.

In Abaqus/Standard an alternative procedure is available for three commonly requested output variables: stress components, Mises equivalent stress, and equivalent pressure stress. To activate this alternate procedure for Mises equivalent stress and equivalent pressure stress, output variables MISESONLY and PRESSONLY, respectively, must be requested. If output variables, MISES and PRESS, are used instead, the old procedure is invoked. If output at the nodes or at the centroid is requested for any of these variables, the interpolation and extrapolation are performed during the analysis as soon as stresses are available at the integration points. This eliminates the need to store stress components at the integration points and reduces the size of the output database. This procedure is invoked automatically when output is requested for any of the supported variables.

Element history output to the output database is always provided at the integration points.

Obtaining output at the integration points in Abaqus/Standard and Abaqus/Explicit

By default, the variables are output at the integration points where they are calculated. In Abaqus/Standard you can obtain the position of the integration points by using output variable COORD (see "Abaqus/Standard output variable identifiers," Section 4.2.1).

Input File Usage: *ELEMENT OUTPUT, POSITION=INTEGRATION POINTS

Abaqus/CAE Usage: You cannot select the position of element output in Abaqus/CAE; it is always given at the integration points.

Obtaining output at the centroid of each element in Abaqus/Standard and Abaqus/Explicit

You can choose to output the variables at the centroid of each element (the midpoint between the end nodes of a beam or a pipe element). Centroidal values are obtained through the postprocessing calculator by interpolation of the integration point values if the integration scheme for the element does not include a centroidal integration point. Element output of the element centroidal values is not available for recovering results within substructures; for more information, see "Using substructures," Section 10.1.1.

Input File Usage: *ELEMENT OUTPUT, POSITION=CENTROIDAL

Abaqus/CAE Usage: You cannot select the position of element output in Abaqus/CAE; it is always given at the integration points.

Obtaining element output extrapolated to the nodes in Abaqus/Standard and Abaqus/Explicit

You can choose to extrapolate the element integration point variables to the nodes of each element independently, without averaging the results from adjoining elements. Element output at the element

nodes is not available for recovering results within substructures; for more information, see "Using substructures," Section 10.1.1.

Input File Usage: *ELEMENT OUTPUT, POSITION=NODES

Abaqus/CAE Usage: You cannot select the position of element output in Abaqus/CAE; it is always given at the integration points.

Extrapolation and interpolation of element output variables in Abaqus/Standard and Abaqus/Explicit

The shape functions of the element are used by the postprocessing calculator for purposes of extrapolation and interpolation of output variables. Extrapolated values are generally not as accurate as the values calculated at the integration points in the areas of high stress gradients, particularly in the case of modified triangles and tetrahedra. Therefore, adequately detailed meshing is necessary around nodes where accurate nodal values of such element results are needed. If a cylindrical or spherical coordinate system is defined for the element (see "Orientations," Section 2.2.5), the orientation at each integration point may be different. When the values at the integration points are extrapolated to the nodes, the difference in the orientation is not taken into account; therefore, if the orientation varies significantly over the elements connected to a node, the extrapolated values are not very accurate. If the material orientation undergoes significant spatial variation in a region of the model where the material behavior is truly anisotropic, a finer mesh is required to obtain accurate results even at the integration points. In that situation once the overall solution has converged with respect to the mesh density, the interpolation or extrapolation away from the integration points can also be assumed to be reasonably accurate. You should also be particularly careful when interpreting output variables extrapolated to the nodes for second-order elements with midside nodes outside the quarter-point region, such as when one edge is collapsed in two dimensions or one face is collapsed in three dimensions.

For derived variables, such as Mises equivalent stress, the components are first extrapolated or interpolated. The derived value is then calculated from the extrapolated or interpolated components. However, in linear mode-based dynamic analysis procedures where derived values are obtained as nonlinear combinations of modal response magnitudes ("Random response analysis," Section 6.3.11, and "Response spectrum analysis," Section 6.3.10), the nonlinear combinations are first calculated at the integration points. These derived values are then extrapolated to the nodes or interpolated to the centroid.

Controlling the output frequency

The frequency of element output is controlled as described above in "Controlling the output frequency."

Requesting preselected output

You can request the preselected, procedure-specific element output variables described in Table 4.1.3–1. In this case you can specify additional variables as part of the output request.

Alternatively, you can request all element variables applicable to the current procedure and material type. In this case any additional variables you specify are ignored.

Input File Usage: Use the following option to request the preselected element output variables:

*ELEMENT OUTPUT, VARIABLE=PRESELECT

Use the following option to request all applicable element output variables:

*ELEMENT OUTPUT, VARIABLE=ALL

Abaqus/CAE Usage: Step module: field or history output request editor: **Preselected defaults** or **All**

Specifying the directions for element output in Abaqus/Standard and Abaqus/Explicit

For components of stress, strain, and similar material variables 1, 2, and 3 refer to the directions for an orthogonal coordinate system. If a local orientation is not defined for the element, the stress/strain components are in the default directions defined by the convention given in "Orientations," Section 2.2.5: global directions for solid elements, surface directions for shell and membrane elements, and axial and transverse directions for beam and pipe elements.

By default, the element material directions for element field output are written to the output database. If a local orientation is associated with the element, by default the results displayed in Abaqus/CAE are in the directions defined by the local orientation. These directions can be visualized in Abaqus/CAE by selecting **Plot→Material Orientations** in the Visualization module. You can choose to suppress the direction output to the output database.

Input File Usage: Use the following option to indicate that the element material directions should not be written to the output database:

*ELEMENT OUTPUT, DIRECTIONS=NO

Abaqus/CAE Usage: Step module: field output request editor: toggle off **Include local coordinate directions when available**

Node output

You can output nodal variables (displacements, reaction forces, etc.) to the output database. The output request can be repeated as often as necessary to define output for different node sets. The same node (or node set) can appear in several output requests.

Selecting the nodal output variables

The nodal variables that can be written to the output database are defined in the "Nodal variables" section of "Abaqus/Standard output variable identifiers," Section 4.2.1, "Abaqus/Explicit output variable identifiers," Section 4.2.2, and "Abaqus/CFD output variable identifiers," Section 4.2.3.

Input File Usage: *NODE OUTPUT
list of output variables

Abaqus/CAE Usage: Step module: field or history output request editor: **Select from list below**

Selecting the nodes for which output is required

For history output you must specify the node set (or, in Abaqus/Explicit, the tracer set) for which output is being requested. For field output the specification of the node set or tracer set is optional; if you do not specify a node set or tracer set, the output will be written for all the nodes in the model.

Input File Usage: *NODE OUTPUT, NSET=*node_set_name*

Abaqus/CAE Usage: Step module: field or history output request editor: **Domain: Set:** *set_name*

Requesting field output for the exterior nodes in the model in Abaqus/Standard and Abaqus/Explicit

You can select output on the node set consisting of all the exterior nodes in the model. This node set is generated internally by Abaqus and includes all the nodes that belong to the exterior three-dimensional elements.

Input File Usage: *NODE OUTPUT, EXTERIOR

Abaqus/CAE Usage: Step module: field output request editor: **Domain**: **Whole model**; toggle on **Exterior only**

Controlling the output frequency

The frequency of nodal output is controlled as described above in "Controlling the output frequency."

Controlling the precision in Abaqus/Standard and Abaqus/Explicit

You can control the precision of nodal output for an analysis.

Input File Usage: Use the following command line option to request single-precision nodal output:

abaqus job=*job-name* **output_precision**=**`single`**

Use the following command line option to request double-precision nodal output:

abaqus job=*job-name* **output_precision**=**`full`**

Abaqus/CAE Usage: Job module: job editor: **Precision**: **Nodal output precision: Single** or **Full**

Requesting preselected output

You can request the preselected, procedure-specific nodal output variables described in Table 4.1.3–1. In this case you can specify additional variables as part of the output request.

Alternatively, you can request all nodal variables applicable to the current procedure type. In this case any additional variables you specify are ignored.

Input File Usage: Use the following option to request the preselected nodal output variables:

*NODE OUTPUT, VARIABLE=PRESELECT

Use the following option to request all applicable nodal output variables:

*NODE OUTPUT, VARIABLE=ALL

Abaqus/CAE Usage: Step module: field or history output request editor: **Preselected defaults** or **All**

Specifying the directions for nodal field output in Abaqus/Standard and Abaqus/Explicit

For nodal variables 1, 2, and 3 refer to the global directions X, Y, and Z, respectively. For axisymmetric elements 1 and 2 refer to the global directions r and z. Nodal field results are written to the output database in the global directions. If a local coordinate system is defined at a node (see "Transformed coordinate systems," Section 2.1.5), the local nodal transformations are written to the output database as well. You can apply these transformations to the results in the Visualization module of Abaqus/CAE to view components in the local systems.

Specifying the directions for nodal history output in Abaqus/Standard and Abaqus/Explicit

For nodal variables 1, 2, and 3 refer to the global directions X, Y, and Z, respectively. For axisymmetric elements 1 and 2 refer to the global directions r and z. Nodal history results are written to the output database in the global directions unless a local coordinate system has been defined at a node (see "Transformed coordinate systems," Section 2.1.5). In this case you can specify whether output is desired in global or local directions.

Obtaining nodal history output in the global directions

You can request vector-valued nodal variables in the global directions, which is the default for nodal history output requests to the output database since most postprocessors assume that components are given in the global system.

Input File Usage: *NODE OUTPUT, GLOBAL=YES

Abaqus/CAE Usage: Step module: history output request editor: **Domain**: **Set**: toggle on **Use global directions for vector-valued output**

Obtaining nodal history output in the local directions defined by nodal transformations

You can request vector-valued nodal variables in the local directions defined by nodal transformations.

Input File Usage: *NODE OUTPUT, GLOBAL=NO

Abaqus/CAE Usage: Step module: history output request editor: **Domain**: **Set**: toggle off **Use global directions for vector-valued output**

Visualizing boundary conditions

Boundary conditions can be visualized in the Visualization module of Abaqus/CAE by selecting **View→ODB Display Options**. Click the **Entity Display** tab in the dialog box that appears.

In an Abaqus/Standard analysis boundary condition information is written to the output database only when some nodal output variables are requested as field output.

Tracer particle output from Abaqus/Explicit

In Abaqus/Explicit tracer particles can be used to obtain output at specific material points that may not correspond to a fixed location in the mesh if adaptive meshing is used. Tracer particles follow the material motion throughout an analysis regardless of the mesh motion, which makes them ideal for use

with adaptive meshing (see "Defining ALE adaptive mesh domains in Abaqus/Explicit," Section 12.2.2). Both nodal and element output can be obtained at tracer particles.

Defining tracer particles

You define the initial location of each tracer particle to be coincident with a node, called the "parent node." These parent nodes are grouped into a tracer set; you must assign a name to the tracer set when you define the tracer particles.

Input File Usage: ∗TRACER PARTICLE, TRACER SET=*tracer_set_name*
list of parent nodes (either node numbers or node set labels)

Abaqus/CAE Usage: Tracer particles are not supported in Abaqus/CAE.

Particle birth stages

Sets of tracer particles can be released from the current locations of the parent nodes at multiple times during a step. Each release of tracer particles is referred to as a "particle birth." After particle birth the tracer particles follow the motion of the associated material regardless of the motion of the mesh. You can indicate the number of particle birth stages in a step, *n*. One particle birth will occur at the beginning of the step, and the rest of the stages will be evenly spaced throughout the step. If you do not specify a number of particle birth stages, a single particle birth will occur at the beginning of the step.

Input File Usage: ∗TRACER PARTICLE, TRACER SET=*tracer_set_name*,
PARTICLE BIRTH STAGES=*n*

Abaqus/CAE Usage: Tracer particles are not supported in Abaqus/CAE.

Tracer particles in the output database

Tracer sets will appear as both node and element sets in the output database. If a tracer set has multiple birth stages, additional node and element sets will be created that group all the tracer particles associated with a given birth stage. These subsets are named by appending the birth stage number to the tracer set name. For example, if a tracer set with the name **INLET** is defined with two particle birth stages, three node sets and three element sets will be created in the output database: **INLET Stage 1**, **INLET Stage 2**, and **INLET** (which contains all the nodes/elements from both **INLET Stage 1** and **INLET Stage 2**).

Internal field output requests are generated automatically for the requested output variables for all the elements or nodes in the domain that completely defines the space of possible tracer particle locations. This region is determined by Abaqus/Explicit and typically corresponds to the elements attached to the parent nodes and any intersecting adaptive mesh domains. The postprocessing calculator (see "The postprocessing calculator," Section 4.3.1) will compute the value of any requested output quantity at a tracer particle by interpolating the results from the element that encompasses the particle at the time of output.

Requesting output at tracer particles

You can request element or nodal output for a particular tracer set. Output will be given for all tracer particles that are associated with the specified tracer set name.

Input File Usage: Use one of the following options:

*NODE OUTPUT, TRACER SET=*tracer_set_name*
*ELEMENT OUTPUT, TRACER SET=*tracer_set_name*

Abaqus/CAE Usage: Tracer particle output is not supported in Abaqus/CAE.

Field output at tracer particles

Displacement is the only valid field request for tracer particles. You can obtain the positions of the tracer particles in a specific tracer set by requesting displacements as nodal field output. Tracer particle displacements are output automatically if displacement output is requested for the entire model. You can use the node and element sets created for tracer particles in the output database to control the display of tracer particles in the Visualization module of Abaqus/CAE.

Input File Usage: Use both of the following options:

*OUTPUT, FIELD
*NODE OUTPUT, TRACER SET=*tracer_set_name*
U

Abaqus/CAE Usage: Tracer particle output is not supported in Abaqus/CAE.

History output at tracer particles

Requesting history output for tracer particles is similar to requesting history output for elements and nodes. Any valid element integration point variable can be requested. U, V, A, and COORD are the only valid nodal requests. Whole element variables and element section variables cannot be requested. History data are available for a tracer particle only after its birth.

A tracer particle history output request triggers an internal field output request for the desired variables for all the elements or nodes in the domain that completely defines the space of possible tracer particle locations.

Input File Usage: Use the following options:

*OUTPUT, HISTORY
*NODE OUTPUT, TRACER SET=*tracer_set_name*
*ELEMENT OUTPUT, TRACER SET=*tracer_set_name*

Abaqus/CAE Usage: Tracer particle output is not supported in Abaqus/CAE.

Tracer particle propagation in multiple steps

Once defined, all tracer particles remain active in subsequent steps. However, no further particle births occur in the steps that follow the tracer set definition. You can define new tracer particles in subsequent steps by specifying a new tracer set name. The same tracer set name cannot be used more than once within an analysis.

Tracer particle deactivation

Individual tracer particles are deactivated if they flow out of the mesh across an Eulerian boundary or are currently tracking material points inside a failed element that has been deleted from the mesh. History data for tracer particles are zero at all times after deactivation.

Controlling the output frequency at tracer particles

The frequency of tracer particle output is controlled as described above in "Controlling the output frequency."

WARNING: Requesting tracer set history output at a high frequency may cause the output database (`.odb`) to become large. The disk space required to store the field data is directly proportional to the size of the adaptive mesh domain and the number of tracer sets. The disk space usage is independent of the number of tracer particles in a tracer set. The output database file size is reduced after the postanalysis calculation is performed.

Integrated output in Abaqus/Explicit

Integrated output can be requested either over a surface or over an element set. An integrated output request is used to write the time history of variables such as the total force transmitted across a surface, the total mass of an element set, or the percentage change of the total mass of an element set.

Selecting the integrated output variables

The integrated variables that can be written to the output database are defined in the "Integrated variables" section of "Abaqus/Explicit output variable identifiers," Section 4.2.2.

Input File Usage: ∗INTEGRATED OUTPUT
list of output variables

Abaqus/CAE Usage: Step module: history output request editor: **Select from list below**

Selecting the surface over which integrated output is required

You can specify the surface directly for an integrated output request. Alternatively, you can associate an integrated output section that identifies the surface (see "Integrated output section definition," Section 2.5.1) with the integrated output request.

Integrated output can be requested for a surface that includes facets, edges, or ends of various types of deformable elements. The surface can include facets of three-dimensional solid elements and continuum shell elements; edges of two-dimensional solid elements, membrane elements, conventional shell, and surface elements; and ends of beam elements, pipe elements, and truss elements.

Specifying the surface for integrated output directly

If you specify the surface for an integrated output request directly, any vector output variables are given with respect to a fixed global coordinate system and the total moment transmitted across the surface, SOM, is computed about the fixed global origin. See "Element-based surface definition," Section 2.3.2, for information on defining element-based surfaces.

Input File Usage: Use both of the following options:

*SURFACE, NAME=*surface_name*, TYPE=ELEMENT
*INTEGRATED OUTPUT, SURFACE=*surface_name*

Abaqus/CAE Usage: You cannot specify the surface for an integrated output request directly in Abaqus/CAE; you must create an integrated output section as described below.

Specifying the surface through an integrated output section definition

If you associate an integrated output section definition with an integrated output request, the integrated output variables can be obtained in a local coordinate system that can translate and/or rotate with the deformation (see Figure 4.1.3–1). In addition, the total moment transmitted across the surface, SOM, can be computed about a moving location.

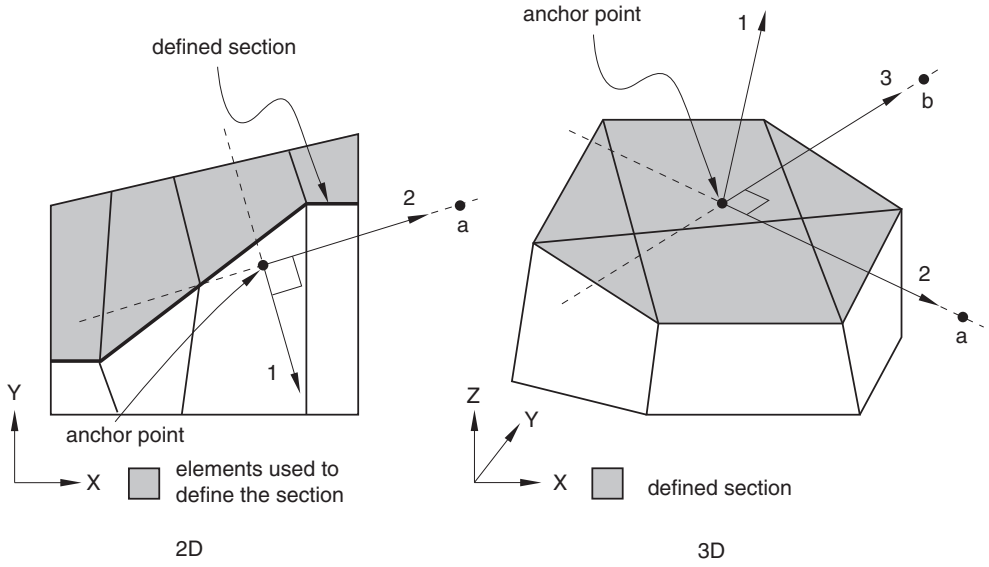


Figure 4.1.3–1 A user-defined local coordinate system.

Input File Usage: Use both of the following options:

*INTEGRATED OUTPUT SECTION, NAME=*section_name*, SURFACE=*surface_name*
*INTEGRATED OUTPUT, SECTION=*section_name*

Abaqus/CAE Usage: Step module:

Output→Integrated Output Sections→Create: **Name:** *section_name*: select regions for the surface

History output request editor: **Domain: Integrated output section:** *section_name*

Requesting integrated output for "force-flow" studies

To study the "force-flow" through various paths in a model, you must create interior surfaces that cut through one or more regions (similar to a cross-section) so that you can request integrated output of the total force transmitted across these surfaces. You can create such interior surfaces over the element facets, edges, or ends by simply cutting through one or more regions of the model with a plane; see "Creating interior cross-section surfaces" in "Element-based surface definition," Section 2.3.2, for more information.

Input File Usage: Use both of the following options:

∗SURFACE, NAME=*surface_name*, TYPE=CUTTING SURFACE
∗INTEGRATED OUTPUT, SURFACE=*surface_name*

Abaqus/CAE Usage: You cannot specify the surface for an integrated output request directly in Abaqus/CAE; you must create an integrated output section as described above.

Requesting integrated output over an element set

You can request integrated output over an element set to output its total mass, the percentage change of its total mass, its average rigid body motion or any combination of these variables. The element set must have been defined previously, and it can include any type of elements.

Input File Usage: Use the following option to request integrated output over an element set:

∗INTEGRATED OUTPUT, ELSET=*element set name*

Abaqus/CAE Usage: Requesting integrated output over an element set is not supported in Abaqus/CAE.

Controlling the output frequency

The frequency of integrated output is controlled as described above in "Controlling the output frequency for history output in Abaqus/Explicit."

Requesting preselected output

Preselected output variables are available only when the integrated output is requested over a surface. If integrated output is requested over an element set, you must specify the variables on the data line.

If the integrated output is requested over a surface, you can request the preselected integrated output variables SOF and SOM. In this case you can also specify additional variables as part of the output request. Alternatively, you can request all integrated variables applicable to the current procedure type. In this case any additional variables that you specify are ignored. If you do not request the preselected variables or all variables, you must specify the variables individually.

Input File Usage: Use the following option to request the preselected integrated output variables:

∗INTEGRATED OUTPUT, VARIABLE=PRESELECT
optional additional variables

Use the following option to request all integrated output variables relevant to the current procedure type:

*INTEGRATED OUTPUT, VARIABLE=ALL

Use the following option to specify individual integrated output variables:

*INTEGRATED OUTPUT
individual variables

Abaqus/CAE Usage: Step module: history output request editor: **Preselected defaults** or **All**

Limitations when using integrated output requests

Integrated output requests over a surface are subject to the following limitations:

- Integrated output can be requested over a surface that includes facets, edges, or ends of various types of deformable elements. The surface can include facets of three-dimensional solid elements and continuum shell elements; edges of two-dimensional solid elements, membrane elements, conventional shell, and surface elements; and ends of beam elements, pipe elements, and truss elements. The surface should not contain facets of axisymmetric elements or facets of rigid elements.
- When defining the surface, elements on only one side of the surface must be used. Abaqus/Explicit computes the integrated output variables using the stresses and hourglass-mode forces in elements underlying the surface as in a free-body diagram.
- The defined surface must cut completely through the mesh, form a closed surface, or be on the exterior of the body. Figure 4.1.3–2 presents some typical cases of valid surfaces. If the surface cuts only partially through the mesh, a valid free-body diagram cannot be isolated (see Figure 4.1.3–3) and incorrect answers may be computed.

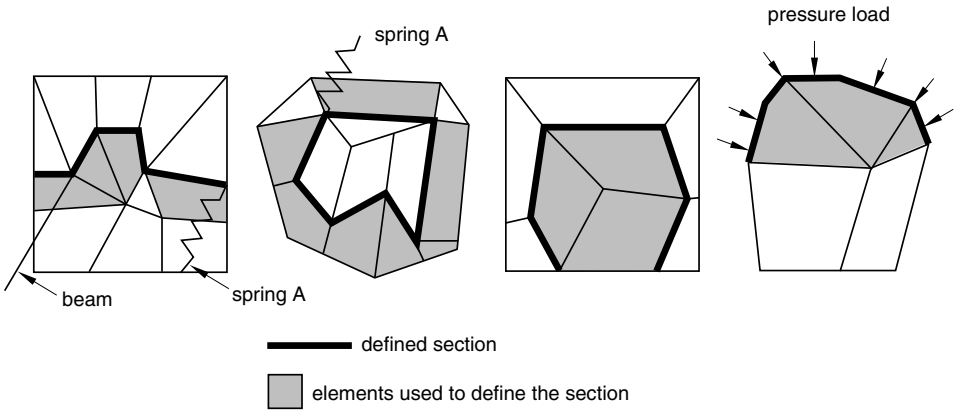


Figure 4.1.3–2 Valid section definitions.

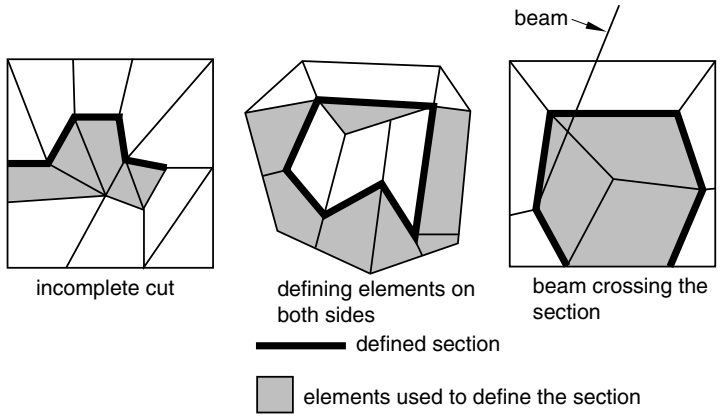


Figure 4.1.3–3 Invalid section definitions.

- Elements attached to the surface can be on either side of the surface but must not cross the defined surface. Figure 4.1.3–3 presents a few invalid cases.
- The total force and the total moment in the section are computed based only on the stresses (internal forces) in the identified elements. Thus, inaccurate results may be obtained if distributed body loads are present in these elements since their effect on the total force in the section is not included. Common examples are the inertial loading in dynamic analyses, gravity loads, distributed body forces, and centrifugal loads. In these cases the total force in the section may depend on the choice of elements used to define the section as illustrated in Figure 4.1.3–4(a). Assuming that gravity loading is the only active load, the element stresses will be different in the two elements. Hence, if the same surface is defined first using element 1 and then using element 2, different answers for the total force will be obtained. In a similar way the effects of any distributed body fluxes (heat, electrical, etc.) prescribed in the identified elements are not included.
- Depending on which side of the surface is used to define the section, different answers will be obtained in analyses similar to the case illustrated in Figure 4.1.3–4(b). Assuming a quasi-static analysis with the concentrated loads shown in the figure being the only active loads, a zero total force is reported if the surface is defined using element 1 and a nonzero force equal to the sum of the concentrated loads is obtained if the surface is defined using element 2.

Total energy output

You can output the total energy of the model or of a specific element set to the output database. Energy output is available only as history output. Energy output requests are not available for the following procedures:

- "Eigenvalue buckling prediction," Section 6.2.3

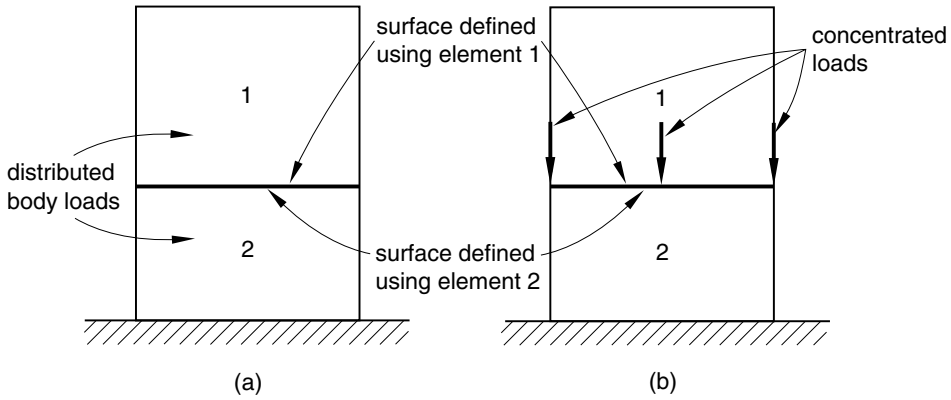


Figure 4.1.3–4 Total force in the section.

- "Natural frequency extraction," Section 6.3.5
- "Complex eigenvalue extraction," Section 6.3.6

Selecting the energy output variables

The energy variables that can be written to the output database are defined in the "Total energy output quantities" section of "Abaqus/Standard output variable identifiers," Section 4.2.1; "Abaqus/Explicit output variable identifiers," Section 4.2.2; and "Abaqus/CFD output variable identifiers," Section 4.2.3.

Input File Usage: *ENERGY OUTPUT
list of output variables

Abaqus/CAE Usage: Step module: history output request editor: **Select from list below**

Selecting the element set for which total energy output is required

You can specify the element set for which total energy output is being requested. In this case the energies are summed for all the elements in the specified set. You cannot specify an element set for the following procedures:

- "Transient modal dynamic analysis," Section 6.3.7
- "Mode-based steady-state dynamic analysis," Section 6.3.8
- "Response spectrum analysis," Section 6.3.10
- "Random response analysis," Section 6.3.11

The following energies are not available as element set quantities: ALLWK, ALLFD, ALLQB, ALLKL, ALLFC, and ETOTAL.

If you do not specify an element set, the total energies for the whole model will be output. If total energy output for both the whole model and for different element sets is desired, the energy output requests must be repeated: once without a specified element set to request energy output for the whole model and once for each specified element set.

Input File Usage: *ENERGY OUTPUT, ELSET=*element_set_name*

Abaqus/CAE Usage: Step module: history output request editor: **Domain: Set:** *set_name*

Controlling the output frequency

The frequency of energy output is controlled as described above in "Controlling the output frequency."

Requesting preselected output

You can request the preselected, procedure-specific energy output variables described in Table 4.1.3–1. In this case you can specify additional variables as part of the output request.

Alternatively, you can request all energy variables applicable to the current procedure and material type. In this case any additional variables you specify are ignored.

Input File Usage: Use the following option to request the preselected energy output variables:

*ENERGY OUTPUT, VARIABLE=PRESELECT

Use the following option to request all applicable energy output variables:

*ENERGY OUTPUT, VARIABLE=ALL

Abaqus/CAE Usage: Step module: history output request editor: **Preselected defaults** or **All**

Sensor definition in Abaqus/Standard and Abaqus/Explicit

For nodal and connector element output variables, history output requests can be used to define sensors. Sensors are named entities that are intended to be used to model physical sensors such as the total force or displacement of a hydraulic piston, the motion of a given point on a structure, or the acceleration as measured by an accelerometer. Sensor values can be fed back into the model to produce actuation that is a function of the sensed quantity thus allowing for modeling of control engineering aspects of your system.

You can use sensors in user subroutine **UAMP** or **VUAMP** to define a customized amplitude that is a function of sensor values at the end of the previous increment as shown in "VUAMP," Section 1.2.7 of the Abaqus User Subroutines Reference Guide, and illustrated in the example in "Crank mechanism," Section 4.1.2 of the Abaqus Example Problems Guide. The amplitude function can be used to actuate any Abaqus feature that can reference an amplitude, such as concentrated loads, boundary conditions, connector motion/load, distributed pressure, and material properties via field variables.

A sensor must be uniquely associated with a particular scalar output variable (U1, CTF3, etc.) and can be defined using history output requests by following some simple rules. The sensor name is specified in the history output definition, and one and only one nodal output or element output request can be specified for each sensor definition. Since the named sensor must point to a unique real number at a given time, the node set or element set used in the definition must contain only one member. Moreover, regardless of the user-specified output frequency, sensors are computed at every increment during the analysis. However, they are written to the output database according to the user-specified frequency.

Input File Usage: Use the following options to specify a sensor definition using element output:

*OUTPUT, HISTORY, SENSOR, NAME=*name*

∗ELEMENT OUTPUT
element output variable

Use the following options to specify a sensor definition using nodal output:

∗OUTPUT, HISTORY, SENSOR, NAME=*name*
∗NODE OUTPUT
nodal output variable

Abaqus/CAE Usage: Step module: history output request editor: **Domain: Set:** *name*, toggle on **Include sensor when available**

Filtering output and operating on output in Abaqus/Explicit

You can pre-filter element and nodal field output and element, nodal, contact, integrated, and fastener interaction history output before it is written to the output database. You can also operate on filtered or unfiltered (raw) output data to extract the maximum, minimum, or absolute maximum of the output variables over time. In addition, you can set a limit value for the output variables, and you can stop the analysis at the time this limit is reached. For field output the time at which the maximum, minimum, and absolute maximum were reached or the time when the limit was reached is output by default for each output variable.

If you filter a field output request that includes many output variables and applies to the entire model, the memory requirements and the running time will both increase. For common output requests consisting of a few element output variables and a few nodal output variables the memory requirements and the running time will not increase substantially.

Defining a low-pass Infinite Impulse Response digital filter

You can define three types of low-pass Infinite Impulse Response filters as part of the model definition. Typical magnitude curves for analog type filters are presented in Figure 4.1.3–5, where Ω_c represents the normalized cutoff frequency, which is the ratio of the cutoff frequency to the sampling frequency (the sampling frequency is the inverse of the time increment). The Butterworth filter is very common; its response in the pass band is known as maximally flat. The Type I Chebyshev filter has a sharper transition between the pass band and the stop band, but it has a ripple in the pass band. The Type II Chebyshev filter also has a sharper transition between the pass band and the stop band than a Butterworth filter of the same order, but it has a ripple in the stop band. The higher the order of the filter, the narrower the transition band. However, the computational cost increases as the order increases. In addition, for high-order filters the phase lag, which is the time delay between the filtered and unfiltered signal, may become significant. For most applications filter orders of two or four are sufficiently accurate.

To define a Butterworth filter, you must specify the cutoff frequency, f_c , and the filter order, N. Since the implementation of the filters is done using cascades of second-order sections, Abaqus expects an even number for the filter order. If you specify an odd number for the order, the order will be increased internally to the next even number. The default value for the order is two, and the highest order that can be prescribed is twenty. For the Chebyshev filters you must also specify an additional parameter, the ripple factor. The ripple factor is equal to ϵ for a Type I Chebyshev filter and is equal to $1/A$ for a Type II Chebyshev filter (see Figure 4.1.3–5).

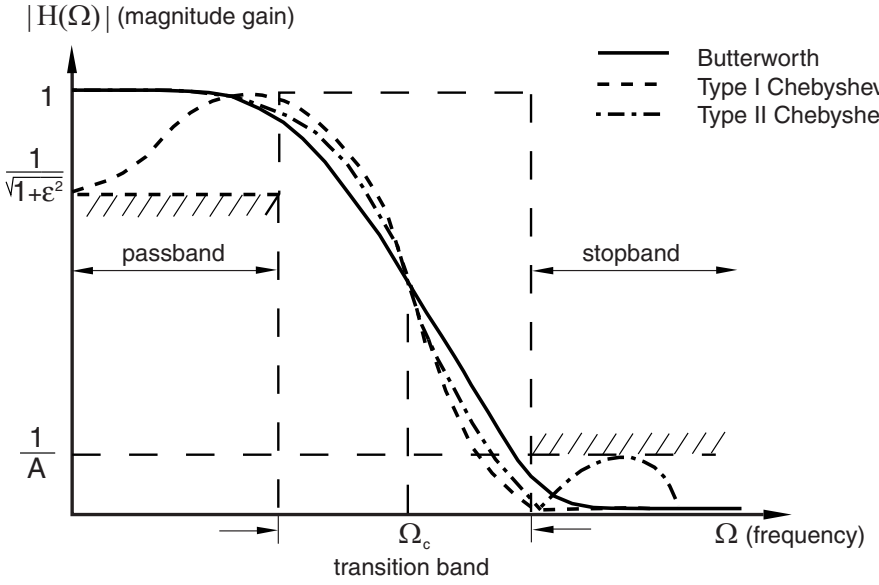


Figure 4.1.3–5 Typical magnitude curves for low-pass filters.

No checks are performed to ensure that the cutoff frequency is appropriate; for example, Abaqus does not check that only the noise of the signal is eliminated. You need to know the range of the physical frequencies that are expected in the solution, and you must prescribe a cutoff frequency greater than these frequencies. In addition, the cutoff frequency should be less than half the sampling frequency; otherwise, no filtering is performed. Abaqus internally remaps (using a quadratic interpolation) the output raw data so that the filtering can satisfy the constant time-increment (sampling) requirement.

You must assign each filter definition a name that can be used to refer to the filter from an output request.

Input File Usage: Use one of the following options to define a filter:

∗FILTER, NAME=*filter_name*, TYPE=BUTTERWORTH
∗FILTER, NAME=*filter_name*, TYPE=CHEBYS1
∗FILTER, NAME=*filter_name*, TYPE=CHEBYS2

Abaqus/CAE Usage: Step module: **Tools→Filter→Create**: **Name:** *filter_name*; **Butterworth**, **Type I Chebyshev**, or **Type II Chebyshev**

Start-up conditions for the filter

By default, the values of the variables at time zero (zero increment) are used as the initial conditions (or start-up conditions); however, you can change this initial value.

Input File Usage: Use the following option to use the default initial conditions:

∗FILTER, NAME=*filter_name*, TYPE=*filter_type*, START CONDITION=DC

Use the following option to specify the initial variable values:

*FILTER, NAME=*filter_name*, TYPE=*filter_type*,
START CONDITION=USER DEFINED

Abaqus/CAE Usage: You cannot specify the initial variable values in Abaqus/CAE.

Filtering using the low-pass Infinite Impulse Response filters

To pre-filter element, nodal, contact, or integrated history output or element and nodal field output based on one of the low-pass Infinite Impulse Response filters that you defined, you refer to this filter by name from the output request.

Input File Usage: Use the following option to apply a filter to an output request:

*OUTPUT, FILTER=*filter_name*

Abaqus/CAE Usage: Step module: field or history output request editor: **Apply filter:** *filter_name*

Filtering the output based on the time interval

For history output you can request that Abaqus/Explicit create an antialiasing filter that is internally based on the time interval specified in the output request. The cutoff frequency is set internally to one-sixth of the time frequency (the time frequency is the inverse of the time interval, t, used for history output). If no time intervals are specified, the default number of history output intervals is used to create the cutoff frequency of the filter. You can also use antialiasing filters for a field output request, but in this case the cutoff frequency is set to one-sixth of a time frequency corresponding to two hundred time intervals per step if less than two hundred field frames are requested. If more than two hundred field frames are requested, the cutoff frequency is set to one-sixth of the requested time frequency. The antialiasing filter is a second-order Butterworth type and a filter definition is not required.

Abaqus/Explicit does not check whether the specified time interval for history output provides an appropriate cutoff frequency to build the internal filter. You should know approximately how many data points are required to describe your history curve (or signal) accurately, and Abaqus/Explicit will give you the most physical (un-aliased) representation of the signal for that number of points. Similarly for field output Abaqus/Explicit does not check whether the cutoff corresponding to two hundred sampling intervals or more (if you request more than two hundred frames) is appropriate for your analysis. If a lower (or higher) cutoff frequency is needed, you should define the filter in the model data.

Filtering field output or history output written at time intervals

You can apply a filter to a field output request or a history output request written at intervals of time in your analysis.

Input File Usage: Use one of the following options:

*OUTPUT, FIELD, FILTER=ANTIALIASING, TIME INTERVAL=t

*OUTPUT, HISTORY, FILTER=ANTIALIASING, TIME INTERVAL=t

Abaqus/CAE Usage: Step module: field or history output request editor: **Frequency**: **Every *x* units of time**: t, **Apply filter**: **Antialiasing**

Filtering field output written at evenly spaced intervals of time

You can apply a filter to a field output request written at evenly spaced time intervals in your analysis.

Input File Usage: *OUTPUT, FIELD, FILTER=ANTIALIASING, NUMBER INTERVAL=*n*

Abaqus/CAE Usage: Step module: field output request editor: **Frequency**: **Evenly spaced time intervals**, **Interval**: *n*, **Apply filter**: **Antialiasing**

Requesting maximum, minimum, or absolute maximum values for an output request

You can apply a filter to a field output request or a history output request to obtain the maximum, minimum, or absolute maximum values for each variable in the output request. The absolute maximum option enables you to obtain the largest absolute value, negative or positive, for each variable in the output request. Abaqus evaluates maximum, minimum, or absolute maximum values at every increment during the analysis and reports these values at the time given by the output interval specified in the output request. For field output requests the last output frame will contain the maximum (or absolute maximum) value and minimum value over the entire step; the intermediate frames will show the maximum, minimum, or absolute maximum value up to the frame time. An additional output variable containing the time when the maximum, minimum, or absolute maximum occurred is output automatically for each output variable requested. This time output is written by default (and it cannot be suppressed).

For field output requests Abaqus filters by default each component of tensor and vector quantities of output variable independently and provides separate maximum, minimum, or absolute maximum values for each component of the variable. You can, however, request the maximum or minimum value or apply a limit value to an invariant such as Mises stress for element output or magnitude for nodal output (see "Applying bounding values to invariants," below).

Requesting maximum, minimum, or absolute maximum values for filtered output

You can define a low-pass digital filter that returns the maximum, minimum, or absolute maximum value for output requests to which it is applied.

Input File Usage: Use one of the following options:

*FILTER, TYPE=*filter_type*, OPERATOR=MAX
*FILTER, TYPE=*filter_type*, OPERATOR=MIN
*FILTER, TYPE=*filter_type*, OPERATOR=ABSMAX

Abaqus/CAE Usage: Step module: **Tools→Filter→Create**: **Butterworth**, **Type I Chebyshev**, or **Type II Chebyshev**: **Determine bounding value**: **Maximum**, **Minimum**, or **Absolute maximum**

Requesting maximum, minimum, or absolute maximum values for unfiltered output

You can define a filter that returns the maximum, minimum, or absolute maximum value for output requests to which it is applied without performing any digital filtering of the data.

Input File Usage: Use one of the following options:

*FILTER, OPERATOR=MAX

*FILTER, OPERATOR=MIN
*FILTER, OPERATOR=ABSMAX

Abaqus/CAE Usage: Step module: **Tools→Filter→Create**: **Type**: **Operator**: **Determine bounding value: Maximum**, **Minimum**, or **Absolute maximum**

Setting an upper or lower limit on variables in an output request

You can apply a filter to a field output request or a history output request to prescribe a bounding value for the variables in the output request. If any of the variables in the output request reach a value higher than the maximum limit, lower than the minimum limit, or greater than the absolute maximum limit, Abaqus returns the limiting value. The time at which the limit was reached is output separately for each requested variable. This time output is written by default (and it cannot be suppressed).

Setting an upper limit or a lower limit for filtered output

You can define a low-pass digital filter that enforces an upper or lower bound for the variables in the output requests to which it is applied.

Input File Usage: *FILTER, TYPE=*filter_type*, OPERATOR=*operator_type*, LIMIT=*value*

Abaqus/CAE Usage: Step module: **Tools→Filter→Create**: **Type**: **Butterworth**, **Type I Chebyshev**, or **Type II Chebyshev**: **Determine bounding value: Maximum**, **Minimum**, or **Absolute maximum**: toggle on **Bounding value limit:** *value*

Setting an upper limit or a lower limit for unfiltered output

You can define a filter that enforces an upper or lower bound for the variables in the output requests to which it is applied but that does not perform any Butterworth or Chebyshev filtering of the data.

Input File Usage: *FILTER, OPERATOR=*operator_type*, LIMIT=*value*

Abaqus/CAE Usage: Step module: **Tools→Filter→Create**: **Type**: **Operator**: **Determine bounding value: Maximum**, **Minimum**, or **Absolute maximum**: toggle on **Bounding value limit:** *value*

Stopping an analysis when an output variable reaches a prescribed limit

You can apply a filter to a field output request or a history output request that stops the analysis when the value of any variable in the output request reaches a specified upper bound or lower bound.

Stopping an analysis of filtered output when a variable reaches a prescribed limit

You can define a low-pass digital filter that stops the analysis if any of the variables in the output requests to which it is applied reach a prescribed limit.

Input File Usage: *FILTER, TYPE=*filter_type*, OPERATOR=*operator_type*, LIMIT=*value*, HALT

Abaqus/CAE Usage: Step module: **Tools→Filter→Create**: **Butterworth**, **Type I Chebyshev**, or **Type II Chebyshev**: **Determine bounding value: Maximum**, **Minimum**,

or **Absolute maximum**: toggle on **Bounding value limit**: *value*: toggle on **Stop analysis upon reaching limit**

Stopping an analysis of unfiltered output when a variable reaches a prescribed limit

You can define a filter that does not perform any Butterworth or Chebyshev filtering of your output data and stops the analysis if any of the variables in the output requests to which it is applied reach a prescribed limit.

Input File Usage: *FILTER, OPERATOR=*operator_type*, LIMIT=*value*, HALT

Abaqus/CAE Usage: Step module: **Tools→Filter→Create**: **Type**: **Operator**: **Determine bounding value: Maximum**, **Minimum**, or **Absolute maximum**: toggle on **Bounding value limit**: *value*: toggle on **Stop analysis upon reaching limit**

Applying bounding values to invariants

By default, each component of a tensor or vector quantity is filtered individually and the maximum, minimum, or absolute maximum value and the limiting values are reported separately for each component. You can, however, apply a filter directly to an invariant. In this case Abaqus internally monitors the invariant you specified. Abaqus still writes the components to the output database, but these components correspond to the maximum, minimum, or limiting values of the invariant. Table 4.1.3–2 shows which invariants are available for output variable categories.

Table 4.1.3–2 Invariants available for output variable categories.

Category	First invariant	Second invariant
All nodal vector output	Magnitude	–
Stress element output	Mises	Press

Applying bounding values to invariants of filtered output

You can define a low-pass digital filter that filters the invariant.

Input File Usage: *FILTER, TYPE=*filter_type*, OPERATOR=*operator_type*, LIMIT=*value*, INVARIANT=FIRST or SECOND

Abaqus/CAE Usage: Step module: **Tools→Filter→Create**: **Type**: **Butterworth**, **Type I Chebyshev**, or **Type II Chebyshev**; toggle on **Bounding value limit**: *value*: **Invariant**: **First** or **Second**

Applying bounding values to invariants of unfiltered output

You can define a filter that does not perform any Butterworth or Chebyshev filtering of your output data and filters the invariant.

Input File Usage: *FILTER, OPERATOR=*operator_type*, LIMIT=*value*, INVARIANT= FIRST or SECOND

Abaqus/CAE Usage: Step module: **Tools→Filter→Create**: **Type**: **Operator**; toggle on **Bounding value limit**: *value*: **Invariant**: **First** or **Second**

Output variables available for filtering

Low-pass Infinite Impulse Response filters such as Butterworth and Chebyshev filters are intended for filtering of output variables susceptible to noise, such as accelerations and reaction forces or, to a lesser degree, stress and strain. However, digital filtering is allowed for most element and nodal output variables, and you can apply bounding values on unfiltered data for nearly all element and nodal output variables. Table 4.1.3–3 shows the set of output variables that cannot be digitally filtered but to which you can apply bounding values, and Table 4.1.3–4 shows the set of output variables for which neither digital filtering nor application of bounding values are allowed.

Table 4.1.3–3 Output variables to which bounding values can be applied but digital filtering cannot be applied.

Category	Output variables
Tensors and invariants	PEEQ
State and field variables	TEMP, FV
Energy densities	ENER, SENER, PENER, CENER, VENER, DMENER
Additional plasticity quantities	PEQC
Cracking model quantities	CKSTAT
Whole element variables	EDT, EMSF, ELEDEN, ESEDEN, EPDDEN, ECDDEN, EVDDEN, EASEDEN, EIHEDEN, EDMDDEN, ECDDEN, ELEN, ELSE, ELCD, ELPD, ELVD, ELASE, ELIHE, ELDMD, ELDC, STATUS
Nodal output variables	NT, COORD

Table 4.1.3–4 Output variables that cannot be digitally filtered or modified with bounding values.

Category	Output variables
Cracking model quantities	CRACK
Element face variables	STAGP, TRNOR, TRSHR
Whole element variables	GRAV, BF, SBF, P
Nodal output variables	CF

Modal output from Abaqus/Standard

You can output generalized coordinate (modal amplitude and phase) values during modal dynamic procedures (see "Dynamic analysis procedures: overview," Section 6.3.1, for an overview of the modal dynamic procedures available in Abaqus/Standard) to the output database. Modal output is available only as history output.

Controlling the frequency of output

The frequency of modal output is controlled as described above in "Controlling the output frequency in Abaqus/Standard."

Requesting output

You can choose to request all modal variables applicable to the current procedure and material type. In this case any additional variables you specify are ignored.

Input File Usage: *MODAL OUTPUT, VARIABLE=ALL

Abaqus/CAE Usage: Step module: history output request editor: **All**

Surface output in Abaqus/Standard and Abaqus/Explicit

You can write variables associated with surfaces in contact, coupled thermal-electrical-structural (Abaqus/Standard only), coupled temperature-displacement (Abaqus/Standard only), coupled thermal-electrical, and crack propagation problems to the output database. Multiple output requests can be used to customize requests among interactions, surfaces, or node sets.

For surface variables associated with cavity radiation, see "Cavity radiation output in Abaqus/Standard" below.

Use element output requests (see "Element output") to obtain database output for contact elements (such as gap elements; see "Gap contact elements," Section 40.2.1).

In Abaqus/Standard contact history output cannot be saved in a linear perturbation step with frequency extraction.

Displacement nodal output is generated automatically in Abaqus/Explicit when requesting surface output.

Selecting the surface output variables

The surface variables that can be written to the output database are listed in the "Surface variables" section of "Abaqus/Standard output variable identifiers," Section 4.2.1, and "Abaqus/Explicit output variable identifiers," Section 4.2.2.

Input File Usage: *CONTACT OUTPUT
list of output variables

Abaqus/CAE Usage: Step module: field or history output request editor: **Select from list below**

Limiting the extent of a surface output request in Abaqus/Standard

Output requests apply to general contact and all contact pair interactions in a model by default in Abaqus/Standard. Options to limit an output request to certain interactions are discussed below.

Limiting output to a node set in Abaqus/Standard

You can limit a surface output request to apply to a subset of surface nodes involved in contact pairs or general contact in Abaqus/Standard.

Input File Usage: ∗CONTACT OUTPUT, NSET=*node_set_name*

Abaqus/CAE Usage: Step module: field or history output request editor: **Domain:** **Interaction:** *contact_interaction_name*

Limiting output for contact pairs based on slave and master surface names in Abaqus/Standard

You can limit output to certain contact pairs based on surface names. If you specify both the slave and master surface names, the output request is limited to a specific contact pair. If you specify the slave surface but not the master surface, output is written for all contact pairs that involve the specified slave surface. If you also specify a node set, the applicability of an output request is further limited (i.e., the output request will generate output only for certain nodes of a certain contact pair (or pairs). Output requests with a specific slave and/or master surface role specified will not generate output for general contact.

Input File Usage: ∗CONTACT OUTPUT, MASTER=*master*, SLAVE=*slave*, NSET=*node_set_name*

Abaqus/CAE Usage: Step module: field or history output request editor: **Domain:** **Interaction:** *contact_interaction_name*

Limiting the extent of a surface field output request in Abaqus/Explicit

Field output requests apply to general contact and all contact pair interactions in a model by default in Abaqus/Explicit. Options to limit a surface field output request to certain interactions are discussed below.

Limiting surface field output to a contact pair set in Abaqus/Explicit

In Abaqus/Explicit you can select the contact pairs for which surface field output is desired. Surface output is contact pair-specific, so that contact output for a particular surface involved in a selected contact pair will include only the contributions from that contact pair if the surface is involved in multiple contact pairs. Surface output is available only for discrete (node-based or element-based) surfaces; it is not available for any analytical surfaces within a contact pair.

Input File Usage: Use the following option to request surface field output for a particular contact pair set:

∗CONTACT OUTPUT, CPSET=*contact_pair_set_name*

Abaqus/CAE Usage: Step module: field output request editor: **Domain: Interaction:** *contact_interaction_name*

Limiting surface field output to general contact in Abaqus/Explicit

You can limit surface field output requests to apply only to general contact in Abaqus/Explicit, but you cannot further limit this output to a subset of the general contact domain.

Input File Usage: *CONTACT OUTPUT, GENERAL CONTACT

Abaqus/CAE Usage: You cannot limit surface field output to general contact in Abaqus/CAE.

Limiting surface field output to a single surface in Abaqus/Explicit

You can limit surface field output requests to a single surface in the general contact domain in Abaqus/Explicit. The contact output for the specified surface will include all the contributions from other contact surfaces interacting with the surface.

Input File Usage: *CONTACT OUTPUT, SURFACE=*surface_name*

Abaqus/CAE Usage: You cannot limit a single surface output to general contact in Abaqus/CAE.

Limiting surface field output to pairwise surfaces in Abaqus/Explicit

You can specify a pair of surfaces in the general contact domain in Abaqus/Explicit for which the interactions on one surface due to the contact with another surface will be output. This type of output cannot be used for surfaces involving Eulerian regions.

Input File Usage: *CONTACT OUTPUT, SURFACE=*first_surface_name*,
SECOND SURFACE=*second_surface_name*

Abaqus/CAE Usage: You cannot limit pairwise surface output to general contact in Abaqus/CAE.

Specifying surface history output regions in Abaqus/Explicit

You must specify an interaction to which a surface history output request applies with one of the methods discussed below.

Specifying surface history output by contact pair set in Abaqus/Explicit

In Abaqus/Explicit you can select the contact pairs for which surface history output is desired. Surface output is contact pair-specific, so that contact output for a particular surface involved in a selected contact pair will include only the contributions from that contact pair if the surface is involved in multiple contact pairs. Surface output is available only for discrete (node-based or element-based) surfaces; it is not available for any analytical surfaces within a contact pair.

Input File Usage: Use the following option to request surface history output for a particular contact pair:

*CONTACT OUTPUT, CPSET=*contact_pair_set_name*

Abaqus/CAE Usage: Step module: history output request editor: **Domain: Interaction:** *contact_interaction_name*

Specifying whole surface history output in Abaqus/Explicit

You can specify a surface in the general contact domain for which whole surface contact force resultants will be output. Whole surface contact force resultants for a surface in the general contact domain are available only as history output.

Input File Usage: *CONTACT OUTPUT, SURFACE=*surface_name*

Abaqus/CAE Usage: Step module: history output request editor: **Domain: General contact surface:** *surface_name*

Specifying pairwise surface history output in Abaqus/Explicit

You can specify a pair of surfaces in the general contact domain for which the resultant contact forces on one surface due to the contact with another surface will be output. The contact force resultants in this case consider only the contact interactions between the two specified surfaces. This type of output cannot be requested for surfaces involving Eulerian regions.

Input File Usage: *CONTACT OUTPUT, SURFACE=*first_surface_name*,
SECOND SURFACE=*second_surface_name*

Abaqus/CAE Usage: You cannot request surface history output for a pair of surfaces in Abaqus/CAE.

Specifying surface history output by fastened node set in Abaqus/Explicit

You can select a fastened node set for which bond history output is desired:

Input File Usage: Use the following option to request surface history output for a particular fastened node set:

*CONTACT OUTPUT, NSET=*node_set_name*

Abaqus/CAE Usage: You cannot request surface history output for a particular fastened node set in Abaqus/CAE.

Controlling the output frequency

The frequency of surface output is controlled as described above in “Controlling the output frequency.”

Requesting preselected output

You can request the preselected, procedure-specific surface output variables described in Table 4.1.3–1. In this case you can specify additional variables as part of the output request.

Alternatively, you can request all surface variables applicable to the current procedure. In this case any additional variables you specify are ignored.

Input File Usage: Use the following option to request the preselected surface output variables:

*CONTACT OUTPUT, VARIABLE=PRESELECT

Use the following option to request all applicable surface output variables:

*CONTACT OUTPUT, VARIABLE=ALL

Abaqus/CAE Usage: Step module: field or history output request editor:
Preselected defaults or **All**

Surface output in Abaqus/CFD

You can write field and history output variables associated with surfaces in an Abaqus/CFD analysis to the output database.

Selecting the surface output variables

The surface variables that can be written to the output database are listed in the "Surface variables" section of "Abaqus/CFD output variable identifiers," Section 4.2.3.

Input File Usage: *SURFACE OUTPUT, SURFACE=*surface_set_name*
list of output variables

Abaqus/CAE Usage: You cannot request surface output in Abaqus/CAE.

Controlling the output frequency

The frequency of surface output is controlled as described above in "Controlling the output frequency."

Time incrementation output in Abaqus/Explicit

You can output incrementation variables for an Abaqus/Explicit analysis to the output database. Incrementation output is available only as history output.

Selecting the incrementation output variables

The available incrementation output variables are the Abaqus/Explicit time increment size, DT; the percent change in mass of the model due to mass scaling, DMASS; and the steady-state detection variables SSPEEQ, SSSPRD, SSFORC, and SSTORQ.

Input File Usage: *INCREMENTATION OUTPUT
list of output variables

Abaqus/CAE Usage: Step module: history output request editor: **Select from list below**

Controlling the output frequency

The frequency of incrementation output is controlled as described above in "Controlling the output frequency for history output in Abaqus/Explicit."

Requesting preselected output

You can request the preselected, procedure-specific incrementation output variables. In this case you can specify additional variables as part of the output request.

Alternatively, you can request all incrementation variables applicable to the current procedure type. In this case any additional variables you specify are ignored.

Input File Usage: Use the following option to request the preselected incrementation output variables:

*INCREMENTATION OUTPUT, VARIABLE=PRESELECT

Use the following option to request all applicable incrementation output variables:

*INCREMENTATION OUTPUT, VARIABLE=ALL

Abaqus/CAE Usage: Step module: history output request editor: **Preselected defaults** or **All**

Cavity radiation output in Abaqus/Standard

You can request that cavity-, element-, or surface-based output such as radiation fluxes, viewfactor totals for a facet, and facet temperatures from an Abaqus/Standard analysis be written to the output database. The output request can be repeated as often as necessary to define output for different variables, different cavities, different element sets, different surfaces, etc.

Selecting the radiation output variables

The radiation output variables that can be written to the output database are listed in the "Cavity radiation variables" section of "Abaqus/Standard output variable identifiers," Section 4.2.1.

Input File Usage: *RADIATION OUTPUT
list of output variables

Abaqus/CAE Usage: Cavity radiation output requests are not supported in Abaqus/CAE.

Selecting the region of the model for which radiation output is required

You can specify the cavity, element set, or surface for which radiation output is required. Each radiation output request can apply to only one type of region. If you do not specify a region of the model, radiation variables are output for all the cavities in the model.

Input File Usage: Use one of the following options:

*RADIATION OUTPUT, CAVITY=*cavity_name*
*RADIATION OUTPUT, ELSET=*element_set_name*
*RADIATION OUTPUT, SURFACE=*surface_name*

Abaqus/CAE Usage: Cavity radiation output requests are not supported in Abaqus/CAE.

Controlling the output frequency

The frequency of radiation output is controlled as described above in "Controlling the output frequency."

Requesting output

You can request all radiation variables applicable to the current procedure. In this case any additional variables you specify are ignored.

Input File Usage: *RADIATION OUTPUT, VARIABLE=ALL

Abaqus/CAE Usage: Cavity radiation output requests are not supported in Abaqus/CAE.

Examples

The examples that follow illustrate how to request multiple types of output over multiple steps in both Abaqus/Standard and Abaqus/Explicit.

Abaqus/Standard example

The input listing below will produce both field and history output for Step 1. Field output will be written every 2 increments. This field output request consists of preselected element variables for the whole model, as well as the variable PEQC. In addition, plastic strains will be written out for element set **SMALL**, and the nodal variables U and RF will be written to the output database for node set **NSMALL**. History output will be written every increment. The variables ALLKE, ALLSE, and ALLWK will be written for the whole model. In addition, ALLPD will be written for element set **SMALL**.

In Step 2 the history output request defined in Step 1 is replaced by a request for the energy variables ALLKE, ALLPD, and ALLSE for element set **SMALL**. The history output request defined in Step 1 is removed. The field output request defined in Step 1 is passed into Step 2 unchanged, but another field output request for element energies at every increment is added.

```
*STEP
*STATIC
...
...
*OUTPUT, FIELD, FREQUENCY=2
*ELEMENT OUTPUT, VARIABLE=PRESELECT
PEQC,
*ELEMENT OUTPUT, ELSET=SMALL
PE,
*NODE OUTPUT, NSET=NSMALL
U, RF
*OUTPUT, HISTORY, FREQUENCY=1
*ENERGY OUTPUT
ALLKE, ALLSE, ALLWK
*ENERGY OUTPUT, ELSET=SMALL
ALLPD
*END STEP
*STEP
*STATIC
...
...
*OUTPUT, HISTORY, OP=REPLACE, FREQUENCY=1
*ENERGY OUTPUT, ELSET=SMALL
ALLKE, ALLPD, ALLSE
*OUTPUT, FIELD, OP=ADD, FREQUENCY=1
```

```
*ELEMENT OUTPUT
ELEN
*END STEP
```

Abaqus/Explicit example

The input listing below will produce both field and history output for Step 1. Field output will be written at 5 equally spaced intervals, and the time marks will be hit exactly. This field output request consists of preselected element variables for the whole model, as well as the variable PEQC. In addition, plastic strains will be written out for element set **SMALL**, and the nodal variables U and RF will be written to the output database for node set **NSMALL**. History output will be written at a time interval of 0.005. The Abaqus/Explicit time step, DT, will be written, along with the variables ALLKE, ALLSE, and ALLWK for the whole model. The output variables SOAREA and SOF integrated over the surface **CROSS_SECTION1** will be written. The preselected variables SOF and SOM integrated over the surface **CROSS_SECTION2** defined by the integrated output section **SECTION1** will be written in the local coordinate system **LOCALSYSTEM**. In addition, ALLPD will be written for element set **SMALL**.

In Step 2 the history output request defined in Step 1 is replaced by a request for the energy variables ALLKE, ALLPD, and ALLSE for element set **SMALL**. The history output request defined in Step 1 is removed. The field output request defined in Step 1 is passed into Step 2 unchanged, but another field output request for element energies at 10 equally spaced intervals is added.

```
*STEP
*DYNAMIC, EXPLICIT,.1...
...
*OUTPUT, FIELD, NUMBER INTERVAL=5, TIME MARKS=YES
*ELEMENT OUTPUT, VARIABLE=PRESELECT
PEQC,
*ELEMENT OUTPUT, ELSET=SMALL
PE,
*NODE OUTPUT, NSET=NSMALL
U, RF
*OUTPUT, HISTORY, TIME INTERVAL=0.005
*INCREMENTATION OUTPUT
DT
*ENERGY OUTPUT
ALLKE, ALLSE, ALLWK
*ENERGY OUTPUT, ELSET=SMALL
ALLPD
*INTEGRATED OUTPUT, SURFACE=CROSS_SECTION1
SOF, SOAREA
*INTEGRATED OUTPUT SECTION, NAME=SECTION1,
SURFACE=CROSS_SECTION2, ORIENTATION=LOCALSYSTEM
*INTEGRATED OUTPUT, SECTION=SECTION1, VARIABLE=PRESELECT
```

```
*END STEP
*STEP
*DYNAMIC, EXPLICIT,.1...
...
*OUTPUT, HISTORY, OP=REPLACE, TIME INTERVAL=0.005
*ENERGY OUTPUT, ELSET=SMALL
ALLKE, ALLPD, ALLSE
*OUTPUT, FIELD, OP=ADD, NUMBER INTERVAL=10
*ELEMENT OUTPUT
ELEN
*END STEP
```

4.1.4 ERROR INDICATOR OUTPUT

Products: Abaqus/Standard Abaqus/CAE

WARNING: Error indicator output variables are approximate and do not represent an accurate or conservative estimate of your solution error. The quality of an error indicator can be particularly poor if your mesh is coarse. The error indicator quality improves as you refine the mesh; however, you should never interpret these variables as indicating what the value of a solution variable would be upon further refinement of the mesh.

References

- "Abaqus/Standard output variable identifiers," Section 4.2.1
- "Adaptive remeshing: overview," Section 12.3.1
- "Selection of error indicators influencing adaptive remeshing," Section 12.3.2
- *CONTACT OUTPUT
- *ELEMENT OUTPUT

Overview

Error indicator output variables:

- indicate discretization error in a solution quantity (the base solution) and have units of the base solution;
- can be requested with element output or contact output options or as part of an adaptive remeshing rule;
- can be normalized by forms of the base solution to obtain nondimensional, such as percentage, indicators of error;
- can increase your analysis solution time significantly in some cases; and
- are available in Abaqus/Standard but not Abaqus/Explicit.

Solution accuracy

The ability of a finite element analysis to make useful predictions of physical behavior depends on many factors, including:

- representation of geometry, material behavior, load history, and various other modeling aspects associated with describing the problem posed;
- spatial and temporal discretization (mesh refinement and incrementation); and
- convergence tolerances.

The primary focus of this section is spacial discretization error. Discussion to help understand and control other potential sources of error appears in "Convergence criteria for nonlinear problems," Section 7.2.3, "Time integration accuracy in transient problems," Section 7.2.4, "Evaluating hyperelastic and viscoelastic material behavior," Section 12.4.7 of the Abaqus/CAE User's Guide, and other portions of the Abaqus documentation. You should perform a detailed study of your analysis methods and assumptions as part of any error assessment.

Spatial discretization error

The finite element discretization of a model domain results in an approximation to the exact solution for all but trivial analyses. To aid you in understanding the extent and spatial distribution of the discretization error in a finite element solution, Abaqus/Standard provides a set of error indicator output variables. Ideally, error indicator output variables should be supplemented by other techniques, such as a mesh refinement study, to gain confidence that discretization error is not significantly degrading the ability of the finite element analysis to make useful predictions. In fact, error indicators can help automate a mesh refinement study through the adaptive remeshing functionality of Abaqus/CAE; error indicators variables are used by this functionality to determine where to refine or coarsen a mesh (see "Adaptive remeshing: overview," Section 12.3.1).

Error indicator and base solution variables available in Abaqus/Standard

Abaqus error indicator variables provide a measure of the local error resulting from mesh discretization. Each error indicator, c_e, provides an indication of error in a particular base solution variable, c_b. For example, the Mises stress error indicator, MISESERI, provides an indicator of error in the Mises stress variable MISESAVG. Table 4.1.4–1 shows the available error indicator variables and the corresponding base solution variables.

Table 4.1.4–1 Error indicator variables and their corresponding base solution variables.

Solution Quantity	Error indicator variable (c_e)	Base solution variable (c_b)
Element energy density	ENDENERI	ENDEN
Mises stress	MISESERI	MISESAVG
Contact pressure	CPRESSERI	CPRESS
Contact shear stress	CSHEARERI	CSHEAR
Equivalent plastic strain	PEEQERI	PEEQAVG
Plastic strain	PEERI	PEAVG
Creep strain	CEERI	CEAVG
Heat flux	HFLERI	HFLAVG
Electric flux	EFLERI	EFLAVG
Electric potential gradient	EPGERI	EPGAVG

The algorithms used by Abaqus/CAE to modify mesh seed sizes for the adaptive remeshing capability consider error indicator values and corresponding base solution values together. When you create a remeshing rule and request a particular error indicator, Abaqus automatically writes the error indicator and corresponding base solution variable to the output database.

Input File Usage: *OUTPUT, FIELD, ELSET=*ElsetName*
*ELEMENT OUTPUT
*CONTACT OUTPUT

Abaqus/CAE Usage: Step module: **Output→Field Output Request**

Or, if you use the following option to specify an adaptive remeshing rule, the associated error indicator and base solution output will occur by default:

Mesh module: **Create Remeshing Rule**: **Step and Indicator**

Effect of error indicator output requests on solution time

Abaqus/Standard determines error indicator variables based on the difference between a smoothed and unsmoothed distribution of the base solution, using a smoothing technique such as the patch recovery technique of Zienkiewicz and Zhu, (1987). The smoothing calculations occasionally noticeably increase analysis time. If you find that adding an error indicator output request significantly increases analysis time, strategies for reducing this effect include reducing the output frequency and limiting the output request to a particular region of interest. Computations for most error indicator variables only occur just prior to writing the error indicator variable to the output database, so reducing the output frequency will tend to reduce the computation time; however this is not the case for the element energy density error indicator, because contributions to this error indicator are accumulated each increment regardless of whether this error indicator is output for a given increment.

Additional considerations for extent of output requests for element error indicator variables

When you request element error indicator output, the request should only apply to elements supported for error indicator output.

The patch recovery technique used to compute element error indicator variables assumes that the solution should be continuous over the element set specified. Abaqus/Standard confirms that your error indicator output specification is consistent with this assumption by checking section property references within the error indicator domain and issues a warning message if the elements in the provided element set refer to distinct section definitions. You can safely ignore this warning if the sections are identical in their properties.

Interpreting error indicator output

When interpreting error indicator output, you should remember that the error indicators are approximate measures of the local error in the base solution and are, themselves, subject to discretization error. The accuracy of the error estimates tends to improve as the mesh is refined. Each error indicator variable has the same units has the corresponding base solution variable, which facilitates comparison of local estimates of the error magnitude with local estimates of the base solution.

Regions of interest of a base solution and corresponding error indicator

Viewing contour plots of a base solution variable and corresponding error indicator variable side-by-side can provide a useful perspective on the solution accuracy. For example, if the base solution is expressed in units of stress, the corresponding error indicator is also expressed in units of stress. Figure 4.1.4–1 shows contour plots of CPRESS and CPRESSERI for an analysis of a sphere pressed into a rigid plate. These plots can be interpreted as follows:

- The contact pressure solution is quite accurate near the center of the active contact region, where the contact pressure is largest, because the error indicator is a small fraction of the base solution in that region.
- The contact pressure solution is less accurate near the perimeter of the active contact region, where local variations in the contact pressure solution are largest (but the contact pressure is significantly less than the maximum value), because the error indicator is quite large compared to the base solution in that region.

The analyst may judge that the level of mesh refinement is adequate if the maximum contact pressure is of primary interest in such a case. Local mesh refinement would be needed to accurately predict the maximum contact pressure if the active contact region was significantly smaller than that shown in Figure 4.1.4–1.

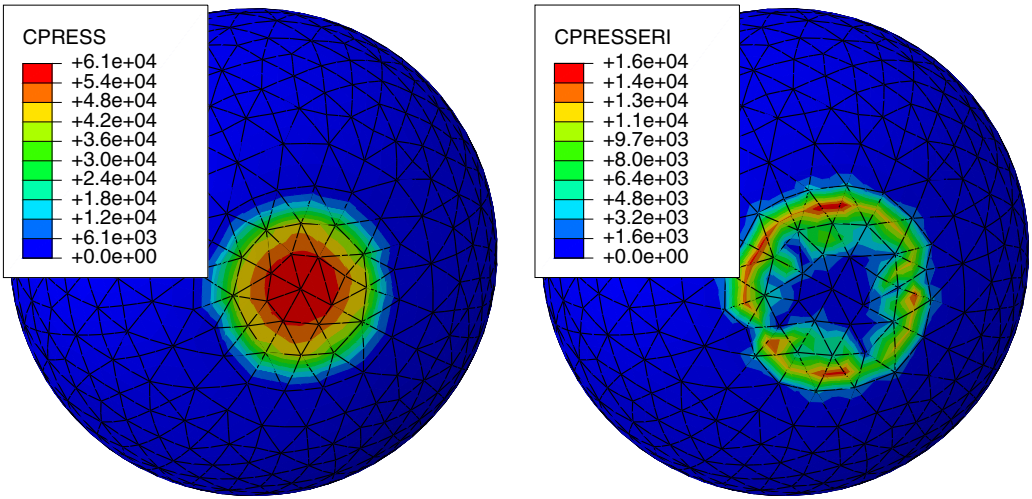


Figure 4.1.4–1 Contour plots of CPRESS and CPRESSERI for contact between a deformable sphere and a rigid plate.

An error indicator tends to give a crude, non-conservative approximation of the deviation from the exact solution if the mesh is coarse relative to local solution variations or the exact solution to the

problem posed involves a stress singularity. The following qualitative interpretations of error indicator results exceeding approximately 10% of base solution results are often appropriate:

- "Significant potential for solution inaccuracy exists in this region."
- "The mesh may be too coarse to give a good estimate of solution error in this region."
- "Perhaps a stress singularity exists at this corner."

Calculating normalized measures of solution error

You can use corresponding error indicator and base solution variables, c_e and c_b, respectively, to compute a field of local, normalized error indicators:

$$\hat{c}_e = \frac{c_e}{c_b},$$

where $\hat{c}_e$ is a normalized error measure. For example,

$$\left(\frac{\text{MISESERI}}{\text{MISESAVG}} \right) \times 100$$

provides a percentage form of the Mises stress-based error indicator; however this normalized error measure may not be particularly useful, because it:

- will tend to draw attention to regions where base solution values are small, which typically are not critical regions of a design; and
- will have divide-by-zero issues where the base solution value is zero.

Other normalization approaches, such as normalizing based on a global norm of the base solution variable or a constant value that you choose (such as the maximum value of the base solution allowed in a design), may be more effective.

Normalized forms of an error indicator are not available directly through the error indicator output variables; however, you can calculate normalized measures using the Visualization module of Abaqus/CAE (Abaqus/Viewer) to operate on field output data. For more information, see "Building valid field output expressions," Section 42.7.1 of the Abaqus/CAE User's Guide. Alternatively, you can use the Abaqus Scripting Interface to read the error indicator and the base solution from the output database and calculate normalized forms. For more information, see Chapter 9, "Using the Abaqus Scripting Interface to access an output database," of the Abaqus Scripting User's Guide.

Limitations

Only the following element types are supported for error indicator computations:

- Planar continuum triangles and quadrilaterals
- Shell triangles and quadrilaterals
- Tetrahedrals
- Hexahedrals

Elements with variable nodes are not supported.

Additional reference

- Zienkiewicz, O. C., and J. Z. Zhu, "A Simple Error Estimator and Adaptive Procedure for Practical Engineering Analysis," International Journal for Numerical Methods in Engineering, vol. 24, pp. 337–357, 1987.

4.2 Output variables

4.2.1 Abaqus/Standard OUTPUT VARIABLE IDENTIFIERS

Product: Abaqus/Standard

References

- "Output," Section 4.1.1
- "Output to the data and results files," Section 4.1.2
- "Output to the output database," Section 4.1.3

Overview

The tables in this section list all of the output variables that are available in Abaqus/Standard. These output variables can be requested for output to the data (**.dat**) and results (**.fil**) files (see "Output to the data and results files," Section 4.1.2) or as either field- or history-type output to the output database (**.odb**) file (see "Output to the output database," Section 4.1.3). As noted specifically in the tables, a few of the output variables are written only to the output database and restart (**.res**) files (they are not available for output to the data or results files). These variables can be accessed only in the Visualization module of Abaqus/CAE (Abaqus/Viewer). Each table contains one variable type:

- Element integration point variables
- Element centroidal variables
- Element section variables
- Whole element variables
- Whole element energy density variables
- Nodal variables
- Modal variables
- Surface variables
- Cavity radiation variables
- Section variables
- Whole and partial model variables
- Solution-dependent amplitude variables
- Structural optimization variables

Symbols used in the tables

The availability of the various output variable identifiers is defined by a • in the columns of the table, under the following headings:

.dat

means that the identifier can be used as a data file output selection.

.fil

means that the identifier can be used as a results file output selection.

.odb Field

means that the identifier can be used as a field-type output selection to the output database.

.odb History

means that the identifier can be used as a history-type output selection to the output database.

The appearance of a ○ in the **.dat**, **.fil**, or **.odb** columns indicates that the variable cannot be requested by name but that it will be written to the data, results, or output database file according to the conditions specified in the table for that particular variable type.

Requesting output of components

Variable identifiers of the form *ABCn* can be used with $n = 1, 2, 3, \ldots$ (*ABC*1, *ABC*2, ...), where the highest value of *n* is determined by the type of variable. Similarly, variable identifiers of the form *DEFij* can be used for the ranges of *i* and *j* indicated (*DEF*11, *DEF*12, ...).

Individual components cannot be requested in the results (`.fil`) file. For postprocessing of a particular component of a variable, request file output for all components of the variable. Output for individual variables can be requested during postprocessing.

Individual components of variables can be requested as history-type output in the output database for *X*–*Y* plotting in Abaqus/CAE. Individual component requests to the output database are not available for field-type output, with the exception of state, field, and user-defined variables (SDV*n*, FV*n*, and UVARM*n*). If a particular component is desired for contouring in Abaqus/CAE, request field output of the generic variable (e.g., S for stress). Output for individual components of field output can be requested within the Visualization module of Abaqus/CAE.

Direction definitions

The direction definitions depend on the variable type.

Direction definitions for element variables

For components of stress, strain, and other tensor quantities 1, 2, and 3 refer to the directions in an orthogonal coordinate system. These directions are global directions for solid elements, surface directions for shell and membrane elements, and axial and transverse directions for beam elements. For finite-membrane-strain shell elements, membrane elements, and continuum elements associated with a local orientation (see "Orientations," Section 2.2.5), the local output directions rotate with the average rotation of the element (integral with respect to time of the spin—see "Stress rates," Section 1.5.3 of the Abaqus Theory Guide). Tensor components in these cases are output in the rotating local directions.

In some cases the local output directions may differ from one integration point to the next within an element. Abaqus/Standard does not take this variation into account when extrapolating output variables to the nodes, which affects output such as element quantities averaged at the nodes or contour plots of

individual tensor components. Invariant quantities at the integration points will not be influenced by the local output directions.

You can control writing the local directions to the output database file or to the results file (see "Specifying the directions for element output in Abaqus/Standard and Abaqus/Explicit" in "Output to the output database," Section 4.1.3, and "Output of local directions to the results file" in "Output to the data and results files," Section 4.1.2). By default, the local directions are written to the output database for all frames that include element field output. The local (material) directions (averaged at the nodes) can be visualized in Abaqus/CAE by selecting **Plot→Material Orientations** in the Visualization module. The directions can be printed to the data file by using user subroutine **UVARM**.

Direction definitions for equivalent rigid body variables

For all equivalent rigid body variables 1, 2, and 3 refer to global directions.

Direction definitions for nodal variables

For nodal variables 1, 2, and 3 are global directions (1=X, 2=Y, and 3=Z; or for axisymmetric elements, 1=r and 2=z). If a local coordinate system is defined at a node (see "Transformed coordinate systems," Section 2.1.5), you can specify whether output to the data or results file of vector-valued quantities at these nodes is in the local or global system (see "Specifying the directions for nodal output" in "Output to the data and results files," Section 4.1.2). By default, nodal output is written to the data file in the local system, whereas it is written to the results file in the global system (since this is more convenient for postprocessing).

If nodal field output is requested for a node that has a local coordinate system defined, a quaternion representing the rotation from the global directions is written to the output database. Abaqus/CAE automatically uses this quaternion to transform the nodal results into the local directions. Nodal history data written to the output database are always stored in the global directions.

Direction definitions for integrated variables

For components of total force, total moment, and similar variables obtained through integration over a surface, the directions 1, 2, and 3 refer to directions in an orthogonal coordinate system. A fixed global coordinate system is used if the surface is specified directly for the integrated output request. If the surface is identified by an integrated output section definition (see "Integrated output section definition," Section 2.5.1) that is associated with the integrated output request, a local coordinate system in the initial configuration can be specified and can translate or rotate with the deformation.

Distributed load output

You need to be aware of limitations that may be encountered when distributed load output is requested.

Distributed load output and user subroutines

Output can be requested for many of the distributed loads discussed in "Loads," Section 34.4. However, contributions to these loads defined through user subroutines (see "Abaqus/Standard subroutines,"

Section 1.1 of the Abaqus User Subroutines Reference Guide) are not displayed, except for the variables FILMCOEF and SINKTEMP.

Distributed load output with modal procedures

For modal procedures only the magnitude of the load is written to the output database.

Strain output

The total strain E is composed of the elastic strain EE, the inelastic strain IE, and the thermal strain THE. The inelastic strain IE consists of the plastic strain PE and the creep strain CE.

For geometrically nonlinear analysis Abaqus/Standard makes it possible to output different strain measures as well as elastic and various inelastic strains. The various total strain measures (integrated strain measure E, nominal strain measure NE, and logarithmic strain measure LE) are described in "Conventions," Section 1.2.2. The default strain measure for output to the data (`.dat`) and results (`.fil`) files is E. However, for geometrically nonlinear analysis using element formulations that support finite strains, E is not available for output to the output database (`.odb`) file, and LE is the default strain measure.

Temperature output

In Abaqus temperature can either be a field variable (stress analysis, mass diffusion, …) or a degree of freedom (heat transfer analysis, fully coupled temperature-displacement analysis, …). For any analysis that involves temperature, you can request the temperature either at nodes (variable NT) or in elements (variable TEMP). If element temperature output is requested at the nodes, the integration point values are extrapolated and, if requested, averaged. These extrapolated values are generally not as accurate as the nodal temperatures themselves. An exception to this is adiabatic analysis, in which the element temperatures change due to plastic heat generation but the nodal temperatures are not updated. In that case the current nodal temperatures are obtained only if element temperature output is requested at the nodes.

For continuum elements there is only one temperature value per node (NT11). For shells and beams more than one temperature is available for each node (NT11, NT12, …) since a temperature gradient can exist through the thickness of a shell or across the cross-section of a beam. In general, variables NT12, NT13, etc. contain temperature values. However, when temperature is defined by specifying temperature gradients, nodal temperatures for a given section point can be obtained only by using the variable TEMP. See "Specifying temperature and field variables" in "Using a beam section integrated during the analysis to define the section behavior," Section 29.3.6, and "Specifying temperature and field variables" in "Using a shell section integrated during the analysis to define the section behavior," Section 29.6.5, for discussions on specifying temperatures in beams and shells.

Principal value output

Output of the principal values can be requested for stresses, strains, and other material tensors. Either all principal values or the minimum, maximum, or intermediate values can be obtained. All principal

values of tensor *ABC* are obtained with the request *ABC*P. The minimum, intermediate, and maximum principal values are obtained with the requests *ABC*P1, *ABC*P2, and *ABC*P3.

For three-dimensional, (generalized) plane strain, and axisymmetric elements all three principal values are obtained. For plane stress, membrane, and shell elements, the out-of-plane principal value cannot be requested for history-type output. For field-type output, Abaqus/CAE always reports the out-of-plane principal value as zero. Principal values cannot be obtained for truss elements or for any beam elements other than the three-dimensional beam elements with torsional shear stresses.

If a principal value or an invariant is requested for field-type output, the output request is replaced with an output request for the components of the corresponding tensor. Abaqus/CAE calculates all principal values and invariants from these components. If a principal value is desired as history-type output, it must be explicitly requested since Abaqus/CAE does no calculations on history data.

Tensor output

Tensor variables that are written to the output database as field-type output are written as components in either the default directions defined by the convention given in "Orientations," Section 2.2.5 (global directions for solid elements, surface directions for shell and membrane elements, and axial and transverse directions for beam elements), or the user-defined local system. Abaqus/CAE calculates all principal values and invariants from these components. See "Writing field output data," Section 9.6.4 of the Abaqus Scripting User's Guide, for a description of the different types of tensor variables.

For plane stress, membrane, and shell elements, only the in-plane tensor components (11, 22, and 12 components) are stored by Abaqus/Standard. The out-of-plane direct component for stress (S33) is reported as zero to the output database as expected, and the out-of-plane component of strain (E33) is reported as zero even though it is not. This is because the thickness direction is computed based on section properties rather than at the material level. The out-of-plane components can be requested for field-type output and cannot be requested for history-type output. The out-of-plane stress components are not reported to the data (**.dat**) file or to the results (**.fil**) file.

For three-dimensional beam elements with torsional shear stresses, only the axial and the torsional components (the 11 and 12 components) are stored by Abaqus/Standard. The other direct component (the 22 component) is reported as zero for field-type output and cannot be requested for history-type output.

The components for tensor variables are written to the output database in single precision. Therefore, a small amount of precision roundoff error may occur when calculating the variables' principal values. Such roundoff error may be observed, for example, when analytically zero values are calculated as relatively small nonzero values.

Element integration point variables

You can request element integration point variable output to the data, results, or output database file (see "Element output" in "Output to the data and results files," Section 4.1.2, and "Element output" in "Output to the output database," Section 4.1.3).

Identifier	.dat	.fil	.odb Field	.odb History	Description
Tensors and associated principal values and invariants					
S	•	•	•	•	All stress components.
S*ij*	•			•	ij-component of stress ($i \le j \le 3$).
SP	•	•	•	•	All principal stresses.
SP*n*	•			•	Minimum, intermediate, and maximum principal stresses (SP1 $\le$ SP2 $\le$ SP3).
SINV	•	•	•	•	All stress invariant components (MISES, TRESC, PRESS, INV3). For field output SINV is converted to a request for the generic variable S.
MISES	•			•	Mises equivalent stress, defined as $q = \sqrt{\frac{3}{2}\mathbf{S} : \mathbf{S}}$, where $\mathbf{S}$ is the deviatoric stress tensor, defined as $\mathbf{S} = \boldsymbol{\sigma} + p\,\mathbf{I}$, where $\boldsymbol{\sigma}$ is the stress, p is the equivalent pressure stress (defined below), and $\mathbf{I}$ is a unit matrix. In index notation $q = \sqrt{\frac{3}{2}S_{ij}S_{ij}}$, where $S_{ij} = \sigma_{ij} + p\,\delta_{ij}$, $p = -\frac{1}{3}\sigma_{ii}$, and δ_{ij} is the Kronecker delta.
MISESMAX			•		Maximum Mises stress among all of the section points. For a shell element it represents the maximum Mises value among all the section points in the layer, for a beam element it is the maximum Mises stress among all the section points in the cross-section, and for a solid element it represents the Mises stress at the integration points.
MISESONLY			•		Mises equivalent stress. When MISESONLY is used instead of MISES, the stress components are not written to the output database; consequently, the size of the database is reduced.

Identifier	.dat	.fil	.odb Field	.odb History	Description
TRESC	•			•	Tresca equivalent stress, defined as the maximum difference between principal stresses.
PRESS	•			•	Equivalent pressure stress, defined as $p = -\frac{1}{3}\text{trace}(\boldsymbol{\sigma}) = -\frac{1}{3}\sigma_{ii}$.
PRESSONLY			•		Equivalent pressure stress. When PRESSONLY is used instead of PRESS, the stress components are not written to the output database; consequently, the size of the database is reduced.
INV3	•			•	Third stress invariant, defined as $r = \left(\frac{9}{2}\mathbf{S}\cdot\mathbf{S}:\mathbf{S}\right)^{1/3} = \left(\frac{9}{2}S_{ij}S_{jk}S_{ki}\right)^{1/3}$, where $\mathbf{S}$ is the deviatoric stress defined in the context of Mises equivalent stress, above.
TRIAX			•	•	Stress triaxiality, $\eta = -p/q$.
YIELDS			•	•	Yield stress, σ^0, available for Mises, Johnson-Cook, and Hill plasticity material models.
ALPHA	•	•	•	•	All total kinematic hardening shift tensor components.
ALPHA*ij*	•			•	ij-component of the total shift tensor ($i \le j \le 3$).
ALPHA*k*			•	•	All k^{th} kinematic hardening shift tensor components ($1 \le k \le 10$).
ALPHA*k_ij*				•	ij-component of the k^{th} kinematic hardening shift tensor ($i \le j \le 3$ and $1 \le k \le 10$).
ALPHAN			•	•	All tensor components of all the kinematic hardening shift tensors, except the total shift tensor, ALPHA.
ALPHAP	•	•	•	•	All principal values of the total shift tensor.
ALPHAP*n*	•			•	Minimum, intermediate, and maximum principal values of the total shift tensor (ALPHAP1 $\le$ ALPHAP2 $\le$ ALPHAP3).
E	•	•	•	•	All strain components. For geometrically nonlinear analysis using element formulations that support finite strains, E is not available for output to the output database (**.odb**) file.
E*ij*	•			•	ij-component of strain ($i \le j \le 3$).
EP	•	•	•	•	All principal strains.
EP*n*	•			•	Minimum, intermediate, and maximum principal strains (EP1 $\le$ EP2 $\le$ EP3).

Identifier	.dat	.fil	.odb		Description
			Field	History	
NE	•	•	•	•	All nominal strain components.
NE*ij*	•			•	ij-component of nominal strain ($i \leq j \leq 3$).
NEP	•	•	•	•	All principal nominal strains.
NEP*n*	•			•	Minimum, intermediate, and maximum principal nominal strains (NEP1 $\leq$ NEP2 $\leq$ NEP3).
LE	•	•	•	•	All logarithmic strain components. For geometrically nonlinear analysis using element formulations that support finite strains, LE is the default strain measure for output to the output database (**.odb**) file.
LE*ij*	•			•	ij-component of logarithmic strain ($i \leq j \leq 3$).
LEP	•	•	•	•	All principal logarithmic strains.
LEP*n*	•			•	Minimum, intermediate, and maximum principal logarithmic strains (LEP1 $\leq$ LEP2 $\leq$ LEP3).
ER	•	•	•	•	All mechanical strain rate components.
ER*ij*	•			•	ij-component of strain rate ($i \leq j \leq 3$).
ERP	•	•	•	•	All principal mechanical strain rates.
ERP*n*	•			•	Minimum, intermediate, and maximum principal mechanical strain rates (ERP1 $\leq$ ERP2 $\leq$ ERP3).
DG	•	•			All components of the total deformation gradient. Available only for hyperelasticity, hyperfoam, and material models defined in user subroutine **UMAT**. For fully integrated first-order quadrilaterals and hexahedra, the selectively reduced integration technique is used. A modified deformation gradient is output for these elements.
DG*ij*	•				ij-component of the total deformation gradient ($i, j \leq 3$).
DGP	•	•			Principal stretches.
DGP*n*	•				Minimum, intermediate, and maximum values of principal stretches (DGP1 $\leq$ DGP2 $\leq$ DGP3).
EE	•	•	•	•	All elastic strain components.
EE*ij*	•			•	ij-component of elastic strain ($i \leq j \leq 3$).
EEP	•	•	•	•	All principal elastic strains.
EEP*n*	•			•	Minimum, intermediate, and maximum principal elastic strains (EEP1 $\leq$ EEP2 $\leq$ EEP3).
IE	•	•	•	•	All inelastic strain components.

Identifier	.dat	.fil	.odb Field	.odb History	Description
IEij	•			•	ij-component of inelastic strain ($i \le j \le 3$).
IEP	•	•	•	•	All principal inelastic strains.
IEPn	•			•	Minimum, intermediate, and maximum principal inelastic strains (IEP1 $\le$ IEP2 $\le$ IEP3).
THE	•	•	•	•	All thermal strain components.
THEij	•			•	ij-component of thermal strain ($i \le j \le 3$).
THEP	•	•	•	•	All principal thermal strains.
THEPn	•			•	Minimum, intermediate, and maximum principal thermal strains (THEP1 $\le$ THEP2 $\le$ THEP3).
PE	•	•	•	•	All plastic strain components. This identifier also provides PEEQ, a yes/no flag telling if the material is currently yielding or not (AC YIELD: "actively yielding"; that is, the plastic strain changed during the increment), and PEMAG when PE is requested for the data or results files. When PE is requested for field output to the output database, PEEQ is also provided.
PEij	•			•	ij-component of plastic strain ($i \le j \le 3$).
PEEQ	•		•	•	Equivalent plastic strain. This identifier also provides a yes/no flag (1/0 on the output database) telling if the material is currently yielding or not (AC YIELD: "actively yielding"; that is, the plastic strain changed during the increment). The equivalent plastic strain is defined as $\bar{\varepsilon}^{pl}\|_0 + \int_0^t \dot{\bar{\varepsilon}}^{pl} dt$, where $\bar{\varepsilon}^{pl}\|_0$ is the initial equivalent plastic strain. The definition of $\dot{\bar{\varepsilon}}^{pl}$ depends on the material model. For classical metal (Mises) plasticity $\dot{\bar{\varepsilon}}^{pl} = \sqrt{\frac{2}{3}\dot{\boldsymbol{\varepsilon}}^{pl} : \dot{\boldsymbol{\varepsilon}}^{pl}}$. For other plasticity models, see the appropriate section in Part V, "Materials." When plasticity occurs in the thickness direction to a gasket element whose plastic behavior is specified as part of a gasket behavior definition, PEEQ is PE11.
PEEQMAX			•		Maximum equivalent plastic strain, PEEQ, among all of the section points. For a shell element it represents the maximumPEEQ value among all the section points in the layer, for a beam element it is the maximum

Identifier	.dat	.fil	.odb Field	.odb History	Description
					PEEQ among all the section points in the cross-section, and for a solid element it represents thePEEQ at the integration points.
PEEQT	•	•	•	•	Equivalent plastic strain in uniaxial tension for cast iron, Mohr-Coulomb tension cutoff, and concrete damaged plasticity, which is defined as $\int \dot{\tilde{\varepsilon}}_t^{pl} dt$. This identifier also provides a yes/no flag (1/0 on the output database) telling if the material is currently yielding or not (AC YIELDT: "actively yielding"; that is, the plastic strain changed during the increment).
PEMAG	•		•	•	Plastic strain magnitude, defined as $\sqrt{\frac{2}{3}\boldsymbol{\varepsilon}^{pl} : \boldsymbol{\varepsilon}^{pl}}$. For most materials, PEEQ and PEMAG are equal only for proportional loading. When plasticity occurs in the thickness direction to a gasket element whose plastic behavior is specified as part of a gasket behavior definition, PEMAG is PE11.
PEP	•	•	•	•	All principal plastic strains.
PEP*n*	•			•	Minimum, intermediate, and maximum principal plastic strains (PEP1 $\leq$ PEP2 $\leq$ PEP3).
CE	•	•	•	•	All creep strain components. This identifier also provides CEEQ, CESW, and CEMAG when CE is requested for the data or results files.
CE*ij*	•			•	ij-component of creep strain ($i \leq j \leq 3$).
CEEQ	•		•	•	Equivalent creep strain, defined as $\int_0^t \dot{\tilde{\varepsilon}}^{cr} dt$. The definition of $\dot{\tilde{\varepsilon}}^{cr}$ depends on the material model. For classical metal (Mises) creep $\dot{\tilde{\varepsilon}}^{cr} = \sqrt{\frac{2}{3}\dot{\boldsymbol{\varepsilon}}^{cr} : \dot{\boldsymbol{\varepsilon}}^{cr}}$. For other creep models, see the appropriate section in Part V, "Materials." When creep occurs in the thickness direction to a gasket element whose creep behavior is specified as part of a gasket behavior definition, CEEQ is CE11.
CESW	•		•	•	Magnitude of swelling strain. For cap creep CESW gives the equivalent creep strain produced by the consolidation creep mechanism,

Identifier	.dat	.fil	.odb Field	.odb History	Description
					defined as $\int \frac{\boldsymbol{\sigma}:d\boldsymbol{\varepsilon}^{cr}}{\bar{p}}$, where $\bar{p}$ is the equivalent creep pressure, $\bar{p} = (R^2\, q^2 + p\,(p - p_a))/G_c^{cr}$.
CEMAG	•		•	•	Magnitude of creep strain (defined by the same formula given above for PEMAG, applied to the creep strains).
CEP	•	•	•	•	All principal creep strains.
CEP*n*	•			•	Minimum, intermediate, and maximum principal creep strains (CEP1 $\leq$ CEP2 $\leq$ CEP3).
Additional element stresses					
CS11	•	•	•	•	Average contact pressure for link and three-dimensional line gasket elements. Available only if the gasket contact area is specified; see "Defining the contact area for average contact pressure output" in "Defining the gasket behavior directly using a gasket behavior model," Section 32.6.6.
TSHR	•	•	•	•	All transverse shear stress components. Available only for thick shell elements such as S3R, S4R, S8R, and S8RT. Contouring of this variable is supported in the Visualization module of Abaqus/CAE.
TSHR*i*3	•			•	$i3$-component of transverse shear stress ($i = 1, 2$). Available only for thick shell elements such as S3R, S4R, S8R, and S8RT.
CTSHR	•		•	•	Transverse shear stress components for stacked continuum shell elements. Available only for SC6R and SC8R elements. Contouring of this variable is supported in the Visualization module of Abaqus/CAE.
CTSHR*i*3	•			•	$i3$-component of transverse shear stress ($i = 1, 2$). Available only for SC6R and SC8R elements.
SS	•	•			All substresses. Available only for ITS elements.
SS*n*	•				*n*th substress ($n = 1, 2$). Available only for ITS elements.
Vibration and acoustic quantities					
INTEN			•	•	Vibration intensity. Available only for the steady-state dynamics procedure. For real-only steady-state

Identifier	.dat	.fil	.odb Field	.odb History	Description
					dynamics analyses, the intensity is a pure imaginary vector, but it is stored as real on the output database. Available for structural, solid, and acoustic elements and for rebar.
ACV			•	•	Acoustic particle velocity. Available only if the steady-state dynamic procedure is used, and available only for acoustic finite elements.
ACV*n*				•	Component *n* of the acoustic particle velocity vector (*n* = 1, 2, 3). Available only if the steady-state dynamic procedure is used, and available only for acoustic finite elements.
GRADP			•	•	Acoustic pressure gradient. Available only if the steady-state dynamic procedure is used, and available only for acoustic finite elements.
Energy densities					
ENER	•	•	•	•	All energy densities. None of the energy densities are available in mode-based procedures; a limited number of them are available for direct-solution steady-state dynamic and subspace-based steady-state dynamic analyses. In steady-state dynamics all energy quantities are net per-cycle values, unless otherwise noted (see "Energy balance," Section 1.5.5 of the Abaqus Theory Guide).
SENER	•		•	•	Elastic strain energy density (with respect to current volume). When the Mullins effect is modeled with hyperelastic materials, this quantity represents only the recoverable part of energy per unit volume. This is the only energy density available in the data file for eigenvalue extraction procedures; to obtain this quantity for eigenvalue extraction procedures in the results file or as field output in the output database, request ENER. In steady-state dynamic analysis this is the cyclic mean value.
PENER	•		•	•	Energy dissipated by rate-independent and rate-dependent plasticity, per unit volume. Not available for steady-state dynamic analysis.

Identifier	.dat	.fil	.odb		Description
			Field	History	
CENER	•		•	•	Energy dissipated by creep, swelling, and viscoelasticity, per unit volume. Not available for steady-state dynamic analysis.
VENER	•		•	•	Energy dissipated by viscous effects (except those from viscoelasticity and static dissipation), per unit volume.
EENER	•		•	•	Electrostatic energy density. Not available for steady-state dynamic analysis.
JENER	•		•	•	Electrical energy dissipated as a result of the flow of current, per unit volume. Not available for steady-state dynamic analysis.
DMENER	•		•	•	Energy dissipated by damage, per unit volume. Not available for steady-state dynamic analysis.
State, field, and user-defined output variables					
SDV	•	•	•	•	Solution-dependent state variables.
SDV*n*	•		•	•	Solution-dependent state variable *n*.
TEMP	•	•	•	•	Temperature.
FV	•	•	•	•	Predefined field variables, including those imported using the FV_i co-simulation field ID.
FV*n*	•		•	•	Predefined field variable *n*.
MFR	•	•	•	•	Predefined mass flow rates.
MFR*n*	•			•	Component *n* of predefined mass flow rate ($n = 1, 2, 3$).
UVARM	•	•	•	•	User-defined output variables.
UVARM*n*	•		•	•	User-defined output variable *n*.
Composite failure measures					
CFAILURE	•	•	•	•	All failure measure components.
MSTRS	•		•	•	Maximum stress theory failure measure.
TSAIH	•		•	•	Tsai-Hill theory failure measure.
TSAIW	•		•	•	Tsai-Wu theory failure measure.
AZZIT	•		•	•	Azzi-Tsai-Hill theory failure measure.
MSTRN	•		•	•	Maximum strain theory failure measure.

Identifier	.dat	.fil	.odb Field	.odb History	Description
Fluid link quantities					
MFL	•	•	•	•	Current value of the mass flow rate.
MFLT	•	•	•	•	Current value of the total mass flow.
Fracture mechanics quantities					
JK	•	•	•	•	*J*-integral, stress intensity factors. Available only for line spring elements. Output is in the following order for LS3S elements: *J*, *K*, J^{el}, and J^{pl}. Output is in the following order for LS6 elements: *J*, J^{el}, J^{pl}, K_I, K_{II}, and K_{III}.
Concrete cracking and additional plasticity					
CRACK	•	•			Unit normal to cracks in concrete.
CONF	•	•			Number of cracks at a concrete material point.
PEQC	•	•	•	•	All equivalent plastic strains when the model has more than one yield/failure surface.
PEQC*n*	•			•	*n*th equivalent plastic strain ($n = 1, 2, 3, 4$).

For jointed materials: PEQC provides equivalent plastic strains for all four possible systems (three joints - PEQC1, PEQC2, PEQC3, and bulk material - PEQC4). This identifier also provides a yes/no flag (1/0 on the output database) telling if each individual system is currently yielding or not (AC YIELD: "actively yielding"; that is, the plastic strain changed during the increment).

For cap plasticity: PEQC provides equivalent plastic strains for all three possible yield/failure surfaces (Drucker-Prager failure surface - PEQC1, cap surface - PEQC2, and transition surface - PEQC3) and the total volumetric inelastic strain (PEQC4). All identifiers also provide a yes/no flag (1/0 on the output database) telling whether the yield surface is currently active or not (AC YIELD: "actively yielding", that is, the plastic strain changed during the increment).

When PEQC is requested as output to the output database, the active yield flags for each component

Identifier	.dat	.fil	.odb Field	.odb History	Description
					are named AC YIELD1, AC YIELD2, etc. and take the value 1 or 0.
Concrete damaged plasticity					
DAMAGEC	•		•	•	Compressive damage variable, d_c.
DAMAGET	•		•	•	Tensile damage variable, d_t.
SDEG	•		•	•	Scalar stiffness degradation variable, d.
PEEQ	•	•	•	•	Equivalent plastic strain in uniaxial compression, which is defined as $\int \dot{\tilde{\varepsilon}}_c^{pl} dt$. This identifier also provides a yes/no flag (1/0 on the output database) telling if the material is currently undergoing compressive failure or not (AC YIELD: "actively yielding"; that is, the plastic strain changed during the increment).
Rebar quantities					
RBFOR	•	•	•	•	Force in rebar.
RBANG	•	•	•	•	Angle in degrees between rebar and the user-specified isoparametric direction. Available only for shell, membrane, and surface elements.
RBROT	•	•	•	•	Change in angle in degrees between rebar and the user-specified isoparametric direction. Available only for shell, membrane, and surface elements.
Heat transfer analysis					
HFL	•	•	•	•	Current magnitude and components of the heat flux per unit area vector. The integration points for these values are located at the Gauss points.
HFLM	•			•	Current magnitude of heat flux per unit area vector.
HFLn	•			•	Component n of the heat flux vector ($n = 1, 2, 3$).
Mass diffusion analysis					
CONC	•	•	•	•	Mass concentration.
ISOL	•	•	•	•	Amount of solute at an integration point, calculated as the product of the mass concentration (CONC) and the integration point volume (IVOL).

Identifier	.dat	.fil	.odb Field	.odb History	Description
MFL	•	•	•	•	Current magnitude and components of the concentration flux vector.
MFLM	•			•	Current magnitude of the concentration flux vector.
MFL*n*	•			•	Component *n* of the concentration flux vector ($n = 1, 2, 3$).
Elements with electrical potential degrees of freedom					
EPG	•	•	•	•	Current magnitude and components of the electrical potential gradient vector.
EPGM	•			•	Current magnitude of the electrical potential gradient vector.
EPG*n*	•			•	Component *n* of the electrical potential gradient vector ($n = 1, 2, 3$).
Piezoelectric analysis					
EFLX	•	•	•	•	Current magnitude and components of the electrical flux vector.
EFLXM	•			•	Current magnitude of the electrical flux vector.
EFLX*n*	•			•	Component *n* of the electrical flux vector ($n = 1, 2, 3$).
Coupled thermal-electrical elements					
ECD	•	•	•	•	Current magnitude and components of the electrical current density.
ECDM	•			•	Current magnitude of the electrical current density.
ECD*n*	•			•	Component *n* of the electrical current density vector ($n = 1, 2, 3$).
Cohesive elements					
MAXSCRT	•		•	•	Maximum nominal stress damage initiation criterion.
MAXECRT	•		•	•	Maximum nominal strain damage initiation criterion.
QUADSCRT	•		•	•	Quadratic nominal stress damage initiation criterion.
QUADECRT	•		•	•	Quadratic nominal strain damage initiation criterion.
DMICRT	•	•	•	•	All active components of the damage initiation criteria.
SDEG	•	•	•	•	Overall scalar stiffness degradation.
STATUS	•	•	•	•	Status of the element (the status of an element is 1.0 if the element is active, 0.0 if the element is not).

Identifier	.dat	.fil	.odb Field	.odb History	Description
Low-cycle fatigue analysis					
CYCLEINI			•	•	Number of cycles to initialize the damage at the material point.
SDEG	•	•	•	•	Overall scalar stiffness degradation.
STATUS	•	•	•	•	Status of the element (the status of an element is 1.0 if the element is active, 0.0 if the element is not).
Pore pressure analysis					
VOIDR	•	•	•	•	Void ratio.
POR	•	•	•	•	Pore pressure.
SAT	•	•	•	•	Saturation.
GELVR	•	•	•	•	Gel volume ratio.
FLUVR	•	•	•	•	Total fluid volume ratio.
FLVEL	•	•	•	•	Current magnitude and components of the pore fluid effective velocity vector.
FLVELM	•			•	Current magnitude of the pore fluid effective velocity vector.
FLVEL*n*	•			•	Component *n* of the pore fluid effective velocity vector ($n = 1, 2, 3$).
Pore pressure cohesive elements					
GFVR	•	•	•	•	Gap flow volume rate.
PFOPEN	•	•	•	•	Pore pressure fracture opening.
LEAKVRT	•	•	•	•	Leak-off flow rate at the top of the element.
LEAKVRB	•	•	•	•	Leak-off flow rate at the bottom of the element.
ALEAKVRT	•	•	•	•	Accumulated leak-off volume at the top of the element.
ALEAKVRB	•	•	•	•	Accumulated leak-off volume at the bottom of the element.
Porous metal plasticity quantities					
RD	•	•	•	•	Relative density.
VVF	•	•	•	•	Void volume fraction.
VVFG	•	•	•	•	Void volume fraction due to void growth.
VVFN	•	•	•	•	Void volume fraction due to void nucleation.

Identifier	.dat	.fil	.odb Field	.odb History	Description
Two-layer viscoplasticity quantities					
VS	•	•	•	•	Stress in the elastic-viscous network.
VS*ij*	•			•	ij-component of stress in the elastic-viscous network ($i \le j \le 3$).
PS	•	•	•	•	Stress in the elastic-plastic network.
PS*ij*	•			•	ij-component of stress in the elastic-plastic network ($i \le j \le 3$).
VE	•	•	•	•	Viscous strain in the elastic-viscous network.
VE*ij*	•			•	ij-component of viscous strain in the elastic-viscous network ($i \le j \le 3$).
PE	•	•	•	•	Plastic strain in the elastic-plastic network.
PE*ij*	•			•	ij-component of plastic strain in the elastic-plastic network ($i \le j \le 3$).
VEEQ	•		•	•	Equivalent viscous strain in the elastic-viscous network, defined as $\int_0^t \dot{\bar{\varepsilon}}^v dt$.
PEEQ	•		•	•	Equivalent plastic strain in the elastic-plastic network, defined as $\int_0^t \dot{\bar{\varepsilon}}^{pl} dt$.
Geometric quantities					
COORD	•	•	•	•	Coordinates of the integration point for solid elements and rebar. These are the current coordinates if the large-displacement formulation is being used.
IVOL	•	•	•	•	Integration point volume. Section point volume in the case of beams and shells. (Not available for eigenfrequency extraction, eigenvalue buckling prediction, complex eigenfrequency extraction, or linear dynamics procedures. Available only for continuum and structural elements not using general beam or shell section definitions.)
LOCALDIR*n*			○		Direction cosines of the local material directions for an anisotropic hyperelastic material model. This variable is output automatically if any other element field output is requested for an anisotropic hyperelastic material (see "Output" in "Anisotropic hyperelastic behavior," Section 22.5.3).

Identifier	.dat	.fil	.odb Field	.odb History	Description
Accuracy indicators					
SJP	•	•			Strain jumps at nodes.
Random response analysis					
The following variables (beginning with R) are available only for random response dynamic analysis:					
RS	•	•	•	•	Root mean square of all stress components.
RS*ij*	•			•	Root mean square of ij-component of stress ($i \leq j \leq 3$).
RMISES			•	•	Root mean square of Mises equivalent stress.
RE	•	•	•	•	Root mean square of all strain components.
RE*ij*	•			•	Root mean square of ij-component of strain ($i \leq j \leq 3$).
RCTF	•	•		•	RMS values of all components of connector total forces and moments.
RCTF*n*	•			•	RMS value of connector total force component *n* ($n = 1, 2, 3$).
RCTM*n*	•			•	RMS value of connector total moment component *n* ($n = 1, 2, 3$).
RCEF	•	•		•	RMS values of all components of connector elastic forces and moments.
RCEF*n*	•			•	RMS value of connector elastic force component *n* ($n = 1, 2, 3$).
RCEM*n*	•			•	RMS value of connector elastic moment component *n* ($n = 1, 2, 3$).
RCVF	•	•		•	RMS values of all components of connector viscous forces and moments.
RCVF*n*	•			•	RMS value of connector viscous force component *n* ($n = 1, 2, 3$).
RCVM*n*	•			•	RMS value of connector viscous moment component *n* ($n = 1, 2, 3$).
RCRF	•	•		•	RMS values of all components of connector reaction forces and moments.
RCRF*n*	•			•	RMS value of connector reaction force component *n* ($n = 1, 2, 3$).

Identifier	.dat	.fil	.odb Field	.odb History	Description
RCRM*n*	•			•	RMS value of connector reaction moment component *n* ($n = 1, 2, 3$).
RCSF	•	•		•	RMS values of all components of connector friction forces and moments.
RCSF*n*	•			•	RMS value of connector friction force component *n* ($n = 1, 2, 3$).
RCSM*n*	•			•	RMS value of connector friction moment component *n* ($n = 1, 2, 3$).
RCSFC	•			•	RMS value of connector friction force in the direction of the instantaneous slip direction. Available only if friction is defined in the slip direction.
RCU	•	•		•	RMS values of all components of connector relative displacements and rotations.
RCU*n*	•			•	RMS value of connector relative displacement in the *n*-direction ($n = 1, 2, 3$).
RCUR*n*	•			•	RMS value of connector relative rotation in the *n*-direction ($n = 1, 2, 3$).
RCCU	•	•		•	RMS values of all components of connector constitutive displacements and rotations.
RCCU*n*	•			•	RMS value of connector constitutive displacement in the *n*-direction ($n = 1, 2, 3$).
RCCUR*n*	•			•	RMS value of connector constitutive rotation in the *n*-direction ($n = 1, 2, 3$).
RCNF	•	•		•	RMS values of all components of connector friction-generating contact forces and moments.
RCNF*n*	•			•	RMS value of connector friction-generating contact force component *n* ($n = 1, 2, 3$).
RCNM*n*	•			•	RMS value of connector friction-generating contact moment component *n* ($n = 1, 2, 3$).
RCNFC	•			•	RMS values of connector friction-generating contact force components in the instantaneous slip direction. Available only if friction is defined in the slip direction.

Steady-state dynamic analysis

The following variables (beginning with P) are available only for steady-state (frequency domain) dynamic analysis. These variables include both the magnitude and phase angle for all components. Phase angles are given in degrees. In the data file there are two lines of output for each request. The

Identifier	.dat	.fil	.odb Field	.odb History	Description
first line contains the magnitude, and the second line (indicated by the SSD footnote) contains the phase angle. In the results file the magnitudes of all components are first, followed by the phase angles of all components.					
PHS	•	•			Magnitude and phase angle of all stress components.
PHS*ij*	•				Magnitude and phase angle of ij-component of stress ($i \le j \le 3$).
PHE	•	•			Magnitude and phase angle of all strain components.
PHE*ij*	•				Magnitude and phase angle of ij-component of strain ($i \le j \le 3$).
PHEPG	•	•			Magnitude and phase angles of the electrical potential gradient vector.
PHEPG*n*	•				Magnitude and phase angle of component *n* of the electrical potential gradient ($n = 1, 2, 3$).
PHEFL	•	•			Magnitude and phase angles of the electrical flux vector.
PHEFL*n*	•				Magnitude and phase angle of component *n* of the electrical flux vector ($n = 1, 2, 3$).
PHMFL	•	•			Magnitude and phase angle of mass flow rate. Available only for fluid link elements.
PHMFT	•	•			Magnitude and phase angle of total mass flow. Available only for fluid link elements.
PHCTF	•	•			Magnitude and phase of all components of connector total forces and moments.
PHCTF*n*	•				Magnitude and phase of connector total force component *n* ($n = 1, 2, 3$).
PHCTM*n*	•				Magnitude and phase of connector total moment component *n* ($n = 1, 2, 3$).
PHCEF	•	•			Magnitude and phase of all components of connector elastic forces and moments.
PHCEF*n*	•				Magnitude and phase of connector elastic force component *n* ($n = 1, 2, 3$).
PHCEM*n*	•				Magnitude and phase of connector elastic moment component *n* ($n = 1, 2, 3$).
PHCVF	•	•			Magnitude and phase of all components of connector viscous forces and moments.

Identifier	.dat	.fil	.odb Field	.odb History	Description
PHCVF*n*	•				Magnitude and phase of connector viscous force component *n* ($n = 1, 2, 3$).
PHCVM*n*	•				Magnitude and phase of connector viscous moment component *n* ($n = 1, 2, 3$).
PHCRF	•	•			Magnitude and phase of all components of connector reaction forces and moments.
PHCRF*n*	•				Magnitude and phase of connector reaction force component *n* ($n = 1, 2, 3$).
PHCRM*n*	•				Magnitude and phase of connector reaction moment component *n* ($n = 1, 2, 3$).
PHCSF	•	•			Magnitude and phase of all components of connector friction forces and moments.
PHCSF*n*	•				Magnitude and phase of connector friction force component *n* ($n = 1, 2, 3$).
PHCSM*n*	•				Magnitude and phase of connector friction moment component *n* ($n = 1, 2, 3$).
PHCSFC	•				Magnitude and phase of connector friction force in the direction of the instantaneous slip direction. Available only if friction is defined in the slip direction.
PHCU	•	•			Magnitude and phase of all components of connector relative displacements and rotations.
PHCU*n*	•				Magnitude and phase of connector relative displacement in the *n*-direction ($n = 1, 2, 3$).
PHCUR*n*	•				Magnitude and phase of connector relative rotation in the *n*-direction ($n = 1, 2, 3$).
PHCCU	•	•			Magnitude and phase of all components of connector constitutive displacements and rotations.
PHCCU*n*	•				Magnitude and phase of connector constitutive displacement in the *n*-direction ($n = 1, 2, 3$).
PHCCUR*n*	•				Magnitude and phase of connector constitutive rotation in the *n*-direction ($n = 1, 2, 3$).
PHCV	•	•			Magnitude and phase of all components of connector relative velocities.
PHCV*n*	•				Magnitude and phase of connector relative velocity in the *n*-direction ($n = 1, 2, 3$).
PHCVR*n*	•				Magnitude and phase of connector relative angular velocity in the *n*-direction ($n = 1, 2, 3$).

Identifier	.dat	.fil	.odb Field	.odb History	Description
PHCA	•	•			Magnitude and phase of all components of connector relative accelerations.
PHCA*n*	•				Magnitude and phase of connector relative acceleration in the *n*-direction ($n = 1, 2, 3$).
PHCAR*n*	•				Magnitude and phase of connector relative angular acceleration in the *n*-direction ($n = 1, 2, 3$).
PHCNF	•	•			Magnitude and phase of all components of connector friction-generating contact forces and moments.
PHCNF*n*	•				Magnitude and phase of connector friction-generating contact force component *n* ($n = 1, 2, 3$).
PHCNM*n*	•				Magnitude and phase of connector friction-generating contact moment component *n* ($n = 1, 2, 3$).
PHCNFC	•				Magnitude and phase of connector friction-generating contact force in the instantaneous slip direction. Available only if friction is defined in the slip direction.
PHCIVC	•	•			Magnitude and phase of connector instantaneous velocity in the slip direction. Available only if friction is defined in the slip direction.
Failure with progressive damage					
SDEG			•	•	Scalar stiffness degradation variable.
DMICRT			•	•	All active components of the damage initiation criteria.
DUCTCRT				•	Ductile damage initiation criterion.
SHRCRT				•	Shear damage initiation criterion.
FLDCRT				•	Forming limit diagram (FLD) damage initiation criterion.
FLSDCRT				•	Forming limit stress diagram (FLSD) damage initiation criterion.
MSFLDCRT				•	Müschenborn-Sonne forming limit stress diagram (MSFLD) damage initiation criterion.
ERPRATIO			•	•	Ratio of principal strain rates, α, used for the MSFLD damage initiation criterion.
SHRRATIO			•	•	Shear stress ratio, $\theta_s = (q + k_s p)/\tau_{\max}$, used for the shear damage initiation criterion.
Fiber-reinforced materials damage					
HSNFTCRT	•		•	•	Hashin's fiber tensile damage initiation criterion.

Identifier	.dat	.fil	.odb		Description
			Field	History	
HSNFCCRT	•		•	•	Hashin's fiber compressive damage initiation criterion.
HSNMTCRT	•		•	•	Hashin's matrix tensile damage initiation criterion.
HSNMCCRT	•		•	•	Hashin's matrix compressive damage initiation criterion.
DMICRT	•	•	•	•	All active components of the damage initiation criteria.
DAMAGEFT	•	•	•	•	Fiber tensile damage variable.
DAMAGEFC	•	•	•	•	Fiber compressive damage variable.
DAMAGEMT	•	•	•	•	Matrix tensile damage variable.
DAMAGEMC	•	•	•	•	Matrix compressive damage variable.
DAMAGESHR	•	•	•	•	Shear damage variable.
STATUS	•	•	•	•	Status of the element (the status of an element is 1.0 if the element is active, 0.0 if the element is not).

Element centroidal variables

For electromagnetic elements, the element output is at the centroid of the element instead of at the integration points. These variables are defined for electromagnetic elements in the element descriptions in Part VI, "Elements," and in "Eddy current analysis," Section 6.7.5, and "Magnetostatic analysis," Section 6.7.6.

Identifier	.dat	.fil	.odb		Description
			Field	History	
EMB			•	•	All components of the magnetic flux density vector.
EMH			•	•	All components of the magnetic field vector.
EME			•	•	All components of the electric field vector.
EMCD			•	•	All components of the eddy current vector in conducting regions.
EMCDA			•	•	Magnitude and components of the applied volume current density vector.
EMJH			•	•	Rate of Joule heat dissipation (amount of heat dissipated per unit volume per unit time) in conductor regions.
EMBF			•	•	Magnetic body force intensity (force per unit volume) vector in conductor regions.
EMBFC			•	•	Complex magnetic body force intensity (force per unit volume) vector in conductor regions in a time-harmonic eddy current analysis.

Element section variables

You can request element section variable output to the data, results, or output database file (see "Element output" in "Output to the data and results files," Section 4.1.2, and "Element output" in "Output to the output database," Section 4.1.3). These variables are available only for beam and shell elements with the exception of STH, which is also available for membrane elements. They are defined for particular elements in the element descriptions in Part VI, "Elements."

Identifier	.dat	.fil	.odb		Description
			Field	History	
SF	•	•	•	•	All section force and moment components.
SF*n*	•			•	Section force component n ($n = 1, 2, 3, 4, 5$ for conventional shells; $n = 1, 2, 3, 4, 5, 6$ for continuum shells; $n = 1, 2, 3$ for beams).
SM*n*	•			•	Section moment component n ($n = 1, 2, 3$).
BIMOM	•			•	Bimoment of beam cross-section. Available only for open-section beam elements.
ESF1	•	•	•	•	Effective axial force for beams and pipes subjected to pressure loading. Available for all stress/displacement procedure types except response spectrum and random response.
SSAVG	•	•	•		All average shell section stress components.
SSAVG*n*	•			•	Average shell section stress component n ($n = 1, 2, 3, 4, 5, 6$).
SE	•	•	•	•	All section strain, curvature change, and twist components.
SE*n*	•			•	Section strain component n ($n = 1, 2, 3, 4, 5, 6$ for shells; $n = 1, 2, 3$ for beams).
SK*n*	•			•	Section curvature change or twist n ($n = 1, 2, 3$).
BICURV	•			•	Bicurvature of beam cross-section. Available only for open-section beam elements.
MAXSS	•	•			Maximum axial stress on the section. (This variable can be used with the following types of general beam section definitions: standard library cross-sections, linear generalized cross-sections, or meshed cross-sections with specified output section points. If the output section points are specified, the MAXSS output will be the maximum of the stresses at the user-specified points.)

Identifier	.dat	.fil	.odb Field	.odb History	Description
COORD	•	•	•	•	Coordinates of the section point. These are the current coordinates if the large-displacement formulation is being used.
STH	•	•	•	•	Section thickness (current thickness for SAX1, SAX2, SAX2T, S3/S3R, S4, S4R, SAXA1*N*, SAXA2*N*, and all membrane elements if the large-displacement formulation is used; initial thickness for all other cases).
SVOL	•	•	•	•	Integrated section volume. (Not available for eigenfrequency extraction, eigenvalue buckling prediction, complex eigenfrequency extraction, or linear dynamics procedures. Available only for continuum and structural elements not using general beam or shell section definitions.)
SPE	•	•	•	•	All generalized plastic strain components. Available only for inelastic nonlinear response in a general beam section.
SPE*n*	•			•	Generalized plastic strain component n ($n = 1, 2, 3, 4$). Representing axial plastic strain, curvature change about the local 1-axis, curvature change about the local 2-axis, and twist of the beam. Available only for inelastic nonlinear response in a general beam section.
SEPE	•	•	•	•	All equivalent plastic strains. Available only for inelastic nonlinear response in a general beam section.
SEPE*n*	•			•	Equivalent plastic strain component n ($n = 1, 2, 3, 4$). Representing axial plastic strain, curvature change about the local 1-axis, curvature change about the local 2-axis, and twist of the beam. Available only for inelastic nonlinear response in a general beam section.
Frame elements					
SEE	•	•	•	•	All elastic section axial, curvature, and twist strain components.
SEE1	•			•	Elastic axial strain component.
SKE*n*	•			•	Elastic section curvature or twist strain component ($n = 1, 2, 3$).

Identifier	.dat	.fil	.odb Field	.odb History	Description
SEP	•	•	•	•	All plastic axial displacements and rotations at the element's ends. This identifier also provides a yes/no flag telling if the frame element's end section is currently yielding or not (AC YIELD: "actively yielding"; that is, the plastic strain changed during the increment) and a yes/no/na flag telling if buckling occurred in the strut response (AC BUCKL) or is not applicable. AC YIELD and AC BUCKL are not available in the output database.
SEP1	•			•	Plastic axial displacement at the element's ends.
SKP*n*	•			•	Plastic rotations, either bending or twisting, at the element's ends ($n = 1, 2, 3$).
SALPHA	•	•	•	•	All generalized backstress components at the element's ends.
SALPHA*n*	•			•	Generalized backstress at the element's ends ($n = 1, 2, 3, 4$). The first component is the axial section backstress, followed by two bending backstress components and the twist backstress component.

Whole element variables

You can request whole element variable output to the data, results, or output database file (see "Element output" in "Output to the data and results files," Section 4.1.2, and "Element output" in "Output to the output database," Section 4.1.3).

Identifier	.dat	.fil	.odb Field	.odb History	Description
LOADS	•	•			Current values of distributed loads (not available for nonuniform loads).
FOUND	•	•			Current values of foundation pressures.
FLUXS	•	•	•		Current values of distributed (heat or concentration) fluxes (not available for nonuniform fluxes), including those imported using the HFL co-simulation field ID.
CHRGS	•	•			Current values of distributed electrical charges.
ECURS	•	•			Current values of distributed electrical currents.
ELEN	•	•	•	•	All energy magnitudes in the element. None of the energies are available in mode-based

Identifier	.dat	.fil	.odb		Description
			Field	History	
					procedures; a limited number of them are available for direct-solution steady-state dynamic and subspace-based steady-state dynamic analyses. In steady-state dynamics all energy quantities are net per-cycle values, unless otherwise noted.
ELKE	•		•	•	Total kinetic energy in the element. In steady-state dynamic analysis this is the cyclic mean value.
ELSE	•		•	•	Total elastic strain energy in the element. When the Mullins effect is modeled with hyperelastic materials, this quantity represents only the recoverable part of energy in the element. This is the only energy request available in the data file for eigenvalue extraction procedures; to obtain this quantity for eigenvalue extraction procedures in the results file or as field output in the output database, request ELEN. In steady-state dynamic analysis this is the cyclic mean value.
ELPD	•		•	•	Total energy dissipated in the element by rate-independent and rate-dependent plastic deformation. Not available for steady-state dynamic analysis.
ELCD	•		•	•	Total energy dissipated in the element by creep, swelling, and viscoelasticity. Not available for steady-state dynamic analysis.
ELVD	•		•	•	Total energy dissipated in the element by viscous effects, not including energy dissipated by static stabilization or viscoelasticity.
ELSD	•		•	•	Total energy dissipated in the element resulting from automatic static stabilization. Not available for steady-state dynamic analysis.
ELCTE	•		•	•	Total electrostatic energy in the element. Not available for steady-state dynamic analysis.
ELJD	•		•	•	Total electrical energy dissipated due to flow of current. Not available for steady-state dynamic analysis.
ELASE	•		•	•	Total “artificial” strain energy in the element (energy associated with constraints used to remove singular modes, such as hourglass control, and with constraints used to make the drill rotation follow the in-plane

Identifier	.dat	.fil	.odb Field	.odb History	Description
					rotation of the shell element). Not available for steady-state dynamic analysis.
ELDMD	•		•	•	Total energy dissipated in the element by damage. Not available for steady-state dynamic analysis.
NFORC	•	•	•	•	Forces at the nodes of an element from both the hourglass and the regular deformation modes of that element (negative of the internal forces in the global coordinate system). The specified position in data and results file requests is ignored.
NFORCSO			•	•	Forces at the nodes of a beam element caused by the stress resultants in the element (internal forces in the beam section orientation coordinate system).
GRAV			•		Uniformly distributed gravity load.
BF			•		Uniformly distributed body force.
CORIOMAG			•		Magnitude of Coriolis load.
ROTAMAG			•		Magnitude of rotary acceleration load.
CENTMAG			•		Magnitude of centrifugal load (measured as $\rho\omega^2$, where ρ is the mass density per unit volume and ω is the angular velocity).
CENTRIFMAG			•		Magnitude of centrifugal load (measured as ω^2, where ω is the angular velocity).
HBF			•		Heat body flux.
NFLUX	•	•	•	•	Fluxes at the nodes of the element caused by the heat conduction or mass diffusion in the element (internal fluxes). (The specified position for data and output database file requests is ignored.)
NFL*n*	•			•	Flux *n* at the nodes of the element ($n = 11, 12, \ldots$) caused by the heat conduction or mass diffusion in the element (internal fluxes). (The specified position for data and output database file requests is ignored.)
NCURS	•	•	•	•	Electrical current at the nodes due to electrical conduction in the element.
FILM	•	•			Current values of film conditions (not available for nonuniform films).
RAD	•	•			Current values of radiation conditions.
EVOL	•	•	•	•	Current element volume. (Not available for eigenfrequency extraction, eigenvalue buckling

Identifier	.dat	.fil	.odb Field	.odb History	Description
					prediction, complex eigenfrequency extraction, or linear dynamics procedures. Available only for continuum and structural elements not using general beam or shell section definitions.)
ESOL	•	•	•	•	Amount of solute in an element, calculated as the sum of ISOL (amount of solute at an integration point) over all the integration points in the element.
Enriched elements					
STATUSXFEM			•	•	Status of the enriched element. (The status of an enriched element is 1.0 if the element is completely cracked; 0.0 if the element is not. If the element is partially cracked, the value lies between 1.0 and 0.0.)
LOADSXFEM			•	•	Distributed pressure loads applied to the XFEM-based crack surface.
Enriched elements when the XFEM-based LEFM approach is used					
ENRRTXFEM			•	•	All components of strain energy release rate.
Enriched elements in low-cycle fatigue analysis					
CYCLEINIXFEM			•	•	Number of cycles to initialize the crack at the enriched element.
Connector elements					
CTF	•	•	•	•	All components of connector total forces and moments.
CTF*n*	•			•	Connector total force component *n* ($n = 1, 2, 3$).
CTM*n*	•			•	Connector total moment component *n* ($n = 1, 2, 3$).
CEF	•	•	•	•	All components of connector elastic forces and moments.
CEF*n*	•			•	Connector elastic force component *n* ($n = 1, 2, 3$).
CEM*n*	•			•	Connector elastic moment component *n* ($n = 1, 2, 3$).
CUE	•	•	•	•	Elastic displacements and rotations in all directions.
CUE*n*	•			•	Elastic displacement in the *n*-direction ($n = 1, 2, 3$).
CURE*n*	•			•	Elastic rotation in the *n*-direction ($n = 1, 2, 3$).
CUP	•	•	•	•	Plastic relative displacements and rotations in all directions.

Identifier	.dat	.fil	.odb		Description
			Field	History	
CUP*n*	•			•	Plastic relative displacement in the *n*-direction ($n = 1, 2, 3$).
CURP*n*	•			•	Plastic relative rotation in the *n*-direction ($n = 1, 2, 3$).
CUPEQ	•	•		•	Equivalent plastic relative displacements and rotations in all directions.
CUPEQ*n*	•			•	Equivalent plastic relative displacement in the *n*-direction ($n = 1, 2, 3$).
CURPEQ*n*	•			•	Equivalent plastic relative rotation in the *n*-direction ($n = 1, 2, 3$).
CUPEQC	•			•	Equivalent plastic relative motion for a coupled plasticity definition.
CALPHAF	•	•		•	All components of connector kinematic hardening shift forces and moments.
CALPHAF*n*	•			•	Connector kinematic hardening shift force component *n* ($n = 1, 2, 3$).
CALPHAM*n*	•			•	Connector kinematic hardening shift moment component *n* ($n = 1, 2, 3$).
CVF	•	•		•	All components of connector viscous forces and moments.
CVF*n*	•			•	Connector viscous force component *n* ($n = 1, 2, 3$).
CVM*n*	•			•	Connector viscous moment component *n* ($n = 1, 2, 3$).
CSF	•	•		•	All components of connector friction forces and moments.
CSF*n*	•			•	Connector friction force component *n* ($n = 1, 2, 3$).
CSM*n*	•			•	Connector friction moment component *n* ($n = 1, 2, 3$).
CSFC	•			•	Connector friction force in the instantaneous slip direction. Available only if friction is defined in the slip direction.
CNF	•	•		•	All components of connector friction-generating contact forces and moments.
CNF*n*	•			•	Connector friction-generating contact force component *n* ($n = 1, 2, 3$).
CNM*n*	•			•	Connector friction-generating contact moment component *n* ($n = 1, 2, 3$).

Identifier	.dat	.fil	.odb Field	.odb History	Description
CNFC	•			•	Connector friction-generating contact force in the instantaneous slip direction. Available only if friction is defined in the slip direction.
CDMG	•	•		•	All components of the overall damage variable.
CDMG*n*	•			•	Overall damage variable component *n* ($n = 1, 2, 3$).
CDMGR*n*	•			•	Overall damage variable component *n* ($n = 1, 2, 3$).
CDIF	•	•		•	Components of connector force-based damage initiation criterion in all directions.
CDIF*n*	•			•	Connector force-based damage initiation criterion in the *n*-translation direction ($n = 1, 2, 3$).
CDIFR*n*	•			•	Connector force-based damage initiation criterion in the *n*-rotation direction ($n = 1, 2, 3$).
CDIFC	•			•	Connector force-based damage initiation criterion in the instantaneous slip direction.
CDIM	•	•		•	Components of connector motion-based damage initiation criterion in all directions.
CDIM*n*	•			•	Connector motion-based damage initiation criterion in the *n*-translation direction ($n = 1, 2, 3$).
CDIMR*n*	•			•	Connector motion-based damage initiation criterion in the *n*-rotation direction ($n = 1, 2, 3$).
CDIMC	•			•	Connector motion-based damage initiation criterion in the instantaneous slip direction.
CDIP	•	•		•	Components of connector plastic motion-based damage initiation criterion in all directions.
CDIP*n*	•			•	Connector plastic motion-based damage initiation criterion in the *n*-translation direction ($n = 1, 2, 3$).
CDIPR*n*	•			•	Connector plastic motion-based damage initiation criterion in the *n*-rotation direction ($n = 1, 2, 3$).
CDIPC	•			•	Connector plastic motion-based damage initiation criterion in the instantaneous slip direction.
CSLST	•	•		•	All flags for connector stop and connector lock status.
CSLST*i*	•			•	Flag for connector stop and connector lock status in the *i*-direction ($i = 1, ..., 6$).
CASU	•	•		•	Components of accumulated slip in all directions.
CASU*n*	•			•	Connector accumulated slip in the *n*-direction ($n = 1, 2, 3$).

Identifier	.dat	.fil	.odb Field	.odb History	Description
CASUR*n*	•			•	Connector angular accumulated slip in the *n*-direction ($n = 1, 2, 3$).
CASUC	•			•	Connector accumulated slip in the instantaneous slip direction. Available only if friction is defined in the slip direction.
CIVC	•	•		•	Connector instantaneous velocity in the slip direction. Available only if friction is defined in the slip direction.
CRF	•	•		•	All components of connector reaction forces and moments.
CRF*n*	•			•	Connector reaction force component *n* ($n = 1, 2, 3$).
CRM*n*	•			•	Connector reaction moment component *n* ($n = 1, 2, 3$).
CCF	•	•		•	All components of connector concentrated forces and moments.
CCF*n*	•			•	Connector concentrated force component *n* ($n = 1, 2, 3$).
CCM*n*	•			•	Connector concentrated moment component *n* ($n = 1, 2, 3$).
CP	•	•		•	Relative positions in all directions.
CP*n*	•			•	Relative position in the *n*-direction ($n = 1, 2, 3$).
CPR*n*	•			•	Relative angular position in the *n*-direction ($n = 1, 2, 3$).
CU	•	•	•	•	Relative displacements and rotations in all directions.
CU*n*	•			•	Relative displacement in the *n*-direction ($n = 1, 2, 3$).
CUR*n*	•			•	Relative rotation in the *n*-direction ($n = 1, 2, 3$).
CCU	•	•		•	Constitutive displacements and rotations in all directions.
CCU*n*	•			•	Constitutive displacement in the *n*-direction ($n = 1, 2, 3$).
CCUR*n*	•			•	Constitutive rotation in the *n*-direction ($n = 1, 2, 3$).
CV	•	•		•	Relative velocities in all directions.
CV*n*	•			•	Relative velocity in the *n*-direction ($n = 1, 2, 3$).
CVR*n*	•			•	Relative angular velocity in the *n*-direction ($n = 1, 2, 3$).
CA	•	•		•	Relative accelerations in all directions.
CA*n*	•			•	Relative acceleration in the *n*-direction ($n = 1, 2, 3$).

Identifier	.dat	.fil	.odb		Description
			Field	History	
CAR*n*	•			•	Relative angular acceleration in the *n*-direction ($n = 1, 2, 3$).
CFAILST	•	•		•	All flags for connector failure status.
CFAILST*i*	•			•	Flag for connector failure status in the *i*-direction ($i = 1, ..., 6$).

Element face variables

You can request element face variable output to the output database (see "Element output" in "Output to the output database," Section 4.1.3). These variables are available only for shell, membrane, and solid elements.

Identifier	.dat	.fil	.odb		Description
			Field	History	
P			•		Uniformly distributed pressure load on element faces, including those imported using the PRESS co-simulation field ID. When the pressure is defined using *DLOAD, the variable name is changed automatically to PDLOAD. When the pressure is defined using *DLOAD on shell or membrane elements, Abaqus changes the sign of its value to make it consistent with the pressure defined using *DSLOAD.
HP			•		Hydrostatic pressure load on element faces. When the pressure is defined using *DLOAD, the variable name is changed automatically to HPDLOAD. When the pressure is defined using *DLOAD on shell or membrane elements, Abaqus changes the sign of its value to make it consistent with the pressure defined using *DSLOAD.
TRNOR			•		Normal component (component along face normal) of traction load on element faces.
TRSHR			•		Shear component (component along face tangent) of traction load on element faces.
FLUXS			•		Uniformly distributed heat fluxes on element faces.
FILMCOEF			•		Reference film coefficient value on element faces.
SINKTEMP			•		Reference sink temperature on element faces.

Whole element energy density variables

The following energy density output variables are written to the restart (**.res**) file and the output database (**.odb**) file (see "Energy balance," Section 1.5.5 of the Abaqus Theory Guide):

Identifier	.dat	.fil	.odb Field	.odb History	Description
ELEDEN			•		All energy density components. None of the energies are available in mode-based procedures; a limited number of them are available for direct-solution steady-state dynamic and subspace-based steady-state dynamic analyses. In steady-state dynamics all energy quantities are net per-cycle values, unless otherwise noted.
EKEDEN			•	•	Kinetic energy density in the element. In steady-state dynamic analysis this is the cyclic mean value.
ESEDEN			•	•	Total elastic strain energy density in the element. When the Mullins effect is modeled with hyperelastic materials, this quantity represents only the recoverable part of energy density in the element. This variable is not available in eigenvalue extraction procedures. In steady-state dynamic analysis this is the cyclic mean value.
EPDDEN			•	•	Total energy dissipated per unit volume in the element by rate-independent and rate-dependent plastic deformation. Not available for steady-state dynamic analysis.
ECDDEN			•	•	Total energy dissipated per unit volume in the element by creep, swelling, and viscoelasticity. Not available for steady-state dynamic analysis.
EVDDEN			•	•	Total energy dissipated per unit volume in the element by viscous effects, not inclusive of energy dissipated through static stabilization or viscoelasticity.
ESDDEN			•	•	Total energy dissipated per unit volume in the element resulting from static stabilization. Not available for steady-state dynamic analysis.
ECTEDEN			•	•	Total electrostatic energy density in the element. Not available for steady-state dynamic analysis.
EASEDEN			•	•	Total "artificial" strain energy density in the element (energy associated with constraints used to remove

Identifier	.dat	.fil	.odb Field	.odb History	Description
					singular modes, such as hourglass control, and with constraints used to make the drill rotation follow the in-plane rotation of the shell element). Not available for steady-state dynamic analysis.
EDMDDEN			•	•	Total energy dissipated per unit volume in the element by damage. Not available for steady-state dynamic analysis.

Whole element error indicator variables

You can request that the following error indicator variables and element average variables be output only to the output database (**.odb**) file (see "Selection of error indicators influencing adaptive remeshing," Section 12.3.2).

Identifier	.dat	.fil	.odb Field	.odb History	Description
ENDEN			•		Element energy density, including plastic dissipation and creep dissipation if present.
ENDENERI			•		Element energy density error indicator, including plastic dissipation error and creep dissipation error if present.
MISESAVG			•		Element average Mises equivalent stress.
MISESERI			•		Element Mises equivalent stress error indicator.
PEEQAVG			•		Element average equivalent plastic strain.
PEEQERI			•		Element equivalent plastic strain error indicator.
PEAVG			•		Element average plastic strain.
PEERI			•		Element plastic strain error indicator.
CEAVG			•		Element average creep strain.
CEERI			•		Element creep strain error indicator.
HFLAVG			•		Element average heat flux.
HFLERI			•		Element heat flux error indicator.
EFLAVG			•		Element average electric flux.
EFLERI			•		Element electric flux error indicator.
EPGAVG			•		Element average electric potential gradient.
EPGERI			•		Element electric potential gradient error indicator.

Nodal variables

You can request nodal variable output to the data, results, or output database file (see "Node output" in "Output to the data and results files," Section 4.1.2, and "Node output" in "Output to the output database," Section 4.1.3).

Identifier	.dat	.fil	.odb		Description
			Field	History	
U	•	•	•	•	All physical displacement components, including rotations at nodes with rotational degrees of freedom (for output to the output database, only field-type output includes the rotations).
UT			•	•	All translational displacement components.
UR			•	•	All rotational displacement components.
U*n*	•			•	u_n displacement component ($n = 1, 2, 3$).
UR*n*	•			•	ϕ_n rotation component ($n = 1, 2, 3$).
WARP	•			•	Warping magnitude. Available only for open-section beam elements.
V	•	•	•	•	All velocity components, including rotational velocities at nodes with rotational degrees of freedom (for output to the output database, only field-type output includes the rotational velocities).
VT			•	•	All translational velocity components.
VR			•	•	All rotational velocity components.
V*n*	•			•	$\dot{u}_n$ velocity component ($n = 1, 2, 3$).
VR*n*	•			•	$\dot{\phi}_n$ rotational velocity component ($n = 1, 2, 3$).
A	•	•	•	•	All acceleration components, including rotational accelerations at nodes with rotational degrees of freedom (for output to the output database, only field-type output includes the rotational accelerations).
AT			•	•	All translational acceleration components.
AR			•	•	All rotational acceleration components.
A*n*	•			•	$\ddot{u}_n$ acceleration component ($n = 1, 2, 3$).
AR*n*	•			•	$\ddot{\phi}_n$ rotational acceleration component ($n = 1, 2, 3$).
POR	•	•	•	•	Pore or acoustic pressure at a node.
CFF	•	•	•	•	Concentrated fluid flow at a node, including those imported using the CFLOW co-simulation field ID.
NT	•	•	•	•	All temperature values at a node, including those imported using the TEMP co-simulation field ID.

Identifier	.dat	.fil	.odb Field	.odb History	Description
					These will be the temperatures defined as degrees of freedom if heat transfer elements are connected to the node, or predefined temperatures if the node is connected only to stress or mass diffusion elements without temperature degrees of freedom.
NT*n*	•			•	Temperature degree of freedom *n* at a node ($n = 11, 12, \ldots$).
EPOT	•	•	•	•	All electrical potential degrees of freedom at a node.
NNC	•	•	•	•	All normalized concentration values at a node.
NNC*n*	•			•	Normalized concentration degree of freedom *n* at a node ($n = 11$).
RF	•	•	•	•	All components of reaction forces, including components of reaction moments at nodes with rotational degrees of freedom (conjugate to prescribed displacements and rotations). For output to the output database, only the field-type output includes the components of reaction moments at nodes with rotational degrees of freedom.
RT			•	•	All reaction force components.
RM			•	•	All reaction moment components.
RF*n*	•			•	Reaction force component *n* ($n = 1, 2, 3$) (conjugate to prescribed displacement u_n).
RM*n*	•			•	Reaction moment component *n* ($n = 1, 2, 3$) (conjugate to prescribed rotation ϕ_n).
RWM	•			•	Reaction bimoment in degree of freedom 7, conjugate to prescribed warping amplitude. Available only for open-section beam elements.
CF	•	•	•	•	All components of point loads and concentrated moments, including loads imported using the CF co-simulation field ID.
CF*n*	•			•	Point load component *n* ($n = 1, 2, 3$).
CM*n*	•			•	Point moment component *n* ($n = 1, 2, 3$).
CW	•			•	Load component in degree of freedom 7. Available only for open-section beam elements.
TF	•	•	•	•	All components of total forces, including components of total moments at nodes with rotational degrees of freedom. Total force is the sum of the reaction force

Identifier	.dat	.fil	.odb Field	.odb History	Description
					and point loads. For output to the output database, only the field-type output includes the components of total moments at nodes with rotational degrees of freedom.
TF*n*	•			•	Total force component *n* ($n = 1, 2, 3$).
TM*n*	•			•	Total moment component *n* ($n = 1, 2, 3$).
VF	•	•	•	•	All components of viscous forces and moments due to static stabilization.
VF*n*	•			•	Stabilization viscous force component *n* ($n = 1, 2, 3$).
VM*n*	•			•	Stabilization viscous moment component *n* ($n = 1, 2, 3$).
COORD	•	•	•	•	Coordinates of the node. These are the current coordinates if the large-displacement formulation is being used.
COOR*n*	•			•	Coordinate *n* ($n = 1, 2, 3$).
STRAINFREE			•		Strain-free adjustments to initial nodal positions (adjusted position minus unadjusted position; only written to the output database (.**odb**) file for the original field output frame at zero time).
RCHG	•	•	•	•	Reactive electrical nodal charge (conjugate to prescribed electrical potential).
CECHG	•	•	•	•	Concentrated electrical nodal charge.
RECUR	•	•	•	•	Reactive electrical nodal current (conjugate to prescribed electrical potential).
CECUR	•	•	•	•	Concentrated electrical nodal current.
PCAV	•	•		•	Hydrostatic fluid gauge pressure (total pressure = ambient pressure + hydrostatic fluid gauge pressure).
CVOL	•	•		•	Hydrostatic fluid cavity volume.
MOT	•	•	•	•	All components of motion in cavity radiation heat transfer analysis.
MOT*n*	•			•	m_n motion component ($n = 1, 2, 3$) in cavity radiation heat transfer analysis.
Acoustic quantities					
POR	•	•	•	•	Acoustic pressure.
INFR			•		Acoustic infinite element “radius,” used in the coordinate map for these elements. Available only if the steady-state dynamic procedure is used, and

Identifier	.dat	.fil	.odb Field	.odb History	Description
					available only for nodes attached to acoustic infinite elements.
INFC			•		Acoustic infinite element "cosine," used in the coordinate map for these elements. Available only if the steady-state dynamic procedure is used, and available only for nodes attached to acoustic infinite elements.
INFN			•		Acoustic infinite element normal vector. Available only if the steady-state dynamic procedure is used, and available only for nodes attached to acoustic infinite elements.
PINF			•		Acoustic pressure coefficients for the higher-order basis functions in acoustic infinite elements. Available only if the steady-state dynamic procedure is used, and available only for acoustic infinite elements.
SPL			•	•	Acoustic sound pressure level at a node.
Enriched element quantities					
PHILSM			•	•	Signed distance function to describe the crack surface.
PSILSM			•	•	Signed distance function to describe the initial crack front.
Heat or mass flux					
The following variables correspond to heat flux in temperature analyses or concentration volumetric flux in mass diffusion analysis:					
RFL	•	•	•	•	All reaction flux values (conjugate to prescribed temperature or normalized concentration).
RFL*n*	•			•	Reaction flux value *n* at a node ($n = 11, 12, \ldots$) (conjugate to prescribed temperature or normalized concentration).
CFL	•	•	•	•	All concentrated flux values, including those imported using the CFL co-simulation field ID.
CFL*n*	•			•	Concentrated flux values *n* at a node ($n = 11, 12, \ldots$).
RFLE	•	•	•	•	The total flux at the node (including flux convected through the node in convection elements), excluding external fluxes (due to concentrated fluxes, distributed fluxes, film conditions, radiation conditions, and

Identifier	.dat	.fil	.odb Field	.odb History	Description
					radiation viewfactors). The value of RFLE is, thus, equal and opposite to the sum of all applied fluxes.
RFLE*n*	•		•		Flux value *n* excluding externally applied flux loads at a node ($n = 11, 12, \ldots$).

Steady-state dynamic analysis

The following variables are available only for steady-state (frequency domain) dynamic analyses (modal and direct). These variables include both magnitude and phase angle for all components. Phase angles are given in degrees. In the data file there are two lines of output for each request. The first line contains the magnitude, and the second line (indicated by the SSD footnote) contains the phase angle. In the results file, the magnitudes of all components are first, followed by the phase angles of all components.

PU	•	•			Magnitude and phase angle of all displacement components at the node and magnitude and phase angle of the rotations at nodes with rotational degrees of freedom.
PU*n*	•				Magnitude and phase angle of component *n* of the displacement ($n = 1, 2, 3$).
PUR*n*	•				Magnitude and phase angle of component *n* of the rotation ($n = 1, 2, 3$).
PPOR	•	•			Magnitude and phase angle of the fluid, pore, or acoustic pressure at the node.
PHPOT	•	•			Magnitude and phase angle of the electrical potential at the node.
PRF	•	•			Magnitude and phase angle of the reaction forces at the node and of the reaction moments at nodes with rotational degrees of freedom.
PRF*n*	•				Magnitude and phase angle of component *n* of the reaction force ($n = 1, 2, 3$).
PRM*n*	•				Magnitude and phase angle of component *n* of the reaction moment ($n = 1, 2, 3$).
PHCHG	•	•			Magnitude and phase angle of the reactive charge at the node.

Modal dynamic, steady-state, and random response analysis

The following variables are available only for modal dynamic, steady-state (frequency domain), and random response analyses. "Relative" values are measured relative to the motion of the primary base and are obtained with the identifiers *U*, *V*, and *A*; "Total" values include the motion of the primary base.

Identifier	.dat	.fil	.odb Field	.odb History	Description
For steady-state dynamic output printed to the data file, there are two lines printed for each request; the first line contains the real part of the variable, and the second line (indicated by the SSD footnote) contains the imaginary part.					
TU	•	•	•	•	All components of the total displacements at the node and of the total rotations at nodes with rotational degrees of freedom.
TU*n*	•			•	Component *n* of the total displacement ($n = 1, 2, 3$).
TUR*n*	•			•	Component *n* of the total rotation ($n = 1, 2, 3$).
TV	•	•	•	•	All components of the total velocity at the node, including rotational velocities at nodes with rotational degrees of freedom.
TV*n*	•			•	Component *n* of the total velocity ($n = 1, 2, 3$).
TVR*n*	•			•	Component *n* of the total rate of rotation ($n = 1, 2, 3$).
TA	•	•	•	•	All components of the total acceleration at the node, including rotational accelerations at nodes with rotational degrees of freedom.
TA*n*	•			•	Component *n* of the total acceleration ($n = 1, 2, 3$).
TAR*n*	•			•	Component *n* of the total rotational acceleration ($n = 1, 2, 3$).

Mode-based steady-state dynamic analysis

The following variables are available only for steady-state (frequency domain) dynamic analysis based on modal superposition. "Total" values include the base motion.					
PTU	•	•			Magnitude and phase angle of the total displacement components at the node and magnitude and phase angle of the total rotations at nodes with rotational degrees of freedom.
PTU*n*	•				Magnitude and phase angle of component *n* of the total displacement ($n = 1, 2, 3$).
PTUR*n*	•				Magnitude and phase angle of component *n* of the total rotation ($n = 1, 2, 3$).

Pore pressure analysis

The following variables correspond to fluid volume flux in pore pressure analyses.					
RVF	•	•	•	•	Reaction fluid volume flux due to prescribed pressure. This flux is the rate at which fluid volume is entering

Identifier	.dat	.fil	.odb Field	.odb History	Description
					or leaving the model through the node to maintain the prescribed pressure boundary condition. A positive value of RVF indicates fluid is entering the model.
RVT	•	•	•	•	Reaction total fluid volume (computed only in a transient coupled pore fluid diffusion/stress analysis). This value is the time integrated value of RVF.

Random response analysis

The following variables are available only for random response dynamic analysis. "Relative" values are measured relative to the base motion; "Total" values include the base motion.

RU	•	•	•	•	Root mean square values of all components of the relative displacement at the node and of the components of rotation at nodes with rotational degrees of freedom.
RU*n*	•			•	Root mean square value of component *n* of the relative displacement ($n = 1, 2, 3$).
RUR*n*	•			•	Root mean square value of component *n* of the relative rotation ($n = 1, 2, 3$).
RTU	•	•	•	•	Root mean square values of all components of the total displacement at the node and of the components of total rotation at nodes with rotational degrees of freedom.
RTU*n*	•			•	Root mean square value of component *n* of the total displacement ($n = 1, 2, 3$).
RTUR*n*	•			•	Root mean square value of component *n* of the total rotation ($n = 1, 2, 3$).
RV	•	•	•	•	Root mean square values of all components of the relative velocity at the node and of the components of the rate of rotation at nodes with rotational degrees of freedom.
RV*n*	•			•	Root mean square value of component *n* of the relative velocity ($n = 1, 2, 3$).
RVR*n*	•			•	Root mean square value of component *n* of the relative rate of rotation ($n = 1, 2, 3$).
RTV	•	•	•	•	Root mean square values of all components of the total velocity at the node and of the components of total rotation at nodes with rotational degrees of freedom.

Identifier	.dat	.fil	.odb		Description
			Field	History	
RTV*n*	•			•	Root mean square value of component *n* of the total velocity ($n = 1, 2, 3$).
RTVR*n*	•			•	Root mean square value of component *n* of the total rate of rotation ($n = 1, 2, 3$).
RA	•	•	•	•	Root mean square values of all components of the relative acceleration at the node and of the components of rotational acceleration at nodes with rotational degrees of freedom.
RA*n*	•			•	Root mean square value of component *n* of the relative acceleration ($n = 1, 2, 3$).
RAR*n*	•			•	Root mean square value of component *n* of the relative rotational acceleration ($n = 1, 2, 3$).
RTA	•	•	•	•	Root mean square values of all components of the total acceleration at the node and of the components of rotational acceleration at nodes with rotational degrees of freedom.
RTA*n*	•			•	Root mean square value of component *n* of the total value of acceleration ($n = 1, 2, 3$).
RTAR*n*	•			•	Root mean square value of component *n* of the total rotational acceleration ($n = 1, 2, 3$).
RRF	•	•	•	•	Root mean square values of all components of the reaction forces and of reaction moments at nodes with rotational degrees of freedom.
RRF*n*	•			•	Root mean square value of component *n* of the reaction force ($n = 1, 2, 3$).
RRM*n*	•			•	Root mean square value of component *n* of the reaction moment ($n = 1, 2, 3$).

Modal variables

You can request modal variable output to the data, results, or output database file (see "Modal output from Abaqus/Standard" in "Output to the data and results files," Section 4.1.2, and "Modal output from Abaqus/Standard" in "Output to the output database," Section 4.1.3). In steady-state dynamics GU, etc. provide the amplitude of the mode.

Identifier	.dat	.fil	.odb Field	.odb History	Description
GU	•	•		•	Generalized displacements for all modes.
GU*n*	•			•	Generalized displacement for mode *n*.
GV	•	•		•	Generalized velocities for all modes.
GV*n*	•			•	Generalized velocity for mode *n*.
GA	•	•		•	Generalized acceleration for all modes.
GA*n*	•			•	Generalized acceleration for mode *n*.
GPU	•	•		•	Phase angle of generalized displacements for all modes.
GPU*n*	•			•	Phase angle of generalized displacement for mode *n*.
GPV	•	•		•	Phase angle of generalized velocities for all modes.
GPV*n*	•			•	Phase angle of generalized velocity for mode *n*.
GPA	•	•		•	Phase angle of generalized acceleration for all modes.
GPA*n*	•			•	Phase angle of generalized acceleration for mode *n*.
SNE	•	•		•	Elastic strain energy for the entire model per each mode (not available for random response analysis).
SNE*n*	•			•	Elastic strain energy for the entire model for mode *n* (not available for random response analysis).
KE	•	•		•	Kinetic energy for the entire model per each mode (not available for random response analysis).
KE*n*	•			•	Kinetic energy for the entire model for mode *n* (not available for random response analysis).
T	•	•		•	External work for the entire model per each mode (not available for random response analysis).
T*n*	•			•	External work for the entire model for mode *n* (not available for random response analysis).
BM	•	•		•	Base motion (not available for random response or response spectrum analyses).

Surface variables

You can request surface variable output to the data, results, or output database file (see "Surface output from Abaqus/Standard" in "Output to the data and results files," Section 4.1.2, and "Surface output in Abaqus/Standard and Abaqus/Explicit" in "Output to the output database," Section 4.1.3). Additional information on these variables is provided in "Defining contact pairs in Abaqus/Standard," Section 36.3.1, and Chapter 37, "Contact Property Models." The letter "M" at the end of an output variable identifier designates the magnitude of the variable. Those variables that are output on both

master and slave surfaces in a single master-slave contact pair are designated below. For exceptions to output on the master surface, see "Defining contact pairs in Abaqus/Standard," Section 36.3.1.

Identifier	.dat	.fil	.odb Field	.odb History	Description
Mechanical analysis–nodal quantities					
CSTRESS	•	•	•	•	Contact pressure (CPRESS) and frictional shear stresses (CSHEAR). Output is also available on the master surface to the **.odb** file in a single master-slave setting.
CSTRESSETOS			•		Contact pressure (CPRESSETOS) and frictional shear stresses (CSHEARETOS) due to edge-to-surface contact constraints. Output is also available on the master surface to the **.odb** file in a single master-slave setting.
CSTRESSERI			•		Error indicators for the contact pressure (CPRESSERI) and frictional shear stresses (CSHEARERI). Output is also available on the master surface to the **.odb** file in a single master-slave setting.
CDSTRESS	•	•	•	•	Viscous pressure (CDPRESS) and viscous shear stresses (CDSHEAR). Output is also available on the master surface to the **.odb** file in a single master-slave setting.
CDISP	•	•	•	•	Contact opening (COPEN) and relative tangential motions (CSLIP).
CDISPETOS			•		Contact opening (COPENETOS) and relative tangential motions (CSLIPETOS) for edge-to-surface contact constraints.
CFORCE			•		Contact normal force (CNORMF) and frictional shear force (CSHEARF). Output is also available on the master surface to the **.odb** file in a single master-slave setting.
CNAREA			•		Contact nodal area. Output is also available on the master surface to the **.odb** file in a single master-slave setting.
CSTATUS			•		Contact status. Output is also available on the master surface to the **.odb** file in a single master-slave setting.

Identifier	.dat	.fil	.odb Field	.odb History	Description
CSMAXSCRT			•	•	Maximum stress-based damage initiation criterion for cohesive surfaces.
CSQUADSCRT			•	•	Quadratic stress-based damage initiation criterion for cohesive surfaces.
CSMAXUCRT			•	•	Maximum separation-based damage initiation criterion for cohesive surfaces.
CSQUADUCRT			•	•	Quadratic separation-based damage initiation criterion for cohesive surfaces.
CSDMG			•	•	Damage variable for cohesive surfaces.
PPRESS	•	•	•	•	Fluid pressure for pressure penetration analysis.
SDV	•	•	•	•	Solution-dependent state variables.
Mechanical analysis–whole surface quantities					
CFN	•	•		•	Total force due to contact pressure (CFN*n*, *n* = 1, 2, 3).
CFNM				•	Magnitude of total force due to contact pressure.
CFS	•	•		•	Total force due to frictional stress (CFS*n*, *n* = 1, 2, 3).
CFSM				•	Magnitude of total force due to frictional stress.
CFT	•	•		•	Total force due to contact pressure and frictional stress (CFT*n*, *n* = 1, 2, 3).
CFTM				•	Magnitude of total force due to contact pressure and frictional stress.
CMN	•	•		•	Total moment about the origin due to contact pressure (CMN*n*, *n* = 1, 2, 3).
CMNM				•	Magnitude of total moment about origin due to contact pressure.
CMS	•	•		•	Total moment about the origin due to frictional stress (CMS*n*, *n* = 1, 2, 3).
CMSM				•	Magnitude of total moment about the origin due to frictional stress.
CMT	•	•		•	Total moment about the origin due to contact pressure and frictional stress (CMT*n*, *n* = 1, 2, 3).
CMTM				•	Magnitude of total moment about the origin due to contact pressure and frictional stress.
CAREA	•	•		•	Total area in contact.

Identifier	.dat	.fil	.odb Field	.odb History	Description
CTRQ	•	•		•	Maximum torque that can be transmitted about the z-axis by a contact surface in an axisymmetric analysis with a friction coefficient of unity.
XN	•	•		•	Center of the total force due to contact pressure (XNn, n = 1, 2, 3).
XS	•	•		•	Center of the total force due to frictional stress (XSn, n = 1, 2, 3).
XT	•	•		•	Center of the total force due to contact pressure and frictional stress (XTn, n = 1, 2, 3).
Heat transfer analysis					
HFL	•	•	•	•	Heat flux per unit area leaving the slave surface.
HFLA	•	•	•	•	HFL multiplied by the nodal area.
HTL	•	•	•	•	Time integrated HFL.
HTLA	•	•	•	•	Time integrated HFLA.
Coupled thermal-electrical analysis					
ECD	•	•	•	•	Electrical current per unit area.
ECDA	•	•	•	•	ECD multiplied by the nodal area.
ECDT	•	•	•	•	Time integrated ECD.
ECDTA	•	•	•	•	Time integrated ECDA.
HFL	•	•	•	•	Heat flux per unit area leaving the slave surface.
HFLA	•	•	•	•	HFL multiplied by the nodal area.
HTL	•	•	•	•	Time integrated HFL.
HTLA	•	•	•	•	Time integrated HFLA.
SJD	•	•	•	•	Heat flux per unit area due to electrical current.
SJDA	•	•	•	•	SJD multiplied by the nodal area.
SJDT	•	•	•	•	Time integrated SJD.
SJDTA	•	•	•	•	Time integrated SJDA.
WEIGHT	•	•	•	•	Weighting factor for heat distribution between the interface surfaces.
Fully coupled temperature-displacement analysis					
HFL	•	•	•	•	Heat flux per unit area leaving the slave surface.
HFLA	•	•	•	•	HFL multiplied by the nodal area.
HTL	•	•	•	•	Time integrated HFL.

Identifier	.dat	.fil	.odb		Description
			Field	History	
HTLA	•	•	•	•	Time integrated HFLA.
SFDR	•	•	•	•	Heat flux per unit area due to frictional dissipation.
SFDRA	•	•	•	•	SFDR multiplied by the nodal area.
SFDRT	•	•	•	•	Time integrated SFDR.
SFDRTA	•	•	•	•	Time integrated SFDRA.
WEIGHT	•	•	•	•	Weighting factor for heat distribution between the interface surfaces.

Fully coupled thermal-electrical-structural analysis

ECD	•	•	•	•	Electrical current per unit area.
ECDA	•	•	•	•	ECD multiplied by the nodal area.
ECDT	•	•	•	•	Time integrated ECD.
ECDTA	•	•	•	•	Time integrated ECDA.
HFL	•	•	•	•	Heat flux per unit area leaving the slave surface.
HFLA	•	•	•	•	HFL multiplied by the nodal area.
HTL	•	•	•	•	Time integrated HFL.
HTLA	•	•	•	•	Time integrated HFLA.
SFDR	•	•	•	•	Heat flux per unit area due to frictional dissipation.
SFDRA	•	•	•	•	SFDR multiplied by the nodal area.
SFDRT	•	•	•	•	Time integrated SFDR.
SFDRTA	•	•	•	•	Time integrated SFDRA.
SJD	•	•	•	•	Heat flux per unit area due to electrical current.
SJDA	•	•	•	•	SJD multiplied by the nodal area.
SJDT	•	•	•	•	Time integrated SJD.
SJDTA	•	•	•	•	Time integrated SJDA.
WEIGHT	•	•	•	•	Weighting factor for heat distribution between the interface surfaces.

Coupled pore fluid-mechanical analysis–nodal quantities

PFL	•	•	•	•	Pore fluid volume flux per unit area leaving the slave surface.
PFLA	•	•	•	•	PFL multiplied by the nodal area.
PTL	•	•	•	•	Time integrated PFL.
PTLA	•	•	•	•	Time integrated PFLA.

Identifier	.dat	.fil	.odb Field	.odb History	Description
Coupled pore fluid-mechanical analysis–whole surface quantities					
TPFL	•	•			Total pore fluid volume flux leaving the slave surface.
TPTL	•	•			Time integrated TPFL.
Bond failure quantities					
DBT	•	•	•	•	Time when bond failure occurs.
DBS	•	•	•	•	All components of remaining stress in the failed bond.
DBSF	•	•	•	•	Fraction of stress that remains at bond failure.
BDSTAT	•	•	•	•	Bond state (varies from 1.0 to 0.0).
CSDMG	•	•	•	•	Damage variable.
OPENBC	•	•	•	•	Relative displacement behind crack when fracture criterion is met.
CRSTS	•	•	•	•	All components of critical stress at failure.
ENRRT	•	•	•	•	All components of strain energy release rate.
EFENRRTR	•	•	•	•	Effective energy release rate ratio.

Cavity radiation variables

The following variables are associated with facets (sides of elements) composing cavities in radiation heat transfer and include contributions due to exchanges with the ambient. You can request cavity radiation variable output to the data, results, or output database file (see “Requesting surface variable output” in “Cavity radiation,” Section 41.1.1, and “Cavity radiation output in Abaqus/Standard” in “Output to the output database,” Section 4.1.3).

Identifier	.dat	.fil	.odb Field	.odb History	Description
RADFL	•	•	•	•	Radiation flux per unit area.
RADFLA	•	•	•	•	Radiation flux over the facet.
RADTL	•	•	•	•	Time integrated radiation per unit area.
RADTLA	•	•	•	•	Time integrated radiation over the facet.
VFTOT	•	•	•	•	Total viewfactor for the facet (sum of viewfactor values in the row of viewfactor matrix corresponding to the facet).
FTEMP	•	•	•	•	Facet temperature.

Section variables

You can request section variable output to the data or results file (see "Section output from Abaqus/Standard" in "Output to the data and results files," Section 4.1.2). By default, all components of forces and moments are given with respect to the global system. If a local coordinate system is defined for the section output request, all components are given with respect to the local system.

Different output variables are available depending on the type of analysis. For coupled analyses the appropriate combination of variables can be requested. For example, in a coupled thermal-electrical analysis both SOH and SOE are valid output requests. Section output variables are not available for random response analysis.

Identifier	.dat	.fil	.odb Field	.odb History	Description
All analysis types					
SOAREA	•	•			Area of the defined section.
Stress/displacement analysis					
SOF	•	•			Total force in the section.
SOM	•	•			Total moment in the section.
SOCF	•	•			Center of the total force in the section.
Heat transfer analysis					
SOH	•	•			Total heat flux associated with the section.
Electrical analysis					
SOE	•	•			Total current associated with the section.
Mass diffusion analysis					
SOD	•	•			Total mass flow associated with the section.
Coupled pore fluid diffusion-stress analysis					
SOP	•	•			Total pore fluid volume flux associated with the section.

Whole and partial model variables

The output variables listed below are available for part of the model as well as the whole model.

Identifier	.dat	.fil	.odb Field	.odb History	Description
Adaptive mesh domains					
The following variable is available only for adaptive domains (see "Defining ALE adaptive mesh domains in Abaqus/Standard," Section 12.2.6).					
VOLC	•	•	•		Change in area or change in volume of an element set solely due to adaptive meshing.
Equivalent rigid body motion variables					
You can request equivalent rigid body motion whole element set variable output to the data, results, or output database file (see "Element output" in "Output to the data and results files," Section 4.1.2, and "Element output" in "Output to the output database," Section 4.1.3). The variables listed are available only for implicit dynamic analyses using direct integration except where indicated.					
XC	•	•	•		Current coordinates of the center of mass for the entire set or the entire model. Not available for eigenfrequency extraction, eigenvalue buckling prediction, complex eigenfrequency extraction, or linear dynamics procedures. Available also for static analyses but only from the output database.
XC*n*	•		•		Coordinate *n* of the center of mass for the entire set or the entire model ($n = 1, 2, 3$).
UC	•	•	•		Current displacement of the center of mass for the entire set or the entire model. Available also for static analyses but only from the output database.
UC*n*	•		•		Displacement component *n* of the center of mass for the entire set or the entire model ($n = 1, 2, 3$).
URC*n*	•		•		Rotation component *n* of the center of mass for the entire set or the entire model ($n = 1, 2, 3$).
VC	•	•	•		Equivalent rigid body velocity components summed over the entire set or the entire model.
VC*n*	•		•		Component *n* of the equivalent rigid body velocity summed over the entire set or the entire model ($n = 1, 2, 3$).
VRC*n*	•		•		Component *n* of the equivalent rigid body angular velocity summed over the entire set or the entire model ($n = 1, 2, 3$).
HC	•	•	•		Current angular momentum about the center of mass for the entire set or the entire model.

Identifier	.dat	.fil	.odb Field	.odb History	Description
HC*n*	•			•	Component n of the angular momentum about the center of mass for the entire set or the entire model ($n = 1, 2, 3$).
HO	•	•		•	Current angular momentum about the origin for the entire set or the entire model.
HO*n*	•			•	Component n of the angular momentum about the origin for the entire set or the entire model ($n = 1, 2, 3$).
RI	•	•		•	Current rotary inertia about the origin of the entire set or the entire model. Not available for eigenfrequency extraction, eigenvalue buckling prediction, complex eigenfrequency extraction, or linear dynamics procedures. Available also for static analyses but only from the output database.
RI*ij*	•			•	ij-component of the rotary inertia about the origin of the entire set or the entire model ($i \le j \le 3$).
MASS	•	•		•	Current mass of the entire set or the entire model. Available also for static analyses but only from the output database.
VOL	•	•		•	Current volume of the entire set or the entire model. Available also for static analyses but only from the output database. (Available only for continuum and structural elements that do not use general beam or shell section definitions.)

Inertia relief output variables

You can request inertia relief whole model variable output to the data or output database file (see "Element output" in "Output to the data and results files," Section 4.1.2, and "Element output" in "Output to the output database," Section 4.1.3). Since these variables have unique values for the entire model, the variable output is independent of the specified region. The variables listed are available only for those analyses that include inertia relief loading (see "Inertia relief," Section 11.1.1).

IRX	•			•	Current coordinates of the reference point.
IRX*n*	•			•	Coordinate *n* of the reference point ($n = 1, 2, 3$).
IRA	•			•	Equivalent rigid body acceleration components.
IRA*n*	•			•	Component *n* of the equivalent rigid body acceleration ($n = 1, 2, 3$).

Identifier	.dat	.fil	.odb Field	.odb History	Description
IRAR*n*	•			•	Component n of the equivalent rigid body angular acceleration with respect to the reference point ($n = 1, 2, 3$).
IRF	•			•	Inertia relief load corresponding to the equivalent rigid body acceleration.
IRF*n*	•			•	Component n of the inertia relief load corresponding to the equivalent rigid body acceleration ($n = 1, 2, 3$).
IRM*n*	•			•	Component n of the inertia relief moment corresponding to the equivalent rigid body angular acceleration with respect to the reference point ($n = 1, 2, 3$).
IRRI	•			•	Rotary inertia about the reference point.
IRRI*ij*	•			•	ij-component of the rotary inertia about the reference point ($i \leq j \leq 3$).
IRMASS	•			•	Whole model mass.

Mass diffusion analysis

You can request variable output from a mass diffusion analysis (“Mass diffusion analysis,” Section 6.9.1) to the data, results, or output database file (see “Element output” in “Output to the data and results files,” Section 4.1.2, and “Element output” in “Output to the output database,” Section 4.1.3). If you specify an output region, the variable is calculated over the user-specified region. If you do not specify an output region, the variable is calculated as the total over the entire model.

SOL	•	•		•	Amount of solute in an element set, calculated as the sum of ESOL (amount of solute in each element) over all the elements in the set.

Analyses with time-dependent material behavior

CRPTIME				•	Creep time, which is equal to the total time in procedures with time-dependent material behavior (see “Rate-dependent plasticity: creep and swelling,” Section 23.2.4).

Eigenvalue extraction

The following variables are output automatically during a frequency extraction analysis (“Natural frequency extraction,” Section 6.3.5).

EIGVAL	○			○	Eigenvalues.
EIGFREQ	○			○	Eigenfrequencies.

Identifier	.dat	.fil	.odb Field	.odb History	Description
GM	○			○	Generalized masses.
CD	○			○	Composite damping factors.
PF*n*	○			○	Modal participation factors 1–7 ($n = 1, 2, 3$ corresponding to displacements, $n = 4, 5, 6$ for the rotations, and $n = 7$ for acoustic pressure).
EM*n*	○			○	Modal effective masses 1–7 ($n = 1, 2, 3$ corresponding to displacements, $n = 4, 5, 6$ for the rotations, and $n = 7$ for acoustic pressure).

Complex eigenvalue extraction

The following variables are output automatically during a complex frequency extraction analysis ("Complex eigenvalue extraction," Section 6.3.6).

EIGREAL	○		○	Real parts of the eigenvalues.
EIGIMAG	○		○	Imaginary parts of the eigenvalues.
EIGFREQ	○		○	Eigenfrequencies.
DAMPRATIO	○		○	Damping ratios.

Total energy output quantities

If the following whole model variables are relevant for a particular analysis, you can request them as output to the data, results, or output database file (see "Total energy output" in "Output to the data and results files," Section 4.1.2, and "Total energy output" in "Output to the output database," Section 4.1.3). If you do not specify an output region, whole model variables are calculated. When you specify an output region, the relevant energy totals are calculated over the user-specified region.

These variables are not available for eigenvalue buckling prediction, eigenfrequency extraction, or complex frequency extraction analysis. You cannot specify an output region for modal dynamic, random response, response spectrum, or steady-state dynamic analysis.

See "Energy balance," Section 1.5.5 of the Abaqus Theory Guide, for details of the energy definitions.

ALLAE	○	○	•	"Artificial" strain energy associated with constraints used to remove singular modes (such as hourglass control), and with constraints used to make the drill rotation follow the in-plane rotation of the shell elements.
ALLCD	○	○	•	Energy dissipated by creep, swelling, viscoelasticity, and energy associated with viscous regularization for cohesive elements.
ALLEE	○	○	•	Electrostatic energy.

Identifier	.dat	.fil	.odb Field	.odb History	Description
ALLFD	○	○		•	Total energy dissipated through frictional effects. (Available only for the whole model.)
ALLIE	○	○		•	Total strain energy. (ALLIE = ALLSE + ALLPD + ALLCD + ALLAE + ALLQB + ALLEE + ALLDMD.)
ALLJD	○	○		•	Electrical energy dissipated due to flow of electrical current.
ALLKE	○	○		•	Kinetic energy.
ALLKL	○	○		•	Loss of kinetic energy at impact. (Available only for the whole model.)
ALLPD	○	○		•	Energy dissipated by rate-independent and rate-dependent plastic deformation.
ALLQB	○	○		•	Energy dissipated through quiet boundaries (infinite elements). (Available only for the whole model.)
ALLSD	○	○		•	Energy dissipated by automatic stabilization. This includes both volumetric static stabilization and automatic approach of contact pairs (the latter part included only for the whole model).
ALLSE	○	○		•	Recoverable strain energy.
ALLVD	○	○		•	Energy dissipated by viscous effects including viscous regularization (except for cohesive elements), not inclusive of energy dissipated by automatic stabilization and viscoelasticity.
ALLDMD	○	○		•	Energy dissipated by damage.
ALLWK	○	○		•	External work. (Available only for the whole model.)
ETOTAL	○	○		•	Total energy balance (available only for the whole model). (ETOTAL = ALLKE + ALLIE + ALLVD + ALLSD + ALLKL + ALLFD + ALLJD − ALLWK.)

Solution-dependent amplitude variables

Solution-dependent amplitude variables are given automatically with any file output or output database request.

Identifier	.dat	.fil	.odb Field	.odb History	Description
LPF		○		○	Load proportionality factor in a static Riks analysis.
AMPCU		○		○	Current value of the solution-dependent amplitude.

Identifier	.dat	.fil	.odb Field	.odb History	Description
RATIO		○		○	Current maximum ratio of creep strain rate and target creep strain rate.

Structural optimization variables

Structural optimization output variables are requested by the Abaqus Topology Optimization Module during each design cycle. For more information, see Chapter 13, “Optimization Techniques.”

Identifier	.dat	.fil	.odb Field	.odb History	Description

Toplogy optimization

The following variable is output automatically during topology optimization (see “Topology optimization” in “Structural optimization: overview,” Section 13.1.1).

MAT_PROP_NORMALIZED		○			Element-based normalized material value.

Shape optimization

The following variables are output automatically during shape optimization (see “Shape optimization” in “Structural optimization: overview,” Section 13.1.1).

CTRL_INPUT(OPT)		○			Material scaling coefficient.
DISP_OPT_VAL		○			The value of the optimization displacement.
DISP_OPT		○			A vector representing the optimization displacement.

4.2.2 Abaqus/Explicit OUTPUT VARIABLE IDENTIFIERS

Product: Abaqus/Explicit

References

- "Output," Section 4.1.1
- "Output to the data and results files," Section 4.1.2
- "Output to the output database," Section 4.1.3

Overview

Except for the information in the status file, results can be obtained from Abaqus/Explicit only by postprocessing.

The tables in this section list all of the output variables that are available in Abaqus/Explicit. These output variables can be requested for output to the results (**`.fil`**) file (see "Output to the data and results files," Section 4.1.2) or as either field- or history-type output to the output database (**`.odb`**) file (see "Output to the output database," Section 4.1.3). When the output variables are requested for output to the results file, Abaqus/Explicit will first output these variables to the selected results (**`.sel`**) file and will then convert the selected results file to the results file after the analysis completes.

Symbols used in the tables

The availability of the various output variable identifiers is defined by a • in the columns of the table, under the following headings:

.fil

means that the identifier can be used as a results file output selection.

.odb Field

means that the identifier can be used as a field-type output selection to the output database.

.odb History

means that the identifier can be used as a history-type output selection to the output database.

Direction definitions

The direction definitions depend on the variable type.

Direction definitions for element variables

For components of stress, strain, and similar material variables, 1, 2, and 3 refer to the directions in an orthogonal coordinate system. These are global directions for solid elements, surface directions for shell and membrane elements, and axial and transverse directions for beam and pipe elements. However, if a

local orientation (“Orientations,” Section 2.2.5) is associated with the elements for which output is being requested, 1, 2, and 3 are local directions.

Direction definitions for nodal variables

For nodal variables, 1, 2, and 3 refer to the global directions (1=*X*, 2=*Y*, 3=*Z* except for axisymmetric elements, in which case 1=*R*, 2=*Z*). Even if a local coordinate system has been defined at a node (“Transformed coordinate systems,” Section 2.1.5), the data in the results file and the selected results file are still output in the global directions.

If nodal field output is requested for a node that has a local coordinate system defined, a quaternion representing the rotation from the global directions is written to the output database. Abaqus/CAE automatically uses this quaternion to transform the nodal results into the local directions. Nodal history data written to the output database are always stored in the global directions.

Direction definitions for integrated variables

For components of total force, total moment, and similar variables obtained through integration over a surface, the directions 1, 2, and 3 refer to directions in an orthogonal coordinate system. A fixed global coordinate system is used if the surface is specified directly for the integrated output request. If the surface is identified by an integrated output section definition (see “Integrated output section definition,” Section 2.5.1) that is associated with the integrated output request, a local coordinate system in the initial configuration can be specified and can translate or rotate with the deformation.

Distributed load output and user subroutines

Output can be requested for many of the distributed loads discussed in “Loads,” Section 34.4. However, contributions to these loads defined through user subroutines (see “Abaqus/Explicit subroutines,” Section 1.2 of the Abaqus User Subroutines Reference Guide) are not displayed.

Principal value output

Output of the principal values can be requested for stresses, logarithmic strains, and nominal strains. Either all principal values or the minimum, intermediate, or maximum values can be obtained. All principal values of tensor *ABC* are obtained with the request *ABC*P, and the minimum, intermediate, and maximum principal values are obtained with the requests *ABC*P1, *ABC*P2, and *ABC*P3, respectively. For three-dimensional, plane strain, and axisymmetric elements all three principal values are obtained. For plane stress, membrane, and shell elements only the in-plane principal values are obtained for history-type output, and the out-of-plane principal value cannot be requested. For field-type output, all three principal values are obtained through Abaqus/CAE. Principal values cannot be obtained for beam, pipe, and truss elements, and principal values of plastic strains cannot be requested.

If a principal value or an invariant is requested for field-type output, the output request is replaced with an output request for the components of the corresponding tensor. Abaqus/CAE calculates all principal values and invariants from these components. If a principal value is desired as history-type output, it must be requested explicitly since Abaqus/CAE does no calculations on history data.

Tensor output

Tensor variables that are written to the output database as field-type output are written as components in either the default directions defined by the convention given in "Orientations," Section 2.2.5 (global directions for solid elements, surface directions for shell and membrane elements, and axial and transverse directions for beam and pipe elements), or the user-defined local system. Abaqus/CAE calculates all principal values and invariants from these components. See "Writing field output data," Section 9.6.4 of the Abaqus Scripting User's Guide, for a description of the different types of tensor variables.

The components for tensor variables are written to the output database in single precision. Therefore, a small amount of precision roundoff error may occur when calculating the variables' principal values. Such roundoff error may be observed, for example, when analytically zero values are calculated as relatively small yet nonzero values.

Requesting output of components

Individual components of variables can be requested as history-type output in the output database for *X–Y* plotting in Abaqus/CAE. Individual component requests are not available for field-type output. If a particular component is desired for contouring in Abaqus/CAE, request field output of the generic variable (e.g., S for stress). Output for individual components of this field output can be requested within the Visualization module of Abaqus/CAE.

Element integration point variables

You can request element integration point variable output to the results or output database file (see "Element output" in "Output to the data and results files," Section 4.1.2, and "Element output" in "Output to the output database," Section 4.1.3).

Identifier	.fil	.odb		Description
		Field	History	
Tensors and invariants				
S	•	•	•	All stress components.
MISESMAX		•		Maximum Mises stress among all of the section points. For a shell element it represents the maximum Mises value among all the section points in the layer, for a beam or pipe element it is the maximum Mises stress among all the section points in the cross-section, and for a solid element it represents the Mises stress at the integration points.
S*ij*			•	ij-component of stress ($i \le j \le 3$).
SP	•	•	•	All principal stress components.

Identifier	.fil	.odb Field	.odb History	Description
SP*n*			•	Minimum, intermediate, and maximum principal stress components (SP1 $\leq$ SP2 $\leq$ SP3).
E	•	•	•	All infinitesimal strain components for geometrically linear analysis.
E*ij*			•	ij-component of infinitesimal strain ($i \leq j \leq 3$).
LE	•	•	•	All logarithmic strain components.
LE*ij*			•	ij-component of logarithmic strain ($i \leq j \leq 3$).
LEP	•	•	•	All principal logarithmic strain components.
LEP*n*			•	Minimum, intermediate, and maximum principal logarithmic strain components (LEP1 $\leq$ LEP2 $\leq$ LEP3).
ER	•	•	•	All logarithmic strain rate components.
ER*ij*			•	ij-component of logarithmic strain rate($i \leq j \leq 3$).
ERP	•	•	•	All principal logarithmic strain rate components.
ERP*n*			•	Minimum, intermediate, and maximum principal strain rate components (ERP1 $\leq$ ERP2 $\leq$ ERP3).
NE	•	•	•	All nominal strain components.
NE*ij*			•	ij-component of nominal strain ($i \leq j \leq 3$).
NEP	•	•	•	All principal nominal strain components.
NEP*n*			•	Minimum, intermediate, and maximum principal nominal strain components (NEP1 $\leq$ NEP2 $\leq$ NEP3).
PE	•	•	•	All plastic strain components.
PE*ij*			•	ij-component of plastic strain ($i \leq j \leq 3$).
PEP		•	•	All principal plastic strains.
PEP*n*			•	Minimum, intermediate, and maximum principal plastic strains.
ERV	•	•	•	Volumetric strain rate.
MISES	•	•	•	Mises equivalent stress, defined as $q = \sqrt{\frac{3}{2}\mathbf{S} : \mathbf{S}}$, where $\mathbf{S}$ is the deviatoric stress tensor, defined as $\mathbf{S} = \boldsymbol{\sigma} + p\mathbf{I}$, where $\boldsymbol{\sigma}$ is the stress and $p = -\frac{1}{3}\mathrm{trace}(\boldsymbol{\sigma})$ is the equivalent pressure stress.
PRESS	•	•	•	Equivalent pressure stress, $p = -\frac{1}{3}\mathrm{trace}(\boldsymbol{\sigma})$.
TRIAX		•	•	Stress triaxiality, $\eta = -p/q$.
YIELDS		•	•	Yield stress, σ^0, available for Mises, Johnson-Cook, and Hill plasticity material models.

Identifier	.fil	.odb Field	.odb History	Description
MASSADJUST		•		Adjusted or redistributed mass in each element that is included in the element sets used with mass adjustment. This output is available only in the first output frame of the first analysis step.
ALPHA	•	•	•	All total kinematic hardening shift tensor components.
ALPHA*ij*			•	ij-component of the total shift tensor ($i \le j \le 3$).
ALPHAP	•	•	•	All principal values of the total shift tensor.
ALPHAP*n*			•	Minimum, intermediate, and maximum principal values of the total shift tensor (ALPHAP1 $\le$ ALPHAP2 $\le$ ALPHAP3).
PEEQ	•	•	•	Equivalent plastic strain. For porous metal plasticity PEEQ is the equivalent plastic strain in the matrix material defined as $\int \frac{\boldsymbol{\sigma}:d\boldsymbol{\varepsilon}^{pl}}{(1-f)\sigma_y}$. For cap plasticity PEEQ gives p_b (the cap position). For crushable foam plasticity with volumetric hardening PEEQ gives the volumetric compacting plastic strain defined as $-\varepsilon_{\text{vol}}^{pl}$. For crushable foam plasticity with isotropic hardening PEEQ gives the equivalent plastic strain defined as $\int \frac{\boldsymbol{\sigma}:d\boldsymbol{\varepsilon}^{pl}}{\sigma_c}$, where σ_c is the uniaxial compression yield stress.
PEEQT		•	•	Equivalent plastic strain in uniaxial tension for cast iron, Mohr-Coulomb tension cutoff, and concrete damaged plasticity, which is defined as $\int \tilde{\varepsilon}_t^{pl}\, dt$.
PEEQMAX		•		Maximum equivalent plastic strain, PEEQ, among all of the section points. For a shell element it represents the maximum PEEQ value among all the section points in the layer, for a beam or a pipe element it is the maximum PEEQ among all the section points in the cross-section, and for a solid element it represents the PEEQ at the integration points.

Identifier	.fil	.odb Field	.odb History	Description
DMICRTMAX		•		Maximum damage initiation among all of the section points and all of the damage initiation criteria. This output variable generates three output quantities as follows: DMICRTMAXVAL outputs the maximum damage initiation value. DMICRTPOS outputs the section point in the layer in which the maximum damage initiation value occurred. For solid elements, the output value is one. DMICRTTYPE outputs a value that represents the damage initiation criteria type that reached the maximum value in the element as follows: For elements that have failure with progressive damage: 1-DUCTCRT, 2-SHRCRT, 3-JCCRT, 4-FLDCRT, 5-MSFLDCRT, 6-FLSDCRT, and 7-MKCRT. For elements that have fiber-reinforced material damage: 11-HSNFTCRT, 12-HSNFCCRT, 13-HSNMTCRT, and 14-HSNMCCRT. For cohesive elements with traction-separation behavior: 21-MAXSCRT, 22-MAXECRT, 23-QUADSCRT, and 24-QUADECRT. The maximum damage initiation output values are retained across the requested output frames until a higher maximum damage initiation value is computed.
Geometric quantities				
COORD		•	•	Coordinates of the integration point for solid elements. These are the current coordinates if the large-displacement formulation is being used.

Identifier	.fil	.odb Field	.odb History	Description
LOCALDIR*n*		○		Direction cosines of the local material directions for an anisotropic hyperelastic material model, or yarn direction cosines for a fabric material model. This variable is output automatically if any other element field output is requested for anisotropic hyperelastic or fabric material (see "Output" in "Anisotropic hyperelastic behavior," Section 22.5.3, and "Output" in "Fabric material behavior," Section 23.4.1).
Additional element stresses				
TSHR	•	•	•	All transverse shear stress components for three-dimensional conventional shell elements.
TSHR13			•	13-component of transverse shear stress.
TSHR23			•	23-component of transverse shear stress.
Energy densities				
ENER	•	•	•	All energy densities.
SENER			•	Elastic strain energy density, per unit volume.
PENER			•	Energy dissipated by rate-independent and rate-dependent plasticity, per unit volume.
CENER			•	Energy dissipated by viscoelasticity, per unit volume (not supported for hyperelastic and hyperfoam material models).
VENER			•	Energy dissipated by viscous effects, per unit volume.
DMENER			•	Energy dissipated by damage, per unit volume.
State and field variables				
SDV	•	•	•	Solution-dependent state variables.
SDV*n*		•	•	Solution-dependent state variable *n*.
TEMP	•	•	•	Temperature.
DENSITY		•	•	Material density.
FV		•	•	Field variables.
FV*n*			•	Field variable *n*.
Composite failure measures				
CFAILURE		•		All failure measure components.
MSTRS				Maximum stress theory failure measure.

Identifier	.fil	.odb Field	.odb History	Description
TSAIH				Tsai-Hill theory failure measure.
TSAIW				Tsai-Wu theory failure measure.
AZZIT				Azzi-Tsai-Hill theory failure measure.
MSTRN				Maximum strain theory failure measure.
Additional plasticity quantities				
PEQC	•	•	•	All equivalent plastic strains, when the model has more than one yield/failure surface.
PEQC*n*			•	*n*th equivalent plastic strain ($n = 1, 2, 3, 4$). For cap plasticity: PEQC provides equivalent plastic strains for all three possible yield/failure surfaces (Drucker-Prager failure surface - PEQC1, cap surface - PEQC2, and transition surface - PEQC3) and the total volumetric plastic strain (PEQC4). All identifiers also provide a yes/no flag (1/0 in the output database), telling whether the yield surface is currently active or not (AC YIELD: "actively yielding"). When PEQC is requested as output to the output database, the active yield flags for each component are named AC YIELD1, AC YIELD2, etc.
Porous metal plasticity quantities				
VVF	•	•	•	Void volume fraction (porous metal plasticity).
VVFG	•	•	•	Void volume fraction due to growth (porous metal plasticity).
VVFN	•	•	•	Void volume fraction due to nucleation (porous metal plasticity).
Concrete damaged plasticity				
DAMAGEC		•	•	Compressive damage variable, d_c.
DAMAGET		•	•	Tensile damage variable, d_t.
SDEG		•	•	Scalar stiffness degradation variable, d.
PEEQ		•	•	Equivalent plastic strain in uniaxial compression, which is defined as $\int \dot{\tilde{\varepsilon}}_c^{pl} dt$.

Identifier	.fil	.odb Field	.odb History	Description
Cracking model quantities				
CKE	•			All cracking strain components.
CKE*ij*				ij-component of cracking strain.
CKLE	•			All cracking strain components in local crack axes.
CKLE*ij*				ij-component of cracking strain in local crack axes.
CKEMAG	•			Cracking strain magnitude, defined as $\sqrt{\left(e_{nn}^{ck}\right)^2 + \left(e_{tt}^{ck}\right)^2 + \left(e_{ss}^{ck}\right)^2}$.
CKLS	•			All stress components in local crack axes.
CKLS*ij*				ij-component of stress in local crack axes.
CRACK	•			Crack orientations.
CKSTAT	•			Crack status of each crack. CKSTAT can have the following values for each crack: 0.0=uncracked, 1.0=closed crack, 2.0=actively cracking, 3.0=crack closing/reopening.
Failure with progressive damage				
DMICRT	•		•	All active components of the damage initiation criteria.
DUCTCRT			•	Ductile damage initiation criterion.
JCCRT			•	Johnson-Cook damage initiation criterion.
SHRCRT			•	Shear damage initiation criterion.
FLDCRT			•	Forming limit diagram (FLD) damage initiation criterion.
FLSDCRT			•	Forming limit stress diagram (FLSD) damage initiation criterion.
MSFLDCRT			•	Müschenborn-Sonne forming limit stress diagram (MSFLD) damage initiation criterion.
MKCRT			•	Marciniak-Kuczynski (M-K) damage initiation criterion.
SDEG	•		•	Overall scalar stiffness degradation.
ERPRATIO	•		•	Ratio of principal strain rates, α, used for the MSFLD damage initiation criterion.
SHRRATIO	•		•	Shear stress ratio, $\theta_s = (q + k_s p)/\tau_{\max}$, used for the shear damage initiation criterion.
Fiber-reinforced materials damage				
DMICRT	•		•	All active components of the damage initiation criteria.

Identifier	.fil	.odb Field	.odb History	Description
HSNFTCRT			•	Hashin's fiber tensile damage initiation criterion.
HSNFCCRT			•	Hashin's fiber compressive damage initiation criterion.
HSNMTCRT			•	Hashin's matrix tensile damage initiation criterion.
HSNMCCRT			•	Hashin's matrix compressive damage initiation criterion.
DAMAGEFT		•	•	Fiber tensile damage variable.
DAMAGEFC		•	•	Fiber compressive damage variable.
DAMAGEMT		•	•	Matrix tensile damage variable.
DAMAGEMC		•	•	Matrix compressive damage variable.
DAMAGESHR		•	•	Shear damage variable.

Fabric material

Output variable LOCALDIR (described above) is output automatically for fabric materials.

SFABRIC		•	•	All fabric stress components.
EFABRIC		•	•	All fabric strain components.
SFABRIC*ij*			•	ij-component of fabric stress ($i \le j \le 3$).
EFABRIC*ij*			•	ij-component of fabric strain ($i \le j \le 3$).

Equation of state

BURNF		•	•	Burn fraction of the ignition and growth material.
DBURNF		•	•	Reaction rate of the ignition and growth material.
RHOE		•	•	Density of the unreacted explosive in the ignition and growth material.
RHOP		•	•	Density of the reacted gas product in the ignition and growth material.
PALPH		•	•	Distension, α, of the $P - \alpha$ porous material.
PALPHMIN		•	•	Minimum value, α_{min}, of the distension attained during plastic compaction of the $P - \alpha$ porous material.

Rebar quantities

RBFOR	•	•	•	Force in rebar.
RBANG	•	•	•	Angle, in degrees, between rebar and the user-specified isoparametric direction. Available only for shell and membrane elements.

Identifier	.fil	.odb		Description
		Field	History	
RBROT	•	•	•	Change in angle, in degrees, between rebar and the user-specified isoparametric direction. Available only for shell and membrane elements.
Integration point coordinates				
COORD		•	•	Coordinates of element integration point.
Coupled thermal-stress elements				
HFL	•	•	•	Current magnitude and components of the heat flux per unit area vector.
HFLM			•	Current magnitude of the heat flux per unit area vector.
HFLn			•	Component n of the heat flux vector ($n = 1, 2, 3$).
Cohesive elements				
MAXSCRT			•	Maximum nominal stress damage initiation criterion.
MAXECRT			•	Maximum nominal strain damage initiation criterion.
QUADSCRT			•	Quadratic nominal stress damage initiation criterion.
QUADECRT			•	Quadratic nominal strain damage initiation criterion.
DMICRT		•	•	All active components of the damage initiation criteria.
SDEG		•	•	Overall scalar stiffness degradation.
STATUS		•	•	Status of the element (the status of an element is 1.0 if the element is active, 0.0 if the element is not).
Eulerian elements				
EVF		•	•	Eulerian volume fraction. Output includes volume fraction data for each material defined in the Eulerian section, plus the volume fraction of void.
DENSITYVAVG		•		Density, computed as a volume fraction weighted average of all materials in the element.
MISESVAVG		•		Mises stress, computed as a volume fraction weighted average of all materials in the element.
PEVAVG		•		Plastic strain components, computed as a volume fraction weighted average of all materials in the element.
PEEQVAVG		•		Equivalent plastic strain, computed as a volume fraction weighted average of all materials in the element.

Identifier	.fil	.odb Field	.odb History	Description
PRESSVAVG		•		Equivalent pressure stress, computed as a volume fraction weighted average of all materials in the element.
SVAVG		•		Stress components, computed as a volume fraction weighted average of all materials in the element.
TEMPMAVG		•		Temperature, computed as a mass fraction weighted average of all materials in the element.

Element section variables

You can request element section variable output to the results or output database file (see "Element output" in "Output to the data and results files," Section 4.1.2, and "Element output" in "Output to the output database," Section 4.1.3). These variables are available only for beam, pipe, and shell elements with the exception of STH, which is also available for membrane and plane stress elements. They are defined for particular elements in the element descriptions in Part VI, "Elements."

Identifier	.fil	.odb Field	.odb History	Description
STH	•	•	•	Section thickness (shell, membrane, and plane stress elements only).
STHIN	•	•	•	Section thinning or thickening is defined as $STHIN = 1 - \frac{STH}{STH_{orig}}$, where STH_{orig} is the original thickness specified on the section definition for shell, membrane, and plane stress elements.
SF	•	•	•	All section resultant components, both translational (forces) and rotational (moments).
SF*n*			•	Section force component *n*, $n = 1, 2, 3, 4, 5$ for conventional shells; $n = 1, 2, 3, 4, 5, 6$ for continuum shells; $n = 1, 2, 3$ for beams and pipes.
SM*n*			•	Section moment component *n*, $n = 1, 2, 3$.
SE	•	•	•	All section nominal strains, both translational and rotational (e.g., midplane strain and curvature in shells).
SE*n*			•	Section nominal strain component *n*, $n = 1, 2, 3, 4, 5, 6$ for shells; $n = 1, 2, 3$ for beams and pipes.
SK*n*			•	Section curvature change or twist *n*, $n = 1, 2, 3$.

Identifier	.fil	.odb		Description
		Field	History	
SSAVG	•	•		All average membrane and transverse shear stress components (shell elements only).
SSAVG*n*			•	Average membrane or transverse shear stress component n, $n = 1, 2, 3, 4, 5, 6$ (shell elements only).

Whole element variables

You can request whole element variable output to the results or output database file (see "Element output" in "Output to the data and results files," Section 4.1.2, and "Element output" in "Output to the output database," Section 4.1.3).

Identifier	.fil	.odb		Description
		Field	History	
ELEN	•	•	•	All energy magnitudes in the element.
ELSE		•	•	Total elastic strain energy in the element (includes energy in transverse shear deformation in shells).
ELCD		•	•	Total energy dissipated in the element by viscoelastic deformation. (Not supported for hyperelastic and hyperfoam material models.)
ELPD		•	•	Total energy dissipated in the element by rate-independent and rate-dependent plastic deformation.
ELVD		•	•	Total energy dissipated in the element by viscous effects. This includes bulk viscosity and material damping.
ELASE		•	•	Total "artificial" strain energy in the element. This includes hourglass energy and drilling stiffness energy in shells.
ELIHE		•	•	Internal heat energy in the element.
ELDMD		•	•	Total energy dissipated in the element by damage.
ELDC		•	•	Total energy dissipated in the element by distortion control.
ELEDEN		•		All element energy density components.
ESEDEN		•		Total elastic strain energy density in the element.
EPDDEN		•		Total energy dissipated per unit volume in the element by rate-independent and rate-dependent plastic deformation.

Identifier	.fil	.odb Field	.odb History	Description
ECDDEN		•		Total energy dissipated per unit volume in the element by viscoelasticity.
EVDDEN		•		Total energy dissipated per unit volume in the element by viscous effects.
EASEDEN		•		Total “artificial” strain energy density in the element (energy associated with constraints used to remove singular modes, such as hourglass control).
EIHEDEN		•		Internal heat energy density in the element.
EDMDDEN		•		Total energy dissipated per unit volume in the element by damage.
EDCDEN		•		Total energy dissipated per unit volume in the element by distortion control.
EDT	•	•	•	Element stable time increment.
EMSF	•	•	•	Element mass scaling factor.
STATUS	•	•	•	Status of element (material failure with progressive damage, shear failure model, tensile failure model, porous failure criterion, brittle failure model, Johnson-Cook plasticity model, and **VUMAT**). The status of an element is 1.0 if the element is active, 0.0 if the element is not.
EVOL		•		Current element volume. (Only available for continuum and structural elements not using general beam or shell section definitions.)
NFORC		•	•	Forces at the nodes of an element from both the hourglass and the regular deformation modes of that element (negative of the internal forces in the global coordinate system).
GRAV		•		Uniformly distributed gravity load.
SBF		•		Stagnation body force.
BF		•		Uniformly distributed body force, including viscous body force.
EDMICRTMAX		•		

Identifier	.fil	.odb Field	.odb History	Description
				Whole shell element maximum damage initiation output among all of the layers, all of the damage initiation criteria, and for fully integrated elements across all of the integration points. This output variable is the same as DMICRTMAX output for solid and beam elements but complements the DMICRTMAX output variable for composite shell elements because it extracts the maximum damage initiation across all of the layers. This output variable generates four element output quantities as follows: EDMICRTMAXVAL outputs the maximum damage initiation value in the entire element. EDMICRTLAYER outputs the layer number in which the maximum damage initiation value occurred. EDMICRTTYPE outputs a value that represents the damage initiation criteria type that reached the maximum value in the element, as described in the DMICRTMAX output variable description. EDMICRTINTP outputs the integration point number for which the maximum damage value occurred. For reduced-integration elements, the output value is one. The maximum damage initiation output values are retained across the requested output frames until a higher maximum damage initiation value is computed.
Connector elements				
CTF	•	•	•	All components of connector total forces and moments.
CTF*n*			•	Connector total force component *n* ($n = 1, 2, 3$).
CTM*n*			•	Connector total moment component *n* ($n = 1, 2, 3$).
CEF	•	•	•	All components of connector elastic forces and moments.
CEF*n*			•	Connector elastic force component *n* ($n = 1, 2, 3$).
CEM*n*			•	Connector elastic moment component *n* ($n = 1, 2, 3$).

Identifier	.fil	.odb		Description
		Field	History	
CUE	•	•	•	Elastic displacements and rotations in all directions.
CUE*n*			•	Elastic displacement in the *n*-direction ($n = 1, 2, 3$).
CURE*n*			•	Elastic rotation in the *n*-direction ($n = 1, 2, 3$).
CUP	•	•	•	Plastic relative displacements and rotations in all directions.
CUP*n*			•	Plastic relative displacement in the *n*-direction ($n = 1, 2, 3$).
CURP*n*			•	Plastic relative rotation in the *n*-direction ($n = 1, 2, 3$).
CUPEQ	•	•	•	Equivalent plastic relative displacements and rotations in all directions, and equivalent plastic relative motion for a coupled plasticity definition.
CUPEQ*n*			•	Equivalent plastic relative displacement in the *n*-direction ($n = 1, 2, 3$).
CURPEQ*n*			•	Equivalent plastic relative rotation in the *n*-direction ($n = 1, 2, 3$).
CUPEQC			•	Equivalent plastic relative motion for a coupled plasticity definition.
CALPHAF	•		•	All components of connector kinematic hardening shift forces and moments.
CALPHAF*n*			•	Connector kinematic hardening shift force component *n* ($n = 1, 2, 3$).
CALPHAM*n*			•	Connector kinematic hardening shift moment component *n* ($n = 1, 2, 3$).
CVF	•	•	•	All components of connector viscous forces and moments.
CVF*n*			•	Connector viscous force component *n* ($n = 1, 2, 3$).
CVM*n*			•	Connector viscous moment component *n* ($n = 1, 2, 3$).
CUF		•	•	All components of connector uniaxial forces and moments.
CUF*n*			•	Connector uniaxial force component *n* ($n = 1, 2, 3$).
CUM*n*			•	Connector uniaxial moment component *n* ($n = 1, 2, 3$).
CSF	•		•	All components of connector friction forces and moments.
CSF*n*			•	Connector friction force component *n* ($n = 1, 2, 3$).
CSM*n*			•	Connector friction moment component *n* ($n = 1, 2, 3$).

Identifier	.fil	.odb Field	.odb History	Description
CSFC			•	Connector friction force in the instantaneous slip direction. Available only if friction is defined in the slip direction.
CNF	•		•	All components of connector friction-generating contact forces and moments.
CNF*n*			•	Connector friction-generating contact force component *n* (*n* = 1, 2, 3).
CNM*n*			•	Connector friction-generating contact moment component *n* (*n* = 1, 2, 3).
CNFC			•	Connector friction-generating contact force in the instantaneous slip direction. Available only if friction is defined in the slip direction.
CDMG	•	•	•	All components of the overall damage variable.
CDMG*n*			•	Overall damage variable component *n* ($n = 1, 2, 3$).
CDMGR*n*			•	Overall damage variable component *n* ($n = 1, 2, 3$).
CDIF	•		•	Components of connector force-based damage initiation criterion in all directions.
CDIF*n*			•	Connector force-based damage initiation criterion in the *n*-translation direction ($n = 1, 2, 3$).
CDIFR*n*			•	Connector force-based damage initiation criterion in the *n*-rotation direction ($n = 1, 2, 3$).
CDIFC			•	Connector force-based damage initiation criterion in the instantaneous slip direction.
CDIM	•		•	Components of connector motion-based damage initiation criterion in all directions.
CDIM*n*			•	Connector motion-based damage initiation criterion in the *n*-translation direction ($n = 1, 2, 3$).
CDIMR*n*			•	Connector motion-based damage initiation criterion in the *n*-rotation direction ($n = 1, 2, 3$).
CDIMC			•	Connector motion-based damage initiation criterion in the instantaneous slip direction.
CDIP	•	•	•	Components of connector plastic motion-based damage initiation criterion in all directions (including the instantaneous slip direction).
CDIP*n*			•	Connector plastic motion-based damage initiation criterion in the *n*-translation direction ($n = 1, 2, 3$).

Identifier	.fil	.odb Field	.odb History	Description
CDIPR*n*			•	Connector plastic motion-based damage initiation criterion in the *n*-rotation direction ($n = 1, 2, 3$).
CDIPC			•	Connector plastic motion-based damage initiation criterion in the instantaneous slip direction.
CSLST	•		•	All flags for connector stop and connector lock status.
CSLST*i*			•	Flag for connector stop and connector lock status in the *i*-direction ($i = 1, ..., 6$).
CASU	•		•	Components of accumulated slip in all directions.
CASU*n*			•	Connector accumulated slip in the *n*-direction ($n = 1, 2, 3$).
CASUR*n*			•	Connector angular accumulated slip in the *n*-direction ($n = 1, 2, 3$).
CASUC			•	Connector accumulated slip in the instantaneous slip direction. Available only if friction is defined in the slip direction.
CIVC	•		•	Connector instantaneous velocity in the slip direction. Available only if friction is defined in the slip direction.
CRF	•		•	All components of connector reaction forces and moments.
CRF*n*			•	Connector reaction force component *n* ($n = 1, 2, 3$).
CRM*n*			•	Connector reaction moment component *n* ($n = 1, 2, 3$).
CCF	•		•	All components of connector concentrated forces and moments.
CCF*n*			•	Connector concentrated force component *n* ($n = 1, 2, 3$).
CCM*n*			•	Connector concentrated moment component *n* ($n = 1, 2, 3$).
CP	•	•	•	Relative positions in all directions.
CP*n*			•	Relative position in the *n*-direction ($n = 1, 2, 3$).
CPR*n*			•	Relative angular position in the *n*-direction ($n = 1, 2, 3$).
CU	•	•	•	Relative displacements and rotations in all directions.
CU*n*			•	Relative displacement in the *n*-direction ($n = 1, 2, 3$).
CUR*n*			•	Relative rotation in the *n*-direction ($n = 1, 2, 3$).

Identifier	.fil	.odb Field	.odb History	Description
CCU	•		•	Constitutive displacements and rotations in all directions.
CCU*n*			•	Constitutive displacement in the *n*-direction ($n = 1, 2, 3$).
CCUR*n*			•	Constitutive rotation in the *n*-direction ($n = 1, 2, 3$).
CV	•	•	•	Relative velocities in all directions.
CV*n*			•	Relative velocity in the *n*-direction ($n = 1, 2, 3$).
CVR*n*			•	Relative angular velocity in the *n*-direction ($n = 1, 2, 3$).
CA	•	•	•	Relative accelerations in all directions.
CA*n*			•	Relative acceleration in the *n*-direction ($n = 1, 2, 3$).
CAR*n*			•	Relative angular acceleration in the *n*-direction ($n = 1, 2, 3$).
CFAILST	•	•	•	All flags for connector failure status.
CFAILST*i*			•	Flag for connector failure status in the *i*-direction ($i = 1, ..., 6$).
CDERU		•	•	Connector derived displacement.
CDERF		•	•	Connector derived force.

Element face variables

You can request element face variable output to the output database file (see "Element output" in "Output to the output database," Section 4.1.3). These variables are available only for shell, membrane, and solid elements.

Identifier	.fil	.odb Field	.odb History	Description
P		•		Uniformly distributed pressure load on element faces. When the pressure is defined using *DLOAD, the variable name is changed automatically to PDLOAD.
STAGP		•		Stagnation pressure load on element faces.
VP		•		Viscous pressure load on element faces.
IWCONWEP		•		Air blast pressure load from the CONWEP model on element faces.
TRNOR		•		Normal component (component along face normal) of traction load on element faces.

Identifier	.fil	.odb		Description
		Field	History	
TRSHR		•		Shear component (component along face tangent) of traction load on element faces.

Nodal variables

You can request nodal variable output to the results or output database file (see "Node output" in "Output to the data and results files," Section 4.1.2, and "Node output" in "Output to the output database," Section 4.1.3).

Identifier	.fil	.odb		Description
		Field	History	
COORD	•	•	•	Coordinates of the node. These are the current coordinates if the large-displacement formulation is being used.
COOR*n*			•	Coordinate *n* ($n = 1, 2, 3$).
U	•	•	•	Displacement components. Results file and field-type output: both translation and rotation. History-type output: translation only. Rotation results should be requested by components.
UT		•	•	Translational displacement components.
UR		•	•	Rotational displacement components.
U*n*			•	u_n displacement component ($n = 1, 2, 3$).
UR*n*			•	ϕ_n rotation component ($n = 1, 2, 3$).
V	•	•	•	Velocity components (both translation and rotation). Results file and field-type output: both translation and rotation. History-type output: translation only. Rotation results should be requested by components.
VT		•	•	Translational velocity components.
VR		•	•	Rotational velocity components.
V*n*			•	$\dot{u}_n$ velocity component ($n = 1, 2, 3$).
VR*n*			•	$\dot{\phi}_n$ rotational velocity component ($n = 1, 2, 3$).

Identifier	.fil	.odb		Description
		Field	History	
A	•	•	•	Acceleration components (both translation and rotation). Results file and field-type output: both translation and rotation. History-type output: translation only. Rotation results should be requested by components.
AT		•	•	Translational acceleration components.
AR		•	•	Rotational acceleration components.
A*n*			•	$\ddot{u}_n$ acceleration component ($n = 1, 2, 3$).
AR*n*			•	$\ddot{\phi}_1$ rotational acceleration component ($n = 1, 2, 3$).
POR	•	•	•	Acoustic pressure at a node.
PABS	•	•	•	Acoustic absolute pressure at a node.
NT	•	•	•	All temperature values at a node. Available only for coupled thermal-stress analysis.
NT*n*			•	Temperature degree of freedom *n* at a node ($n = 11$). Available only for coupled thermal-stress analysis.
RF	•	•	•	Reaction force and moment components. Results file and field-type output: both translation and rotation. History-type output: translation only. Rotation results should be requested by components.
RT		•	•	Reaction force components.
RM		•	•	Reaction moment components.
RF*n*			•	Reaction force component *n* ($n = 1, 2, 3$) (conjugate to prescribed displacement u_n).
RFL	•	•	•	All reaction flux values. Available only for coupled thermal-stress analysis.
RFL*n*		•	•	Reaction flux value *n* at a node ($n = 11$). Available only for coupled thermal-stress analysis.
RM*n*			•	Reaction moment component *n* ($n = 1, 2, 3$) (conjugate to prescribed rotation ϕ_n).
CF		•	•	All components of point loads and concentrated moments.
CF*n*			•	Point load component *n* ($n = 1, 2, 3$).

Identifier	.fil	.odb Field	.odb History	Description
CM*n*			•	Point moment component *n* ($n = 1, 2, 3$).
NVF		•		Nodal volume fraction.
STRAINFREE		•		Strain-free adjustments to initial positions (adjusted position minus unadjusted position). Only written to the output database (**.odb**) file for the original field output frame at zero time.
TIEDSTATUS		•		Status of the tied slave nodes (the status of a slave node is 2 if the slave node is not tied, 1 if the slave node is tied, and 0 for nodes that do not participate in a tie constraint).
TIEADJUST		•		Position adjustment vector components of the tied slave nodes. Only written to the output database (**.odb**) file for the original field output frame at zero time.
Fluid cavity variables				
PCAV	•		•	Fluid cavity gauge pressure.
CVOL	•		•	Fluid cavity volume.
CTEMP			•	Fluid cavity temperature for an ideal gas model used under adiabatic conditions.
CSAREA			•	Fluid cavity surface area.
CLAREA			•	Fluid cavity unblocked leakage area.
CBLARAT			•	Ratio of the blocked leakage area to the unblocked leakage area.
CMASS			•	Mass of the fluid contained in a fluid cavity.
APCAV			•	Average gauge pressures for multiple fluid cavities.
TCVOL			•	Total volume of multiple fluid cavities.
ACTEMP			•	Average fluid cavity temperature for an ideal gas model used under adiabatic conditions for multiple fluid cavities.
TCSAREA			•	Total surface area of multiple fluid cavities.
TCMASS			•	Total mass of the fluid contained in the multiple fluid cavities.
CMF			•	Molecular mass fraction of fluid species contained in a fluid cavity.
CMFL			•	Mass flow rate out of a fluid cavity.

Identifier	.fil	.odb Field	.odb History	Description
CMFLT			•	Accumulated mass flow out of a fluid cavity.
CEFL			•	Heat energy flow rate out of a fluid cavity.
CEFLT			•	Accumulated heat energy flow out of a fluid cavity.
MINFL			•	Inflator mass flow rate into a fluid cavity.
MINFLT			•	Accumulated inflator mass flow into a fluid cavity.
TINFL			•	Inflator temperature.

Surface variables

You can request surface variable output to the output database file (see "Surface output in Abaqus/Standard and Abaqus/Explicit" in "Output to the output database," Section 4.1.3); additional information on these variables is provided in "Defining general contact interactions in Abaqus/Explicit," Section 36.4.1; "Defining contact pairs in Abaqus/Explicit," Section 36.5.1; and "Thermal contact properties," Section 37.2.1.

Identifier	.fil	.odb Field	.odb History	Description
Mechanical analysis–nodal quantities				
CFORCE		•		Contact normal force (CNORMF) and frictional shear force (CSHEARF).
CSTRESS		•		Contact pressure (CPRESS) and frictional shear stress (CSHEAR). CSHEAR is not available for general contact analyses.
CTHICK		•		Contact thickness in general contact or contact pairs.
CSMAXSCRT		•		Maximum stress-based damage initiation criterion for cohesive surfaces in general contact.
CSQUADSCRT		•		Quadratic stress-based damage initiation criterion for cohesive surfaces in general contact.
CSMAXUCRT		•		Maximum separation-based damage initiation criterion for cohesive surfaces in general contact.
CSQUADUCRT		•		Quadratic separation-based damage initiation criterion for cohesive surfaces in general contact.
CSDMG		•		Damage variable for cohesive surfaces in general contact.

Identifier	.fil	.odb Field	.odb History	Description
FSLIP		•		Length of contact slip path at slave nodes during contact (FSLIPEQ) and in some cases (see "Defining contact pairs in Abaqus/Explicit," Section 36.5.1) components of net contact slip in local tangent directions (FSLIP1 and FSLIP2). These variables remain constant while a slave node is not in contact.
FSLIPR		•		Magnitude of contact slip rate at slave nodes during contact (FSLIPR) and in some cases (see "Defining contact pairs in Abaqus/Explicit," Section 36.5.1) components of contact slip rate in local tangent directions (FSLIPR1 and FSLIPR2). These variables are set to zero while a slave node is not in contact.
BONDSTAT			•	Spot weld bond status.
BONDLOAD			•	Spot weld bond load.
Crack bond failure quantities				
DBT		•		Time when bond failure occurs.
DBS		•		All components of remaining stress in the failed bond.
DBSF		•		Fraction of stress that remains at bond failure.
BDSTAT		•		Bond state (the state is 1.0 if bonded, 0.0 if unbonded).
OPENBC		•		Relative displacement behind crack when fracture criterion is met.
CRSTS		•		All components of critical stress at failure.
ENRRT		•		All components of strain energy release rate.
EFENRRTR		•		Effective energy release rate ratio.
Mechanical analysis–whole surface quantities				
CFN			•	Total force due to contact pressure (CFNn, n = 1, 2, 3).
CFNM			•	Magnitude of total force due to contact pressure.
CFS			•	Total force due to frictional stress (CFSn, n = 1, 2, 3).
CFSM			•	Magnitude of total force due to frictional stress.
CFT			•	Total force due to contact pressure and frictional stress (CFTn, n = 1, 2, 3).
CFTM			•	Magnitude of total force due to contact pressure and frictional stress.
CMN			•	Total moment about the origin due to contact pressure (CMNn, n = 1, 2, 3).

Identifier	.fil	.odb Field	.odb History	Description
CMNM			•	Magnitude of total moment about the origin due to contact pressure.
CMS			•	Total moment about the origin due to frictional stress (CMS*n*, *n* = 1, 2, 3).
CMSM			•	Magnitude of total moment about the origin due to frictional stress.
CMT			•	Total moment about the origin due to contact pressure and frictional stress (CMT*n*, *n* = 1, 2, 3).
CMTM			•	Magnitude of total moment about the origin due to contact pressure and frictional stress.
CAREA			•	Total area in contact.
XN			•	Center of the total force due to contact pressure (XN*n*, *n* = 1, 2, 3).
XS			•	Center of the total force due to frictional stress (XS*n*, *n* = 1, 2, 3).
XT			•	Center of the total force due to contact pressure and frictional stress (XT*n*, *n* = 1, 2, 3).
Fully coupled temperature-displacement analysis				
HFL		•		Heat flux per unit area leaving the surface.
HFLA		•		HFL multiplied by the nodal area.
HTL		•		Time integrated HFL.
HTLA		•		HTL multiplied by the nodal area.
SFDR		•		Heat flux per unit area due to frictional dissipation.
SFDRA		•		SFDR multiplied by the nodal area.
SFDRT		•		Time integrated SFDR.
SFDRTA		•		SFDRT multiplied by the nodal area.

Integrated variables

You can request integrated variable output to the output database (see "Integrated output in Abaqus/Explicit" in "Output to the output database," Section 4.1.3). The output quantity is computed by integration over a surface or an element set that is specified either directly in the integrated output request or by associating an integrated output section definition (see "Integrated output section definition," Section 2.5.1) or an element set definition with the integrated output request.

The components of the vector output variables are given with respect to a global coordinate system when no integrated output section definition is associated with the integrated output request. When an integrated output section is associated with the integrated output request and a local coordinate system is

defined for the integrated output section, the components are given in the local system. The local system will rotate with the deformation if a reference node with rotation degrees of freedom is associated with the section definition.

Identifier	.fil	.odb Field	.odb History	Description
SOAREA			•	Area of the surface as projected onto a plane normal to the average surface normal.
SOF			•	Total force transmitted through the surface.
SOM			•	Total moment transmitted through the surface. The moment of the forces transmitted through the surface is taken about the current location of the reference node if one is specified on an integrated output section and is associated with the integrated output request. The moment is taken about the global origin either if no section definition is associated with the integrated output request or if there is no reference node defined in the associated section definition.
MASS			•	Total mass of the element set.
DMASS			•	Total mass change in percentage of the element set due to mass scaling.
UCOM			•	Equivalent rigid-body translational displacement of the element set.
VCOM			•	Equivalent rigid-body translational velocity of the element set.
ACOM			•	Equivalent rigid-body translational acceleration of the element set.
COORDCOM			•	Coordinates of the center of mass of the element set.
MASSEUL			•	Total mass of each Eulerian material instance in the element set.
VOLEUL			•	Total volume of each Eulerian material instance in the element set.

Total energy output

You can request total energy variable output to the results or output database file (see "Total energy output" in "Output to the data and results files," Section 4.1.2, and "Total energy output" in "Output to the output database," Section 4.1.3). All of these variables are written when total energy output is requested. Energy history totals can be requested to the output database for part of the model as well as the whole model.

Identifier	.fil	.odb Field	.odb History	Description
ALLAE	•		•	"Artificial" strain energy associated with constraints used to remove singular modes (such as hourglass control) and with constraints used to make the drill rotation follow the in-plane rotation of the shell elements.
ALLCD	•		•	Energy dissipated by viscoelasticity. (Not supported for hyperelastic and hyperfoam material models).
ALLFD	•		•	Total energy dissipated through frictional effects. (Available only for the whole model).
ALLIE	•		•	Total strain energy. (ALLIE=ALLSE + ALLPD + ALLCD + ALLAE + ALLDMD+ ALLDC+ ALLFC.)
ALLKE	•		•	Kinetic energy.
ALLPD	•		•	Energy dissipated by rate-independent and rate-dependent plastic deformation.
ALLSE	•		•	Recoverable strain energy.
ALLVD	•		•	Energy dissipated by viscous effects.
ALLWK	•		•	External work. (Available only for the whole model).
ALLIHE	•		•	Internal heat energy.
ALLHF	•		•	External heat energy through external fluxes.
ALLDMD	•		•	Energy dissipated by damage.
ALLDC	•		•	Energy dissipated by distortion control.
ALLFC			•	Fluid cavity energy, defined as the negative of the work done by all fluid cavities. (Available only for the whole model.)
ALLPW			•	Work done by contact penalties, including general contact and penalty/kinematic contact pairs. (Available only for the whole model.)
ALLCW			•	Work done by constraint penalties. (Available only for the whole model.)
ALLMW			•	Work done in propelling mass added in mass scaling. (Available only for the whole model.)
ETOTAL	•		•	Energy balance defined as: ALLKE + ALLIE + ALLVD + ALLFD + ALLIHE − ALLWK − ALLPW − ALLCW − ALLMW − ALLHF. (Available only for the whole model.)

Time increment and mass output

The DT and DMASS variables are always written when any results file output is requested (see "Output to the Abaqus/Explicit results file" in "Output to the data and results files," Section 4.1.2). You can request output of the time increment and the steady-state detection variables SSPEEQ, SSSPRD, SSFORC, and SSTORQ to the output database (see "Time incrementation output in Abaqus/Explicit" in "Output to the output database," Section 4.1.3).

Identifier	.fil	.odb		Description
		Field	History	
DT	•		•	Time increment.
DMASS	•		•	Percent change in mass of the model due to mass scaling.
SSPEEQ			•	Steady-state equivalent plastic strain norms.
SSPEEQ*n*			•	Steady-state equivalent plastic strain norm *n*.
SSSPRD			•	Steady-state spread strain norms.
SSSPRD*n*			•	Steady-state spread norm *n*.
SSFORC			•	Steady-state force norms.
SSFORC*n*			•	Steady-state force norm *n*.
SSTORQ			•	Steady-state torque norms.
SSTORQ*n*			•	Steady-state torque norm *n*.

4.2.3 Abaqus/CFD OUTPUT VARIABLE IDENTIFIERS

Products: Abaqus/CFD Abaqus/CAE

References

- "Output," Section 4.1.1
- "Output to the data and results files," Section 4.1.2
- "Output to the output database," Section 4.1.3

Overview

Results can be obtained from Abaqus/CFD only by postprocessing.

The tables in this section list all of the output variables that are available in Abaqus/CFD. The output variables can be requested for either field- or history-type output to the output database (**.odb**) file (see "Output to the output database," Section 4.1.3). The field type variables can be requested at the nodes, elements, or element faces attached to a surface.

Symbols used in the tables

The availability of the various output variable identifiers is defined by a • in the columns of the table, under the following headings:

.odb Field

means that the identifier can be used as a field-type output selection to the output database.

.odb History

means that the identifier can be used as a history-type output selection to the output database.

Direction definitions

The direction definitions depend on the variable type.

Direction definitions for element variables

For element variables, 1, 2, and 3 refer to the global directions (1=*X*, 2=*Y*, and 3=*Z*). Even if a local coordinate system has been defined at a node ("Transformed coordinate systems," Section 2.1.5), the data are still output in the global directions.

Direction definitions for nodal variables

For nodal variables, 1, 2, and 3 refer to the global directions (1=*X*, 2=*Y*, and 3=*Z*). Even if a local coordinate system has been defined at a node ("Transformed coordinate systems," Section 2.1.5), the data are still output in the global directions.

Requesting output of components

Individual components of variables can be requested as history-type output in the output database for *X–Y* plotting in Abaqus/CAE. Individual component requests are not available for field-type output. If a particular component is desired for contouring in Abaqus/CAE, request field output of the generic variable (e.g., V for velocity). Output for individual components of this field output can then be requested within the Visualization module of Abaqus/CAE.

Element variables

You can request element variable output to the output database file (see "Element output" in "Output to the output database," Section 4.1.3).

Identifier	.odb Field	.odb History	Description
Geometric quantities			
COORD	•	•	Coordinates of the element centroid for solid elements. These are the current coordinates if the mesh has moved.
EVOL	•	•	Element volume.
State and field variables			
DENSITY	•	•	Fluid density.
DIV	•	•	Divergence of the fluid velocity.
ENSTROPHY	•	•	Enstrophy per unit mass.
HELICITY	•	•	Dot product of vorticity and velocity.
PRESSURE	•	•	Fluid pressure.
TEMP	•	•	Fluid temperature.
V	•	•	Fluid velocity.
VGINV2	•		Second invariant of the rate-of-strain tensor (symmetric part of the velocity gradient tensor).
VORTICITY	•	•	Curl of the velocity vector.
VISCOSITY	•		Element molecular viscosity.
SHEARRATE	•		Shear rate computed using the second invariant of the rate-of-strain tensor.
Turbulence variables			
DIST	•	•	Wall-normal distance.
TURBEPS	•	•	Energy dissipation rate.

Identifier	.odb Field	.odb History	Description
TURBKE	•	•	Turbulent kinetic energy.
TURBNU	•	•	Turbulent eddy viscosity.

Nodal variables

You can request nodal variable output to the output database file (see "Node output" in "Output to the output database," Section 4.1.3).

Identifier	.odb Field	.odb History	Description
Geometric quantities			
COORD	•		Coordinates of the node. These are the current coordinates if the mesh has moved.
COOR*n*	•		Coordinate *n* ($n = 1, 2, 3$).
State and field variables			
DENSITY	•		Fluid density at a node.
DIV	•		Divergence of the fluid velocity at a node.
ENSTROPHY	•		Enstrophy per unit mass at a node.
HELICITY	•		Helicity at a node.
PRESSURE	•		Fluid pressure at a node.
TEMP	•		Fluid temperature at a node.
U	•		Fluid displacement components at a node.
U*n*	•		u_n fluid displacement component ($n = 1, 2, 3$).
V	•		Fluid velocity components at a node.
V*n*	•		$\dot{u}_n$ fluid velocity component ($n = 1, 2, 3$).
VGINV2	•		Second invariant of the rate-of-strain tensor (symmetric part of the velocity gradient tensor).
VORTICITY	•		Vorticity components at a node.
VORTICITY*n*	•		Vorticity$_n$ vorticity component ($n = 1, 2, 3$).
SHEARRATE	•		Shear rate at the nodes computed using the second invariant of the rate-of-strain tensor.
Turbulence variables			
DIST	•		Wall-normal distance.
TURBEPS	•		Energy dissipation rate.

Identifier	.odb Field	.odb History	Description
TURBKE	•		Turbulent kinetic energy.
TURBNU	•		Turbulent eddy viscosity at a node.

Surface variables

You can request surface variable output to the output database file (see "Surface output in Abaqus/CFD" in "Output to the output database," Section 4.1.3). The field output corresponds to the element faces attached to a surface.

Identifier	.odb Field	.odb History	Description
Geometric quantities			
SURFAREA		•	Area of a surface. For deforming meshes, it is the surface area in the current configuration.
State and field variables			
AVGPRESS		•	Area-averaged surface pressure.
AVGTEMP		•	Area-averaged surface temperature.
AVGVEL		•	Area-averaged surface velocity vector.
FORCE		•	Total fluid force components on the surface.
HEATFLOW		•	Integrated normal heat flux on a given surface. Heat flow is considered positive if heat is added to the system and negative otherwise.
HFL	•		Heat flux vector on a surface.
HFLN	•		Normal heat flux on a surface.
MASSFLOW		•	Integrated mass flow rate across a given surface.
NTRACTION	•		Fluid normal traction on a surface.
PRESSFORCE		•	Fluid pressure force on a given surface.
STRACTION	•		Fluid surface (or shear) traction on a surface.
TRACTION	•		Fluid total traction on a surface. This is equal to the sum of the normal traction (NTRACTION) and the shear traction (STRACTION).
VISCFORCE		•	Fluid viscous force on a given surface.
VOLFLOW		•	Integrated volume flow rate across a given surface.
WALLSHEAR	•		Fluid shear stress magnitude on a surface. It is the magnitude of the shear traction (STRACTION) vector.

Identifier	.odb Field	.odb History	Description
Turbulence variables			
YPLUS	•		Wall-normal distance measured in viscous lengths or wall units. A default value of 0 is output for surfaces that are not attached to a wall boundary.
YSTAR	•		Wall-normal distance scaled using turbulent kinetic energy and viscosity. YSTAR output is available only when TYPE=RNG KEPSILON is specified. A default value of 0 is output for surfaces that are not attached to a wall boundary.

Whole and partial model variables

The output variables listed below are available for part of the model as well as the whole model.

Identifier	.odb Field	.odb History	Description
Geometric quantities			
VOL	•		Current volume of the entire set or the entire model.
Total energy output quantities			

If the following whole model variables are relevant for a particular analysis, you can request them as output to the output database file (see “Total energy output” in “Output to the output database,” Section 4.1.3). If you do not specify an output region, whole model variables are calculated. When you specify an output region, the relevant energy totals are calculated over the user-specified region.

ALLKE		•	Kinetic energy.

4.3 The postprocessing calculator

- “The postprocessing calculator,” Section 4.3.1

4.3.1 THE POSTPROCESSING CALCULATOR

Products: Abaqus/Standard Abaqus/Explicit

References

- "Output to the output database," Section 4.1.3
- "Abaqus/Standard output variable identifiers," Section 4.2.1
- "Abaqus/Explicit output variable identifiers," Section 4.2.2
- "Abaqus/Standard, Abaqus/Explicit, and Abaqus/CFD execution," Section 3.2.2

Overview

The postprocessing calculator can perform operations on output quantities written to the output database (*job-name*`.odb`) by Abaqus. It then expands the output database by writing these new output quantities to the output database. Once this expansion is done, it is not possible to convert the output database back to its original form. The postprocessing calculator is for use only with the Visualization module of Abaqus/CAE (Abaqus/Viewer).

Functionality of the calculator

The postprocessing calculator performs the following calculations on data written to the output database:

- Extrapolation of integration point quantities to the nodes or interpolation of integration point quantities to the centroid of an element, according to the user-specified position for element output; see "Selecting the position of element integration point and section point output" in "Output to the output database," Section 4.1.3, for details.
- Calculation of history output at tracer particles; see "Tracer particle output from Abaqus/Explicit" in "Output to the output database," Section 4.1.3.

Running the calculator

By default, the postprocessing calculator will run automatically upon the completion of an analysis. During the execution of the analysis, Abaqus will determine if there are keywords in the input file that require the use of the calculator and will initiate the calculator upon completion if it is required. You can override this default behavior by using the environment variable **auto_calculate** in the Abaqus environment file. See "Using the Abaqus environment settings," Section 3.3.1, for details.

You can run the postprocessing calculator manually by using the **convert**=`odb` option on the **abaqus** execution procedure.

To see the postprocessed results before an analysis is complete, you can run the postprocessing calculator manually while the analysis is still running, using the **oldjob** option in conjunction with the **convert**=`odb` option on the **abaqus** execution procedure. The postprocessing calculator will write a new output database using the value of the **job** parameter as the file name. Due to the fact that the

analysis is writing to the output database at the same time the postprocessing calculator is attempting to read it, the output database may be in an inconsistent state that makes reading it impossible. If this problem occurs, the postprocessing calculator will stop attempting to read the output database and exit. A warning message explaining what has happened will be output to the screen. You can then attempt to run the postprocessing calculator again. If the inconsistent state has cleared, the postprocessing calculator will run normally.

If the postprocessing calculator is run during an analysis without the **oldjob** option, Abaqus will ask you to confirm that the existing output database can be overwritten. You should make sure the analysis is complete before running the postprocessing calculator manually without the **oldjob** option. If the analysis is still running when the postprocessing calculator is run without using the **oldjob** option, the output database will be corrupted.

For a detailed description of the procedure for running the postprocessing calculator manually, see "Abaqus/Standard, Abaqus/Explicit, and Abaqus/CFD execution," Section 3.2.2.

If an analysis aborts because available CPU time has expired and you restart the analysis, the postprocessing calculator will not automatically expand the output database from the original, aborted run. You must manually run the postprocessing calculator to expand the original output database using the procedure outlined above.

5. File Output Format

5.1 Accessing the results file

5.1.1 ACCESSING THE RESULTS FILE: OVERVIEW

Writing information to the results file

The Abaqus results file is the medium through which analysis results can be carried over into other software, such as postprocessing programs. The following types of output can be written to the results file:

- element output, nodal output, energy output, modal output, contact surface output, and section output (see "Output to the data and results files," Section 4.1.2)
- element matrix output (see "Element matrix output in Abaqus/Standard" in "Output," Section 4.1.1)
- substructure matrix output (see "Writing the recovery matrix, reduced stiffness matrix, mass matrix, load case vectors, and gravity vectors to a file" in "Defining substructures," Section 10.1.2)
- cavity radiation viewfactor matrices (see "Writing the viewfactor matrices to the results file" in "Cavity radiation," Section 41.1.1)

"Output," Section 4.1.1, describes the general format of the results file.

An Abaqus model can be defined in terms of an assembly of part instances (see "Defining an assembly," Section 2.10.1). However, the results file is not organized by part; it contains internal node and element numbers (see "Output," Section 4.1.1). A map between the original numbers and part instance names and the internal numbers is written to the data file.

Accessing information in the results file

This chapter contains technical descriptions of the results file and is intended to be read by users or programmers who need to write programs that use the results file.

- "Results file output format," Section 5.1.2, describes the format of the individual records in the results file.
- "Accessing the results file information," Section 5.1.3, describes the subroutine calls required to read the file output, contains an example of a program written to use the Abaqus results file, and shows how you can write (or modify) a results file using the Abaqus file format.
- "Utility routines for accessing the results file," Section 5.1.4, describes the utility subroutines that can be used to access the results file.

5.1.2 RESULTS FILE OUTPUT FORMAT

Products: Abaqus/Standard Abaqus/Explicit

References

- "Accessing the results file: overview," Section 5.1.1
- "Abaqus/Standard output variable identifiers," Section 4.2.1
- "Abaqus/Explicit output variable identifiers," Section 4.2.2

Overview

This section describes the format of the individual records in the Abaqus results file. Where applicable, the output variable identifier used in writing a given value to the file is printed below the corresponding record type description. Records that are available only in Abaqus/Standard are designated with an $^{(S)}$; records that are available only in Abaqus/Explicit are designated with an $^{(E)}$. The record key for a particular record may differ between Abaqus/Standard and Abaqus/Explicit.

Record format

The results file is written as a sequential file. Each record has the following format:

Location	Length	Description
1	1	Record length (NW)
2	1	Record type key
3, 4...	$(NW - 2)$	Attributes

All words in the results file are of the same length, whether they contain integer, floating point number, or character string data. The word length is that of a double precision floating point number (8 bytes).

The attributes in a given record may depend on the element type being considered. For example, the stress components associated with three-dimensional shell elements are σ_{11}, σ_{22}, and σ_{12} (in local directions), while those associated with three-dimensional solids are σ_{xx}, σ_{yy}, σ_{zz}, σ_{xy}, σ_{xz}, and σ_{yz} (in global directions if no local orientation is specified). Thus, care must be used in interpreting the data when postprocessing the file output. Refer to Part VI, "Elements," for a definition of the ordering of element-dependent attributes.

In steady-state dynamic analyses, complex values are stored as the real components followed by the imaginary components. For example, the stress components associated with three-dimensional shell elements are $\Re(\sigma_{11})$, $\Re(\sigma_{22})$, and $\Re(\sigma_{12})$ followed by $\Im(\sigma_{11})$, $\Im(\sigma_{22})$, and $\Im(\sigma_{12})$.

In models that are defined in terms of an assembly of part instances, the results file contains internal (global) node and element numbers, as explained in "Output," Section 4.1.1. Part and assembly records are not included in the results file.

Local coordinate system

If the components of an element quantity are in local directions, a record of type 85 defining these directions is generated for each point at which component output is requested if the local coordinate directions were requested in Abaqus/Standard (see "Output of local directions to the results file" in "Output to the data and results files," Section 4.1.2) and automatically in Abaqus/Explicit. The local coordinate system may be inherent to the element, as is the case in shells and membranes, or may have been defined by a local orientation (see "Orientations," Section 2.2.5).

For shell elements a direction record is written for every material point in the section for which component output is requested, and a separate direction record is written for section forces and section strains. For geometrically nonlinear analysis in Abaqus/Standard the record contains the current, updated directions, except for small-strain shells, in which case the original directions are given. Direction output is not provided for trusses, two-dimensional beams, axisymmetric shells or membranes, or for values averaged at nodes.

Label record

Some record types include labels, such as element and node set names, written in A8 format. If a label exceeds 8 characters, an integer identifier will be written instead. This identifier can then be used to cross-reference the actual label stored in 10A8 format on record type 1940.

Records written for any file output request

Record key	Record type	Attributes
1900	Element definitions	1. Element number. 2. Element type (characters, A8 format, left justified). 3. First node on the element. 4. Second node on the element. 5. Etc.
1990$^{(S)}$	Element definition continuation	1. Node on the element in the previous 1900 record. 2. Etc.

In Abaqus/Explicit quadrilateral/brick elements that are degenerate (i.e., possessing identical nodes) are written out in record 1900 as corresponding triangular/tetrahedral/wedge elements. For example, a CPE4R element with two identical nodes is written as a CPE3 element, and a C3D8R element with identical third and fourth nodes and identical seventh and eighth nodes is written as a C3D6 element.

1901	Node definitions	1. Node number. 2. First coordinate. 3. Second coordinate. 4. Etc.

Record key	Record type	Attributes

Record key 1902 (below) defines the location of each active degree of freedom. For example, if the model contains only two-dimensional beam elements, the only active degrees of freedom are 1, 2, and 6. Therefore, this record would have the attributes (1, 2, 0, 0, 0, 3), meaning that degree of freedom 1 (u_x) is the first active variable at each node; degree of freedom 2 (u_y) is the second active variable at each node; degrees of freedom 3, 4, and 5 are not active in the model; and degree of freedom 6 is the third active variable at each node.

1902	Active degrees of freedom	1. Location in nodal arrays of degree of freedom 1 (0 if DOF 1 is not active in the model). 2. Location in nodal arrays of degree of freedom 2 (0 if DOF 2 is not active in the model). 3. Etc.
1910$^{(S)}$	Substructure path	1. 0 substructure enter record; 1 substructure leave record. 2. Element number on usage level. 3. Substructure type identifier (*Zn*). 4. Element number at the previous level if it is not the usage level. 5. Etc.
1911	Output request definition	1. Flag for element-based output (0), nodal output (1), modal output (2), or element set energy output (3). 2. Set name (node or element set) used in the request (A8 format). This attribute is blank if no set was specified. 3. Element type (only for element output, A8 format).
1921	Abaqus release, etc.	1. Abaqus release number (A8 format). 2. Date (2A8 format). 3. Date cont'd. 4. Time (A8 format). 5. Number of elements in the model. 6. Number of nodes in the model. 7. Typical element length in the model.
1922	Heading	1. Attributes 1–10. The heading entered as the first data line of the *HEADING option (A8 format). Equivalent to the job description in Abaqus/CAE.

Record key	Record type	Attributes
1931	Node set	1. Node set name (A8 format). In Abaqus/Explicit only node sets defined as part of the model definition are written. 2. First node in the node set. 3. Second node in the node set. 4. Etc.
1932	Node set continuation	1. Node number in the node set of the previous 1931 record. 2. Etc.
1933	Element set	1. Element set name (A8 format). In Abaqus/Explicit only element sets defined as part of the model definition are written. 2. First element in the element set. 3. Second element in the element set. 4. Etc.
1934	Element set continuation	1. Element number in the element set of the previous 1933 record. 2. Etc.
1940	Label cross-reference	1. Integer reference. 2. Label (10A8 format).

Record written once per eigenvalue in natural frequency extraction

Record key	Record type	Attributes
1980(S)	Modal	1. Eigenvalue number. 2. Eigenvalue. 3. Generalized mass. 4. Composite damping. 5. Participation factor for degree of freedom 1. 6. Effective mass for degree of freedom 1. 7. Participation factor for degree of freedom 2. 8. Effective mass for degree of freedom 2. 9. Etc.

Any nodal or element data after this record refer to the eigenvector, until a new record key 1980 or a record key 2001 is encountered. Eigenvalue output for substructures (see "Writing the recovery matrix, reduced stiffness matrix, mass matrix, load case vectors, and gravity vectors to a file" in "Defining substructures," Section 10.1.2) also uses these records to divide up elemental and nodal results. This record is written if

Record key	Record type	Attributes

there are any results file output requests for an eigenvalue buckling prediction or eigenfrequency extraction step. The generalized mass, etc. are not written for an eigenvalue buckling prediction step. This record is not written for a complex eigenfrequency extraction step.

Records written once per increment

Record key	Record type	Attributes
2000	Increment start record	1. Total time. 2. Step time. 3. Maximum creep strain-rate ratio (control of solution-dependent amplitude) in Abaqus/Standard; currently not used in Abaqus/Explicit. 4. Solution-dependent amplitude in Abaqus/Standard; currently not used in Abaqus/Explicit. 5. Procedure type: gives a key to the step type. See Table 5.1.2–1 at the end of this section. 6. Step number. 7. Increment number. 8. Linear perturbation flag in Abaqus/Standard: 0 if general step, 1 if linear perturbation step; currently not used in Abaqus/Explicit. 9. Load proportionality factor: nonzero only in static Riks steps; currently not used in Abaqus/Explicit. 10. Frequency (cycles/time) in a steady-state dynamic response analysis or steady-state transport angular velocity (rad/time) in a steady-state transport analysis; currently not used in Abaqus/Explicit. 11. Time increment. 12. Attributes 12–21. The step subheading entered as the first data line of the *STEP option (A8 format). Equivalent to the step description in Abaqus/CAE.

The following record is written once per increment, after all data records have been written for that increment.

2001	Increment end record	1. No attributes.

Record key	Record type	Attributes

Note: When binary format is used, the results file is written in blocks of 512 words for each increment. If there are fewer than 512 words in the last block of the current increment, record 2001 has zeros appended to it so that the total length of the block is 512. Hence, the length of record 2001 is 2 + the number of zeros appended. For an ASCII format results file record 2001 is extended to complete an 80 character logical record, and a logical record of 80 blank characters is added after this record. See "Accessing the results file information," Section 5.1.3.

Records written for any element file output request

These records contain data about element variables at integration points within the elements, at the centroid of elements, or at the nodes of an element.

Record key	Record type	Attributes
1	Element header record	1. Element number or the node number if the subsequent records contain nodal averaged element values. 2. Integration point number if the subsequent records contain integration point data. Node number if the subsequent records contain data at the nodes of the element. Integration plane number if the subsequent records contain centroidal values for CAXA and SAXA elements. 0 if the subsequent records contain centroidal values or nodal averaged values. 3. Section point number if this is a shell, beam, or layered solid element and the subsequent records contain data at a section point through the thickness. 0 for continuum elements and for section values in beams and shell elements. 4. Location identification. 0 if the subsequent records contain data at an integration point; 1 if the subsequent records contain values at the centroid of the element; 2 if the subsequent records contain data at the nodes of the element; 3 if the subsequent records contain data associated with rebar within an element; 4 if the subsequent records contain nodal averaged values; 5 if the subsequent records contain values associated with the whole element.

Record key	Record type	Attributes
		5. Rebar name if the subsequent records contain values associated with a named rebar. 6. Number of direct stresses at a point (**NDI**). 7. Number of shear stresses at a point (**NSHR**). 8. 0, currently not used in Abaqus/Standard; number of directions in which displacement or temperature gradients are computed in the element (**NDIR**) in Abaqus/Explicit. 9. Number of section force or section strain components (**NSFC**).
2	Temperature Output variable: TEMP	1. Temperature.
3(S)	Distributed load Output variable: LOADS	1. Load type. 2. Magnitude.
4(S)	Distributed flux Output variable: FLUXS	1. Flux type. 2. Magnitude.
5	Solution-dependent state variables Output variable: SDV	1. State variable 1. 2. State variable 2. 3. Etc. The record can have up to 80 words in ASCII format or 512 words in binary format. Repeat this record as often as necessary to output all active state variables in the model.
6(S)	Void ratio Output variable: VOIDR	1. Void ratio.
7(S)	Foundation pressure Output variable: FOUND	1. Foundation type. 2. Magnitude.
8(S)	Coordinates Output variable: COORD	1. First coordinate. 2. Etc.
9(S)	Field variables Output variable: FV	1. First field variable. 2. Etc.
10(S)	Nodal flux caused by heat Output variable: NFLUX	1. Node number. 2. First flux component. 3. Etc.
11	Stresses Output variable: S	1. First stress component. 2. Second stress component.

Record key	Record type	Attributes
		3. Etc. (See the element description in Part VI, "Elements," for a definition of the number and type of the components for the element type.)
475(S)	Average contact pressure (for link and three-dimensional line gasket elements) Output variable: CS11	1. Magnitude (available only when the gasket contact area is specified; see "Defining the contact area for average contact pressure output" in "Defining the gasket behavior directly using a gasket behavior model," Section 32.6.6).
12(S)	Stress invariants Output variable: SINV	1. Mises stress. 2. Tresca stress. 3. Hydrostatic pressure. 4. Currently not used. 5. Currently not used. 6. Currently not used. 7. Third stress invariant.
13	Section forces and moments Output variable: SF	1. First section force. 2. Second section force. 3. Etc. (See Part VI, "Elements," for a description of which section forces are available for each beam or shell element type.)
449(S)	Effective axial section force Output variable: ESF1	1. Effective axial section force for beams and pipes subjected to pressure loading.
14(S)	Energy densities Output variable: ENER	1. Strain energy. Elastic strain energy is the only energy density request available in eigenvalue extractions. None of the energy densities are available in modal procedures or direct-solution steady-state dynamics analyses. 2. Plastic dissipation. 3. Creep dissipation. 4. Viscous dissipation. 5. Electrostatic energy. 6. Energy dissipated due to electrical conduction. 7. Damage dissipation.
14(E)	Energy densities Output variable: ENER	1. Elastic strain energy. 2. Plastic dissipation. 3. Viscoelastic dissipation (not supported for hyperelastic and hyperfoam material models).

Record key	Record type	Attributes
		4. Viscous dissipation. 5. Currently not used. 6. Currently not used. 7. Damage dissipation.
15(S)	Nodal forces caused by stress Output variable: NFORC	1. Node number. 2. First force component. 3. Etc.
16(S)	Maximum section stresses	1. Maximum stress on section.

The order of the data and the number of data items for record 17 depends on the element type. For LS3S elements:

17(S)	*J*s, *K* for LS3S line springs Output variable: JK	1. *J* (*J*-integral). 2. *K* (stress intensity). 3. J^{el} (elastic part of *J*-integral). 4. J^{pl} (plastic part of *J*-integral).

For LS6 elements:

17(S)	*J*s, *K*s for LS6 line springs Output variable: JK	1. *J* (*J*-integral). 2. J^{el} (elastic part of *J*-integral). 3. J^{pl} (plastic part of *J*-integral). 4. K_I (Mode I stress intensity factor). 5. K_{II} (Mode II stress intensity factor). 6. K_{III} (Mode III stress intensity factor).
18(S)	Pore or acoustic pressure Output variable: POR	1. Liquid pressure.
19(S)	Energy summed over element Output variable: ELEN	1. Kinetic energy. 2. Strain energy. Elastic strain energy is the only whole element energy request available in eigenvalue extractions. None of the element energies are available in modal procedures or direct-solution steady-state dynamics analyses. 3. Plastic dissipation. 4. Creep dissipation. 5. Viscous dissipation, not including dissipation due to stabilization. 6. Static dissipation (due to stabilization). 7. Artificial strain energy.

Record key	Record type	Attributes
		8. Electrostatic energy. 9. Electrical energy dissipated in a conductor. 10. Damage dissipation.
19(E)	Energy summed over element Output variable: ELEN	1. Currently not used. 2. Strain energy. 3. Plastic dissipation. 4. Viscoelastic dissipation (not supported for hyperelastic and hyperfoam material models). 5. Viscous dissipation. 6. Artificial strain energy. 7. Distortion control dissipation. 8. Currently not used. 9. Internal heat energy. 10. Damage dissipation.
21	Total strain in Abaqus/Standard; infinitesimal strain in Abaqus/Explicit Output variable: E	1. First strain component. 2. Second strain component. 3. Etc. (See Part VI, “Elements,” for a definition of the components for a given element type.)
22	Plastic strains Output variable: PE	1. First plastic strain component. 2. Second plastic strain component. 3. Etc; followed by the equivalent plastic strain, actively yielding flag (yes or no, A8 format), and magnitude of plastic strain in Abaqus/Standard; followed by “0.0, UNUSED, 0.0” in Abaqus/Explicit for consistency with the length of the Abaqus/Standard record. (See Part VI, “Elements,” for a definition of the components for a given element type.)
23(S)	Creep strains (including swelling) Output variable: CE	1. First creep strain component. 2. Second creep strain component. 3. Etc; followed by the equivalent creep strain, volumetric swelling strain, and magnitude of creep strain.
24(S)	Total inelastic strains Output variable: IE	1. First inelastic strain component. 2. Second inelastic strain component. 3. Etc. (See the element description in Part VI, “Elements,” for a definition of the number and type of the components for the element type.)

Record key	Record type	Attributes
25(S)	Total elastic strains Output variable: EE	1. First elastic strain component. 2. Second elastic strain component. 3. Etc. (See the element description in Part VI, "Elements," for a definition of the number and type of the components for the element type.)
26	Unit normal to crack in concrete Output variable: CRACK	1. 11-component (if a 1D, 2D, or 3D analysis). 2. 12-component (if a 2D or 3D analysis). 3. 13-component (if a 3D analysis). 4. 21-component (if a 2D or 3D analysis). 5. 22-component (if a 2D or 3D analysis). 6. 23-component (if a 3D analysis). 7. 31-component (if a 3D analysis). 8. 32-component (if a 3D analysis). 9. 33-component (if a 3D analysis).
27	Section thickness Output variable: STH	1. Current section thickness for membranes and finite-strain shells in Abaqus/Standard and for plane stress elements, membranes, and all shells in Abaqus/Explicit.
28	Heat flux vector Output variable: HFL	1. Magnitude. 2. First component. 3. Second component. 4. Etc.
29	Section strains and curvatures Output variable: SE	1. First section strain. 2. Second section strain. 3. Etc. (See the element description in Part VI, "Elements," for a definition of what section strains are available for each beam or shell element type.)
30(S)	Deformation gradient Output variable: DG	1. F_{11}. 2. Etc. The record will have **NDI** diagonal components of $\mathbf{F}$, then **NSHR** above diagonal components (F_{12}, F_{13}, F_{23}), then **NSHR** below diagonal components (F_{21}, F_{31}, F_{32}), where **NDI** and **NSHR** are given in the element header record (record key 1). Available only for hyperelasticity, hyperfoam, and material models defined in user subroutine **UMAT**.

Record key	Record type	Attributes
31(S)	Concrete failure Output variable: CONF	1. Summary of the state of a concrete material point. This is the number of cracks or −1 if the concrete has crushed.
32(S)	Strain jumps at nodes Output variable: SJP	1. First strain jump component. 2. Second strain jump component. 3. Etc. (See the element description in Part VI, "Elements," for a definition of the number and type of the components for the element type.)
33(S)	Film Output variable: FILM	1. Type. 2. Sink temperature. 3. Film coefficient.
34(S)	Radiation Output variable: RAD	1. Type. 2. Sink temperature. 3. Radiation constant.
35(S)	Saturation (pore pressure analysis) Output variable: SAT	1. Saturation.
36(S)	Substresses (for ITT elements) Output variable: SS	1. First substress. 2. Second substress.
38(S)	Mass concentration (mass diffusion analysis) Output variable: CONC	1. Concentration.
446(S)	Amount of solute at the integration point (mass diffusion analysis) Output variable: ISOL	1. Amount of solute.
447(S)	Amount of solute in the current element (mass diffusion analysis) Output variable: ESOL	1. Amount of solute.
448(S)	Amount of solute in the element set or model (mass diffusion analysis) Output variable: SOL	1. Amount of solute.

The number of data items for record 39 depends on the element type. For pore pressure elements and mass diffusion analysis:

39(S)	Mass concentration flux vector Output variable: MFL	1. Magnitude. 2. First component.

Record key	Record type	Attributes
		3. Second component. 4. Etc.
For fluid link elements:		
39(S)	Mass flow rate Output variable: MFL	1. Current flow rate.
40(S)	Gel (pore pressure analysis) Output variable: GELVR	1. Gel volume ratio.
43(S)	Total fluid volume ratio Output variable: FLUVR	1. Total fluid volume ratio.
61(E)	Element status Output variable: STATUS	1. Status of element (shear failure model, tensile failure model, porous failure criterion, brittle failure model, Johnson-Cook plasticity model, and **VUMAT**). The status of an element is 1.0 if the element is active, 0.0 if the element is not.
73(E)	Equivalent plastic strain Output variable: PEEQ	1. Equivalent plastic strain. For crushable foam plasticity with volumetric hardening, it is the volumetric compacting plastic strain. For cap plasticity it is p_b (the cap position).
74(E)	Mean pressure stress Output variable: PRESS	1. Mean pressure stress.
75(E)	Mises equivalent stress Output variable: MISES	1. Mises stress.
79(S)	Creep strain rate ratio Output variable: RATIO	1. Current maximum ratio of creep strain rate and target creep strain rate.
79(E)	Volumetric strain rate Output variable: ERV	1. Volumetric strain rate.
80(S)	Solution-dependent amplitude value Output variable: AMPCU	1. Current value of the solution-dependent amplitude.
83(S)	Average shell section stresses Output variable: SSAVG	1. First section stress. 2. Second section stress. 3. Etc. (See Part VI, “Elements,” for a description of which section stresses are available for each shell element type.)

Record key	Record type	Attributes

The following record is generated in Abaqus/Standard when the local coordinate directions are requested, component output is requested for a material or section point, and the components are given in a local coordinate system (see "Output of local directions to the results file" in "Output to the data and results files," Section 4.1.2); it is generated automatically in Abaqus/Explicit when component output is requested for a material or a section point and the components are given in a local coordinate system. Only the first two directions are given; if needed, the third direction can be obtained as the cross product of the first two. The direction record is not generated for trusses, two-dimensional beams, axisymmetric shells or membranes, or for values averaged at nodes.

85	Local coordinate directions	1. First component of the first direction. 2. Second component of the first direction. 3. Third component of the first direction. 4. First component of the second direction. 5. Second component of the second direction. 6. Third component of the second direction.
86	Backstress for kinematic hardening plasticity Output variable: ALPHA	1. First α component. 2. Second α component. 3. Etc. (The number of components is equal to the number of stress components; see the element description in Part VI, "Elements.")
87(S)	User-defined output variables Output variable: UVARM	1. Output variable 1. 2. Output variable 2. 3. Etc.
88(S)	Thermal strains Output variable: THE	1. First thermal strain component. 2. Second thermal strain component. 3. Etc. (See the element description in Part VI, "Elements," for a definition of the number and type of the components for the element type.)
89	Logarithmic strains Output variable: LE	1. First logarithmic strain component. 2. Second logarithmic strain component. 3. Etc. (See the element description in Part VI, "Elements," for a definition of the number and type of the components for the element type.)
90	Nominal strains Output variable: NE	1. First nominal strain component. 2. Second nominal strain component.

Record key	Record type	Attributes
		3. Etc. (See the element description in Part VI, "Elements," for a definition of the number and type of the components for the element type.)
91(S)	Mechanical strain rates Output variable: ER	1. First strain rate component. 2. Second strain rate component. 3. Etc. (See the element description in Part VI, "Elements," for a definition of the number and type of the components for the element type.)
96(S)	Total mass flow through fluid link Output variable: MFLT	1. Magnitude.
97(S)	Pore fluid effective velocity vector Output variable: FLVEL	1. Magnitude. 2. First component. 3. Second component. 4. Etc.
476(E)	Scaling factor Output variable: EMSF	1. Element mass scaling factor.
477(E)	Element time increment Output variable: EDT	1. Element stable time increment.

Principal value records

For all principal values, the number of components equals **NDI** unless **NDI** equals 1, in which case the number of components equals **NDI** plus **NSHR**, where **NDI** and **NSHR** are given on the element header record. In the cases where **NDI** equals 2, only the in-plane values are given.

401	Principal stresses Output variable: SP	1. Minimum principal stress. 2. Etc.
402	Principal values of backstress tensor for kinematic hardening plasticity Output variable: ALPHAP	1. Minimum principal value. 2. Etc.
403	Principal strains Output variable: EP	1. Minimum principal strain. 2. Etc.
404	Principal nominal strains Output variable: NEP	1. Minimum principal nominal strain. 2. Etc.
405	Principal logarithmic strains Output variable: LEP	1. Minimum principal logarithmic strain. 2. Etc.

Record key	Record type	Attributes
406(S)	Principal mechanical strain rates Output variable: ERP	1. Minimum principal strain rate. 2. Etc.
407(S)	Principal values of deformation gradient Output variable: DGP	1. Minimum principal value. 2. Etc.
408(S)	Principal elastic strains Output variable: EEP	1. Minimum principal elastic strain. 2. Etc.
409(S)	Principal inelastic strains Output variable: IEP	1. Minimum principal inelastic strain. 2. Etc.
410(S)	Principal thermal strains Output variable: THEP	1. Minimum principal thermal strain. 2. Etc.
411(S)	Principal plastic strains Output variable: PEP	1. Minimum principal plastic strain. 2. Etc.
412(S)	Principal creep strains Output variable: CEP	1. Minimum principal creep strain. 2. Etc.
Records for porous metal plasticity		
413	Void volume fraction Output variable: VVF	1. f.
414	Void volume fraction (growth) Output variable: VVFG	1. f_{gr}.
415	Void volume fraction (nucleation) Output variable: VVFN	1. f_{nucl}.
416(S)	Relative density Output variable: RD	1. $r = 1 - f$
Records for brittle cracking		
421(E)	Cracking strains Output variable: CKE	1. First cracking strain component. 2. Second cracking strain component. 3. Etc. (See Part VI, “Elements,” for a definition of the number and the type of the components for the element type.)
422(E)	Local cracking strains Output variable: CKLE	1. First strain component in local crack directions. 2. Second strain component in local crack directions.

Record key	Record type	Attributes
		3. Etc. (See Part VI, "Elements," for a definition of the number and the type of the components for the element type.)
423(E)	Local cracking stresses Output variable: CKLS	1. First stress component in local crack directions. 2. Second stress component in local crack directions. 3. Etc. (See Part VI, "Elements," for a definition of the number and the type of the components for the element type.)
424(E)	Status of cracks Output variable: CKSTAT	1. Status of first crack (if a 1D, 2D, or 3D analysis). CKSTAT can have the following values: 0.0=uncracked, 1.0=closed crack, 2.0=actively cracking, 3.0=crack closing/reopening. 2. Status of second crack (if a 2D or 3D analysis). 3. Status of third crack (if a 3D analysis).
441(E)	Cracking strain magnitude Output variable: CKEMAG	1. Magnitude of cracking strain.
Records for inelastic nonlinear response in a beam general section		
42(S)	Plastic strain components Output variable: SPE	1. Axial plastic strain. 2. Curvature change about the local 1-axis. 3. Curvature change about the local 2-axis (available only for 3D beams). 4. Twist of the beam (available only for 3D beams).
47(S)	Equivalent plastic strains Output variable: SEPE	1. Axial equivalent plastic strain. 2. Curvature change about the local 1-axis. 3. Curvature change about the local 2-axis (available only for 3D beams). 4. Twist of the beam (available only for 3D beams).
Records for elastic-plastic response in frame elements		
462(S)	Elastic section strain components Output variable: SEE	1. Elastic axial strain. 2. Elastic curvature change about the local 1-axis. 3. Elastic curvature change about the local 2-axis (available only for 3D frame elements). 4. Elastic twist of the beam (available only for 3D frame elements).

Record key	Record type	Attributes
463(S)	Plastic displacements at frame element's ends Output variable: SEP	1. Plastic axial displacement. 2. Plastic rotation about the local 1-axis. 3. Plastic rotation about the local 2-axis (available only for 3D frame elements). 4. Plastic rotation about the element axis (available only for 3D frame elements). 5. Actively yielding flag (yes or no, A8 format) for frame element's end sections. 6. Buckling flag (yes, no, or na; A8 format) for frame element's end sections.
464(S)	Generalized backstress components Output variable: SALPHA	1. Axial backstress component. 2. Bending backstress about the local 1-axis. 3. Bending backstress about the local 2-axis (available only for 3D frame elements). 4. Twist backstress of the beam (available only for 3D frame elements).
Records for connector elements		
495	Connector total force Output variable: CTF	1. First component of total force. 2. Second component of total force. 3. Etc.
496	Connector elastic force Output variable: CEF	1. First component of elastic force. 2. Second component of elastic force. 3. Etc.
497	Connector viscous force Output variable: CVF	1. First component of viscous force. 2. Second component of viscous force. 3. Etc.
498	Connector friction force Output variable: CSF	1. First component of friction force. 2. Second component of friction force. 3. Etc.
499	Connector lock and connector stop status flags Output variable: CSLST	1. Flag in the 1-direction. 2. Flag in the 2-direction. 3. Etc.
500	Connector reaction force Output variable: CRF	1. First component of reaction force. 2. Second component of reaction force. 3. Etc.

Record key	Record type	Attributes
501	Connector concentrated force Output variable: CCF	1. First component of concentrated force. 2. Second component of concentrated force. 3. Etc.
502	Connector relative position Output variable: CP	1. First component of relative position. 2. Second component of relative position. 3. Etc.
503	Connector relative displacement Output variable: CU	1. First component of relative displacement. 2. Second component of relative displacement. 3. Etc.
504	Connector constitutive displacement Output variable: CCU	1. First component of constitutive displacement. 2. Second component of constitutive displacement. 3. Etc.
505	Connector relative velocity Output variable: CV	1. First component of relative velocity. 2. Second component of relative velocity. 3. Etc.
506	Connector relative acceleration Output variable: CA	1. First component of relative acceleration. 2. Second component of relative acceleration. 3. Etc.
507(E)	Connector failure status flags Output variable: CFAILST	1. Flag in the 1-direction. 2. Flag in the 2-direction. 3. Etc.
542	Connector friction-generating contact force Output variable: CNF	1. First component of friction-generating force. 2. Second component of friction-generating force. 3. Etc.
546	Connector relative velocity in the direction of instantaneous slip Output variable: CIVC	1. Relative velocity in the direction of instantaneous slip.
548	Accumulated frictional slip Output variable: CASU	1. First component of accumulated frictional slip. 2. Second component of accumulated frictional slip. 3. Etc.
556	Connector elastic displacement Output variable: CUE	1. First component of elastic displacement. 2. Second component of elastic displacement. 3. Etc.

Record key	Record type	Attributes
557	Connector plastic relative displacement Output variable: CUP	1. First component of plastic relative displacement. 2. Second component of plastic relative displacement. 3. Etc.
558	Connector equivalent plastic relative displacement Output variable: CUPEQ	1. First component of equivalent plastic relative displacement. 2. Second component of equivalent plastic relative displacement. 3. Etc.
559(E)	Connector overall damage variable Output variable: CDMG	1. First component of overall damage variable. 2. Second component of overall damage variable. 3. Etc.
560(E)	Connector force-based damage initiation criterion Output variable: CDIF	1. First component of connector force-based damage initiation criterion. 2. Second component of connector force-based damage initiation criterion. 3. Etc.
561(E)	Connector motion-based damage initiation criterion Output variable: CDIM	1. First component of connector motion-based damage initiation criterion. 2. Second component of connector motion-based damage initiation criterion. 3. Etc.
562(E)	Connector plastic motion-based damage initiation criterion Output variable: CDIP	1. First component of connector plastic motion-based damage initiation criterion. 2. Second component of connector plastic motion-based damage initiation criterion. 3. Etc.
563	Connector kinematic hardening shift force Output variable: CALPHAF	1. First component of connector kinematic hardening shift force. 2. Second component of connector kinematic hardening shift force. 3. Etc.
Record for plane stress orthotropic failure measures		
44(S)	Failure measures Output variable: CFAILURE	1. Maximum stress theory. 2. Tsai-Hill theory. 3. Tsai-Wu theory.

Record key	Record type	Attributes
		4. Azzi-Tsai-Hill theory. 5. Maximum strain theory.
Record for equivalent plastic strain components for cap plasticity		
45	Equivalent plastic strain components Output variable: PEQC	1. Equivalent plastic strain for Drucker-Prager failure surface. 2. Actively yielding flag (yes or no, A8 format) for Drucker-Prager failure surface. 3. Equivalent plastic strain for cap surface. 4. Actively yielding flag (yes or no, A8 format) for cap surface. 5. Equivalent plastic strain for transition surface. 6. Actively yielding flag (yes or no, A8 format) for transition surface. 7. Total volumetric inelastic strain. 8. Actively yielding flag (yes or no, A8 format).
Record for equivalent plastic strain components for jointed materials		
45(S)	Equivalent plastic strain components Output variable: PEQC	1. Equivalent plastic strain for joint 1. 2. Actively yielding flag (yes or no, A8 format) for joint 1. 3. Equivalent plastic strain for joint 2. 4. Actively yielding flag (yes or no, A8 format) for joint 2. 5. Equivalent plastic strain for joint 3. 6. Actively yielding flag (yes or no, A8 format) for joint 3. 7. Equivalent plastic strain for bulk material. 8. Actively yielding flag (yes or no, A8 format) for bulk material.
Record for equivalent plastic strain in uniaxial tension for cast iron plasticity		
473(S)	Equivalent plastic strain in uniaxial tension Output variable: PEEQT	1. Equivalent plastic strain in uniaxial tension for cast iron plasticity model. 2. Actively yielding flag (yes or no, A8 format).
Records for two-layer viscoplasticity		
22(S)	Plastic strains in the elastic-plastic network Output variable: PE	1. First plastic strain component. 2. Second plastic strain component.

Record key	Record type	Attributes
		3. Etc.; followed by the equivalent plastic strain, actively yielding flag (yes or no, A8 format), and magnitude of plastic strain. (See Part VI, "Elements," for a definition of the components for a given element type.)
524(S)	Stresses in the elastic-viscous network Output variable: VS	1. First stress component. 2. Second stress component. 3. Etc. (See the element description in Part VI, "Elements," for a definition of the number and type of the components for the element type.)
525(S)	Stresses in the elastic-plastic network Output variable: PS	1. First stress component. 2. Second stress component. 3. Etc. (See the element description in Part VI, "Elements," for a definition of the number and type of the components for the element type.)
526(S)	Viscous strains in the elastic-viscous network Output variable: VE	1. First viscous strain component. 2. Second viscous strain component. 3. Etc.; followed by the equivalent viscous strain.
Record for elements with electric potential degrees of freedom		
50(S)	Electrical potential gradients Output variable: EPG	1. Magnitude. 2. First potential gradient. 3. Etc. (See the element description in Part VI, "Elements," for a definition of the number and type of the components for the element type.)
Records for rebar quantities		
442	Force in rebar Output variable: RBFOR	1. Magnitude.
443	Rebar angle Output variable: RBANG	1. Angle in degrees between the reinforcing and the user-specified isoparametric direction. Available only for membrane, shell, and surface elements.
444	Change in rebar angle Output variable: RBROT	1. Change in angle in degrees between the reinforcing and the user-specified isoparametric direction. Available only for membrane, shell, and surface elements.

Record key	Record type	Attributes
Record for forced convection/diffusion heat transfer elements		
445(S)	Mass flow rates Output variable: MFR	1. First mass flow rate. 2. Etc.
Records for piezoelectric materials		
46(S)	Magnitudes and phases of potential gradients (linear dynamics only) Output variable: PHEPG	1. Magnitude of first electrical potential gradient. 2. Magnitude of second electrical potential gradient. 3. Etc. (See the element description in Part VI, "Elements," for a definition of the number and type of the components for the element type.) 4. Phase angle of first electrical potential gradient. 5. Phase angle of second electrical potential gradient. 6. Etc.
49(S)	Magnitudes and phases of electrical charge fluxes (linear dynamics only) Output variable: PHEFL	1. Magnitude of first charge flux. 2. Magnitude of second charge flux. 3. Etc. (See the element description in Part VI, "Elements," for a definition of the number and type of the components for the element type.) 4. Phase angle of first charge flux. 5. Phase angle of second charge flux. 6. Etc.
51(S)	Electrical charge fluxes Output variable: EFLX	1. Magnitude. 2. First charge flux. 3. Etc. (See the element description in Part VI, "Elements," for a definition of the number and type of the components for the element type.)
60(S)	Distributed electrical charges Output variable: CHRGS	1. Charge type. 2. Magnitude.
Records for coupled thermal-electric elements		
425(S)	Electrical current density Output variable: ECD	1. Magnitude. 2. First current density. 3. Etc. (See the element description in Part VI, "Elements," for a definition of the number and type of the components for the element type.)

Record key	Record type	Attributes
426(S)	Distributed electrical current density Output variable: ECURS	1. Electrical current type. 2. Magnitude.
427(S)	Nodal current due to electric conduction Output variable: NCURS	1. Node number. 2. Magnitude.

Records for cohesive elements

252(S)	All active components of the damage initiation criteria Output variable: DMICRT	1. MAXSCRT, maximum nominal stress damage initiation criterion. 2. MAXECRT, maximum nominal strain damage initiation criterion. 3. QUADSCRT, quadratic nominal stress damage initiation criterion. 4. QUADECRT, quadratic nominal strain damage initiation criterion.
235(S)	Overall scalar stiffness degradation Output variable: SDEG	1. Magnitude.
61(S)	Element status Output variable: STATUS	1. Status of the element (the status of an element is 1.0 if the element is active, 0.0 if the element is not).

Records for equivalent rigid body variables in direct-integration implicit dynamic analyses

Records 52–59 provide values summed over an element set. These variables are available only in direct-integration implicit dynamic analyses (see "Implicit dynamic analysis using direct integration," Section 6.3.2).

52(S)	Current coordinates of center of mass Output variable: XC	1. Coordinate 1. 2. Coordinate 2. 3. Etc. (The number of components depends upon the overall dimensionality of the element set.)
53(S)	Displacement of the center of mass Output variable: UC	1. Displacement 1. 2. Displacement 2. 3. Etc. (The number of components depends upon the overall dimensionality of the element set.)
54(S)	Equivalent rigid body velocity Output variable: VC	1. Component 1. 2. Component 2. 3. Etc. (The number of components depends upon the overall dimensionality of the element set.)

Record key	Record type	Attributes
55(S)	Angular momentum about center of mass Output variable: HC	1. Component 1. 2. Component 2. 3. Etc. (The number of components depends upon the overall dimensionality of the element set.)
56(S)	Angular momentum about origin Output variable: HO	1. Component 1. 2. Component 2. 3. Etc. (The number of components depends upon the overall dimensionality of the element set.)
57(S)	Rotary inertia about the origin Output variable: RI	1. Component 11. 2. Component 22. 3. Etc. (The number of components depends upon the overall dimensionality of the element set.)
58(S)	Current mass of element set Output variable: MASS	1. Mass.
59(S)	Current volume of element set Output variable: VOL	1. Volume. (Only available for continuum and structural elements not using general beam or shell section definitions.)
Record for transverse shear stress in thick shell elements such as S3R, S4R, S8R, and S8RT		
48	Transverse shear stresses in 13 and 23 planes Output variable: TSHR	1. Component 13. 2. Component 23.
Records for linear dynamics		
62(S)	Magnitude and phase angle of stress components Output variable: PHS	1. Magnitude of first stress component. 2. Magnutude of second stress component. 3. Etc. 4. Phase angle of first stress component. 5. Phase angle of second stress component. 6. Etc.
63(S)	RMS values of stress components Output variable: RS	1. First component of stress. 2. Second component of stress. 3. Etc.
65(S)	Magnitude and phase angle of strain components Output variable: PHE	1. Magnitude of first strain component. 2. Magnitude of second strain component. 3. Etc. 4. Phase angle of first strain component.

Record key	Record type	Attributes
		5. Phase angle of second strain component. 6. Etc.
66(S)	RMS values of strain components Output variable: RE	1. First component of strain. 2. Second component of strain. 3. Etc.
Records for connector elements (available only for linear dynamics)		
508(S)	Magnitude and phase angle of connector total forces Output variable: PHCTF	1. Magnitude of the first component. 2. Magnitude of the second component. 3. Etc. 4. Phase angle of the first component. 5. Phase angle of the second component. 6. Etc.
509(S)	Magnitude and phase angle of connector elastic forces Output variable: PHCEF	1. Magnitude of the first component. 2. Magnitude of the second component. 3. Etc. 4. Phase angle of the first component. 5. Phase angle of the second component. 6. Etc.
510(S)	Magnitude and phase angle of connector viscous forces Output variable: PHCVF	1. Magnitude of the first component. 2. Magnitude of the second component. 3. Etc. 4. Phase angle of the first component. 5. Phase angle of the second component. 6. Etc.
511(S)	Magnitude and phase angle of connector reaction forces Output variable: PHCRF	1. Magnitude of the first component. 2. Magnitude of the second component. 3. Etc. 4. Phase angle of the first component. 5. Phase angle of the second component. 6. Etc.
520(S)	Magnitude and phase angle of connector friction forces Output variable: PHCSF	1. Magnitude of the first component. 2. Magnitude of the second component. 3. Etc. 4. Phase angle of the first component. 5. Phase angle of the second component. 6. Etc.

Record key	Record type	Attributes
512(S)	Magnitude and phase angle of connector relative displacements Output variable: PHCU	1. Magnitude of the first component. 2. Magnitude of the second component. 3. Etc. 4. Phase angle of the first component. 5. Phase angle of the second component. 6. Etc.
513(S)	Magnitude and phase angle of connector constitutive displacements Output variable: PHCCU	1. Magnitude of the first component. 2. Magnitude of the second component. 3. Etc. 4. Phase angle of the first component. 5. Phase angle of the second component. 6. Etc.
522(S)	Magnitude and phase angle of connector relative velocities Output variable: PHCV	1. Magnitude of the first component. 2. Magnitude of the second component. 3. Etc. 4. Phase angle of the first component. 5. Phase angle of the second component. 6. Etc.
523(S)	Magnitude and phase angle of connector relative accelerations Output variable: PHCA	1. Magnitude of the first component. 2. Magnitude of the second component. 3. Etc. 4. Phase angle of the first component. 5. Phase angle of the second component. 6. Etc.
543(S)	Magnitude and phase angle of friction-generating connector force Output variable: PHCNF	1. Magnitude of the first component of friction-generating connector force. 2. Magnitude of the second component of friction-generating connector force. 3. Etc. 4. Phase angle of the first component of friction-generating connector force. 5. Phase angle of the second component of friction-generating connector force. 6. Etc.

Record key	Record type	Attributes
547(S)	Magnitude and phase angle of connector relative velocity in the direction of instantaneous slip Output variable: PHCIVSL	1. Magnitude of connector relative velocity in the direction of instantaneous slip. 2. Phase angle of connector relative velocity in the direction of instantaneous slip.
514(S)	RMS values of connector total forces Output variable: RCTF	1. First component of force. 2. Second component of force. 3. Etc.
515(S)	RMS values of connector elastic forces Output variable: RCEF	1. First component of force. 2. Second component of force. 3. Etc.
516(S)	RMS values of connector viscous forces Output variable: RCVF	1. First component of force. 2. Second component of force. 3. Etc.
517(S)	RMS values of connector reaction forces Output variable: RCRF	1. First component of force. 2. Second component of force. 3. Etc.
521(S)	RMS values of connector friction forces Output variable: RCSF	1. First component of force. 2. Second component of force. 3. Etc.
518(S)	RMS values of connector relative displacements Output variable: RCU	1. First component of relative displacements. 2. Second component of relative displacements. 3. Etc.
519(S)	RMS values of connector constitutive displacements Output variable: RCCU	1. First component of constitutive displacements. 2. Second component of constitutive displacements. 3. Etc.
544(S)	RMS values of connector force generating friction Output variable: RCNF	1. RMS values of first component of friction-generating connector force. 2. RMS values of second component of friction-generating connector force. 3. Etc.
Records for fluid link elements (available only for linear dynamics)		
94(S)	Magnitude and phase angle of mass flow rate Output variable: PHMFL	1. Magnitude. 2. Phase angle.

Record key	Record type	Attributes
95(S)	Magnitude and phase angle of total mass flow Output variable: PHMFT	1. Magnitude. 2. Phase angle.

Records for output of element volumes

The following three variables are not available for eigenfrequency extraction, complex eigenfrequency extraction, eigenvalue buckling prediction, or linear dynamics procedures. They are available only for continuum and structural elements not using general beam or shell section definitions.

76(S)	Integration point volume Output variable: IVOL	1. Current integration point volume. Section point volume in the case of beams and shells.
77(S)	Section volume Output variable: SVOL	1. Current section volume.
78(S)	Whole element volume Output variable: EVOL	1. Current element volume.

Record for solid elements in an adaptive mesh domain in Abaqus/Standard

264(S)	Change in volume. Output variable: VOLC	1. Change in area or volume of an element set solely due to adaptive meshing.

Records written for any node file output request

Record key	Record type	Attributes
101	Displacements Output variable: U	1. Node number. 2. First component of displacement. 3. Second component of displacement. 4. Etc.
102	Velocities Output variable: V	1. Node number. 2. First component of velocity. 3. Second component of velocity. 4. Etc.
103	Accelerations Output variable: A	1. Node number. 2. First component of acceleration. 3. Second component of acceleration. 4. Etc.
104	Reaction forces Output variable: RF	1. Node number. 2. First component of reaction force.

Record key	Record type	Attributes
		3. Second component of reaction force. 4. Etc.
105(S)	Electrical potential Output variable: EPOT	1. Node number. 2. Magnitude.
106(S)	Point loads, moments, fluxes Output variable: CF	1. Node number. 2. First component of load or flux. 3. Second component of load or flux. 4. Etc.
107	Coordinates Output variable: COORD	1. Node number. 2. First coordinate. 3. Second coordinate. 4. Etc.
108	Pore or acoustic pressure Output variable: POR	1. Node number. 2. Pressure.
109(S)	Reactive fluid volume flux Output variable: RVF	1. Node number. 2. Reaction fluid volume flux.
110(S)	Reactive fluid total volume Output variable: RVT	1. Node number. 2. Reaction fluid total volume.
119(S)	Electrical reaction charges Output variable: RCHG	1. Node number. 2. Charge scalar value.
120(S)	Concentrated electrical nodal charges Output variable: CECHG	1. Node number. 2. Current scalar value.
136	Fluid cavity pressure Output variable: PCAV	1. Fluid cavity reference node number. 2. Pressure.
137	Fluid cavity volume Output variable: CVOL	1. Fluid cavity reference node number. 2. Volume.
138(S)	Electrical reaction current Output variable: RECUR	1. Node number. 2. Electrical current.
139(S)	Concentrated electrical nodal current Output variable: CECUR	1. Node number. 2. Electrical current.

Record key	Record type	Attributes
145(S)	Viscous forces due to static stabilization Output variable: VF	1. Node number. 2. First component of viscous force. 3. Second component of viscous force. 4. Etc.
146(S)	Total forces Output variable: TF	1. Node number. 2. First component of total force. 3. Second component of total force. 4. Etc.
151(E)	Acoustic absolute pressure Output variable: PABS	1. Node number. 2. Absolute pressure.
201	Temperatures Output variable: NT	1. Node number. 2. Temperature. 3. Etc. (for heat shells)
204(S)	Residual fluxes Output variable: RFL	1. Node number. 2. Residual flux. 3. Etc. (for heat shells)
204(E)	Reaction fluxes Output variable: RFL	1. Node number. 2. First component of reaction flux. 3. Second component of reaction flux. 4. Etc.
206(S)	Concentrated fluxes Output variable: CFL	1. Node number. 2. Concentrated flux. 3. Etc. (for heat shells)
214(S)	Internal fluxes Output variable: RFLE	1. Node number. 2. Flux, excluding external flux. 3. Etc. (for heat shells)
221(S)	Normalized concentration (mass diffusion analysis) Output variable: NNC	1. Node number. 2. Concentration.
237(S)	Motions (in cavity radiation analysis) Output variable: MOT	1. Node number. 2. First component of motion. 3. Second component of motion. 4. Etc.
320(S)	Concentrated fluid flow Output variable: CFF	1. Node number. 2. Magnitude of fluid flow.

Record key	Record type	Attributes
Records for linear dynamics		
111(S)	Magnitude and phase angle of relative displacement Output variable: PU	1. Node number. 2. Magnitude of first displacement component. 3. Magnitude of second displacement component. 4. Etc. 5. Phase angle of first displacement component. 6. Phase angle of second displacement component. 7. Etc.
112(S)	Magnitude and phase angle of total displacement Output variable: PTU	1. Node number. 2. Magnitude of first displacement component. 3. Magnitude of second displacement component. 4. Etc. 5. Phase angle of first displacement component. 6. Phase angle of second displacement component. 7. Etc.
113(S)	Total displacement Output variable: TU	1. Node number. 2. First component of displacement. 3. Second component of displacement. 4. Etc.
114(S)	Total velocity Output variable: TV	1. Node number. 2. First component of velocity. 3. Second component of velocity. 4. Etc.
115(S)	Total acceleration Output variable: TA	1. Node number. 2. First component of acceleration. 3. Second component of acceleration. 4. Etc.
116(S)	Magnitude and phase angle of acoustic or fluid cavity pressure Output variable: PPOR	1. Node number. 2. Magnitude of pressure. 3. Phase angle of pressure.
117(S)	Magnitude and phase angle of electrical potential Output variable: PHPOT	1. Node number. 2. Magnitude of potential. 3. Phase angle of potential.

Record key	Record type	Attributes
118(S)	Magnitude and phase angle of reactive charge (piezoelectric analysis) Output variable: PHCHG	1. Node number. 2. Magnitude of charge. 3. Phase angle of charge.
123(S)	RMS values of relative displacement Output variable: RU	1. Node number. 2. First component of displacement. 3. Second component of displacement. 4. Etc.
124(S)	RMS values of total displacement Output variable: RTU	1. Node number. 2. First component of displacement. 3. Second component of displacement. 4. Etc.
127(S)	RMS values of relative velocity Output variable: RV	1. Node number. 2. First component of velocity. 3. Second component of velocity. 4. Etc.
128(S)	RMS values of total velocity Output variable: RTV	1. Node number. 2. First component of velocity. 3. Second component of velocity. 4. Etc.
131(S)	RMS values of relative acceleration Output variable: RA	1. Node number. 2. First component of acceleration. 3. Second component of acceleration. 4. Etc.
132(S)	RMS values of total acceleration Output variable: RTA	1. Node number. 2. First component of acceleration. 3. Second component of acceleration. 4. Etc.
134(S)	RMS values of reaction forces Output variable: RRF	1. Node number. 2. First component of reaction force. 3. Second component of reaction force. 4. Etc.
135(S)	Magnitude and phase angle of reaction force Output variable: PRF	1. Node number. 2. Magnitude of first component of reaction force. 3. Magnitude of second component of reaction force.

Record key	Record type	Attributes
		4. Etc. 5. Phase angle of first component of reaction force. 6. Phase angle of second component of reaction force. 7. Etc.

Records written for any modal file output request during mode-based dynamic analysis

Record key	Record type	Attributes
301(S)	Generalized displacements Output variable: GU	1. First generalized displacement. 2. Second generalized displacement. 3. Etc.
302(S)	Generalized velocities Output variable: GV	1. First generalized velocity. 2. Second generalized velocity. 3. Etc.
303(S)	Generalized accelerations Output variable: GA	1. First generalized acceleration. 2. Second generalized acceleration. 3. Etc.
304(S)	Base motions Output variable: BM	1. 1 if displacement, 2 if velocity, 3 if acceleration. 2. x-direction component. 3. y-direction component. 4. z-direction component. 5. x-rotation component. 6. y-rotation component. 7. z-rotation component. 8. Base name.
305(S)	Phase angle of generalized displacement Output variable: GPU	1. Phase angle of generalized displacement for first mode. 2. Phase angle of generalized displacement for second mode. 3. Etc.
306(S)	Phase angle of generalized velocity Output variable: GPV	1. Phase angle of generalized velocity for first mode. 2. Phase angle of generalized velocity for second mode. 3. Etc.

Record key	Record type	Attributes
307(S)	Phase angle of generalized acceleration Output variable: GPA	1. Phase angle of generalized acceleration for first mode. 2. Phase angle of generalized acceleration for second mode. 3. Etc.
308(S)	Strain energy per mode Output variable: SNE	1. Strain energy for first mode. 2. Strain energy for second mode. 3. Etc.
309(S)	Kinetic energy per mode Output variable: KE	1. Kinetic energy for first mode. 2. Kinetic energy for second mode. 3. Etc.
310(S)	External work per mode Output variable: T	1. External work for first mode. 2. External work for second mode. 3. Etc.

Records written for any element matrix or substructure matrix file output request

The ordering of variables on element matrices is the same as that used for user elements (see "User-defined elements," Section 32.15.1): first the variables at the element's first node, then those at its second node, etc. Abaqus allows elements to have repeated nodes.

Record key	Record type	Attributes
1001(S)	Element matrix header record	1. Element number (zero if this is a substructure). 2. Element or substructure type in A8 format. 3. Number of nodes on the element. 4. Node number of the element's first node. 5. Node number of the element's second node. 6. Etc.
1002(S)	Element or substructure recovery matrix nodal DOF	1. First DOF at the element's or at the recovery matrix's first retained node. 2. Second DOF at the element's or at the recovery matrix's first retained node. 3. Etc.
1003(S)	Element or substructure recovery matrix nodal DOF change	1. Node where the DOFs change. 2. First DOF at this node. 3. Second DOF at this node. 4. Etc.

Record key	Record type	Attributes
1004(S)	Element matrix record size	1. Maximum record length (including the record length and record key words) for element matrix and load vector records that follow. The matrix or load vector records will be subdivided into multiple records as needed to fit within this maximum length. The record key for any continuation record will be the same as for the first record.
1005(S)	Element matrix header (continued)	1. Element node number continued from record 1001 (if necessary). 2. Etc.
1011(S)	Symmetric element stiffness matrix	1. (1, 1) stiffness. 2. (1, 2) stiffness. 3. (2, 2) stiffness. 4. Etc., stored in columns, from the first row to the diagonal term of each column.
1012(S)	Nonsymmetric element stiffness matrix	1. (1, 1) stiffness. 2. (2, 1) stiffness. 3. (3, 1) stiffness. 4. Etc., stored in columns.
1021(S)	Symmetric element mass matrix	1. (1, 1) mass. 2. (1, 2) mass. 3. (2, 2) mass. 4. Etc., stored in columns, from the first row to the diagonal term of each column.
1022(S)	Nonsymmetric element mass matrix	1. (1, 1) mass. 2. (2, 1) mass. 3. (3, 1) mass. 4. Etc., stored in columns.
1031(S)	Load vector	1. Load case. 2. Load on first DOF. 3. Load on second DOF. 4. Etc.

Record key	Record type	Attributes
1032(S)	Substructure load case vector	1. Load case name (A8 format). 2. Load on first DOF. 3. Load on second DOF. 4. Etc.
1041(S)	Substructure recovery matrix header record	1. Zero. 2. Element or substructure type in A8 format. 3. Number of eliminated nodes. 4. Node number of the first eliminated node. 5. Node number of the second eliminated node. 6. Etc.
1042(S)	Substructure recovery matrix	1. Column number corresponding to the retained DOFs list. 2. Coefficient of first eliminated DOF. 3. Coefficient of second eliminated DOF. 4. Etc.
1043(S)	Substructure recovery matrix header (continued)	1. Node number continued from record 1041 (if necessary). 2. Etc.

Record written for any energy file output request

When you do not specify an element set for which energy output is being requested in Abaqus/Standard, record 1999 provides values summed over the entire model; when you specify an element set for energy output, record 1999 provides values summed over all the elements in the specified element set. You can distinguish between a whole model 1999 energy record and an element set 1999 energy record by searching for a 1911 output request definition record containing the element set name; this 1911 record will be written just before the element set 1999 energy record. This 1911 record also has the first attribute set to 3 to indicate element set output. In Abaqus/Explicit you cannot specify selected element sets for an energy output request; record 1999 provides the total energies for the whole model.

Record key	Record type	Attributes
1999(S)	Total energies record	1. Total kinetic energy (ALLKE). 2. Total recoverable (elastic) strain energy (ALLSE). 3. Total external work (ALLWK, available only for the whole model.) 4. Total plastic dissipation (ALLPD). 5. Total creep dissipation (ALLCD).

Record key	Record type	Attributes
		6. Total viscous dissipation, not including dissipation due to stabilization (ALLVD). 7. Total loss of kinetic energy at impacts (ALLKL, available only for the whole model). 8. Total artificial strain energy (ALLAE). 9. Total energy dissipated through quiet boundaries (ALLQB, available only for the whole model). 10. Total electrostatic energy (ALLEE). 11. Total strain energy (ALLIE). 12. Total energy balance (ETOTAL, available only for the whole model). 13. Total energy dissipated through frictional effects (ALLFD, available only for the whole model). 14. Total electrical energy dissipated in conductors (ALLJD). 15. Total static dissipation (due to stabilization, ALLSD). 16. Total damage dissipation (ALLDMD). 17. Currently not used. 18. Currently not used.
1999(E)	Total energies record	1. Total kinetic energy (ALLKE). 2. Total recoverable (elastic) strain energy (ALLSE). 3. Total external work (ALLWK). 4. Total plastic dissipation (ALLPD). 5. Total viscoelastic dissipation (ALLCD). 6. Total viscous dissipation (ALLVD, not supported for hyperelastic and hyperfoam material models). 7. Currently not used. 8. Total artificial strain energy (ALLAE). 9. Total distortion control dissipation energy (ALLDC). 10. Currently not used. 11. Total strain energy (ALLIE). 12. Total energy balance (ETOTAL). 13. Total energy dissipated through frictional effects (ALLFD). 14. Currently not used. 15. Percent change in mass (DMASS). 16. Total damage dissipation (ALLDMD).

Record key	Record type	Attributes
		17. Internal heat energy (ALLIHE). 18. External heat energy (ALLHF).

Records written for contour integrals

Calculations of the *J*-integral and the C_t-integral, the stress intensity factors, the crack propagation direction, and the *T*-stress can be requested. The record is written for each crack, one record per crack front location. See record key 17 for *J*-integral values for line spring elements.

Record key	Record type	Attributes
1991(S)	*J*-integral values	1. Crack number. 2. Node set (A8 format). 3. Number of contours. 4. *J*-integral value estimated by first contour. 5. *J*-integral value estimated by second contour. 6. Etc.
1992(S)	C_t-integral values	1. Crack number. 2. Node set (A8 format). 3. Number of contours. 4. C_t-integral value estimated by first contour. 5. C_t-integral value estimated by second contour. 6. Etc.
1995(S)	Stress intensity factors	1. Crack number. 2. Node set (A8 format). 3. Number of contours. 4. K_I (Mode I stress intensity factor) estimated by first contour. 5. K_{II} (Mode II stress intensity factor) estimated by first contour. 6. K_{III} (Mode III stress intensity factor) estimated by first contour (available only for 3D elements). 7. Crack propagation direction (in degrees) estimated by first contour (available only for homogeneous, isotropic elastic materials). 8. *J*-integral value estimated from stress intensity factors of first contour. 9. K_I (Mode I stress intensity factor) estimated by second contour.

Record key	Record type	Attributes
		10. K_{II} (Mode II stress intensity factor) estimated by second contour. 11. K_{III} (Mode III stress intensity factor) estimated by second contour (available only for 3D elements). 12. Crack propagation direction (in degrees) estimated by second contour (available only for homogeneous, isotropic elastic materials). 13. *J*-integral value estimated from stress intensity factors of second contour. 14. Etc.
1996(S)	*T*-stress values	1. Crack number. 2. Node set (A8 format). 3. Number of contours. 4. *T*-stress value estimated by first contour. 5. *T*-stress value estimated by second contour. 6. Etc.

Record written for crack propagation analysis

The following record is written for each crack that is identified in the crack propagation analysis:

Record key	Record type	Attributes
1993(S)	Crack tip location and associated quantities	1. Crack number. 2. Slave surface (A8 format). 3. Master surface (A8 format). 4. Initial crack-tip node number. 5. Current crack-tip node number. 6. Flag to indicate crack propagation criterion. 1 for crack length criterion. 2 for critical stress criterion. 3 for crack opening displacement criterion. 5 for VCCT criterion. 7. Cumulative incremental crack length. 8. Value of σ_f if critical stress criterion is used. Current value of critical crack opening displacement if crack opening displacement criterion is used. 9. Value of τ_f if critical stress criterion is used.

Records written once for any file output request when surfaces are defined in Abaqus/Standard

The number of data items for the following record depends on the type of surface being defined.

Record key	Record type	Attributes
Rigid surfaces		
1501(S)	Surface definition header	1. Surface name. 2. Dimension key (1-1D, 2-2D, 3-3D, 4-Axisymmetric). 3. Type key (1-Deformable, 2-Rigid). 4. Number of facets making up the surface. 5. Reference node label.
Deformable surfaces		
1501(S)	Surface definition header	1. Surface name. 2. Dimension key (1-1D, 2-2D, 3-3D, 4-Axisymmetric). 3. Type key (1-Deformable, 2-Rigid). 4. Number of facets making up the surface. 5. Number of contact master surfaces associated with this surface through contact pairing (0 if this surface is a master surface). 6. First master surface name. 7. Second master surface name. 8. Etc.
1502(S)	Surface facet	1. Underlying element number. 2. Element face key (1–S1, 2–S2, 3–S3, 4–S4, 5–S5, 6–S6, 7–SPOS, 8–SNEG). 3. Number of nodes in facet. 4. Node number of the facet's first node. 5. Node number of the facet's second node. 6. Etc.

Records written for any contact surface file output request

Record key	Record type	Attributes
5(S)	Solution-dependent state variables Output variable: SDV	1. State variable 1. 2. State variable 2. 3. Etc. The record can have up to 80 words in ASCII format or 512 words in binary format. Repeat this record as often as necessary to output all active state variables in the model.
1503(S)	Output request definition	1. Contact file output (0). 2. Slave surface name. 3. Master surface name. 4. Node set containing a subset of the nodes making up the slave surface.
1504(S)	Node header	1. Node number. 2. Number of traction components (2 for 2D or axisymmetric cases, 3 for 3D cases).
1511(S)	Contact tractions Output variable: CSTRESS	1. Contact pressure between the node on the slave surface and the master surface with which it interacts. 2. Frictional shear traction component in the local 1-direction on the master surface. 3. Frictional shear traction component in the local 2-direction on the master surface for 3D.
1512(S)	Viscous tractions Output variable: CDSTRESS	1. Viscous pressure between the node on the slave surface and the master surface with which it interacts. 2. Viscous shear traction component in the local 1-direction on the master surface. 3. Viscous shear traction component in the local 2-direction on the master surface for 3D.
1521(S)	Contact clearances Output variable: CDISP	1. Separation of the surfaces in the direction of the normal to the master surface. 2. Accumulated relative tangential displacement of the surfaces in the local 1-direction on the master surface.

Record key	Record type	Attributes
		3. Accumulated relative tangential displacement of the surfaces in the local 2-direction on the master surface for 3D.
1522(S)	Total force due to contact pressure Output variable: CFN	1. Magnitude. 2. Force component in the global 1-direction. 3. Force component in the global 2-direction. 4. Force component in the global 3-direction.
1523(S)	Total force due to frictional stress Output variable: CFS	1. Magnitude. 2. Force component in the global 1-direction. 3. Force component in the global 2-direction. 4. Force component in the global 3-direction.
1575(S)	Total force due to contact pressure and frictional stress Output variable: CFT	1. Magnitude. 2. Force component in the global 1-direction. 3. Force component in the global 2-direction. 4. Force component in the global 3-direction.
1524(S)	Total area in contact Output variable: CAREA	1. Magnitude.
1526(S)	Total moment about the origin due to contact pressure Output variable: CMN	1. Magnitude. 2. Moment component about the global 1-axis. 3. Moment component about the global 2-axis. 4. Moment component about the global 3-axis.
1527(S)	Total moment about the origin due to frictional stress Output variable: CMS	1. Magnitude. 2. Moment component about the global 1-axis. 3. Moment component about the global 2-axis. 4. Moment component about the global 3-axis.
1576(S)	Total moment about the origin due to contact pressure and frictional stress Output variable: CMT	1. Magnitude. 2. Moment component about the global 1-axis. 3. Moment component about the global 2-axis. 4. Moment component about the global 3-axis.
1578(S)	Maximum torque that can be transmitted about the *z*-axis by a contact surface in an axisymmetric analysis with a friction coefficient of unity Output variable: CTRQ	1. Magnitude.

Record key	Record type	Attributes
1573(S)	Coordinates of the center of the force due to contact pressure Output variable: XN	1. Coordinate in the global 1-direction. 2. Coordinate in the global 2-direction. 3. Coordinate in the global 3-direction.
1574(S)	Coordinates of the center of the force due to frictional stress Output variable: XS	1. Coordinate in the global 1-direction. 2. Coordinate in the global 2-direction. 3. Coordinate in the global 3-direction.
1577(S)	Coordinates of the center of the force due to contact pressure and frictional stress Output variable: XT	1. Coordinate in the global 1-direction. 2. Coordinate in the global 2-direction. 3. Coordinate in the global 3-direction.
1528(S)	Heat flux density Output variable: HFL	1. Magnitude.
1529(S)	HFL multiplied by the nodal area Output variable: HFLA	1. Magnitude.
1530(S)	Time integrated HFL Output variable: HTL	1. Magnitude.
1531(S)	Time integrated HFLA Output variable: HTLA	1. Magnitude.
1532(S)	Heat flux density due to frictional dissipation Output variable: SFDR	1. Magnitude.
1533(S)	SFDR multiplied by the nodal area Output variable: SFDRA	1. Magnitude.
1534(S)	Time integrated SFDR Output variable: SFDRT	1. Magnitude.
1535(S)	Time integrated SFDRA Output variable: SFDRTA	1. Magnitude.
1536(S)	Weighting factor Output variable: WEIGHT	1. Magnitude.
1537(S)	Heat flux density due to electrical current Output variable: SJD	1. Magnitude.
1538(S)	SJD multiplied by the nodal area Output variable: SJDA	1. Magnitude.

Record key	Record type	Attributes
1539(S)	Time integrated SJD Output variable: SJDT	1. Magnitude.
1540(S)	Time integrated SJDA Output variable: SJDTA	1. Magnitude.
1541(S)	Electrical current density Output variable: ECD	1. Magnitude.
1542(S)	ECD multiplied by area Output variable: ECDA	1. Magnitude.
1543(S)	Time integrated ECD Output variable: ECDT	1. Magnitude.
1544(S)	Time integrated ECDA Output variable: ECDTA	1. Magnitude.
1545(S)	Pore fluid volume flux per unit area Output variable: PFL	1. Magnitude.
1546(S)	PFL multiplied by the nodal area Output variable: PFLA	1. Magnitude.
1547(S)	Time integrated PFL Output variable: PTL	1. Magnitude.
1548(S)	Time integrated PFLA Output variable: PTLA	1. Magnitude.
1549(S)	Total pore fluid volume flux leaving the slave surface Output variable: TPFL	1. Magnitude.
1550(S)	Time integrated TPFL Output variable: TPTL	1. Magnitude.
Records for bond failure quantities from crack propagation analysis		
1570(S)	Time when bond failure occurs Output variable: DBT	1. Magnitude.
1571(S)	Fraction of stress that remains at bond failure Output variable: DBSF	1. Magnitude.
1572(S)	Remaining stress in the failed bond Output variable: DBS	1. 11-component of debond stress. 2. 12-component of debond stress.

Record key	Record type	Attributes
290(S)	Relative displacement behind crack when fracture criterion is met Output variable: OPENBC	1. Magnitude.
293(S)	Effective energy release rate ratio Output variable: EFENRRTR	1. Magnitude.
294(S)	Bond state (varies from 1.0 to 0.0) Output variable: BDSTAT	1. Magnitude.
235(S)	Damage variable Output variable: CSDMG	1. Magnitude.
295(S)	Critical stress at failure Output variable: CRSTS	1. 11-component of critical stress. 2. 12-component of critical stress. 3. 13-component of critical stress (only available to three-dimensional models).
296(S)	Strain energy release rate Output variable: ENRRT	1. 11-component of strain energy release rate. 2. 12-component of strain energy release rate. 3. 13-component of strain energy release rate (only available to three-dimensional models).
Record for surface-based pressure penetration analysis		
1592(S)	Fluid pressure for surface-based pressure penetration analysis Output variable: PPRESS	1. Magnitude.
Records for surface-based cohesive behavior with damage		
253(S)	Overall value of the scalar damage variable Output variable: CSDMG	1. Magnitude.
345(S)	Maximum contact stress damage initiation criterion Output variable: CSMAXSCRT	1. Magnitude.
346(S)	Maximum separation damage initiation criterion Output variable: CSMAXUCRT	1. Magnitude.
347(S)	Quadratic contact stress damage initiation criterion Output variable: CSQUADSCRT	1. Magnitude.

Record key	Record type	Attributes
348(S)	Quadratic separation damage initiation criterion Output variable: CSQUADUCRT	1. Magnitude.

Records written once for any file output request when cavities are defined

Record key	Record type	Attributes
1601(S)	Cavity definition header	1. Number of surfaces making up the cavity. 2. Cavity name. 3. Name of cavity's first surface. 4. Name of cavity's second surface. 5. Etc.
1610(S)	Facet order record size	1. Maximum record length (including the record length and record key words) for cavity facet order records that follow. The cavity facet order data will be subdivided into multiple records as needed to fit within this maximum length. The record key for any continuation record will be the same as for the first record.
1602(S)	Cavity facet order	1. Number of facets making up the cavity. 2. Cavity name. 3. Cavity's first (underlying) element number. 4. First element face key (1-S1, 2–S2, 3–S3, 4–S4, 5–S5, 6–S6, 7–SPOS, 8–SNEG) 5. Cavity's second (underlying) element number. 6. Second element face key (1–S1, 2–S2, 3–S3, 4–S4, 5–S5, 6–S6, 7–SPOS, 8–SNEG) 7. Etc.

Records written for any viewfactor matrix output request

The ordering of the facets (each facet corresponds to one row of the viewfactor matrix) is that appearing in the cavity facet order record 1602.

Record key	Record type	Attributes
1608(S)	Output request definition	1. Viewfactor output (0). 2. Cavity name.

Record key	Record type	Attributes
1605(S)	Viewfactor matrix header	1. Number of facets in the cavity. 2. Cavity name.
1609(S)	Viewfactor matrix record size	1. Maximum record length (including the record length and record key words) for viewfactor matrix and facet area records that follow. The matrix or facet area records will be subdivided into multiple records as needed to fit within this maximum length. The record key for any continuation record will be the same as for the first record.
1606(S)	Nonsymmetric viewfactor matrix	1. (1, 1) dimensionless viewfactor. 2. (1, 2) dimensionless viewfactor. 3. (1, 3) dimensionless viewfactor. 4. Etc., stored in rows.
1607(S)	Facet areas	1. Area of first facet. 2. Area of second facet. 3. Area of third facet. 4. Etc.

Records written for any radiation file output request

Record key	Record type	Attributes
1603(S)	Output request definition	1. Radiation file output (1). 2. Cavity name. 3. Surface name. 4. Element set name.
1604(S)	Facet header record	1. (Underlying) user element number. 2. Element face key (1–S1, 2–S2, 3–S3, 4–S4, 5–S5, 6–S6, 7–SPOS, 8–SNEG) 3. Facet area.
231(S)	Radiation flux density	1. Magnitude.
232(S)	Radiation flux	1. Magnitude.
233(S)	Time integrated radiation flux density	1. Magnitude.
234(S)	Time integrated radiation flux	1. Magnitude.

Record key	Record type	Attributes
235(S)	Total viewfactor (sum of viewfactor matrix row)	1. Magnitude.
236(S)	Facet temperature	1. Magnitude.

Records written for any section file output request

The output variables described below are not available for random response analysis.

Record key	Record type	Attributes
1580(S)	Output request definition	1. Surface section output (1). 2. Section name.
1581(S)	Section output header record	1. Surface name. 2. System of coordinates used for output (1–Global, 2–Local). 3. Flag to indicate whether or not the local coordinate system and the output are updated during the analysis (1–Yes, 2–No).

For all analysis types

The following two records are generated only when section output is requested in a local coordinate system. In that case all components of forces and moments are given with respect to the local system. Only the first two directions of the local coordinate system are given; if needed, the third direction can be calculated as the cross product of the first two.

1582(S)	Global coordinates of the anchor point	1. First coordinate. 2. Etc.
1583(S)	Direction cosines of the local coordinate system	1. First component of the first direction. 2. Second component of the first direction. 3. Third component of the first direction. 4. First component of the second direction. 5. Second component of the second direction. 6. Third component of the second direction.
1584(S)	Area of the defined section Output variable: SOAREA	1. Magnitude.

Record key	Record type	Attributes
For stress/displacement analyses		
1585(S)	Total force in the section in the selected system Output variable: SOF	1. Magnitude. 2. First force component. 3. Etc.
1586(S)	Total moment in the section about the origin of the selected system Output variable: SOM	1. Magnitude. 2. First moment component. 3. Etc.
1587(S)	Global coordinates of the center of the total force in the section Output variable: SOCF	1. First coordinate. 2. Etc.
For heat transfer analyses		
1588(S)	Total heat flux across the section Output variable: SOH	1. Magnitude.
For electrical analyses		
1589(S)	Total current across the section Output variable: SOE	1. Magnitude.
For mass diffusion analyses		
1590(S)	Total mass flow across the section Output variable: SOD	1. Magnitude.
For coupled pore fluid diffusion-stress analyses		
1591(S)	Total pore fluid volume flux across the section Output variable: SOP	1. Magnitude.

For coupled analyses the appropriate combination of records is available. For example, in a thermal-electrical analysis both SOH and SOE are valid output requests.

Procedure type keys

Table 5.1.2–1 Keys to procedure types.

Key	Description
1	Static, automatic incrementation
2	Static, direct incrementation

Key	Description
4	Direct cyclic, automatic time incrementation
5	Direct cyclic, fixed time incrementation
11	Implicit dynamic, half-increment residual tolerance given
12	Implicit dynamic, fixed time increments
13	Implicit dynamic, subspace projection
17	Explicit dynamic
21	Quasi-static, explicit time integration
22	Quasi-static, implicit integration
31	Heat transfer, steady-state
32	Heat transfer, transient, fixed time increments
33	Heat transfer, transient, maximum allowable nodal temperature change given
34	Mass diffusion, steady-state
35	Mass diffusion, transient, fixed time increments
36	Mass diffusion, transient, maximum allowable normalized concentration change given
41	Eigenvalue frequency extraction
42	Eigenvalue buckling prediction
51	Substructure generation
61	Geostatic stress field
62	Coupled pore fluid diffusion/stress, steady-state, fixed time incrementation
63	Coupled pore fluid diffusion/stress, steady-state, automatic time incrementation
64	Coupled pore fluid diffusion/stress, transient, fixed time incrementation
65	Coupled pore fluid diffusion/stress, transient, automatic time incrementation
71	Coupled thermal-stress, steady-state
72	Coupled thermal-stress, transient, fixed time increments
73	Coupled thermal-stress, transient, maximum allowable nodal temperature change and/or accuracy tolerance parameter given
74	Explicit dynamic coupled thermal-stress
75	Coupled thermal-electrical, steady-state
76	Coupled thermal-electrical, transient analysis, fixed time increments

Key	Description
77	Coupled thermal-electrical, transient analysis, maximum allowable nodal temperature change given
85	Steady-state transport, automatic incrementation
86	Steady-state transport, direct incrementation
91	Response spectrum
92	Modal dynamic
93	Steady-state dynamic
94	Random response
95	Direct-solution steady-state dynamic
98	Annealing

5.1.3 ACCESSING THE RESULTS FILE INFORMATION

Products: Abaqus/Standard Abaqus/Explicit

References

- "Accessing the results file: overview," Section 5.1.1
- "Results file output format," Section 5.1.2
- "Utility routines for accessing the results file," Section 5.1.4

Overview

The Abaqus results (**.fil**) file is written using internal data management routines to minimize I/O cost. A postprocessing program must use these same Abaqus data management routines to read the results file. The following utility routines must be called to obtain data from the Abaqus results file:

- **INITPF**
- **DBRNU**
- **DBFILE**
- **POSFIL**

You can also write a file in the format of the Abaqus results file by using the following utility subroutines:

- **INITPF**
- **DBFILW**

The syntax of these utility subroutines is described in "Utility routines for accessing the results file," Section 5.1.4.

Reading floating point and integer variables

To read both floating point and integer variables in the records, the following coding can be used in the postprocessing program:

```
INCLUDE 'aba_param.inc'
      DIMENSION ARRAY(513), JRRAY(NPRECD,513)
      EQUIVALENCE (ARRAY(1),JRRAY(1,1))
```

With this technique, for example, the record key is available after each call to **DBFILE** with **LOP**=0 as

```
KEY =  JRRAY (1,2)
```

The use of **aba_param.inc** eliminates the need to have different versions of the code for single and double precision. The file **aba_param.inc** defines an appropriate **IMPLICIT REAL** statement and sets the value of **NPRECD** to 1 or 2, depending upon whether the machine uses single or double precision.

The file **aba_param.inc** is referenced from the **site** subdirectory of the Abaqus installation when the postprocessing program is compiled and linked using the **abaqus make** utility (explained below).

Linking the postprocessing program

The postprocessing program must be linked using the **make** parameter when running the Abaqus execution procedure (see "Making user-defined executables and subroutines," Section 3.2.16). To link properly, the postprocessing program cannot contain a FORTRAN PROGRAM statement. Instead, the program must begin with a FORTRAN SUBROUTINE with the name ABQMAIN.

Compiling, linking, and running a postprocessing program consists of two steps. For example, if the name of the postprocessing program is **postproc.f**, use the following command to compile and link **postproc.f**:

```
abaqus make job=postproc
```

The program must then be run using the command:

```
abaqus postproc
```

Calling the utility subroutines for reading the results file

Subroutine **INITPF** must be called before any results file is accessed. This subroutine contains FORTRAN OPEN statements for all FORTRAN units assigned to results files through the call to **INITPF**; therefore, your code must not contain any OPEN statements for these units. Abaqus constructs a file name for a given unit based on information supplied as **LRUNIT(1,K1)** and **FNAME**, as discussed in "Utility routines for accessing the results file," Section 5.1.4.

Subroutine **DBRNU** must also be called before reading the first results file and then again each time you need to change to reading another results file. This subroutine simply establishes the FORTRAN unit number of the results file being read; no information is returned. **DBRNU** can be called before or after **INITPF** but must be called before **DBFILE**.

Subroutine **DBFILE** is used to read each record from the results file. This subroutine will return one record at a time in the format described in "Results file output format," Section 5.1.2.

Example

The following program reads all the von Mises stresses in the results file and obtains the maximum value. Then, it prints this value along with the element, section point, and integration point numbers where it occurred.

In this example FORTRAN unit 8 is used to read the results file, and the name of the results file is assumed to be **TEST.fil**. The results file is assumed to be a binary file, and only one results file will be read. Thus, **LRUNIT** is dimensioned as **LRUNIT(2,1)**; and in the call to the **INITPF** routine **NRU** is set to 1, **LRUNIT(1,1)** is set to 8, and **LRUNIT(2,1)** is set to 2. A new results file will not be written, so **LOUTF** is set to zero.

```
      SUBROUTINE ABQMAIN
C     Calculate the maximum von Mises stress and its location
C
      INCLUDE 'aba_param.inc'
      CHARACTER*80 FNAME
      DIMENSION ARRAY(513),JRRAY(NPRECD,513),LRUNIT(2,1)
      EQUIVALENCE (ARRAY(1),JRRAY(1,1))
C
C     File initialization
C
      FNAME='TEST'
      NRU=1
      LRUNIT(1,1)=8
      LRUNIT(2,1)=2
      LOUTF=0
      CALL INITPF(FNAME,NRU,LRUNIT,LOUTF)
      JUNIT=8
      CALL DBRNU(JUNIT)
C
C     Loop on all records in results file
C
      STRESS=0.
      DO 100 K1=1,99999
C
        CALL DBFILE(0,ARRAY,JRCD)
        IF(JRCD.NE.0)GO TO 110
        KEY=JRRAY(1,2)
C
        IF(KEY.EQ.1) THEN
C
C          Element header record:
C          extract element, sec pt, int pt numbers
C
           JEL=JRRAY(1,3)
           JPNT=JRRAY(1,4)
           JSPNT=JRRAY(1,5)
C
C     Stress invariant record for Abaqus/Standard
        ELSE IF(KEY.EQ.12)THEN
C     Stress invariant record for Abaqus/Explicit
        ELSE IF(KEY.EQ.75)THEN
C
```

```
C          Extract von Mises stress
C
           IF(ARRAY(3).GT.STRESS)THEN
              STRESS=ARRAY(3)
              KEL=JEL
              KPNT=JPNT
              KSPNT=JSPNT
           END IF
         END IF
C
 100   CONTINUE
 110   CONTINUE
C
       WRITE(6,120) KEL,KPNT,KSPNT,STRESS
 120   FORMAT(5X,'ELEMENT',I5,5X,'POINT',I4,5X,'SECTION POINT',
      1 I4,5X,'STRESS',1PG12.3)
       STOP
       END
```

See Chapter 15, "Postprocessing of Abaqus Results," of the Abaqus Example Problems Guide for additional examples.

Writing a file in the results file format

Subroutine **DBFILW** can be used to write a file in the format of the Abaqus results file to modify the file information or to add additional information before postprocessing. Subroutine **INITPF** must be called before **DBFILW**.

The file will be written to FORTRAN unit 9 with the extension **.fin**. Unit 9 is opened by Abaqus when **DBFILW** is first called; your coding must not open or redefine unit 9, but you must ensure that FORTRAN unit 9 is saved following the job.

"Joining data from multiple results files and converting file format: FJOIN," Section 15.1.2 of the Abaqus Example Problems Guide, contains an example of the use of subroutine **DBFILW** to merge specific records of discontinuous results files. Continuous results files are required for postprocessing purposes; if you have written a results file during an analysis and a new results file on the restart of the analysis without making the files continuous, they must be made continuous before postprocessing. "Analysis of a cantilever subject to earthquake motion," Section 1.4.13 of the Abaqus Benchmarks Guide, also shows the use of **DBFILW** for merging results files. Alternatively, results files can be merged using the **abaqus append** utility as described in "Joining results (**.fil**) files," Section 3.2.13.

The **DBFILW** subroutine can also be used to convert the Abaqus results file from binary to ASCII format to transfer it from one computer system to another. Alternatively, this conversion can be done automatically by using the **abaqus ascfil** execution procedure, as described in "ASCII translation of results (**.fil**) files," Section 3.2.12.

5.1.4 UTILITY ROUTINES FOR ACCESSING THE RESULTS FILE

Products: Abaqus/Standard Abaqus/Explicit

References

- "Accessing the results file information," Section 5.1.3
- "URDFIL," Section 1.1.49 of the Abaqus User Subroutines Reference Guide
- "Joining data from multiple results files and converting file format: FJOIN," Section 15.1.2 of the Abaqus Example Problems Guide
- "Calculation of principal stresses and strains and their directions: FPRIN," Section 15.1.3 of the Abaqus Example Problems Guide
- "Creation of a perturbed mesh from original coordinate data and eigenvectors: FPERT," Section 15.1.4 of the Abaqus Example Problems Guide

Overview

The Abaqus results (**.fil**) file can be accessed with the utility routines described in this section. Access is subsequent to an analysis by a user-written postprocessing program or, in Abaqus/Standard, from within an analysis by user subroutine **URDFIL**.

The following utility subroutines are available:

- **DBFILE** (read from a file)
- **DBFILW** (write to a file)
- **DBRNU** (set a unit number for a file)
- **INITPF** (initialize a file)
- **POSFIL** (determine position in a file; available only in Abaqus/Standard)

These utility subroutines are described below in alphabetical order.

Only the subroutines **DBFILE** and **POSFIL** can be called from user subroutine **URDFIL**.

DBFILE (read from a file)

Interface

```
CALL DBFILE(LOP,ARRAY,JRCD)
```

Variable to be provided to the utility routine

LOP

A flag, which you must set before calling **DBFILE**, indicating the operation. Set **LOP**=0 to read the next record in the file; set **LOP**=2 to rewind the file currently being read (for example, if it is necessary

to read the file more than once, it must be rewound since it is a sequential file). If **LOP**=2 is used, the file must first be read to the end, and it should be rewound only when the end-of-file is reached.

Variables returned from the utility routine

ARRAY
The array containing one record from the file, in the format described in "Results file output format," Section 5.1.2. When **LOP**=0, this array will be filled by the data management routines with the contents of the next record in the file as each call to **DBFILE** is executed. **ARRAY** must be dimensioned adequately in your routines to contain the largest record in the file. For almost all cases 500 words is sufficient. The exceptions arise if the problem definition includes user elements or user materials that use more than this many state variables or if substructures with a large number of retained degrees of freedom are used (see "Using substructures," Section 10.1.1, for more details regarding substructures). When the results file has been written on a system on which Abaqus runs in double precision, **ARRAY** must be declared double precision in your routine.

JRCD
Returned as nonzero if an end-of-file marker is read when **DBFILE** is called with **LOP**=0.

DBFILW (write to a file)

Interface

```
CALL DBFILW(LOP,ARRAY,JRCD)
```

Variables to be provided to the utility routine

ARRAY
The array containing one record to be written to the file, in the format described in "Results file output format," Section 5.1.2.

JRCD
Return code (0 – record written successfully, 1 – record not written).

LOP
Not currently used.

DBRNU (set a unit number for a file)

Interface

```
CALL DBRNU(JUNIT)
```

Variable to be provided to the utility routine

JUNIT

The FORTRAN unit number of the results file to be read. Valid unit numbers are 8 to read the **.fil** file, 15–18, or numbers greater than 100.

INITPF (initialize a file)

Interface

```
CALL INITPF(FNAME,NRU,LRUNIT,LOUTF)
```

Variables to be provided to the utility routine

FNAME

A character string defining the root file name (that is, the name without an extension) of the files being read or written. **FNAME** must be declared as **CHARACTER*80** and can include the directory specification as well as the root file name. The extension of each individual file is defined by the **LRUNIT** array below. See the discussion below for file naming conventions.

NRU

An integer giving the number of results files that the postprocessing program will read. Normally only one results file is read, but sometimes it is necessary to read several results files—for example, to merge them into a single file.

LRUNIT

An integer array that must be dimensioned **LRUNIT(2,NRU)** in the postprocessing program and must contain the following data before **INITPF** is called:

LRUNIT(1,K1) is the FORTRAN unit number on which the **K1**th results file will be read. Valid unit numbers are 8 to read the **.fil** file, 15–18, or numbers greater than 100. All other units are reserved by Abaqus. See below for naming conventions based on the unit numbers.

LRUNIT(2,K1) is an integer that must be set to 2 if the **K1**th results file was written as a binary file or set to 1 if the **K1**th results file was written in ASCII format.

LOUTF

Needs to be defined only if the program that is making the call to **INITPF** will also write an output file in the Abaqus results file format (for example, if results files are being merged into a single results file or if a results file is being converted from binary to ASCII format). In that case **LOUTF** should be set to 2 if the output file is to be written as a binary file or set to 1 if the output file is to be written as an ASCII file. This results file will be written with the file name extension **.fin**. See "Accessing the results file information," Section 5.1.3, for a discussion of writing results files; see below for information on the naming of this file.

File naming conventions

The file extension is derived from the value of **LRUNIT(1,K1)**. If **LRUNIT(1,K1)** is 8, the file name will be constructed with the extension **fil**. Any other unit number will result in a file extension of **0nn**, where **nn** is the number assigned to **LRUNIT(1,K1)**. For example, if **LRUNIT(1,K1)** is 15, the file extension is **.015**. If an output file has been indicated by a nonzero value of **LOUTF**, its extension will be **.fin**.

For example, to read a file **xxxx.fil**, set **LRUNIT(1,K1)** to 8 and the character variable **FNAME** to **xxxx** using assignment or data statements. If desired, **FNAME** can include a directory specification, device name, or path. Operating system environment and shell variables will not be translated properly and, therefore, should not be used.

All error messages generated by Abaqus are written to FORTRAN unit 6. On most machines error messages will be printed by default directly to the screen if the program is run interactively. You can include an open statement for unit 6 in the main program to redirect messages to a file. If you wish to read or write to units other than those units specified in **LRUNIT**, OPEN statements for those units may have to be included in the program (depending upon the computer being used). Unit numbers of such auxiliary files should be greater than 100 to avoid any conflict with Abaqus internal files.

POSFIL (determine position in a file)

The **POSFIL** utility routine is available only in Abaqus/Standard.

Interface

```
CALL POSFIL(NSTEP,NINC,ARRAY,JRCD)
```

Variables to be provided to the utility routine

NSTEP
Desired step. If this variable is set to 0, the first available step will be read.

NINC
Desired increment. If this variable is set to 0, the first available increment of the specified step will be read.

Variables returned from the utility routine

ARRAY
Real array containing the values of record 2000 from the results file for the requested step and increment.

JRCD

Return code (0 – specified increment found, 1 – specified increment not found). If the step and increment requested are not found in the results file, **POSFIL** will return an error and leave you positioned at the end of the results file.

Positioning with POSFIL

You may find it convenient to call **POSFIL** with both **NSTEP** and **NINC** set to 0 to skip over the information that is written to the results file at the beginning of an analysis (see "Results file output format," Section 5.1.2) and, thus, start reading from the first increment written to the file.

POSFIL cannot be used to move backward in the results file: you cannot use **POSFIL** to find a given increment in the file and then make a second call to **POSFIL** later to read an increment earlier than the first one found. If this is attempted, **POSFIL** will return an error indicating that the requested increment was not found.

OI.1 Abaqus/Standard OUTPUT VARIABLE INDEX

This index provides a reference to all of the output variables that are available in Abaqus/Standard. Output variables are listed in alphabetical order.

OI.2 Abaqus/Explicit OUTPUT VARIABLE INDEX

This index provides a reference to all of the output variables that are available in Abaqus/Explicit. Output variables are listed in alphabetical order.

OI.3 Abaqus/CFD OUTPUT VARIABLE INDEX

This index provides a reference to all of the output variables that are available in Abaqus/CFD. Output variables are listed in alphabetical order.

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