Composite Modeling with Abaqus

Lecture 4

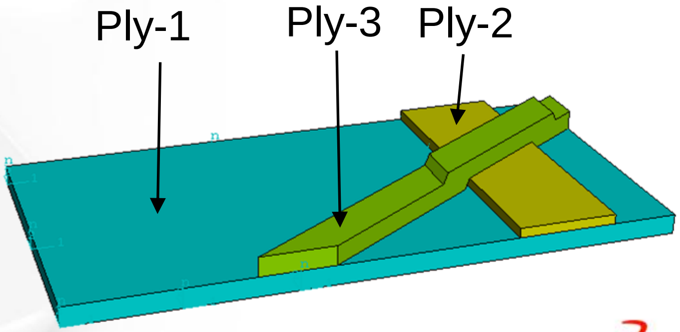
Overview

- **Introduction**
- **Understanding Composite Layups**
- **Understanding Composite Layup Orientations**
- **Defining Composite Layup Output**
- **Viewing a Composite Layup**
- **Abaqus/CAE Demonstration: Three-ply composite**
- **Composites Modeler for Abaqus/CAE**

Introduction

Introduction

- **A composite layup contains a number of plies.**
  - Plies represent the materials as placed in a mold.
    - A ply is composed of an orthotropic material, typically with fibers oriented along a reference orientation, or
    - can be also an isotropic material, e.g., a foam core.
    - Generally each ply has a uniform thickness.
  - Plies are usually the data that the CAD designers/manufacturers know.
  - Plies are inherently easy to conceptualize.



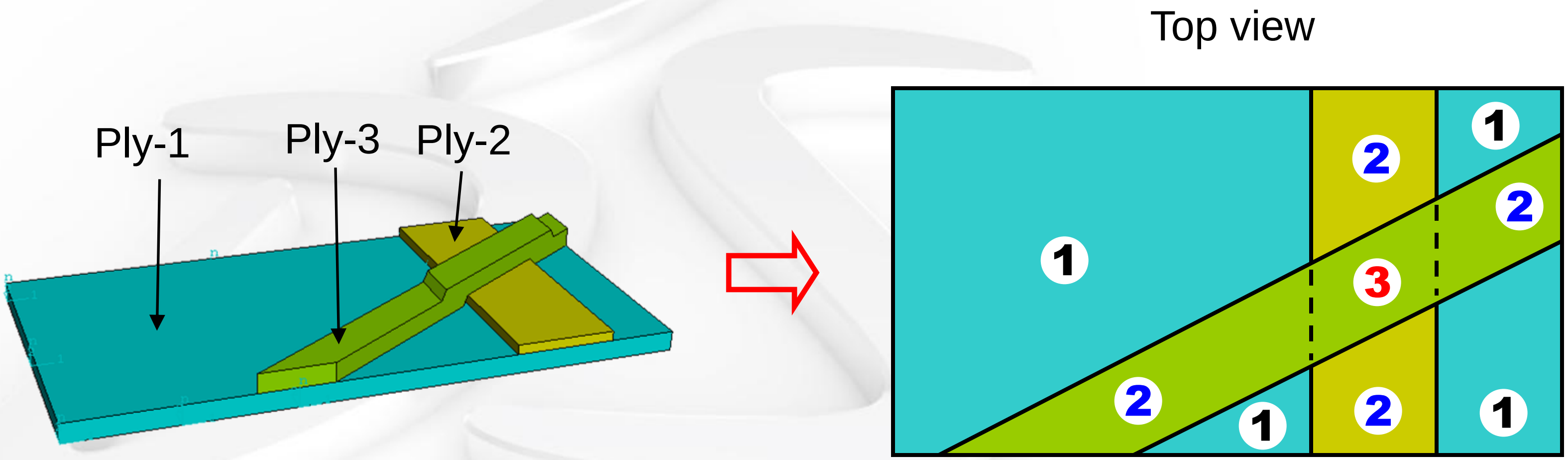
Introduction

- A different number of plies can be contained in different regions of a composite layup.
  - For example, the following composite layup includes

1 regions containing a single ply,

2 regions containing two plies, and

3 a region that contains three plies.



Introduction

- **The composite layup interface in Abaqus/CAE is designed to help you manage a large number of plies in a typical composite model.**
  - The procedure for creating a composite layup with Abaqus/CAE mirrors the procedure for creating a real composite part:
    - start with a basic shape (partitioned into appropriate regions), then
    - add plies of different materials and thickness to selected regions, and
    - orient the plies in particular directions.
  - The composite modeling and postprocessing are ply-based.
  - Layered conventional shell, continuum shell, and solid elements are supported.
    - conventional shell composite layup ↔ conventional shell elements
    - continuum shell composite layup ↔ continuum shell elements
    - solid composite layup ↔ solid elements

Introduction

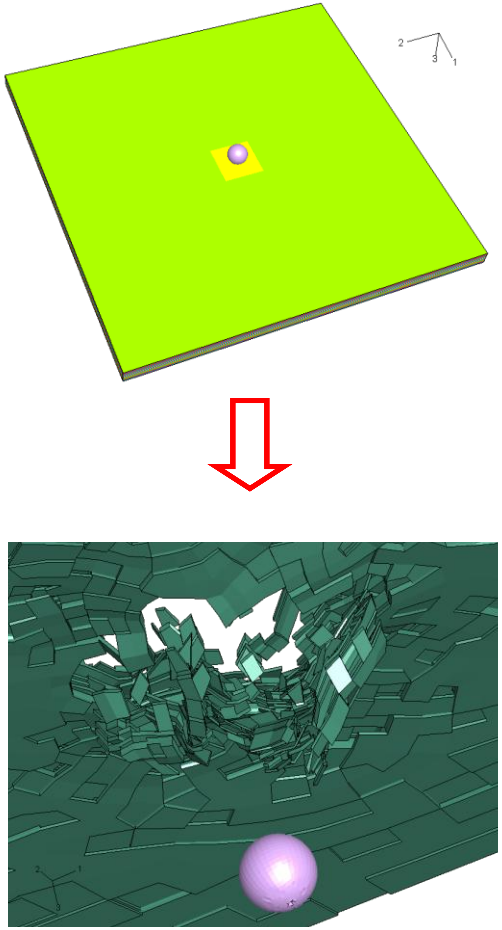
- The GUI is designed for easy manipulation of large numbers (hundreds) of plies and ply data, and large-scale composite structures.
- Ply Management is available.
  - Easily add new plies.
  - Delete, suppress, reposition, or pattern existing plies.
- The ply data can be read from/written to a text file.
- Discrete fields are supported for composite layup reference orientations, shell element offsets, and shell thicknesses.
- Output requests are available for composite layups.
- User-specified ply names are available in the ODB and Abaqus/Viewer for easy tracking in postprocessing operations.
- A ply region can be either Abaqus/CAE geometry, a native mesh, or an orphan mesh.
- Composite layup definitions are suppressible.

Introduction

- **In addition to the built-in layup feature, Abaqus also offers fiber simulation capabilities and advanced modeling tools via “Composites Modeler for Abaqus/CAE”.**
  - Composites Modeler for Abaqus/CAE is an add-on product developed by Simulayt Ltd.
  - A brief description of Composites Modeler for Abaqus/CAE will be given later in this lecture; more information can be found in the *Composites Modeler for Abaqus/CAE* lecture notes.

Introduction

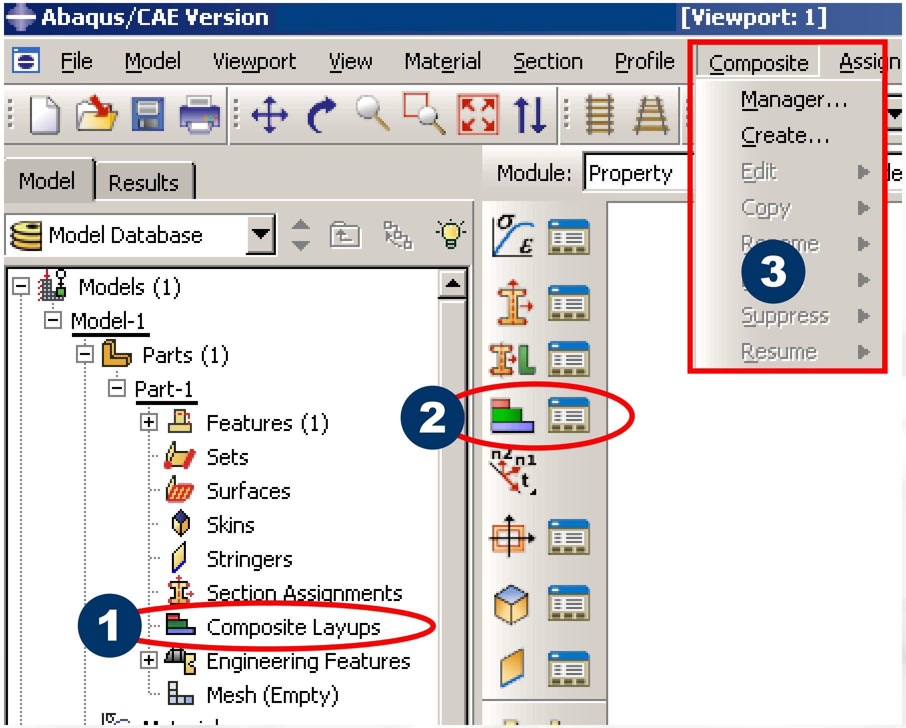
- **This lecture discusses the layup approach to defining composites with Abaqus.**
- **There exist, however, limitations in this capability when modeling <u>stacked</u> continuum shell/solid elements that require the use of an alternative modeling approach.**
  - By *stacked* we mean multiple elements through the thickness
  - If a composite layup is assigned to such a region, each element in the stack will contain the plies defined in the ply table and the analysis results will not be as expected.
  - The alternative modeling methods discussed in Lecture 5 can be used instead to model stacked continuum shell/solid elements.
    - Example: Delamination of composite plates under ballistic impact
      - "Modeling Composite Material Impact with Abaqus/Explicit," Lecture 10 applies the alternative modeling technique to this problem.



Understanding Composite Layups

Understanding Composite Layups

- **The composite layup GUI interface:**
  - You can access the composite layup editor in one of the following ways:



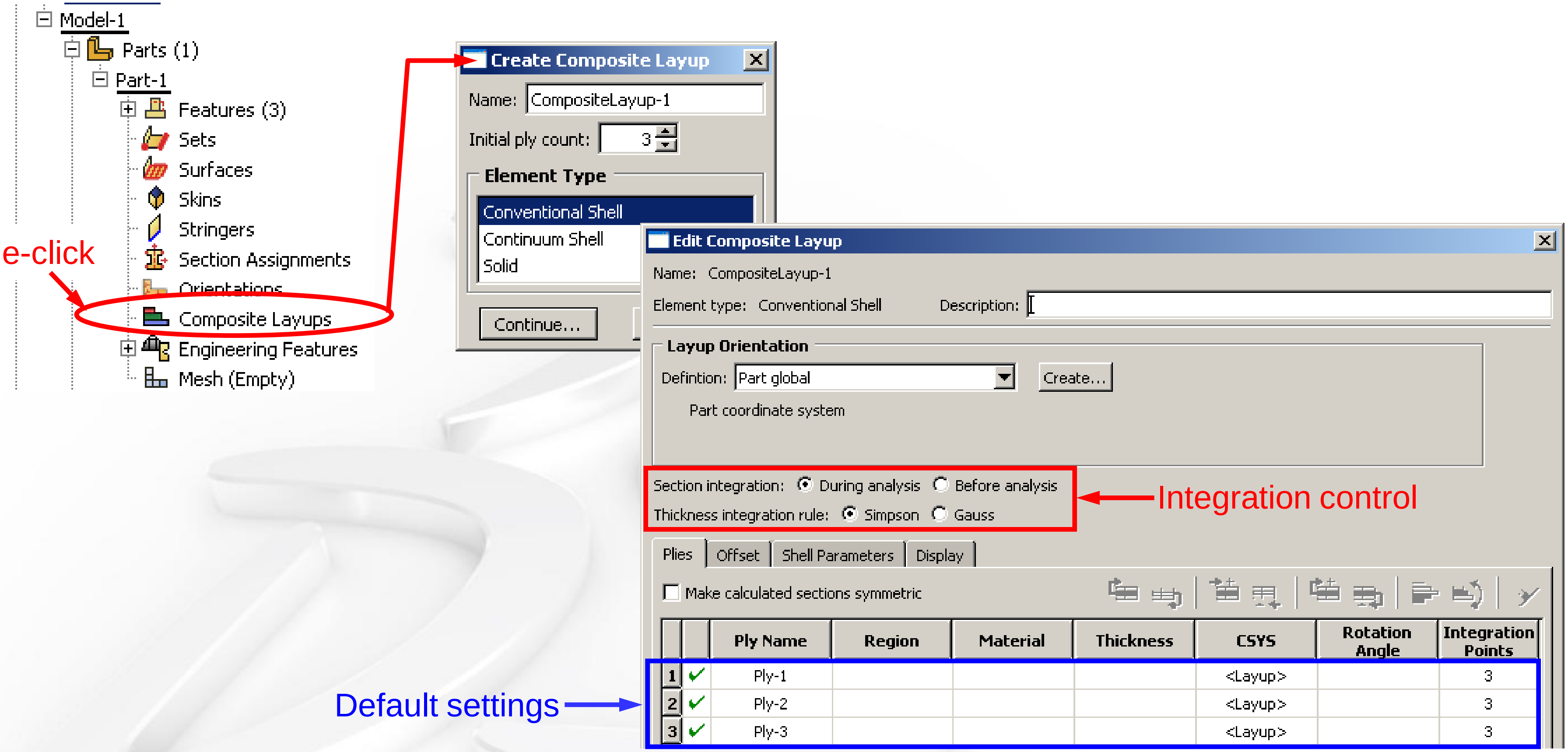
① The Composite Layups container in the Model Tree

② The Create Composite Layup and Composite Layup Manager tools in the Property module

③ The Composite drop-down menu in the Property module

Understanding Composite Layups

- **Creating a conventional shell composite layup**
  - Select the conventional shell element type



double-click

Create Composite Layup

Name: CompositeLayup-1

Initial ply count: 3

Element Type: Conventional Shell

Edit Composite Layup

Name: CompositeLayup-1

Element type: Conventional Shell

Description:

Layup Orientation

Defintion: Part global

Part coordinate system

Section integration: ● During analysis ○ Before analysis

Thickness integration rule: ● Simpson ○ Gauss

Integration control

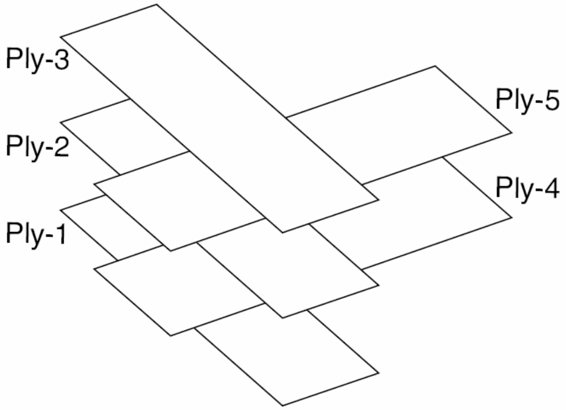
☐ Make calculated sections symmetric

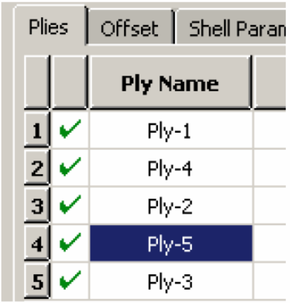
Default settings

		Ply Name	Region	Material	Thickness	CSYS	Rotation Angle	Integration Points
1	✓	Ply-1				<Layup>		3
2	✓	Ply-2				<Layup>		3
3	✓	Ply-3				<Layup>		3

Understanding Composite Layups

- A ply table in the composite layup editor is used to define the name, region, thickness, material, relative orientation, and number of integration points for each ply.
  - Enter the plies that overlap in the composite layup in the order that they appear in the overlapping region.
  - The first ply in the ply table represents the bottom ply in the layup.

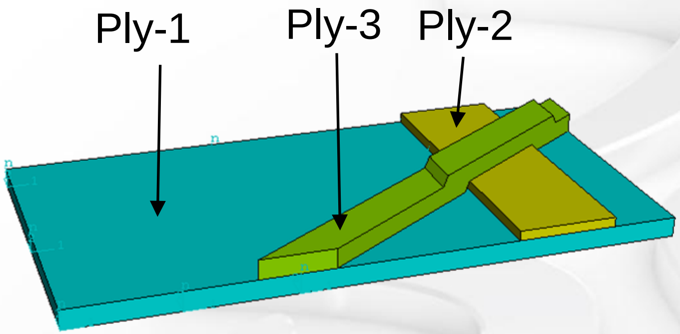




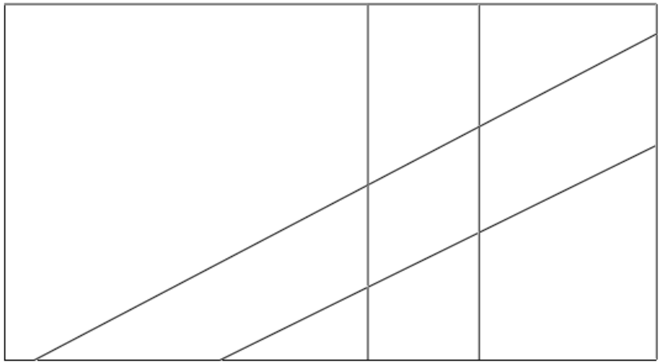
		Ply Name
1	✓	Ply-1
2	✓	Ply-4
3	✓	Ply-2
4	✓	Ply-5
5	✓	Ply-3

Understanding Composite Layups

- Example: Three-ply composite
  - Conventional shell elements are used.
  - Before creating the layup and defining plies, partition the model to create the regions to which plies will be assigned, if necessary.



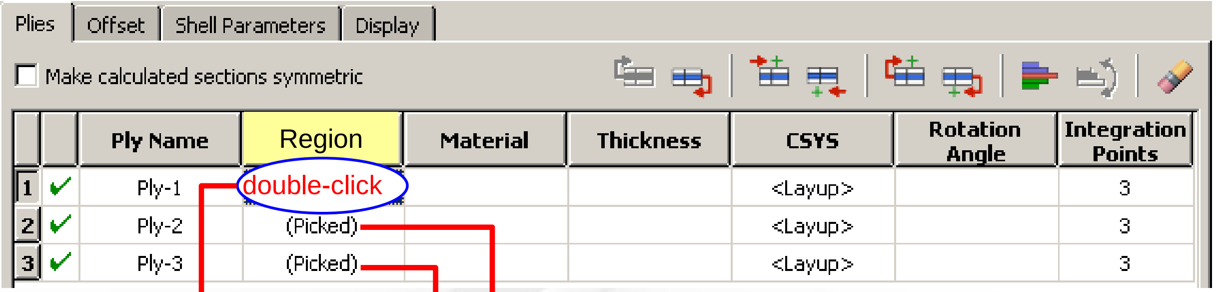
geometry of the three-ply composite



partitioned Abaqus/CAE geometry

Understanding Composite Layups

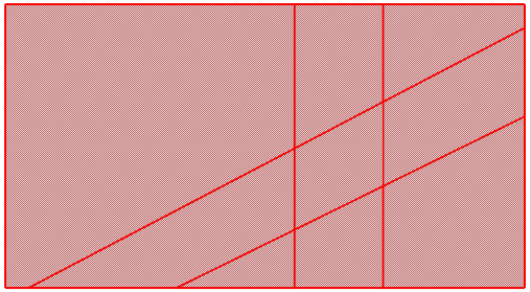
- Select the region for each ply
  - The region can be picked directly from the part in the current viewport or a named set that refers to the region.

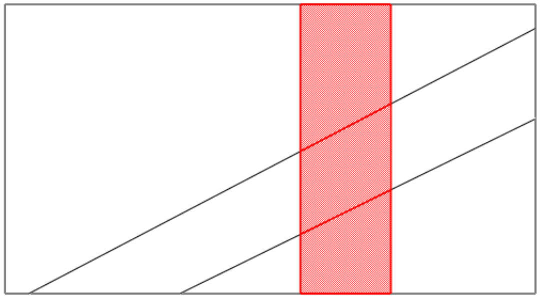


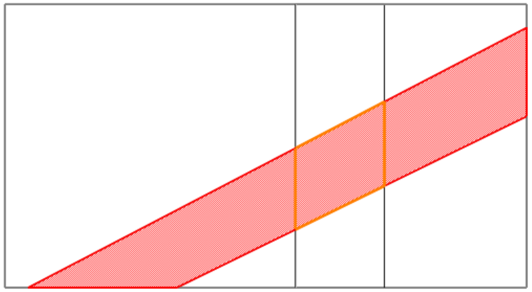
☐ Make calculated sections symmetric

		Ply Name	Region	Material	Thickness	CSYS	Rotation Angle	Integration Points
1	✓	Ply-1				<Layup>		3
2	✓	Ply-2	(Picked)			<Layup>		3
3	✓	Ply-3	(Picked)			<Layup>		3

double-click

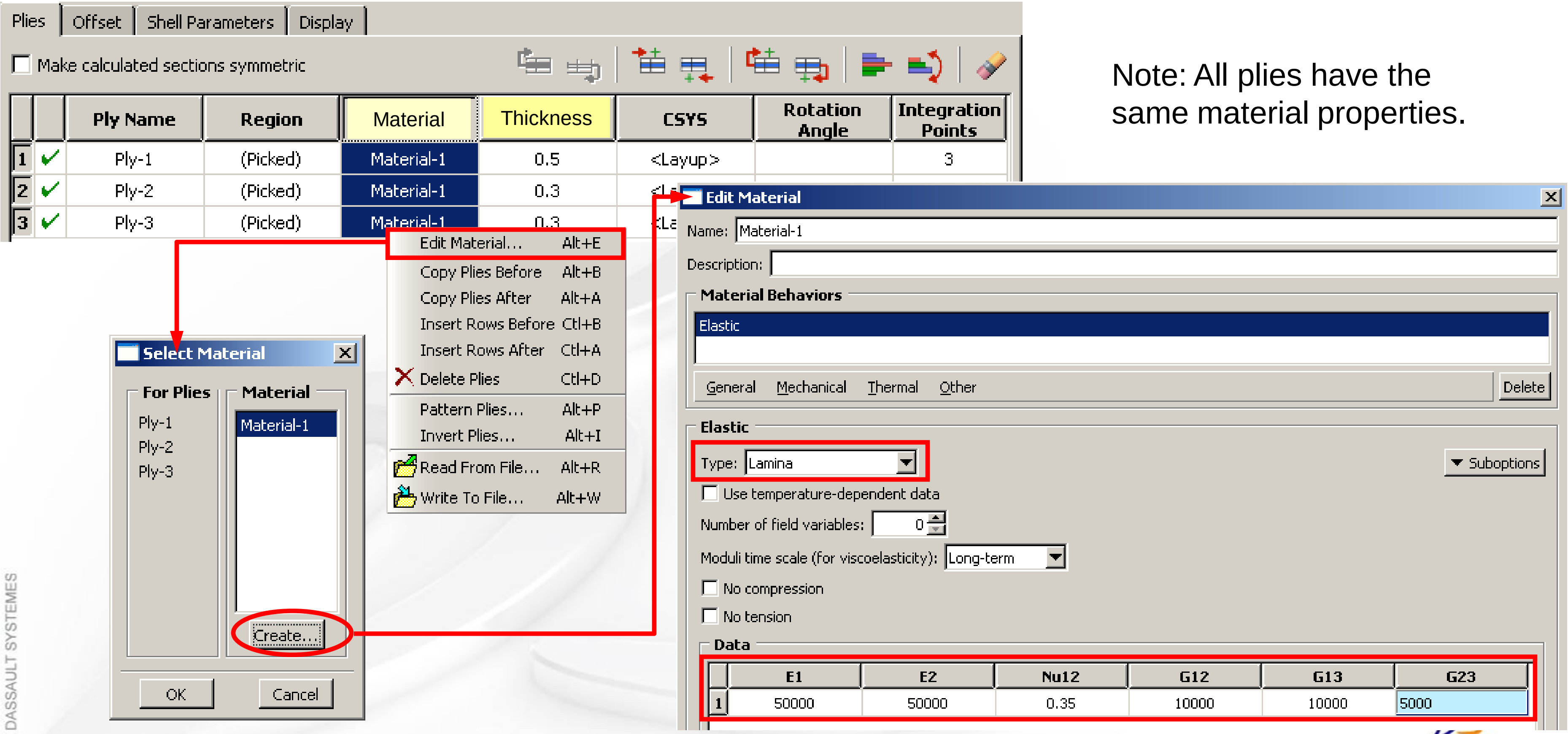

region (highlighted) for `ply-1`


region (highlighted) for `ply-2`


region (highlighted) for `ply-3`

Understanding Composite Layups

- Define the material properties and thicknesses for each ply.
  - Set the material properties for all plies at the same time by clicking mouse button 3 on the header row.



☐ Make calculated sections symmetric

		Ply Name	Region	Material	Thickness	CSYS	Rotation Angle	Integration Points
1	✓	Ply-1	(Picked)	Material-1	0.5	<Layup>		3
2	✓	Ply-2	(Picked)	Material-1	0.3	<L		
3	✓	Ply-3	(Picked)	Material-1	0.3	<La		

Select Material

For Plies	Material
Ply-1	Material-1
Ply-2	
Ply-3	

Edit Material

Name: Material-1

Description:

Material Behaviors

Elastic

Elastic

Type: Lamina

☐ Use temperature-dependent data

Number of field variables: 0

Moduli time scale (for viscoelasticity): Long-term

☐ No compression

☐ No tension

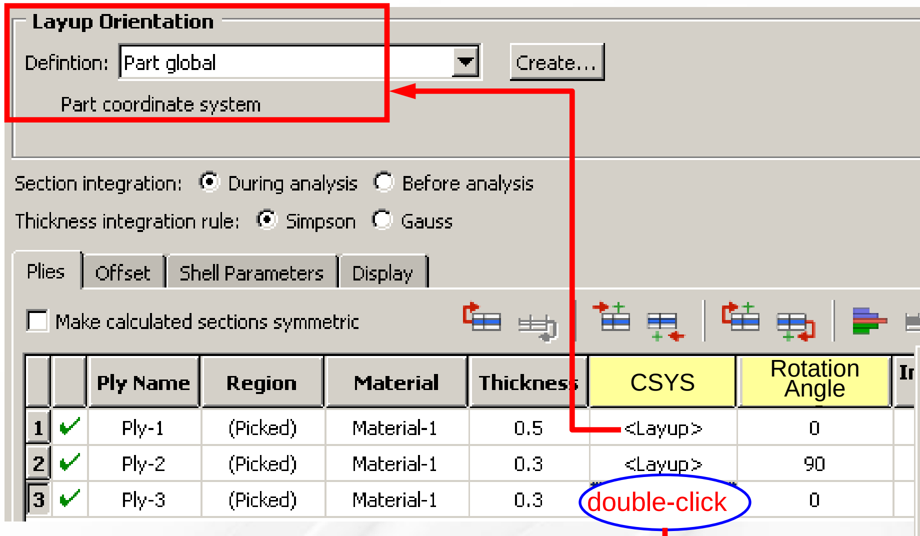
Data

	E1	E2	Nu12	G12	G13	G23
1	50000	50000	0.35	10000	10000	5000

Note: All plies have the same material properties.

Understanding Composite Layups

- Orient each ply
  - <Layup> is the default orientation.
  - The rotation angle defines the orientation of the fibers within each ply relative to the ply's coordinate system (CSYS column).
  - Details of ply orientations will be discussed in next section.



Layup Orientation

Defintion: Part global

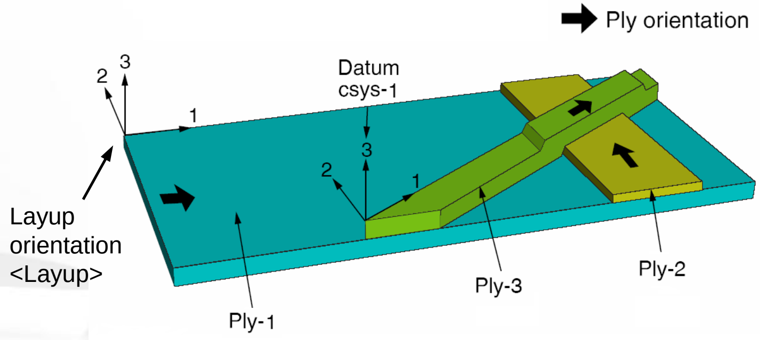
Part coordinate system

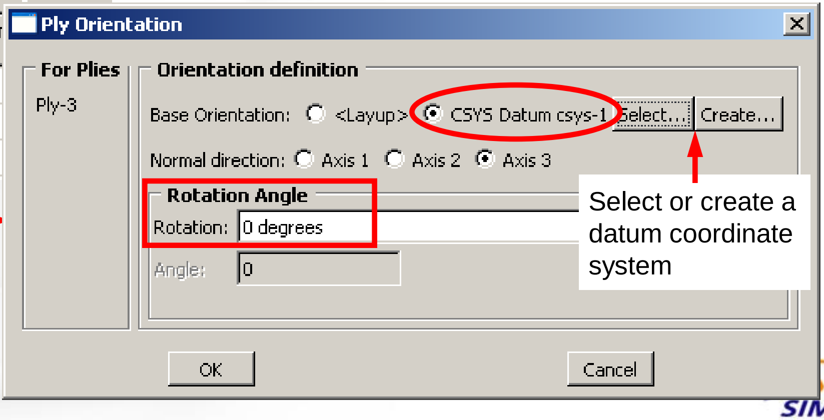
Section integration: ● During analysis ○ Before analysis

Thickness integration rule: ● Simpson ○ Gauss

☐ Make calculated sections symmetric

		Ply Name	Region	Material	Thickness	CSYS	Rotation Angle	In
1	✓	Ply-1	(Picked)	Material-1	0.5	<Layup>	0	
2	✓	Ply-2	(Picked)	Material-1	0.3	<Layup>	90	
3	✓	Ply-3	(Picked)	Material-1	0.3	double-click	0	





Ply Orientation

For Plies

Ply-3

Orientation definition

Base Orientation: ○ <Layup> ● CSYS Datum csys-1

Normal direction: ○ Axis 1 ○ Axis 2 ● Axis 3

Rotation Angle

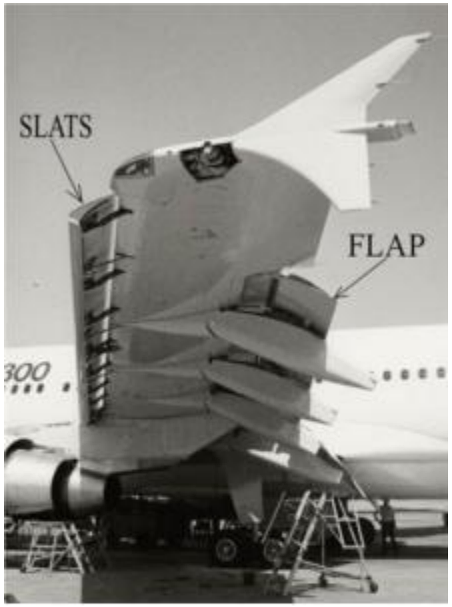
Rotation: 0 degrees

Angle: 0

Select or create a datum coordinate system

Understanding Composite Layups

- **The composite layup GUI interface is very convenient for analyzing large-scale composite structures.**
- **Example: Composite wing slat**
  - A wing slat is an aerodynamic device used at the leading edge of an aircraft wing in order to provide smooth air-flow at a higher angle of attack.
  - Each wing typically has a number of slats that are operated during take-off and landing to provide greater lift at slower speeds.
  - In order to reduce the overall structural weight of the aircraft, many structural components are made using high-performance fiber-reinforced composite materials.
  - Each composite layup has a large number of plies, which is typical of aircraft design.



An aircraft wing showing the slats

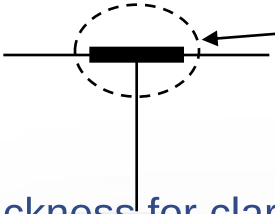
Understanding Composite Layups

- The wing slat consists of a number of ribs and spars and the skin.
  - The geometry is meshed using conventional shell elements, S4R.
  - Since a shell offset will be defined for the skin, two composite layups will be defined:
    - `Ribs_and_Spars_layup` for the ribs and spars
    - `skin_layup` for the skin

Geometry of a wing slat

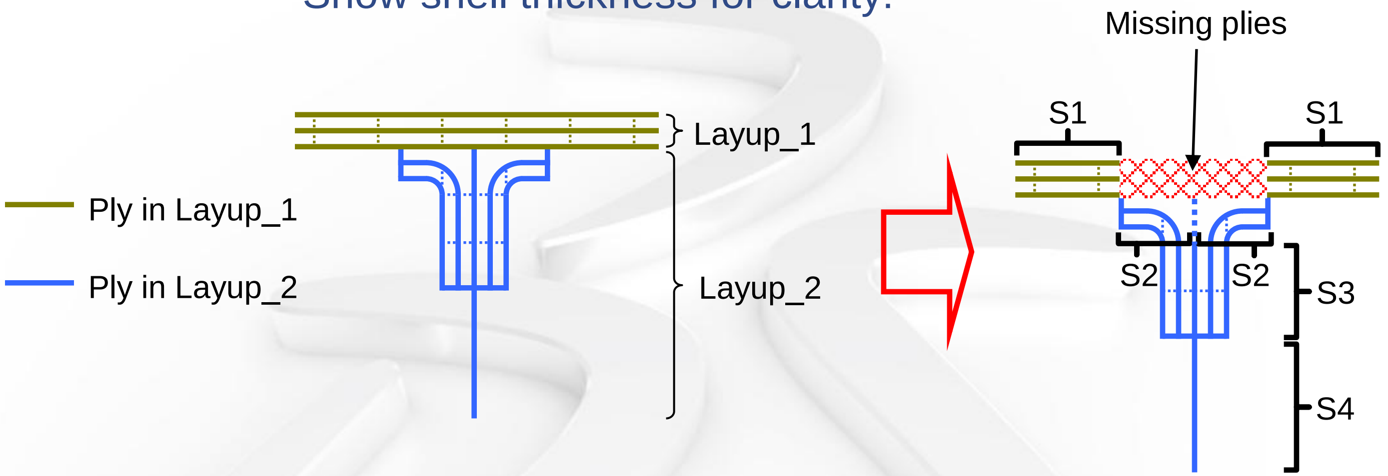
Understanding Composite Layups

- **Note**: If you apply two or more composite layups to regions that overlap, Abaqus/CAE uses the properties of the last layup (based on the names of the composite layups in alphabetical order).
- For example:



Region with overlapping layups in a conventional shell model of a T-intersection

- Show shell thickness for clarity:

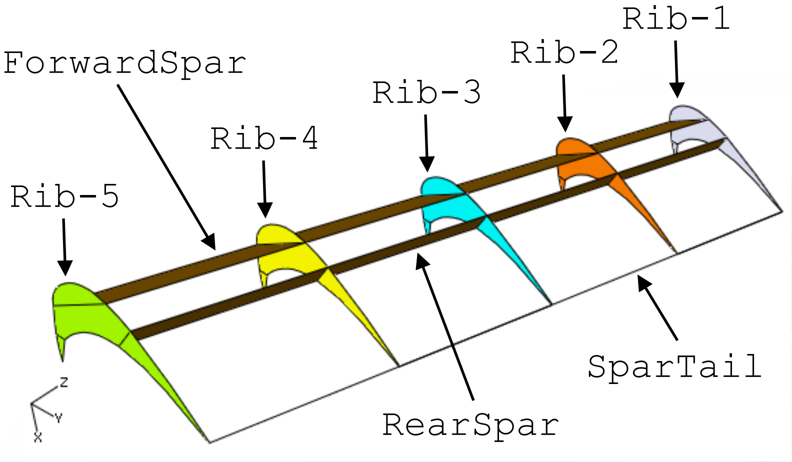


S1, S2, S3, and S4: shell sections generated by Abaqus to group plies in different regions.

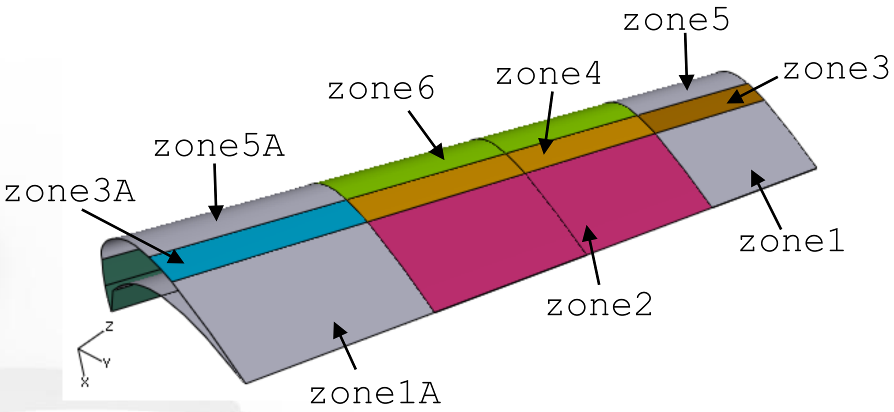
- **Resolution**: A single layup should be defined for the entire part to avoid missing plies when meshing connections between structural components.

Understanding Composite Layups

- Define named sets for the regions to which plies will be assigned.



Ribs_and_spars_layup



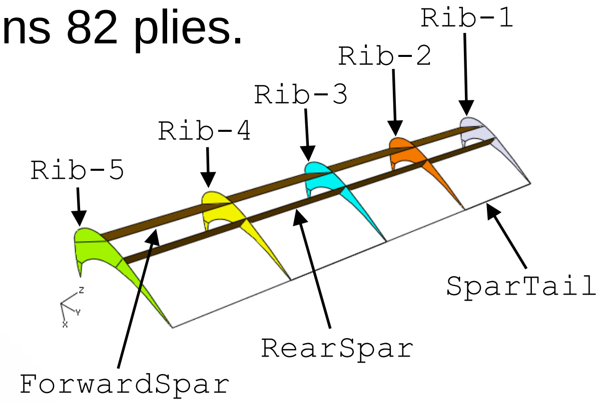
skins_layup

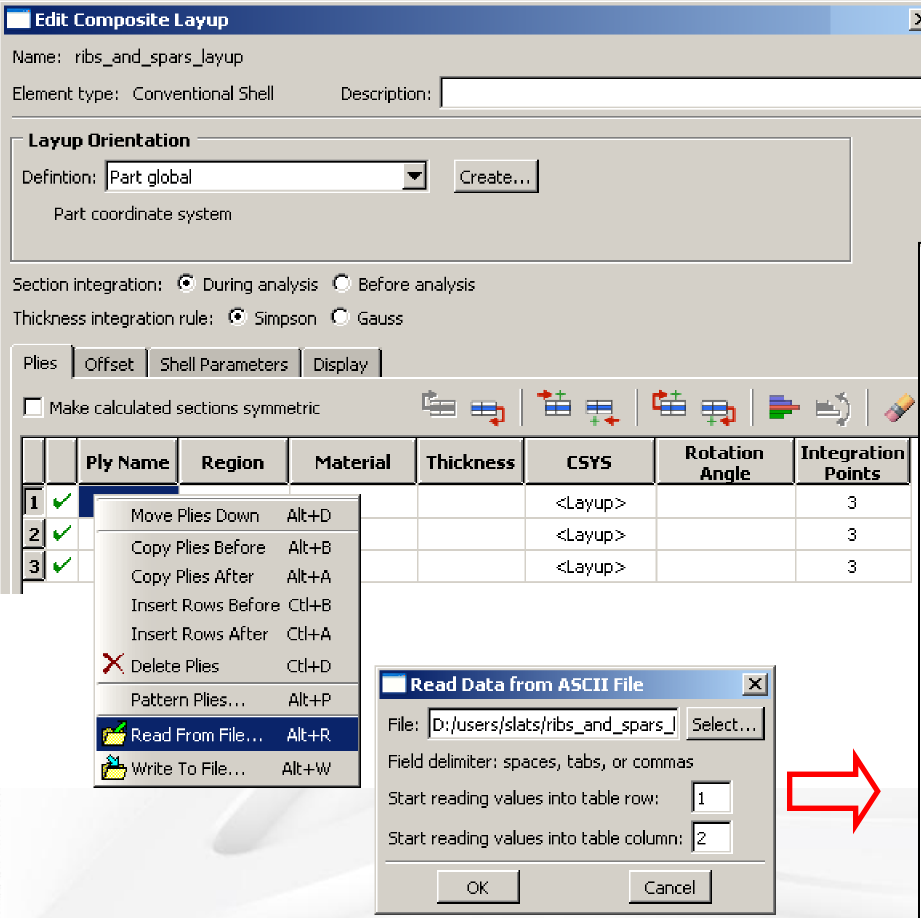
Note: Not all sets used for defining the skin layup are shown in the figure

Regions for plies (color code by sets)

Understanding Composite Layups

- Define the ribs and spars layup which contains 82 plies.
    - Read the ply data from a text file.




Edit Composite Layup

Name: ribs_and_spars_layup

Element type: Conventional Shell

Description:

Layup Orientation

Defintion: Part global

Part coordinate system

Section integration: ● During analysis ○ Before analysis

Thickness integration rule: ● Simpson ○ Gauss

☐ Make calculated sections symmetric

		Ply Name	Region	Material	Thickness	CSYS	Rotation Angle	Integration Points
1	✓					<Layup>		3
2	✓					<Layup>		3
3	✓					<Layup>		3

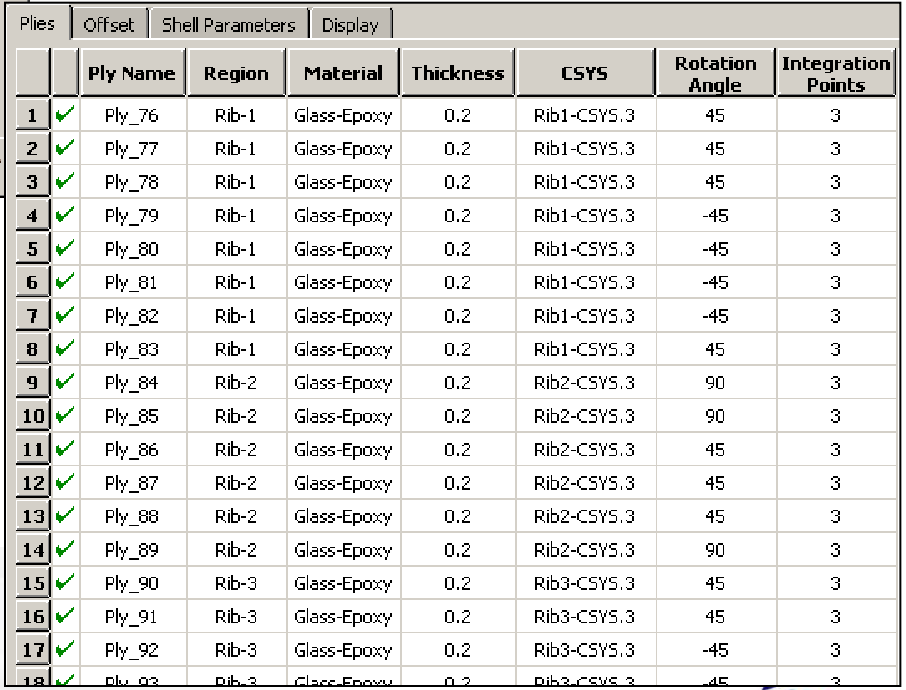
Read Data from ASCII File

File: D:/users/slats/ribs_and_spars_l

Field delimiter: spaces, tabs, or commas

Start reading values into table row: 1

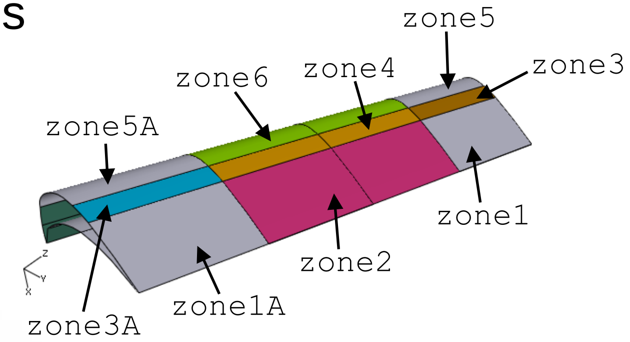
Start reading values into table column: 2

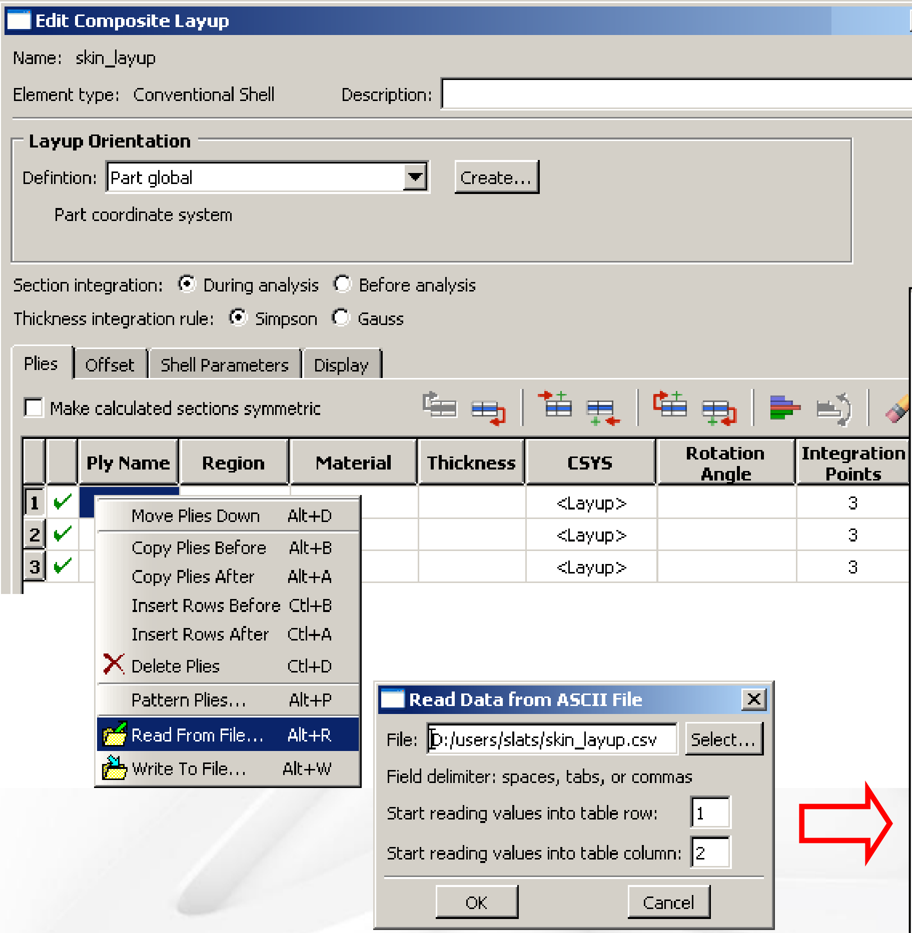


		Ply Name	Region	Material	Thickness	CSYS	Rotation Angle	Integration Points
1	✓	Ply_76	Rib-1	Glass-Epoxy	0.2	Rib1-CSYS.3	45	3
2	✓	Ply_77	Rib-1	Glass-Epoxy	0.2	Rib1-CSYS.3	45	3
3	✓	Ply_78	Rib-1	Glass-Epoxy	0.2	Rib1-CSYS.3	45	3
4	✓	Ply_79	Rib-1	Glass-Epoxy	0.2	Rib1-CSYS.3	-45	3
5	✓	Ply_80	Rib-1	Glass-Epoxy	0.2	Rib1-CSYS.3	-45	3
6	✓	Ply_81	Rib-1	Glass-Epoxy	0.2	Rib1-CSYS.3	-45	3
7	✓	Ply_82	Rib-1	Glass-Epoxy	0.2	Rib1-CSYS.3	-45	3
8	✓	Ply_83	Rib-1	Glass-Epoxy	0.2	Rib1-CSYS.3	45	3
9	✓	Ply_84	Rib-2	Glass-Epoxy	0.2	Rib2-CSYS.3	90	3
10	✓	Ply_85	Rib-2	Glass-Epoxy	0.2	Rib2-CSYS.3	90	3
11	✓	Ply_86	Rib-2	Glass-Epoxy	0.2	Rib2-CSYS.3	45	3
12	✓	Ply_87	Rib-2	Glass-Epoxy	0.2	Rib2-CSYS.3	45	3
13	✓	Ply_88	Rib-2	Glass-Epoxy	0.2	Rib2-CSYS.3	45	3
14	✓	Ply_89	Rib-2	Glass-Epoxy	0.2	Rib2-CSYS.3	90	3
15	✓	Ply_90	Rib-3	Glass-Epoxy	0.2	Rib3-CSYS.3	45	3
16	✓	Ply_91	Rib-3	Glass-Epoxy	0.2	Rib3-CSYS.3	45	3
17	✓	Ply_92	Rib-3	Glass-Epoxy	0.2	Rib3-CSYS.3	-45	3
18	✓	Ply_93	Rib-3	Glass-Epoxy	0.2	Rib3-CSYS.3	-45	3

Understanding Composite Layups

- Define the skin layup which contains 59 plies




Edit Composite Layup

Name: skin_layup

Element type: Conventional Shell

Description:

Layup Orientation

Definition: Part global

Part coordinate system

Section integration: ● During analysis ○ Before analysis

Thickness integration rule: ● Simpson ○ Gauss

☐ Make calculated sections symmetric

		Ply Name	Region	Material	Thickness	CSYS	Rotation Angle	Integration Points
1	✓					<Layup>		3
2	✓					<Layup>		3
3	✓					<Layup>		3

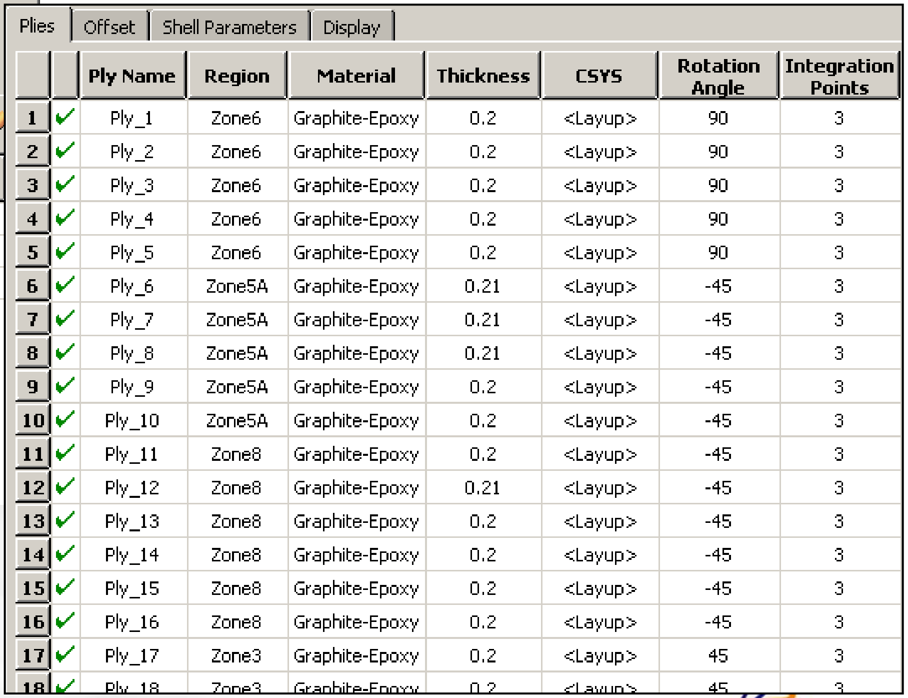
Read Data from ASCII File

File: D:/users/slats/skin_layup.csv

Field delimiter: spaces, tabs, or commas

Start reading values into table row: 1

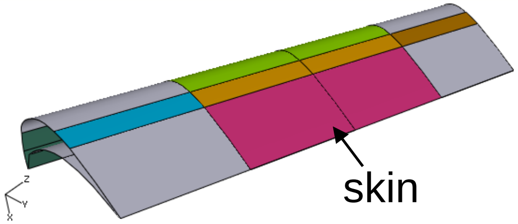
Start reading values into table column: 2

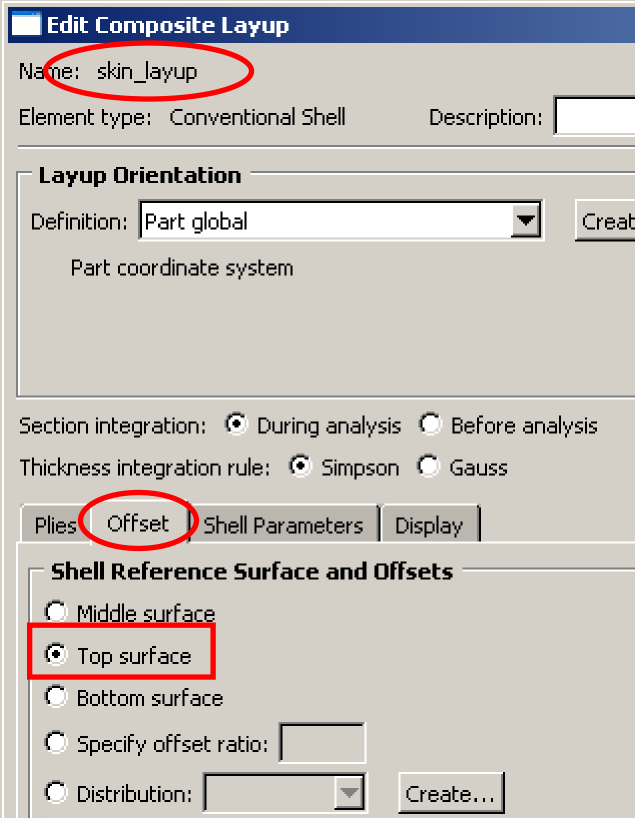


		Ply Name	Region	Material	Thickness	CSYS	Rotation Angle	Integration Points
1	✓	Ply_1	Zone6	Graphite-Epoxy	0.2	<Layup>	90	3
2	✓	Ply_2	Zone6	Graphite-Epoxy	0.2	<Layup>	90	3
3	✓	Ply_3	Zone6	Graphite-Epoxy	0.2	<Layup>	90	3
4	✓	Ply_4	Zone6	Graphite-Epoxy	0.2	<Layup>	90	3
5	✓	Ply_5	Zone6	Graphite-Epoxy	0.2	<Layup>	90	3
6	✓	Ply_6	Zone5A	Graphite-Epoxy	0.21	<Layup>	-45	3
7	✓	Ply_7	Zone5A	Graphite-Epoxy	0.21	<Layup>	-45	3
8	✓	Ply_8	Zone5A	Graphite-Epoxy	0.21	<Layup>	-45	3
9	✓	Ply_9	Zone5A	Graphite-Epoxy	0.2	<Layup>	-45	3
10	✓	Ply_10	Zone5A	Graphite-Epoxy	0.2	<Layup>	-45	3
11	✓	Ply_11	Zone8	Graphite-Epoxy	0.2	<Layup>	-45	3
12	✓	Ply_12	Zone8	Graphite-Epoxy	0.21	<Layup>	-45	3
13	✓	Ply_13	Zone8	Graphite-Epoxy	0.2	<Layup>	-45	3
14	✓	Ply_14	Zone8	Graphite-Epoxy	0.2	<Layup>	-45	3
15	✓	Ply_15	Zone8	Graphite-Epoxy	0.2	<Layup>	-45	3
16	✓	Ply_16	Zone8	Graphite-Epoxy	0.2	<Layup>	-45	3
17	✓	Ply_17	Zone3	Graphite-Epoxy	0.2	<Layup>	45	3
18	✓	Ply_18	Zone3	Graphite-Epoxy	0.2	<Layup>	45	3

Understanding Composite Layups

- Offset the reference surface to the top surface (outer surface) of the skin
  - By default, the middle surface is the reference surface.
  - In the composite layup editor, choose **Top surface** to offset the reference surface to the top surface of the skins.
    - You can also specify an offset ratio, or
    - choose an existing element-based discrete field.
      - Note: Abaqus/CAE allows you to select only valid distributions, which, for an offset, are scalar distributions applied to elements.





Edit Composite Layup

Name: skin_layup

Element type: Conventional Shell

Description:

Layup Orientation

Definition: Part global

Part coordinate system

Section integration: ● During analysis ○ Before analysis

Thickness integration rule: ● Simpson ○ Gauss

Shell Reference Surface and Offsets

○ Middle surface

● Top surface

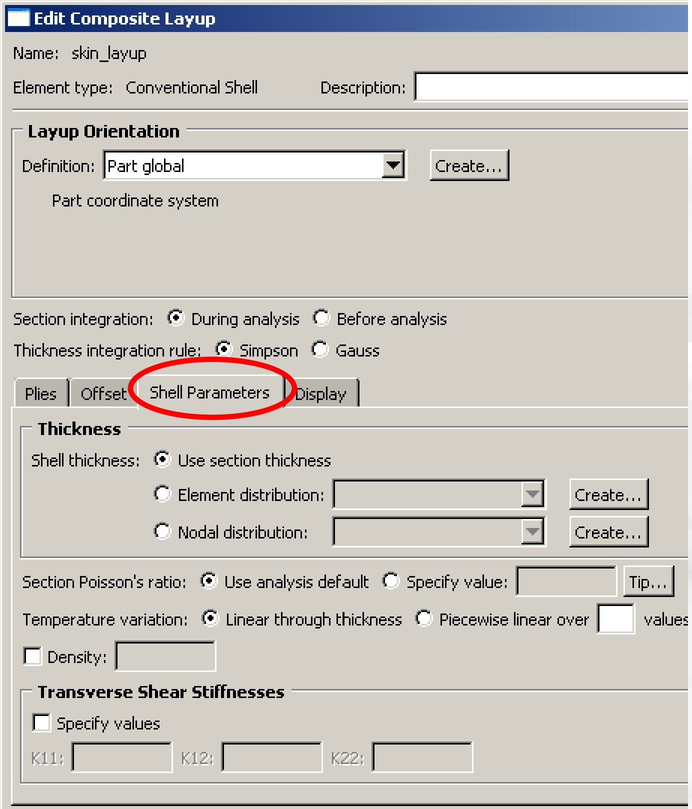
○ Bottom surface

○ Specify offset ratio:

○ Distribution:

Understanding Composite Layups

- **The composite layup editor also supports**
  - Defining shell parameters, including
    - Section Poisson’s ratio and transverse shear stiffness.
  - Changing composite layup display options



Name: skin_layup

Element type: Conventional Shell   Description:

Layup Orientation

Definition: Part global

Part coordinate system

Section integration: ● During analysis ○ Before analysis

Thickness integration rule: ● Simpson ○ Gauss

Thickness

Shell thickness: ● Use section thickness

○ Element distribution:

○ Nodal distribution:

Section Poisson's ratio: ● Use analysis default ○ Specify value:

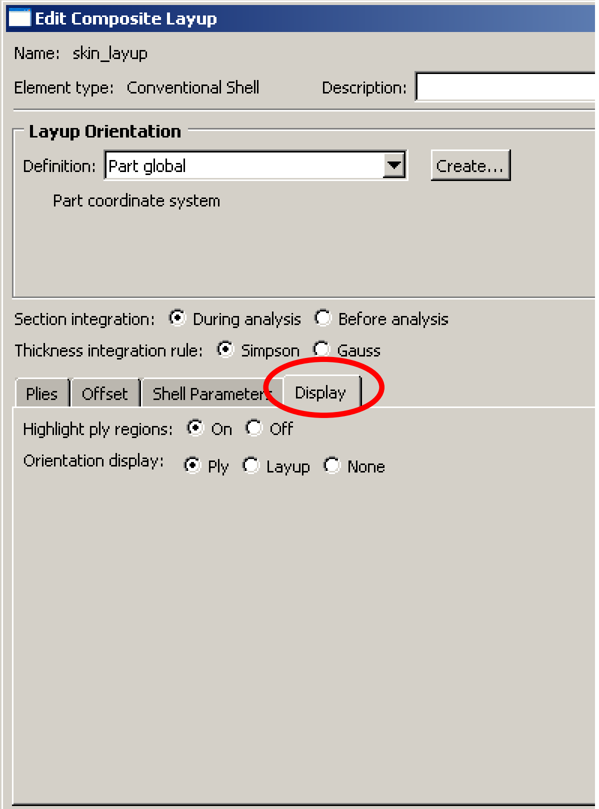
Temperature variation: ● Linear through thickness ○ Piecewise linear over values

☐ Density:

Transverse Shear Stiffnesses

☐ Specify values

K11: K12: K22:



Name: skin_layup

Element type: Conventional Shell   Description:

Layup Orientation

Definition: Part global

Part coordinate system

Section integration: ● During analysis ○ Before analysis

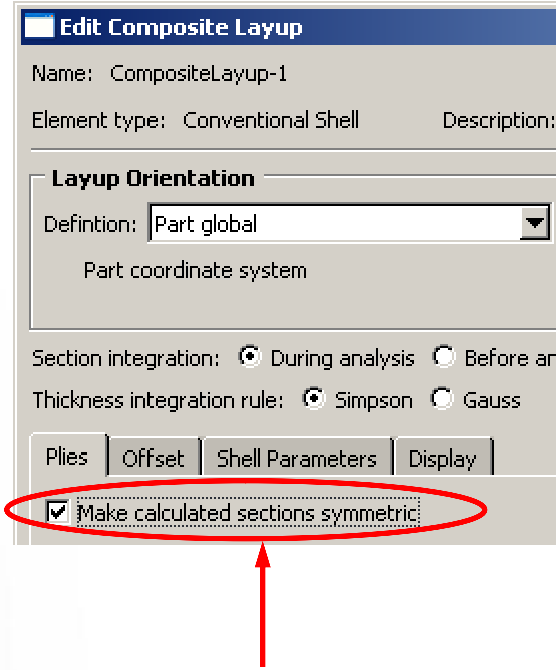
Thickness integration rule: ● Simpson ○ Gauss

Highlight ply regions: ● On ○ Off

Orientation display: ● Ply ○ Layup ○ None

Understanding Composite Layups

- **Symmetry option**
  - This option simplifies the process of defining composite layups whose plies are symmetric about a central layer.
    - You only need to specify half of the plies in the composite layup, starting with the bottom ply in the first row and ending with the central ply.
    - Abaqus automatically appends plies to the layup definition by repeating all of the specified plies (including the central ply) in the reverse order.



Edit Composite Layup

Name: CompositeLayup-1

Element type: Conventional Shell

Description:

Layup Orientation

Defintion: Part global

Part coordinate system

Section integration: ● During analysis ○ Before ar

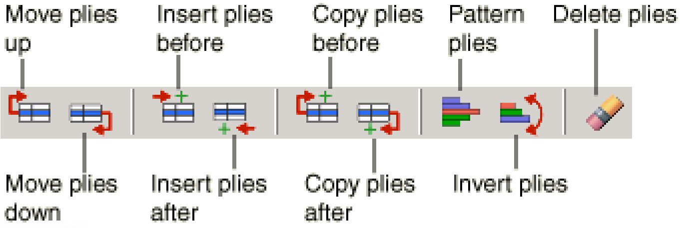
Thickness integration rule: ● Simpson ○ Gauss

☑ Make calculated sections symmetric

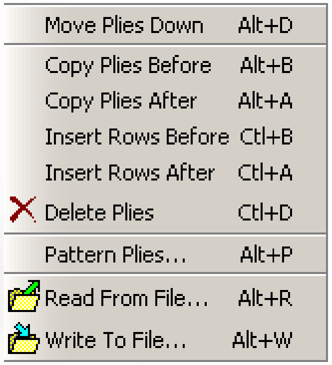
Toggle on this option to activate simplified modeling of symmetric composites

Understanding Composite Layups

- **Ply Management**
  - is very convenient to ...
    - Move plies
    - Copy plies
    - Delete plies
    - Invert plies
    - Pattern a group of selected plies
      - Create symmetric layup
      - Copy plies multiple times
    - Read from a file
    - Write to a file
  - is activated by clicking mouse button 3 on the ply table.



These actions can be performed using the icons in the composite layup editor above the ply table.



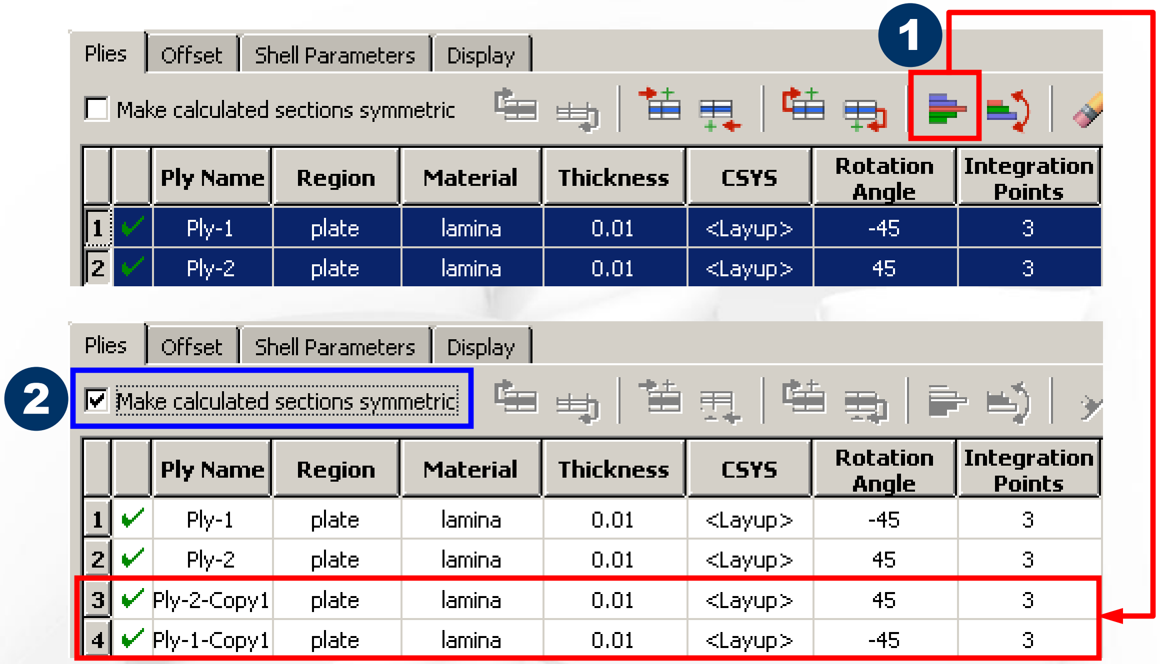
Move Plies Down	Alt+D
Copy Plies Before	Alt+B
Copy Plies After	Alt+A
Insert Rows Before	Ctl+B
Insert Rows After	Ctl+A
Delete Plies	Ctl+D
Pattern Plies...	Alt+P
Read From File...	Alt+R
Write To File...	Alt+W

Understanding Composite Layups

- **Symmetry option vs. symmetry pattern**
    - Symmetry option
        - Plies generated using the symmetry option cannot be viewed in the layup editor.
            - However, they can be viewed in ply stack plots (will be discussed later in section “Viewing a Composite Layup”) and Abaqus/Viewer, and are labeled using `Sym_` as the prefix to the repeated ply’s original name.
        - Any manipulation of the original plies will automatically propagate to the symmetric plies.
    - Symmetry pattern
        - Plies generated using the symmetry pattern can be viewed in the layup editor.
        - Manipulations of the original plies will NOT propagate to the symmetric plies.

Understanding Composite Layups

- The combination of the symmetry option and symmetry pattern can significantly simplify the process of defining composite layups with certain symmetric stacking sequences.
  - For example, defining an 8-ply layup with the following stacking sequence: $[(-45, 45)_S]_S$:



☐ Make calculated sections symmetric

		Ply Name	Region	Material	Thickness	CSYS	Rotation Angle	Integration Points
1	✓	Ply-1	plate	lamina	0.01	<Layup>	-45	3
2	✓	Ply-2	plate	lamina	0.01	<Layup>	45	3

☑ Make calculated sections symmetric

		Ply Name	Region	Material	Thickness	CSYS	Rotation Angle	Integration Points
1	✓	Ply-1	plate	lamina	0.01	<Layup>	-45	3
2	✓	Ply-2	plate	lamina	0.01	<Layup>	45	3
3	✓	Ply-2-Copy1	plate	lamina	0.01	<Layup>	45	3
4	✓	Ply-1-Copy1	plate	lamina	0.01	<Layup>	-45	3

① Apply the symmetry pattern: Symmetric about last ply in the layup

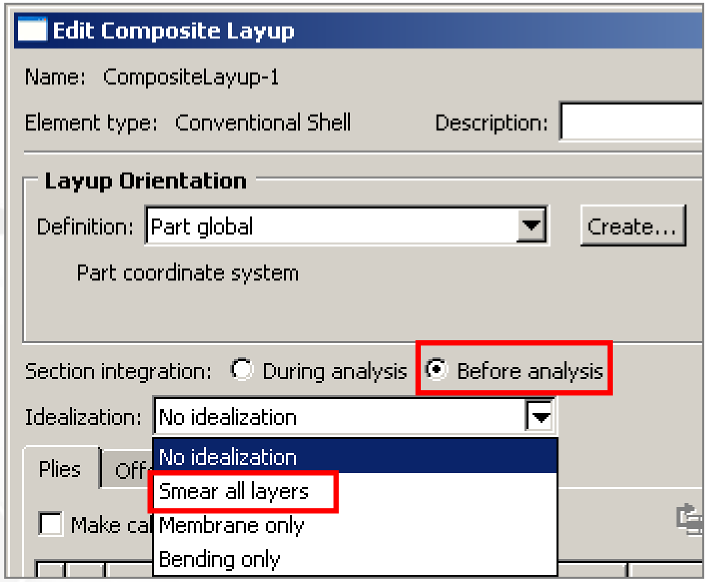
② Toggle on the Make calculated sections symmetric option

Understanding Composite Layups

- **Idealizations for a shell composite layup integrated before the analysis**
  - Idealizations allow you to modify the stiffness coefficients in a shell section based on assumptions about the shell's makeup or expected behavior.
  - The following idealizations are available:

① **Smeared layers**

- Ignores the effects of the stacking sequence for the plies in the composite layup.
- Contributions from each specified ply are smeared across the entire thickness of the layup, resulting in a general response independent of the stacking sequence.



Edit Composite Layup

Name: CompositeLayup-1

Element type: Conventional Shell

Description:

Layup Orientation

Definition: Part global

Part coordinate system

Section integration: ○ During analysis ● Before analysis

Idealization: No idealization

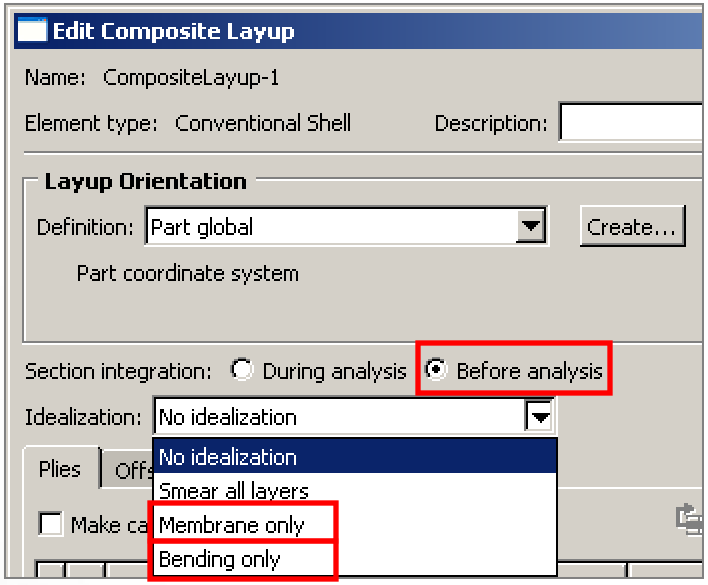
Understanding Composite Layups

② Membrane only

- Retains only the membrane stiffness for shells whose predominant response will be in-plane stretching.

③ Bending only

- Retains only the bending stiffness for shells whose predominant response will be pure bending.



Name: CompositeLayup-1

Element type: Conventional Shell

Description:

Definition: Part global

Part coordinate system

Section integration: ○ During analysis ● Before analysis

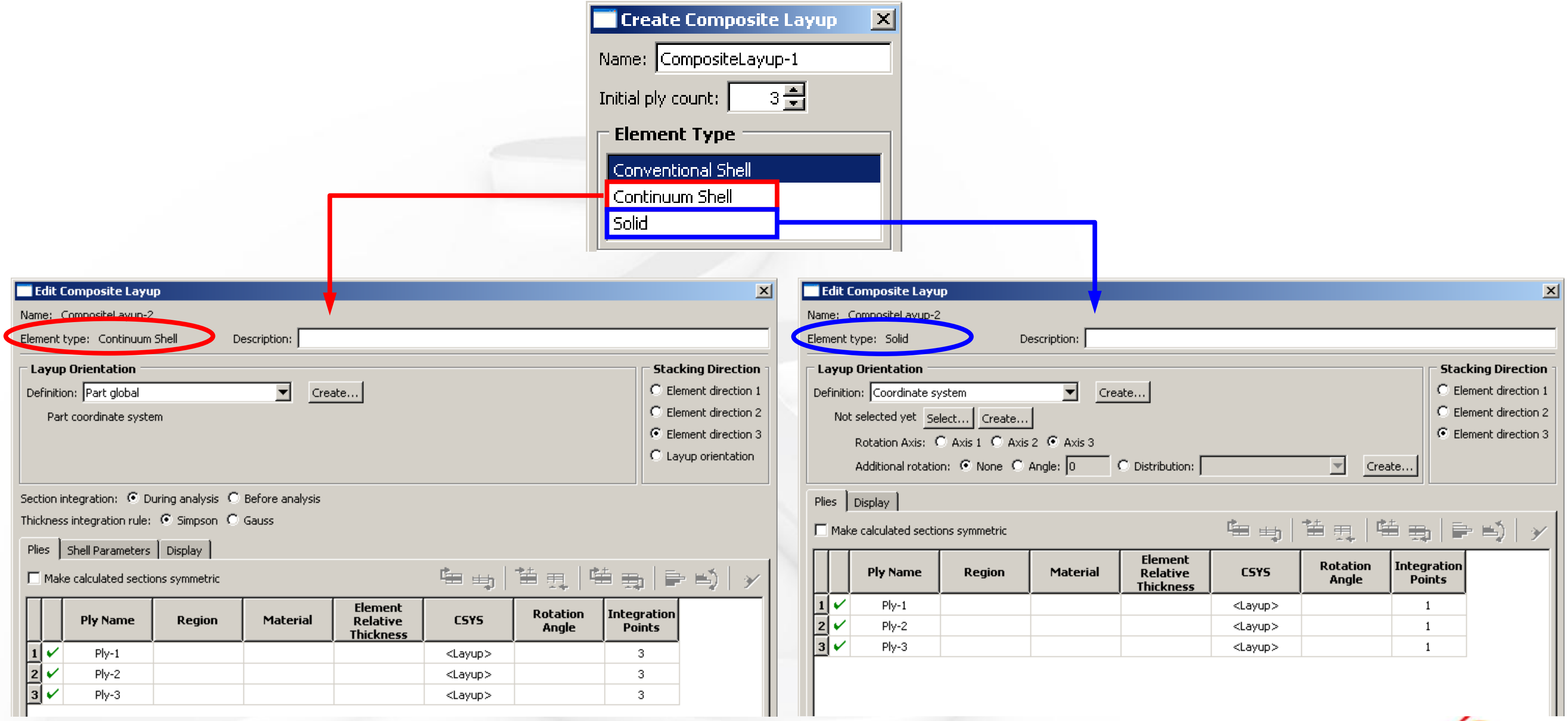
Idealization: No idealization

☐ Make ca

- Idealizations modify the shell general stiffness coefficients after they have been computed normally, including the effects of any offsets.
- **Note:** Select **No idealization** (default) to account for the complete stiffness of the shell as determined by the material assignments and ply composition.

Understanding Composite Layups

- **Defining a continuum shell/solid composite layup**
  - Use a similar procedure to that described for a conventional shell composite layup; therefore, the details will not be discussed.



Create Composite Layup

Name: CompositeLayup-1

Initial ply count: 3

Element Type

Conventional Shell

Continuum Shell

Solid

Edit Composite Layup

Name: CompositeLayup-2

Element type: Continuum Shell

Description:

Layup Orientation

Definition: Part global

Part coordinate system

Stacking Direction

○ Element direction 1

○ Element direction 2

● Element direction 3

○ Layup orientation

Section integration: ● During analysis ○ Before analysis

Thickness integration rule: ● Simpson ○ Gauss

Plies | Shell Parameters | Display

☐ Make calculated sections symmetric

		Ply Name	Region	Material	Element Relative Thickness	CSYS	Rotation Angle	Integration Points
1	✓	Ply-1				<Layup>		3
2	✓	Ply-2				<Layup>		3
3	✓	Ply-3				<Layup>		3

Edit Composite Layup

Name: CompositeLayup-2

Element type: Solid

Description:

Layup Orientation

Definition: Coordinate system

Not selected yet

Rotation Axis: ○ Axis 1 ○ Axis 2 ● Axis 3

Additional rotation: ● None ○ Angle: 0 ○ Distribution:

Stacking Direction

○ Element direction 1

○ Element direction 2

● Element direction 3

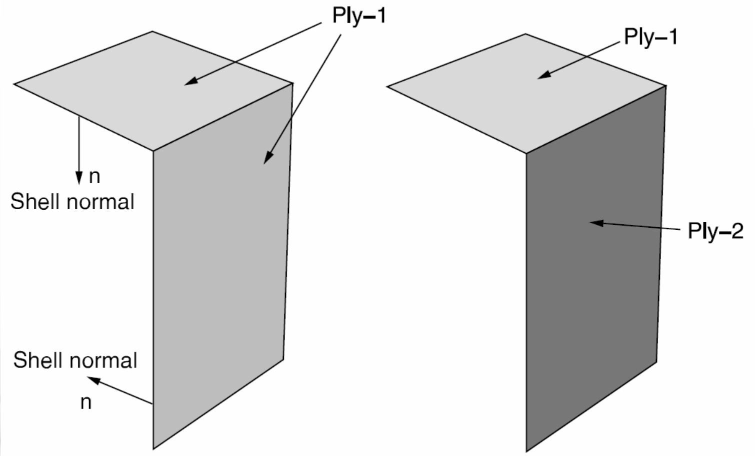
Plies | Display

☐ Make calculated sections symmetric

		Ply Name	Region	Material	Element Relative Thickness	CSYS	Rotation Angle	Integration Points
1	✓	Ply-1				<Layup>		1
2	✓	Ply-2				<Layup>		1
3	✓	Ply-3				<Layup>		1

Understanding Composite Layups

- **Limitations**
  - Abaqus cannot analyze a composite layup if the shell normal of a single ply makes a sharp transition through an angle of 90º or greater.
    - Separate plies should be used to model such a region.



  - The composite layup editor does not support the rebar option.
    - However, alternative methods are available to define rebar layers (discussed in Lecture 6).

Understanding Composite Layup Orientations

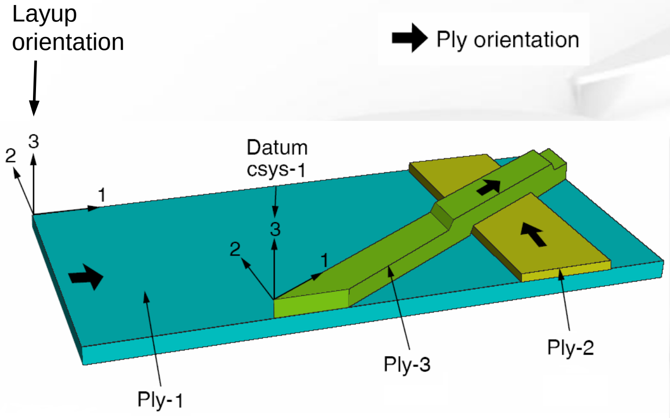
Understanding Composite Layup Orientations

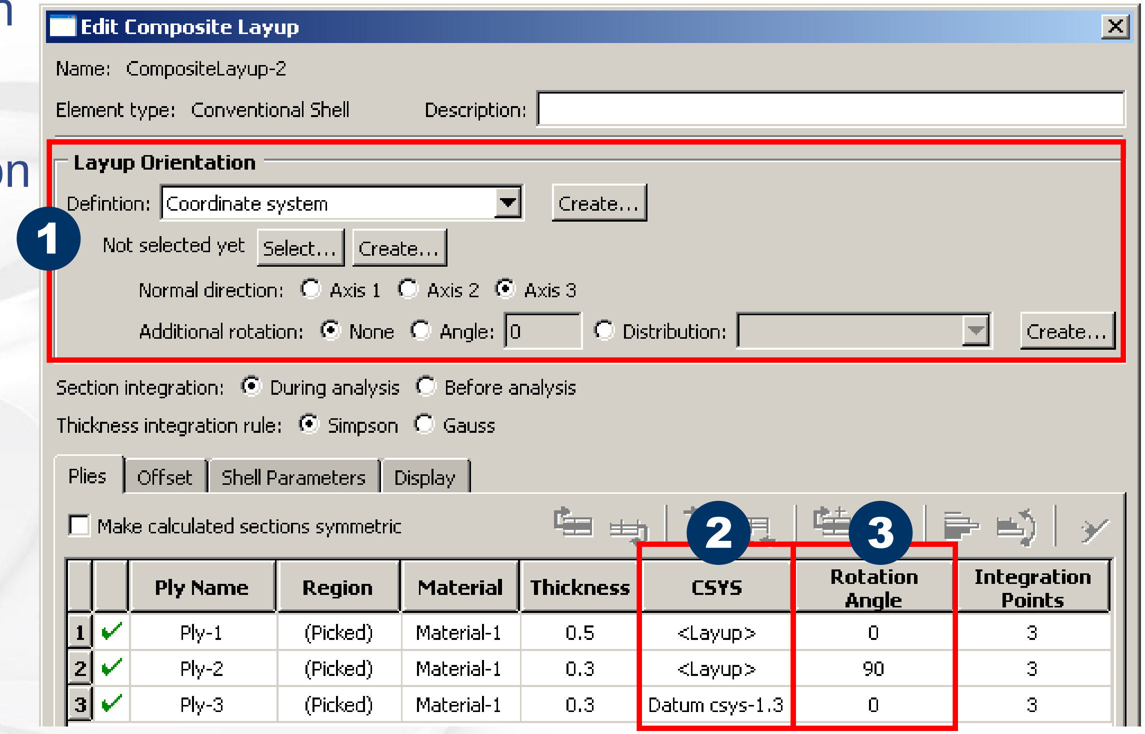
- The orientation of the fibers within each ply of a composite layup plays an important role in determining the physical description of the model.
- The composite layup editor derives the orientation of the fibers from three parameters that are relative to each other:

① Layup orientation

② Ply orientation

③ Additional rotation





Edit Composite Layup

Name: CompositeLayup-2

Element type: Conventional Shell Description:

Layup Orientation

Defintion: Coordinate system Create...

Not selected yet Select... Create...

Normal direction: ○ Axis 1 ○ Axis 2 ● Axis 3

Additional rotation: ● None ○ Angle: 0 ○ Distribution: Create...

Section integration: ● During analysis ○ Before analysis

Thickness integration rule: ● Simpson ○ Gauss

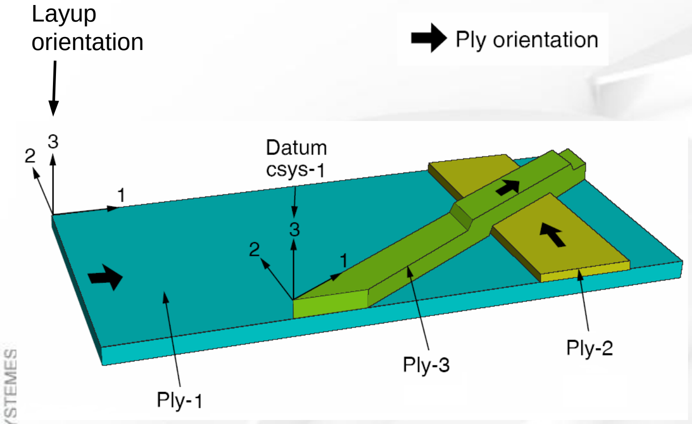
Plies | Offset | Shell Parameters | Display

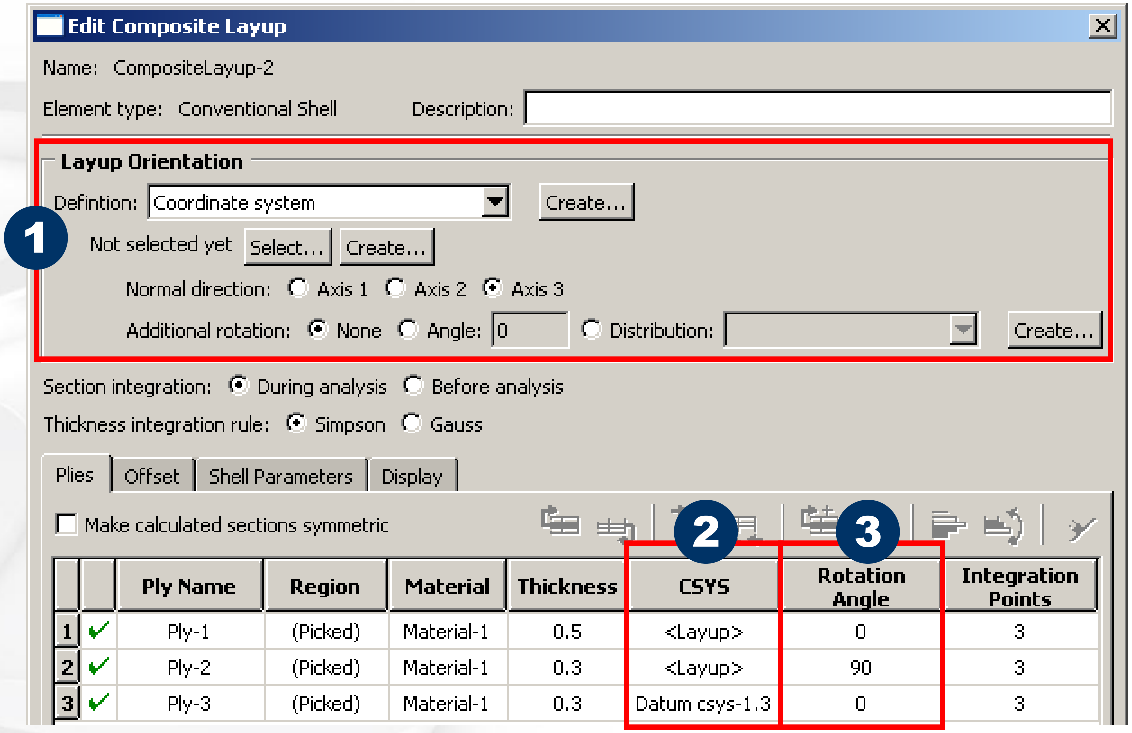
☐ Make calculated sections symmetric

		Ply Name	Region	Material	Thickness	CSYS	Rotation Angle	Integration Points
1	✓	Ply-1	(Picked)	Material-1	0.5	<Layup>	0	3
2	✓	Ply-2	(Picked)	Material-1	0.3	<Layup>	90	3
3	✓	Ply-3	(Picked)	Material-1	0.3	Datum csys-1.3	0	3

Understanding Composite Layup Orientations

- By default, ply angles are given with respect to a reference coordinate system listed for each ply.
- If no system is specified, then the default is to use the layup orientation system which, by default, is the same as the part's Global Cartesian system.





Edit Composite Layup

Name: CompositeLayup-2

Element type: Conventional Shell   Description:

Layup Orientation

Defintion: Coordinate system   Create...

Not selected yet   Select...   Create...

Normal direction: ○ Axis 1 ○ Axis 2 ● Axis 3

Additional rotation: ● None ○ Angle: 0 ○ Distribution: Create...

Section integration: ● During analysis ○ Before analysis

Thickness integration rule: ● Simpson ○ Gauss

Plies | Offset | Shell Parameters | Display

☐ Make calculated sections symmetric

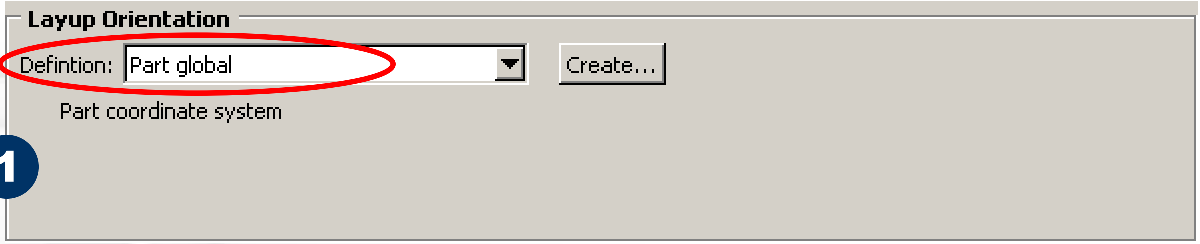
		Ply Name	Region	Material	Thickness	CSYS	Rotation Angle	Integration Points
1	✓	Ply-1	(Picked)	Material-1	0.5	<Layup>	0	3
2	✓	Ply-2	(Picked)	Material-1	0.3	<Layup>	90	3
3	✓	Ply-3	(Picked)	Material-1	0.3	Datum csys-1.3	0	3

Understanding Composite Layup Orientations

- **Layup orientation**
  - Defines the base or reference orientation <Layup> for the layup.
  - Determined by one of the following options available in the composite layup editor:

Use the default layup orientation (same as that of the part)

1



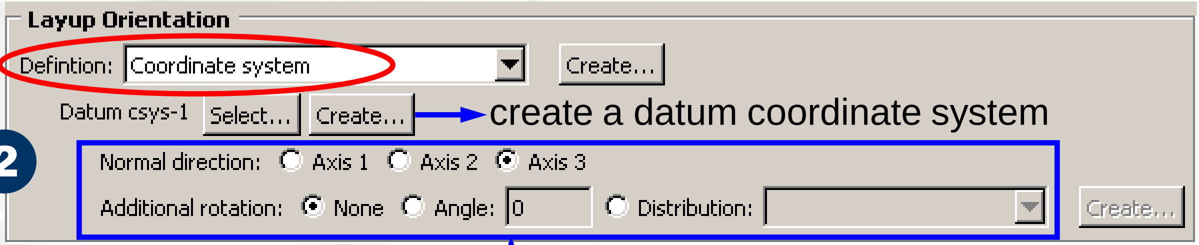
Layup Orientation

Defintion: Part global ▾ Create...

Part coordinate system

Select a datum coordinate system that defines the orientation

2



Layup Orientation

Defintion: Coordinate system ▾ Create...

Datum csys-1 Select... Create...

create a datum coordinate system

Normal direction: ○ Axis 1 ○ Axis 2 ● Axis 3

Additional rotation: ● None ○ Angle: 0 ○ Distribution: ▾ Create...

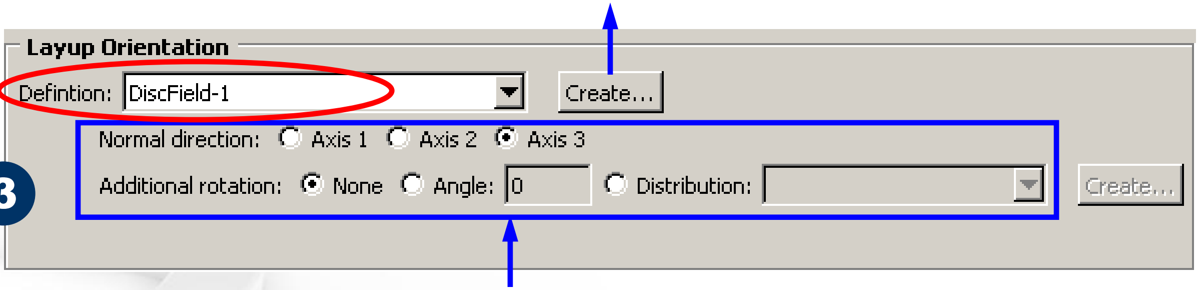
Define normal direction of the layup and additional rotation about the layup normal direction

Understanding Composite Layup Orientations

create a new orientation discrete field

Select an orientation discrete field that defines a spatially varying orientation

3



Layup Orientation

Defintion: DiscField-1 Create...

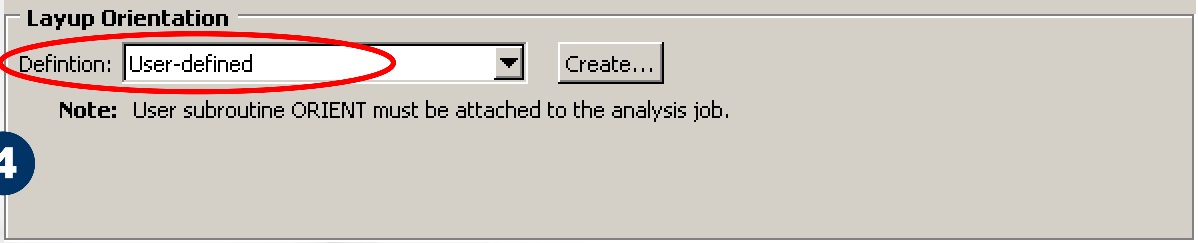
Normal direction: ○ Axis 1 ○ Axis 2 ● Axis 3

Additional rotation: ● None ○ Angle: 0 ○ Distribution: Create...

define normal direction of the layup and additional rotation about the layup normal direction

Select an orientation defined in user subroutine `ORIENT` (Abaqus/Standard only)

4



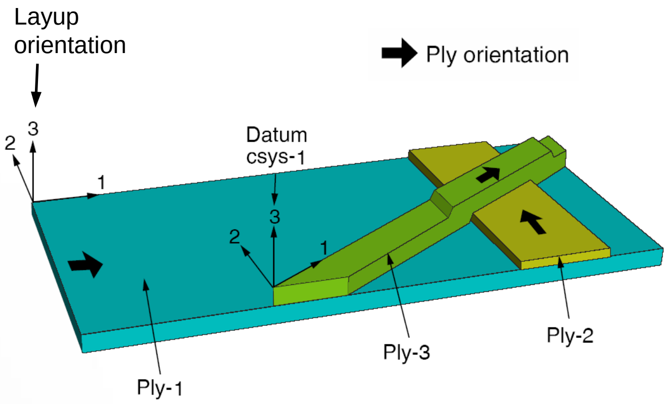
Layup Orientation

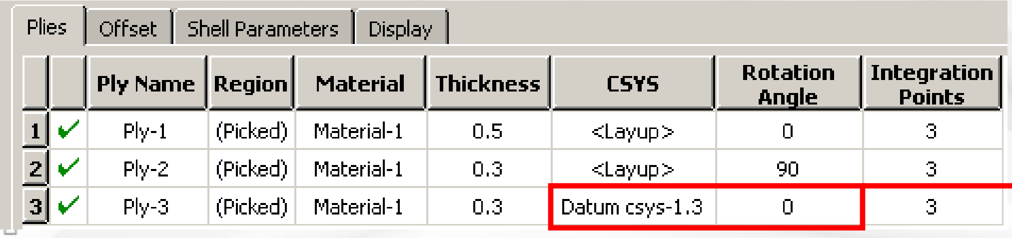
Defintion: User-defined Create...

Note: User subroutine ORIENT must be attached to the analysis job.

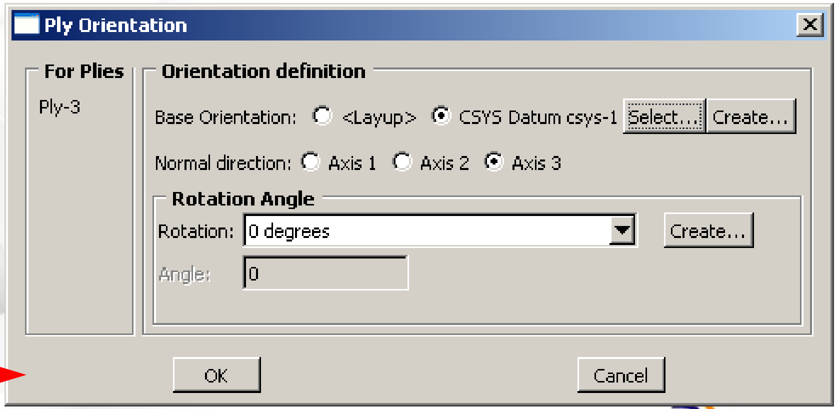
Understanding Composite Layup Orientations

- **Ply orientation**
  - defines the relative orientation of each ply combined with a CSYS and a rotation angle.
  - is determined by
    - selecting 0°, +/–45° or 90° from the base orientation <layup>,
    - specifying a floating point value between –90° and +90° from the base orientation <layup>, or
    - selecting a coordinate system and additional rotation angle.





		Ply Name	Region	Material	Thickness	CSYS	Rotation Angle	Integration Points
1	✓	Ply-1	(Picked)	Material-1	0.5	<Layup>	0	3
2	✓	Ply-2	(Picked)	Material-1	0.3	<Layup>	90	3
3	✓	Ply-3	(Picked)	Material-1	0.3	Datum csys-1.3	0	3



For Plies

Ply-3

Orientation definition

Base Orientation: ○ <Layup> ● CSYS Datum csys-1

Normal direction: ○ Axis 1 ○ Axis 2 ● Axis 3

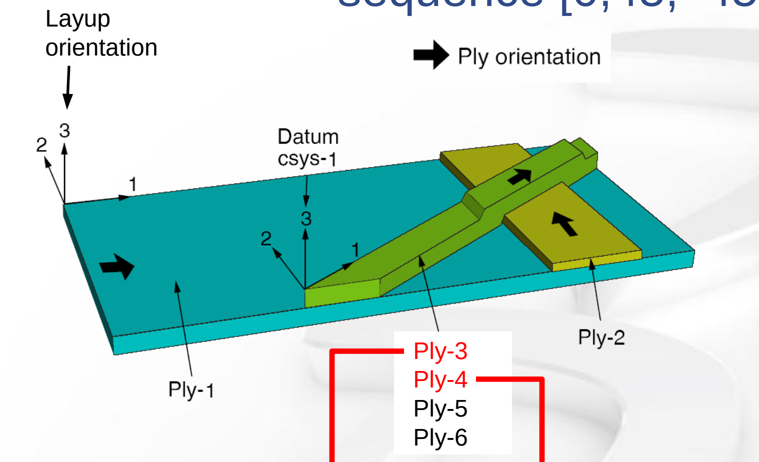
Rotation Angle

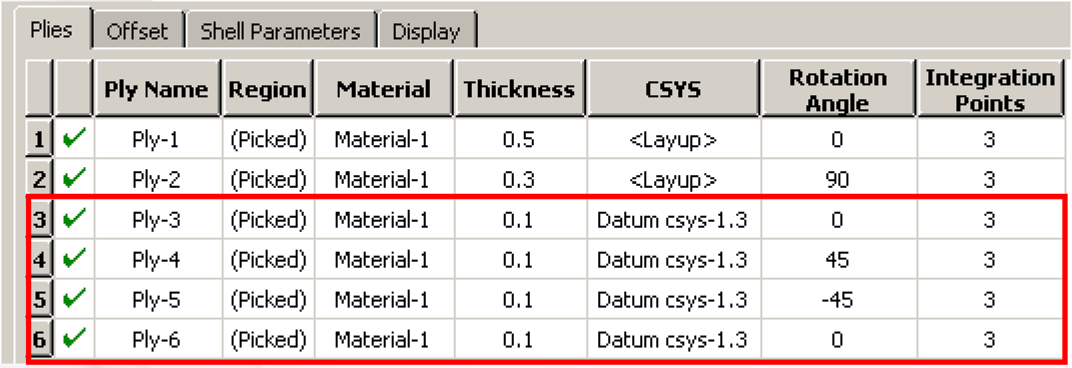
Rotation: 0 degrees

Angle: 0

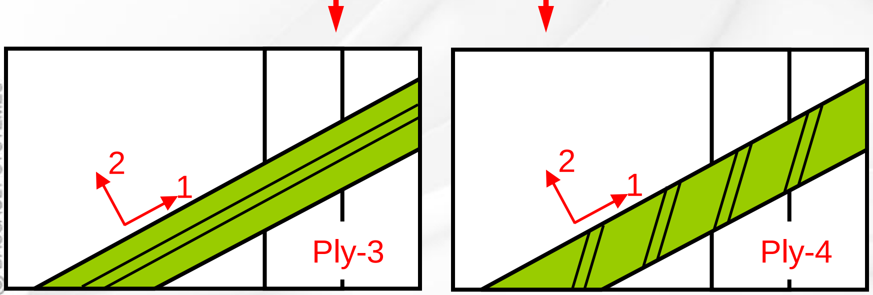
Understanding Composite Layup Orientations

- For plies that are not aligned along the layup orientation, the user-specified reference coordinate system makes it easy to define their orientations.
  - For example, consider an extension to the previous model where the top strip now consists of four plies arranged in the stacking sequence [0,45,–45,0].





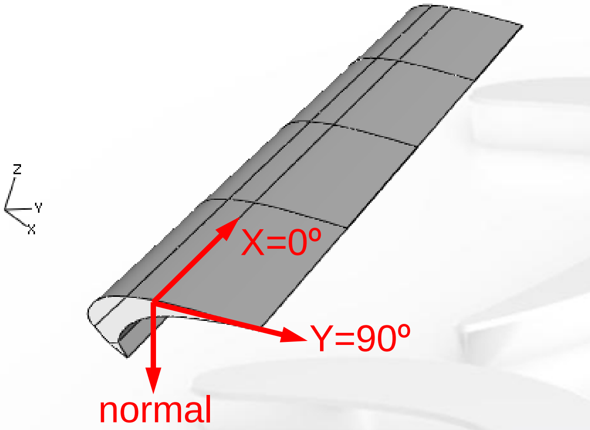
		Ply Name	Region	Material	Thickness	CSYS	Rotation Angle	Integration Points
1	✓	Ply-1	(Picked)	Material-1	0.5	<Layup>	0	3
2	✓	Ply-2	(Picked)	Material-1	0.3	<Layup>	90	3
3	✓	Ply-3	(Picked)	Material-1	0.1	Datum csys-1.3	0	3
4	✓	Ply-4	(Picked)	Material-1	0.1	Datum csys-1.3	45	3
5	✓	Ply-5	(Picked)	Material-1	0.1	Datum csys-1.3	-45	3
6	✓	Ply-6	(Picked)	Material-1	0.1	Datum csys-1.3	0	3



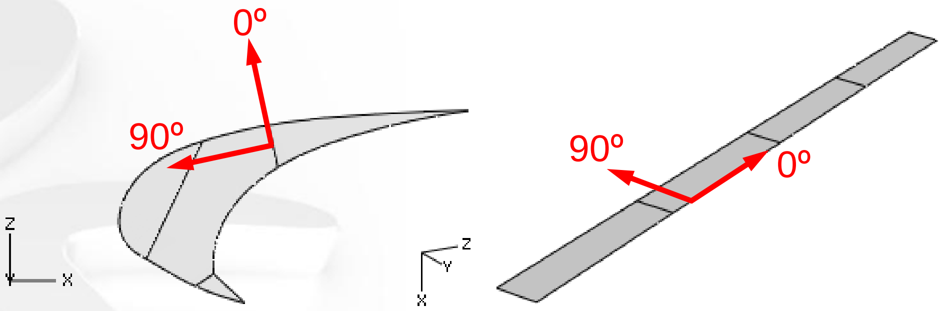
Note: The label of the user-specified CSYS is *CSYS name.#* where *#* is the normal axis/additional rotation axis.

Understanding Composite Layup Orientations

- **Defining the layup and ply orientations**
  - Example: Composite wing slat



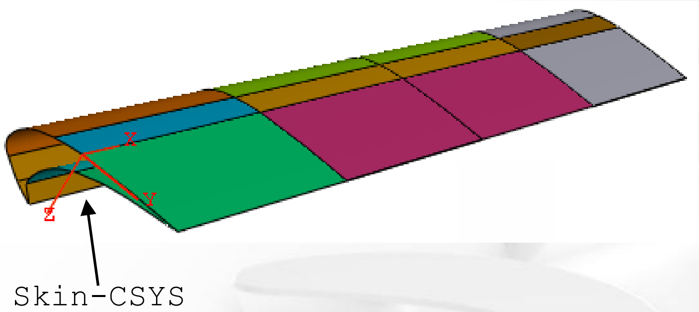
Layup orientations for skin of the slat



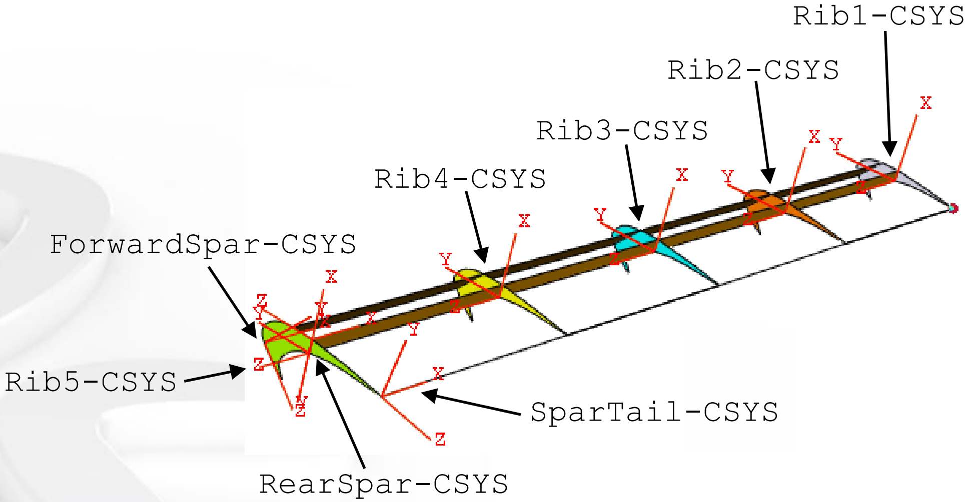
Layup orientations for ribs and spars of the slat

Understanding Composite Layup Orientations

1. Create the datum coordinate systems as indicated in the following figures.



Layup orientations for skin of the slat

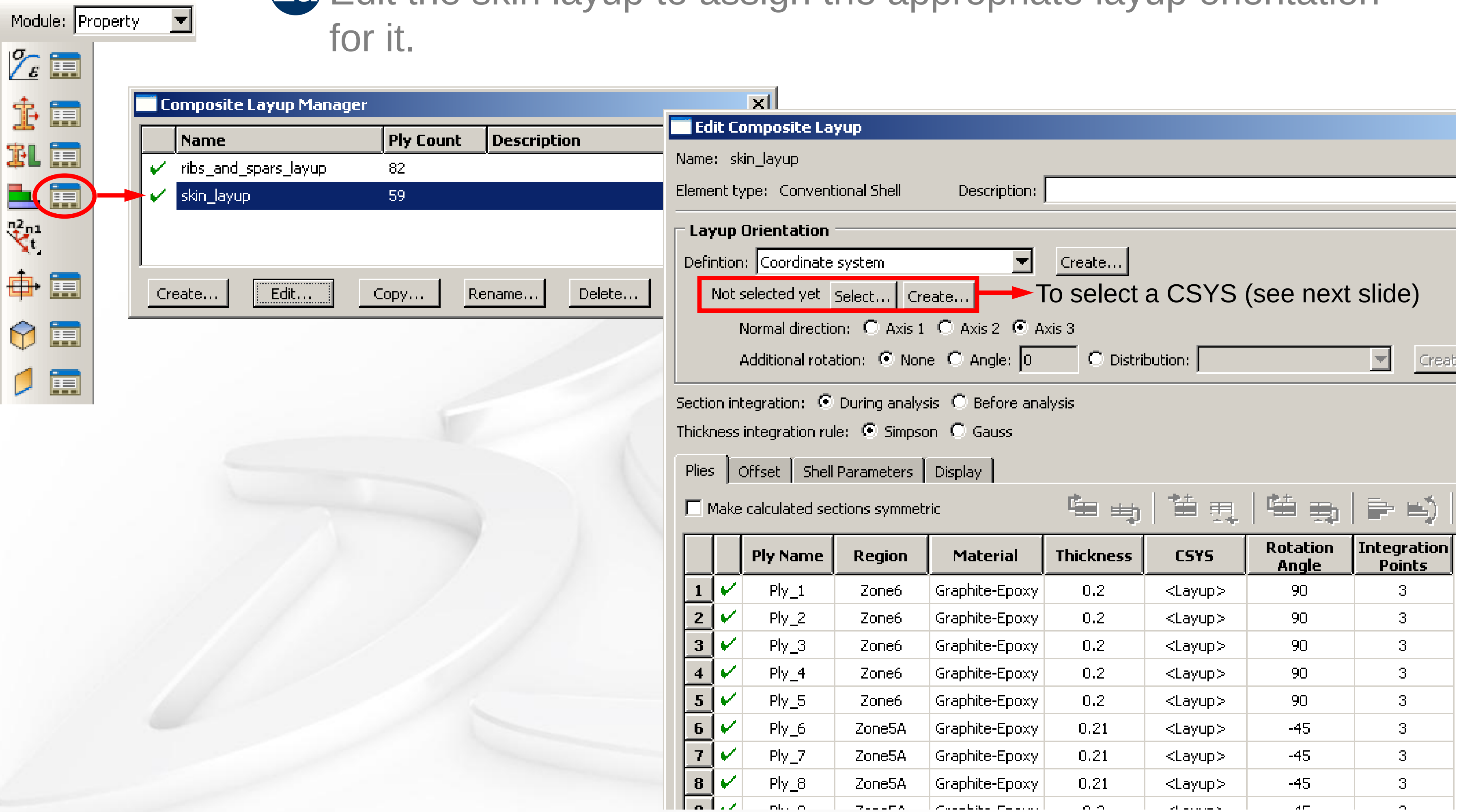


Layup orientations for ribs and spars of the slat

Understanding Composite Layup Orientations

2 Define the layup orientation for the skin layup.

2a Edit the skin layup to assign the appropriate layup orientation for it.



Module: Property

Composite Layup Manager

	Name	Ply Count	Description
✓	ribs_and_spars_layup	82	
✓	skin_layup	59	

Edit Composite Layup

Name: skin_layup

Element type: Conventional Shell

Description:

Layup Orientation

Defintion: Coordinate system

Not selected yet

To select a CSYS (see next slide)

Normal direction: ○ Axis 1 ○ Axis 2 ● Axis 3

Additional rotation: ● None ○ Angle: 0 ○ Distribution:

Section integration: ● During analysis ○ Before analysis

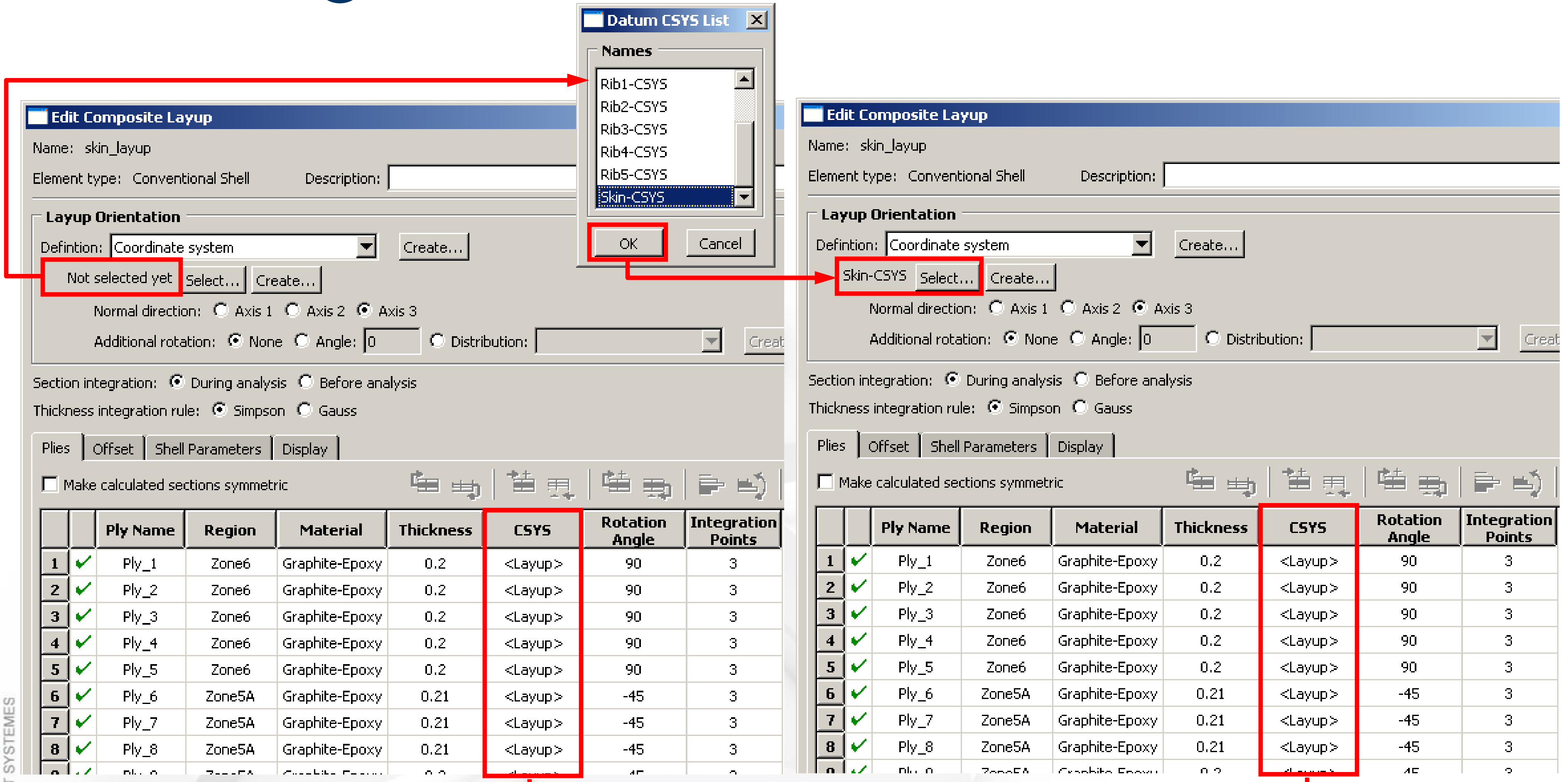
Thickness integration rule: ● Simpson ○ Gauss

☐ Make calculated sections symmetric

		Ply Name	Region	Material	Thickness	CSYS	Rotation Angle	Integration Points
1	✓	Ply_1	Zone6	Graphite-Epoxy	0.2	<Layup>	90	3
2	✓	Ply_2	Zone6	Graphite-Epoxy	0.2	<Layup>	90	3
3	✓	Ply_3	Zone6	Graphite-Epoxy	0.2	<Layup>	90	3
4	✓	Ply_4	Zone6	Graphite-Epoxy	0.2	<Layup>	90	3
5	✓	Ply_5	Zone6	Graphite-Epoxy	0.2	<Layup>	90	3
6	✓	Ply_6	Zone5A	Graphite-Epoxy	0.21	<Layup>	-45	3
7	✓	Ply_7	Zone5A	Graphite-Epoxy	0.21	<Layup>	-45	3
8	✓	Ply_8	Zone5A	Graphite-Epoxy	0.21	<Layup>	-45	3

Understanding Composite Layup Orientations

2b Select the predefined datum CSYS named `Skin-CSYS`.



Edit Composite Layup

Name: skin_layup

Element type: Conventional Shell

Description:

Layup Orientation

Defintion: Coordinate system

Not selected yet

Normal direction: ○ Axis 1 ○ Axis 2 ● Axis 3

Additional rotation: ● None ○ Angle: 0 ○ Distribution:

Section integration: ● During analysis ○ Before analysis

Thickness integration rule: ● Simpson ○ Gauss

☐ Make calculated sections symmetric

		Ply Name	Region	Material	Thickness	CSYS	Rotation Angle	Integration Points
1	✓	Ply_1	Zone6	Graphite-Epoxy	0.2	<Layup>	90	3
2	✓	Ply_2	Zone6	Graphite-Epoxy	0.2	<Layup>	90	3
3	✓	Ply_3	Zone6	Graphite-Epoxy	0.2	<Layup>	90	3
4	✓	Ply_4	Zone6	Graphite-Epoxy	0.2	<Layup>	90	3
5	✓	Ply_5	Zone6	Graphite-Epoxy	0.2	<Layup>	90	3
6	✓	Ply_6	Zone5A	Graphite-Epoxy	0.21	<Layup>	-45	3
7	✓	Ply_7	Zone5A	Graphite-Epoxy	0.21	<Layup>	-45	3
8	✓	Ply_8	Zone5A	Graphite-Epoxy	0.21	<Layup>	-45	3

Datum CSYS List

Names:
- Rib1-CSYS
- Rib2-CSYS
- Rib3-CSYS
- Rib4-CSYS
- Rib5-CSYS
- Skin-CSYS

Edit Composite Layup

Name: skin_layup

Element type: Conventional Shell

Description:

Layup Orientation

Defintion: Coordinate system

Skin-CSYS

Normal direction: ○ Axis 1 ○ Axis 2 ● Axis 3

Additional rotation: ● None ○ Angle: 0 ○ Distribution:

Section integration: ● During analysis ○ Before analysis

Thickness integration rule: ● Simpson ○ Gauss

☐ Make calculated sections symmetric

		Ply Name	Region	Material	Thickness	CSYS	Rotation Angle	Integration Points
1	✓	Ply_1	Zone6	Graphite-Epoxy	0.2	<Layup>	90	3
2	✓	Ply_2	Zone6	Graphite-Epoxy	0.2	<Layup>	90	3
3	✓	Ply_3	Zone6	Graphite-Epoxy	0.2	<Layup>	90	3
4	✓	Ply_4	Zone6	Graphite-Epoxy	0.2	<Layup>	90	3
5	✓	Ply_5	Zone6	Graphite-Epoxy	0.2	<Layup>	90	3
6	✓	Ply_6	Zone5A	Graphite-Epoxy	0.21	<Layup>	-45	3
7	✓	Ply_7	Zone5A	Graphite-Epoxy	0.21	<Layup>	-45	3
8	✓	Ply_8	Zone5A	Graphite-Epoxy	0.21	<Layup>	-45	3

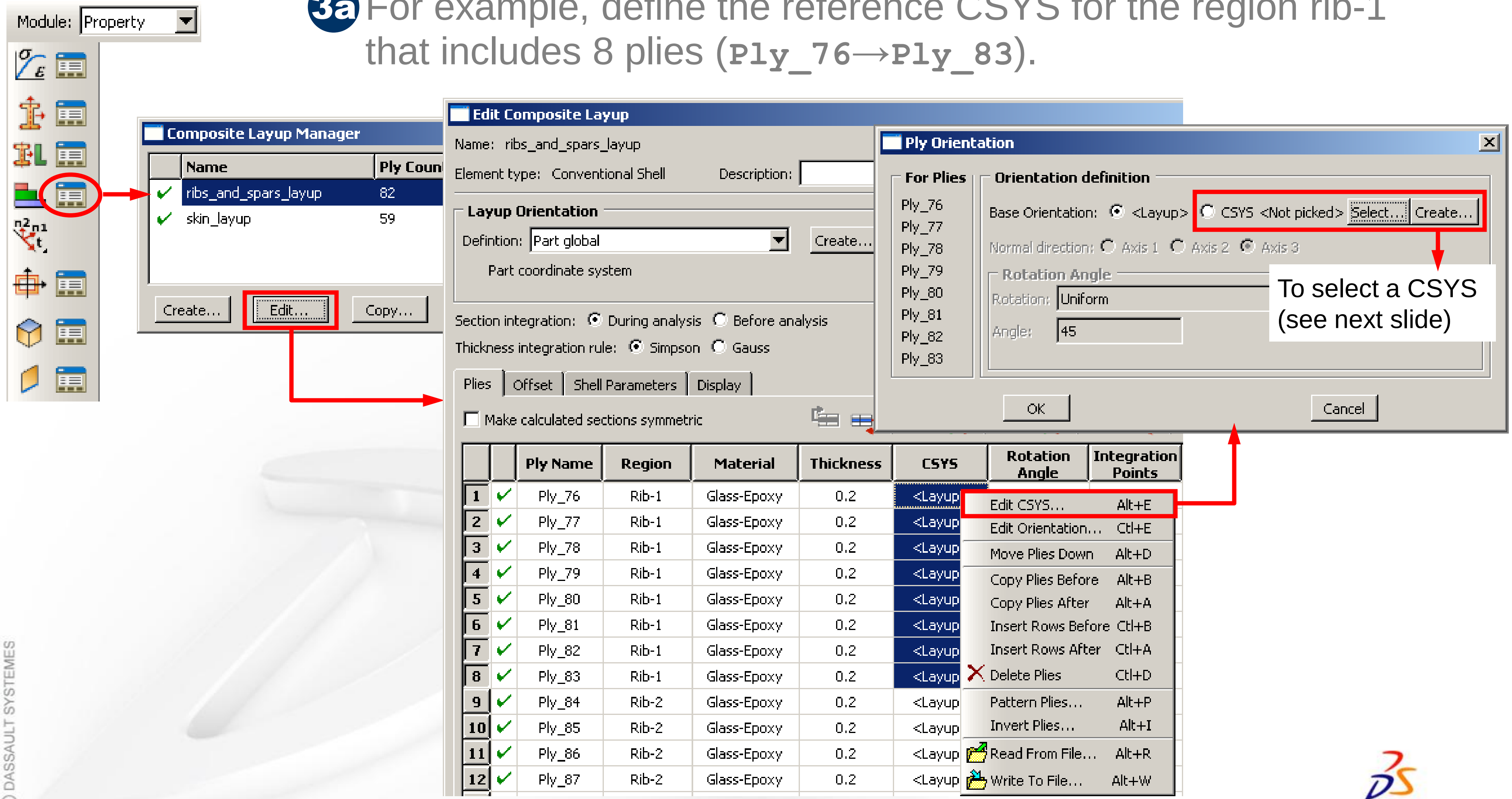
(initially) part global

(currently) `Skin-CSYS`

Understanding Composite Layup Orientations

③ Define the reference coordinate systems for ribs and spars.

3a For example, define the reference CSYS for the region rib-1 that includes 8 plies (`Ply_76`→`Ply_83`).



Composite Layup Manager

	Name	Ply Coun
✓	ribs_and_spars_layup	82
✓	skin_layup	59

Edit Composite Layup

Name: ribs_and_spars_layup

Element type: Conventional Shell

Description:

Layup Orientation

Defintion: Part global

Part coordinate system

Section integration: ● During analysis ○ Before analysis

Thickness integration rule: ● Simpson ○ Gauss

☐ Make calculated sections symmetric

		Ply Name	Region	Material	Thickness	CSYS	Rotation Angle	Integration Points
1	✓	Ply_76	Rib-1	Glass-Epoxy	0.2	<Layup		
2	✓	Ply_77	Rib-1	Glass-Epoxy	0.2	<Layup		
3	✓	Ply_78	Rib-1	Glass-Epoxy	0.2	<Layup		
4	✓	Ply_79	Rib-1	Glass-Epoxy	0.2	<Layup		
5	✓	Ply_80	Rib-1	Glass-Epoxy	0.2	<Layup		
6	✓	Ply_81	Rib-1	Glass-Epoxy	0.2	<Layup		
7	✓	Ply_82	Rib-1	Glass-Epoxy	0.2	<Layup		
8	✓	Ply_83	Rib-1	Glass-Epoxy	0.2	<Layup		
9	✓	Ply_84	Rib-2	Glass-Epoxy	0.2	<Layup		
10	✓	Ply_85	Rib-2	Glass-Epoxy	0.2	<Layup		
11	✓	Ply_86	Rib-2	Glass-Epoxy	0.2	<Layup		
12	✓	Ply_87	Rib-2	Glass-Epoxy	0.2	<Layup		

Ply Orientation

For Plies
Ply_76
Ply_77
Ply_78
Ply_79
Ply_80
Ply_81
Ply_82
Ply_83

Orientation definition

Base Orientation: ● <Layup> ○ CSYS <Not picked> Select... Create...

Normal direction: ○ Axis 1 ○ Axis 2 ● Axis 3

Rotation Angle

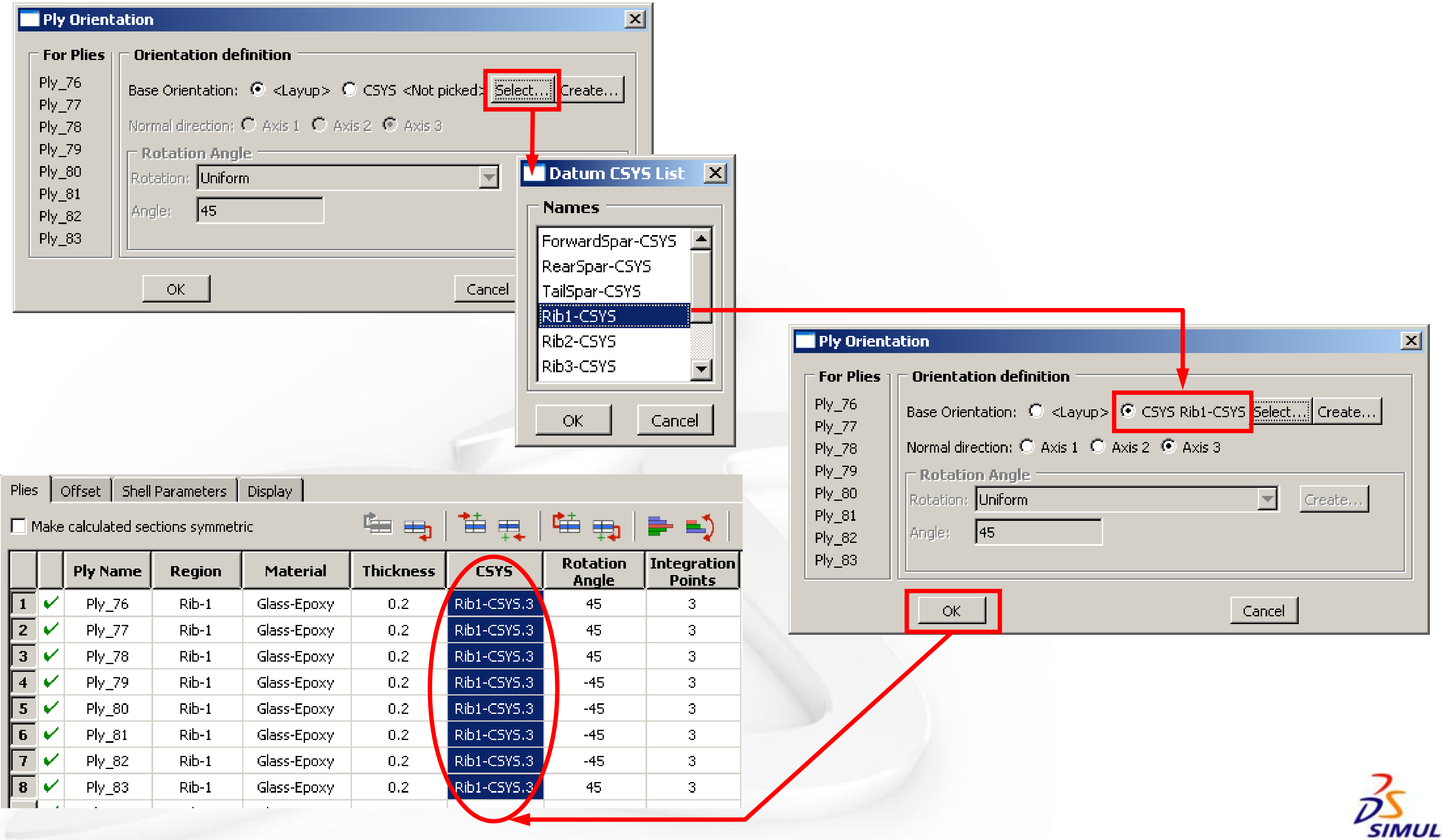
Rotation: Uniform

Angle: 45

To select a CSYS (see next slide)

Understanding Composite Layup Orientations

3b Select the predefined datum coordinate system `Rib1-CSYS`.



Ply Orientation

For Plies

- Ply_76
- Ply_77
- Ply_78
- Ply_79
- Ply_80
- Ply_81
- Ply_82
- Ply_83

Orientation definition

Base Orientation: ● <Layup> ○ CSYS <Not picked>

Normal direction: ○ Axis 1 ○ Axis 2 ● Axis 3

Rotation Angle

Rotation: Uniform

Angle: 45

Datum CSYS List

Names

- ForwardSpar-CSYS
- RearSpar-CSYS
- TailSpar-CSYS
- Rib1-CSYS
- Rib2-CSYS
- Rib3-CSYS

Ply Orientation

For Plies

- Ply_76
- Ply_77
- Ply_78
- Ply_79
- Ply_80
- Ply_81
- Ply_82
- Ply_83

Orientation definition

Base Orientation: ○ <Layup> ● CSYS Rib1-CSYS

Normal direction: ○ Axis 1 ○ Axis 2 ● Axis 3

Rotation Angle

Rotation: Uniform

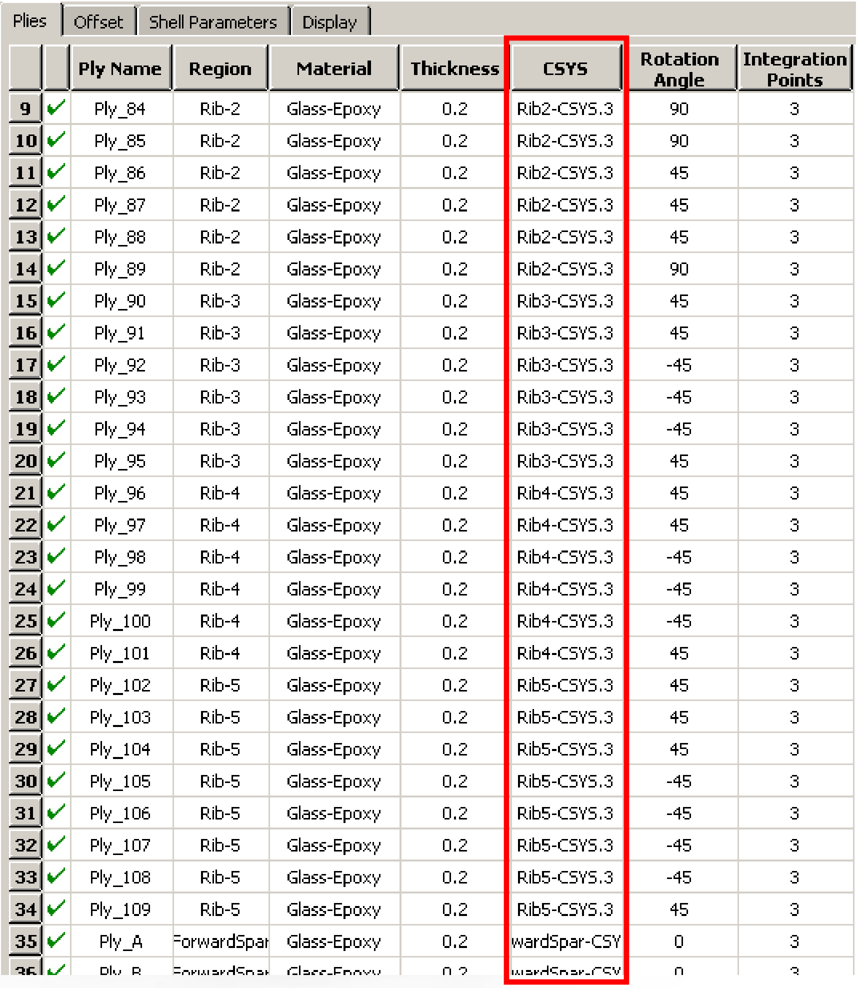
Angle: 45

☐ Make calculated sections symmetric

		Ply Name	Region	Material	Thickness	CSYS	Rotation Angle	Integration Points
1	✓	Ply_76	Rib-1	Glass-Epoxy	0.2	Rib1-CSYS.3	45	3
2	✓	Ply_77	Rib-1	Glass-Epoxy	0.2	Rib1-CSYS.3	45	3
3	✓	Ply_78	Rib-1	Glass-Epoxy	0.2	Rib1-CSYS.3	45	3
4	✓	Ply_79	Rib-1	Glass-Epoxy	0.2	Rib1-CSYS.3	-45	3
5	✓	Ply_80	Rib-1	Glass-Epoxy	0.2	Rib1-CSYS.3	-45	3
6	✓	Ply_81	Rib-1	Glass-Epoxy	0.2	Rib1-CSYS.3	-45	3
7	✓	Ply_82	Rib-1	Glass-Epoxy	0.2	Rib1-CSYS.3	-45	3
8	✓	Ply_83	Rib-1	Glass-Epoxy	0.2	Rib1-CSYS.3	45	3

Understanding Composite Layup Orientations

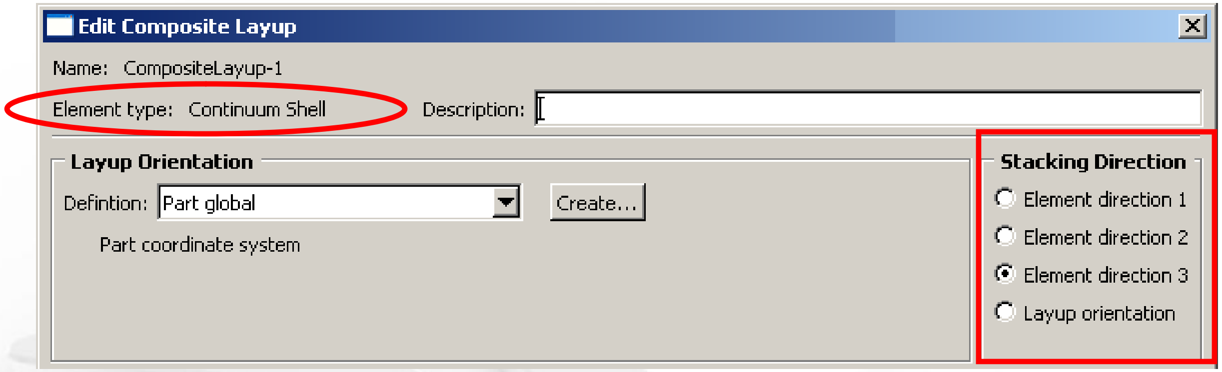
3c Using a similar procedure, define the layup orientations for the other ribs and spars.



		Ply Name	Region	Material	Thickness	CSYS	Rotation Angle	Integration Points
9	✓	Ply_84	Rib-2	Glass-Epoxy	0.2	Rib2-CSYS.3	90	3
10	✓	Ply_85	Rib-2	Glass-Epoxy	0.2	Rib2-CSYS.3	90	3
11	✓	Ply_86	Rib-2	Glass-Epoxy	0.2	Rib2-CSYS.3	45	3
12	✓	Ply_87	Rib-2	Glass-Epoxy	0.2	Rib2-CSYS.3	45	3
13	✓	Ply_88	Rib-2	Glass-Epoxy	0.2	Rib2-CSYS.3	45	3
14	✓	Ply_89	Rib-2	Glass-Epoxy	0.2	Rib2-CSYS.3	90	3
15	✓	Ply_90	Rib-3	Glass-Epoxy	0.2	Rib3-CSYS.3	45	3
16	✓	Ply_91	Rib-3	Glass-Epoxy	0.2	Rib3-CSYS.3	45	3
17	✓	Ply_92	Rib-3	Glass-Epoxy	0.2	Rib3-CSYS.3	-45	3
18	✓	Ply_93	Rib-3	Glass-Epoxy	0.2	Rib3-CSYS.3	-45	3
19	✓	Ply_94	Rib-3	Glass-Epoxy	0.2	Rib3-CSYS.3	-45	3
20	✓	Ply_95	Rib-3	Glass-Epoxy	0.2	Rib3-CSYS.3	45	3
21	✓	Ply_96	Rib-4	Glass-Epoxy	0.2	Rib4-CSYS.3	45	3
22	✓	Ply_97	Rib-4	Glass-Epoxy	0.2	Rib4-CSYS.3	45	3
23	✓	Ply_98	Rib-4	Glass-Epoxy	0.2	Rib4-CSYS.3	-45	3
24	✓	Ply_99	Rib-4	Glass-Epoxy	0.2	Rib4-CSYS.3	-45	3
25	✓	Ply_100	Rib-4	Glass-Epoxy	0.2	Rib4-CSYS.3	-45	3
26	✓	Ply_101	Rib-4	Glass-Epoxy	0.2	Rib4-CSYS.3	45	3
27	✓	Ply_102	Rib-5	Glass-Epoxy	0.2	Rib5-CSYS.3	45	3
28	✓	Ply_103	Rib-5	Glass-Epoxy	0.2	Rib5-CSYS.3	45	3
29	✓	Ply_104	Rib-5	Glass-Epoxy	0.2	Rib5-CSYS.3	45	3
30	✓	Ply_105	Rib-5	Glass-Epoxy	0.2	Rib5-CSYS.3	-45	3
31	✓	Ply_106	Rib-5	Glass-Epoxy	0.2	Rib5-CSYS.3	-45	3
32	✓	Ply_107	Rib-5	Glass-Epoxy	0.2	Rib5-CSYS.3	-45	3
33	✓	Ply_108	Rib-5	Glass-Epoxy	0.2	Rib5-CSYS.3	-45	3
34	✓	Ply_109	Rib-5	Glass-Epoxy	0.2	Rib5-CSYS.3	45	3
35	✓	Ply_A	ForwardSpar	Glass-Epoxy	0.2	wardSpar-CSY	0	3
36	✓	Ply_B	ForwardSpar	Glass-Epoxy	0.2	wardSpar-CSY	0	3

Understanding Composite Layup Orientations

- **For a continuum shell/solid composite layup, you can directly specify a stacking direction.**
  - Choosing a stacking direction of the continuum shell elements is also discussed in Appendix 3, “Modeling Issues for Continuum Shell Elements.”



Edit Composite Layup

Name: CompositeLayup-1

Element type: Continuum Shell

Description:

Layup Orientation

Defintion: Part global

Part coordinate system

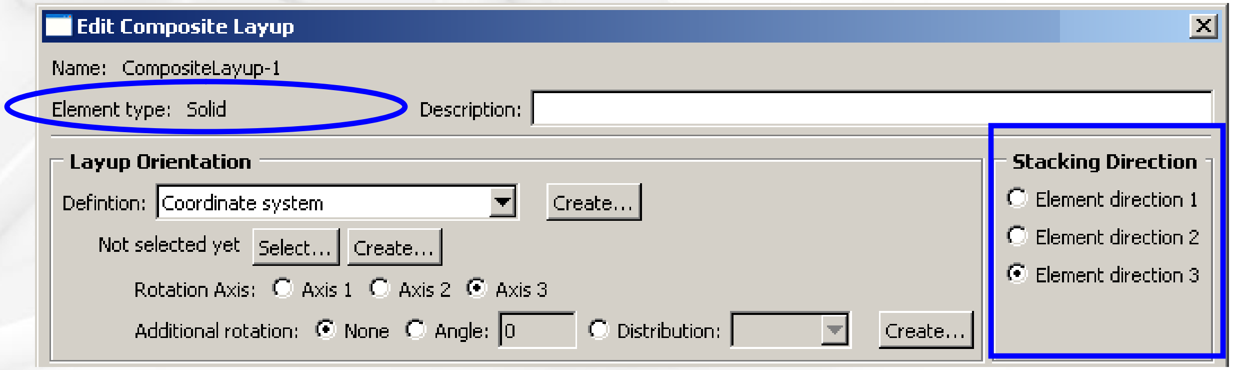
Stacking Direction

○ Element direction 1

○ Element direction 2

● Element direction 3

○ Layup orientation



Edit Composite Layup

Name: CompositeLayup-1

Element type: Solid

Description:

Layup Orientation

Defintion: Coordinate system

Not selected yet

Rotation Axis: ○ Axis 1 ○ Axis 2 ● Axis 3

Additional rotation: ● None ○ Angle: 0 ○ Distribution:

Stacking Direction

○ Element direction 1

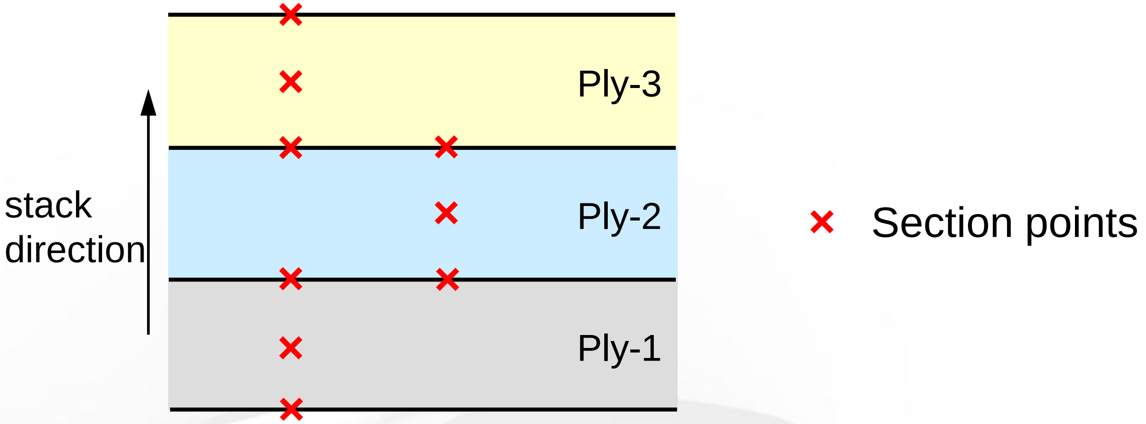
○ Element direction 2

● Element direction 3

Defining Composite Layup Output

Defining Composite Layup Output

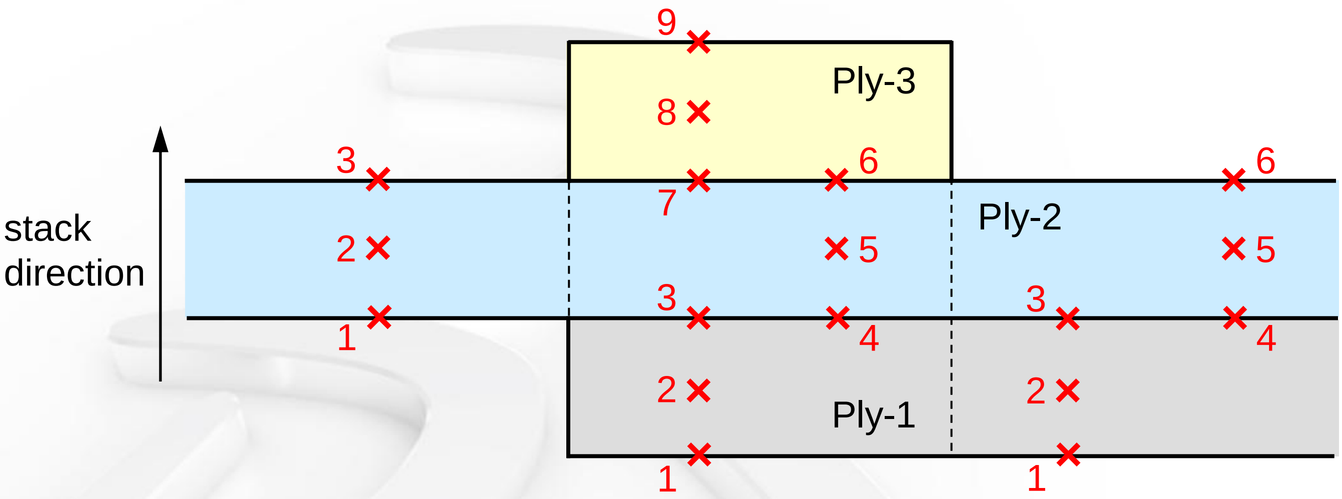
- **Overview**
  - Section points are integration points through the element thickness and are used as the locations to output the results.



  - By default, a shell composite layup has three integration points for each ply; a solid composite layup has one integration point for each ply.
    - For the shell composite layup integrated during the analysis, you can specify the number of integration points in each ply.
    - For a pre-integrated shell layup, three integration points are used for each ply in the layup.

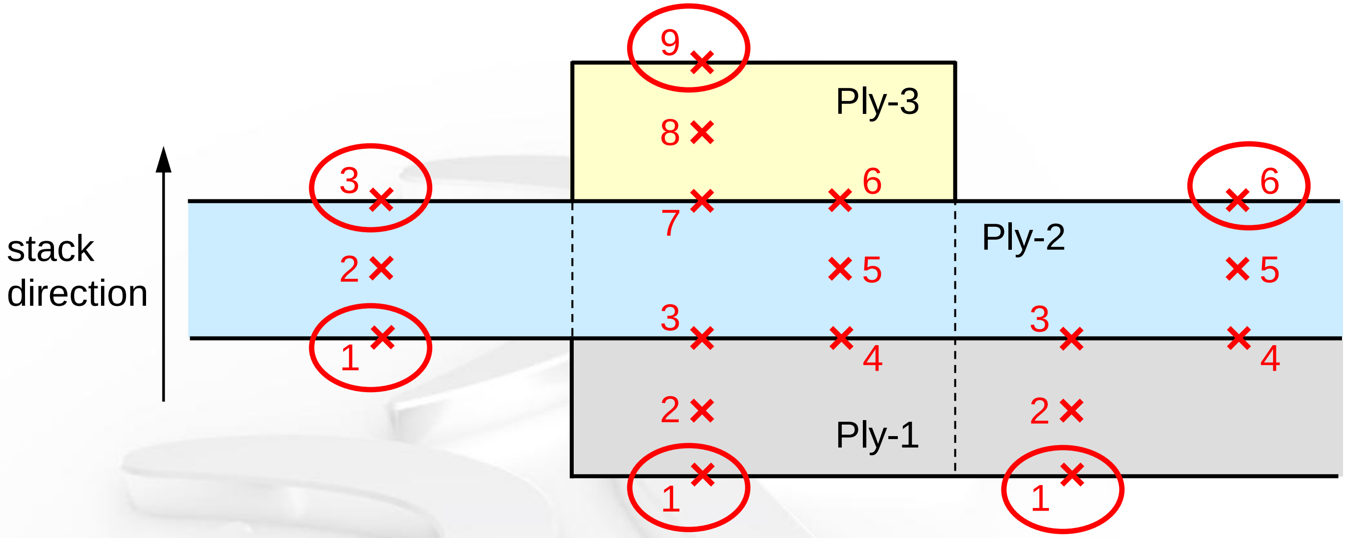
Defining Composite Layup Output

- Section points are numbered sequentially from the bottom of the bottom ply to the top of the top ply.
  - Note that the bottom ply is the first ply defined in a composite layup.
  - Example: Section point numbering for a three-ply composite layup.



Defining Composite Layup Output

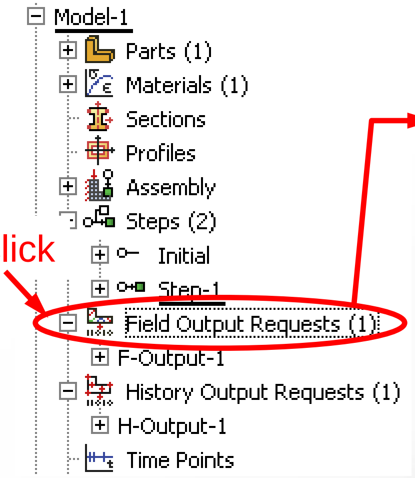
- By default, Abaqus writes field output data from only the top and bottom of a conventional/continuum shell composite layup (circled section points).



- To output data from individual plies, create a field/history output request for a composite layup.

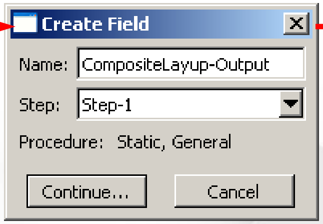
Defining Composite Layup Output

- **Define composite layup output**
  - Example: Three-ply composite layup



double-click

Model-1
- Parts (1)
- Materials (1)
- Sections
- Profiles
- Assembly
- Steps (2)
  - Initial
  - Step-1
- Field Output Requests (1)
  - F-Output-1
- History Output Requests (1)
  - H-Output-1
- Time Points

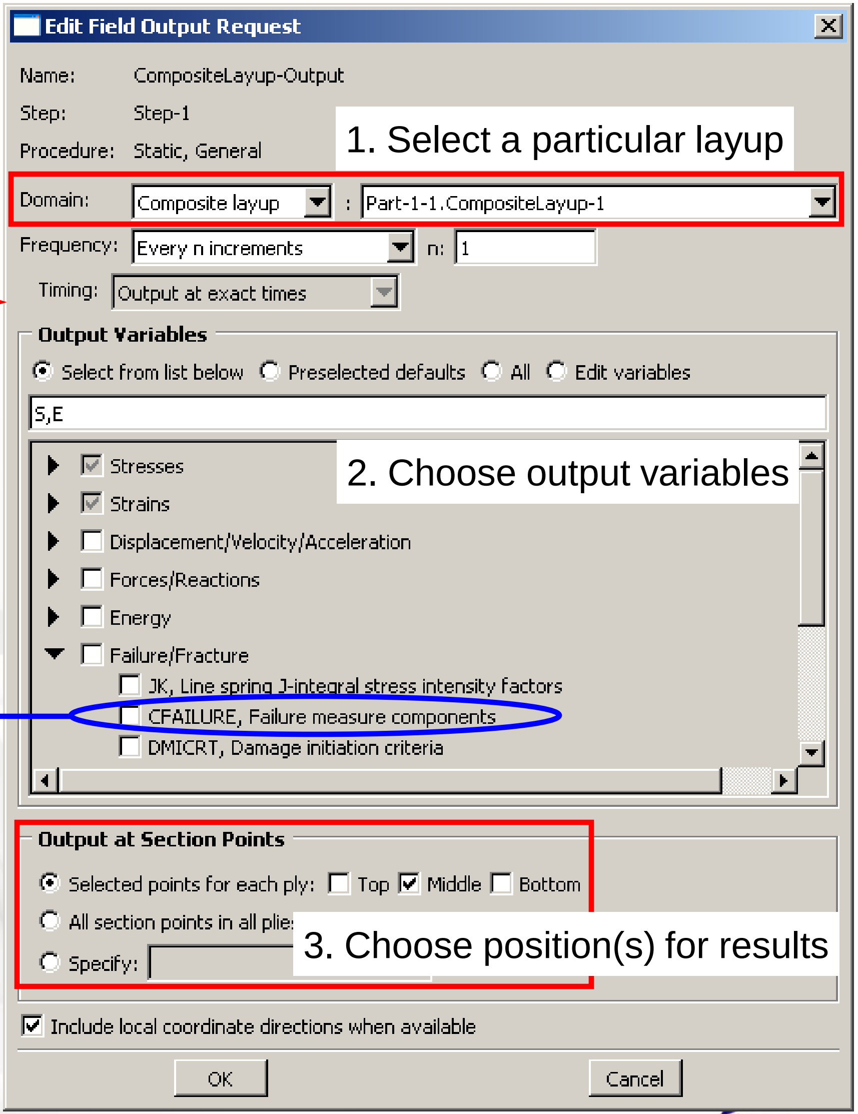


Create Field

Name: CompositeLayup-Output

Step: Step-1

Procedure: Static, General



Edit Field Output Request

Name: CompositeLayup-Output

Step: Step-1

Procedure: Static, General

1. Select a particular layup

Domain: Composite layup : Part-1-1.CompositeLayup-1

Frequency: Every n increments n: 1

Timing: Output at exact times

Output Variables

● Select from list below ○ Preselected defaults ○ All ○ Edit variables

S,E

2. Choose output variables

- ☑ Stresses
- ☑ Strains
- ☐ Displacement/Velocity/Acceleration
- ☐ Forces/Reactions
- ☐ Energy
- ☐ Failure/Fracture
  - ☐ JK, Line spring J-integral stress intensity factors
  - ☐ CFAILURE, Failure measure components
  - ☐ DMICRT, Damage initiation criteria

Output at Section Points

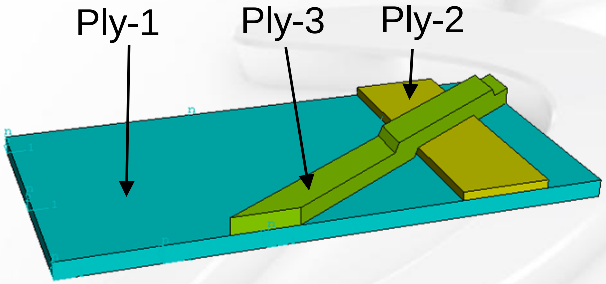
● Selected points for each ply: ☐ Top ☑ Middle ☐ Bottom

○ All section points in all plies

○ Specify:

3. Choose position(s) for results

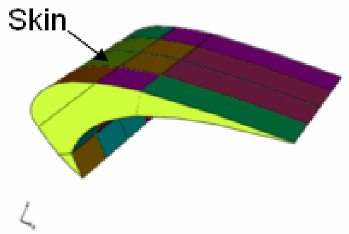
☑ Include local coordinate directions when available

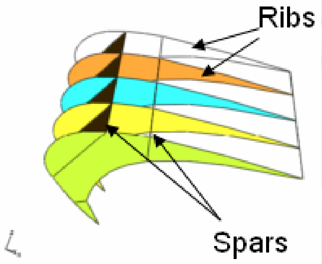


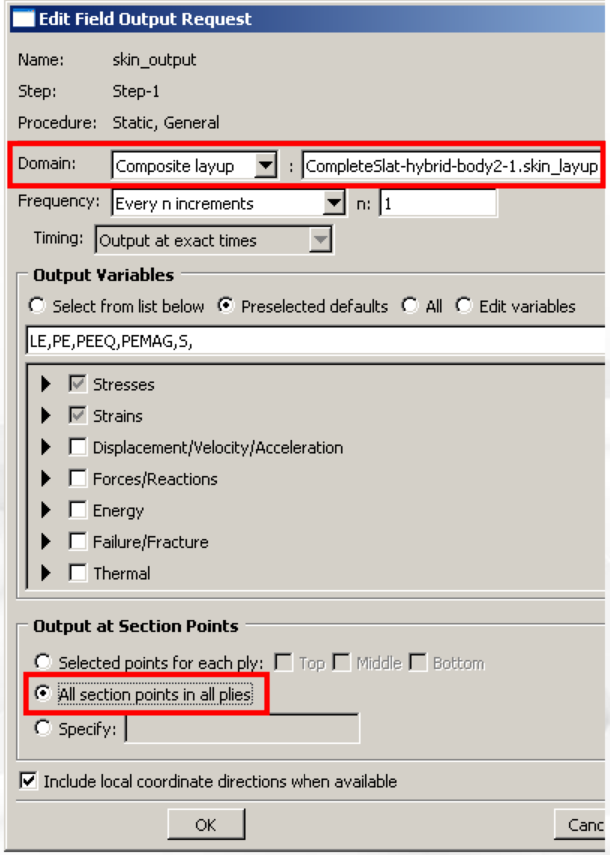
Note: Requests for failure to get TSAI-WU, Tsai-Hill, etc., need to be done here.

Defining Composite Layup Output

- Example: Composite Wing Slat
  - For the skin layup, request output at all section points in all plies; for the spars and ribs layup, at the middle section point for each ply.







Name: skin_output
Step: Step-1
Procedure: Static, General
Domain: Composite layup : CompleteSlat-hybrid-body2-1.skin_layup
Frequency: Every n increments n: 1
Timing: Output at exact times

Output Variables

○ Select from list below ● Preselected defaults ○ All ○ Edit variables

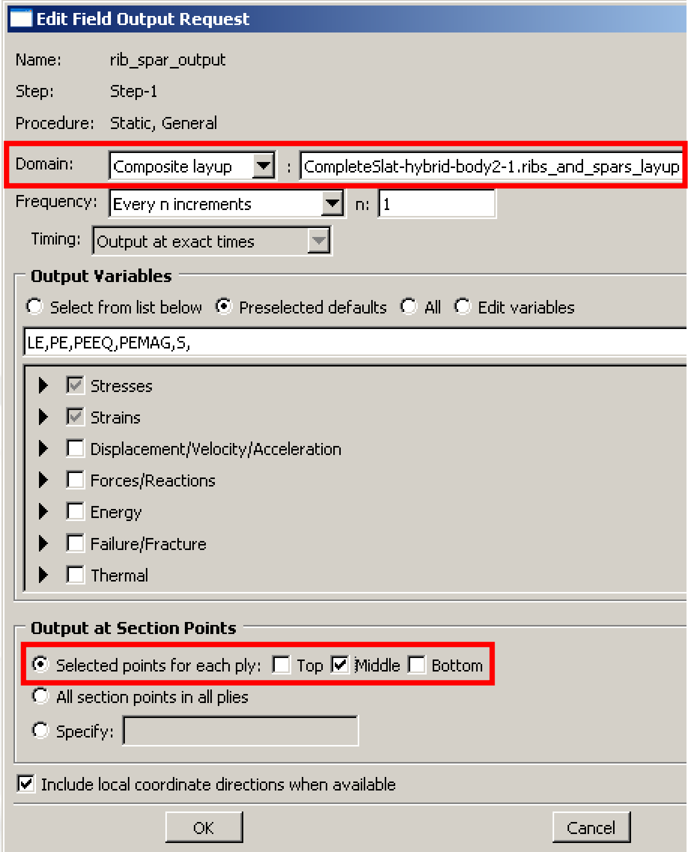
LE,PE,PEEQ,PEMAG,S,

- ☑ Stresses
- ☑ Strains
- ☐ Displacement/Velocity/Acceleration
- ☐ Forces/Reactions
- ☐ Energy
- ☐ Failure/Fracture
- ☐ Thermal

Output at Section Points

○ Selected points for each ply: ☐ Top ☐ Middle ☐ Bottom
● All section points in all plies
○ Specify:

☑ Include local coordinate directions when available



Name: rib_spar_output
Step: Step-1
Procedure: Static, General
Domain: Composite layup : CompleteSlat-hybrid-body2-1.ribs_and_spars_layup
Frequency: Every n increments n: 1
Timing: Output at exact times

Output Variables

○ Select from list below ● Preselected defaults ○ All ○ Edit variables

LE,PE,PEEQ,PEMAG,S,

- ☑ Stresses
- ☑ Strains
- ☐ Displacement/Velocity/Acceleration
- ☐ Forces/Reactions
- ☐ Energy
- ☐ Failure/Fracture
- ☐ Thermal

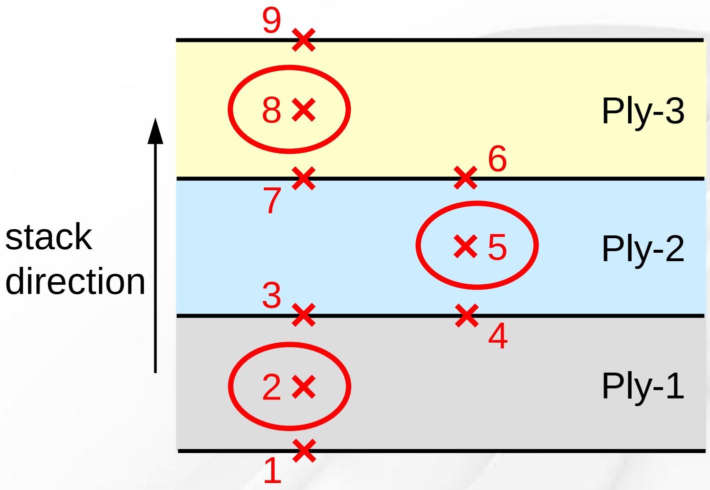
Output at Section Points

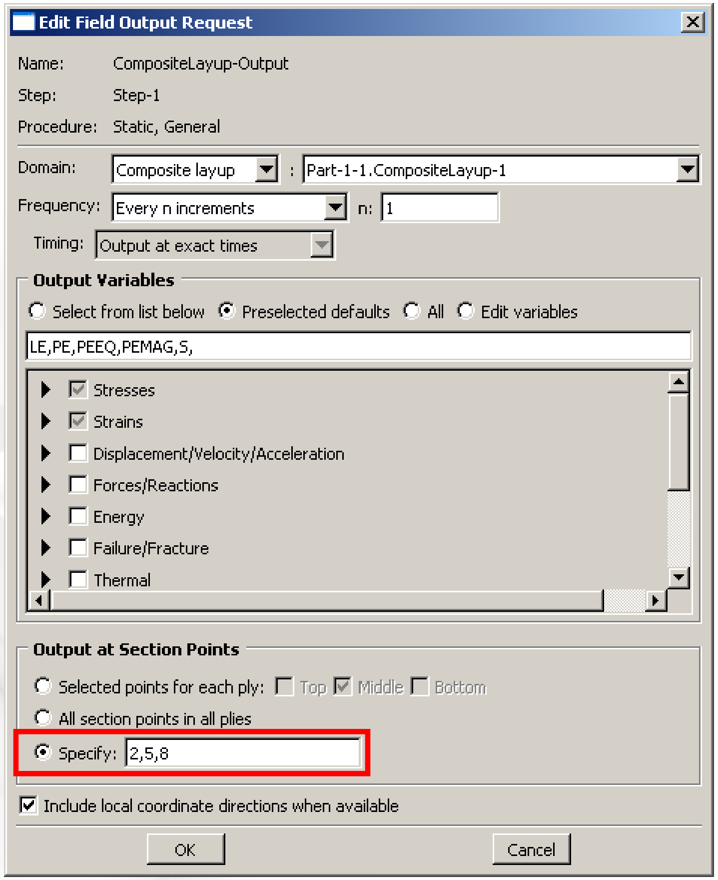
● Selected points for each ply: ☐ Top ☑ Middle ☐ Bottom
○ All section points in all plies
○ Specify:

☑ Include local coordinate directions when available

Defining Composite Layup Output

- Alternatively use the **Specify** option to specify the section point numbers.
  - For example, request output at the middle section points of each ply (circled section points).




Edit Field Output Request

Name: CompositeLayup-Output

Step: Step-1

Procedure: Static, General

Domain: Composite layup : Part-1-1.CompositeLayup-1

Frequency: Every n increments n: 1

Timing: Output at exact times

Output Variables

○ Select from list below ● Preselected defaults ○ All ○ Edit variables

LE,PE,PEEQ,PEMAG,S,

- ☑ Stresses
- ☑ Strains
- ☐ Displacement/Velocity/Acceleration
- ☐ Forces/Reactions
- ☐ Energy
- ☐ Failure/Fracture
- ☐ Thermal

Output at Section Points

○ Selected points for each ply: ☐ Top ☑ Middle ☐ Bottom

○ All section points in all plies

● Specify: 2,5,8

☑ Include local coordinate directions when available

Viewing a Composite Layup

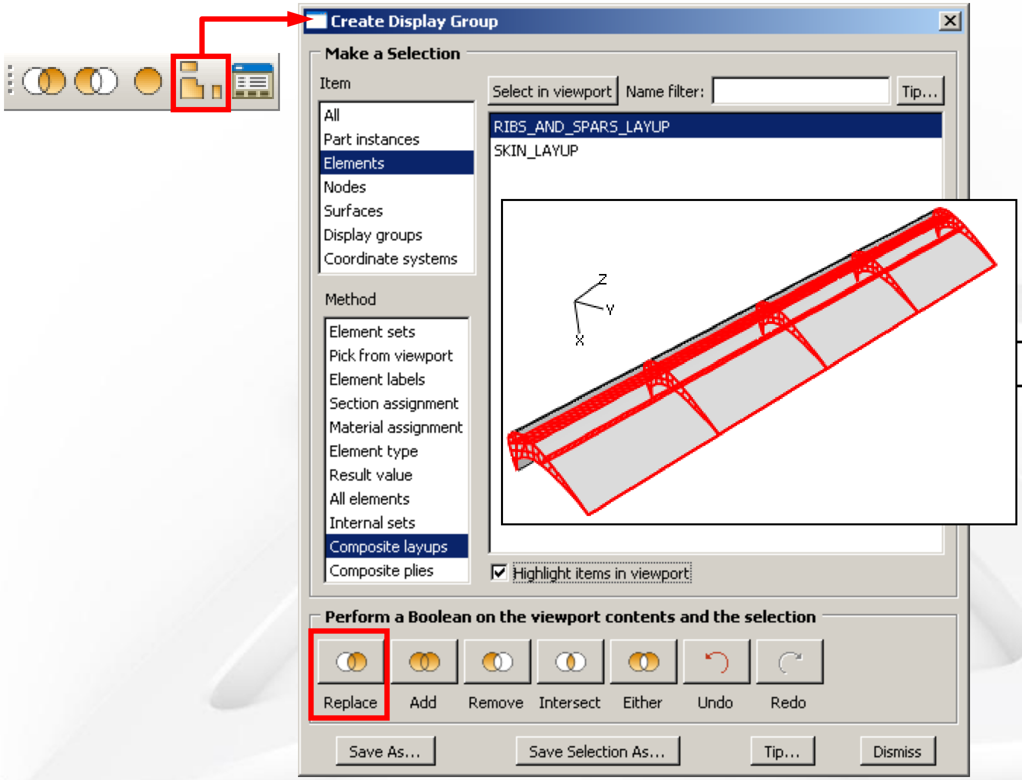
Viewing a Composite Layup

- **Abaqus/CAE provides several tools to view a composite layup in pre- and postprocessing:**
  - Display group by composite layup or ply
  - Color code by composite layup or ply
  - Color code by section shows sections computed from the layup.
  - Ply stack plot
    - Display a “core sample” of the layup for a probed region.
  - Ply-based postprocessing
    - View contour, symbol, or material orientation plots by ply.
  - Envelope plot
    - Display the critical value (absolute maximum, maximum, or minimum) across all of the plies in the layup in a contour plot.
  - Through thickness *X*-*Y* plot

Viewing a Composite Layup

- **Display by composite layup or ply**
  - Example: Composite wing slat

❶ Create a **Display Group** based on **Composite layups** to display the ribs and spars layup.



Create Display Group

Make a Selection

Item

- All
- Part instances
- **Elements**
- Nodes
- Surfaces
- Display groups
- Coordinate systems

Select in viewport | Name filter: | Tip...

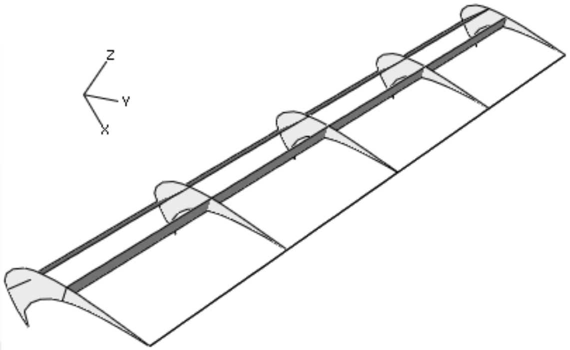
- **RIBS_AND_SPARS_LAYUP**
- SKIN_LAYUP

Method

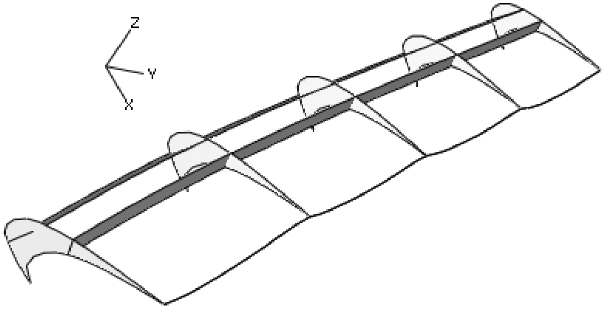
- Element sets
- Pick from viewport
- Element labels
- Section assignment
- Material assignment
- Element type
- Result value
- All elements
- Internal sets
- **Composite layups**
- Composite plies

☑ Highlight items in viewport

Perform a Boolean on the viewport contents and the selection



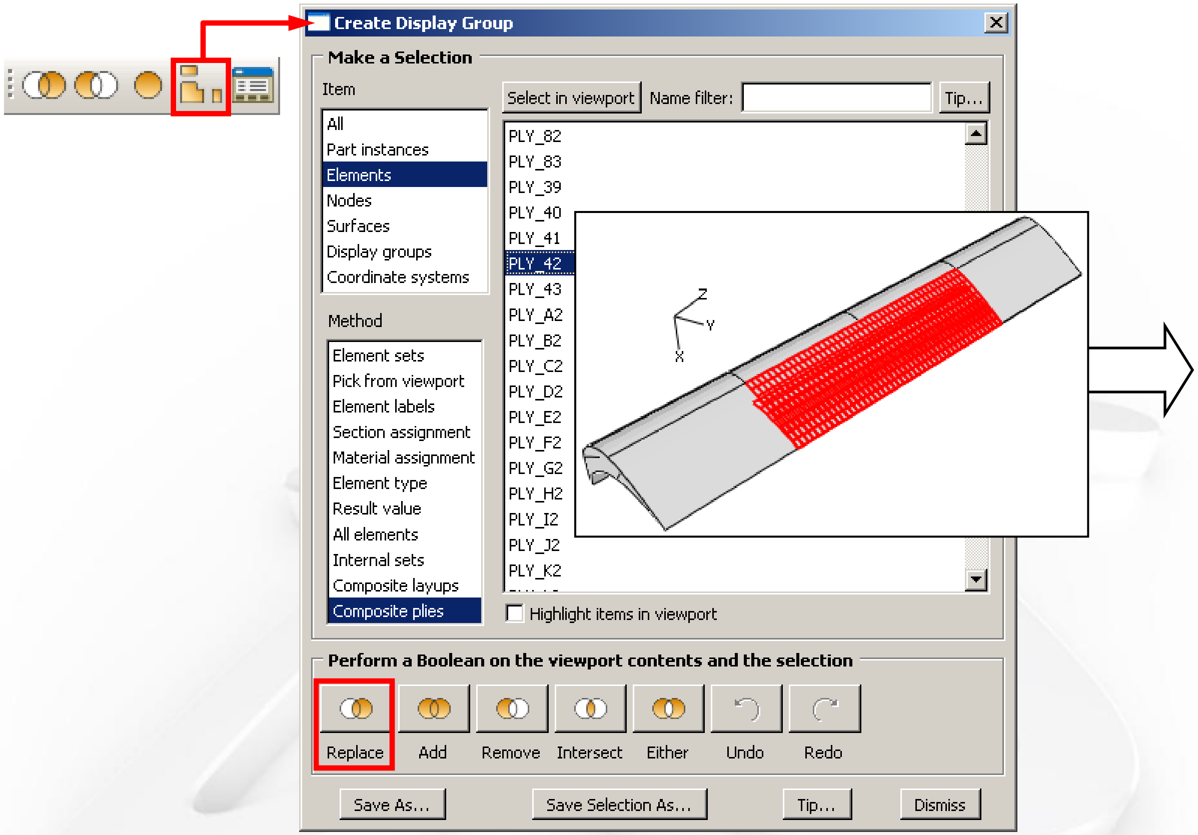
Undeformed shape

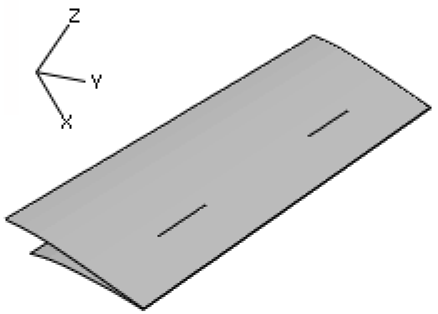


Deformed shape

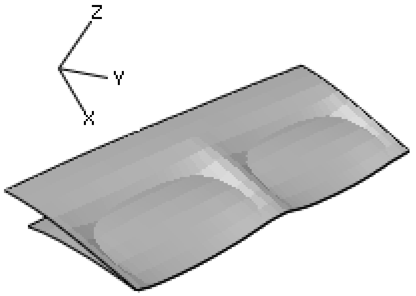
Viewing a Composite Layup

② Create a **Display Group** based on **Composite plies** to display a ply (e.g., **`PLY_42`**) in the skin composite layup





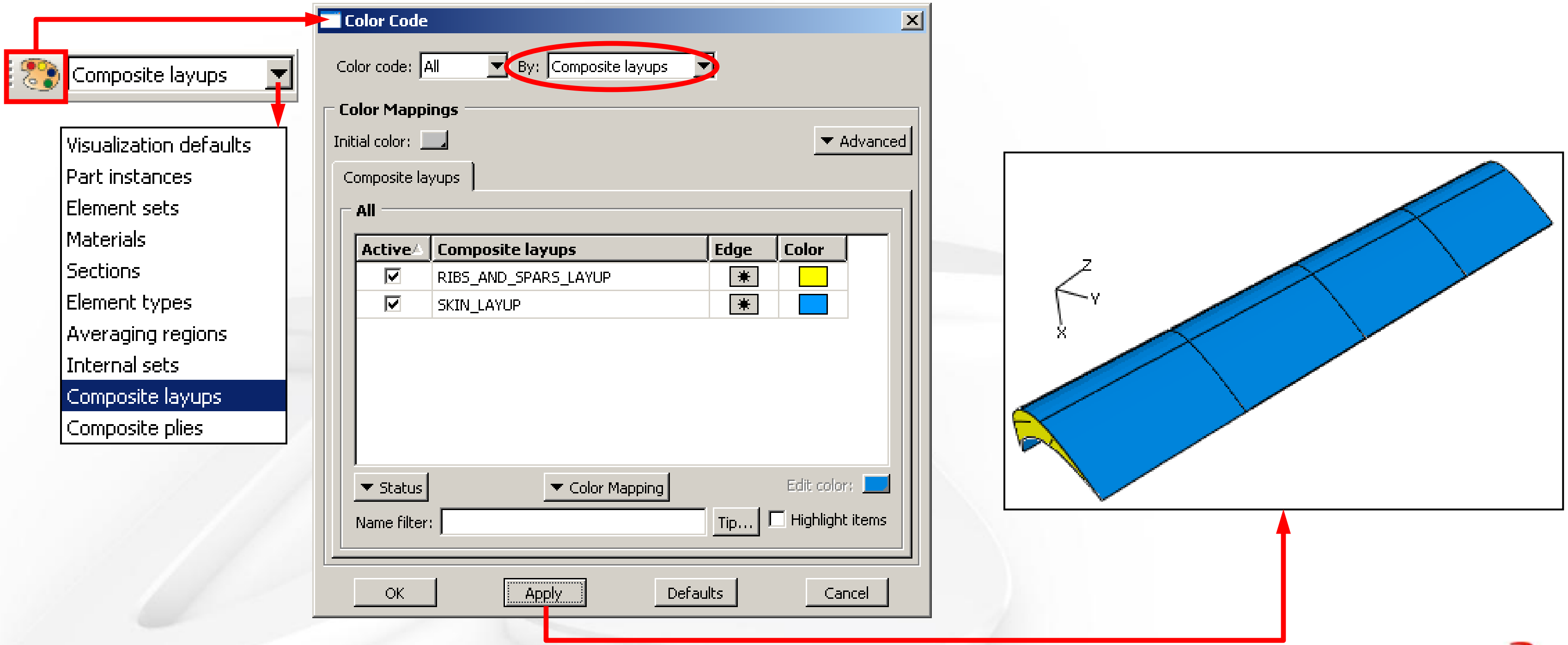
Undeformed shape



Deformed shape

Viewing a Composite Layup

- **Color code by composite layup or ply**
  - ❶ Color code by composite layups
    - Example: Composite wing slat



Composite layups

Visualization defaults
Part instances
Element sets
Materials
Sections
Element types
Averaging regions
Internal sets
Composite layups
Composite plies

Color Code

Color code: All By: Composite layups

Color Mappings

Initial color:

Active	Composite layups	Edge	Color
☑	RIBS_AND_SPARS_LAYUP	✳	🟨
☑	SKIN_LAYUP	✳	🟦

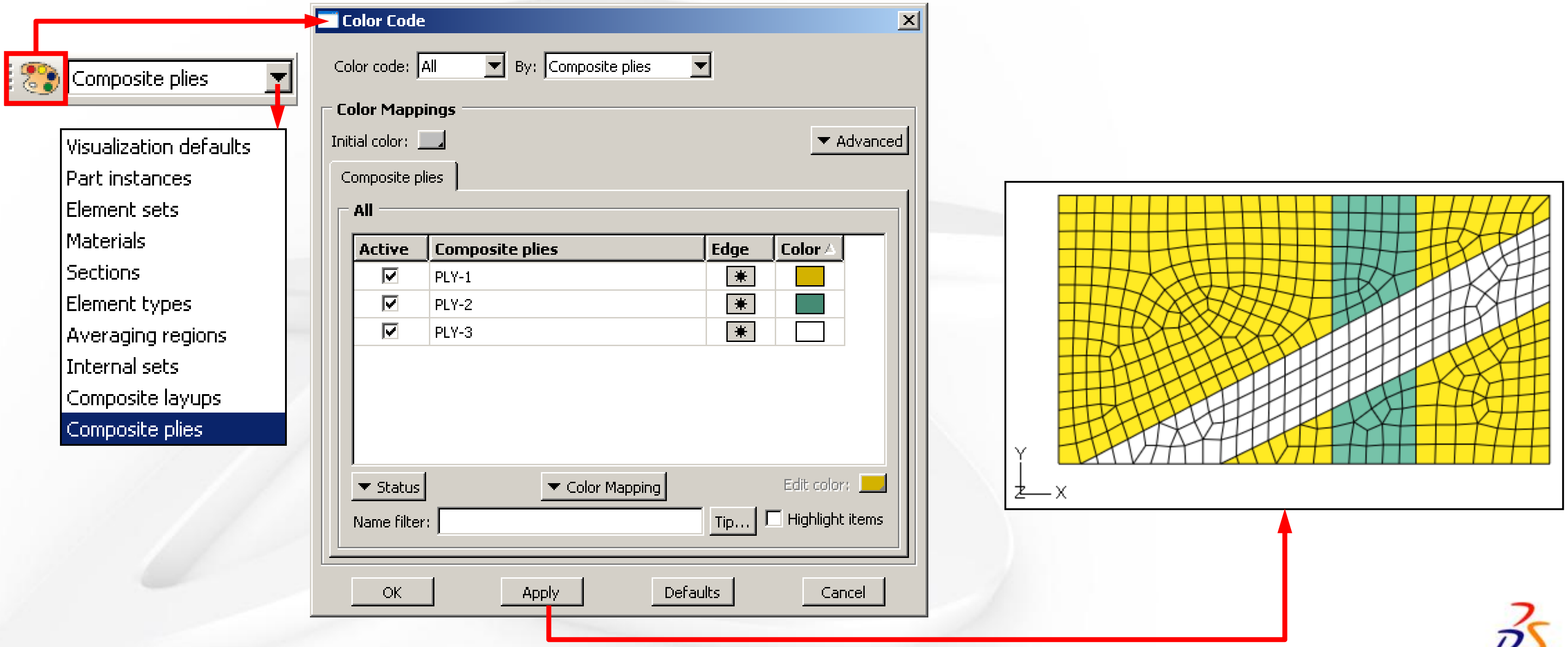
Name filter:

☐ Highlight items

Viewing a Composite Layup

② Color code by composite ply

- Abaqus/CAE applies color coding on only one ply in a region, which by default is the last ply (in alphabetical order).
  - To view a different ply, deactivate selected plies.
- Example: Three-ply composite layup



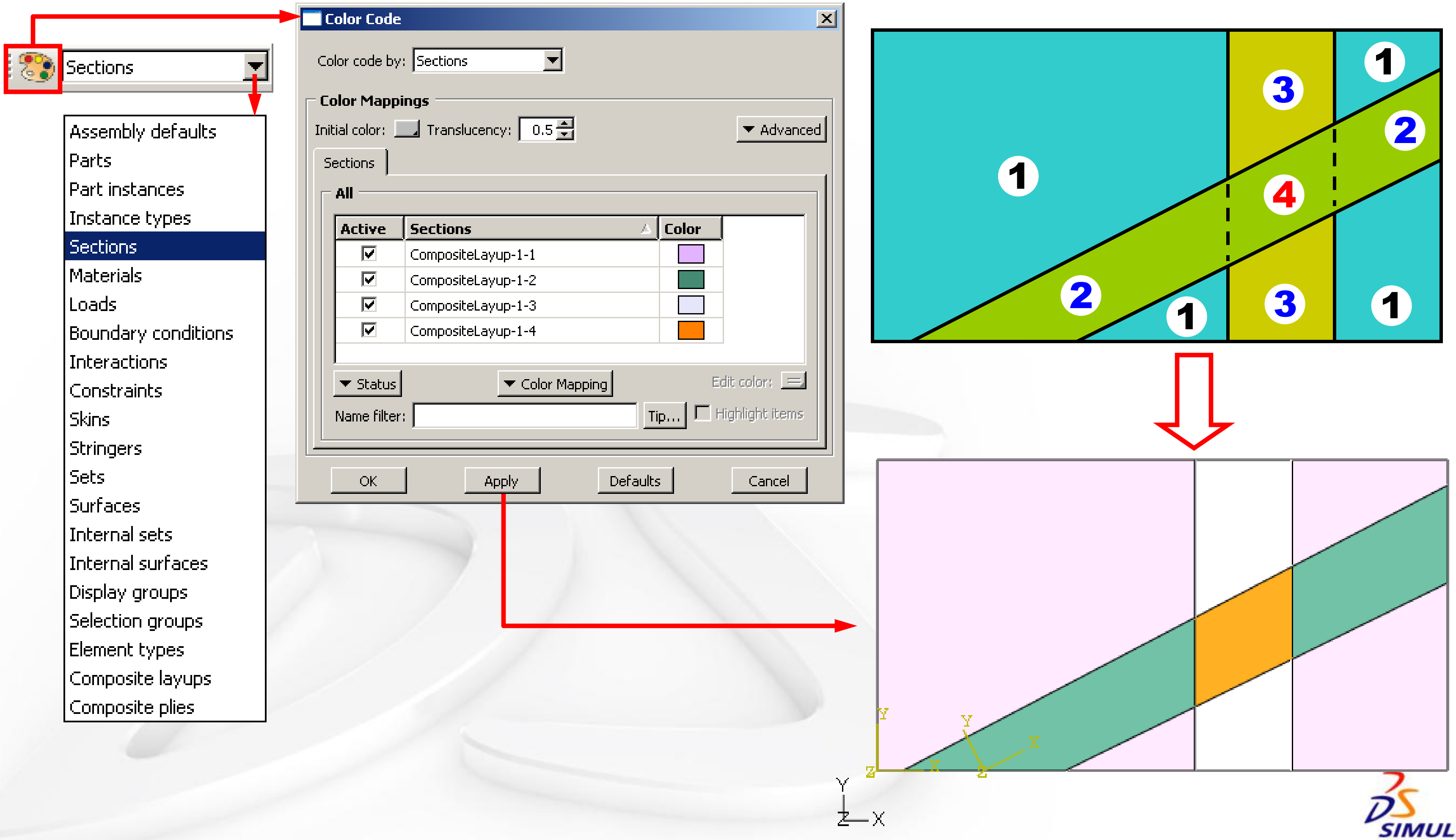
Color code: All By: Composite plies

Active	Composite plies	Edge	Color
☑	PLY-1	✱	🟨
☑	PLY-2	✱	🟩
☑	PLY-3	✱	⬜

☐ Highlight items

Viewing a Composite Layup

- **Color code by section shows sections computed from the layup.**



Color Code

Color code by: Sections

Color Mappings

Initial color: ☐ Translucency: 0.5

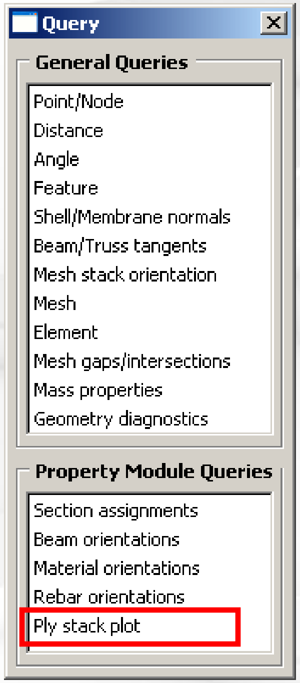
Sections

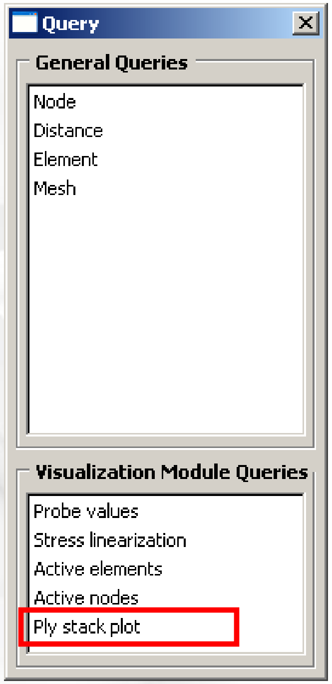
All

Active	Sections	Color
☑	CompositeLayup-1-1	🟪
☑	CompositeLayup-1-2	🟩
☑	CompositeLayup-1-3	⬜
☑	CompositeLayup-1-4	🟧

Viewing a Composite Layup

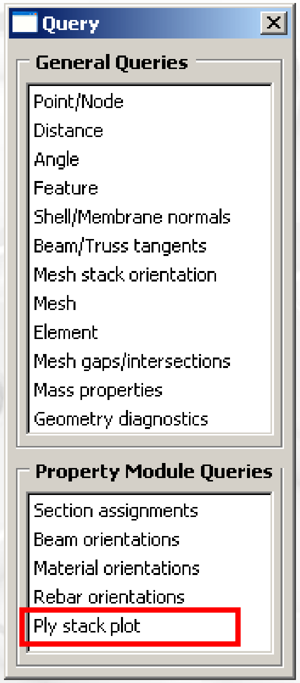
- **Ply stack plot**
  - is a graphical representation from a selected region of a composite model.
  - can be accessed using the **Query** tool in either the Property module or the Visualization module.

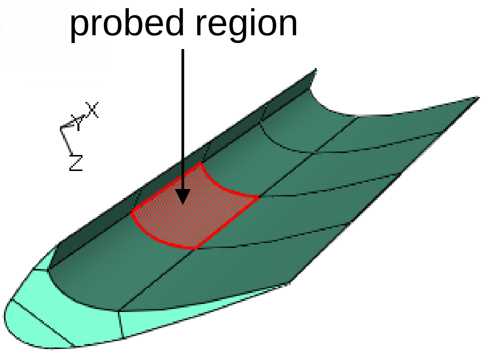




Viewing a Composite Layup

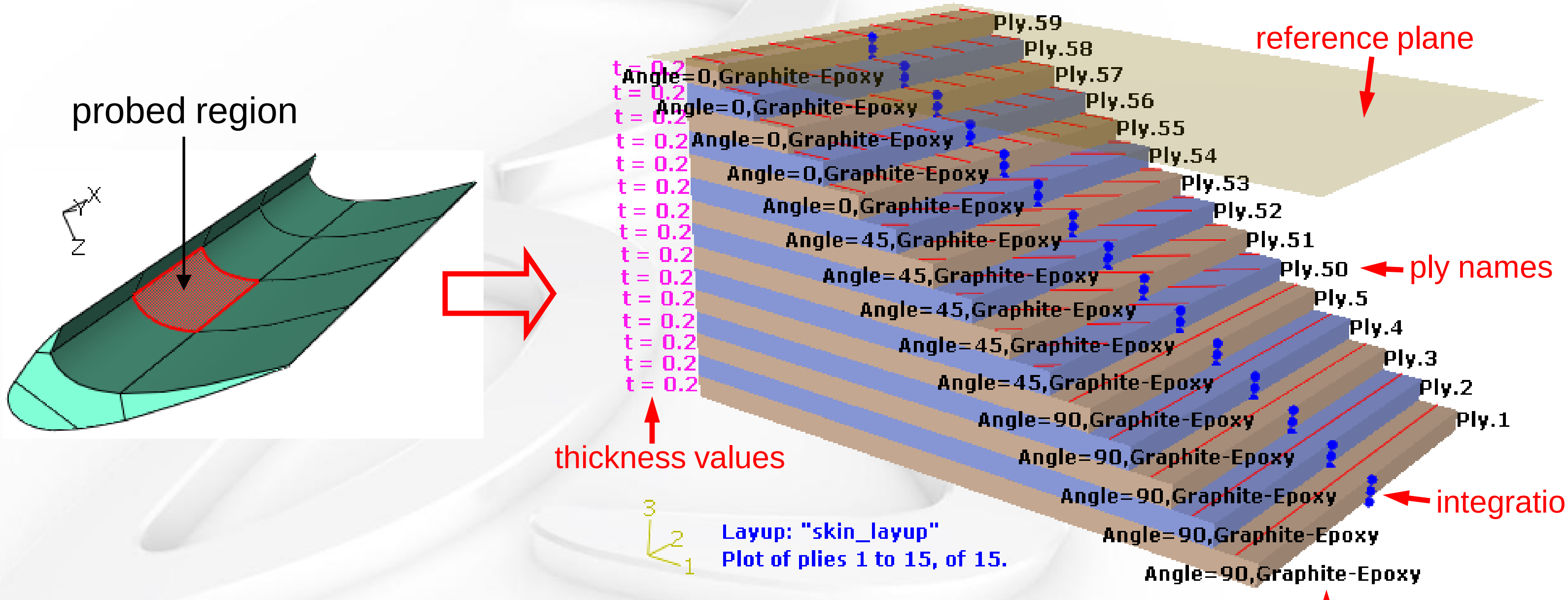
- **Display the ply stack plot**
  - Example: Composite slat wing
    - In the Property module, click the **Query** tool and select a region to be queried for ply stack plot.





Viewing a Composite Layup

- The ply stack plot will reside in its own viewport.
  - The user can do the usual view manipulations and printing.
  - The staircase appearance has no physical meaning.
  - Lines drawn on the plies show the orientation angles with respect to the local 1-direction, if the layup orientation is used to define the ply's orientation.



Layup: "skin_layup"
Plot of plies 1 to 15, of 15.

probed region

reference plane

ply names

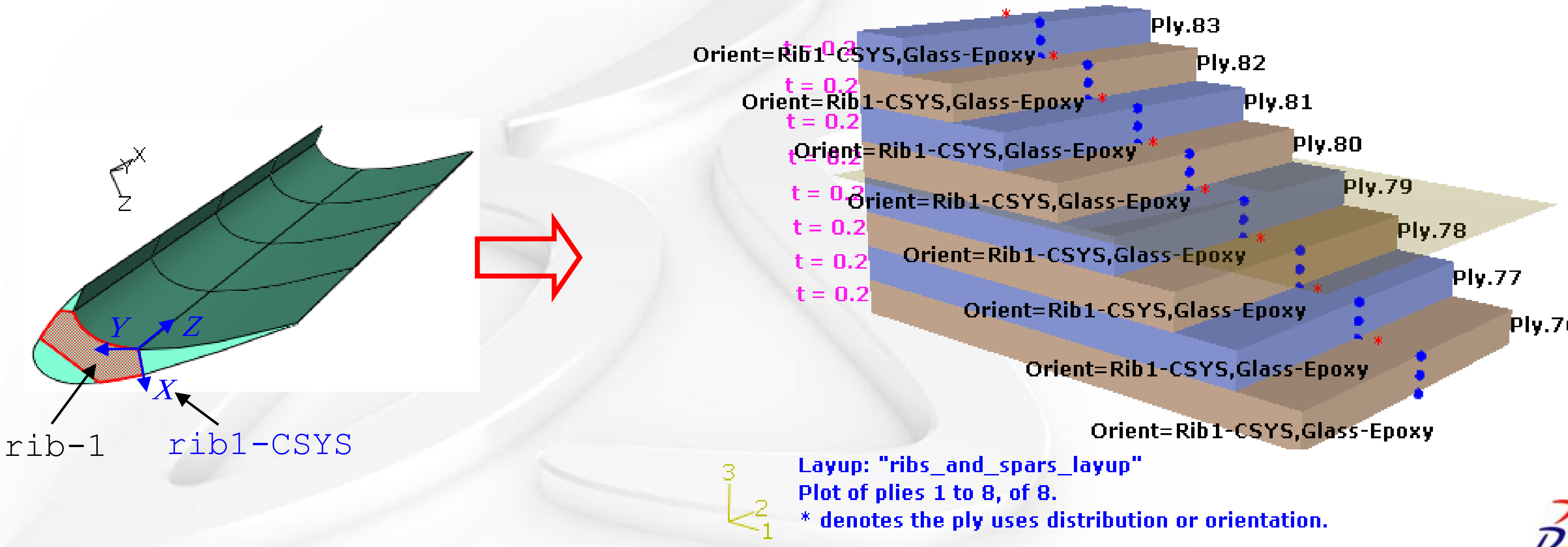
thickness values

integration points

fiber angles, material names

Viewing a Composite Layup

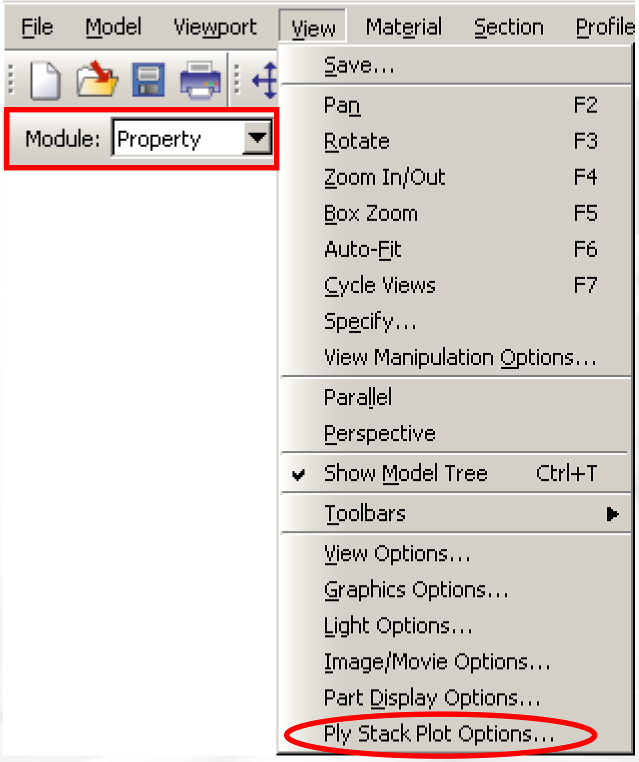
- Note: If a user-defined reference CSYS is used to define a ply’s orientation, Abaqus/CAE cannot project the CSYS onto the shell element without knowing the spatial orientation of the element; therefore, no fiber direction will be drawn on the plies.
  - For example, the ply stack plot of the region **`rib-1`**.
  - For the same reason, no fiber direction is drawn on the plies if you use a distribution to define the ply’s orientation.

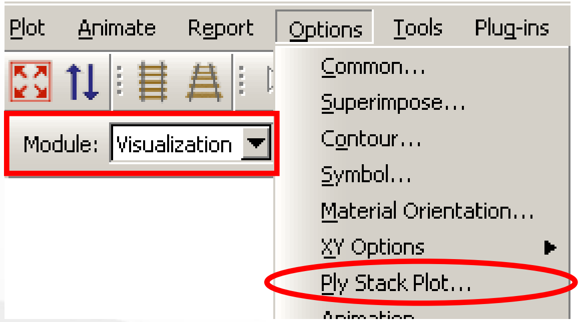


Layup: "ribs_and_spars_layup"
Plot of plies 1 to 8, of 8.
* denotes the ply uses distribution or orientation.

Viewing a Composite Layup

- **Customize the appearance of a ply stack plot**
  - The **Ply Stack Plot Options** dialog box is used to customize the appearance of a ply stack plot and can be accessed in either the Property module or the Visualization module.

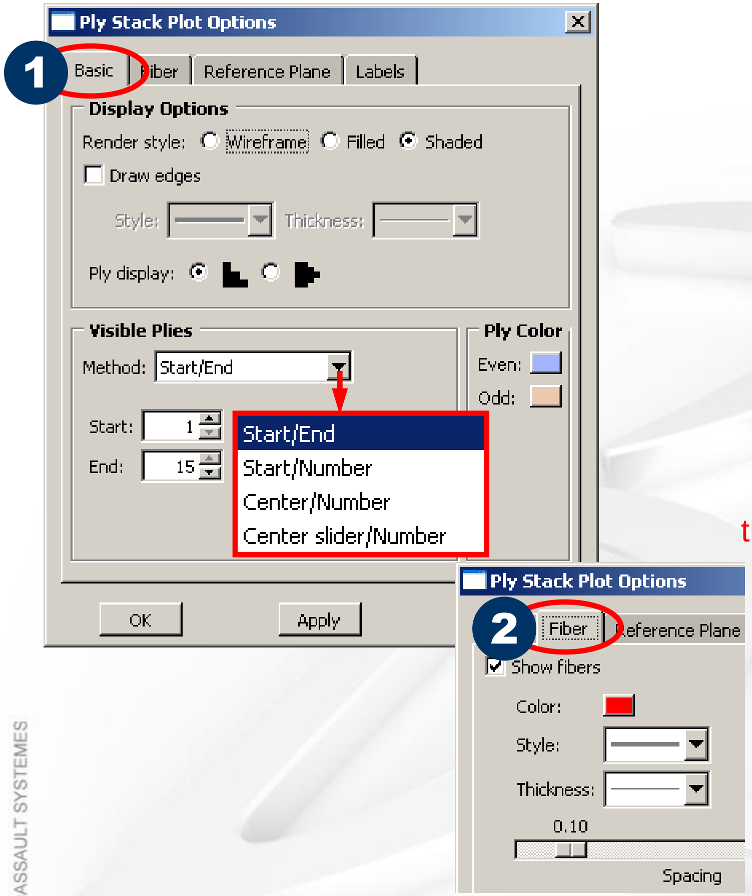




Viewing a Composite Layup

① Control the display options to view a certain number of plies.

② Customize the appearance of the plot.



Ply Stack Plot Options

① Basic | Fiber | Reference Plane | Labels

Display Options

Render style: ○ Wireframe ○ Filled ● Shaded

☐ Draw edges

Style: Thickness:

Ply display: ● ○

Visible Plies

Method: Start/End

Start: 1

End: 15

- Start/End
- Start/Number
- Center/Number
- Center slider/Number

Ply Color

Even: 🟦

Odd: 🟫

OK Apply

Ply Stack Plot Options

② Fiber | Reference Plane

☑ Show fibers

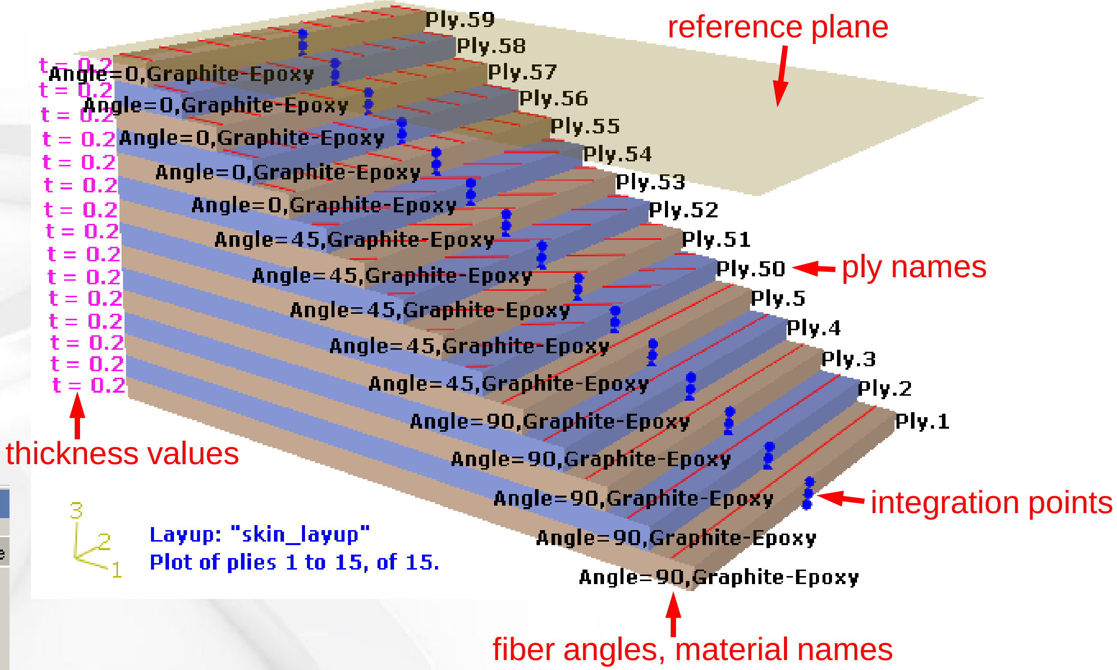
Color: 🟥

Style:

Thickness:

0.10

Spacing



Layup: "skin_layup"
Plot of plies 1 to 15, of 15.

reference plane

ply names

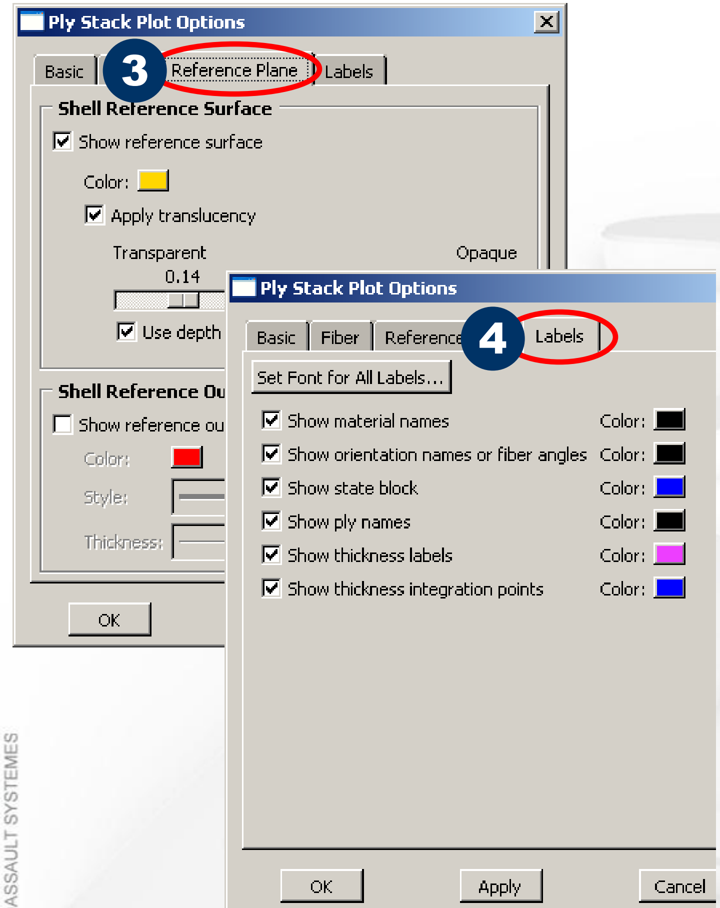
thickness values

integration points

fiber angles, material names

Viewing a Composite Layup

3. Control the appearance of the reference surface.
4. Customize the labels.



Ply Stack Plot Options

Basic | Reference Plane | Labels

Shell Reference Surface

☑ Show reference surface

Color: 🟨

☑ Apply translucency

Transparent — Opaque

0.14

☑ Use depth

Shell Reference Ou

☐ Show reference ou

Color: 🟥

Style:

Thickness:

OK

Ply Stack Plot Options

Basic | Fiber | Reference | Labels

Set Font for All Labels...

☑ Show material names — Color: ■

☑ Show orientation names or fiber angles — Color: ■

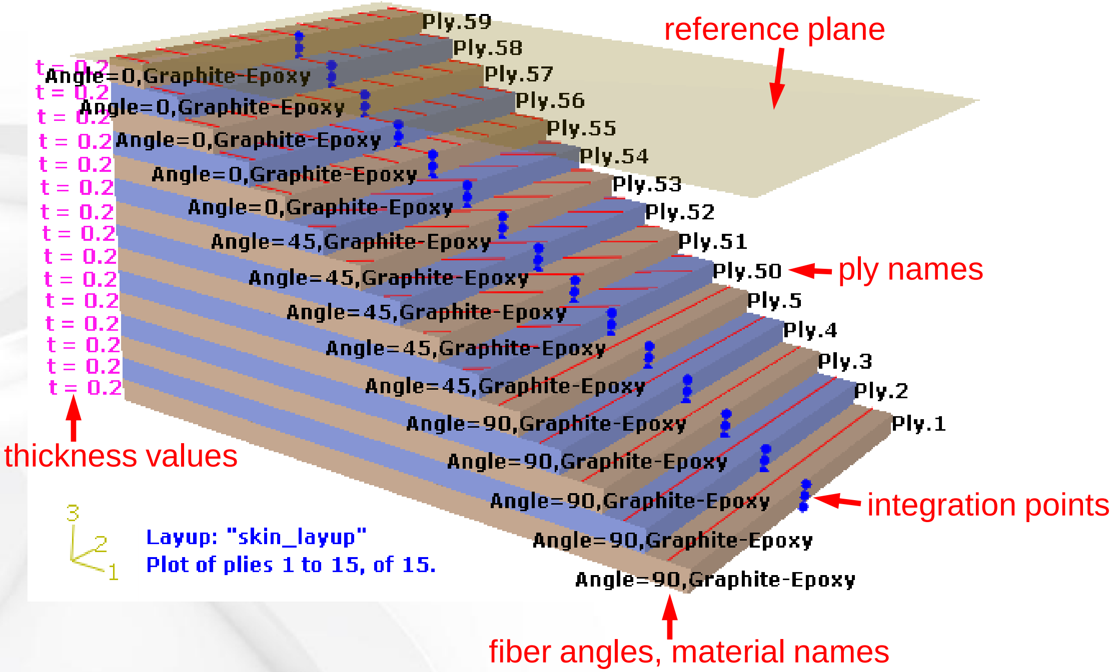
☑ Show state block — Color: 🟦

☑ Show ply names — Color: ■

☑ Show thickness labels — Color: 🟪

☑ Show thickness integration points — Color: 🟦

OK | Apply | Cancel



Layup: "skin_layup"
Plot of plies 1 to 15, of 15.

reference plane

ply names

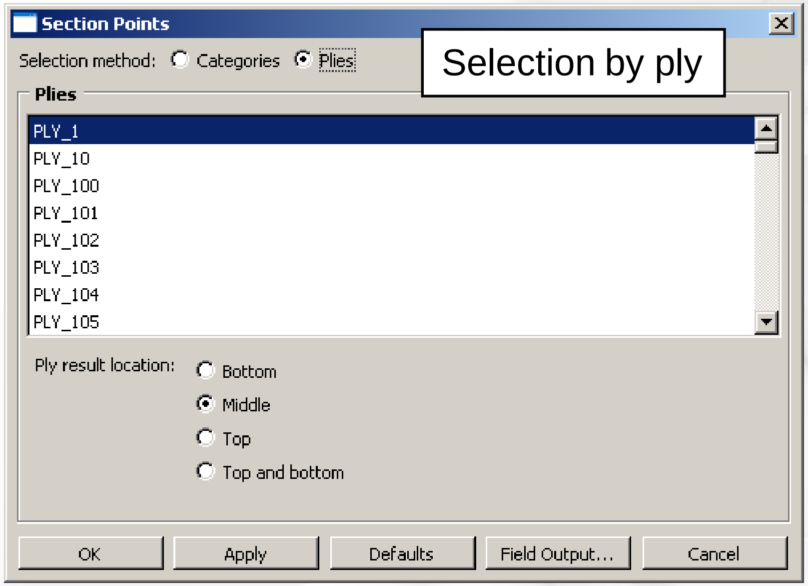
thickness values

integration points

fiber angles, material names

Viewing a Composite Layup

- **Ply-based postprocessing**
  - displays contour, symbol, or material orientation plots by selecting a particular ply and the location in the ply.
  - works with section point based postprocessing (selection by category).
    - Section point based postprocessing will be discussed in next lecture, “Alternative Modeling Techniques for Composites.”

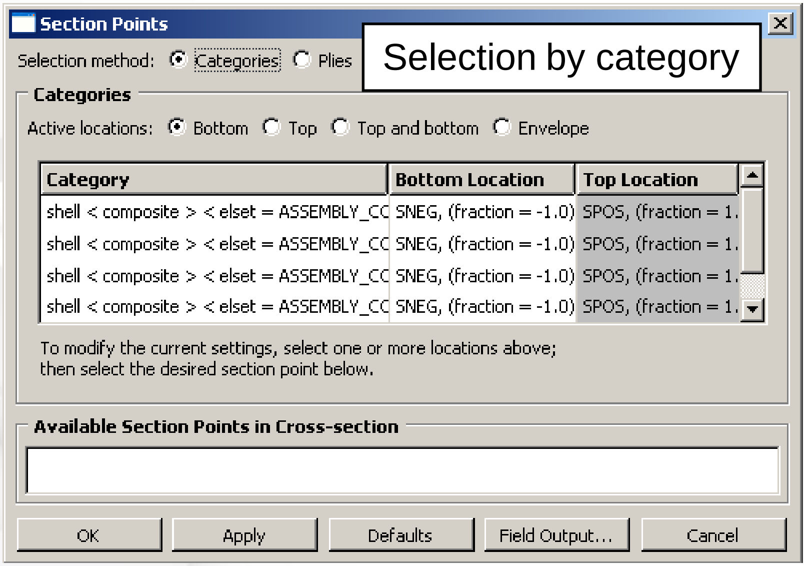


Selection method: ○ Categories ● Plies

Plies

PLY_1
PLY_10
PLY_100
PLY_101
PLY_102
PLY_103
PLY_104
PLY_105

Ply result location: ○ Bottom ● Middle ○ Top ○ Top and bottom



Selection method: ● Categories ○ Plies

Categories

Active locations: ● Bottom ○ Top ○ Top and bottom ○ Envelope

Category	Bottom Location	Top Location
shell < composite > < elset = ASSEMBLY_CC	SNEG, (fraction = -1.0)	SPOS, (fraction = 1.
shell < composite > < elset = ASSEMBLY_CC	SNEG, (fraction = -1.0)	SPOS, (fraction = 1.
shell < composite > < elset = ASSEMBLY_CC	SNEG, (fraction = -1.0)	SPOS, (fraction = 1.
shell < composite > < elset = ASSEMBLY_CC	SNEG, (fraction = -1.0)	SPOS, (fraction = 1.

To modify the current settings, select one or more locations above;
then select the desired section point below.

Available Section Points in Cross-section

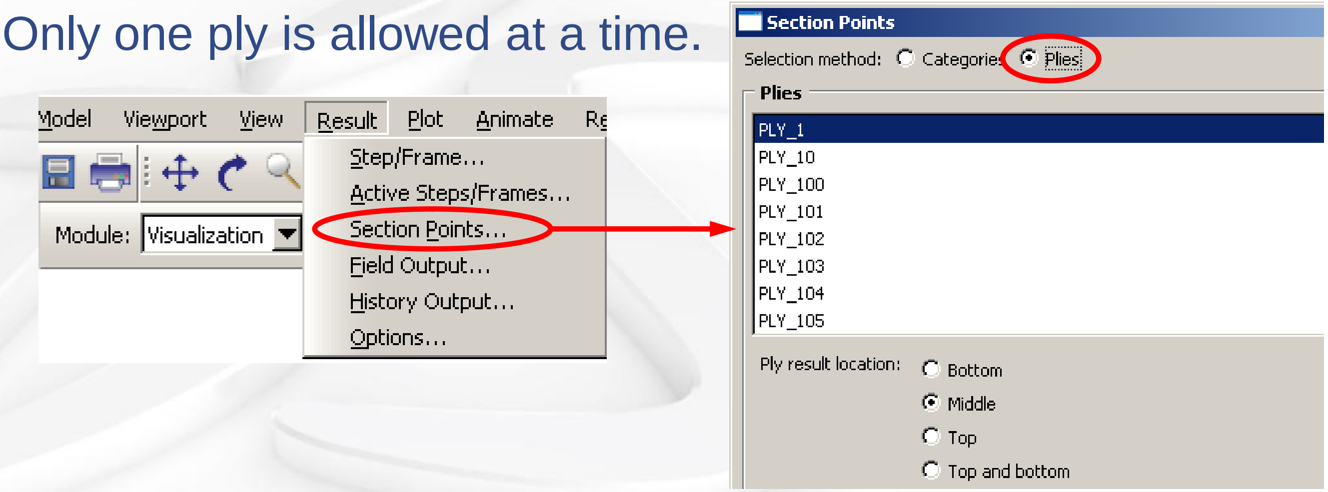
Viewing a Composite Layup

- **Example: Composite wing slat**

  ① Open the **Section Points** dialog box and choose the selection method by ply.

  ② Select a ply and ply result location.

  - The ply result location can be bottom, middle, top, or both top and bottom.
    - The middle location is either precise (e.g., 3rd out of 5) or imprecise (e.g., 3rd out of 6).
  - Only one ply is allowed at a time.



Selection method: ○ Categories ● Plies

Plies

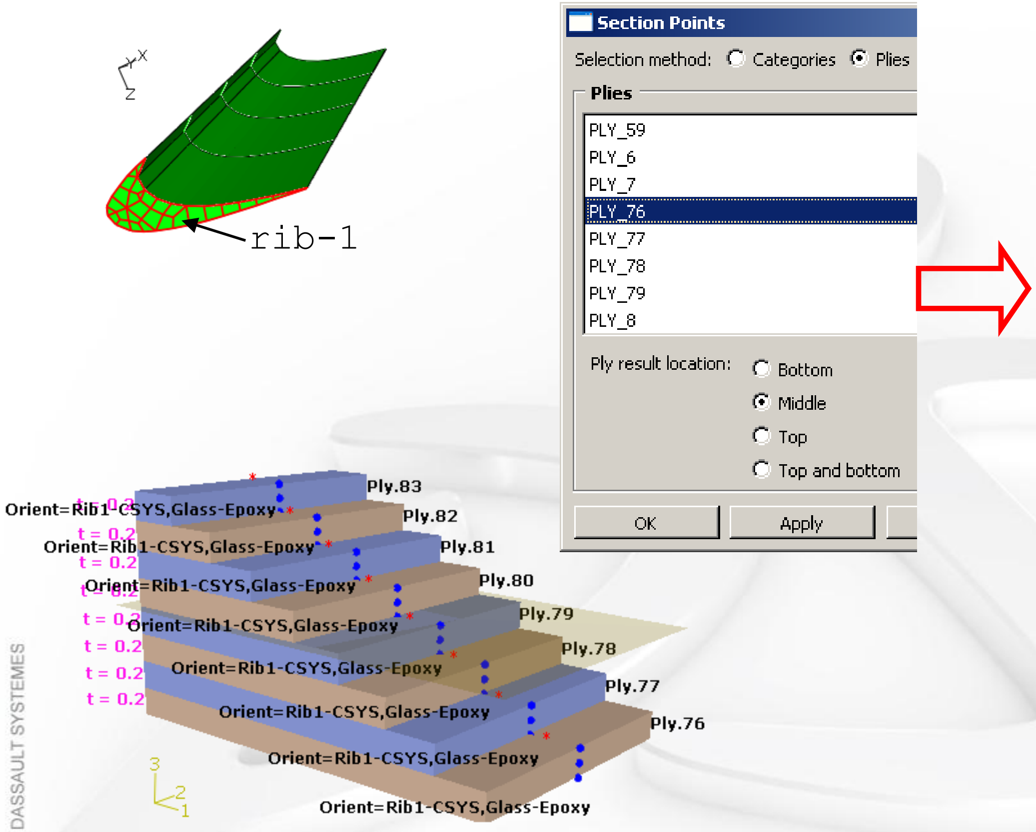
PLY_1
PLY_10
PLY_100
PLY_101
PLY_102
PLY_103
PLY_104
PLY_105

Ply result location:
○ Bottom
● Middle
○ Top
○ Top and bottom

Viewing a Composite Layup

3a Display the results from a selected ply of the rib composite layup:

- Any area of the model beyond the specified ply will be colored grey (no results color).

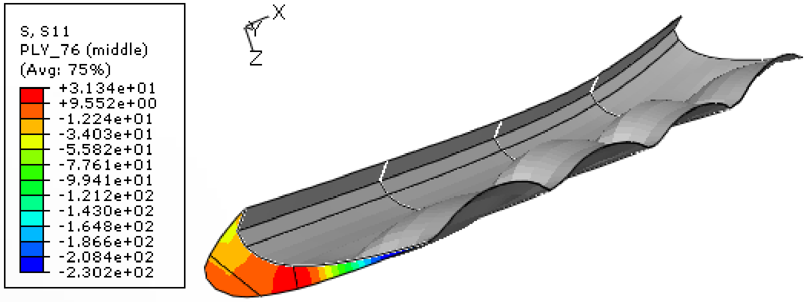


Section Points

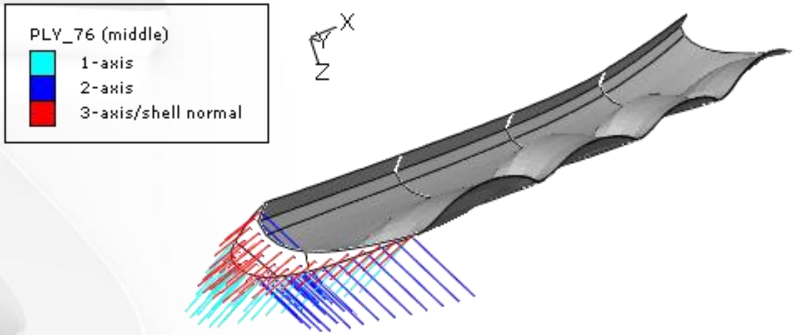
Selection method: ○ Categories ● Plies

Plies
- PLY_59
- PLY_6
- PLY_7
- PLY_76
- PLY_77
- PLY_78
- PLY_79
- PLY_8

Ply result location:
- ○ Bottom
- ● Middle
- ○ Top
- ○ Top and bottom



S11 stress: `PLY_76`

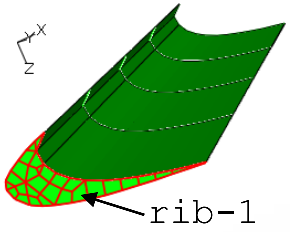


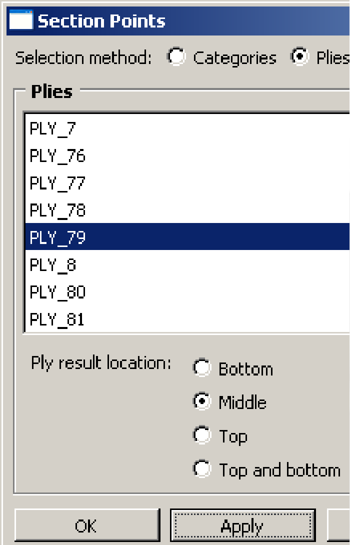
Material orientations: `PLY_76`

Note: The deformation is scaled

Viewing a Composite Layup

3b Display the results from a selected ply of the rib composite layup:





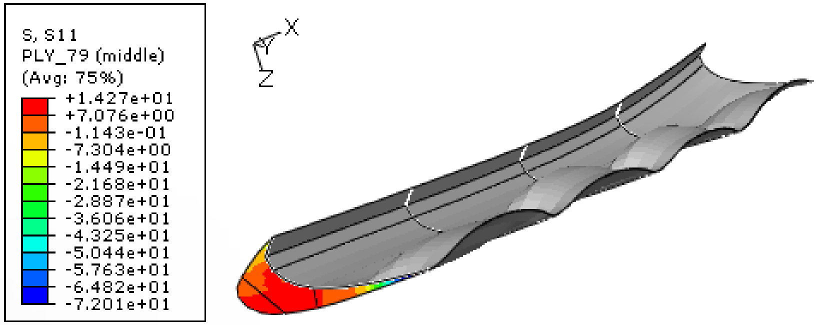
Section Points

Selection method: ○ Categories ● Plies

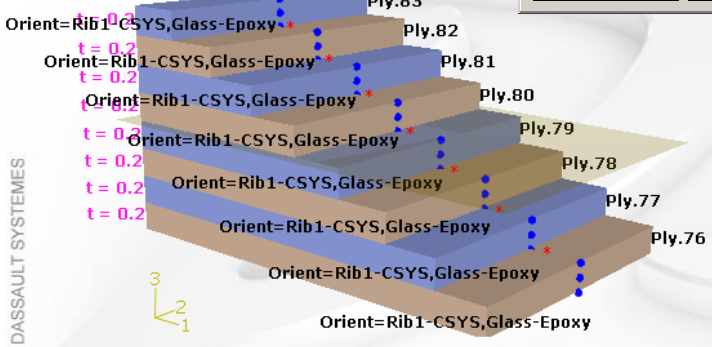
Plies

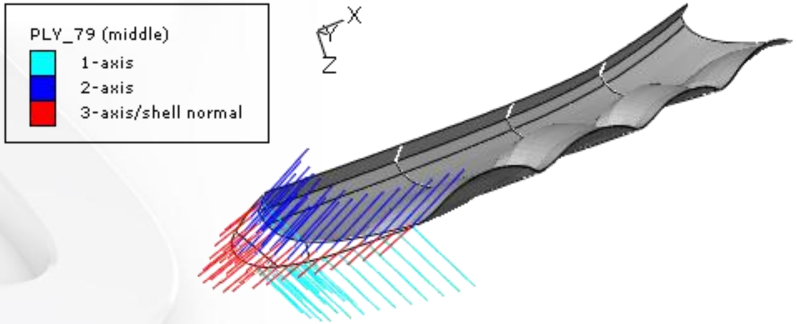
PLY_7
PLY_76
PLY_77
PLY_78
PLY_79
PLY_8
PLY_80
PLY_81

Ply result location: ○ Bottom ● Middle ○ Top ○ Top and bottom



S11 stress: `PLY_79`

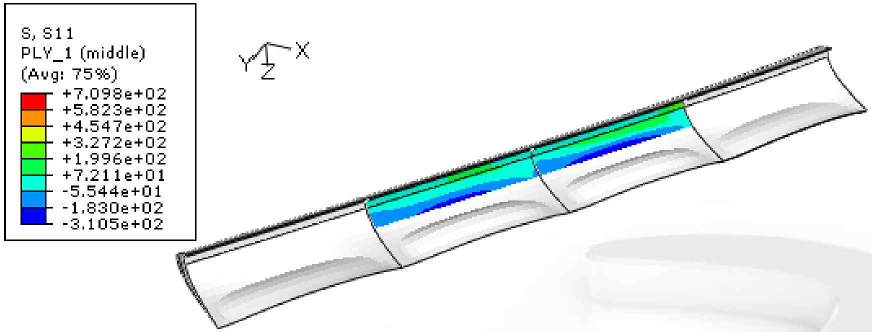




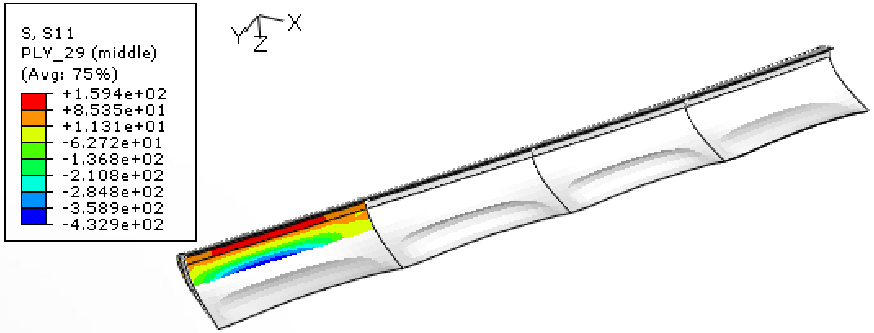
Material orientations: `PLY_79`

Viewing a Composite Layup

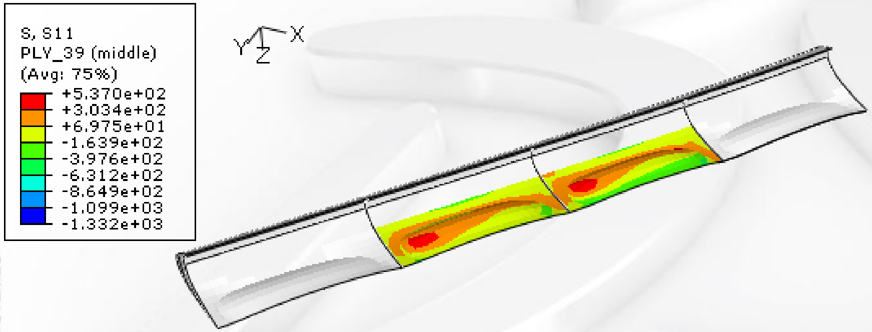
3c Display the results from selected plies of the skin composite layup:



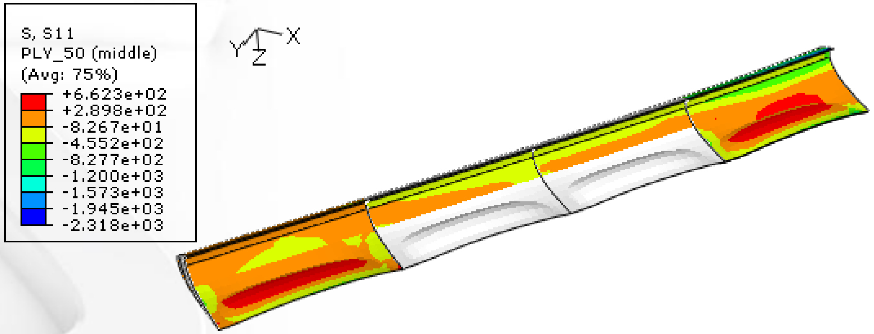
S11 stress : `PLY_1`



S11 stress: `PLY_29`



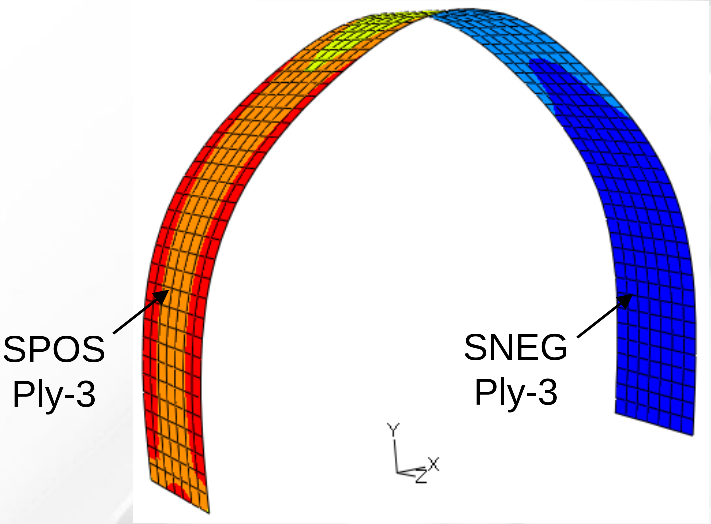
S11 stress : `PLY_39`



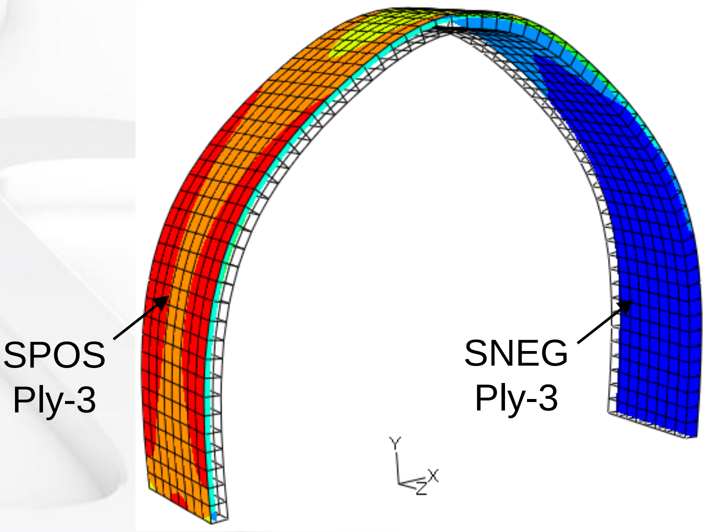
S11 stress : `PLY_50`

Viewing a Composite Layup

- **Contour plots displaying output at both the top and bottom of the selected ply vary in appearance depending on the type of composite layup.**
  - In a conventional shell composite layup the two contours appear as a double-sided shell with different contours on each side.
  - In a continuum shell composite layup the two contours appear as distinct single-sided contours at each section point location.



Conventional shell composite layup (three plies)



Continuum shell composite layup (three plies)

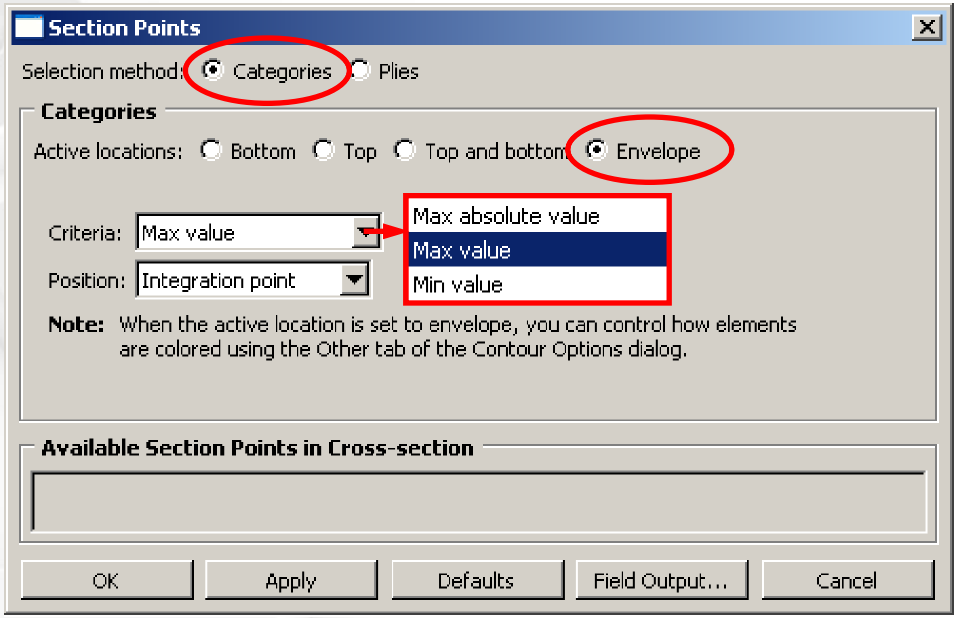
Viewing a Composite Layup

- **Envelope plot**
  - Envelope plot displays the critical value (maximum absolute value, maximum, or minimum) across all of the plies at each material point in the model in a contour plot.
  - Example: Composite wing slat

① Choose the selection method by category.

② Select

- **Envelope** as the active location,
- **Max value** as the criterion, and
- **Integration point** as the position.



Section Points

Selection method: ● Categories ○ Plies

Categories

Active locations: ○ Bottom ○ Top ○ Top and bottom ● Envelope

Criteria: Max value

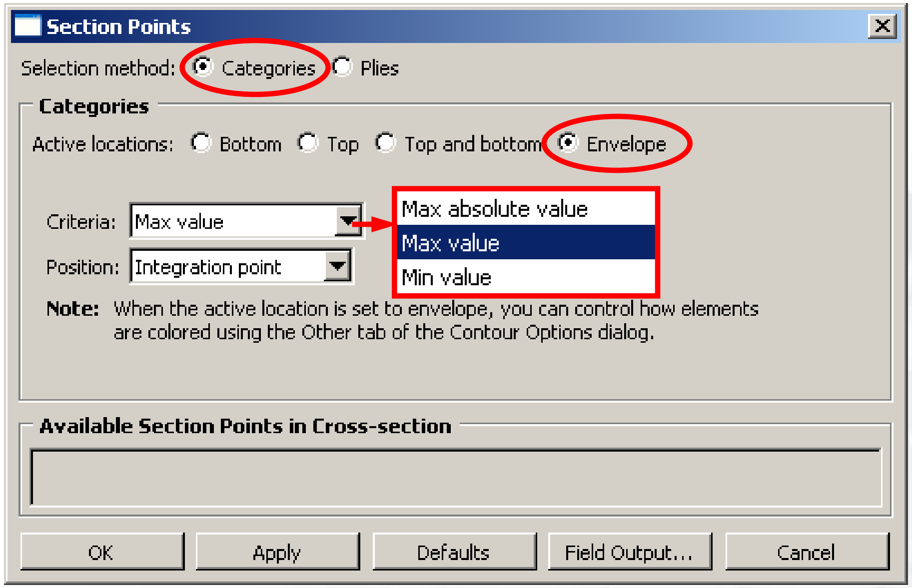
Position: Integration point

Note: When the active location is set to envelope, you can control how elements are colored using the Other tab of the Contour Options dialog.

Available Section Points in Cross-section

Viewing a Composite Layup

③ Plot the envelope plot on the wing slat model.



Section Points

Selection method: ● Categories ○ Plies

Categories

Active locations: ○ Bottom ○ Top ○ Top and bottom ● Envelope

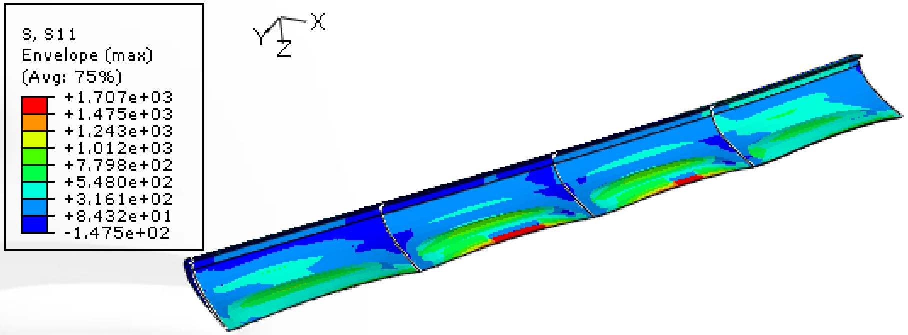
Criteria: Max value

- Max absolute value
- Max value
- Min value

Position: Integration point

Note: When the active location is set to envelope, you can control how elements are colored using the Other tab of the Contour Options dialog.

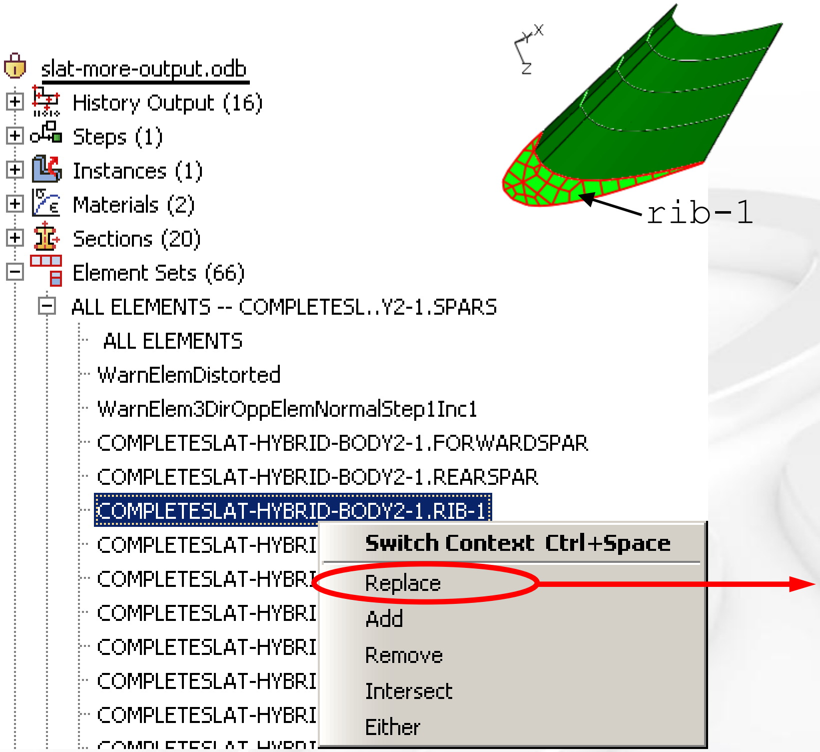
Available Section Points in Cross-section



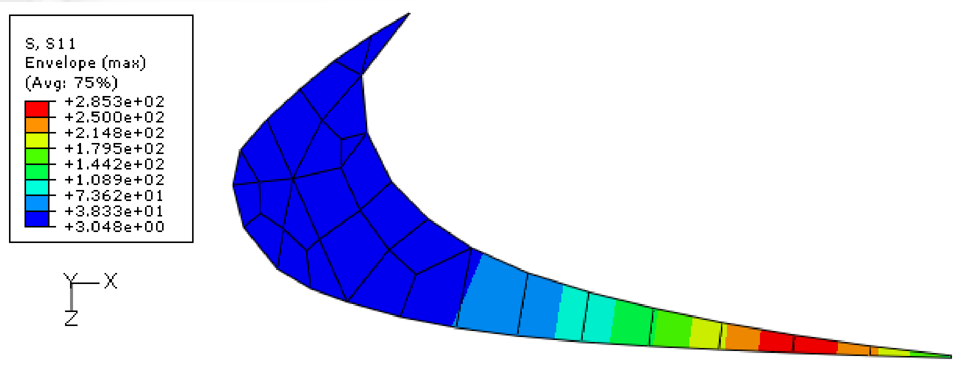
Viewing a Composite Layup

④ Display an envelope plot on a selected region, e.g. **`rib-1`**.

- Create a display group by element set rib-1.



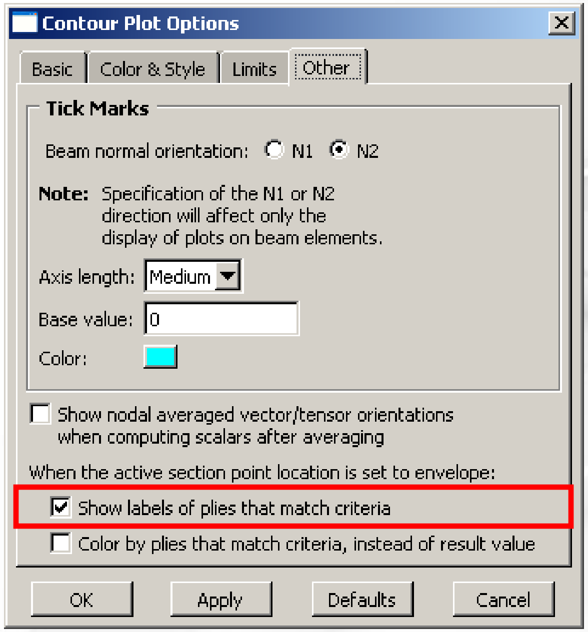
slat-more-output.odb
- History Output (16)
- Steps (1)
- Instances (1)
- Materials (2)
- Sections (20)
- Element Sets (66)
  - ALL ELEMENTS -- COMPLETESL..Y2-1.SPARS
    - ALL ELEMENTS
    - WarnElemDistorted
    - WarnElem3DirOppElemNormalStep1Inc1
    - COMPLETESLAT-HYBRID-BODY2-1.FORWARDSPAR
    - COMPLETESLAT-HYBRID-BODY2-1.REARSPAR
    - COMPLETESLAT-HYBRID-BODY2-1.RIB-1
    - COMPLETESLAT-HYBRI
    - COMPLETESLAT-HYBRI
    - COMPLETESLAT-HYBRI
    - COMPLETESLAT-HYBRI
    - COMPLETESLAT-HYBRI
    - COMPLETESLAT-HYBRI



S, S11
Envelope (max)
(Avg: 75%)

Viewing a Composite Layup

- **Determine the critical plies from an envelope plot**
  - Show names of critical plies
    - Example: Composite wing slat
      - Create the envelope plot on the selected region, e.g. `rib-1`.
      - In the **Contour Plot Options** dialog box, select **Show labels of plies that match criteria**.



Contour Plot Options

Basic | Color & Style | Limits | Other

Tick Marks

Beam normal orientation: ○ N1 ● N2

Note: Specification of the N1 or N2 direction will affect only the display of plots on beam elements.

Axis length: Medium

Base value: 0

Color: 🟦

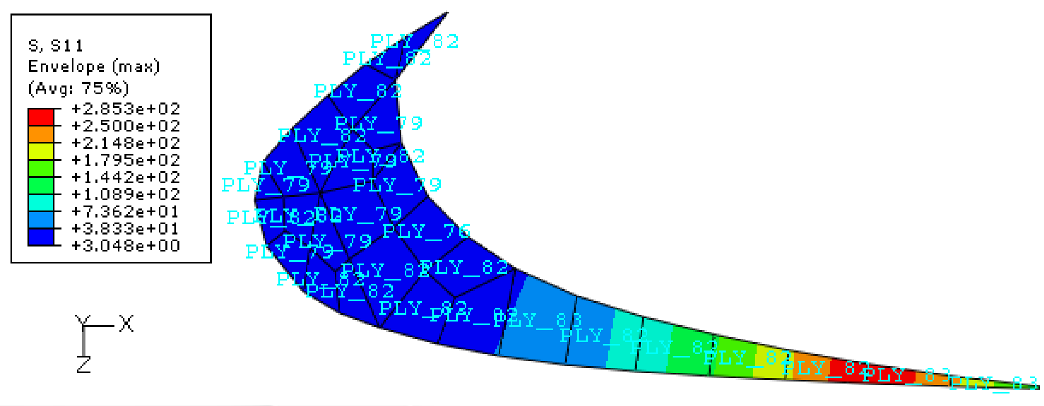
☐ Show nodal averaged vector/tensor orientations when computing scalars after averaging

When the active section point location is set to envelope:

☑ Show labels of plies that match criteria

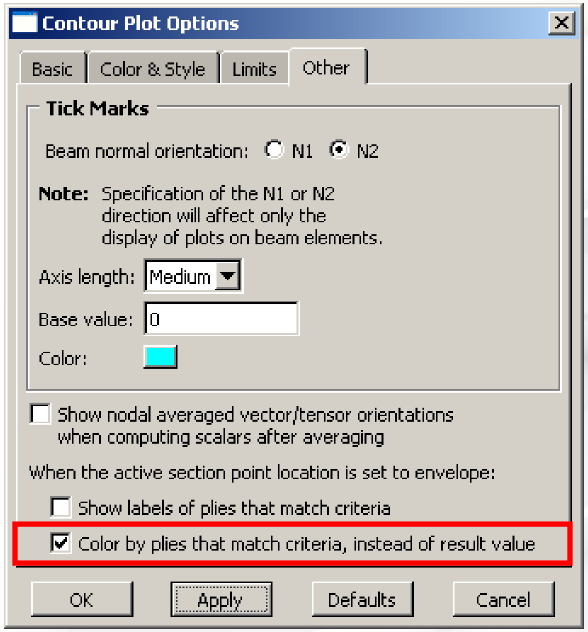
☐ Color by plies that match criteria, instead of result value

OK | Apply | Defaults | Cancel



Viewing a Composite Layup

- Show quilt plot of critical plies
  - Example: Composite wing slat
    - Create the envelope plot on the selected region, e.g. `rib-1`.
    - In the **Contour Plot Options** dialog box, select **Color by plies that match criteria, instead of result value**.



Contour Plot Options

Basic | Color & Style | Limits | Other

Tick Marks

Beam normal orientation: ○ N1 ● N2

Note: Specification of the N1 or N2 direction will affect only the display of plots on beam elements.

Axis length: Medium

Base value: 0

Color:

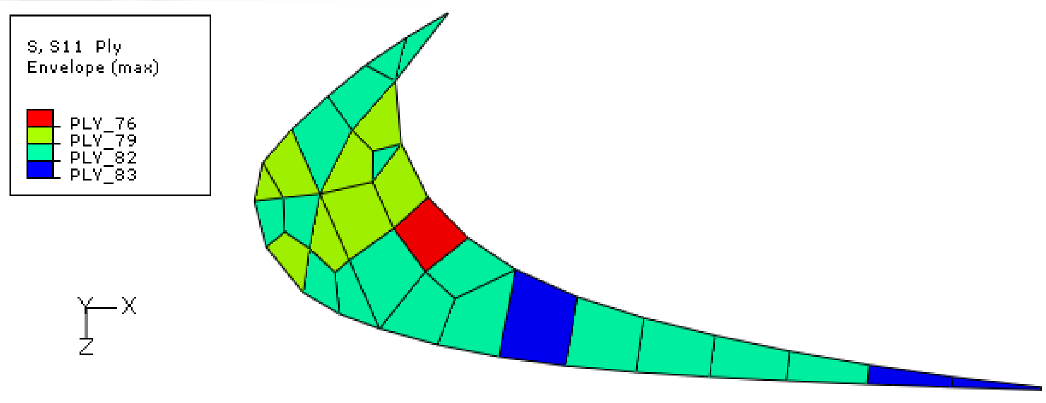
☐ Show nodal averaged vector/tensor orientations when computing scalars after averaging

When the active section point location is set to envelope:

☐ Show labels of plies that match criteria

☑ Color by plies that match criteria, instead of result value

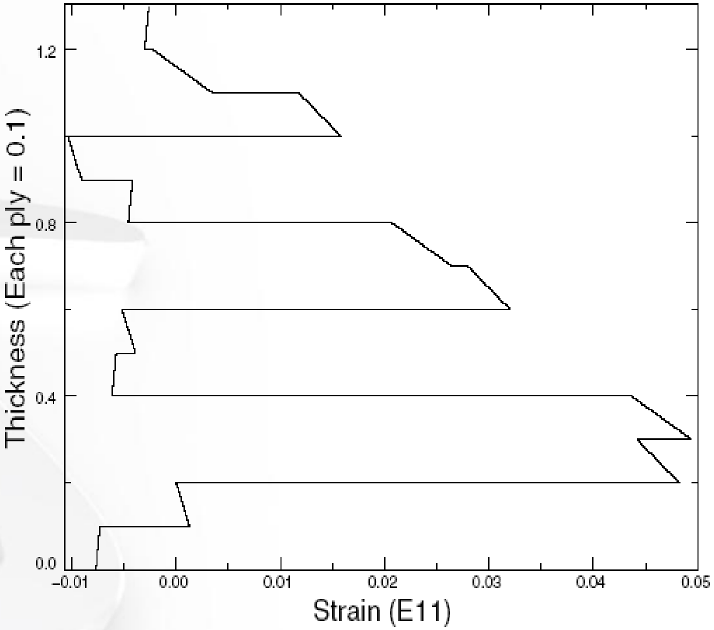
OK | Apply | Defaults | Cancel



Note: using a combination of these plots, you can determine both the value of S11 in the critical ply and the location of the critical ply in the layup.

Viewing a Composite Layup

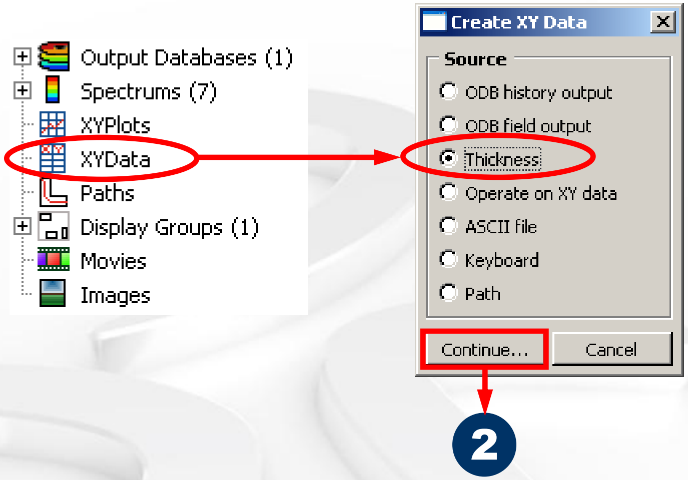
- **Through-thickness *X*–*Y* plots**
  - Display the behavior of the plies across the entire thickness of the layup.
  - Read *X*–*Y* data from field output results at the section points in a shell element.
  - For example, the figure illustrates a through-thickness plot of the strain in the fiber direction through 13 plies of a composite layup.
    - The strain is discontinuous because the orientation of the fiber changes between plies.



Viewing a Composite Layup

- **Creating a through-thickness *X*–*Y* plot**
  - Example: Composite wing slat

① Locate the **Thickness** option.

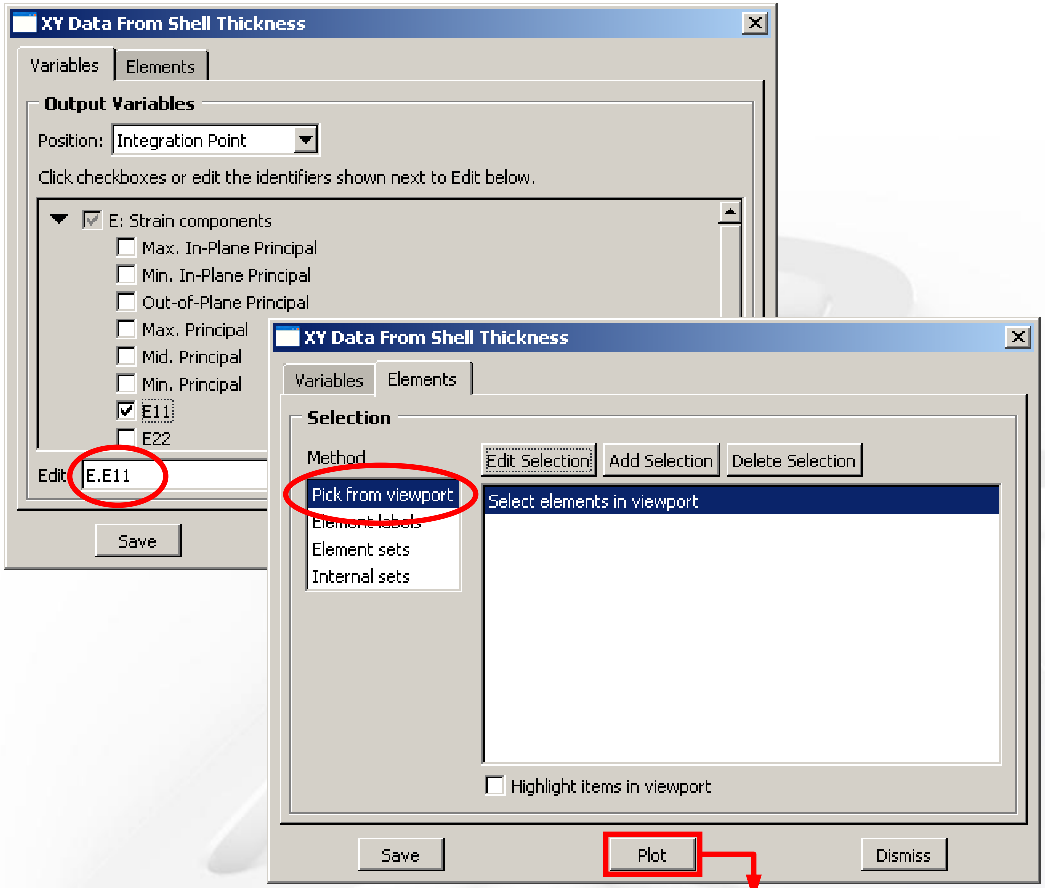


Source

○ ODB history output
○ ODB field output
● Thickness
○ Operate on XY data
○ ASCII file
○ Keyboard
○ Path

Viewing a Composite Layup

② Select an output variable for an element (or a set of elements).



XY Data From Shell Thickness

Variables | Elements

Output Variables

Position: Integration Point

Click checkboxes or edit the identifiers shown next to Edit below.

- ☑ E: Strain components
  - ☐ Max. In-Plane Principal
  - ☐ Min. In-Plane Principal
  - ☐ Out-of-Plane Principal
  - ☐ Max. Principal
  - ☐ Mid. Principal
  - ☐ Min. Principal
  - ☑ E11
  - ☐ E22

Edit: E.E11

XY Data From Shell Thickness

Variables | Elements

Selection

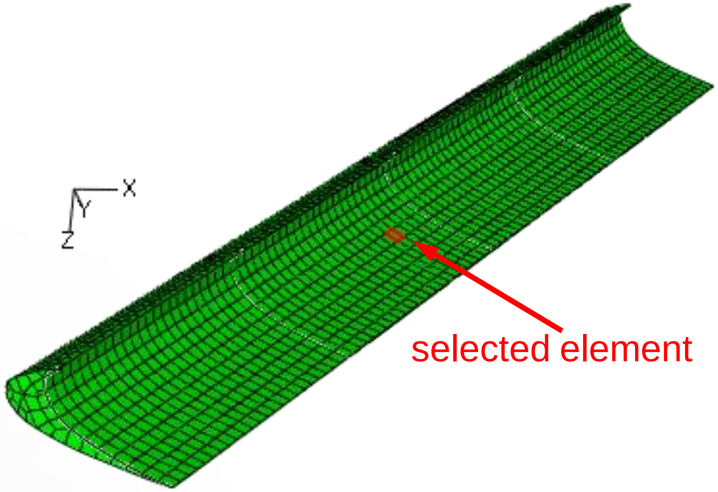
Method

- Pick from viewport
- Element labels
- Element sets
- Internal sets

Select elements in viewport

☐ Highlight items in viewport

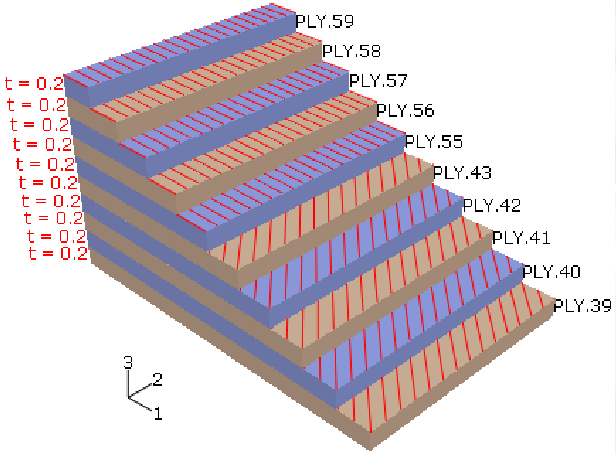
③



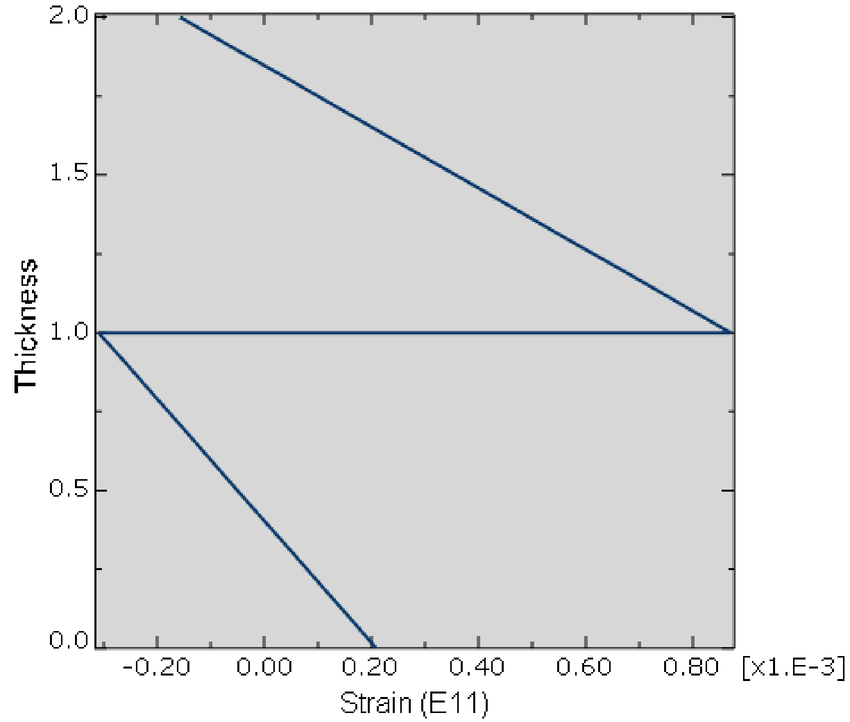
selected element

Viewing a Composite Layup

3 Plot the through-thickness variation.



The stack plot of the selected element

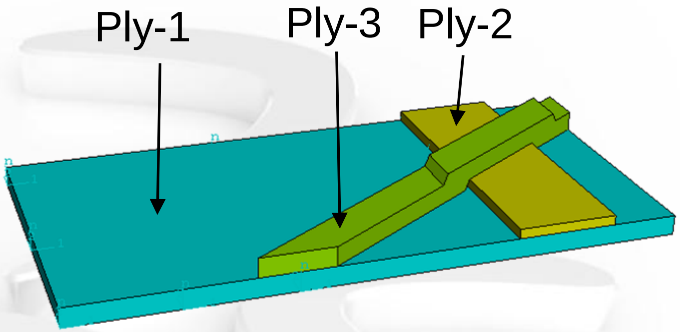


The through-thickness *X*–*Y* plot

Abaqus/CAE Demonstration: Three-ply composite

Abaqus/CAE Demonstration: Three-ply composite

- **In this demonstration Abaqus/CAE is used to model the three-ply composite plate and postprocess the results.**
  - Note: The narrated version of this demonstration can be accessed via the link to the Web based training provided in SIMULIA Answer 3417.

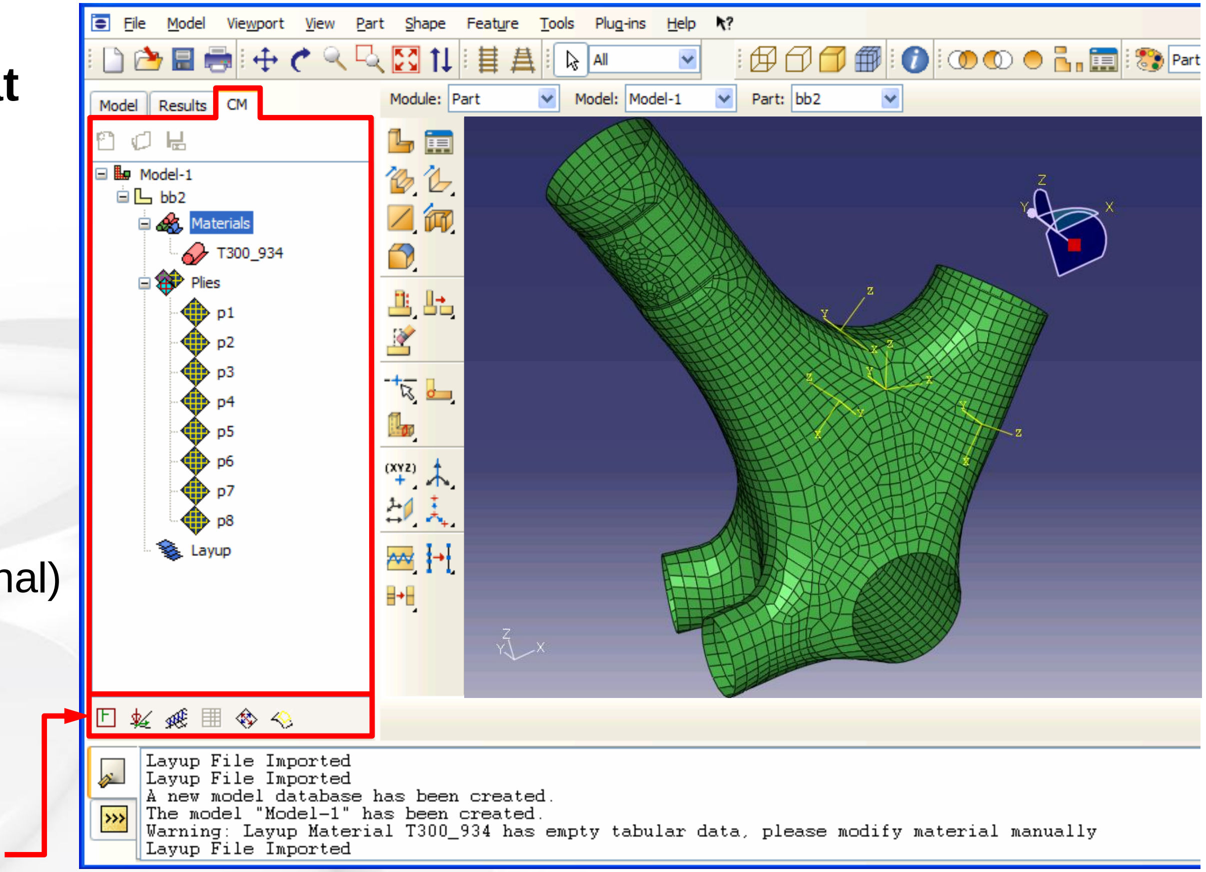


Play Demo

Composites Modeler for Abaqus/CAE

Composites Modeler for Abaqus/CAE

- **Composites Modeler for Abaqus/CAE (CMA) is an add-on product that extends the Abaqus built-in ply modeling features by providing**
  - Advanced fiber modeling (draping)
  - Import/export of **`.Layup`** files
  - Integration (bidirectional) between Abaqus and CATIA Composite Design (CPD)
  - Ply visualization tools

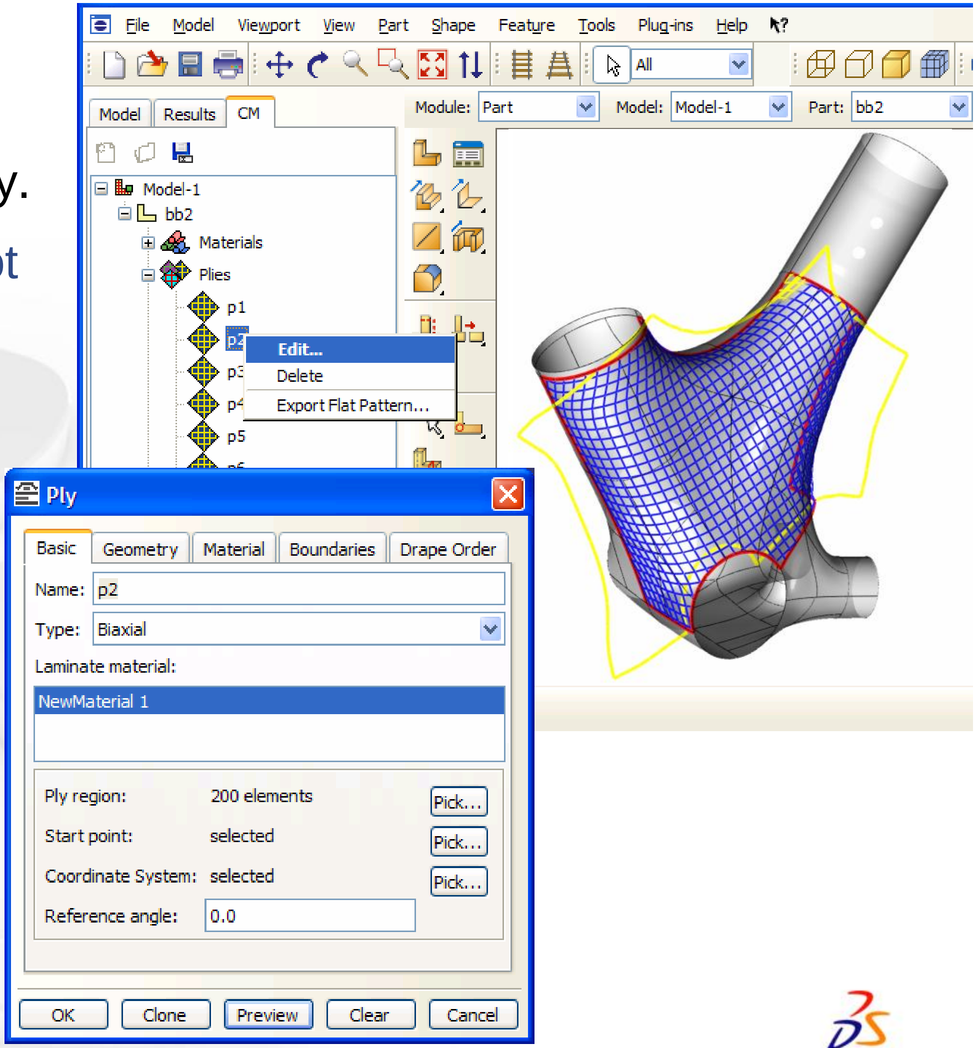


```
Layup File Imported
Layup File Imported
A new model database has been created.
The model "Model-1" has been created.
Warning: Layup Material T300_934 has empty tabular data, please modify material manually
Layup File Imported
```

GUI interface: Composites Modeler of Abaqus/CAE

Composites Modeler for Abaqus/CAE

- **Draping calculation**
  - Accounts for local fiber directions when tape/cloth is draped over curved geometry.
    - Projected CSYS may not account for the curved geometry correctly.
  - Producibility (flat pattern prediction) to ensure that manufacturable plies are proposed.



Module: Part
Model: Model-1
Part: bb2

Ply

Name: p2

Type: Biaxial

Laminate material: NewMaterial 1

Ply region: 200 elements

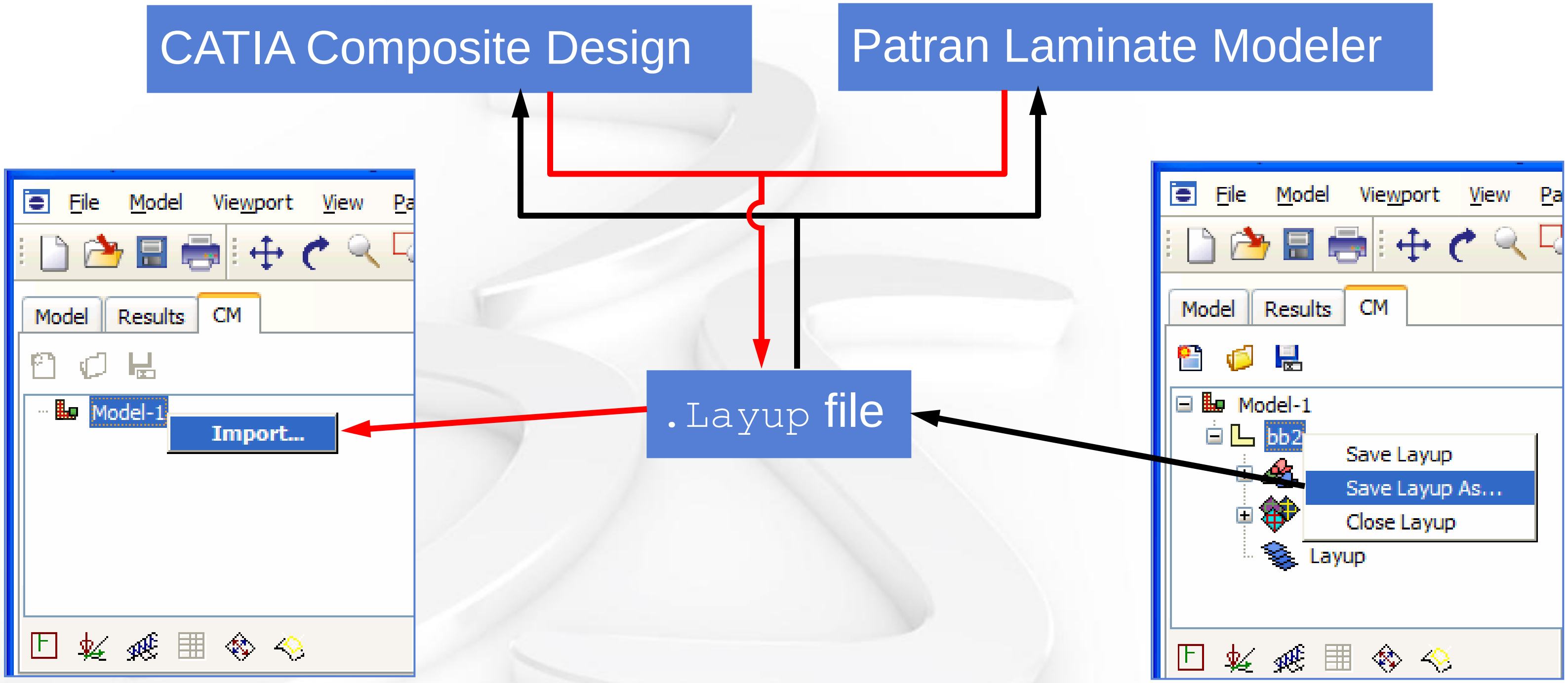
Start point: selected

Coordinate System: selected

Reference angle: 0.0

Composites Modeler for Abaqus/CAE

- **Import/export of `.Layup` files**
  - The **`.Layup`** file is supported by Patran Laminate Modeler, CATIA Composite Design (CPD), ……
    - It is the neutral interchange format between these products and Abaqus.



CATIA Composite Design

Patran Laminate Modeler

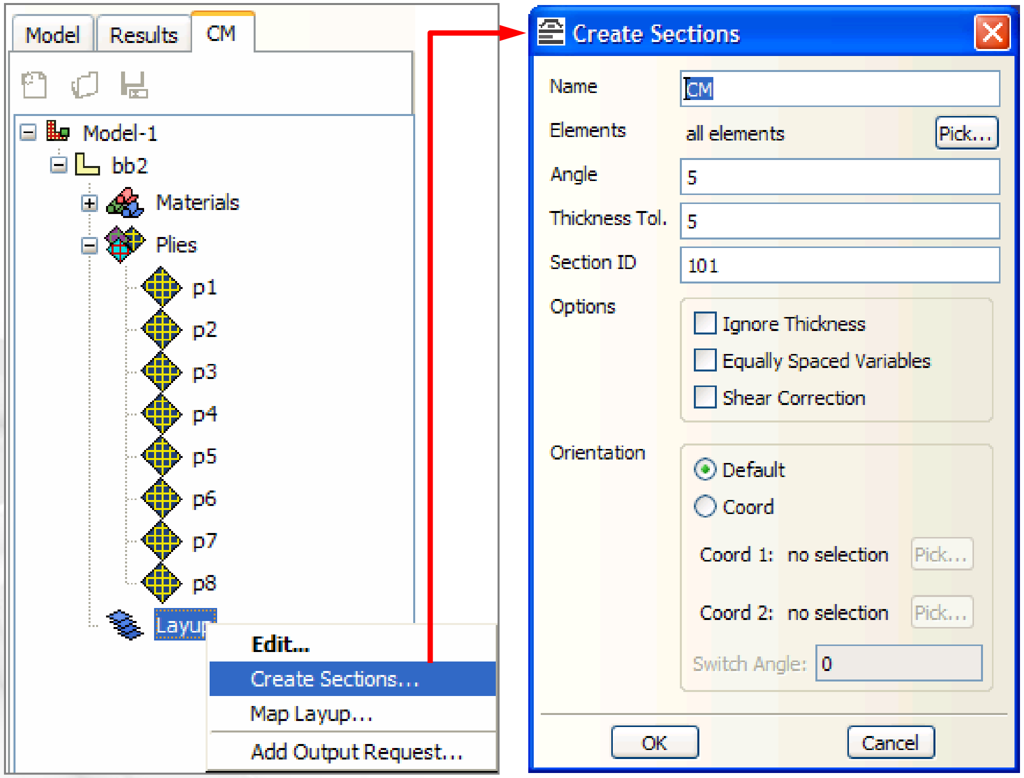
`.Layup` file

Importing `.Layup` file into Abaqus

Exporting `.Layup` file from Abaqus

Composites Modeler for Abaqus/CAE

- **The layup created by CMA is incorporated into shell section definitions.**
    - After creating sections from the layup, you can use the built-in ply stack plot tool to display the layup from a probed region/element.
- **Ply-based postprocessing is also supported.**
- **To learn more about CMA, please consult the *Composites Modeler for Abaqus/CAE* lecture notes.**



Name: CM
Elements: all elements
Angle: 5
Thickness Tol.: 5
Section ID: 101
Options:
☐ Ignore Thickness
☐ Equally Spaced Variables
☐ Shear Correction
Orientation:
● Default
○ Coord
Coord 1: no selection
Coord 2: no selection
Switch Angle: 0

Creation of shell sections