

# Workshop – Composite Panel – Phase D – Core Shape and Core Thickness Optimization

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AN MSC NASTRAN SOL 200 TUTORIAL

# Composite Workshop

This workshop is phase D of a 3-phase workshop.

## Phase B

Workshop – Composite Panel – Phase B –  
Baseline Core Thickness Optimization

- Perform a core thickness optimization with a constant thickness core
- Tools Used: SOL 200 Web App (Viewer and Optimization web apps) and MSC Nastran

## Phase C

Workshop – Composite Panel – Phase C –  
Topometry Optimization to Determine Optimal  
Core Shape

- Generate PLY000i Files via Topometry Optimization
- Tools Used: Patran, MSC Nastran and SOL 200 Web App

## Phase D

Workshop – Composite Panel – Phase D – Core  
Shape and Core Thickness Optimization

- Input BDF and PLY000i Files
- Create Core Shapes
- Perform Core Thickness Optimization
- Inspect Core
- Tools Used: SOL 200 Web App (Viewer and Optimization web apps) and MSC Nastran

Baseline Core Thickness  
Optimization

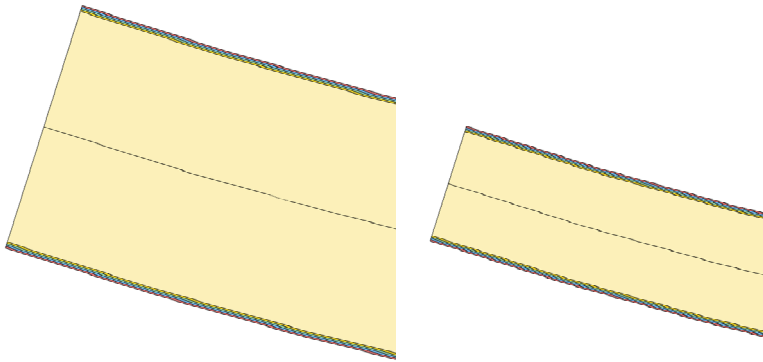
Core Shape Optimization

Core Thickness  
Optimization

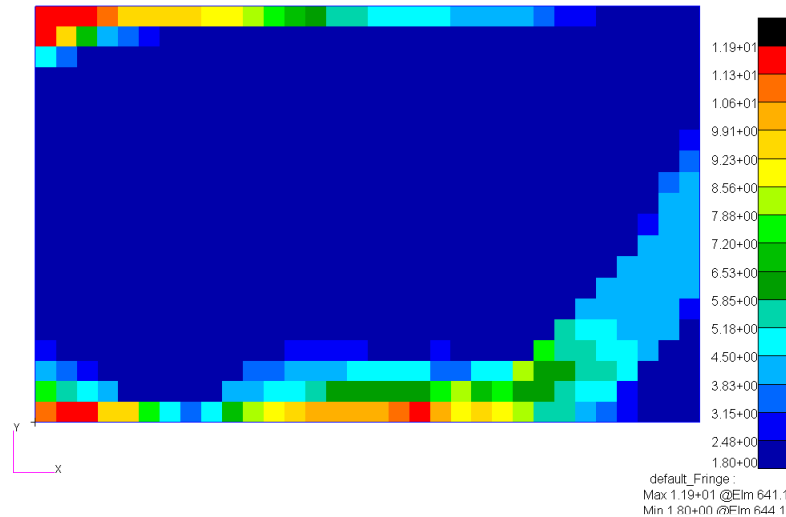
# Composite Workshop

This workshop is phase D of a 3-phase workshop.

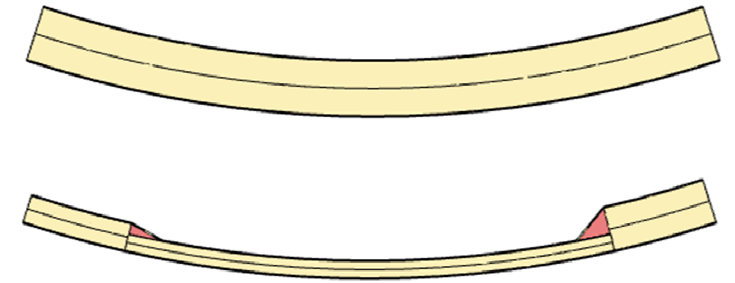
Phase B



Phase C



Phase D



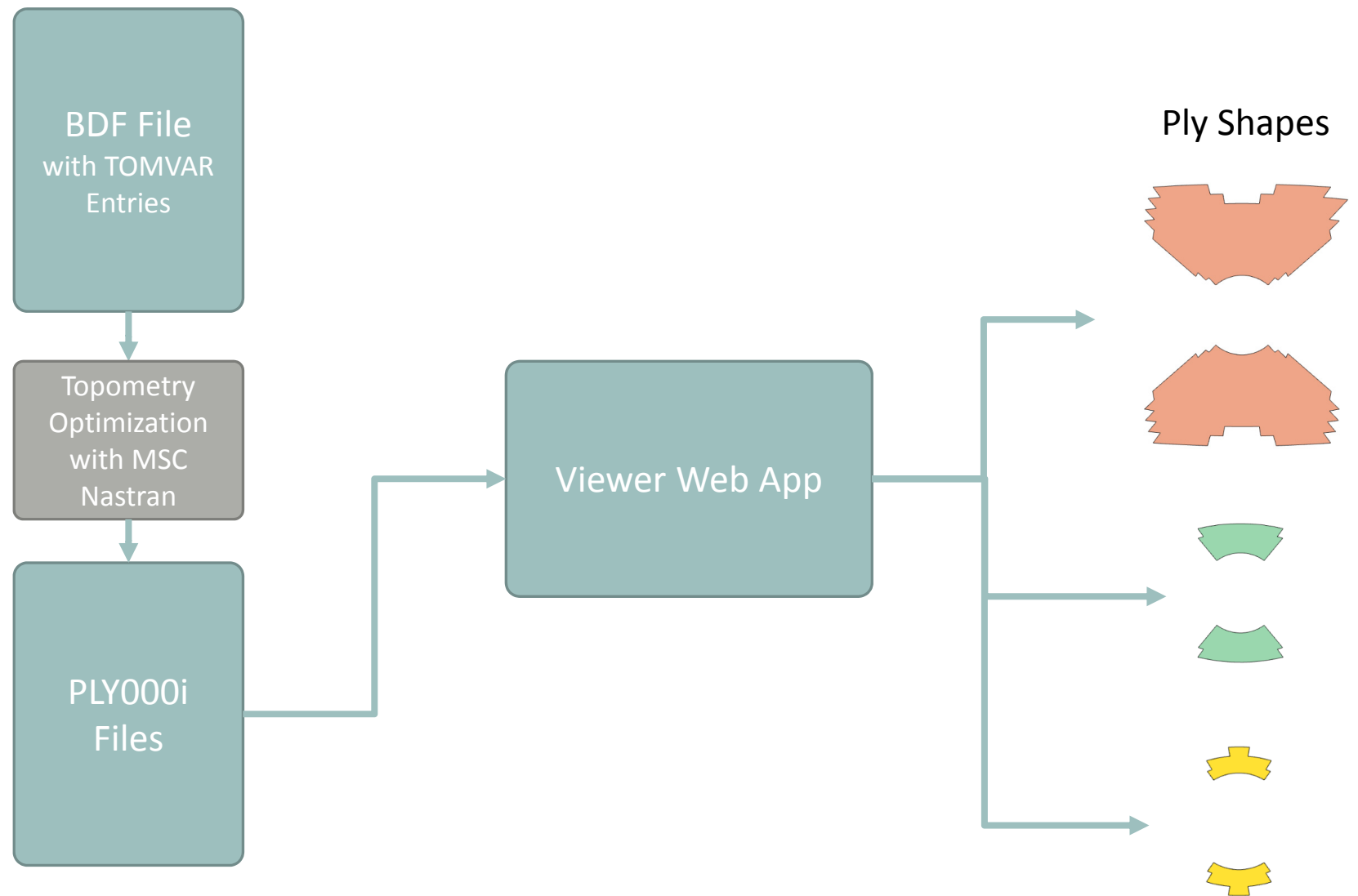
Baseline Core Thickness  
Optimization

Core Shape Optimization

Core Thickness  
Optimization

## Goal: Construct Optimal Core Shapes and Perform Core Thickness Optimization

- The goal is to construct core shapes that produce a lightweight composite but satisfy buckling constraints.
- This tutorial discusses how to operate the Viewer web app to construct new optimized core shapes and perform a core thickness optimization.
- The word “core” and “ply” are used interchangeably throughout this exercise.



# Summary of Optimized Designs

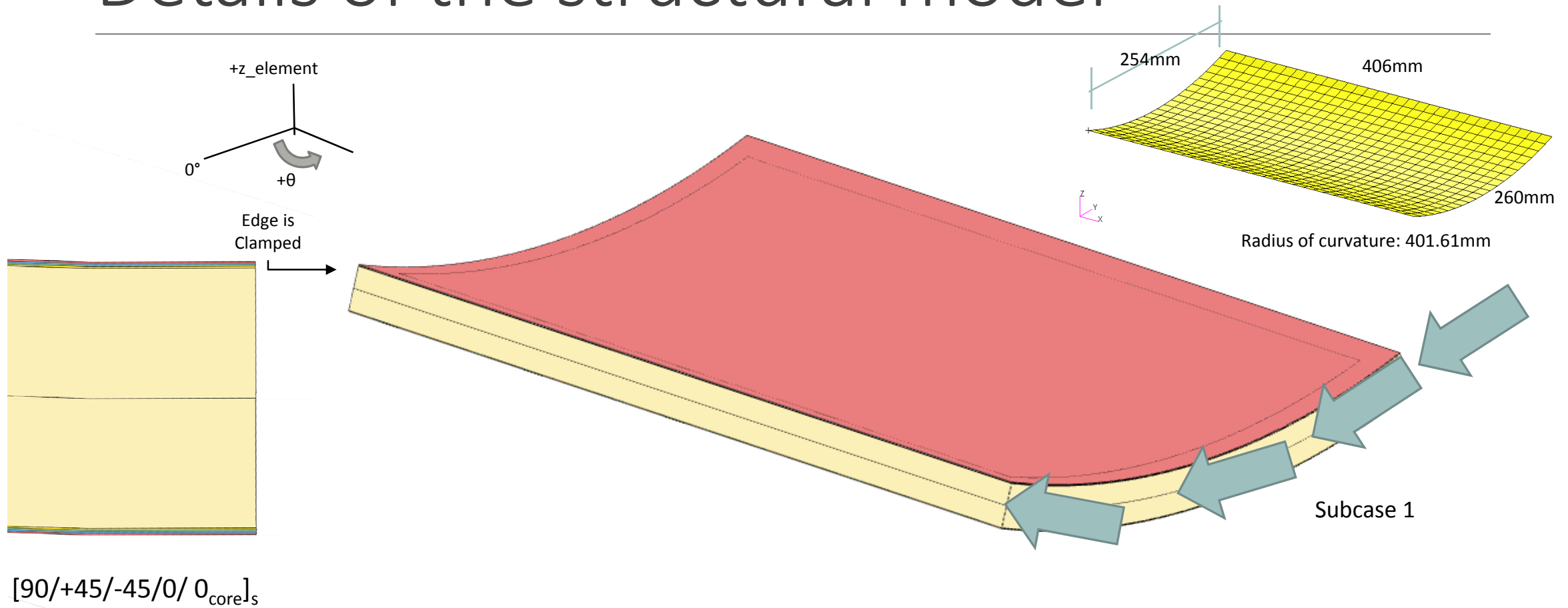
By the end of this tutorial, the mass of the new composite panel is expected to be reduced by approximately 23% .

A comparison is made between the starting and final composite designs from phase B and D. Observe the following:

1. ~23% mass savings. The mass of the core was reduced from 2.203330E-04 to 1.70E-04.
2. In both designs, the buckling load factor is greater than 1.0, so both designs are feasible.

	Starting Design	Design After Topometry Optimization	Design After Core Shape and Core Number Optimization
	Tutorial Phase B	Tutorial Phase C	Tutorial Phase D
Total Mass	3.9503E-04	2.97E-4	
Mass of Non-design Region (Plies)	1.746926E-04	1.746926E-04	
Mass of Design Region (Core)	<b>2.203330E-04</b>	<b>1.22E-04</b>	
Buckling Load Factor, Subcase 2	1.064771 (OK)	9.9758E-01 (NOT OK)	


# Details of the structural model


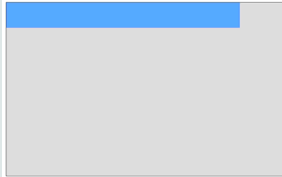
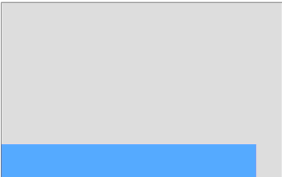
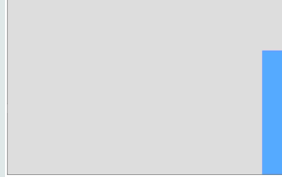
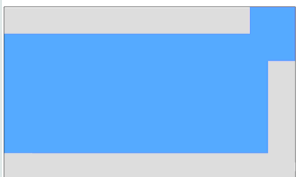


# Using PLY000i Files to Create Optimal Ply Shapes

- The data contained in PLY000i files, e.g. model.ply0005, are critical to construct optimal ply shapes. BDF and PLY000i files are used in this tutorial to construct new optimal ply shapes.
- The SOL 200 Web App's Viewer is used to create new ply shapes.

- Each ply shape candidate is assigned a unique GPLY ID, e.g. 111000, 2111000. For more details on the GPLY ID numbering convention, refer to the appendix, section *GPLY ID Numbering Convention (sPLC00)*.
- Ply shapes are created based on the data contained in the PLY000 files. The PLY000i files are generated by Topometry Optimization or may be created manually, as done in this tutorial. Alternatively, both methods may be combined for a hybrid method.
- Some GPLY IDs have a number 2 as a suffix. This composite is symmetric and the suffix of 2 indicates a symmetric ply. For example, GPLY ID 151000 has a corresponding 2151000 mirror ply.

 Ply Shape

Layer, Theta	Ply Shape Candidate 1 (Not used)	Ply Shape Candidate 2	Ply Shape Candidate 3	Ply Shape Candidate 4	Ply Shape Candidate 5
5  0° (Core)	151000, 2151000 	152000, 2152000 	153000, 2153000 	154000, 2154000 	185000, 2185000 

# Optimization Problem Statement

## Design Variables

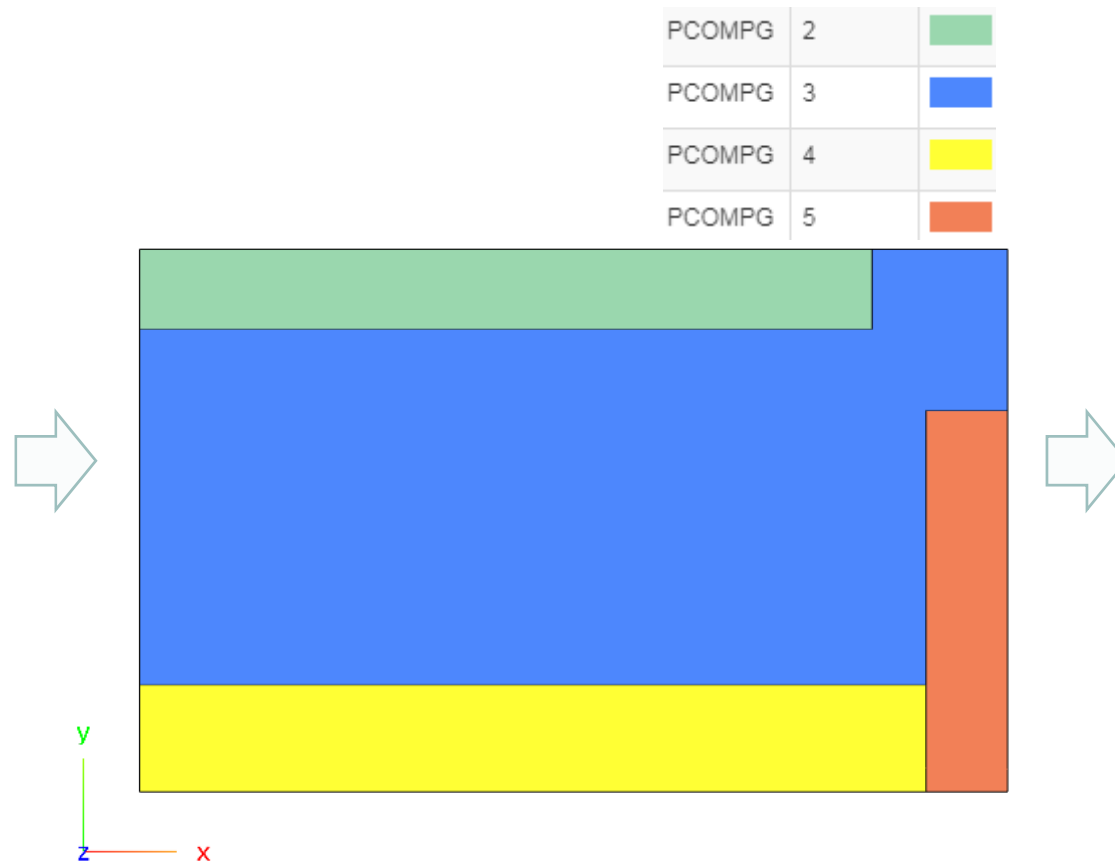
y1: Thickness of core layers for 0°, GPLY IDs: 152000, 2152000

y2: Thickness of core layers for 0°, GPLY IDs: 153000, 2153000

y3: Thickness of core layers for 0°, GPLY IDs: 154000, 2154000

y4: Thickness of core layers for 0°, GPLY IDs: 155000, 2155000

The core is allowed to range between 6mm and 50mm. Since the composite is symmetric, the variables range between 3mm and 25mm. The final thickness value is allowed to be in increment of 1mm.



## Design Objective

Minimize r0: weight

## Design Constraints

r1: 1<sup>st</sup> buckling load factor

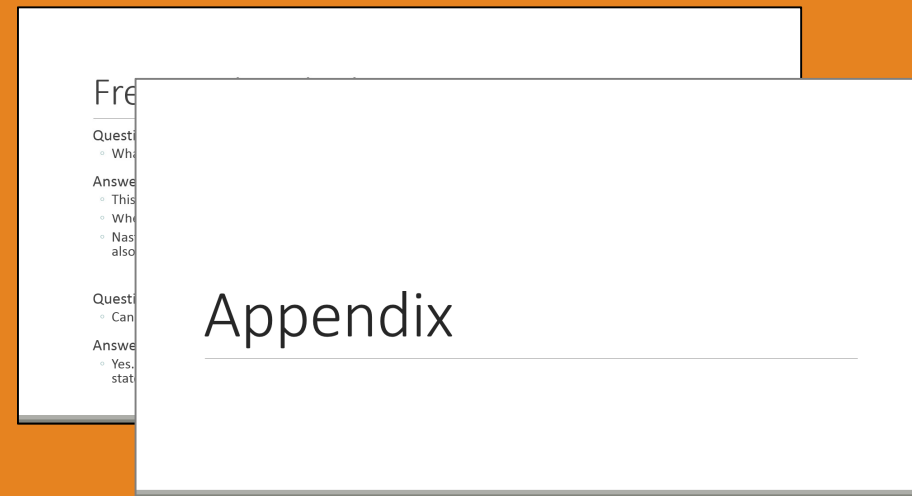
$1.0 < r1$



# More Information Available in the Appendix

The Appendix includes information regarding the following:

- PCOMPG Zones
- Options for Ply Number Optimization
- GPLY ID Numbering Convention (sPLC000)



# Contact me

- Nastran SOL 200 training
- Nastran SOL 200 questions
- Structural or mechanical optimization questions
- Access to the SOL 200 Web App

christian@ the-engineering-lab.com

# Tutorial

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# Tutorial Overview

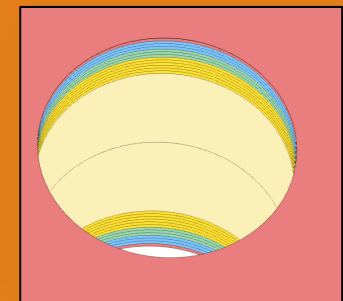
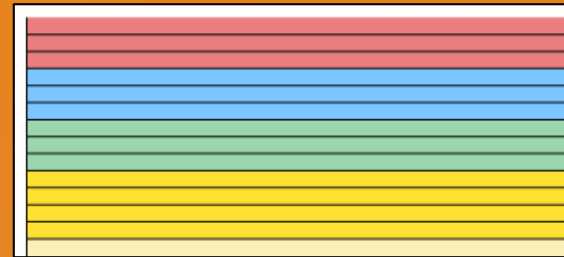
1. Part 1 – Core Shape Creation
2. Part 2 – Core Thickness Optimization
3. Part 3 – View New Core Thickness

## Special Topics Covered

**Core Shape Editing** - The current composite panel uses a constant thickness core. This tutorial discusses a procedure to segment the core and each core will be sized to a different thickness. Ultimately, the goal is to minimize the weight of the composite.

**Core Thickness Optimization** – Once multiple core segments are defined, a core thickness optimization is performed for each segment.

**Core Thickness Inspection** - Finally, the final composite core and plies are visually inspected.



# SOL 200 Web App Capabilities

The Post-processor Web App and HDF5 Explorer are free to MSC Nastran users.

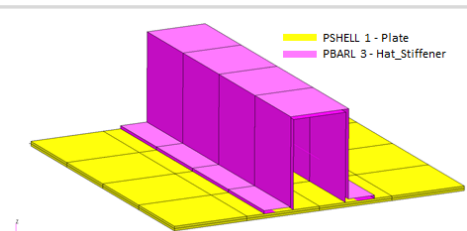
## Compatibility

- Google Chrome, Mozilla Firefox or Microsoft Edge
- Windows and Red Hat Linux
- Installable on a company laptop, workstation or server. All data remains within your company.

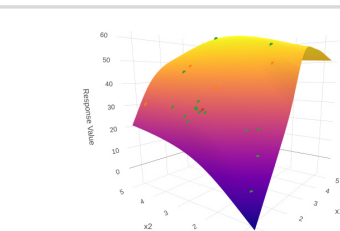
## Benefits

- REAL TIME error detection. 200+ error validations.
- REAL TIME creation of bulk data entries.
- Web browser accessible
- Free Post-processor web apps
- +80 tutorials

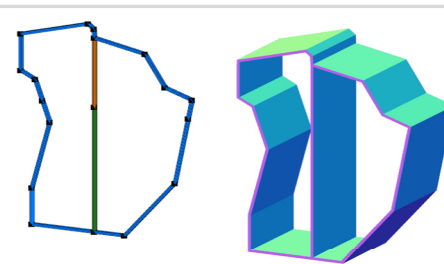
## Web Apps



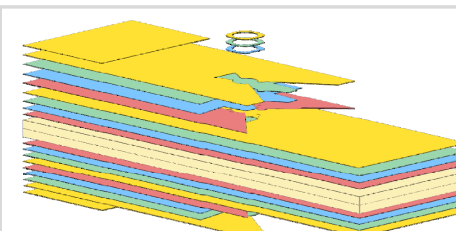
**Web Apps for MSC Nastran SOL 200**  
Pre/post for MSC Nastran SOL 200.  
Support for size, topology, topometry, topography, multi-model optimization.



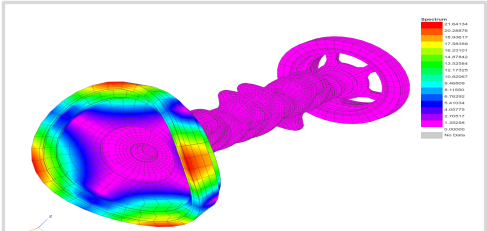
**Machine Learning Web App**  
Bayesian Optimization for nonlinear response optimization (SOL 400)



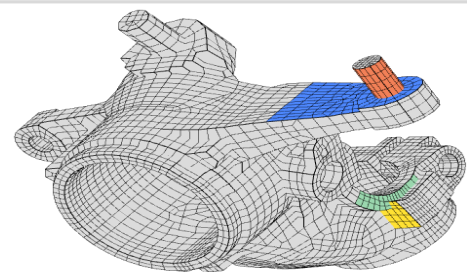
**PBMSECT Web App**  
Generate PBMSECT and PBRSECT entries graphically



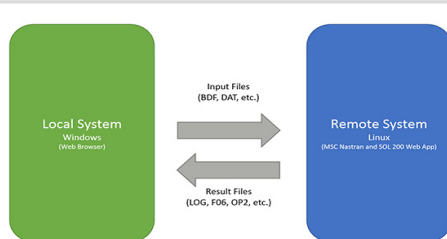
**Ply Shape Optimization Web App**  
Optimize composite ply drop-off locations, and generate new PCOMPG entries



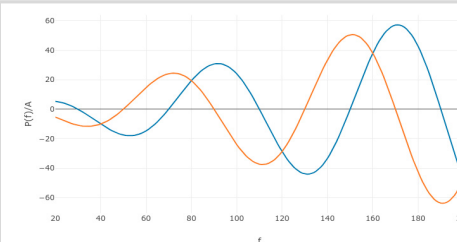
**Post-processor Web App**  
View MSC Nastran results in a web browser on Windows and Linux



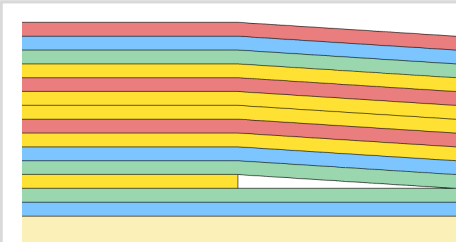
**Shape Optimization Web App**  
Use a web application to configure and perform shape optimization.



**Remote Execution Web App**  
Run MSC Nastran jobs on remote Linux or Windows systems available on the local network



**Dynamic Loads Web App**  
Generate RLOAD1, RLOAD2 and DLOAD entries graphically



**Stacking Sequence Web App**  
Optimize the stacking sequence of composite laminate plies



**HDF5 Explorer Web App**  
Create graphs (XY plots) using data from the H5 file

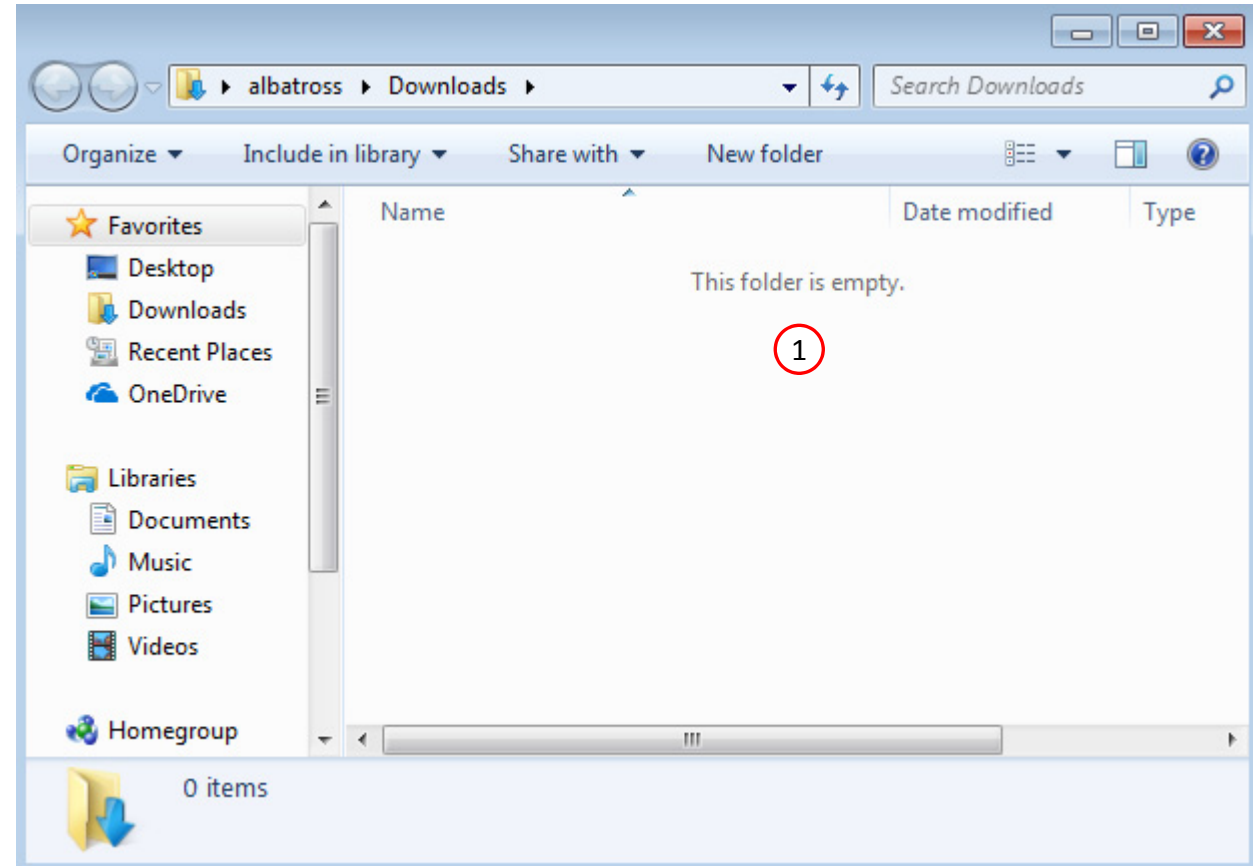
# Part 1 – Core Shape Creation

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# Before Starting

1. Ensure the Downloads directory is empty in order to prevent confusion with other files

- Throughout this workshop, you will be working with multiple file types and directories such as:
  - .bdf/.dat
  - nastran\_working\_directory
  - .f06, .log, .pch, .h5, etc.
- To minimize confusion with files and folders, it is encouraged to start with a clean directory.



# Go to the User's Guide

1. Click on the indicated link

- The necessary BDF files for this tutorial are available in the Tutorials section of the User's Guide.

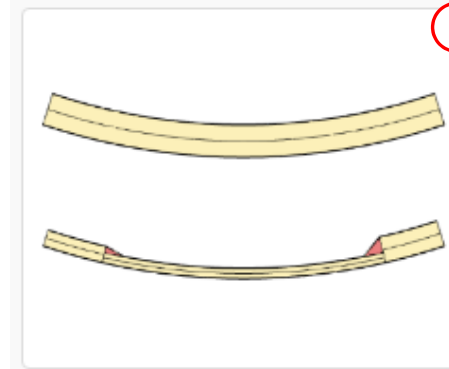




# Obtain Starting Files

1. Find the indicated example
2. Click Link
3. The starting file has been downloaded

- When starting the procedure, all the necessary BDF files must be collected together.



1

## Composite Panel – Phase D – Core Shape and Core Thickness Optimization

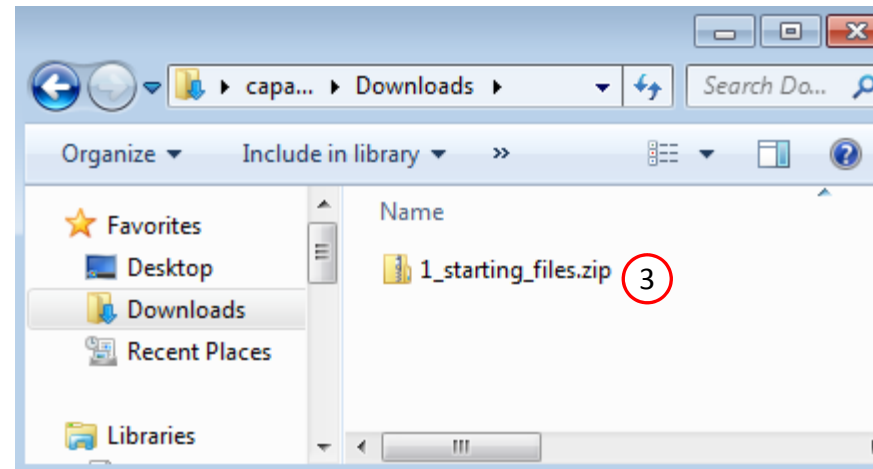
This tutorial details the process to build optimal core shapes and perform a core thickness optimization. The optimal core shapes are constructed to follow the contours of thickness results generated by a topometry optimization. The core thickness optimization involves minimizing weight and constraining the buckling load factor. The PLY000i files and BDF files from the previous tutorial, phase C, are used in this tutorial. Comparisons are made between this optimization in phase D and the baseline optimization performed in phase B.

This is the third phase in a 3-phase tutorial series.

Starting BDF Files: [Link](#)

Solution BDF Files: [Link](#)

2

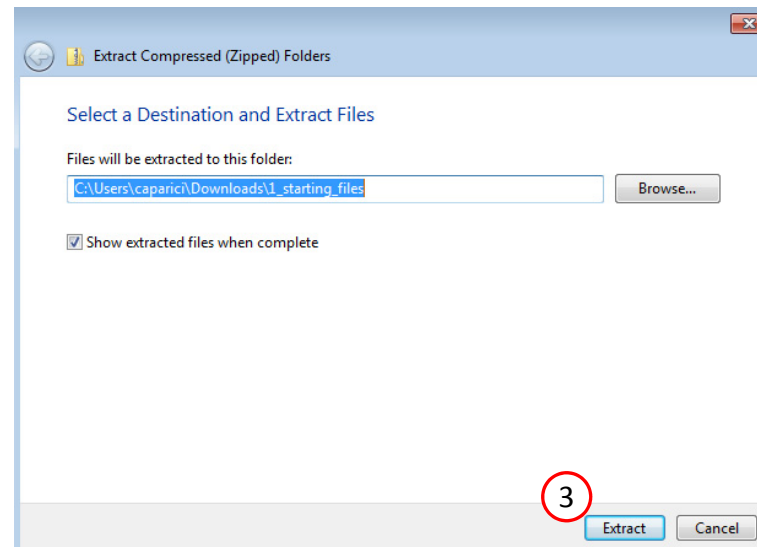
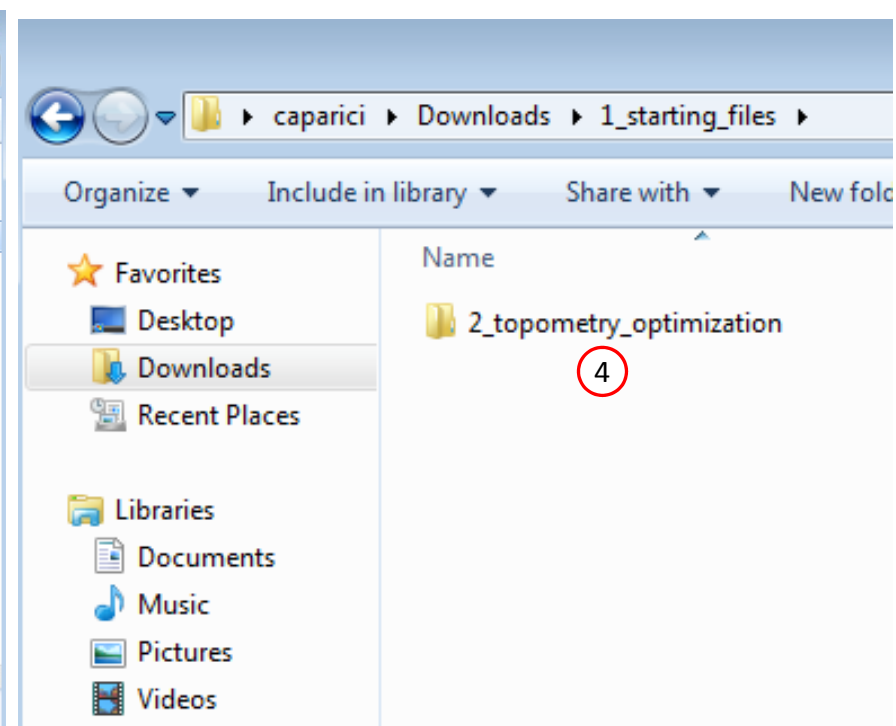
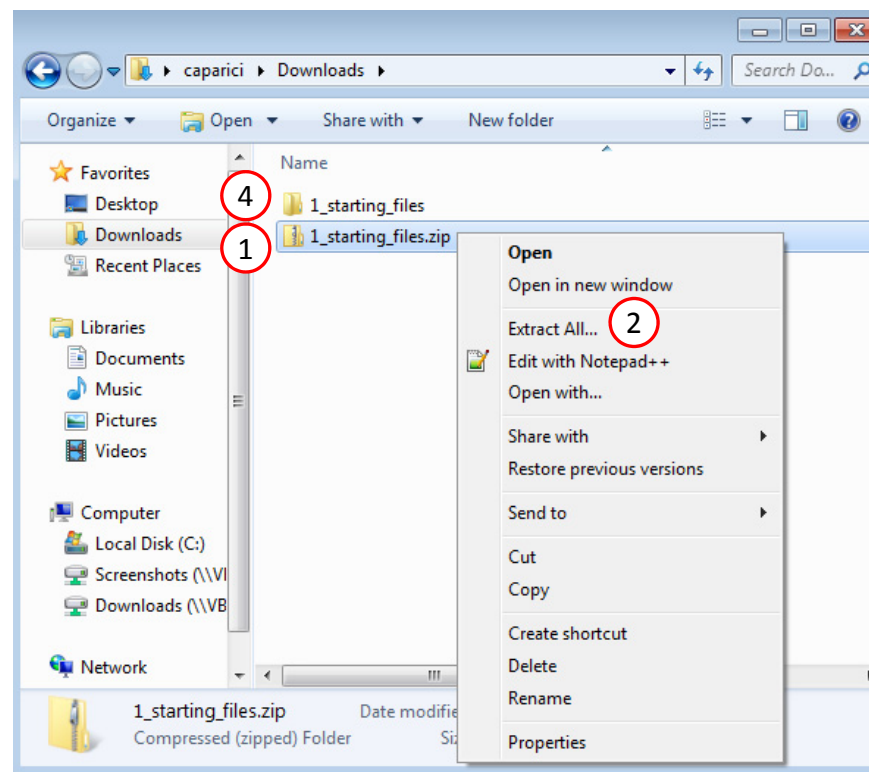


3

# Obtain Starting Files

1. Right click on the zip file
2. Select Extract All...
3. Click Extract
4. The starting files are now available in a folder

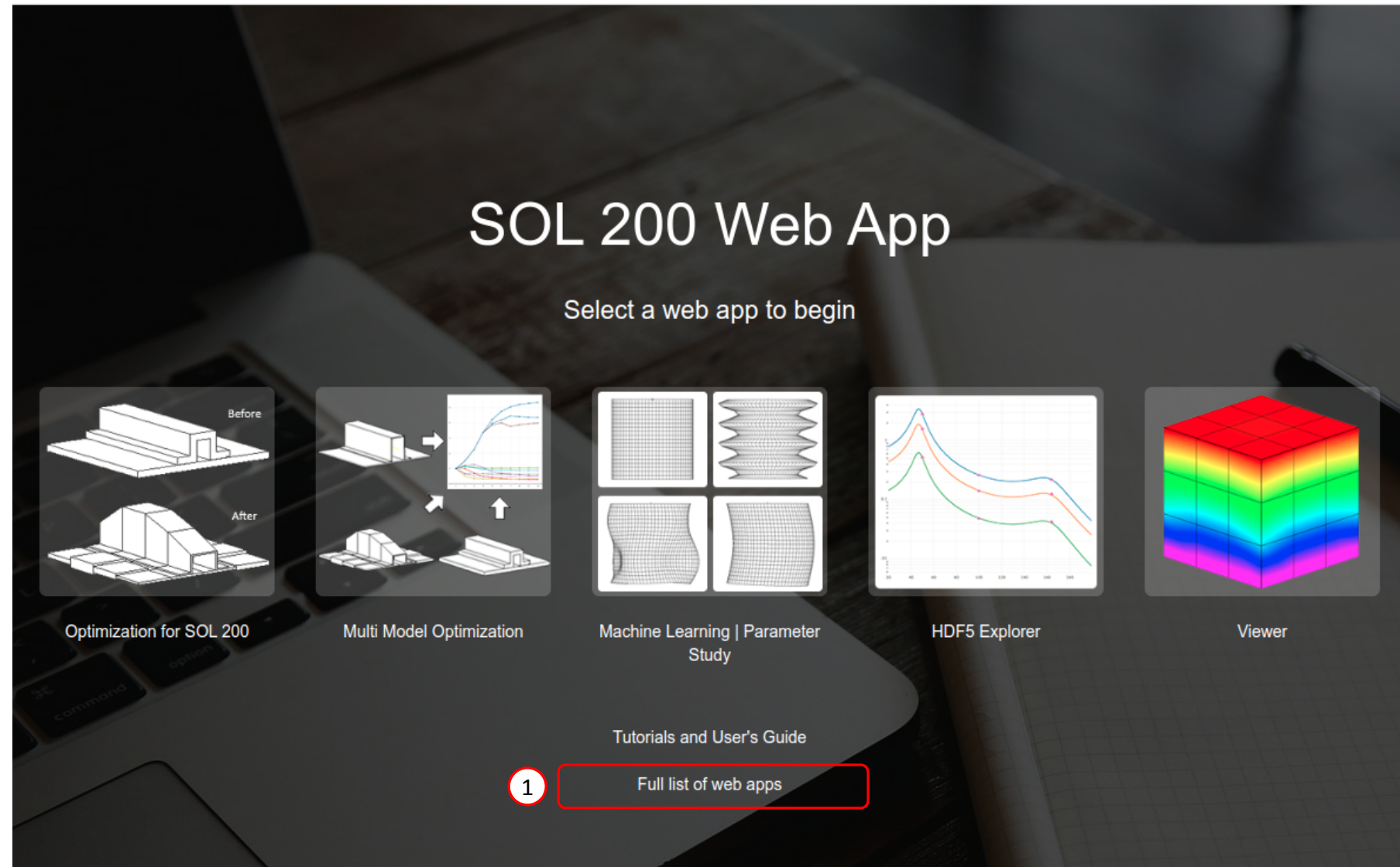
- This example is using a previously created design model. The design model is a model that has been converted to SOL 200 and contains bulk data entries describing the optimization problem statement, e.g. variables, objective and constraints.



# Open the Correct Page

1. Click on the indicated link

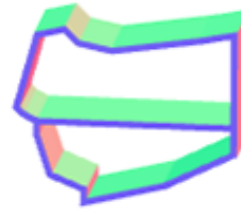
- MSC Nastran can perform many optimization types. The SOL 200 Web App includes dedicated web apps for the following:
  - Optimization for SOL 200 (Size, Topology, Topometry, Topography, Local Optimization, Sensitivity Analysis and Global Optimization)
  - Multi Model Optimization
  - Machine Learning
- The web app also features the HDF5 Explorer, a web application to extract results from the H5 file type.



## Open the Viewer

1. Navigate to the Composites section
2. Click Viewer

## Beams

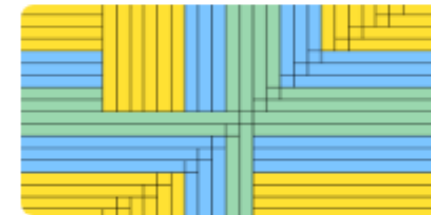


PBMSECT

## ① Composites

Ply	Theta (°)	GPPLY ID
1	45	121001
2	-45	131001
3	0	141001
4	30	111001
5	0	141002
6	90	110004
7	0	141003
8	45	121002
9	-45	131002

Stacking Sequence

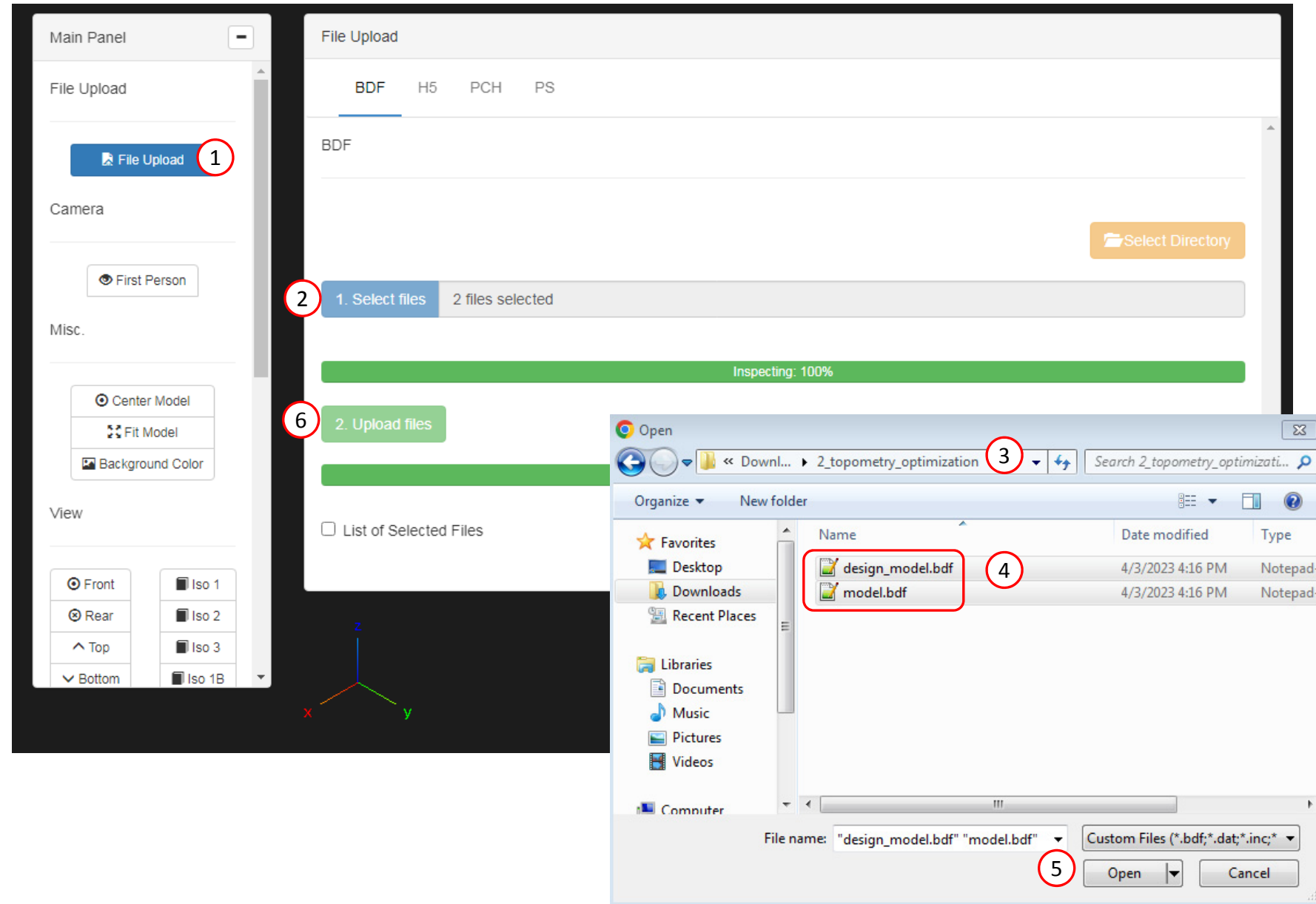


Viewer (.des, .ply000i)

②

# Import BDF Files

1. Click File Upload
2. Click Select files
3. Navigate to directory  
2\_topometry\_optimization
4. Select the indicated files
5. Click Open
6. Click Upload files



# Import PLY000i Files

1. Click Topometry
2. Click Select files
3. Navigate to directory 3\_manual\_ply000i\_files
4. Select the indicated files
5. Click Open
6. Click Upload files

The screenshot displays the Topometry software interface. On the left, the Main Panel shows navigation controls (Bottom, Left, Right, Rotate) and tool options (Model Display Panel, FEM Label, Post-processor, Optimization). The Topometry section on the right features tabs for 'Upload Ply000i Files', 'Select a PCOMP', 'Ply Shapes', 'New Entries', and 'Download'. The 'Upload Ply000i Files' tab is active, showing a progress bar for 'model.ply0005' and a green bar indicating 'Uploading: 100 % Success!'. A file explorer window is overlaid on the bottom right, showing the file 'model.ply0005' selected in the '2\_topometry\_optimization' directory. The file explorer window has a search bar, a list of files, and a file name field. The file name field contains 'model.ply0005' and the file type is set to 'Custom Files (\*.ply0000;\*.ply000i)'. The 'Open' button is highlighted.

# Create Ply Shape Candidates

1. Click Ply Shapes
2. Click the plus (icon) 3 times to create 3 ply shape candidates
3. Move the 3 sliders to values in the range between 2.3 and 3.0, e.g. 2.5222 and 2.34

Topometry

Upload Ply000i Files   Select a PCOMP   **Ply Shapes**   New Entries   Download



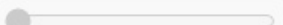
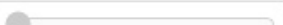
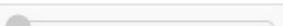


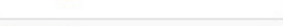

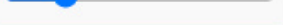

**1**

View PCOMPG Zones

Ply Shape Candidates - PCOMP 1

Clean Ply Shape

+ Options

Display Ply Shape	Include in PCOMPGs	GPLY ID	Ply	Candidate	Dependent On Ply	Theta	Action	Threshold Slider	Threshold	Pick Mode	Number of Elements
<input type="checkbox"/>	<input checked="" type="checkbox"/>	111000	1	1		90°	<input type="button" value="+"/>		0		640
<input type="checkbox"/>	<input checked="" type="checkbox"/>	121000	2	1		45°	<input type="button" value="+"/>		0		640
<input type="checkbox"/>	<input checked="" type="checkbox"/>	131000	3	1	2	-45°	<input type="button" value="+"/>		0		640
<input type="checkbox"/>	<input checked="" type="checkbox"/>	141000	4	1		0°	<input type="button" value="+"/>		0		640
<input type="checkbox"/>	<input checked="" type="checkbox"/>	151000	5	1		0°	<input type="button" value="+"/>		0		640
<input type="checkbox"/>	<input checked="" type="checkbox"/>	152000	5	2		0°	<input type="button" value="x"/>		2.5222414		153
<input type="checkbox"/>	<input checked="" type="checkbox"/>	153000	5	3		0°	<input type="button" value="x"/>		2.3420813		158
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	154000	5	4		0°	<input type="button" value="x"/>		2.3420813		158

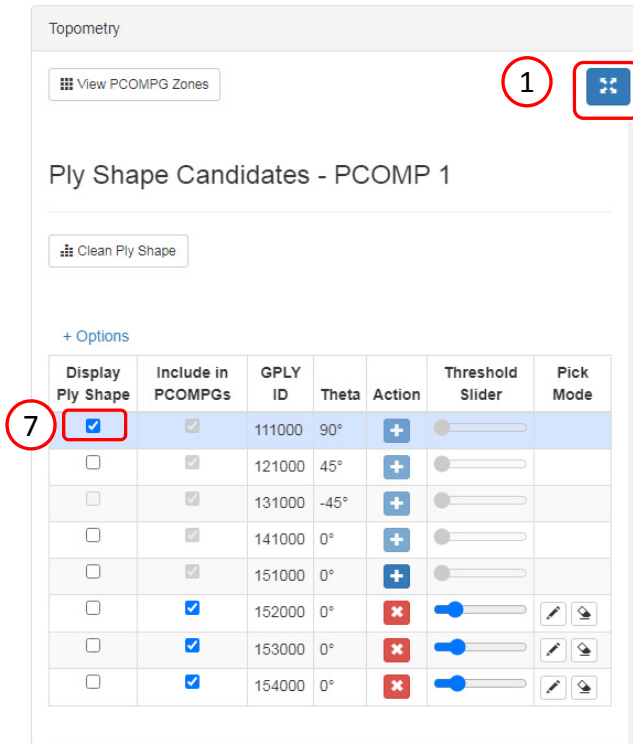
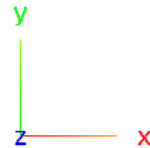
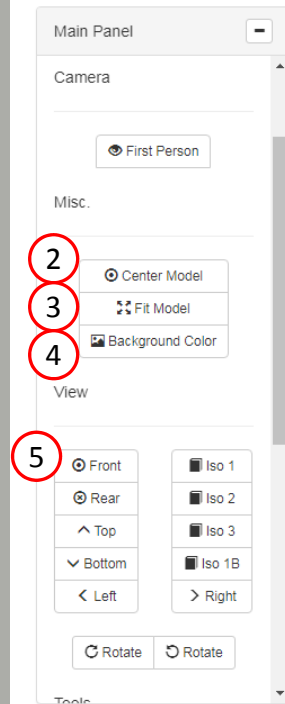
**2**

**3**



# Position the Model

1. Click the indicated icon to minimize the width of the panel
2. Click Center Model
3. Click Fit Model
4. Click Background Color
5. Click Front
6. Use the mouse scroll wheel to zoom out, and press and hold the right mouse button, and drag the mouse left ward to drag the model into view.
7. Mark the indicated checkbox to display the first ply shape



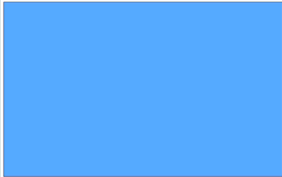
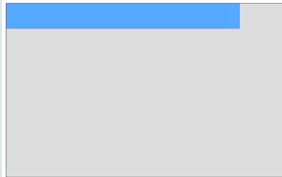
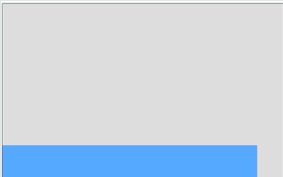
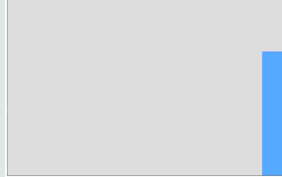


# Ply Shape Candidates Creation

1. The indicated ply shape candidates will be created

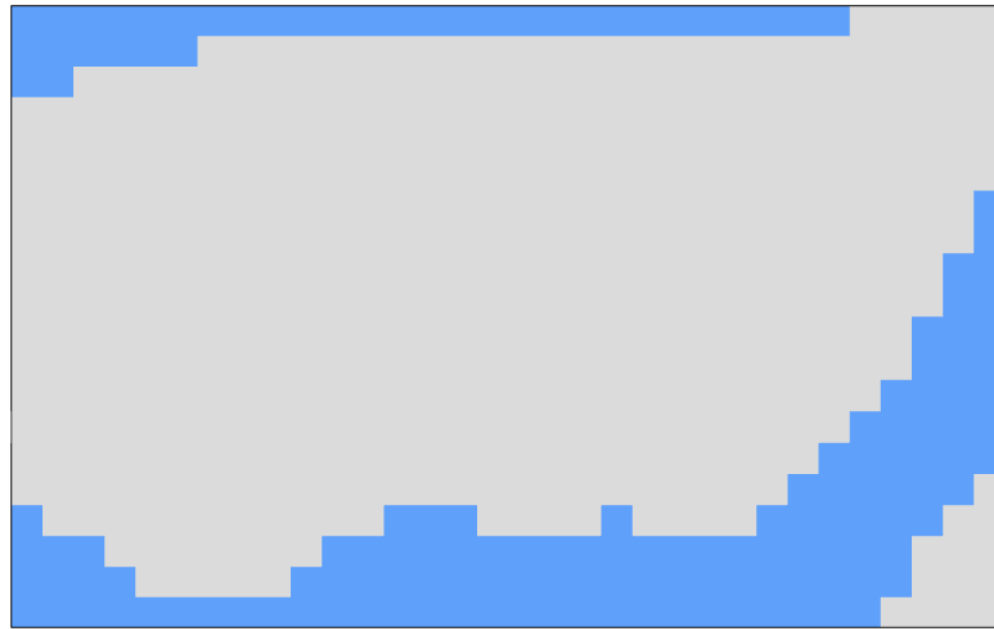
1

Ply Shape

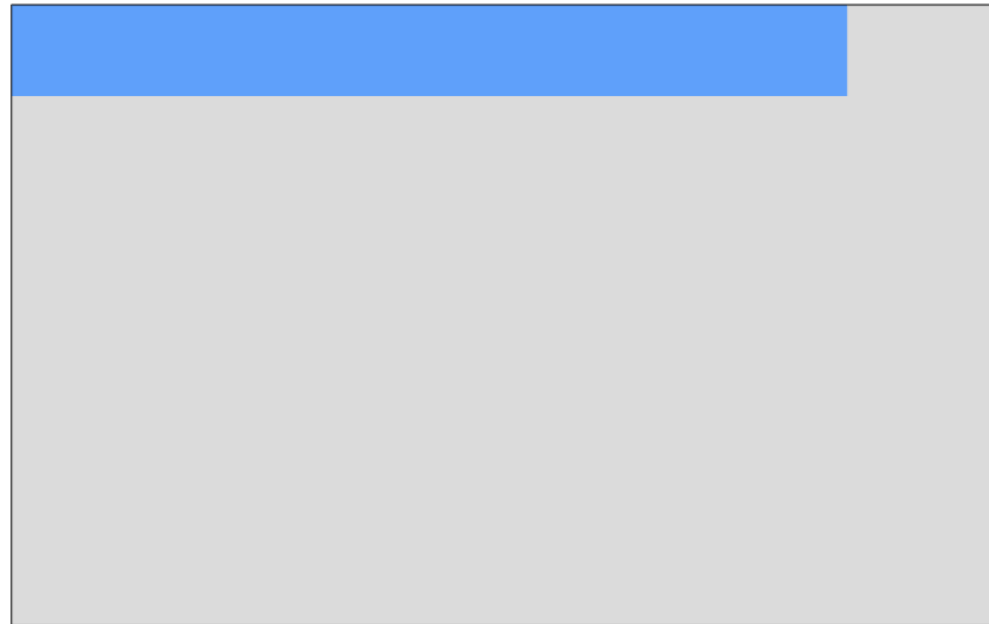
Layer, Theta	Ply Shape Candidate 1 (Not used)	Ply Shape Candidate 2	Ply Shape Candidate 3	Ply Shape Candidate 4	Ply Shape Candidate 5
5  0° (Core)	151000, 2151000 	152000, 2152000 	153000, 2153000 	154000, 2154000 	185000, 2185000

# Ply Shape Editing: Candidate 2 for 0° (Core)

Before



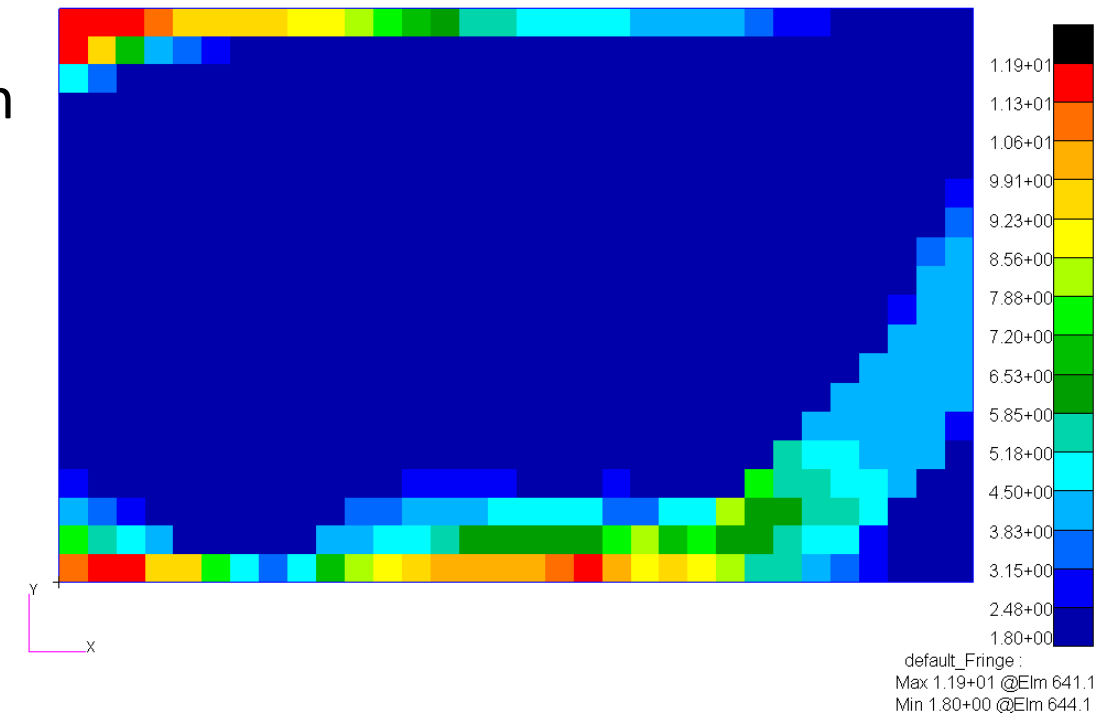
After



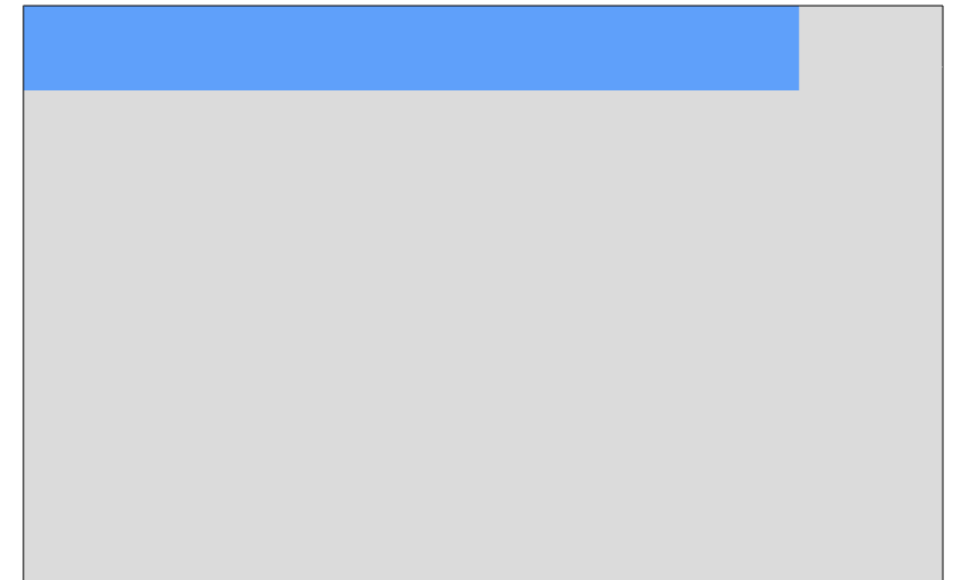
## Ply Shape Editing: Candidate 2 for 0° (Core)

- The ply shape candidate takes a form that aligns with the contour of thickness results from a topometry optimization

## Thickness Results From Topometry Optimization

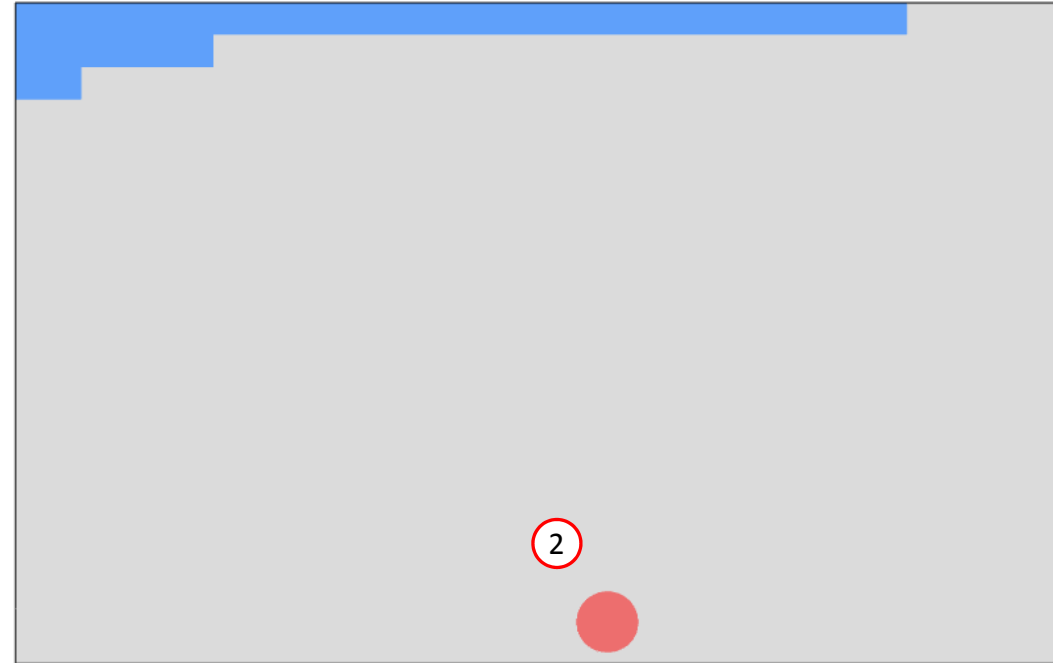


## Ply Shape Candidate 2

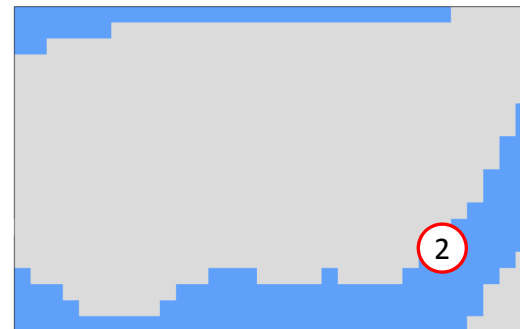


# Ply Shape Editing: Candidate 2 for 0° (Core)

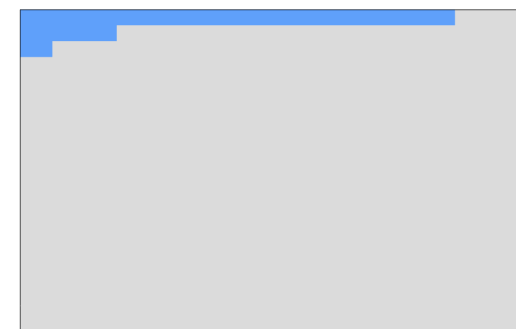
1. Click the indicated icon
2. A red sphere appears. Press and hold the left mouse button, and drag the sphere to remove the ply from the indicated region.



Before



After



Topometry

View PCOMPG Zones

Pick mode on. Model rotation disabled. Click to exit pick mode.

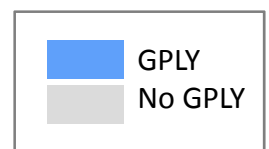
Ply Shape Candidates - PCOMP 1

Clean Ply Shape

Picking Sphere Radius (Real World Units)  
11.9838

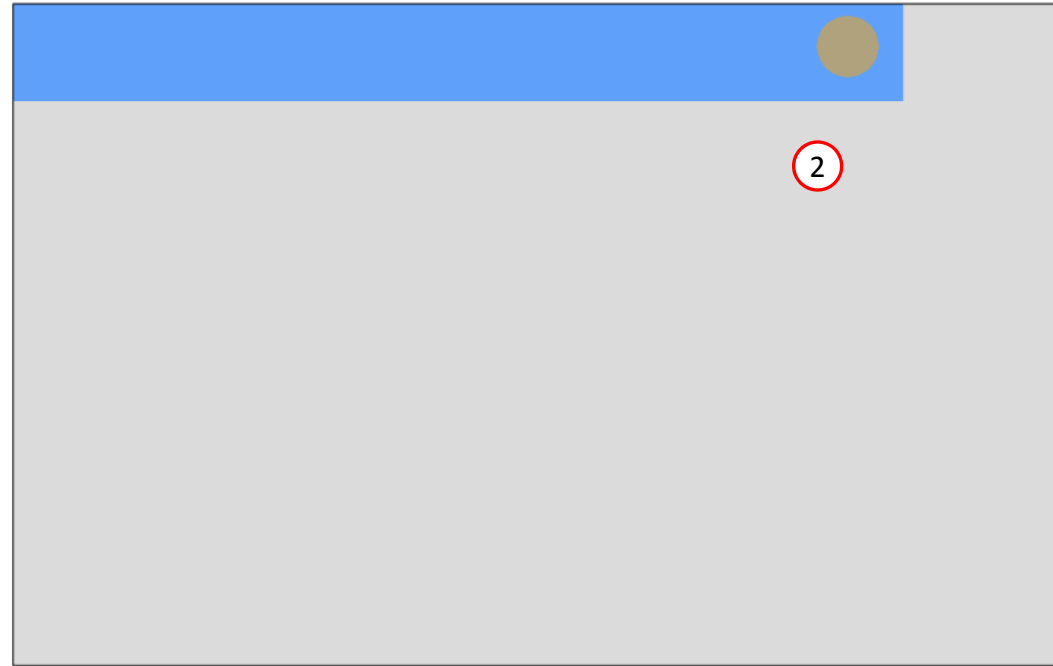
+ Options

Display Ply Shape	Include in PCOMPGs	GPLY ID	Theta	Action	Threshold Slider	Pick Mode
<input type="checkbox"/>	<input checked="" type="checkbox"/>	111000	90°	+	<div></div>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	121000	45°	+	<div></div>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	131000	-45°	+	<div></div>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	141000	0°	+	<div></div>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	151000	0°	+	<div></div>	
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	152000	0°	×	<div></div>	<div></div>
<input type="checkbox"/>	<input checked="" type="checkbox"/>	153000	0°	×	<div></div>	<div></div>
<input type="checkbox"/>	<input checked="" type="checkbox"/>	154000	0°	×	<div></div>	<div></div>

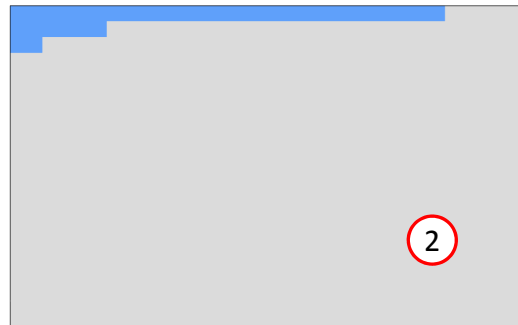


# Ply Shape Editing: Candidate 2 for 0° (Core)

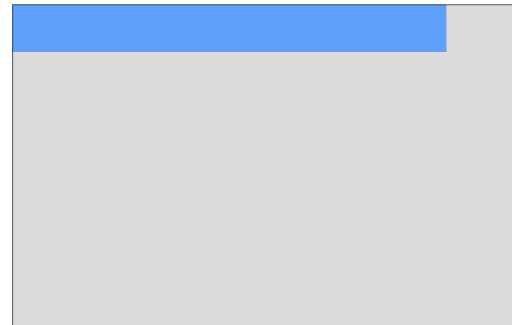
1. Click the indicated icon
2. A yellow sphere appears. Press and hold the left mouse button, and drag the sphere to add the ply from the indicated region.



Before



After



Topometry

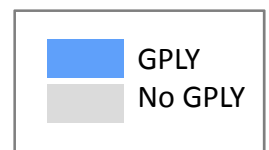
View PCOMPG Zones
Pick mode on. Model rotation disabled. Click to exit pick mode.

Ply Shape Candidates - PCOMP 1

Clean Ply Shape
Picking Sphere Radius (Real World Units)  
11.9838

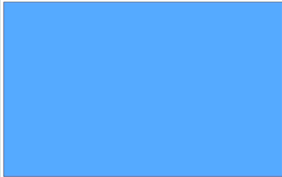
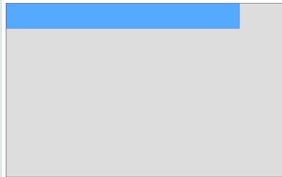
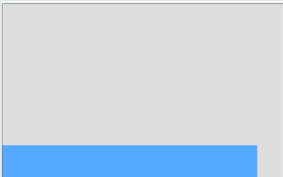
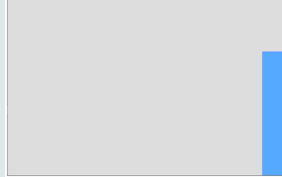
+ Options

Display Ply Shape	Include in PCOMPGs	GPLY ID	Theta	Action	Threshold Slider	Pick Mode
<input type="checkbox"/>	<input checked="" type="checkbox"/>	111000	90°	+	<input type="range"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	121000	45°	+	<input type="range"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	131000	-45°	+	<input type="range"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	141000	0°	+	<input type="range"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	151000	0°	+	<input type="range"/>	
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	152000	0°	×	<input type="range"/>	<input checked="" type="checkbox"/>
<input type="checkbox"/>	<input checked="" type="checkbox"/>	153000	0°	×	<input type="range"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input checked="" type="checkbox"/>	154000	0°	×	<input type="range"/>	<input type="checkbox"/>



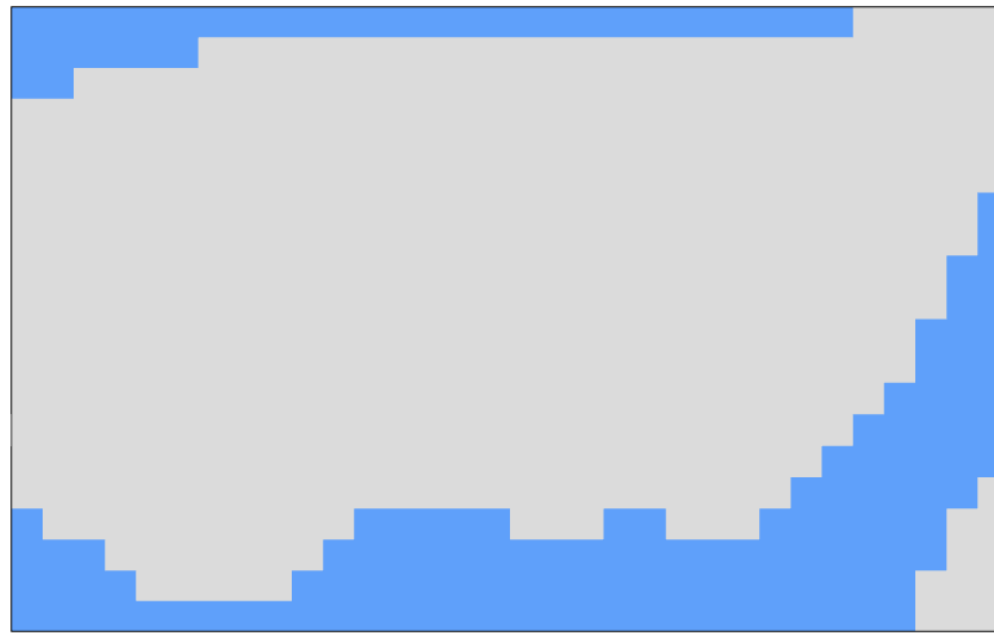
# Ply Shape Candidates Creation

1. The indicated ply shape candidates will be created

Layer, Theta	Ply Shape Candidate 1 (Not used)	Ply Shape Candidate 2	1		
			Ply Shape Candidate 3	Ply Shape Candidate 4	Ply Shape Candidate 5
5  0° (Core)	151000, 2151000 	152000, 2152000 	153000, 2153000 	154000, 2154000 	185000, 2185000

Ply Shape Editing:  
Candidate 3 for 0°  
(Core)

Before



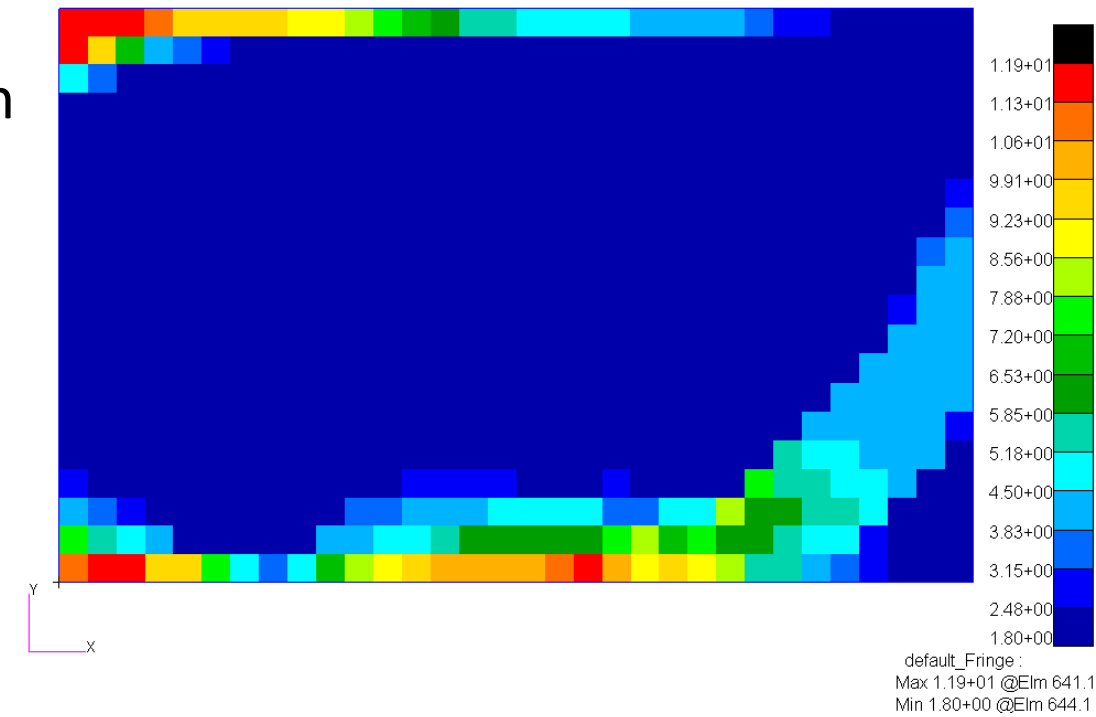
After



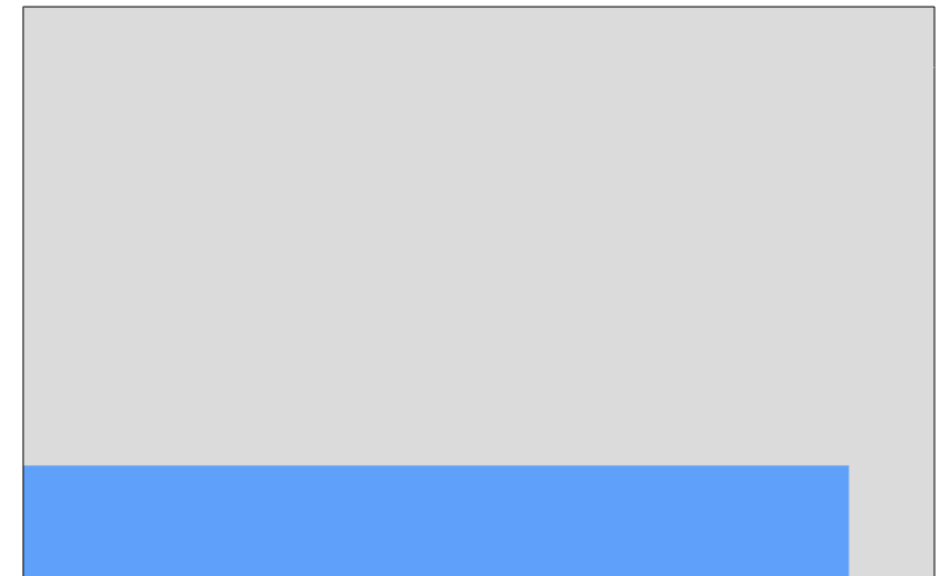
## Ply Shape Editing: Candidate 3 for 0° (Core)

- The ply shape candidate takes a form that aligns with the contour of thickness results from a topometry optimization

## Thickness Results From Topometry Optimization



## Ply Shape Candidate 3



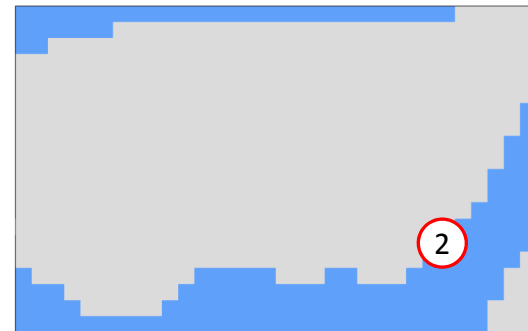


# Ply Shape Editing: Candidate 3 for 0° (Core)

1. Click the indicated icon
2. A red sphere appears. Press and hold the left mouse button, and drag the sphere to remove the ply from the indicated region.



Before



After



Topometry

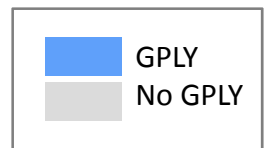
View PCOMP Zones
Pick mode on. Model rotation disabled. Click to exit pick mode.

Ply Shape Candidates - PCOMP 1

Clean Ply Shape
Picking Sphere Radius (Real World Units)
11.9838

+ Options

Display Ply Shape	Include in PCOMPs	GPLY ID	Theta	Action	Threshold Slider	Pick Mode
<input type="checkbox"/>	<input checked="" type="checkbox"/>	111000	90°	+	<input type="range"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	121000	45°	+	<input type="range"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	131000	-45°	+	<input type="range"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	141000	0°	+	<input type="range"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	151000	0°	+	<input type="range"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	152000	0°	×	<input type="range"/>	
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	153000	0°	×	<input type="range"/>	<input checked="" type="checkbox"/>
<input type="checkbox"/>	<input checked="" type="checkbox"/>	154000	0°	×	<input type="range"/>	

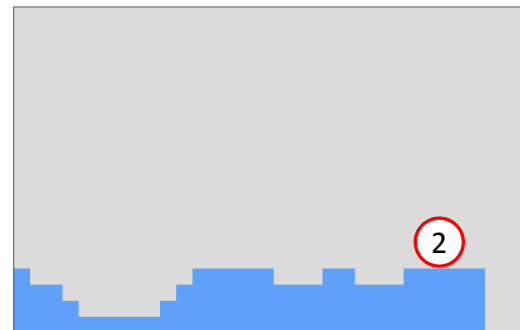


# Ply Shape Editing: Candidate 3 for 0° (Core)

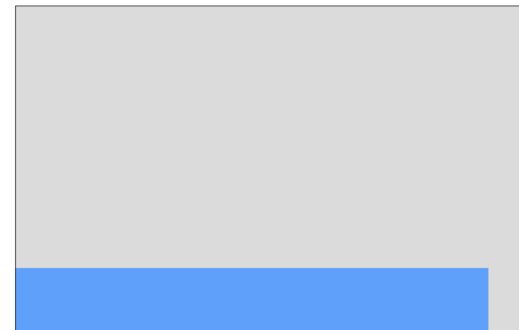
1. Click the indicated icon
2. A yellow sphere appears. Press and hold the left mouse button, and drag the sphere to add the ply from the indicated region.



Before



After



Topometry

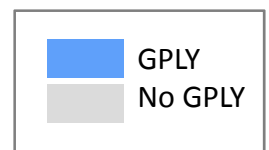
View PCOMP Zones
Pick mode on. Model rotation disabled. Click to exit pick mode.

Ply Shape Candidates - PCOMP 1

Clean Ply Shape
Picking Sphere Radius (Real World Units)
11.9838

+ Options

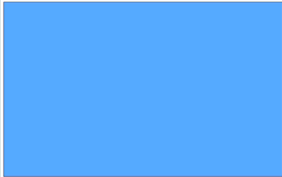
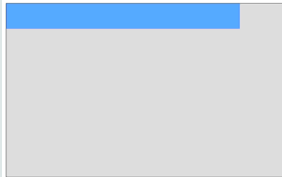
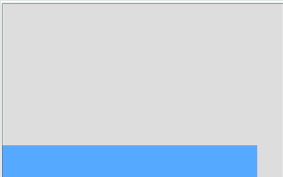
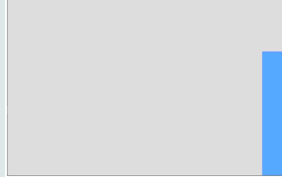
Display Ply Shape	Include in PCOMPGs	GPLY ID	Theta	Action	Threshold Slider	Pick Mode
<input type="checkbox"/>	<input checked="" type="checkbox"/>	111000	90°	+	<input type="range"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	121000	45°	+	<input type="range"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	131000	-45°	+	<input type="range"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	141000	0°	+	<input type="range"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	151000	0°	+	<input type="range"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	152000	0°	x	<input type="range"/>	
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	153000	0°	x	<input type="range"/>	<input checked="" type="checkbox"/>
<input type="checkbox"/>	<input checked="" type="checkbox"/>	154000	0°	x	<input type="range"/>	



# Ply Shape Candidates Creation

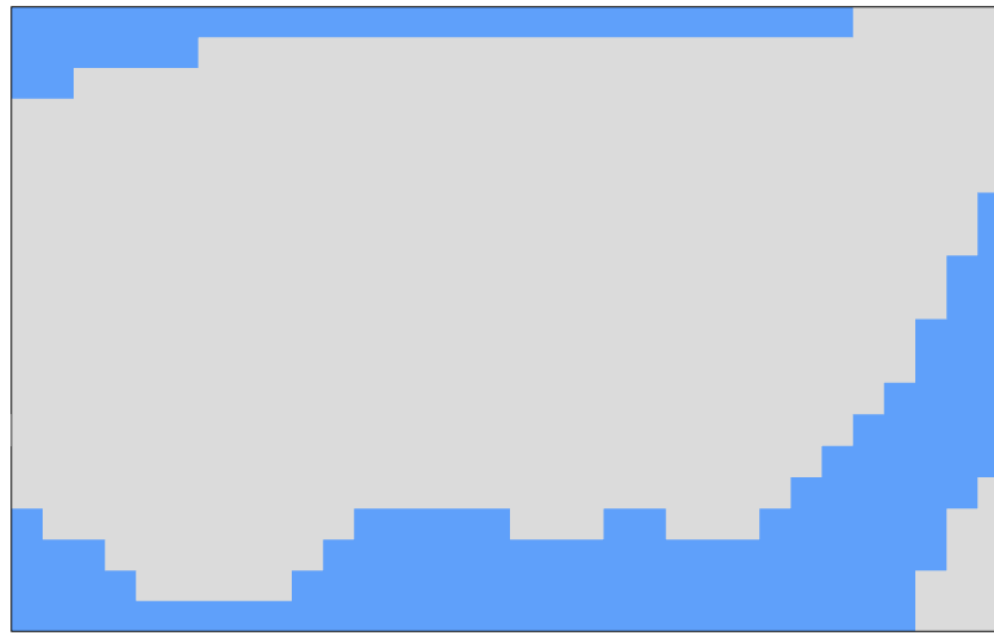
1. The indicated ply shape candidates will be created

1
 Ply Shape

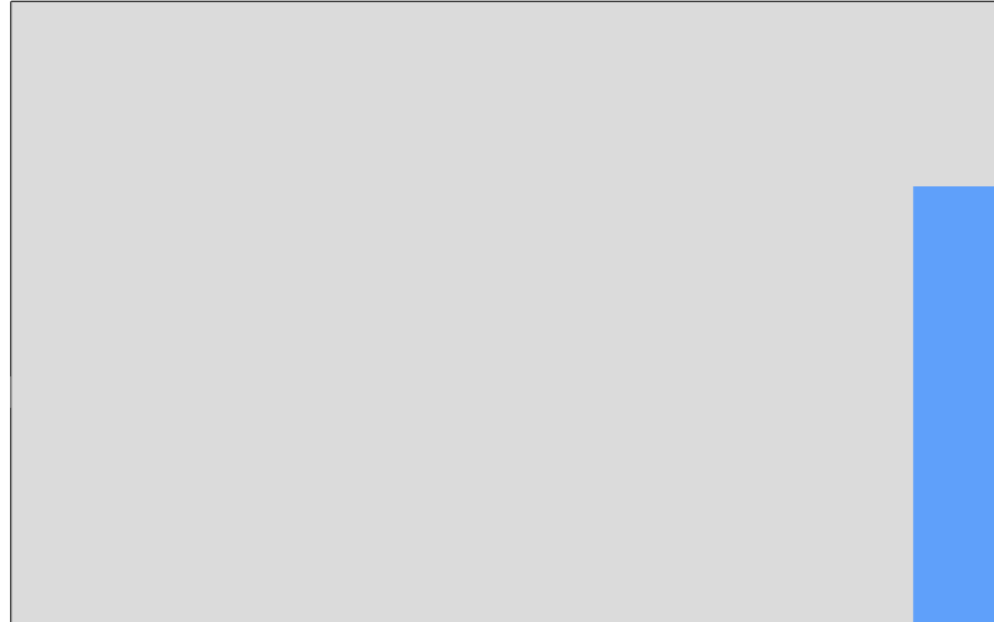
Layer, Theta	Ply Shape Candidate 1 (Not used)	Ply Shape Candidate 2	Ply Shape Candidate 3	Ply Shape Candidate 4	Ply Shape Candidate 5
5  0° (Core)	151000, 2151000  	152000, 2152000  	153000, 2153000  	154000, 2154000  	185000, 2185000

Ply Shape Editing:  
Candidate 4 for 0°  
(Core)

Before



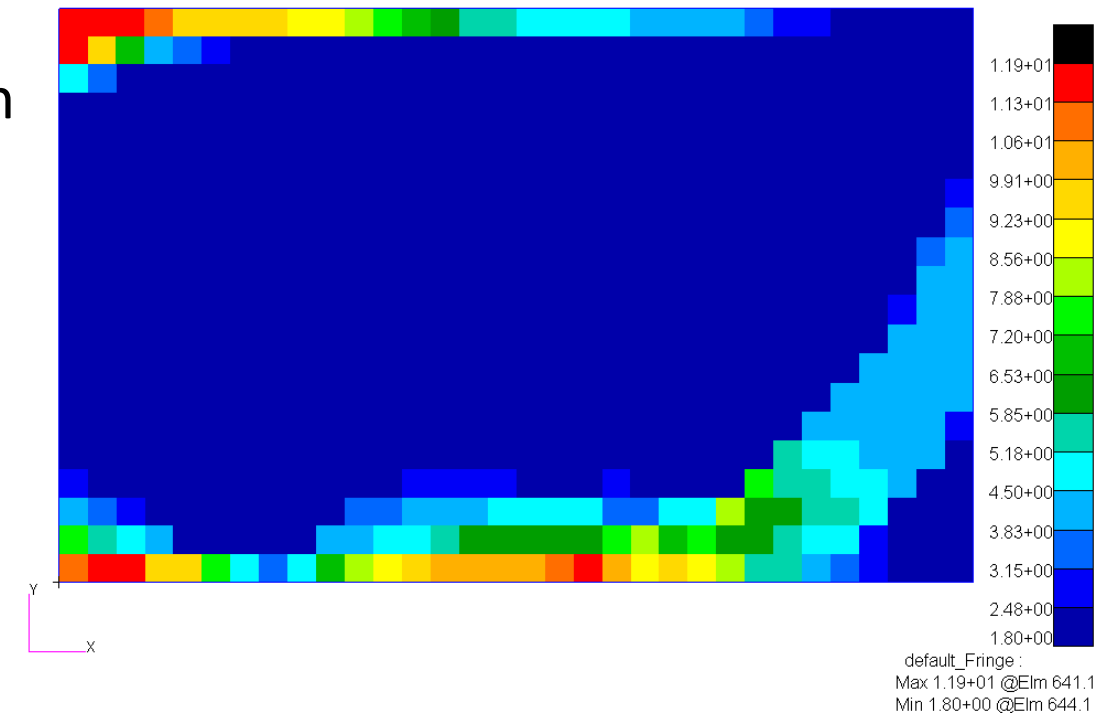
After



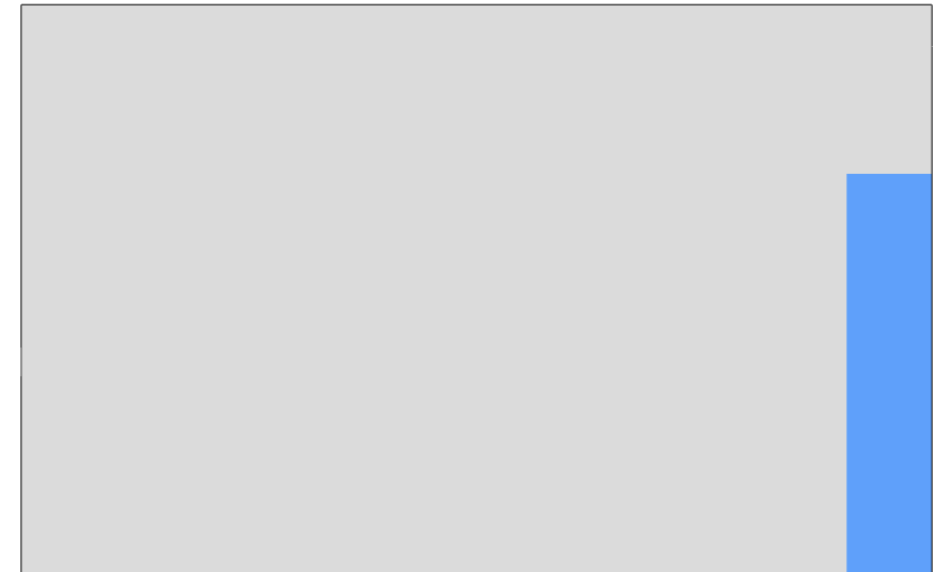
## Ply Shape Editing: Candidate 4 for 0° (Core)

- The ply shape candidate takes a form that aligns with the contour of thickness results from a topometry optimization

## Thickness Results From Topometry Optimization

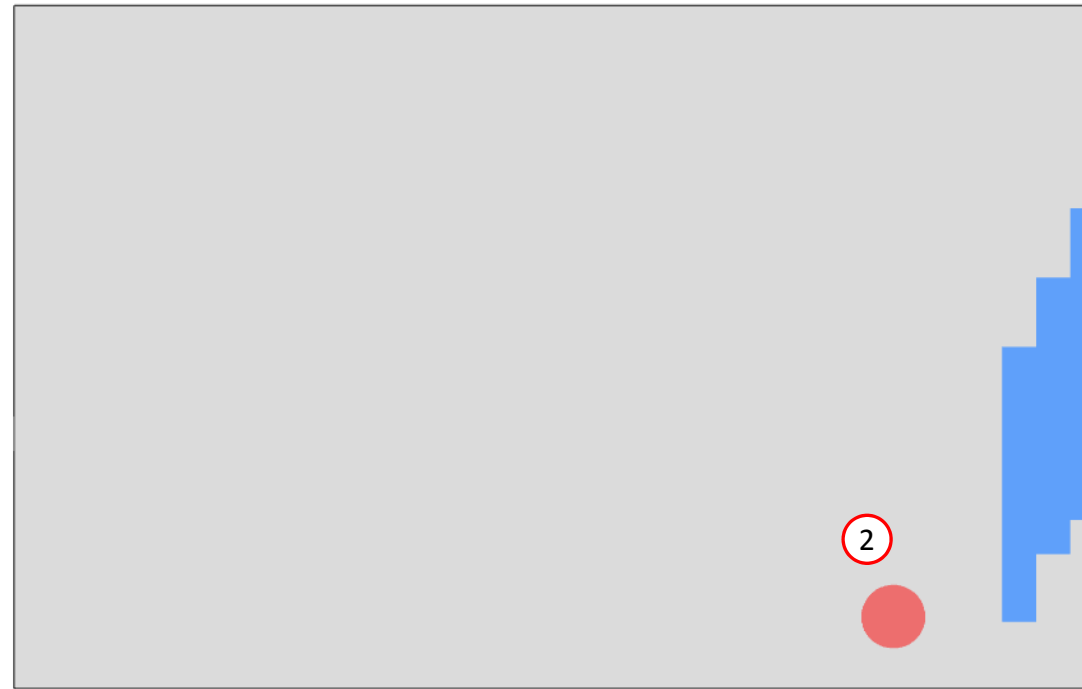


## Ply Shape Candidate 4

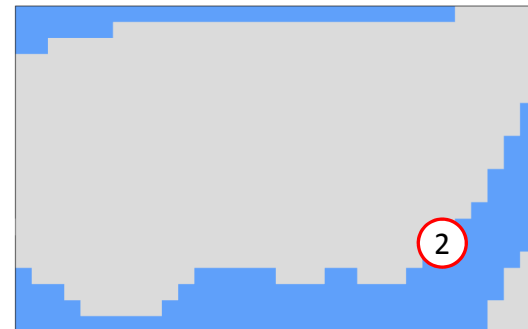


# Ply Shape Editing: Candidate 4 for 0° (Core)

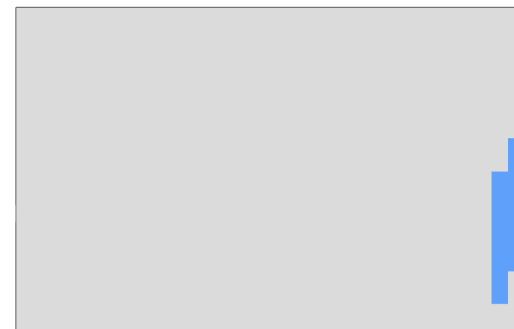
1. Click the indicated icon
2. A red sphere appears. Press and hold the left mouse button, and drag the sphere to remove the ply from the indicated region.



Before



After



Topometry

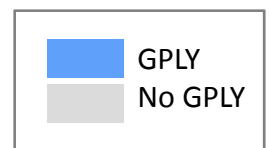
View PCOMP Zones
Pick mode on. Model rotation disabled. Click to exit pick mode.

Ply Shape Candidates - PCOMP 1

Clean Ply Shape
Picking Sphere Radius (Real World Units)
11.9838

+ Options

Display Ply Shape	Include in PCOMPs	GPLY ID	Theta	Action	Threshold Slider	Pick Mode
<input type="checkbox"/>	<input checked="" type="checkbox"/>	111000	90°	+	<input type="range"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	121000	45°	+	<input type="range"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	131000	-45°	+	<input type="range"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	141000	0°	+	<input type="range"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	151000	0°	+	<input type="range"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	152000	0°	×	<input type="range"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input checked="" type="checkbox"/>	153000	0°	×	<input type="range"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	154000	0°	×	<input type="range"/>	<input checked="" type="checkbox"/>

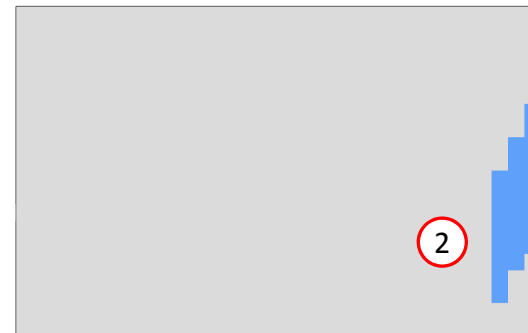


# Ply Shape Editing: Candidate 4 for 0° (Core)

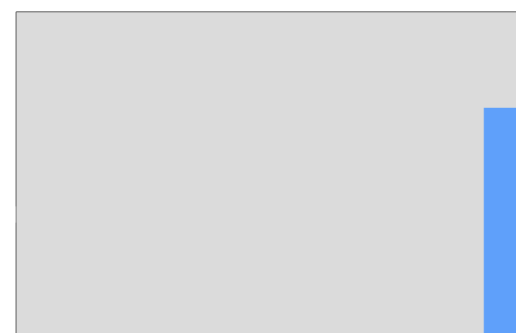
1. Click the indicated icon
2. A yellow sphere appears. Press and hold the left mouse button, and drag the sphere to add the ply from the indicated region.



Before



After



Topometry

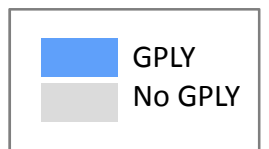
View PCOMPG Zones
Pick mode on. Model rotation disabled. Click to exit pick mode.

Ply Shape Candidates - PCOMP 1

Clean Ply Shape
Picking Sphere Radius (Real World Units)
11.9838

+ Options





Display Ply Shape	Include in PCOMPGs	GPLY ID	Theta	Action	Threshold Slider	Pick Mode
<input type="checkbox"/>	<input checked="" type="checkbox"/>	111000	90°	+	<input type="range"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	121000	45°	+	<input type="range"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	131000	-45°	+	<input type="range"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	141000	0°	+	<input type="range"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	151000	0°	+	<input type="range"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	152000	0°	×	<input type="range"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	153000	0°	×	<input type="range"/>	
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	154000	0°	×	<input type="range"/>	1







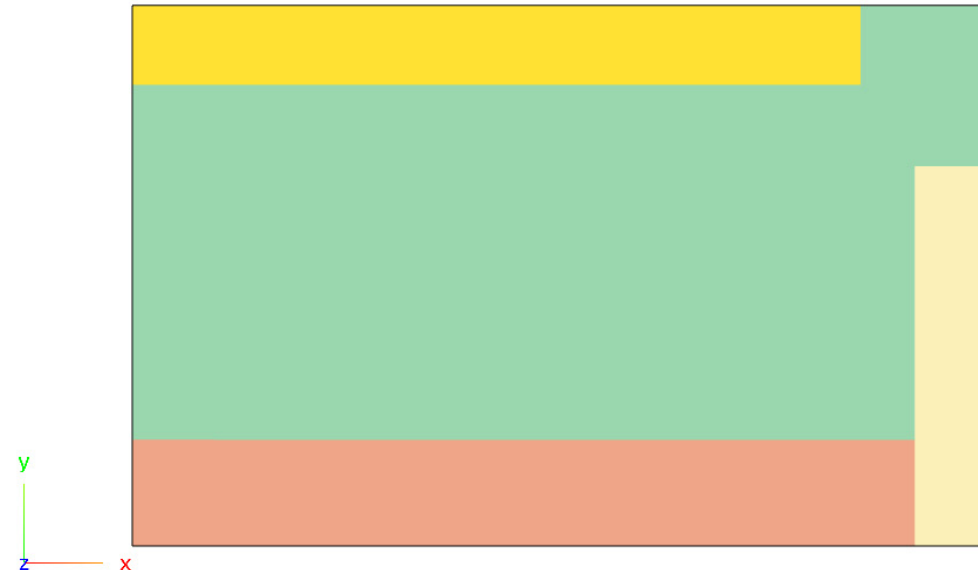
# Ply Shape Consolidation












1. Click View PCOMP Zones
2. Notice the stack has the core layer twice. This is not desired, each zone should have only one core layer.

- Refer to the appendix, section PCOMP Zones, for more information regarding PCOMP zones.

PCOMP ID	Color	Stack
2		[ 90, 45, -45, 0, 0Core2]s
3		[ 90, 45, -45, 0, 0Core]s
4		[ 90, 45, -45, 0, 0Core2]s
5		[ 90, 45, -45, 0, 0Core2]s

PCOMP Zones		
Ply Shape Consolidation		
Legend		
PCOMP ID	Color	Stack
2		[ 90, 45, -45, 0, 0Core2]s
3		[ 90, 45, -45, 0, 0Core]s
4		[ 90, 45, -45, 0, 0Core2]s
5		[ 90, 45, -45, 0, 0Core2]s







Topometry						
View PCOMP Zones						
Clean Ply Shape						
+ Options						
Threshold Slider			Clean Ply Shape			
Slider Step Size			Number of Elements in Isolated Groups to Clean			
0.1801601			10			
Other			Core			
Link Plies			Enable Checkboxes - Include in PCOMP Zones			
			Add Complement Core			
Display Ply Shape	Include in PCOMP Zones	GPLY ID	Theta	Action	Threshold Slider	Pick Mode
<input type="checkbox"/>	<input checked="" type="checkbox"/>	111000	90°	+		
<input type="checkbox"/>	<input checked="" type="checkbox"/>	121000	45°	+		
<input type="checkbox"/>	<input checked="" type="checkbox"/>	131000	-45°	+		
<input type="checkbox"/>	<input checked="" type="checkbox"/>	141000	0°	+		
<input type="checkbox"/>	<input checked="" type="checkbox"/>	151000	0°	+		
<input type="checkbox"/>	<input checked="" type="checkbox"/>	152000	0°	x		
<input type="checkbox"/>	<input checked="" type="checkbox"/>	153000	0°	x		
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	154000	0°	x		







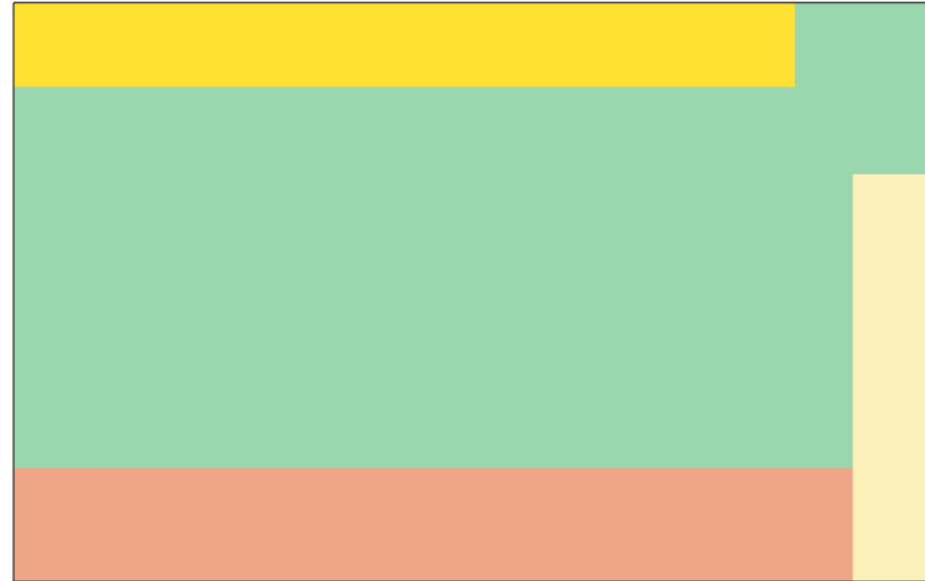
# Ply Shape Consolidation

1. Click +Options
2. Click Enable Checkboxes – Included in PCOMPGs
3. Unmark the indicated checkbox for GPLY 151000. This action removes a continuous core layer that spanned the entire model and all PCOMPG zones.
4. Now the zones have at most one core layer
5. The PCOMPG 2 zone no longer has a core layer and will be address in the next page

- Refer to the appendix, section PCOMPG Zones, for more information regarding PCOMPG zones.

PCOMPG ID	Color	Stack	4
2		[ 90, 45, -45, 0, 0Core]s	
3		[ 90, 45, -45, 0]s	
4		[ 90, 45, -45, 0, 0Core]s	
5		[ 90, 45, -45, 0, 0Core]s	

MPG ID	Color	Stack	4
2		[ 90, 45, -45, 0, 0Core]s	
3		[ 90, 45, -45, 0]s	
4		[ 90, 45, -45, 0, 0Core]s	
5		[ 90, 45, -45, 0, 0Core]s	



View PCOMPG Zones

Clean Ply Shape

+ Options 1

Threshold Slider

Slider Step Size

0.1801601

Other

Link Plies

Clean Ply Shape

Number of Elements in Isolated Groups to Clean












10

Core

2

Enable Checkboxes - Include in PCOMPGs





Add Complement Core




Display Ply Shape	Include in PCOMPGs	GPLY ID	Theta	Action	Threshold Slider	Pick Mode
<input type="checkbox"/>	<input checked="" type="checkbox"/>	111000	90°	+		
<input type="checkbox"/>	<input checked="" type="checkbox"/>	121000	45°	+		
<input type="checkbox"/>	<input checked="" type="checkbox"/>	131000	-45°	+		
<input type="checkbox"/>	<input checked="" type="checkbox"/>	141000	0°	+		
<input type="checkbox"/>	<input type="checkbox"/>	151000	0°	+		
<input type="checkbox"/>	<input checked="" type="checkbox"/>	152000	0°	x		
<input type="checkbox"/>	<input checked="" type="checkbox"/>	153000	0°	x		
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	154000	0°	x		

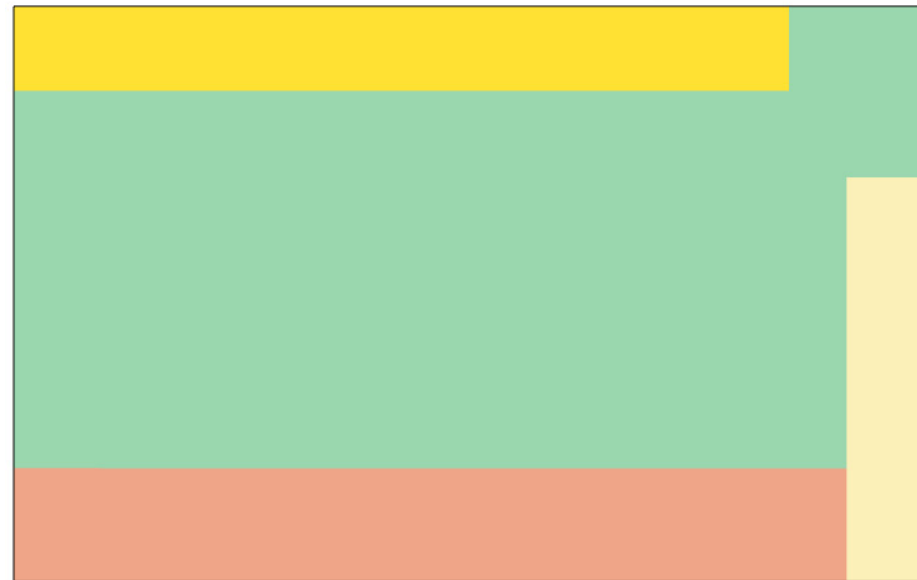
# Ply Shape Consolidation

1. Click Add Complement Core
2. A new core layer has been created that spans only PCOMP 3
3. Now each zone has one core layer

- Refer to the appendix, section PCOMP Zones, for more information regarding PCOMP zones.

PCOMP ID	Color	Stack
2		[ 90, 45, -45, 0, 0Core]s
3		[ 90, 45, -45, 0, 0Core]s
4		[ 90, 45, -45, 0, 0Core]s
5		[ 90, 45, -45, 0, 0Core]s

PCOMP ID	Color	Stack
3		[ 90, 45, -45, 0, 0Core]s
4		[ 90, 45, -45, 0, 0Core]s
5		[ 90, 45, -45, 0, 0Core]s



View PCOMP Zones

Clean Ply Shape

+ Options

Threshold Slider

Slider Step Size

0.1801601

Other

Link Plies

Clean Ply Shape










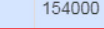

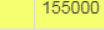

Number of Elements in Isolated Groups to Clean

10

Core

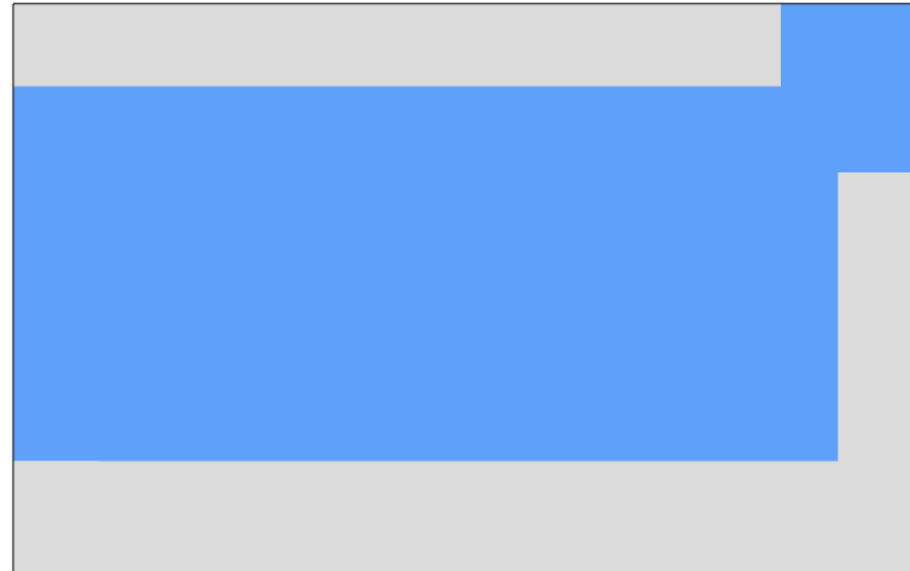
Enable Checkboxes - Include in PCOMP

Add Complement Core

Display Ply Shape	Include in PCOMP	GPLY ID	Theta	Action	Threshold Slider	Pick Mode
<input type="checkbox"/>	<input checked="" type="checkbox"/>	111000	90°	+		
<input type="checkbox"/>	<input checked="" type="checkbox"/>	121000	45°	+		
<input type="checkbox"/>	<input checked="" type="checkbox"/>	131000	-45°	+		
<input type="checkbox"/>	<input checked="" type="checkbox"/>	141000	0°	+		
<input type="checkbox"/>	<input type="checkbox"/>	151000	0°	+		
<input type="checkbox"/>	<input checked="" type="checkbox"/>	152000	0°	x		
<input type="checkbox"/>	<input checked="" type="checkbox"/>	153000	0°	x		
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	154000	0°	x		
<input type="checkbox"/>	<input checked="" type="checkbox"/>	155000	0°	x		

# Ply Shape Consolidation

1. Mark the indicated checkbox. The newest core layer is displayed.



Topometry

View PCOMP Zones

Clean Ply Shape

+ Options

Threshold Slider

Slider Step Size

0.1801601

Clean Ply Shape

Number of Elements in Isolated Groups to Clean

10

Other

Link Plies

Core

Enable Checkboxes - Include in PCOMP

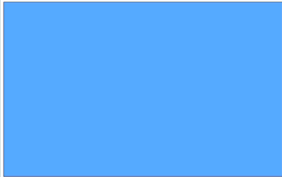
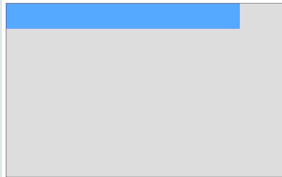
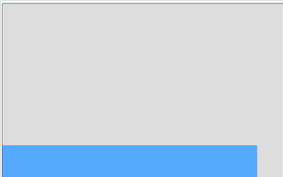
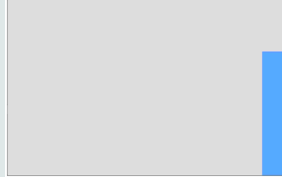
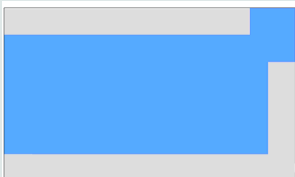
Add Complement Core

Display Ply Shape	Include in PCOMP	GPLY ID	Theta	Action	Threshold Slider	Pick Mode
<input type="checkbox"/>	<input checked="" type="checkbox"/>	111000	90°	+	<input type="range"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	121000	45°	+	<input type="range"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	131000	-45°	+	<input type="range"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	141000	0°	+	<input type="range"/>	
<input type="checkbox"/>	<input type="checkbox"/>	151000	0°	+	<input type="range"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	152000	0°	x	<input type="range"/>	<input type="button" value="edit"/> <input type="button" value="delete"/>
<input type="checkbox"/>	<input checked="" type="checkbox"/>	153000	0°	x	<input type="range"/>	<input type="button" value="edit"/> <input type="button" value="delete"/>
<input type="checkbox"/>	<input checked="" type="checkbox"/>	154000	0°	x	<input type="range"/>	<input type="button" value="edit"/> <input type="button" value="delete"/>
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	155000	0°	x	<input type="range"/>	<input type="button" value="edit"/> <input type="button" value="delete"/>

# Ply Shape Candidates Creation

1. So far, ply shape candidates 2, 3, 4 and 5 have been created

Ply Shape

Layer, Theta	Ply Shape Candidate 1 (Not used)	Ply Shape Candidate 2	Ply Shape Candidate 3	Ply Shape Candidate 4	Ply Shape Candidate 5
5  0° (Core)	151000, 2151000 	152000, 2152000 	153000, 2153000 	154000, 2154000 	185000, 2185000 

# Ply Shape Consolidation

1. If any PCOMPG zones have more than one core layer, this is not desired and the previous steps should be revisited and the created core shapes should be corrected.
2. In this example, a core shape overlaps the adjacent core shape which causes PCOMPG 5 to have 2 core layers. This is not desired and should be corrected.

PCOMPG ID	Color	Stack
2	Yellow	[ 90, 45, -45, 0, 0Core]s
3	Green	[ 90, 45, -45, 0, 0Core]s
4	Orange	[ 90, 45, -45, 0, 0Core]s
5	Light Yellow	[ 90, 45, -45, 0, 0Core2]s
6	Brown	[ 90, 45, -45, 0, 0Core]s

PCOMPG Zones

Ply Shape Consolidation

Legend

PCOMPG ID	Color	Stack
2	Yellow	[ 90, 45, -45, 0, 0Core]s
3	Green	[ 90, 45, -45, 0, 0Core]s
4	Orange	[ 90, 45, -45, 0, 0Core]s
5	Light Yellow	[ 90, 45, -45, 0, 0Core2]s
6	Brown	[ 90, 45, -45, 0, 0Core]s



Topometry

View PCOMPG Zones

Clean Ply Shape

+ Options

Threshold Slider

Clean Ply Shape

Slider Step Size

0.1801601

Number of Elements in Isolated Groups to Clean

10

Other

Core

Link Plies

Enable Checkboxes - Include in PCOMPGs

Add Complement Core

Display Ply Shape	Include in PCOMPGs	GPLY ID	Theta	Action	Threshold Slider	Pick Mode
<input type="checkbox"/>	<input checked="" type="checkbox"/>	111000	90°	+	<input type="range"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	121000	45°	+	<input type="range"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	131000	-45°	+	<input type="range"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	141000	0°	+	<input type="range"/>	
<input type="checkbox"/>	<input type="checkbox"/>	151000	0°	+	<input type="range"/>	
<input type="checkbox"/>	<input checked="" type="checkbox"/>	152000	0°	x	<input type="range"/>	<input type="button" value="edit"/>
<input type="checkbox"/>	<input checked="" type="checkbox"/>	153000	0°	x	<input type="range"/>	<input type="button" value="edit"/>
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	154000	0°	x	<input type="range"/>	<input type="button" value="edit"/>
<input type="checkbox"/>	<input checked="" type="checkbox"/>	155000	0°	x	<input type="range"/>	<input type="button" value="edit"/>

# Confirm Ply Number Optimization Configuration

1. Click View PCOMP Zones to hide the PCOMP Zones window
2. Navigate to section Ply Number Optimization Configuration

Topometry

Upload Ply000i Files

Select a PCOMP

Ply Shapes

New Entries

Download

1 

View PCOMP Zones

2

3 Ply Number Optimization Configuration

$\epsilon_f$  Maximum Ply Strain

$\sigma_f$  Maximum Ply Stress

$FI$  Failure Index

$SR$  Strength Ratio

GPLY ID	Theta	Candidate	Ply Thickness	Initial Number of Plies
111000	90°	1	Thickness of Ply	.01
121000	45°	1	Thickness of Ply	.01
131000	-45°	1	Thickness of Ply	.01
141000	0°	1	Thickness of Ply	.01
152000	0°	2	1.	.01
153000	0°	3	1.	.01
154000	0°	4	1.	.01
155000	0°	5	1.	.01

4

# Consider Additional Optimization Options

- 1. Scroll to section Additional Optimization Options
- 2. Set Z0 Offset Relationship to Above
- 3. Using Above will set Z0=0.0 in the PCOMPG entries.
  - If Below is used, DVPREL2 entries for Z0 are created to impose the correct offset. If blank is used, Z0 is assumed to be -T/2, where T is the total thickness of the composite.

Refer to the appendix for more information about these options.

Topometry

Upload Ply000i Files   Select a PCOMP   **Ply Shapes**   New Entries   Download

View PCOMPG Zones

Additional Optimization Options 1

Z0 Offset Relationship

Above 2

Distance from the reference plane to the bottom surface. The element thickness is the total thickness of all layers.

- Default: -0.5 times the element thickness
- Above: 0.0 times the element thickness
- Below: -1.0 times the element thickness

% Rule Design

Theta [θ]	% Lower Allowed Limit	% Upper Allowed Limit
90°	Lower	Upper
45°	Lower	Upper
-45°	Lower	Upper
0°	Lower	Upper

Total Thickness

Lower Allowed Limit	Upper Allowed Limit
Lower	Upper

\$	1		2		3		4		5		6	
PCOMPG	2		0.0 3				90.				HILL	
	111000		101				.125		90.		YES	
	121000		101				.125		45.		YES	
	131000		101				.125		-45.		YES	
	141000		101				.125		0.		YES	
	152000		501				1.00000		0.		YES	

# Save New Entries

1. Navigate to section Respective PCOMP/PCOMPG Entries
2. The newest entries are displayed. There are approximately 4 new PCOMPG entries (PCOMPG 2-5) and multiple SOL 200 entries (DESVAR, DVPREL1, etc.)
3. Click Save New Entries
4. A checkbox confirm the entries has been saved.

Always be sure to click Save New Entries to commit any changes to the final downloaded BDF files.

Topometry

Upload Ply000i Files

Select a PCOMP

**Ply Shapes**

New Entries

Download

View PCOMPG Zones

1

Respective PCOMP/PCOMPG Entries

Laminate Option

SYM

Ply Number Optimization Checklist

✓ Ply Thickness

✓ Z0 Offset

! % Rule Design

! Total Thickness

! Constraints

3

Save New Entries

4

\$	1	2	3	4	5	6	7	8	9	10
PCOMP	2	0.0		90.		HILL				
	111000	101	.125	90.	YES					
	121000	101	.125	45.	YES					
	131000	101	.125	-45.	YES					
	141000	101	.125	0.	YES					
	152000	501	1.00000	0.	YES					
	2152000	501	1.00000	0.	YES					
	2141000	101	.125	0.	YES	2				
	2131000	101	.125	-45.	YES					
	2121000	101	.125	45.	YES					
	2111000	101	.125	90.	YES					
PCOMP	3	0.0		90.		HILL				
	111000	101	.125	90.	YES					
	121000	101	.125	45.	YES					
	131000	101	.125	-45.	YES					
	141000	101	.125	0.	YES					
	155000	501	1.00000	0.	YES					
	2155000	501	1.00000	0.	YES					
	2141000	101	.125	0.	YES					
	2131000	101	.125	-45.	YES					
	2121000	101	.125	45.	YES					
	2111000	101	.125	90.	YES					
PCOMP	4	0.0		90.		HILL				
	111000	101	.125	90.	YES					
	121000	101	.125	45.	YES					
	131000	101	.125	-45.	YES					



# Save New Entries

1. Click New Entries
2. All the newest bulk data entries are displayed. These entries will be added to the downloaded BDF files.

Topometry

Upload Ply000i Files

Select a PCOMP

Ply Shapes

**New Entries**

Download

1

New Entries

Entries originating from PCOMP 1

×

\$	1	2	3	4	5	6	7	8	9	10
PCOMPG	2	0.0			90.	HILL				
	111000	101	.125	90.	YES					
	121000	101	.125	45.	YES					
	131000	101	.125	-45.	YES					
	141000	101	.125	0.	YES					
	152000	501	1.00000	0.	YES					
	2152000	501	1.00000	0.	YES					
	2141000	101	.125	0.	YES					
	2131000	101	.125	-45.	YES					
	2121000	101	.125	45.	YES					
	2111000	101	.125	90.	YES					
PCOMPG	3	0.0			90.	HILL				
	111000	101	.125	90.	YES					
	121000	101	.125	45.	YES					
	131000	101	.125	-45.	YES					
	141000	101	.125	0.	YES					
	155000	501	1.00000	0.	YES					
	2155000	501	1.00000	0.	YES					
	2141000	101	.125	0.	YES					
	2131000	101	.125	-45.	YES					
	2121000	101	.125	45.	YES					
	2111000	101	.125	90.	YES					
PCOMPG	4	0.0			90.	HILL				
	111000	101	.125	90.	YES					
	121000	101	.125	45.	YES					
	131000	101	.125	-45.	YES					
	141000	101	.125	0.	YES					

# Download

1. Click Download
2. Click Download BDF Files
3. A reminder is displayed. The downloaded BDF files require additional configuration. Click the indicated link to open the Optimization web app.

The screenshot shows the 'Topometry' application window. At the top, there is a navigation bar with five tabs: 'Upload Ply000i Files', 'Select a PCOMP', 'Ply Shapes', 'New Entries', and 'Download'. The 'Download' tab is selected and highlighted with a red circle containing the number '1'. Below the navigation bar, the main area is titled 'Download'. In the center, there is a green button labeled 'Download BDF Files' with a download icon. To the right of this button is a red circle containing the number '2'. Below the button, it says 'Compressing: 100%' and 'Last Item Compressed: design\_pcompgs.bdf'. At the bottom, there is a light green reminder box. It starts with an information icon and the text 'Reminder! Upload the new BDF files to the Optimization web app to and do the following.' The link 'Optimization web app' is highlighted with a red circle containing the number '3'. Below this text are three bullet points: 'Update the objective and constraints', 'Assign constraints to subcases', and 'Inspect design model for any errors'.

Topometry

Upload Ply000i Files   Select a PCOMP   Ply Shapes   New Entries   **Download**

**Download**

**Download BDF Files**   **2**

Compressing: 100%

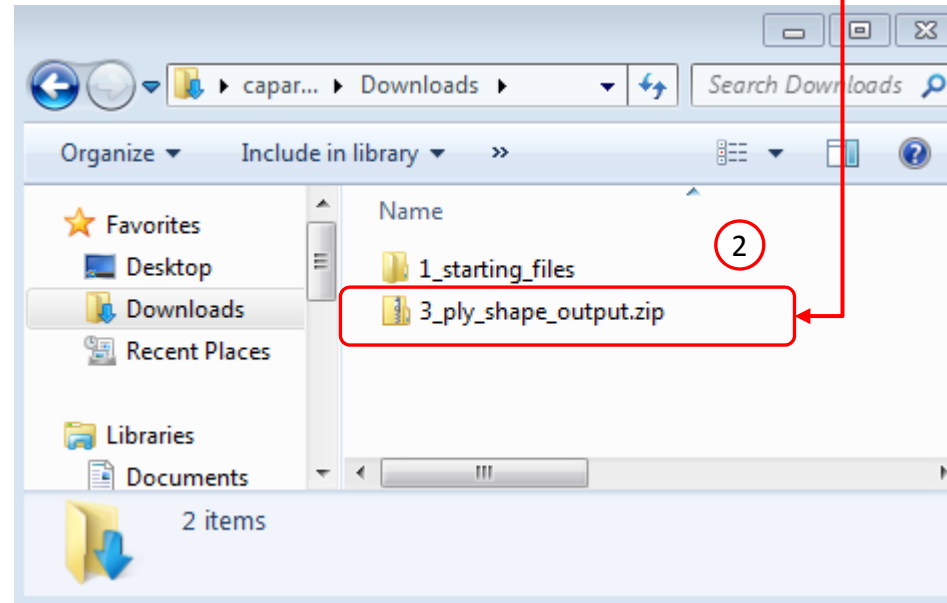
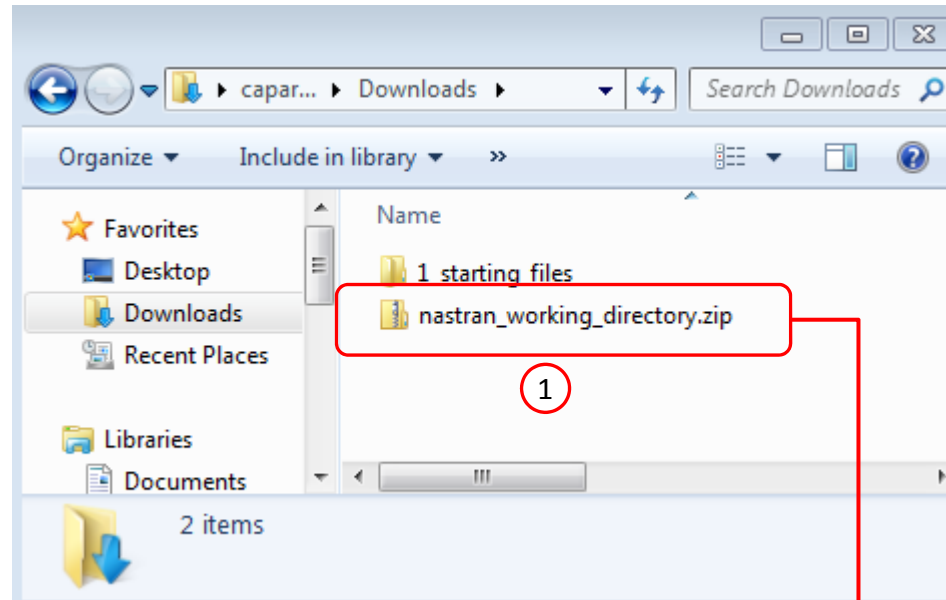
Last Item Compressed: design\_pcompgs.bdf

**Reminder!** Upload the new BDF files to the [Optimization web app](#) to and do the following.   **3**

- Update the objective and constraints
- Assign constraints to subcases
- Inspect design model for any errors

# Rename ZIP File

1. A new ZIP file has been downloaded
2. Rename the downloaded ZIP file to 3\_ply\_shape\_output.zip

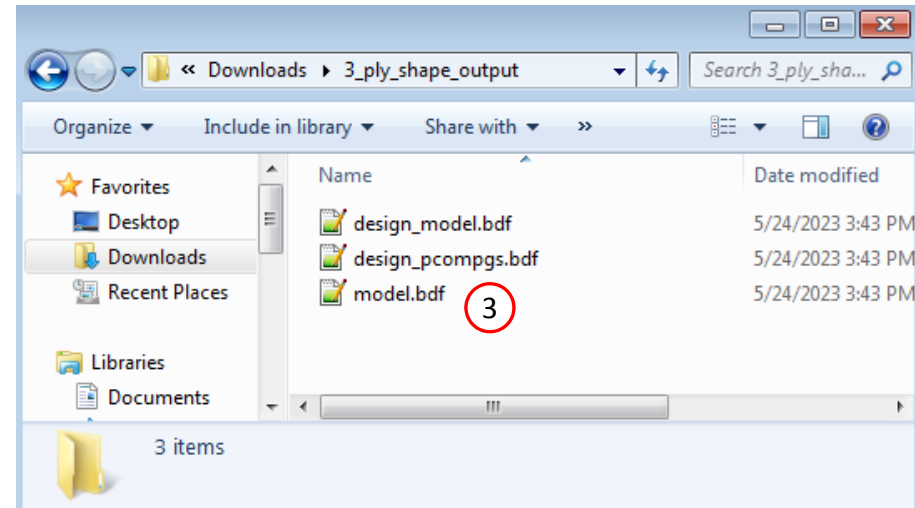
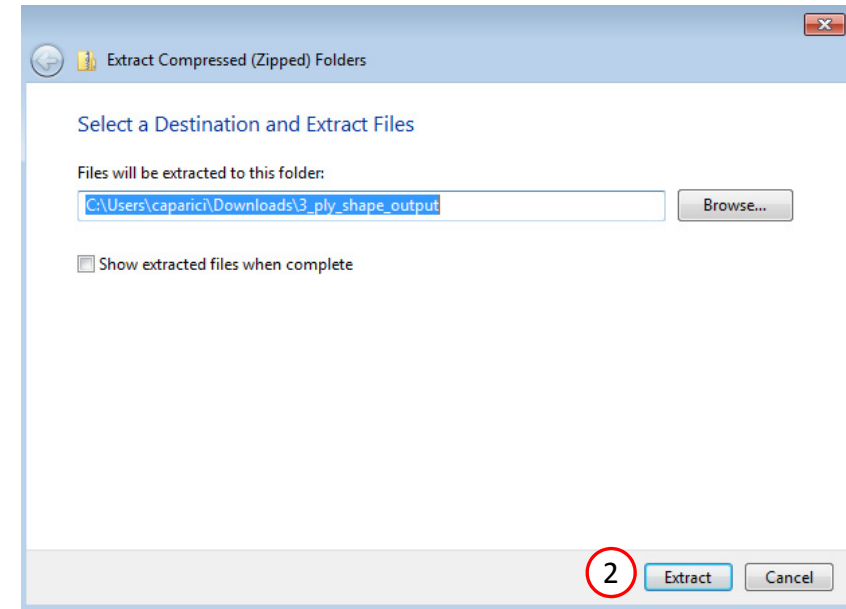
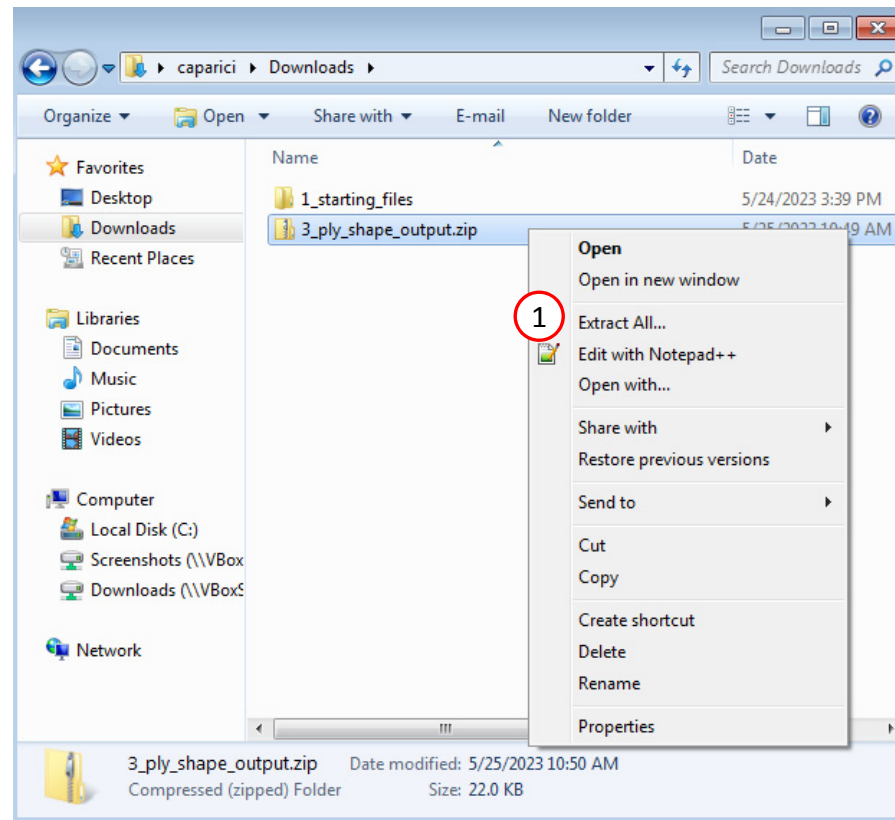


# Part 2 – Core Thickness Optimization

---

# Extract the ZIP File

1. Right click on the ZIP file and click Extract All
2. Click Extract
3. A new folder with the new BDF files has been created



# Upload BDF Files

1. Switch to the Optimization web app
2. Click Select files
3. Navigate to directory 3\_ply\_shape\_output
4. Select the indicated files
5. Click Open
6. Click Upload files

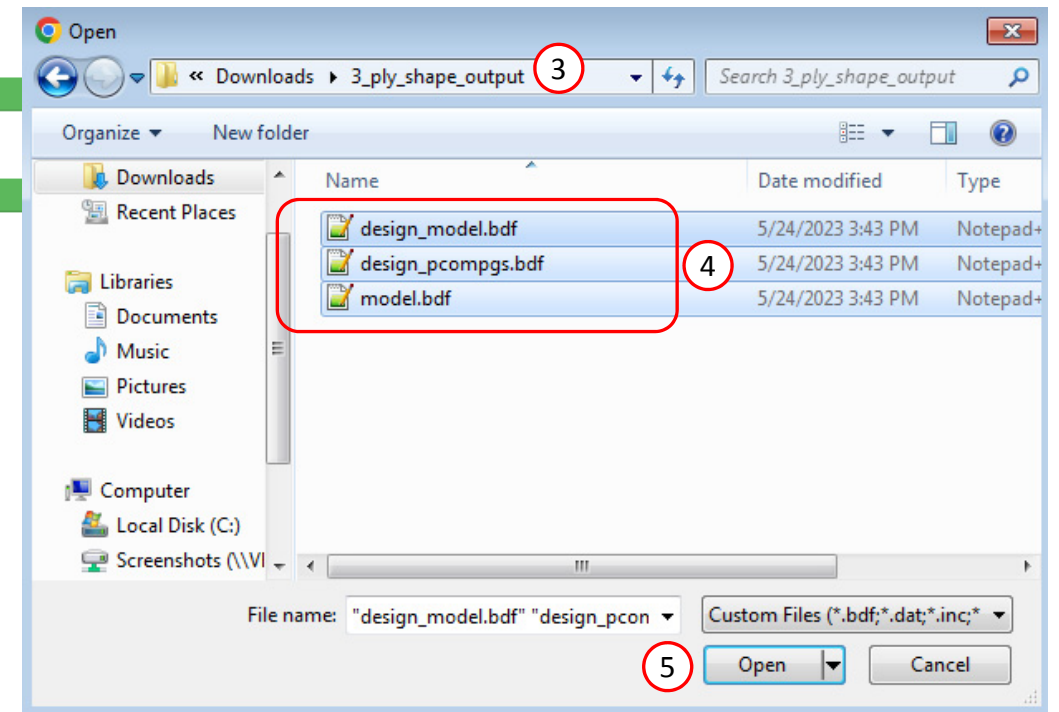
## Step 1 - Upload .BDF Files

2 1. Select files 3 files selected

Inspecting: 100%

6 2. Upload files

☐ List of Selected Files



# Variables

1. Click Variables
2. Navigate to section Step 4 – Adjust design variables
3. Make the following changes to the variables
  - Initial Value: 5.0
  - Lower Bound: 3.0
  - Upper Bound: 25.0
  - Allowed Discrete Values: 3.0, THRU, 25.0, BY, 1.0
4. Click +Options
5. Mark the checkbox for Label Comments
6. Update the label to partly read: Thickness of core layer

- The previous design variables were configured to be ply number variables. In this step, the initial value, bounds and allowed values are in terms of thickness.

## Step 4 - Adjust design variables 2

+ Options 4

☒ Label Comments 5

+ Create Variable

CSV Export

Export

CSV Import

Select files

Select a CSV File

Import

	Label	Status	Initial Value	Lower Bound	Upper Bound	Allowed Discrete Values	Label Comments
	<input type="text" value="Search"/>	<input type="text" value="Search"/>			3		6
<input checked="" type="checkbox"/>	y1	<input checked="" type="checkbox"/>	<input type="text" value="5.0"/>	<input type="text" value="3.0"/>	<input type="text" value="25.0"/>	<input type="text" value="3.0, THRU, 25.0, BY, 1.0"/>	Parent PCOMP 1 - Thickness of core layer GPLY IDs: 1:
<input checked="" type="checkbox"/>	y2	<input checked="" type="checkbox"/>	<input type="text" value="5.0"/>	<input type="text" value="3.0"/>	<input type="text" value="25.0"/>	<input type="text" value="3.0, THRU, 25.0, BY, 1.0"/>	Parent PCOMP 1 - Thickness of core layer GPLY IDs: 1:
<input checked="" type="checkbox"/>	y3	<input checked="" type="checkbox"/>	<input type="text" value="5.0"/>	<input type="text" value="3.0"/>	<input type="text" value="25.0"/>	<input type="text" value="3.0, THRU, 25.0, BY, 1.0"/>	Parent PCOMP 1 - Thickness of core layer GPLY IDs: 1:
<input checked="" type="checkbox"/>	y4	<input checked="" type="checkbox"/>	<input type="text" value="5.0"/>	<input type="text" value="3.0"/>	<input type="text" value="25.0"/>	<input type="text" value="3.0, THRU, 25.0, BY, 1.0"/>	Parent PCOMP 1 - Thickness of core layer GPLY IDs: 1:

# Objective

1. Click Objective
2. The weight is already set as an objective

- The objective was previously defined in the BDF files when the TOMVAR entries were defined. The weight objective is left as is.

SOL 200 Web App - Optimization   Upload   Variables   **Objective**   Constraints   Subcases   Exporter   Results   Settings   Match   Other   User's Guide   Home

Objective   Equation Objective   **1**

### Step 1 - Select an objective

Select an analysis type

SOL 101 - Statics

Select a response

	Response Description	Response Type
	<input type="text" value="Search"/>	<input type="text" value="Search"/>
<input type="checkbox"/>	Weight	WEIGHT
<input type="checkbox"/>	Volume	VOLUME
<input type="checkbox"/>	Displacement	DISP
<input type="checkbox"/>	Strain	STRAIN
<input type="checkbox"/>	Element Strain Energy	ESE

« 1 2 3 4 5 »   5 10 20 30 40 50

### Step 2 - Adjust objective

+ Options

	Label	Status	Response Type	Maximize or Minimize	Property Type	ATTA	ATTB	ATTI
<input type="checkbox"/>	r0	<input checked="" type="checkbox"/>	WEIGHT	MIN	<b>2</b>	3	3	

### BDF Output - Design Model

```
$
$
$----- Design Objective -----
$
$
$
DRESP1 8000000 r0 WEIGHT 3 3
```

Developed by The Engineering Lab



# Constraints

1. Click Constraints
2. Navigate to section Step 2 – Adjust constraints
3. Ensure the constraint on buckling load factor is present

- Recall the constraint on buckling load factor was created during the topometry optimization and is carried over in the BDF files until now

## Step 1 - Select constraints

Select an analysis type

SOL 101 - Statics

Select a response

	Response Description ▾	Response Type ▾
	<input type="text" value="Search"/>	<input type="text" value="Search"/>
	Weight	WEIGHT
	Volume	VOLUME
	Displacement	DISP
	Strain	STRAIN
	Element Strain Energy	ESE

« 1 2 3 4 5 »

5 10 20 30 40 50

## Step 2 - Adjust constraints 2

+ Options

	Label ▾	Status ▾	Response Type ▾	Property Type ▾	ATTA ▾	ATTB ▾	ATTi ▾	Lower Allowed Limit	Upper Allowed Limit
	<input type="text" value="Search"/>	<input type="text" value="Search"/>	<input type="text" value="Search"/>	<input type="text" value="Search"/>	<input type="text" value="Search"/>	<input type="text" value="Search"/>	<input type="text" value="Search"/>	<input type="text" value="Search"/>	<input type="text" value="Search"/>
	r1		LAMA	3	1			1.0	Upper

# Subcases

1. Click Subcases
2. Ensure the following is configured
  - Subcase 1
    - Analysis: Statics
  - Subcase 2
    - Analysis: Buckling
    - Constraint r1 is assigned to subcase 2

1

## Step 1 - Assign constraints to subcases

Display Columns

Global Constraints  
SUBCASE 1  
SUBCASE 2

☐ Uncheck visible boxes

☒ Check visible boxes

+ Options

Status	Label	Response Type	Analysis Type	Description
	<input type="text" value="Search"/>	<input type="text" value="Search"/>	<input type="text" value="Search"/>	<input type="text" value="Search"/>
		r1	LAMA	BUCK
				Buckling load factor of mode 1

Global Constraints	SUBCASE 1	SUBCASE 2
Analysis Types →	Statics ▾	Buckling ▾
		<input checked="" type="checkbox"/>

2

10 25 50 100 200

# Settings

1. Click Settings
2. Set the maximum number of design cycles to 20
3. Ensure the trust region setting is set to 1 – Trust Region On

1

## Optimization Settings

Parameter ▾	Description ▾	Configure ▾
<input type="text" value="Search"/>	<input type="text" value="Search"/>	<input type="text" value="Search"/>
APRCOD	Approximation method to be used	<input type="checkbox"/> 2 - Mixed Method ▾
CONV1	Relative criterion to detect convergence	<input type="checkbox"/> Enter a positive real number
CONV2	Absolute criterion to detect convergence	<input type="checkbox"/> Enter a positive real number
DELX	Fractional change allowed in each design variable during any optimization cycle	<input type="checkbox"/> Enter a positive real number
DESMAX	Maximum number of design cycles to be performed	<input checked="" type="checkbox"/> 20 2
DISBEG	Design cycle number for discrete variable processing initiation	<input type="checkbox"/> Enter a positive integer
GMAX	Maximum constraint violation allowed at the converged optimum	<input type="checkbox"/> Enter a positive real number
P1	Print items, e.g. objective, design variables, at every n-th design cycle to the .f06 file	<input checked="" type="checkbox"/> 1
P2	Items to be printed to the .f06 file	<input checked="" type="checkbox"/> 12 - Print constraints and responses ▾
TCHECK	Topology Checkerboarding	<input type="checkbox"/> -1 - Automatic selection (Default) ▾
TDMIN	Minimum diameter of members in topology optimization	<input type="checkbox"/> Enter a positive real number
TREGION	Trust Region	<input checked="" type="checkbox"/> 1 - Trust Region On 3 ▾

# Export New BDF Files

1. Click on Exporter
2. Click on Download BDF Files

- When the download button is clicked a new file named “nastran\_working\_directory” is downloaded. If the file already exists in your local folder, the folder name is appended with a number, e.g. “nastran\_working\_directory (1).zip”

1

## BDF Output - Model

```
assign userfile = 'optimization_results.csv', status = unknown,
form = formatted, unit = 52
$ MSC.Nastran input file created on May    23, 2023 at 07:05:29 by
$ Patran 2022.2
$ Direct Text Input for Nastran System Cell Section
$
SOL 200
CEND

TITLE = MSC.NASTRAN JOB CREATED ON 22-MAY-23 AT 09:49:34
ECHO = NONE
  DESOBJ(MIN) = 8000000
  $ DESGLB Slot
  $ DSAPRT(FORMATTED, EXPORT, END=SENS) = ALL
SUBCASE 1
  ANALYSIS = STATICS
  $ DESSUB Slot
  $ DRSPAN Slot
$ Subcase name : Default
SUBTITLE=Default
SPC = 2
LOAD = 5
DISPLACEMENT(PLOT,SORT1,REAL)=ALL
SPCFORCES(PLOT,SORT1,REAL)=ALL
SUBCASE 2
  ANALYSIS = BUCK
  DESSUB = 40000002
  $ DRSPAN Slot
$ Subcase name : Default
```

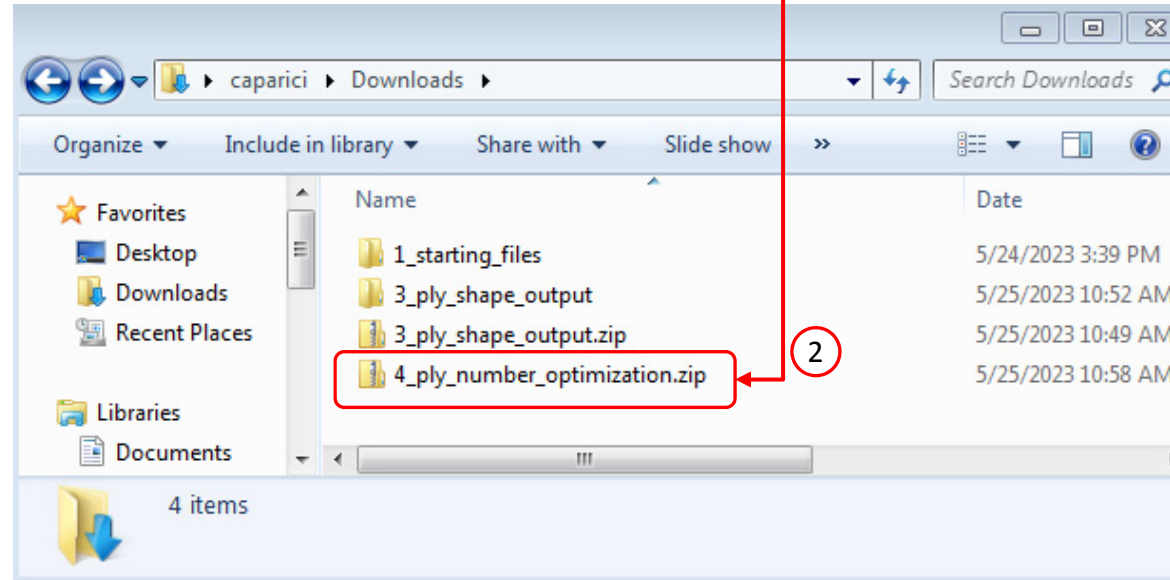
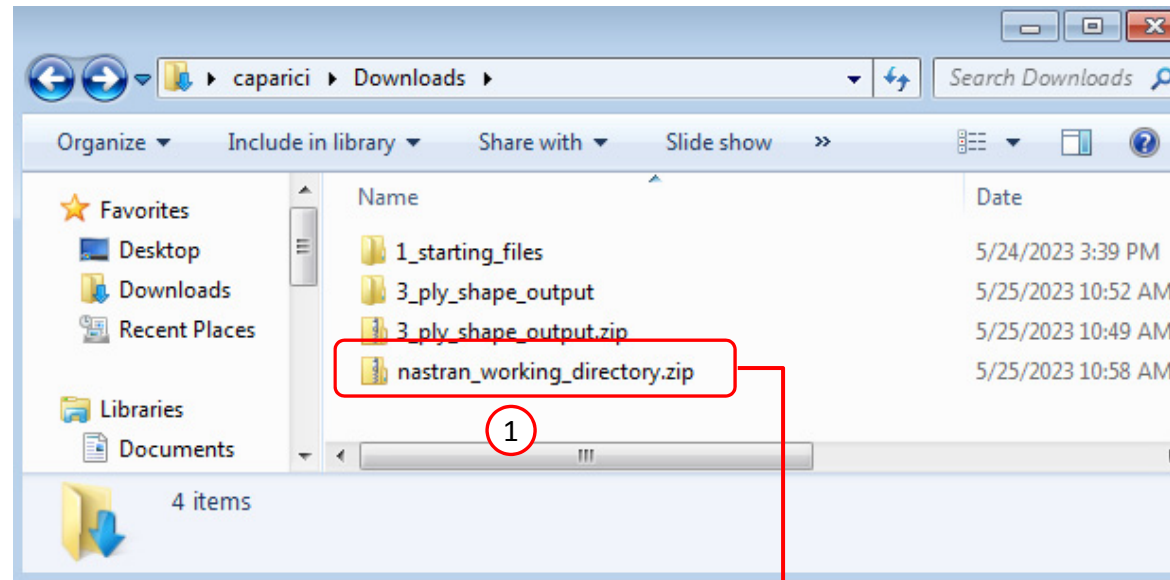
## Download BDF Files

Download BDF Files

2

# Rename ZIP File

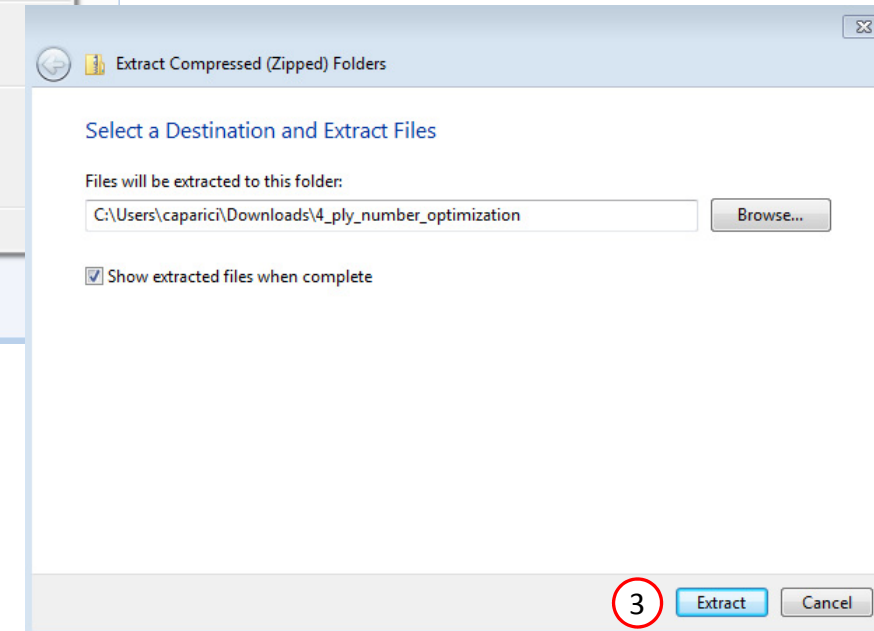
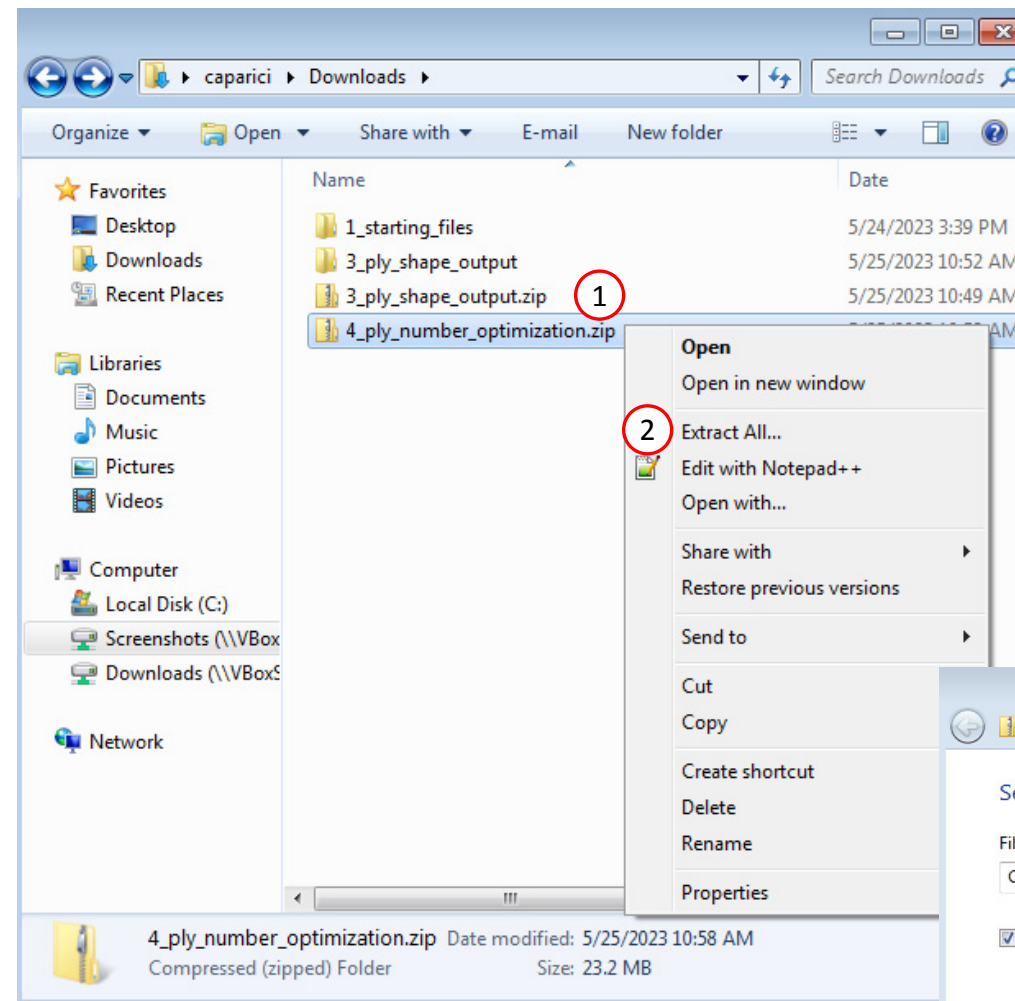
1. A new ZIP file has been downloaded
2. Rename the downloaded ZIP file to 4\_ply\_number\_optimization.zip



# Perform the Optimization with Nastran SOL 200

1. A new .zip file has been downloaded
2. Right click on the file and click Extract All
3. Click Extract on the following window

- Always extract the contents of the ZIP file to a new, empty folder.



# Perform the Optimization with Nastran SOL 200

1. Inside of the new folder, double click on Start MSC Nastran
2. Click Open, Run or Allow Access on any subsequent windows
3. MSC Nastran will now start

- After a successful optimization, the results will be automatically displayed as long as the following files are present: BDF, F06 and LOG.
- One can run the Nastran job on a remote machine as follows:
  - 1) Copy the BDF files and the INCLUDE files to a remote machine.
  - 2) Run the MSC Nastran job on the remote machine.
  - 3) After completion, copy the BDF, F06, LOG, H5 files to the local machine.
  - 4) Click "Start MSC Nastran" to display the results.

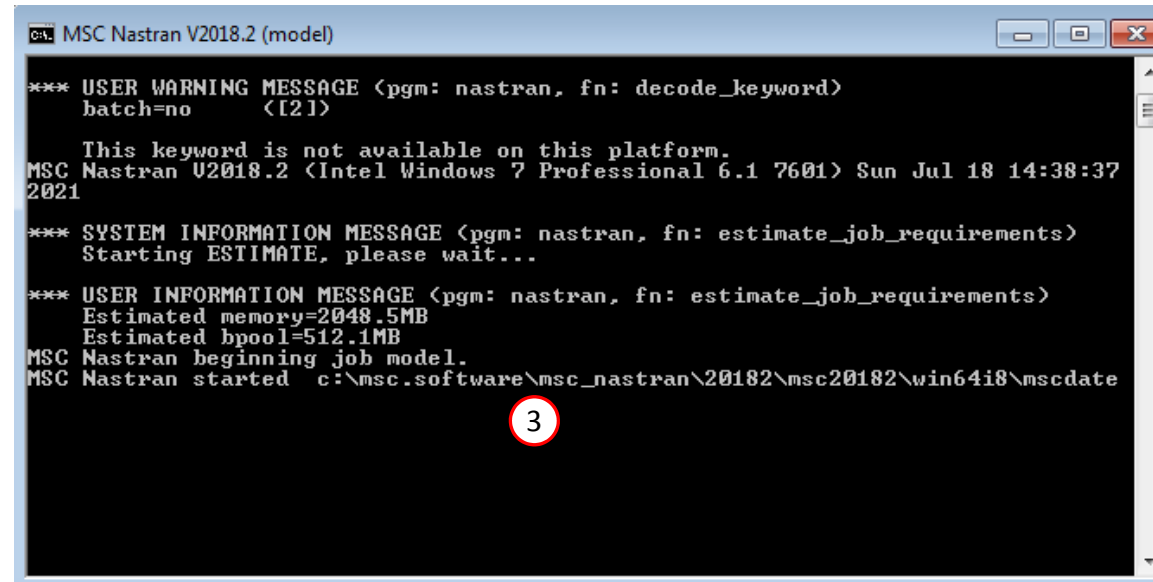
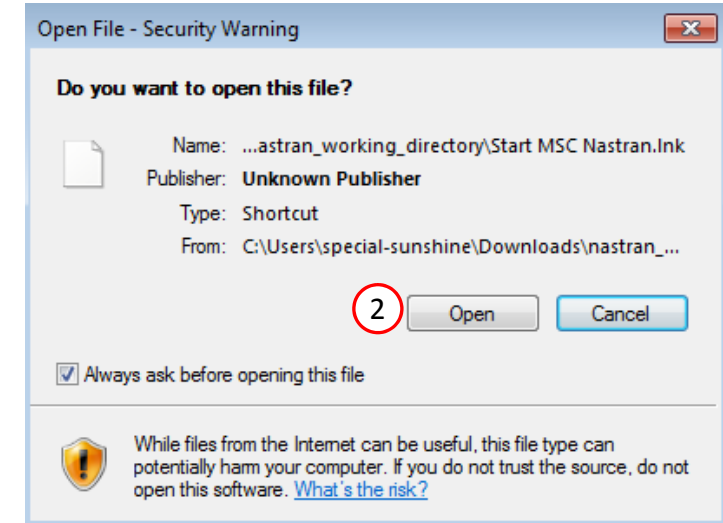
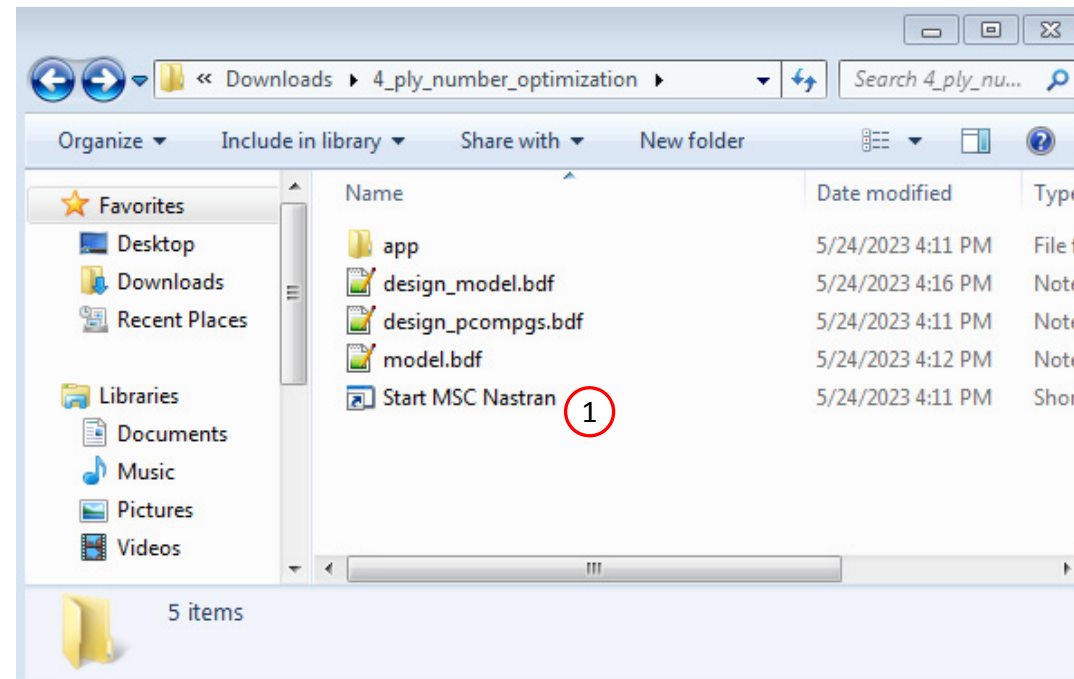
## Using Linux?

Follow these instructions:

- 1) Open Terminal
- 2) Navigate to the nastran\_working\_directory  
`cd ./nastran_working_directory`
- 3) Use this command to start the process  
`./Start_MSC_Nastran.sh`

In some instances, execute permission must be granted to the directory. Use this command. This command assumes you are one folder level up.

```
sudo chmod -R u+x ./nastran_working_directory
```



# Status

- 1. While MSC Nastran is running, a status page will show the current state of MSC Nastran

- The status of the MSC Nastran job is reported on the Status page. Note that Windows 7 users will experience a delay in the status updates. All other users of Windows 10 and Red Hat Linux will see immediate status updates.

## SOL 200 Web App - Status

 Python  MSC Nastran

### Status

Name	Status of Job	Design Cycle	RUN TERMINATED DUE TO
model.bdf	Running	None	



# Review Optimization Results

After MSC Nastran is finished, the results will be automatically uploaded.

1. Ensure the messages shown have green checkmarks. This is indication of success. Any red icons indicate challenges.
2. The final value of objective, normalized constraints (not shown) and design variables can be reviewed.

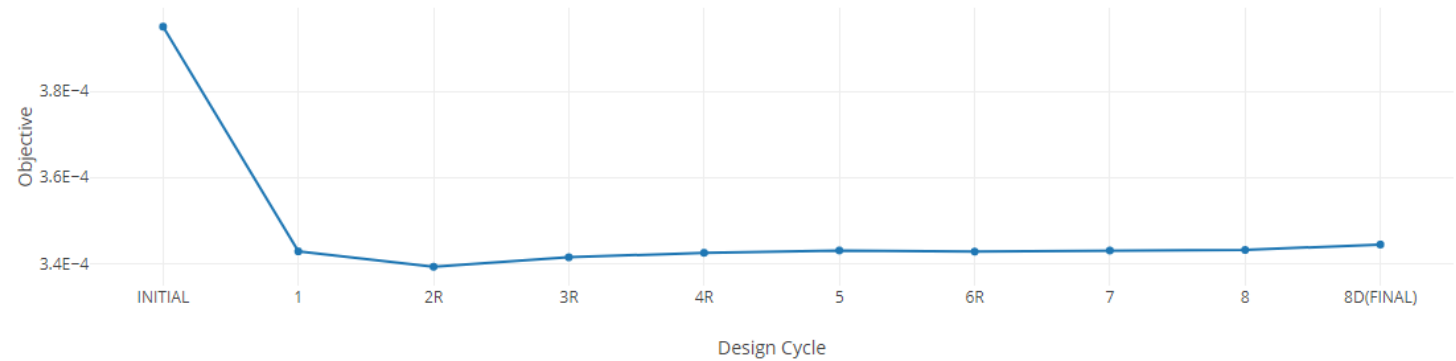
- After an optimization, the results will be automatically displayed as long as the following files are present: BDF, F06 and LOG.
- Note that the optimization solutions is sensitive to different system configurations. This optimization yielded an objective of  $2.303103\text{E-}05$  on Windows 7, but on Linux, yielded an objective of  $2.305057\text{E-}05$ . Alternatively, the difference in the converged solution may be due to a difference in the surface area of the ply shape candidates. A difference of one 2D element may yield a different solution.
- Normalized constraint values that are positive indicate a design that violates at least one design constraint, and such designs are named infeasible designs. Negative normalized constraint values are desired and indicated the design satisfies all design constraints. Such designs are named feasible designs. The normalized constraint of the final design is negative, indicating a feasible design.

## Final Message in .f06

1

✓ RUN TERMINATED DUE TO HARD CONVERGENCE TO AN OPTIMUM AT CYCLE NUMBER = 8.  
✓ AND HARD FEASIBLE DISCRETE DESIGN OBTAINED

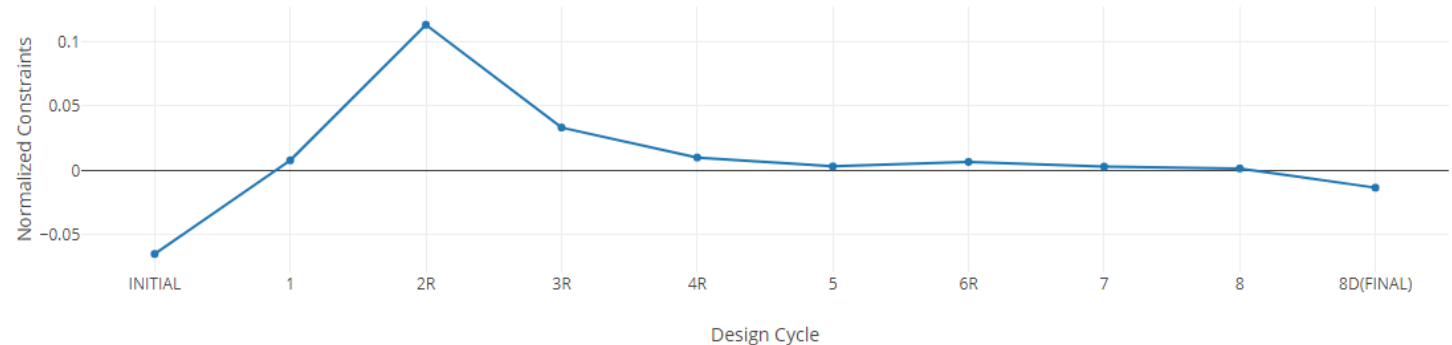
## Objective



2

## Normalized Constraints

+ Info

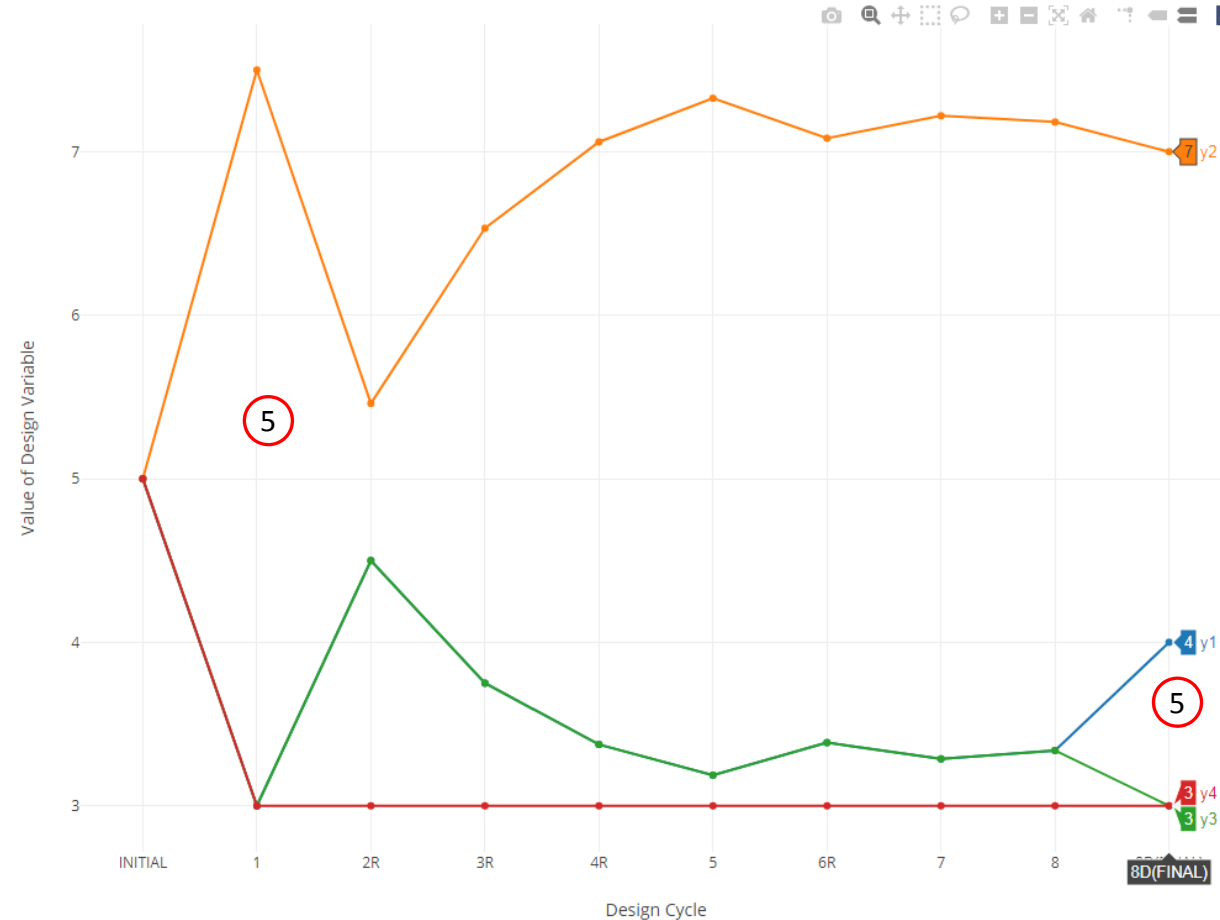


# Review Optimization Results

1. Navigate to section Design Variables
2. Click Display None
3. In the search box, type y
4. Click Display All
5. Only the ply number variables, e.g. y1, y2, ..., are displayed
6. Move the mouser cursor to hover over the last design cycle and labels displaying the final variable values are visible

## SOL 200 Web App - Local Optimization Results

Design Variables



Reset Table

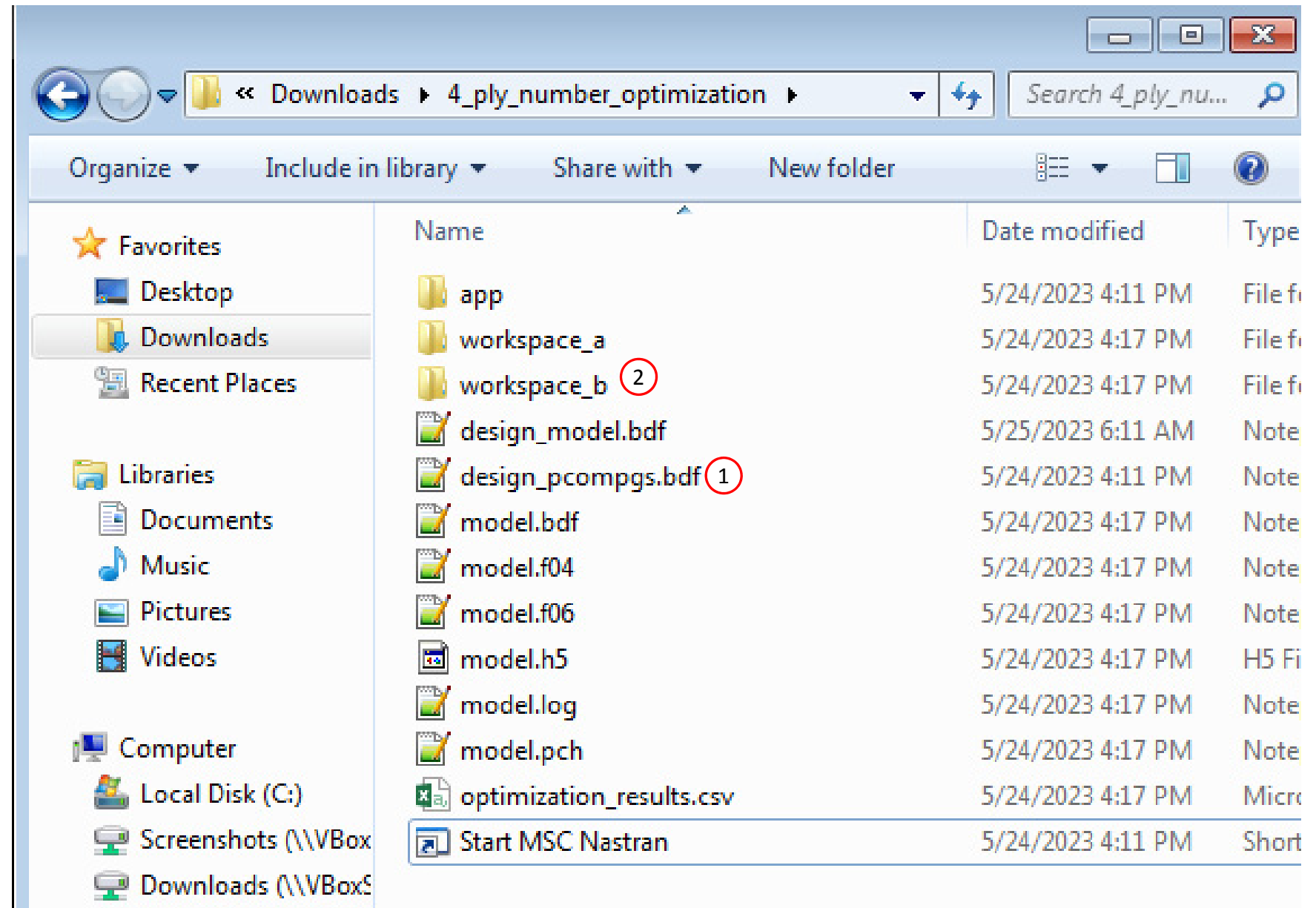
Display None Display All

Display	Color	Label	Label Comments
		y	Search
<input checked="" type="checkbox"/>	Blue	y1	Parent PCOMP 1 - Number of plies for 0°, GPLY IDs: 152000, 2152000
<input checked="" type="checkbox"/>	Orange	y2	Parent PCOMP 1 - Number of plies for 0°, GPLY IDs: 153000, 2153000
<input checked="" type="checkbox"/>	Green	y3	Parent PCOMP 1 - Number of plies for 0°, GPLY IDs: 154000, 2154000
<input checked="" type="checkbox"/>	Red	y4	Parent PCOMP 1 - Number of plies for 0°, GPLY IDs: 155000, 2155000

5 10 20 50 100 200

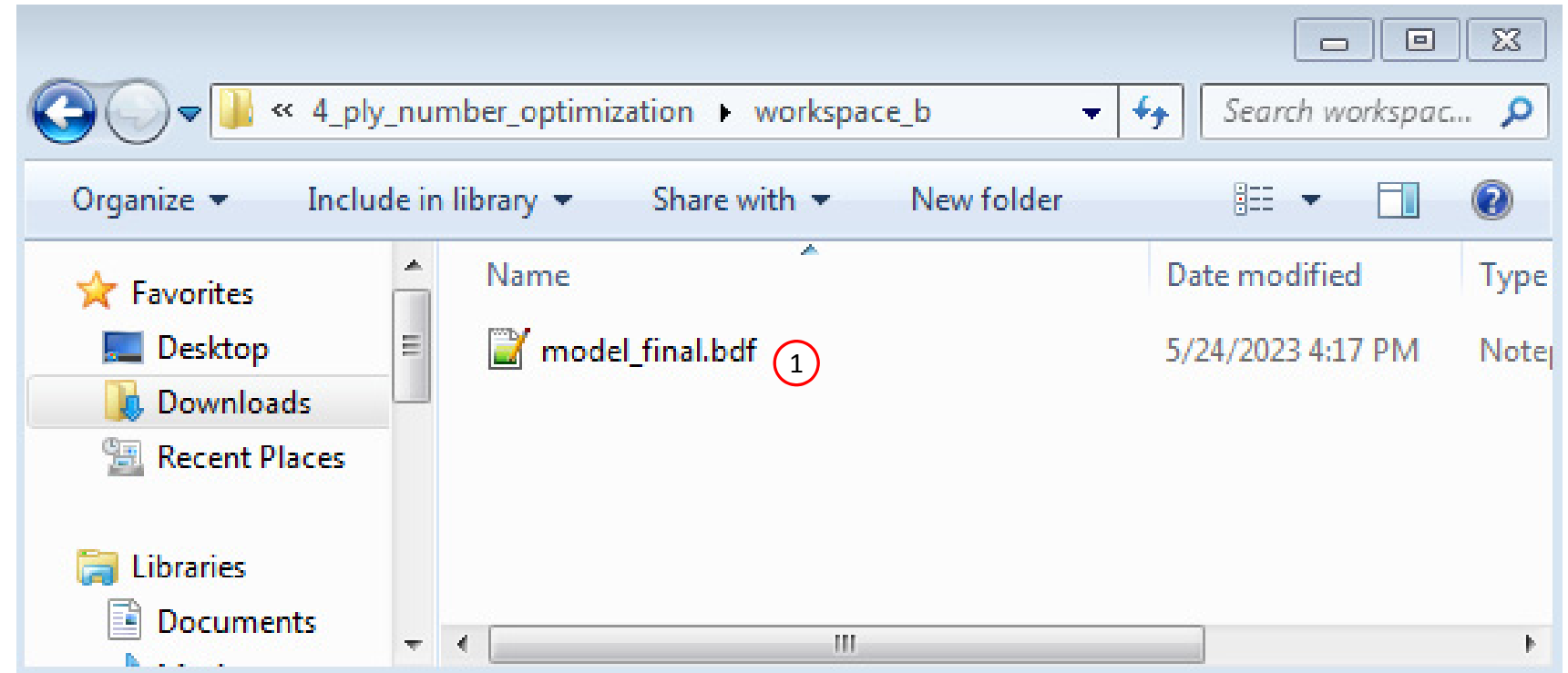
# Review Optimization Results

1. Open file design\_pcompgs.bdf in a text editor. A comparison will be made.
2. A new directory workspace\_b has been created. Open this directory.



# Review Optimization Results

1. Inside of workspace\_b, open file model\_final.bdf in a text editor.



# Review Optimization Results

Recall the following variable results.

- Variable  $y_1$ , which corresponds to GPLY ID 152000 and 2152000, has a final value of 4. This is the core layer

The following changes have been made in the BDF files found in workspace\_c

- Refer to PCOMPG 2 in both files
- GPLY ID 152000 now has a thickness of 4.0.
  - Since the composite is symmetric, the same layers are mirrored as 2152000.
  - Since the core is represented by both 152000 and 2152000, the total thickness of the core is now 8.0.
- The same is done for the other core layers

.\4\_ply\_number\_optimization\design\_pcompgs.bdf

design\_pcompgs.bdf

1	\$	1	2	3	4	5	6
2	PCOMPG	2	0.0		90.	HILL	
3		111000	101	.125	90.	YES	
4		121000	101	.125	45.	YES	
5		131000	101	.125	-45.	YES	
6		141000	101	.125	0.	YES	
7		152000	501	1.00000	0.	YES	
8		2152000	501	1.00000	0.	YES	
9		2141000	101	.125	0.	YES	
10		2131000	101	.125	-45.	YES	
11		2121000	101	.125	45.	YES	
12		2111000	101	.125	90.	YES	
13	PCOMPG	3	0.0		90.	HILL	
14		111000	101	.125	90.	YES	
15		121000	101	.125	45.	YES	
16		131000	101	.125	-45.	YES	
17		141000	101	.125	0.	YES	
18		155000	501	1.00000	0.	YES	
19		2155000	501	1.00000	0.	YES	
20		2141000	101	.125	0.	YES	
21		2131000	101	.125	-45.	YES	
22		2121000	101	.125	45.	YES	
23		2111000	101	.125	90.	YES	
24	PCOMPG	4	0.0		90.	HILL	
25		111000	101	.125	90.	YES	
26		121000	101	.125	45.	YES	
27		131000	101	.125	-45.	YES	
28		141000	101	.125	0.	YES	
29		153000	501	1.00000	0.	YES	
30		2153000	501	1.00000	0.	YES	
31		2141000	101	.125	0.	YES	
32		2131000	101	.125	-45.	YES	
33		2121000	101	.125	45.	YES	

.\4\_ply\_number\_optimization\workspace\_b\model\_final.bdf

model\_final.bdf

136	\$	1	2	3	4	5	6
137	PCOMPG	2	0.0	0.0	90.	HILL	
138		111000	101	.125	90.	YES	
139		121000	101	.125	45.	YES	
140		131000	101	.125	-45.	YES	
141		141000	101	.125	0.0	YES	
142		152000	501	4.	0.0	YES	
143		2152000	501	4.	0.0	YES	
144		2141000	101	.125	0.0	YES	
145		2131000	101	.125	-45.	YES	
146		2121000	101	.125	45.	YES	
147		2111000	101	.125	90.	YES	
148	PCOMPG	3	0.0	0.0	90.	HILL	
149		111000	101	.125	90.	YES	
150		121000	101	.125	45.	YES	
151		131000	101	.125	-45.	YES	
152		141000	101	.125	0.0	YES	
153		155000	501	3.	0.0	YES	
154		2155000	501	3.	0.0	YES	
155		2141000	101	.125	0.0	YES	
156		2131000	101	.125	-45.	YES	
157		2121000	101	.125	45.	YES	
158		2111000	101	.125	90.	YES	
159	PCOMPG	4	0.0	0.0	90.	HILL	
160		111000	101	.125	90.	YES	
161		121000	101	.125	45.	YES	
162		131000	101	.125	-45.	YES	
163		141000	101	.125	0.0	YES	
164		153000	501	7.	0.0	YES	
165		2153000	501	7.	0.0	YES	
166		2141000	101	.125	0.0	YES	
167		2131000	101	.125	-45.	YES	
168		2121000	101	.125	45.	YES	

# Update the Original Model

1. It should be noted that since this was a multidisciplinary optimization, the update to the file model\_fina.bdf is incomplete. Manually copy the section above the BEGIN BULK delimiter from the original file (model\_curved\_panel\_with\_core.bdf) to the new file (model\_final.bdf).

- If you were using multiple INCLUDE files, model\_final.bdf is a combination of all INCLUDE files. The next few slides discuss an alternative method of using the PCH to BDF web app to update the values for the designed properties while preserving separate INCLUDE files.

```
model_curved_panel_with_core.bdf [3]
1 $ MSC.Nastran input file created on May      23, 2023 at 07:05:29 by
2 $ Patran 2022.2
3 $ Direct Text Input for Nastran System Cell Section
4 $
5 SOL 105
6 CEND
7 TITLE = MSC.NASTRAN JOB CREATED ON 22-MAY-23 AT 09:49:34
8 ECHO = NONE
9 SUBCASE 1
10 $ Subcase name : Default
11   SUBTITLE=Default
12   SPC = 2
13   LOAD = 5
14   DISPLACEMENT (PLOT, SORT1, REAL) =ALL
15   SPCFORCES (PLOT, SORT1, REAL) =ALL
16 SUBCASE 2
17 $ Subcase name : Default
18   SUBTITLE=Default
19   SPC = 2
20   METHOD = 1
21   VECTOR (PLOT, SORT1, REAL) =ALL
22   SPCFORCES (PLOT, SORT1, REAL) =ALL
23   STATSUB = 1
24 BEGIN BULK
25 param grdpnt 0
26 HDF5OUT PRCISION 32 CMPRTHD LZ4 LEVEL 5
27 PARAM PRTMAXIM YES
28 EIGRL 1 0.0 1 0
29 $ Elements and Element Properties for region : pcomp.1
30 $ Composite Property Reference Material: pcomp.502
31 $ Composite Material Description :
32 PCOMP 1 0.0 90. HILL SYM
33 101 .125 90. YES
34 101 .125 45. YES
35 101 .125 -45. YES
36 101 .125 0. YES
37 501 5. 0. YES
38 $ Pset: "pcomp.1" will be imported as: "pcomp.1"
39 CQUAD4 641 1 725 726 798 724 0. 0.
```

```
model_final.bdf [3]
1 $ Message from the SOL 200 Web App
2 $ This file was generated as follows:
3 $ - The head, or every line above the BEGIN BULK line, was sourced
4 $   from model.bdf
5 $ - The head is only added if the following conditions are met:
6 $   - There exists no INCLUDEs
7 $   - There is only one ANALYSIS type used
8 $   - SOL 200 was changed to its respective SOL number
9 $   - The bulk data section was sourced from model.pch
10 $ MSC.Nastran input file created on May      23, 2023 at 07:05:29 by
11 $ Patran 2022.2
12 $ Direct Text Input for Nastran System Cell Section
13 $
14 SOL 105
15 CEND
16 TITLE = MSC.NASTRAN JOB CREATED ON 22-MAY-23 AT 09:49:34
17 ECHO = NONE
18 SUBCASE 1
19 $ Subcase name : Default
20   SUBTITLE=Default
21   SPC = 2
22   LOAD = 5
23   DISPLACEMENT (PLOT, SORT1, REAL) =ALL
24   SPCFORCES (PLOT, SORT1, REAL) =ALL
25 SUBCASE 2
26 $ Subcase name : Default
27   SUBTITLE=Default
28   SPC = 2
29   METHOD = 1
30   VECTOR (PLOT, SORT1, REAL) =ALL
31   SPCFORCES (PLOT, SORT1, REAL) =ALL
32   STATSUB = 1
33 BEGIN BULK
34 $*****
35 $*
36 $*
37 $*
38 $*****
39 $
```

# Part 3 – View New Core Thickness

---



# Open the Correct Page

1. Click on the indicated link

- MSC Nastran can perform many optimization types. The SOL 200 Web App includes dedicated web apps for the following:
  - Optimization for SOL 200 (Size, Topology, Topometry, Topography, Local Optimization, Sensitivity Analysis and Global Optimization)
  - Multi Model Optimization
  - Machine Learning
- The web app also features the HDF5 Explorer, a web application to extract results from the H5 file type.

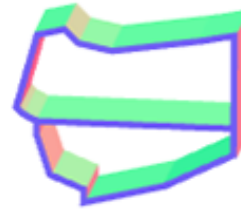




## Open the Viewer

1. Navigate to the Composites section
2. Click Viewer

# Beams

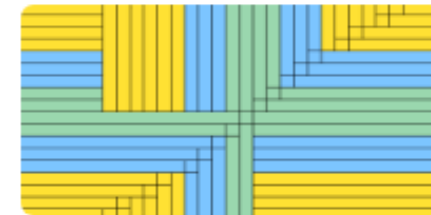


PBMSECT

## ① Composites

Ply	Theta (°)	GPPLY ID
1	45	121001
2	-45	131001
3	0	141001
4	30	111001
5	0	141002
6	90	110004
7	0	141003
8	45	121002
9	-45	131002

Stacking Sequence

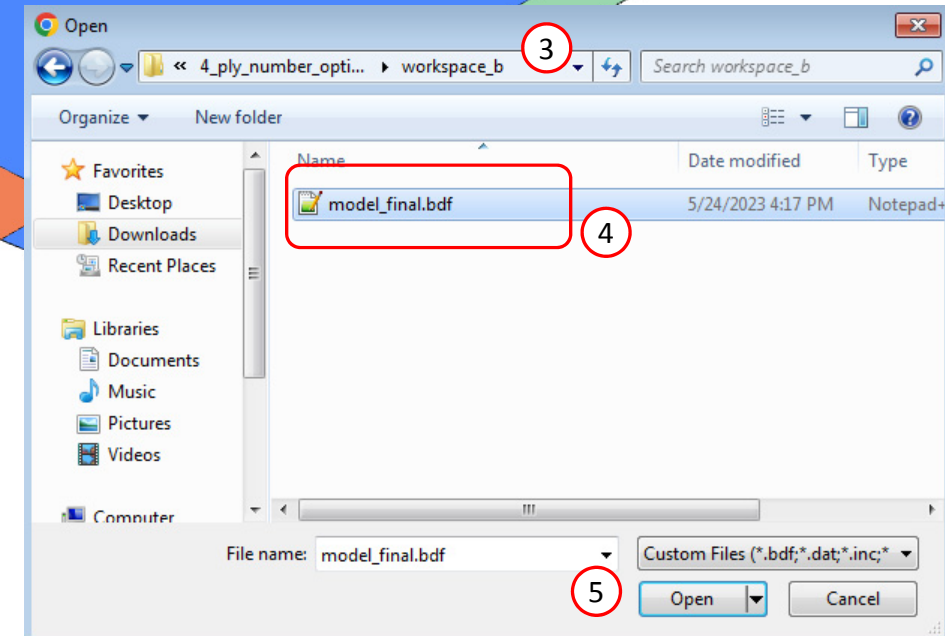
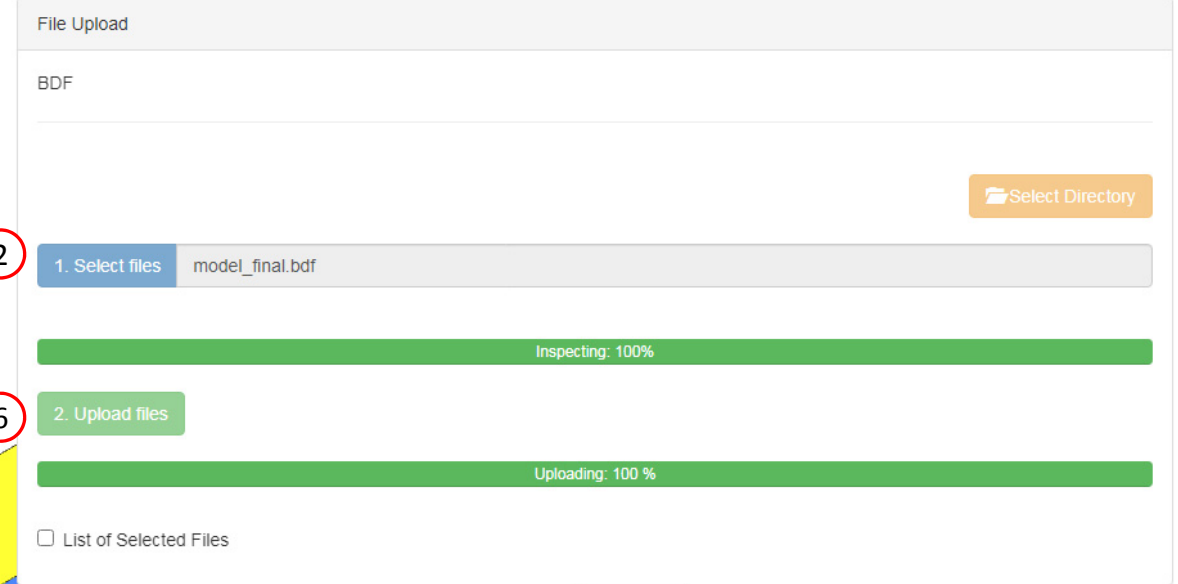
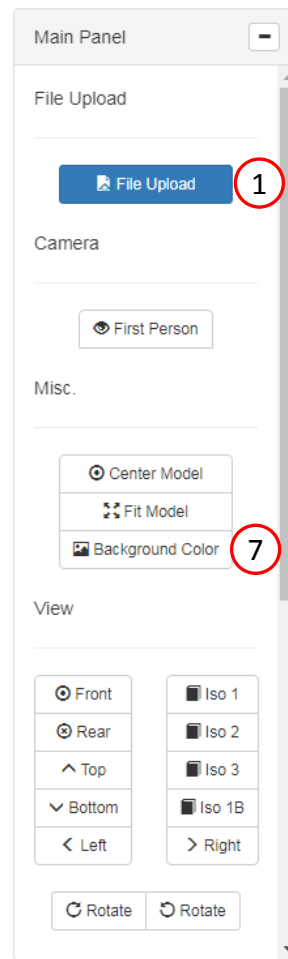


Viewer (.des, .ply000i)

②

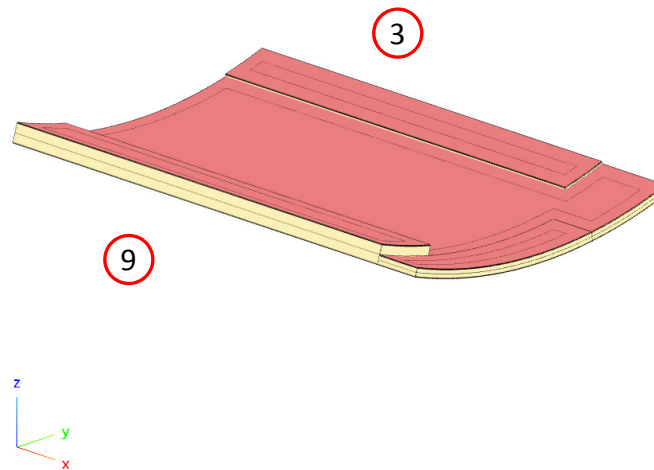
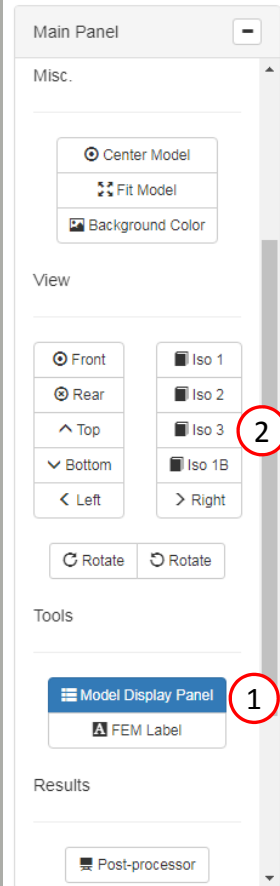
# Upload BDF Files

1. Click File Upload
2. Click Select files
3. Navigate to directory workspace\_b
4. Select the indicated files
5. Click Open
6. Click Upload files
7. Click Background Color (Optional)



# Display PCOMPGs

1. Click Model Display Panel
2. Click Iso 3
3. Right click and hold the right mouse button, and move the mouse to translate the model into view.
4. In the search box, type: pcomp
5. Click the indicated icon
6. Click the indicated icon
7. If an update message appears, wait until the update is complete, then continue
8. Click the indicated icon to recolor the plies
9. The ply thickness is now displayed



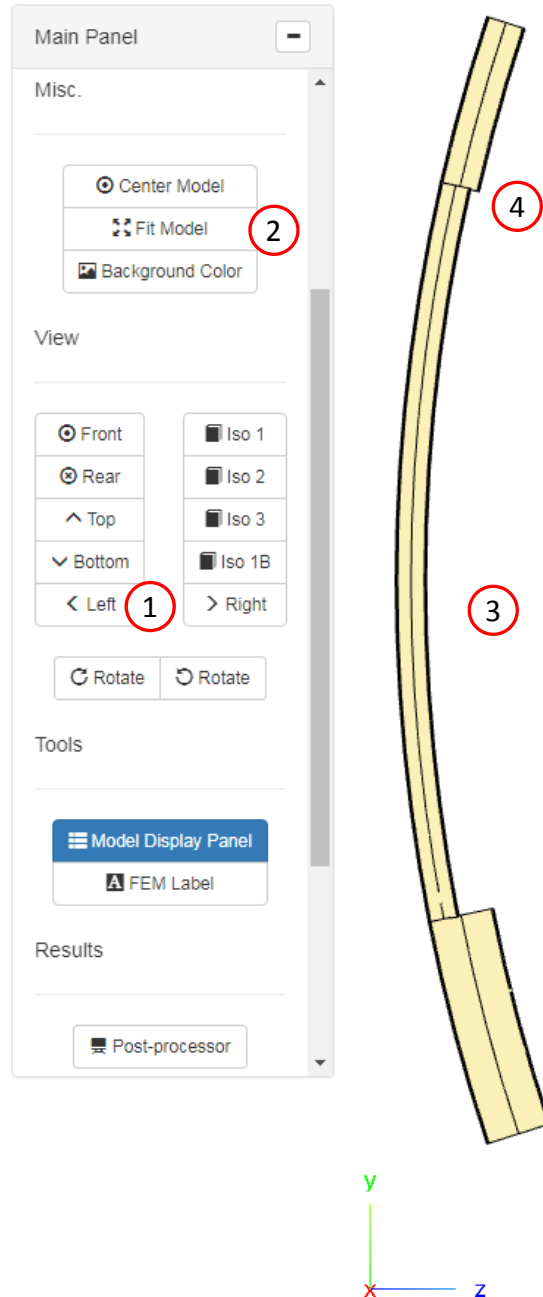
Model Display Panel

Full thickness update complete 7 Reset Table

Property Name	Property ID	Color	Display Mesh	Display Wireframe	Layer	GPLY ID	THETA	Color of Detail	Display Detail	Display Detail Wireframe
pcom	Search				S	Sea	Se			
PCOMPG 2										
					1	111000	90°			
					2	121000	45°			
					3	131000	-45°			
					4	141000	0°			
					5	152000	0°			
					6	2152000	0°			
					7	2141000	0°			
					8	2131000	-45°			
					9	2121000	45°			
					10	2111000	90°			
PCOMPG 3										
					1	111000	90°			
					2	121000	45°			
					3	131000	-45°			
					4	141000	0°			
					5	155000	0°			

# Display PCOMPGs

1. Click Left
2. Click Fit Model
3. Use the mouse scroll wheel to zoom in
4. The core thickness varies throughout the composite. The current view is a literal view of the PCOMPG entries.



Model Display Panel

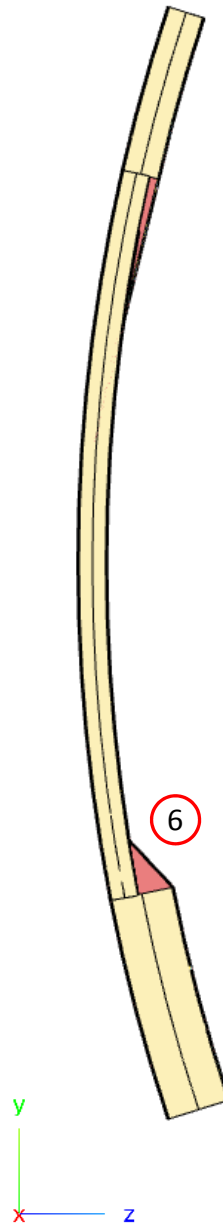
Reset Table

Property Name	Property ID	Color	Display Mesh	Display Wireframe	Layer	GPLY ID	THETA	Color of Detail	Display Detail	Display Detail Wireframe
pcom	Sear				S	Sea	Se			
PCOMPG	2		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>						
					1	111000	90°		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
					2	121000	45°		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
					3	131000	-45°		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
					4	141000	0°		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
					5	152000	0°		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
					6	2152000	0°		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
					7	2141000	0°		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
					8	2131000	-45°		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
					9	2121000	45°		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
					10	2111000	90°		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
PCOMPG	3		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>						
					1	111000	90°		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
					2	121000	45°		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
					3	131000	-45°		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
					4	141000	0°		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
					5	155000	0°		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

# Display GPLYs

1. Click the indicated icons
2. Click Reset Table
3. In the search box, type: gply
4. Click the indicated icons
5. Click the indicated icon 2 times
6. A more realistic view of the plies is displayed

- Alternate between the literal and realistic views to gain a good understanding of how the plies are distributed across the model.



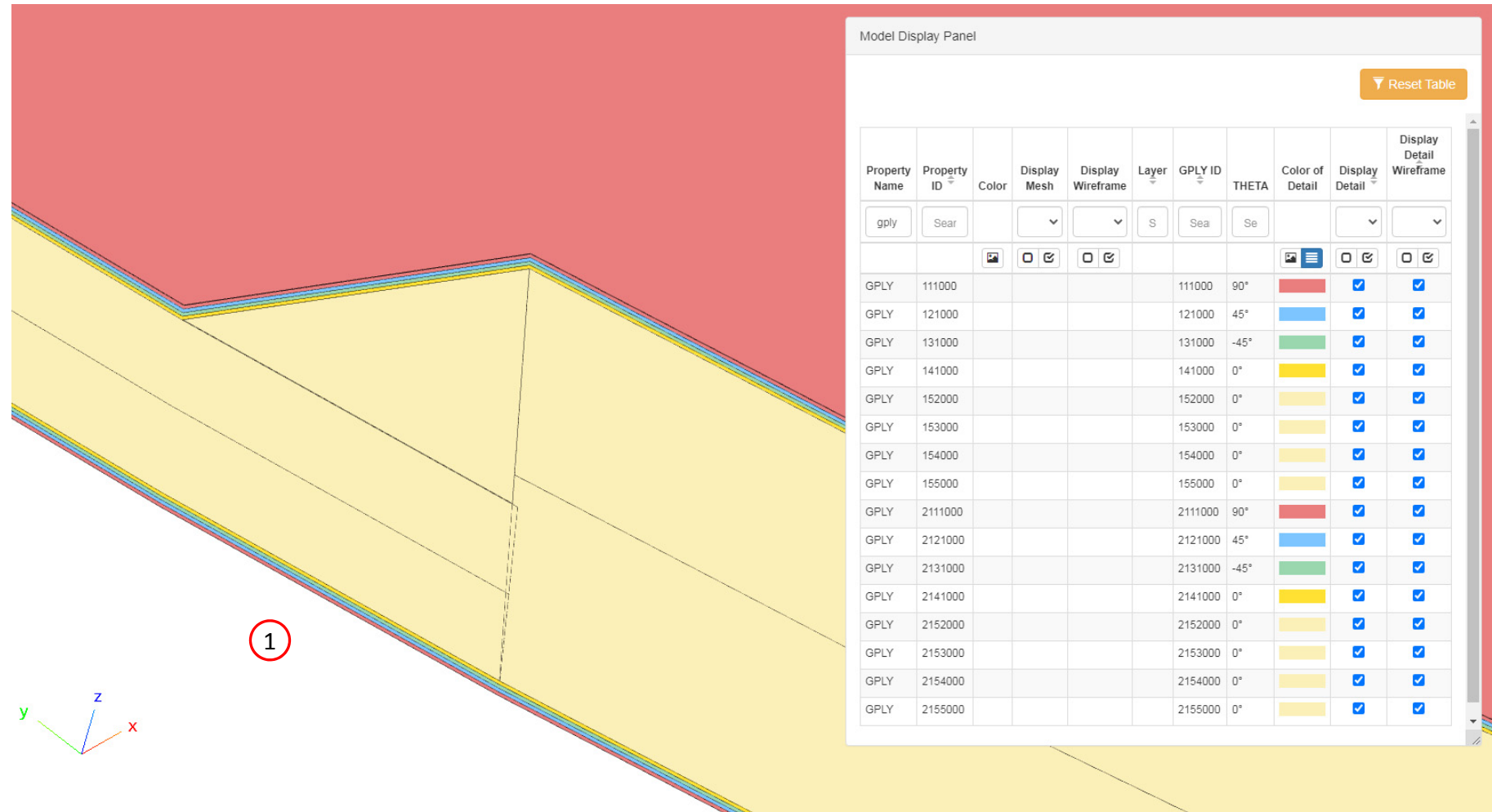
Model Display Panel

Reset Table

Property Name	Property ID	Color	Display Mesh	Display Wireframe	Layer	GPLY ID	THETA	Color of Detail	Display Detail	Display Detail Wireframe
gply	Sear				S	Sea	Se			
GPLY	111000					111000	90°			
GPLY	121000					121000	45°			
GPLY	131000					131000	-45°			
GPLY	141000					141000	0°			
GPLY	152000					152000	0°			
GPLY	153000					153000	0°			
GPLY	154000					154000	0°			
GPLY	155000					155000	0°			
GPLY	2111000					2111000	90°			
GPLY	2121000					2121000	45°			
GPLY	2131000					2131000	-45°			
GPLY	2141000					2141000	0°			
GPLY	2152000					2152000	0°			
GPLY	2153000					2153000	0°			
GPLY	2154000					2154000	0°			
GPLY	2155000					2155000	0°			

# Display GPLYs

1. Rotate and zoom in to the model to see how the plies are tapered around the new core thicknesses



# Summary of Optimized Designs

A comparison is made between the starting and final composite designs from phase B and D. Observe the following:

1. ~23% mass savings. The mass of the core was reduced from 2.203330E-04 to 1.70E-04.
2. In both designs, the buckling load factor is greater than 1.0, so both designs are feasible.

The core shape and core number optimization has been a success.

	Starting Design	Design After Topometry Optimization	Design After Core Shape and Core Number Optimization
	Tutorial Phase B	Tutorial Phase C	Tutorial Phase D
Total Mass	3.9503E-04	2.97E-4	3.444094E-04
Mass of Non-design Region (Plies)	1.746926E-04	1.746926E-04	1.746926E-04
Mass of Design Region (Core)	<b>2.203330E-04</b>	<b>1.22E-04</b>	<b>1.70E-04</b>
Buckling Load Factor, Subcase 2	1.064771 (OK)	9.9758E-01 (NOT OK)	1.013359 (OK)

End of Tutorial



# Appendix

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# Appendix Contents

---

- PCOMPG Zones
- Options for Ply Number Optimization
- GPLY ID Numbering Convention (sPLC000)

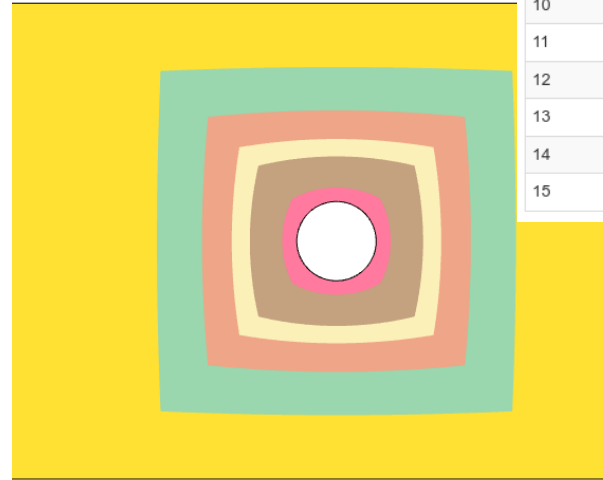
# PCOMPG Zones

---

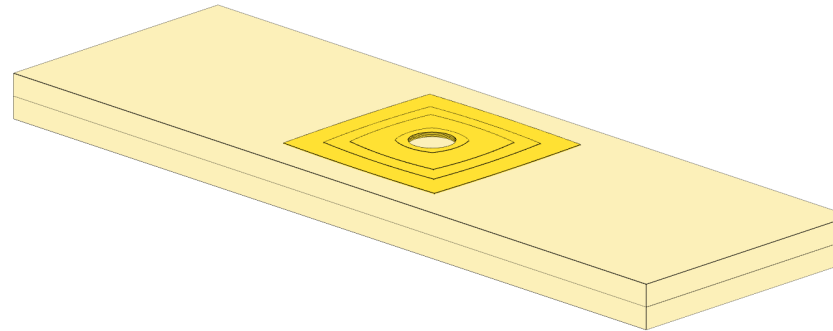
# PCOMPG Zones

The ply shapes in the final composite may be controlled. When ply shapes are included or excluded, the PCOMPG zones will vary. Inspect the PCOMPG zones since these zones indicate what the final composite will look like.

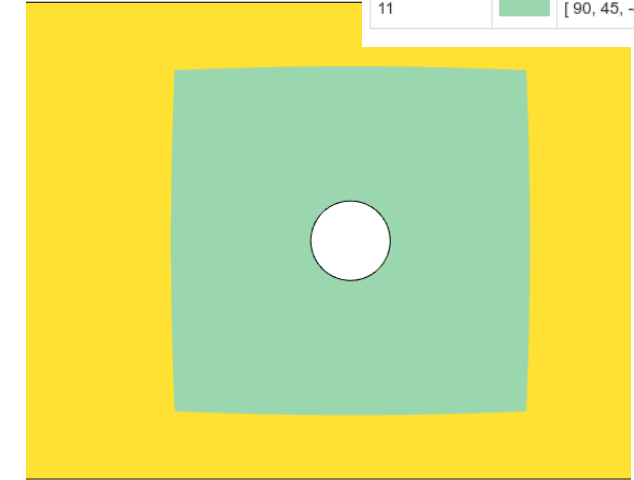
## More Ply Shapes



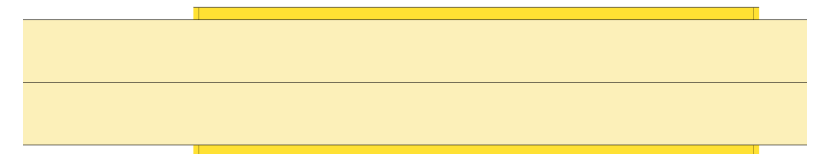
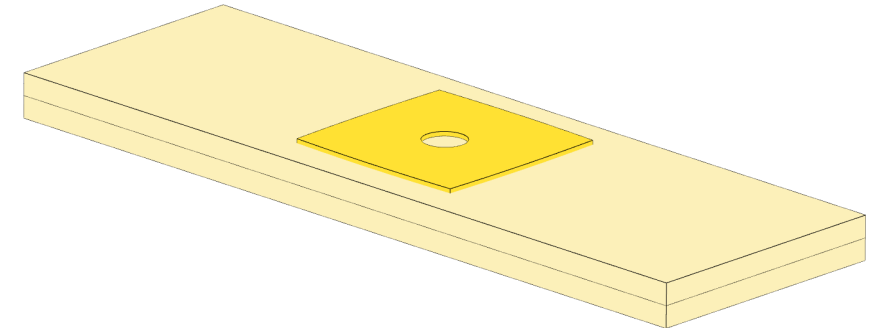
PCOMPG ID	Color	Stack
10	Yellow	[ 90, 45, -45, 0, 0 <sub>Core</sub> ]S
11	Green	[ 90, 45, -45, 0 <sub>2</sub> , 0 <sub>Core</sub> ]S
12	Orange	[ 90, 45, -45, 0 <sub>3</sub> , 0 <sub>Core</sub> ]S
13	Light Yellow	[ 90, 45, -45, 0 <sub>4</sub> , 0 <sub>Core</sub> ]S
14	Brown	[ 90, 45, -45, 0 <sub>5</sub> , 0 <sub>Core</sub> ]S
15	Pink	[ 90, 45, -45, 0 <sub>6</sub> , 0 <sub>Core</sub> ]S



## Fewer Ply Shapes



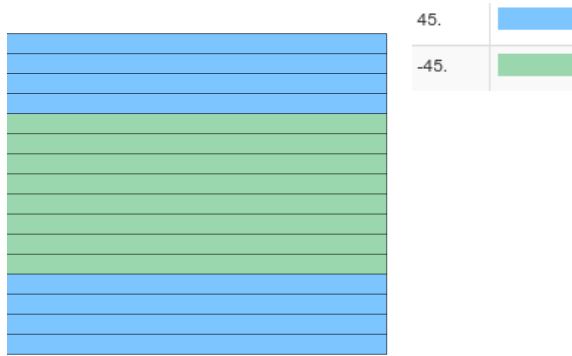
PCOMPG ID	Color	Stack
10	Yellow	[ 90, 45, -45, 0, 0 <sub>Core</sub> ]S
11	Green	[ 90, 45, -45, 0 <sub>2</sub> , 0 <sub>Core</sub> ]S



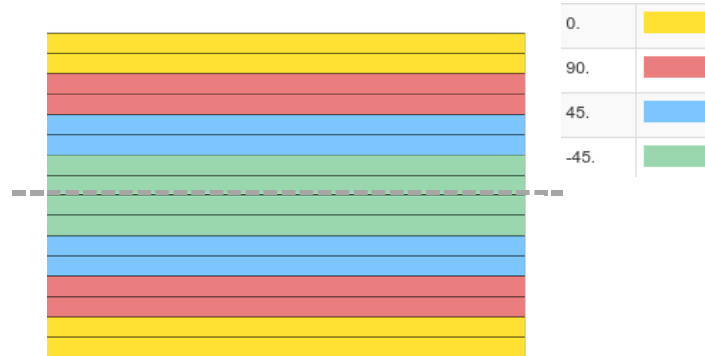
# Options for Ply Number Optimization

---

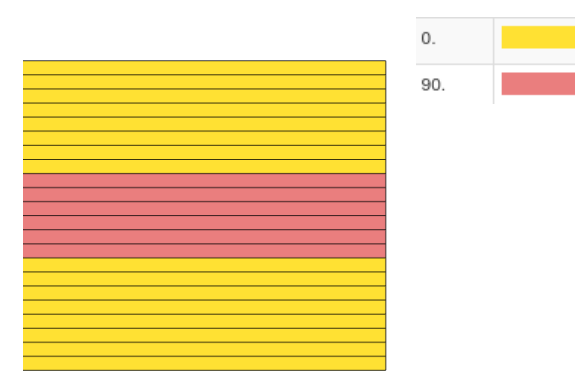
# Options for Ply Number Optimization



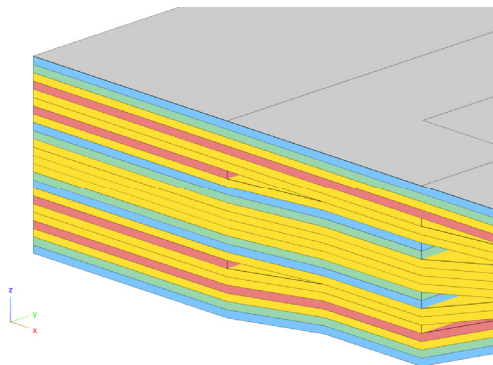
Balance



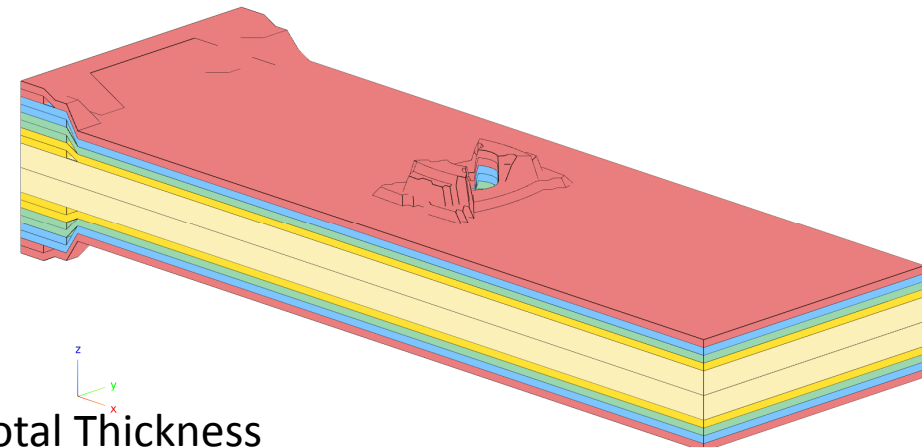
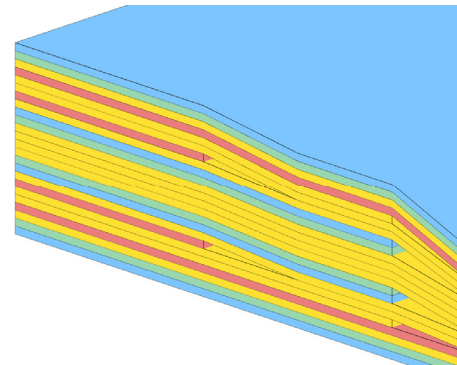
Symmetry



X% Design Rule



Z0 Offset



Total Thickness

# Options for Ply Number Optimization

## Constraints on Responses

### Constraints on Responses

- Ply Stress
- Ply Strain
- Failure Index
- Strength Ratio
- And more

$\epsilon_j$ Maximum Ply Strain	$\sigma_j$ Maximum Ply Stress	<b>FI</b> Failure Index	<b>SR</b> Strength Ratio
---------------------------------	-------------------------------	-------------------------	--------------------------

**Response to Show**

- Normal-1
- Normal-2
- Shear-12
- Shear-1Z
- Shear-2Z
- Shear angle
- Major principal
- Minor principal
- Maximum shear
- Failure Index(FP) for direct stresses/strains
- Failure Index(FB) for interlaminar shear-stress
- Strength Ratio(SP) for direct stresses/strains
- Strength Ratio(SB) for interlaminar shear-stress

# Options for Ply Number Optimization

## Constraints on Responses

Response	Stress	Strain
Normal-1	$\sigma_1$	$\varepsilon_1$
Normal-2	$\sigma_2$	$\varepsilon_2$
Shear-12	$\tau_{12}$	$\gamma_{12}$
Shear-1Z	$\tau_{xz}$	$\gamma_{xz}$
Shear-2Z	$\tau_{yz}$	$\gamma_{yz}$
Shear Angle	$\theta_p$	$\theta_p$
Major Principal	$\sigma_{max}$	$\varepsilon_{max}$
Minor Principal	$\sigma_{min}$	$\varepsilon_{min}$
Maximum shear	$\tau_{max}$	$\gamma_{max}$
Failure Index(FP) for direct stresses/strains	FP	
Failure Index(FB) for interlaminar shear-stress	FB	
Strength Ratio(SP) for direct stresses/strains	SP	
Strength Ratio(SB) for interlaminar shear-stress	SB	



# Options for Ply Number Optimization

## Responses in F06 File

STRESSES IN LAYERED COMPOSITE ELEMENTS (QUAD4)											
ELEMENT	PLY	STRESSES IN FIBER AND MATRIX DIRECTIONS				INTER-LAMINAR STRESSES		PRINCIPAL STRESSES (ZERO SHEAR)			MAX
ID	ID	NORMAL-1	NORMAL-2	SHEAR-12		SHEAR XZ-MAT	SHEAR YZ-MAT	ANGLE	MAJOR	MINOR	SHEAR
0	8264	1	1.78751E+01	-1.68306E+01	2.41331E+00	4.82031E-02	-1.05478E-01	3.96	1.80421E+01	-1.69976E+01	1.75198E+01
0	8264	2	-4.22498E+01	-6.36100E+00	1.10039E+01	1.43883E-01	-1.50335E-01	74.24	-3.25576E+00	-4.53551E+01	2.10497E+01
0	8264	3	-2.06818E+01	-9.60743E+00	-1.06974E+01	2.36897E-01	-1.93942E-01	-58.68	-3.09908E+00	-2.71901E+01	1.20455E+01
			$\sigma_1$	$\sigma_2$	$\tau_{12}$	$\tau_{xz}$	$\tau_{yz}$	$\theta_p$	$\sigma_{max}$	$\sigma_{min}$	$\tau_{max}$

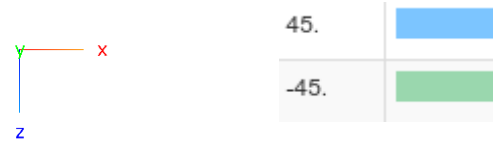
STRAINS IN LAYERED COMPOSITE ELEMENTS (QUAD4)											
ELEMENT	PLY	STRAINS IN FIBER AND MATRIX DIRECTIONS				INTER-LAMINAR	STRAINS	PRINCIPAL	STRAINS (ZERO SHEAR)		MAX
ID	ID	NORMAL-1	NORMAL-2	SHEAR-12	SHEAR XZ-MAT	SHEAR YZ-MAT	ANGLE	MAJOR	MINOR	SHEAR	
0	8264	1	-3.81162E-04	1.87582E-03	2.83217E-04	0.0	0.0	86.42	1.88467E-03	-3.90012E-04	2.27468E-03
0	8264	2	6.05720E-04	8.88938E-04	-2.25698E-03	0.0	0.0	-48.58	1.88467E-03	-3.90012E-04	2.27468E-03
0	8264	3	8.88938E-04	6.05720E-04	2.25698E-03	0.0	0.0	41.42	1.88467E-03	-3.90012E-04	2.27468E-03
		$\epsilon_1$	$\epsilon_2$	$\gamma_{12}$	$\gamma_{xz}$	$\gamma_{yz}$	$\theta_p$	$\epsilon_{max}$	$\epsilon_{min}$	$\gamma_{max}$	

FAILURE INDICES FOR LAYERED COMPOSITE ELEMENTS (QUAD4)					FAILURE INDEX FOR ELEMENT			FLAG
ELEMENT	FAILURE THEORY	PLY ID	FP=FAILURE INDEX FOR PLY (DIRECT STRESSES/STRAINS)	FB=FAILURE INDEX FOR BONDING (INTER-LAMINAR STRESSES)	MAX OF FP,FB FOR ALL PLIES			
8264	HILL	1	0.0226					
[...]					0.0012			
		17	0.0668					
					0.0012			
		18	0.2976					
			$FP$		$FB$		0.2976	

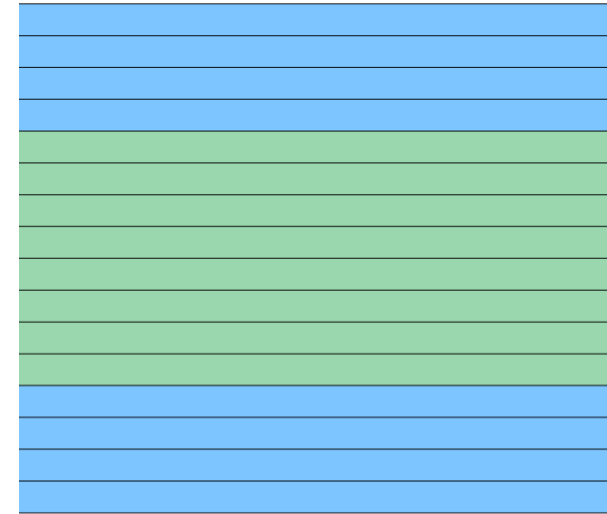
# Balance

1. Ensure the starting composite has both  $+\theta$  AND  $-\theta$  plies, e.g.  $\pm 45^\circ$ ,  $\pm 60^\circ$ , etc.
2. Use Link Plies in the web app

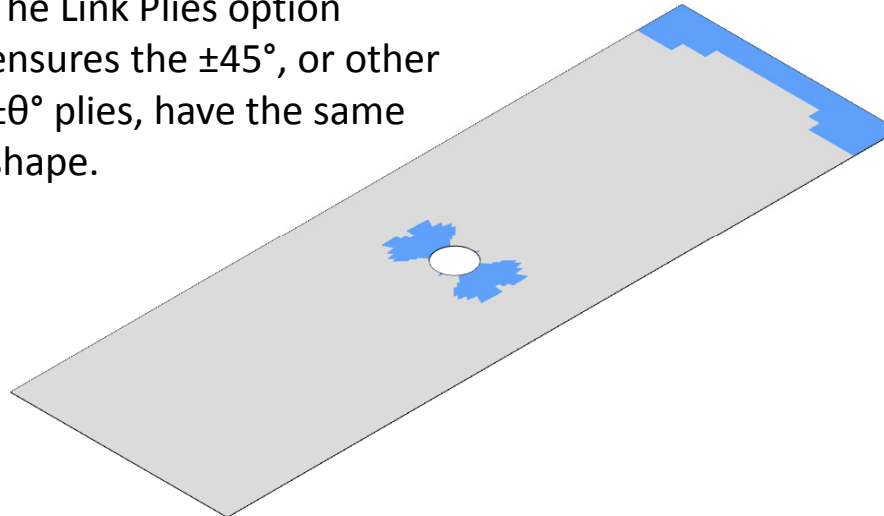
Not Balanced  
[45°]



Balanced  
[45°/-45°]



The Link Plies option ensures the  $\pm 45^\circ$ , or other  $\pm \theta^\circ$  plies, have the same shape.



Topometry

Ply Shape Candidates - PCOMP 1

Threshold Step Size: 0.0187567

Options: [Link Plies](#)

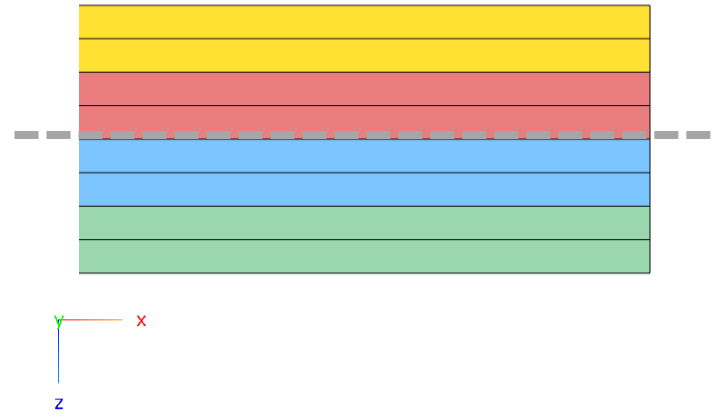
Display Ply Shape	GPLY ID	Ply	Theta	Candidate	Action	Filter Slider	Pick Mode
<input type="checkbox"/>	11100	1	90.	1	+		
<input type="checkbox"/>	12100	2	45.	1	+		
<input checked="" type="checkbox"/>	12200	2	45.	2	x		
<input type="checkbox"/>	13100	3	-45.	1	+		
<input type="checkbox"/>	13200	3	-45.	2	x		
<input type="checkbox"/>	14100	4	0.	1	+		
<input type="checkbox"/>	15100	5	0.	1	+		

Options: [Link Plies](#)

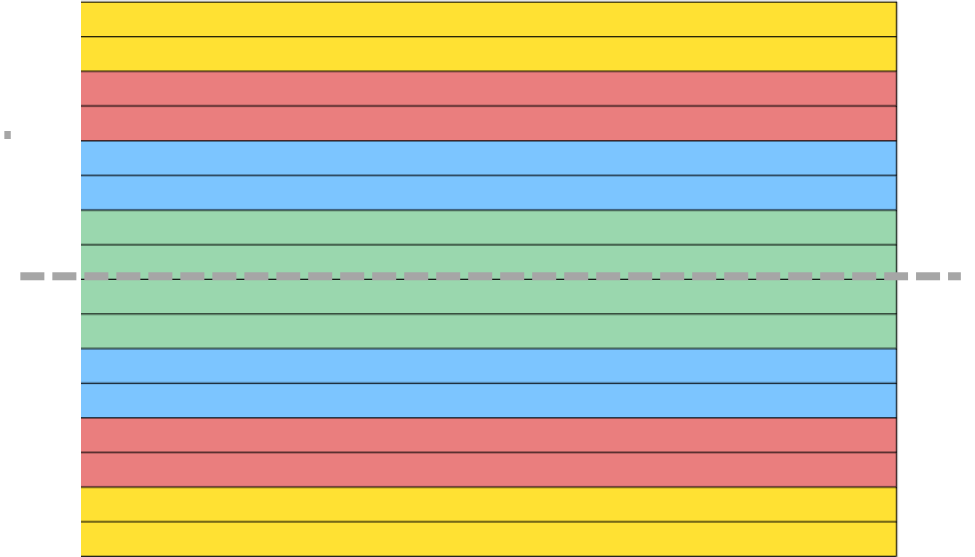
# Symmetry

1. Set the laminate option (LAM) to symmetry (SYM)

## Asymmetric



## Symmetric



## Respective PCOMP/PCOMPG Entries

Entry Name  
PCOMPG

Laminate Option  
SYM 1

Ply Number Optimization Checklist

- ☒ Ply Thickness
- ☒ Z0 Offset
- ☒ % Rule Design
- ☒ Total Thickness
- ☒ Constraints

Save New Entries

\$	1	2	3	4	5	6
PCOMPG	2				90.	HILL
	11100	101	.3755	90.	YES	
	12100	101	.3755	45.	YES	
	13100	101	.3755	-45.	YES	
	14100	101	.3755	0.	YES	
	15100	501	3.175	0.	YES	
	215100	501	3.175	0.	YES	
	214100	101	.3755	0.	YES	
	213100	101	.3755	-45.	YES	
	212100	101	.3755	45.	YES	
	211100	101	.3755	90.	YES	
PCOMPG	3				90.	HILL
	11100	101	.3755	90.	YES	
	12100	101	.3755	45.	YES	
	12200	101	.3755	45.	YES	
	13100	101	.3755	-45.	YES	
	13200	101	.3755	-45.	YES	
	14100	101	.3755	0.	YES	
	15100	501	3.175	0.	YES	
	215100	501	3.175	0.	YES	
	214100	101	.3755	0.	YES	
	213200	101	.3755	-45.	YES	

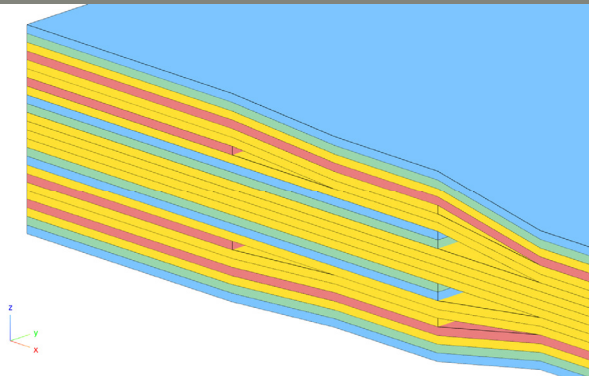
0.	
90.	
45.	
-45.	

# Offset to Outer Mold Line

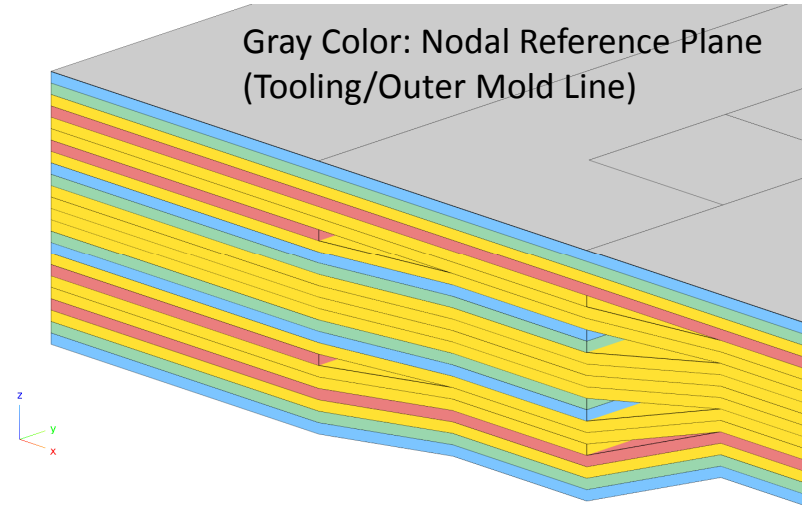
Different manufacturing methods require different offsets.

1. Use Z0 Offset Relationship to ensure the composite is offset to reflect the manufacturing tooling, e.g. outer mold line

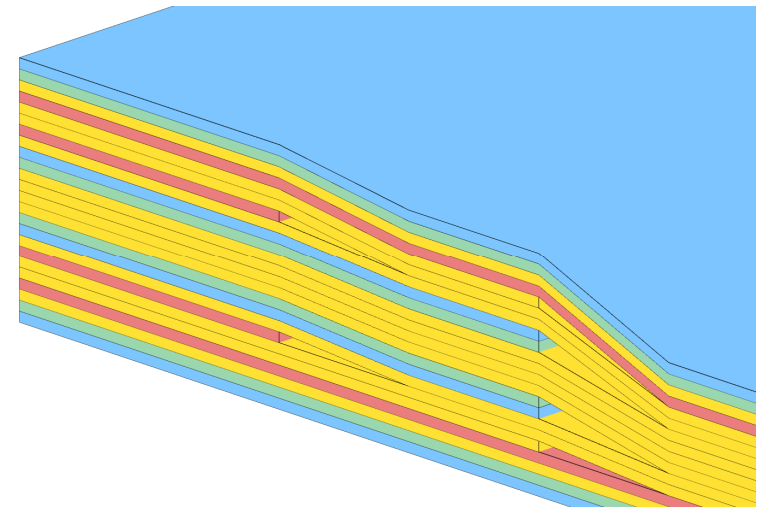
## Offset Default (No Offset)



## Offset Bottom



## Offset Top



**Additional Optimization Options**

**Z0 Offset Relationship** 1

Default ▼

Default

Above

Below

Default: -0.5 times the element thickness

- Default: -0.5 times the element thickness
- Above: 1.0 times the element thickness
- Below: -1.0 times the element thickness

### % Rule Design

Theta [°]	% Lower Allowed Limit	% Upper Allowed Limit
-45.	Lower	Upper
0.	Lower	Upper
45.	Lower	Upper
90.	Lower	Upper

### Total Thickness

Lower Allowed Limit	Upper Allowed Limit
Lower	Upper

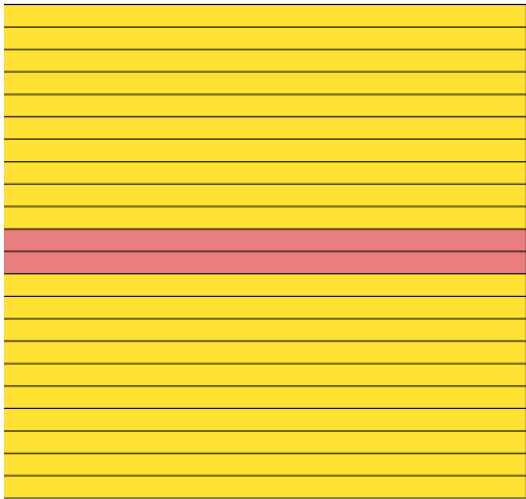
0.	
90.	
45.	
-45.	

# 10% Design Rule

During optimization, there may be too few plies of a particular angle, e.g. 90°

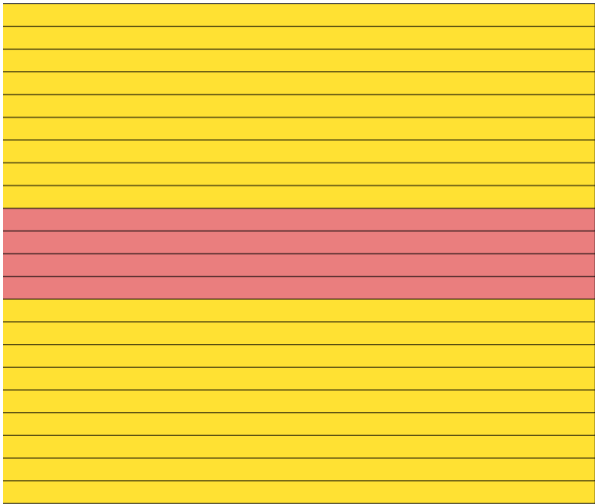
- 1. Use % Rule Design to put a lower bound on the percentage of specific ply angles

No percent constraint



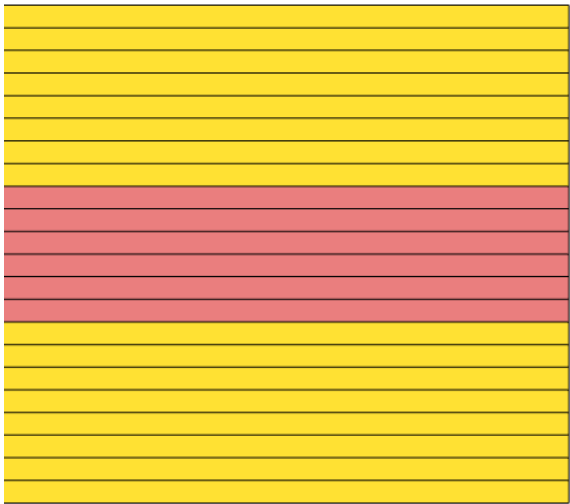
$2 \text{ plies} / 22 \text{ plies} \times 100 = 9\%$

Minimum of 10% of plies are 90°



$4 \text{ plies} / 22 \text{ plies} \times 100 = 18\%$

Minimum 20% of plies are 90°



$6 \text{ plies} / 22 \text{ plies} \times 100 = 27\%$

## Additional Optimization Options

### Z0 Offset Relationship

Default

Distance from the reference plane to the bottom surface. The element thickness is the total thickness of all layers.

- Default: -0.5 times the element thickness
- Above: 1.0 times the element thickness
- Below: -1.0 times the element thickness

% Rule Design		
Theta [°]	% Lower Allowed Limit	% Upper Allowed Limit
-45.	Lower	Upper
0.	Lower	Upper
45.	Lower	Upper
90.	10.	1

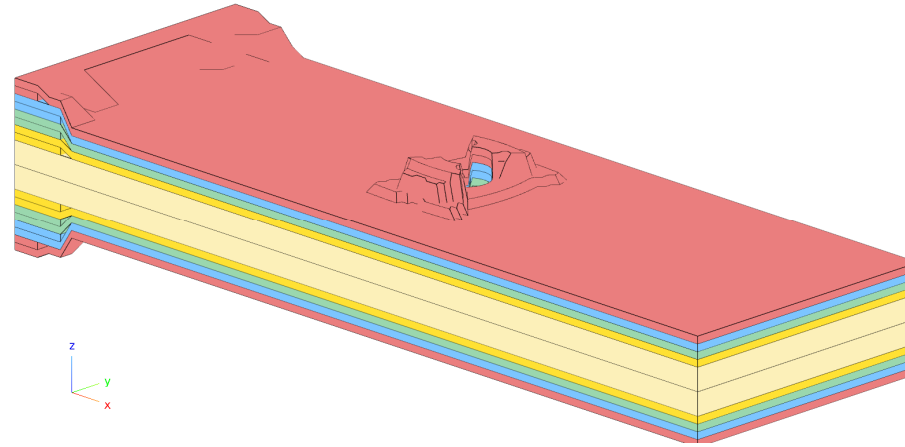
Thickness	0.	
	90.	
Lower Allowed Limit	Upper Allowed Limit	
	Upper	

# Total Thickness

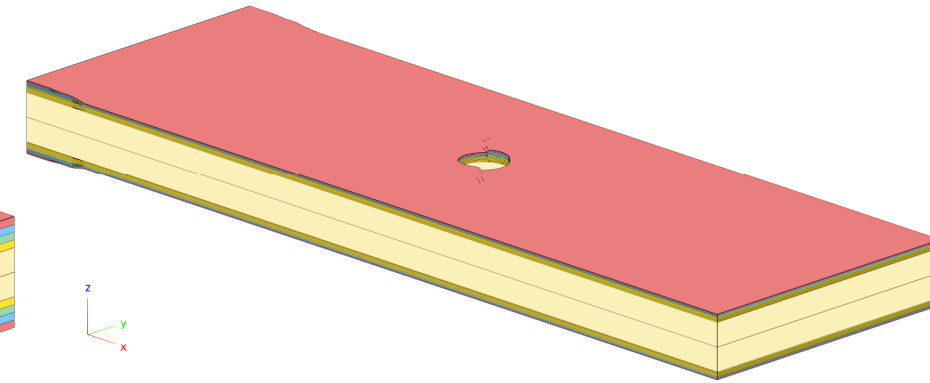
The optimizer may inadvertently produce a composite that is very thick.

1. Use the Total Thickness option to limit the total thickness of the composite

No Total Thickness Constraint



With Total Thickness Constraint



## Additional Optimization Options

### Z0 Offset Relationship

Default

Distance from the reference plane to the bottom surface. The element thickness is the total thickness of all layers.

- Default: -0.5 times the element thickness
- Above: 1.0 times the element thickness
- Below: -1.0 times the element thickness

### % Rule Design

Theta [°]	% Lower Allowed Limit	
-45.	Lower	
0.	Lower	
45.	Lower	Upper
90.	Lower	Upper

### Total Thickness

#### Lower Allowed Limit

Lower

#### Upper Allowed Limit

8.85

1

# GPLY ID Numbering Convention (sPLC000)

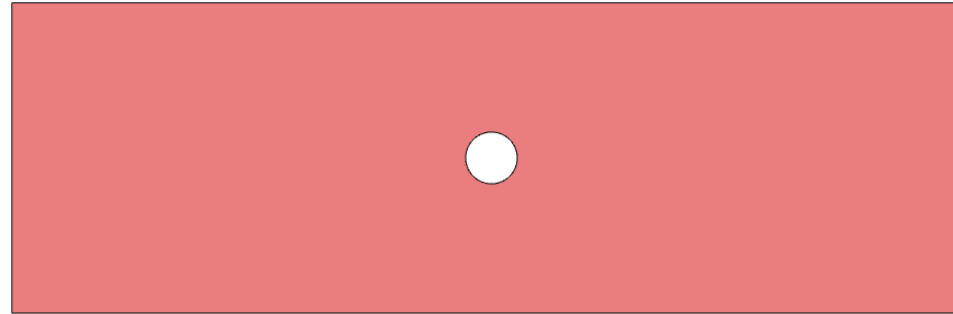
---

# GPLY ID Numbering Convention (sPLC000)

- When configuring ply shapes, the original PCOMP entry will be replaced by multiple PCOMPG entries. The original PCOMP entry is said to be the parent PCOMP and the new PCOMPG entries are said to be the child PCOMPG entries.
- A ply numbering convention is used by the web app to help identify the origin of the various new plies.

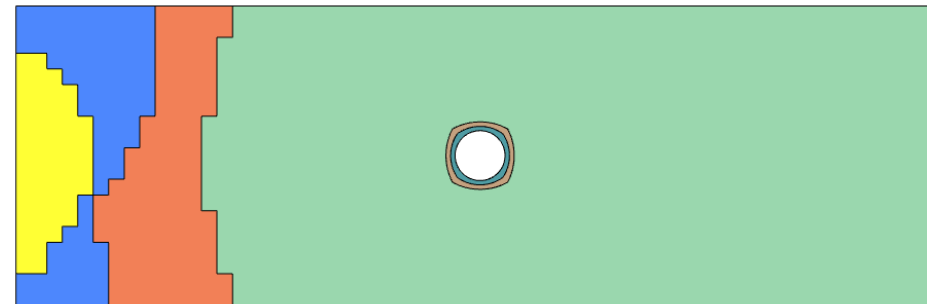
## Parent PCOMP

PCOMP	1	
-------	---	---









PCOMP	8			90.
	101	.3755	90.	YES
	101	.3755	45.	YES
	101	.3755	-45.	YES
	101	.3755	0.	YES
	501	3.175	0.	YES

## Child PCOMPGs



PCOMPG	2			90.	HILL
	111000	101	1.00000	90.	YES
	121000	101	1.00000	45.	YES
	131000	101	1.00000	-45.	YES
	141000	101	1.00000	0.	YES
	151000	501	3.175	0.	YES
	2151000	501	3.175	0.	YES
	2141000	101	1.00000	0.	YES
	2131000	101	1.00000	-45.	YES
	2121000	101	1.00000	45.	YES
	2111000	101	1.00000	90.	YES
PCOMPG	3			90.	HILL
	111000	101	1.00000	90.	YES
	152000	101	1.00000	90.	YES
	121000	101	1.00000	45.	YES
	162000	101	1.00000	45.	YES
	131000	101	1.00000	-45.	YES
	132000	101	1.00000	-45.	YES

PCOMPG	2	
PCOMPG	3	
PCOMPG	4	
PCOMPG	5	
PCOMPG	6	
PCOMPG	7	

[...]



# GPLY ID Numbering Convention (sPLC000)

Each ply shape candidate is assigned a GPLY ID formatted in a special numbering convention. This formatted GPLY ID is read from right to left.

- The last 3 digits 000 is a place holder used by the ply number optimization. After ply number optimization, the 3 digits 000 are replaced by 001, 002, 003, etc. and will depend on the number of plies determined by the ply number optimization.
- The next digit C indicates the candidate number of that ply shape. The Viewer web app is used to construct multiple ply shape candidates.
- The digit L indicates the layer in the original parent PCOMP.
- The digit P indicates the ID of the original parent PCOMP entry. If the original ID is long, for example 1008, the ID is reduced to a single digit.
- A leading digit of 2 indicates the ply is a mirror ply and is used when the composite is symmetric.

For example, GPLY ID 141000 indicates the ply shape candidate was constructed based on a parent PCOMP ID=1 AND the ply shape was constructed based on the model.ply0004 file (layer 4 of the parent PCOMP).

Parent PCOMP					
PCOMP	1			90.	HILL
	101	.3755	90.	YES	Layer 1
	101	.3755	45.	YES	Layer 2
	101	.3755	-45.	YES	Layer 3
	101	.3755	0.	YES	Layer 4
	501	3.175	0.	YES	Layer 5

Child PCOMPG					
PCOMPG	2			90.	HILL
	111000	101	1.00000	90.	YES
	121000	101	1.00000	45.	YES
	131000	101	1.00000	-45.	YES
	141000	101	1.00000	0.	YES
	151000	501	3.175	0.	YES
	2151000	501	3.175	0.	YES
	2141000	101	1.00000	0.	YES
	2131000	101	1.00000	-45.	YES
	2121000	101	1.00000	45.	YES
	2111000	101	1.00000	90.	YES

## Ply Numbering Convention (sPLC000)

GPLYID=2141000					
	2	1	4	1	000
Symmetry Flag	<				
PCOMP ID P	<--				
LAYER L	<----				
Candidate C	<-----				
ith Ply 000	<-----				