Workshop – Composite Coupon – Phase C – Data Preparation for Ply Shape Optimization

AN MSC NASTRAN SOL 200 TUTORIAL

Questions? Email: christian@ the-engineering-lab.com

Composite Workshop

This workshop is phase C of a 5-phase workshop.

Phase A

Workshop – Composite Coupon – Phase A – Determination of the optimal 0° direction of a composite

- Perform an optimization on the angle of ply 1 to maximize stiffness
- Tools Used: MSC Nastran and SOL 200 Web App

Phase B

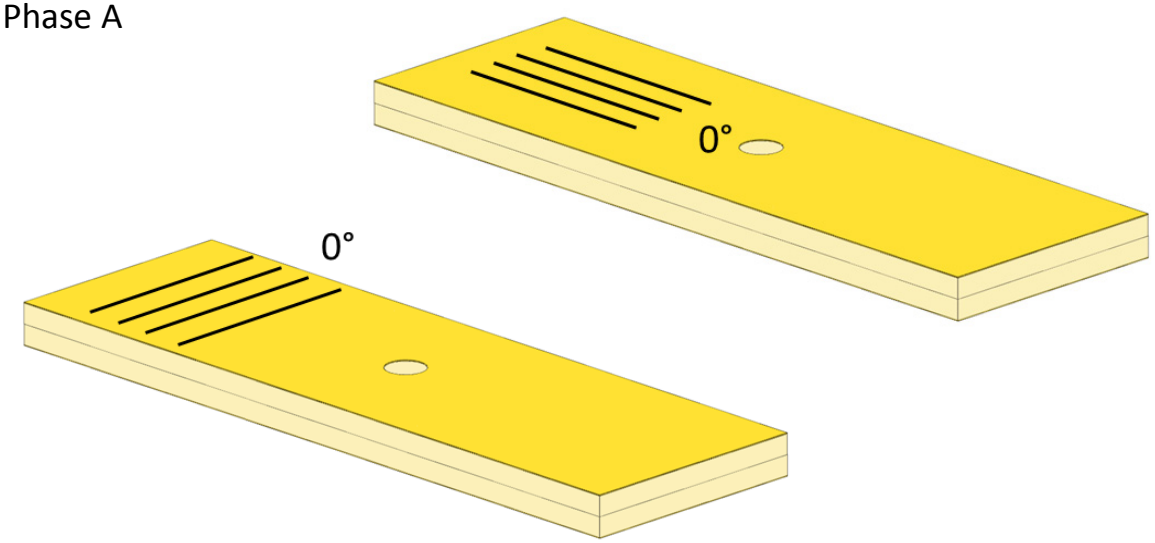
Workshop – Composite Coupon – Phase B – Baseline Ply Number Optimization

- Perform a ply number optimization with full and continuous ply shapes
- Tools Used: SOL 200 Web App (Viewer and Optimization web apps) and MSC Nastran

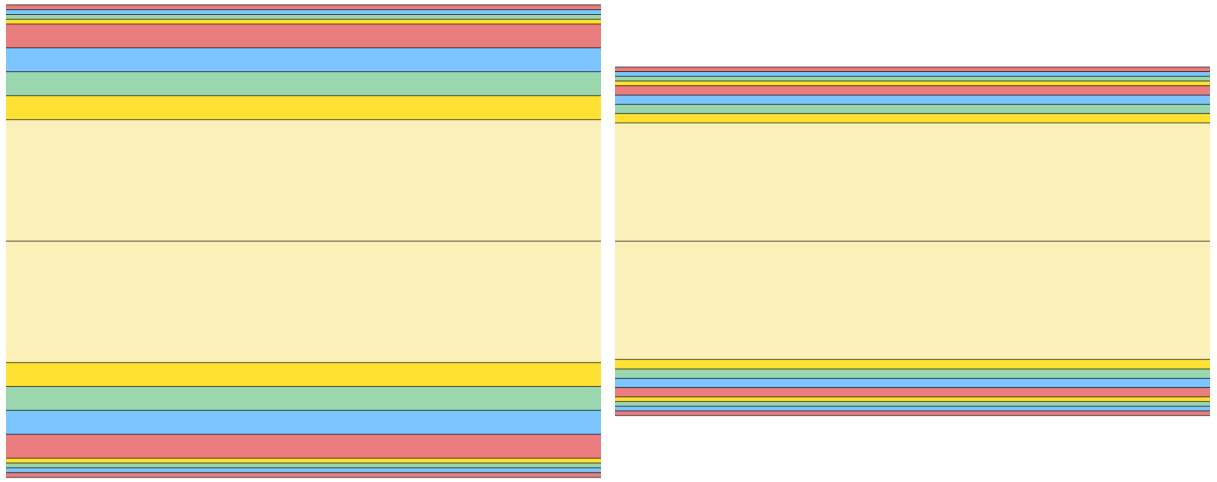
Composite Workshop

This workshop is phase C of a 5-phase workshop.

Phase A



Phase B



0° Direction Optimization

Baseline Ply Number Optimization

Composite Workshop

This workshop is phase C of a 5-phase workshop.

Phase C

Workshop – Composite Coupon – Phase C – Data Preparation for Ply Shape Optimization

- Manually create PLY000i Files
- Tools Used: Patran, MSC Nastran and SOL 200 Web App

Phase D

Workshop – Composite Coupon – Phase D – Ply Shape and Ply Number Optimization

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

Phase E

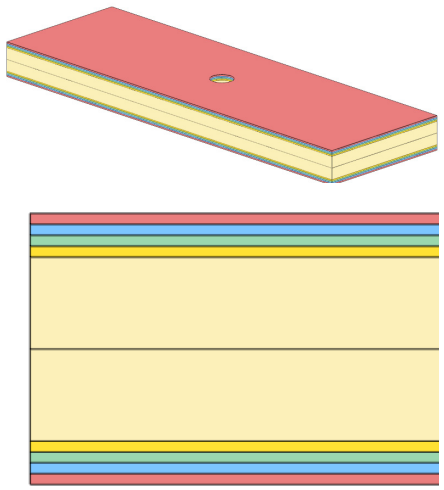
Workshop – Composite Coupon – Phase E – Stacking Sequence Optimization

- Input BDF
- Perform Stacking Sequence Optimization
- Validate Performance
- Inspect Plies
- Tools Used: SOL 200 Web App (Stacking Sequence and Viewer web apps) and MSC Nastran

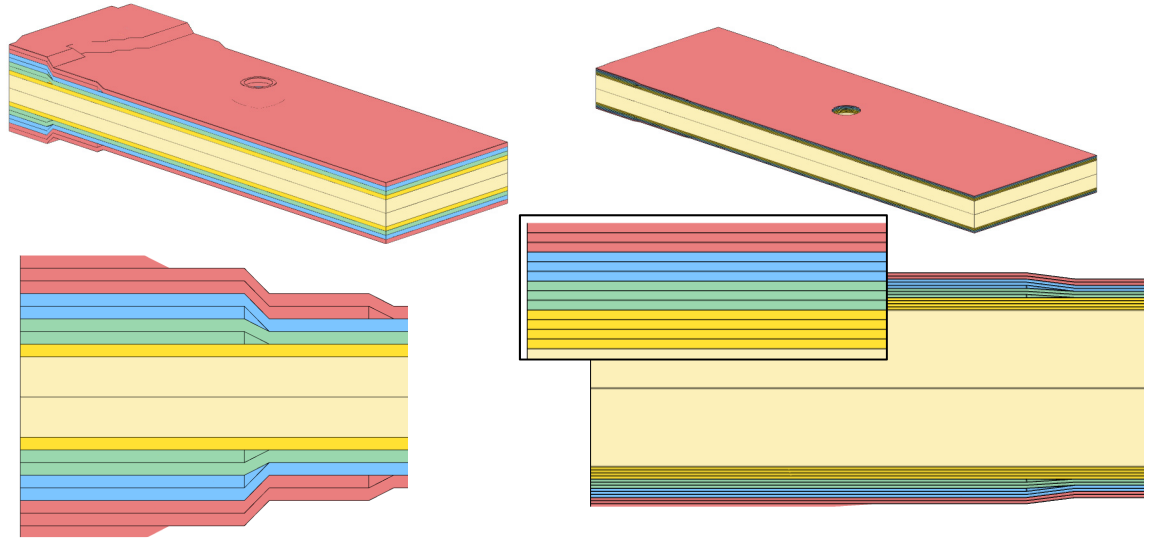
Composite Workshop

This workshop is phase C of a 5-phase workshop.

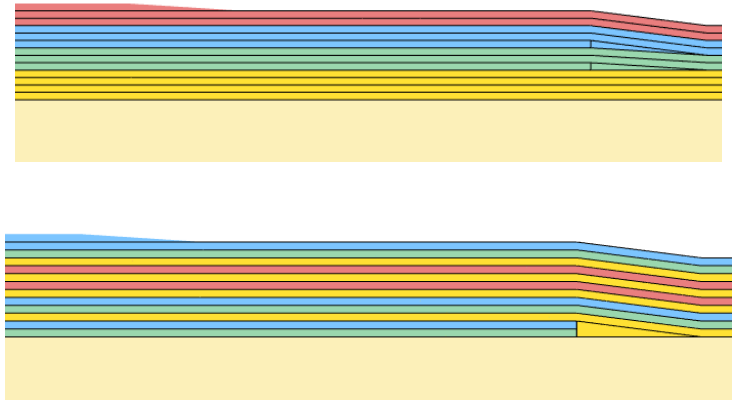
Phase C



Phase D



Phase E



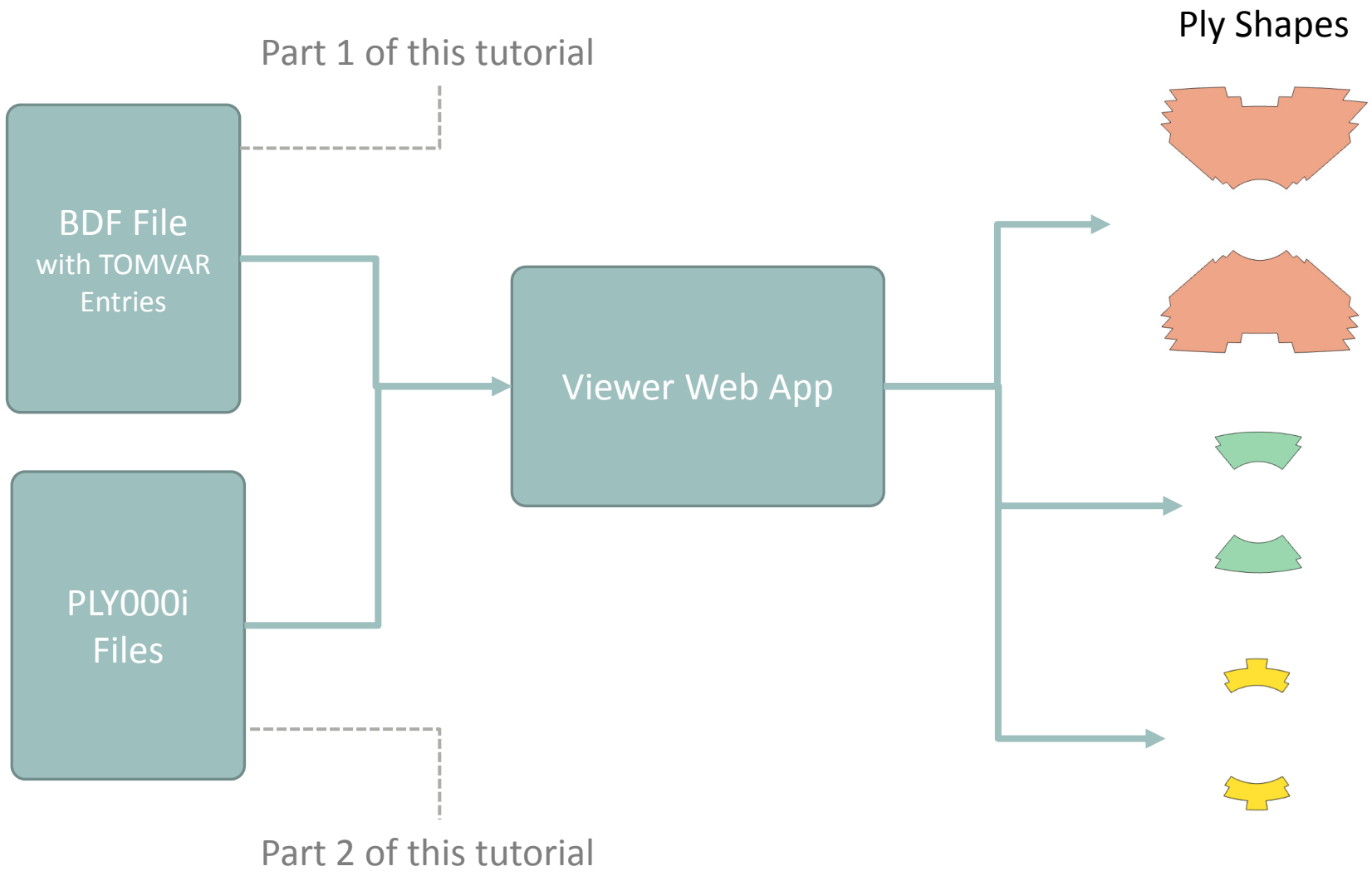
Ply Shape Optimization

Ply Number Optimization

Stacking Sequence Optimization

Goal: Prepare Data for Ply Shape Creation

- The goal is to construct ply shapes that produce a lightweight composite but satisfy failure index constraints.
- The Viewer web app will be used to construct new ply shapes, but first, BDF and PLY000i files must be prepared.
- This tutorial discusses how to prepare the BDF and PLY000i files. A separate tutorial discusses how to upload these files to the Viewer web app and how to construct new ply shapes.



Summary of Optimized Designs

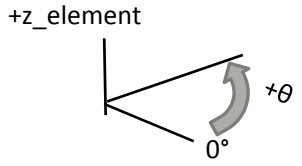
This tutorial is part of a 5-phase tutorial. Phase D and E yield optimized composites.

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

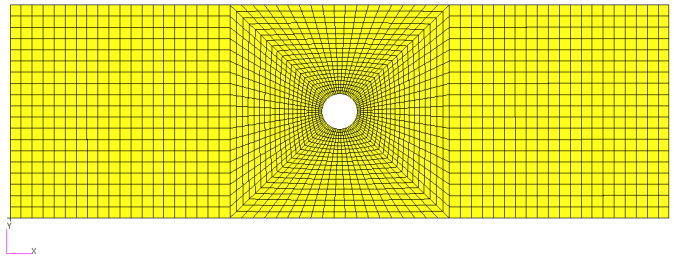
1. ~21% mass savings. The mass of the plies was reduced from 2.229851E-05 to 1.76E-05.
2. For the final composite, after stacking sequence optimization, the maximum failure index is .838 and is well under the upper allowed limit of .95.

	Starting Design	Design After Ply Shape and Ply Number Optimization	Design After Stacking Sequence Optimization
	Tutorial Phase B	Tutorial Phase D	Tutorial Phase E
Total Mass	2.825148E-05	2.356787E-05	2.356787E-05
Mass of Non-design Region (Core)	5.952966E-06	5.952966E-06	5.952966E-06
Mass of Design Region (Plies)	**2.229851E-05**	**1.76E-05**	**1.76E-05**
Max Failure Index , Subcase 1	.905 (OK)	.838 (OK)	.838 (OK)
Max Failure Index, Subcase 2	.934 (OK)	.856 (OK)	.654 (OK)

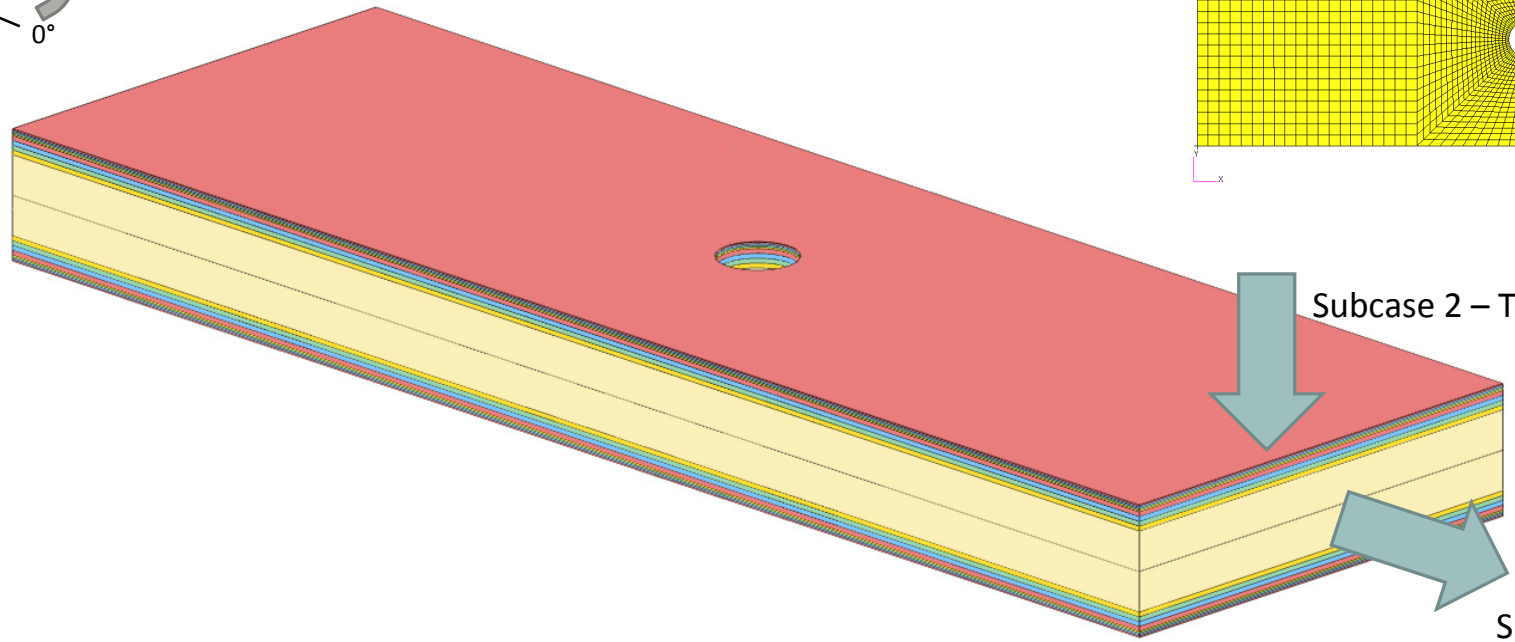
Details of the structural model



118mm x 38.1mm
Radius: 3.175mm



Edge is Clamped



Subcase 2 – Transverse Load

Subcase 1 - Tension

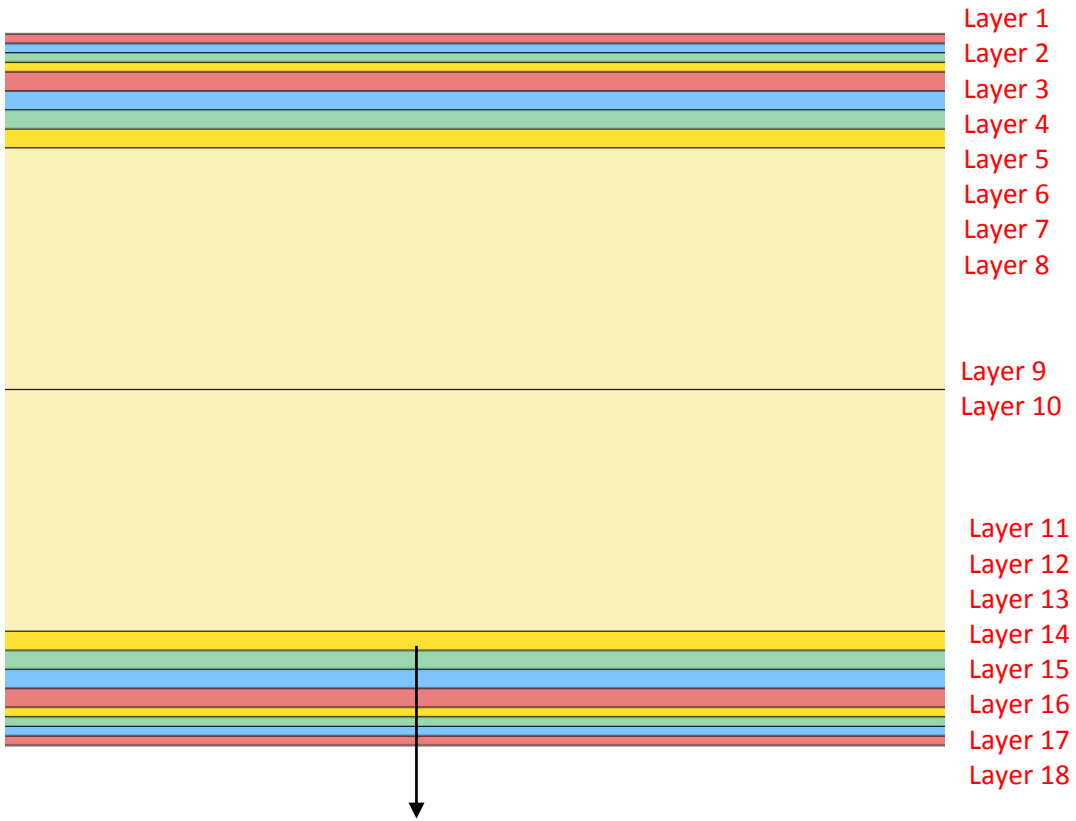
$[90/+45/-45/0/90/+45/-45/0/\ 0_{core}]_s$

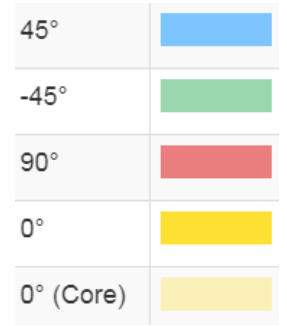
Details of the Composite Layers

This composite consists of 18 layers.

The PCOMP entry defines only 9 layers, but the LAM=SYM option indicates that the composite is symmetric. Internally, layers 10, 11, …, 18 are generated and stored.

- Layers 9 and 10 correspond to the core.
- These layers are NOT optimized.
  - Layers 1 and 18 correspond to 90° layers.
  - Layers 2 and 17 correspond to 45° layers.
  - Layers 3 and 16 correspond to -45° layers.
  - Layers 4 and 15 correspond 0° layers.
- These layers are optimized.
  - Layers 5 and 14 correspond to 90 ° layers.
  - Layers 6 and 13 correspond to 45° layers.
  - Layers 7 and 12 correspond to -45° layers.
  - Layers 8 and 11 correspond 0° layers.



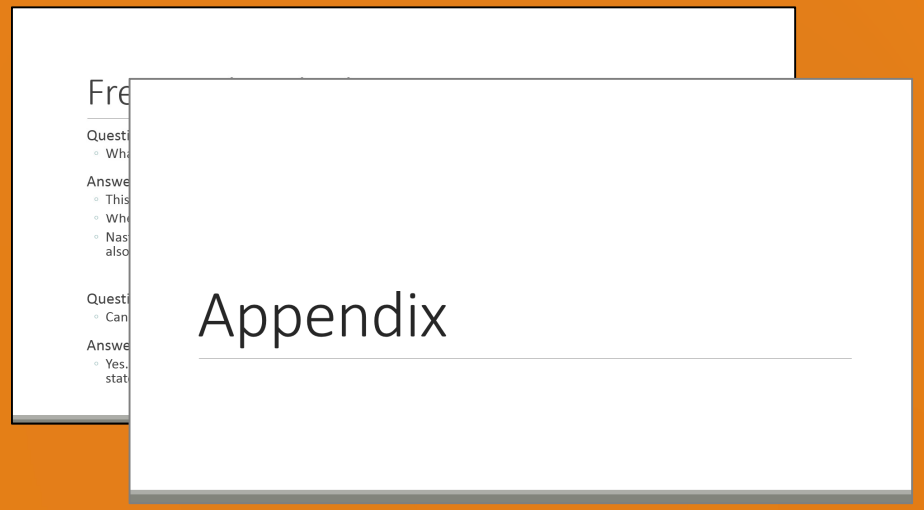



```
PCOMP     1                              90.      HILL                    SYM
          101       .125       90.       YES Layer 1
          101       .125       45.       YES Layer 2
          101       .125      -45.       YES Layer 3
          101       .125        0.       YES Layer 4
          101       .25        90.       YES Layer 5
          101       .25        45.       YES Layer 6
          101       .25        -45.      YES Layer 7
          101       .25        0.        YES Layer 8
          501      3.175       0.        YES Layer 9
```

More Information Available in the Appendix

The Appendix includes information regarding the following:

- Comments on bulk data entries compatible with ply shape optimization
- Why is a topometry optimization skipped?
- Methods to Create PLY000i Files



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

Tutorial Overview

1. Start with a .bdf or .dat file
2. Use the SOL 200 Web App to:
   - Convert the .bdf file to SOL 200
     - Design Variables
     - Design Objective
3. Manually create PLY000i files

Special Topics Covered

PLY000i Files - The PLY000i files contain information that is used to construct ply shapes. This tutorial discusses how to manually create PLY000i files.

SOL 200 Web App Capabilities

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

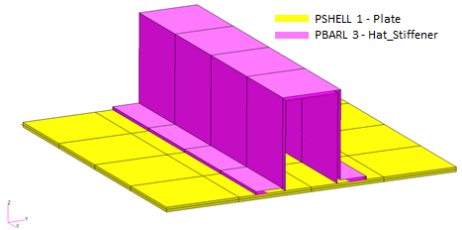
Compatibility

- 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.

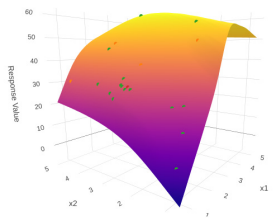
Benefits

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

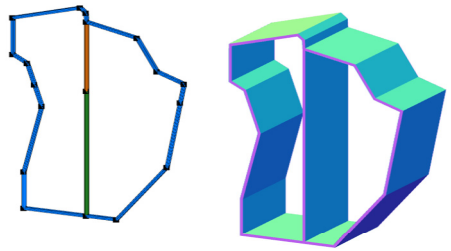
Web Apps



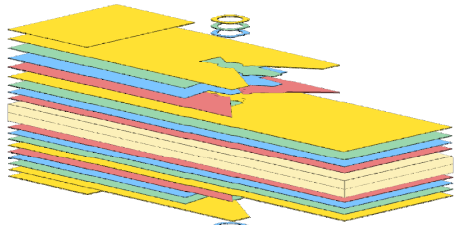
Web Apps for MSC Nastran SOL 200
Pre/post for MSC Nastran SOL 200. Support for size, topology, topometry, topography, multi-model optimization.



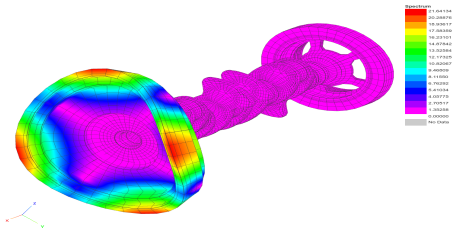
Machine Learning Web App
Bayesian Optimization for nonlinear response optimization (SOL 400)



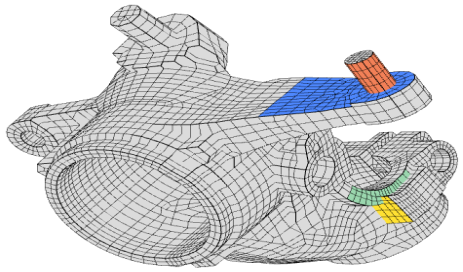
PBMSECT Web App
Generate PBMSECT and PBRSECT entries graphically



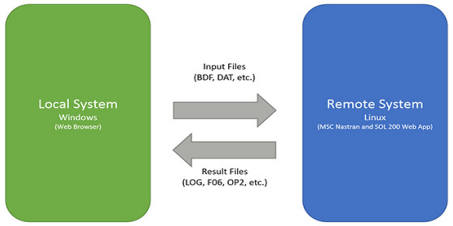
Ply Shape Optimization Web App
Optimize composite ply drop-off locations, and generate new PCOMPG entries



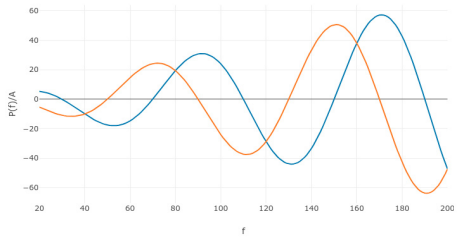
Post-processor Web App
View MSC Nastran results in a web browser on Windows and Linux



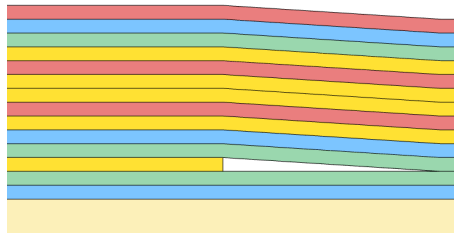
Shape Optimization Web App
Use a web application to configure and perform shape optimization.



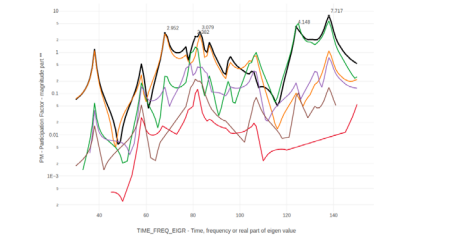
Remote Execution Web App
Run MSC Nastran jobs on remote Linux or Windows systems available on the local network



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



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



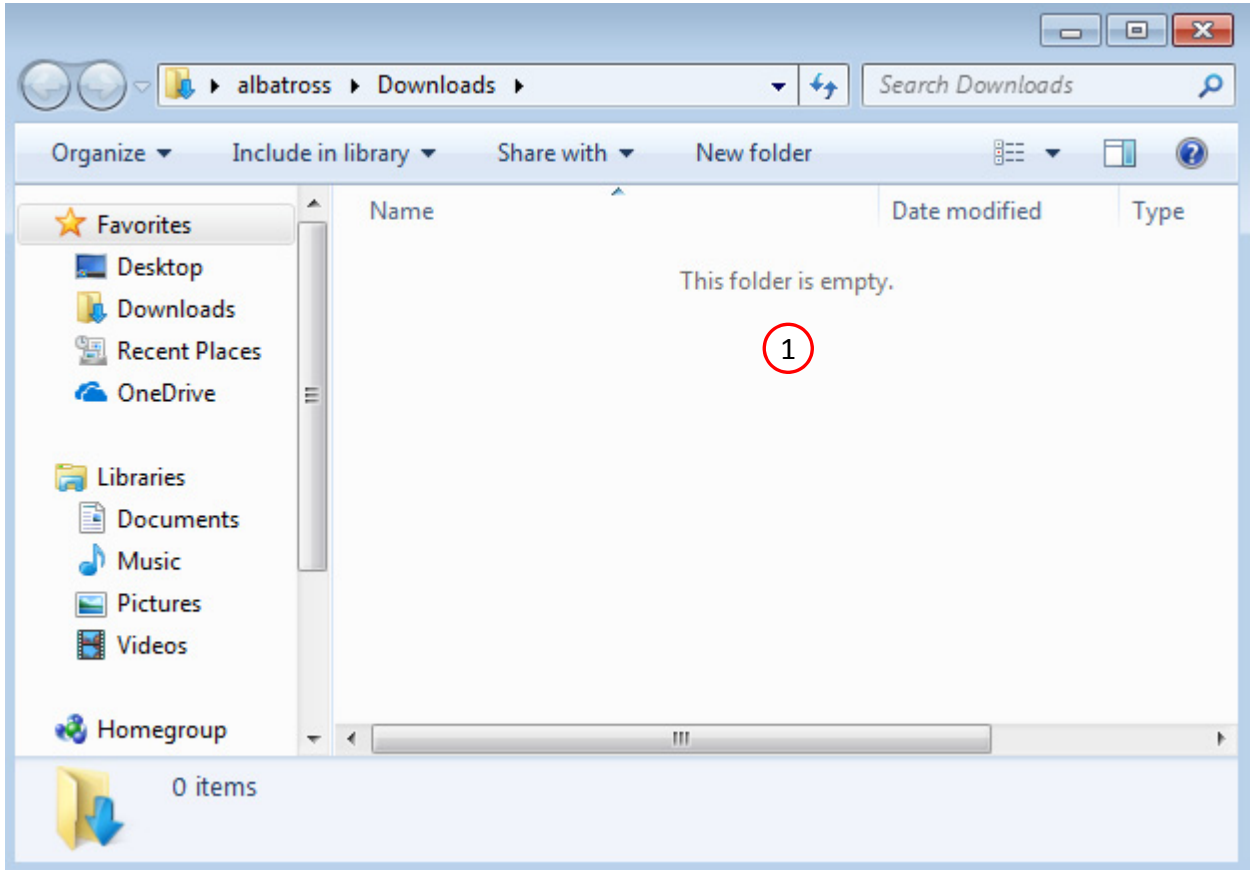
HDF5 Explorer Web App
Create graphs (XY plots) using data from the H5 file

Part 1 - BDF File with TOMVAR Entries

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

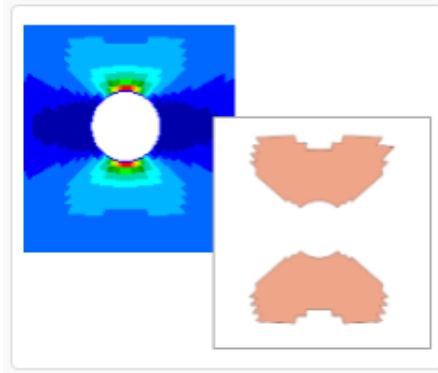
1. Click on the indicated link

- 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.



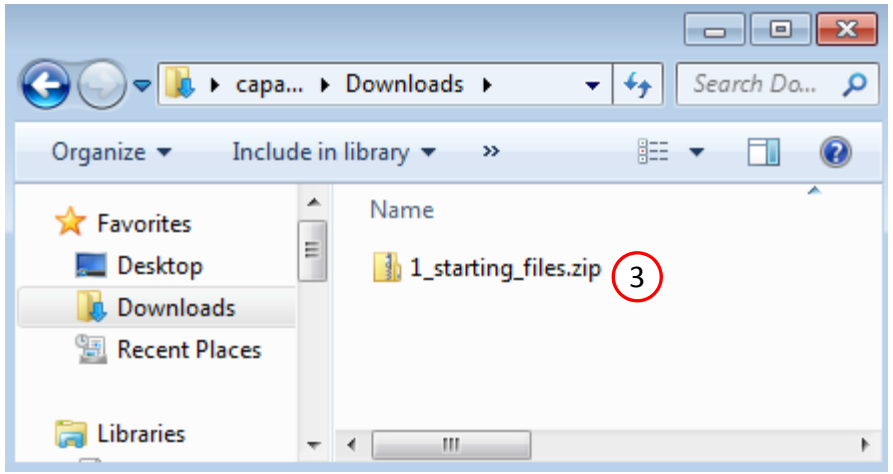
1

Composite Coupon – Phase C – Data Preparation for Ply Shape Optimization

This tutorial is a guide to preparing data for ply shape optimization in a subsequent tutorial. The maximum failure index values of the outer plies of the composite are determined and saved to specially formatted PLY000i files. The PLY000i files will be used to construct optimal ply shapes in a subsequent tutorial.

This is the third phase in a 5-phase tutorial series.

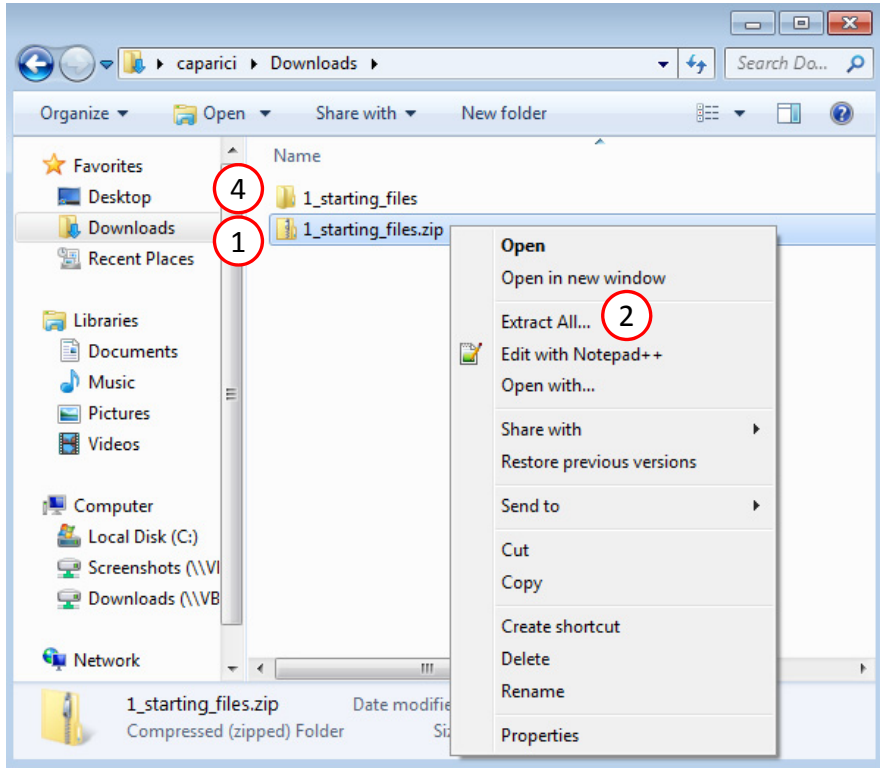
Starting BDF Files: Link 2
Solution BDF Files: Link

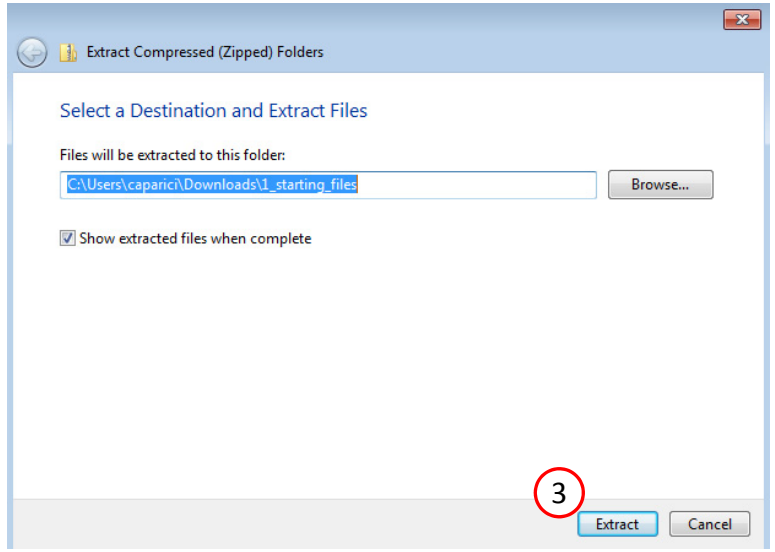


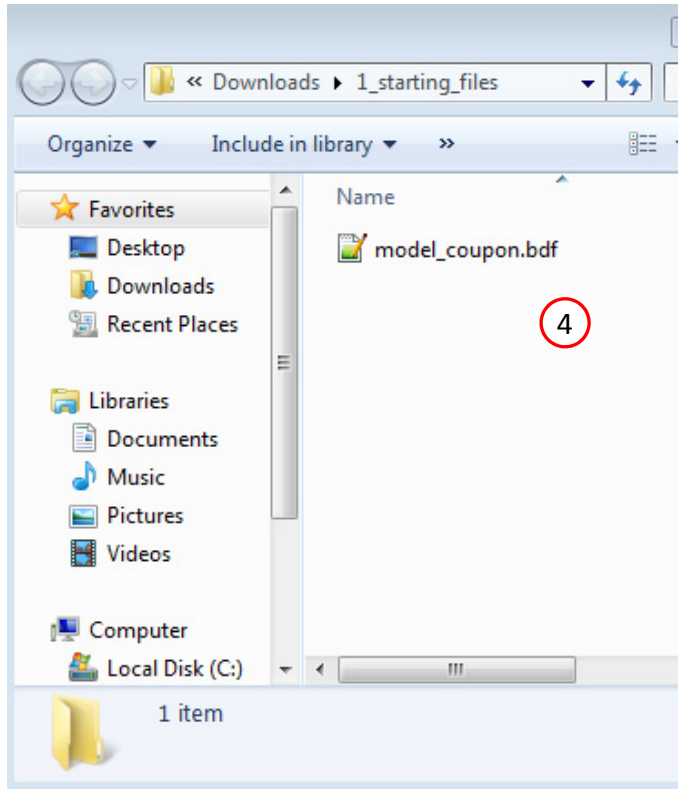
Obtain Starting Files

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 workflow works best when the BDF has the following configuration:
  - PCOMP entries are used
  - The Ti fields on the 2D element entries, e.g. CQUAD4 and CTRIA3, are NOT used
- See the appendix for more information







Open the Correct Page

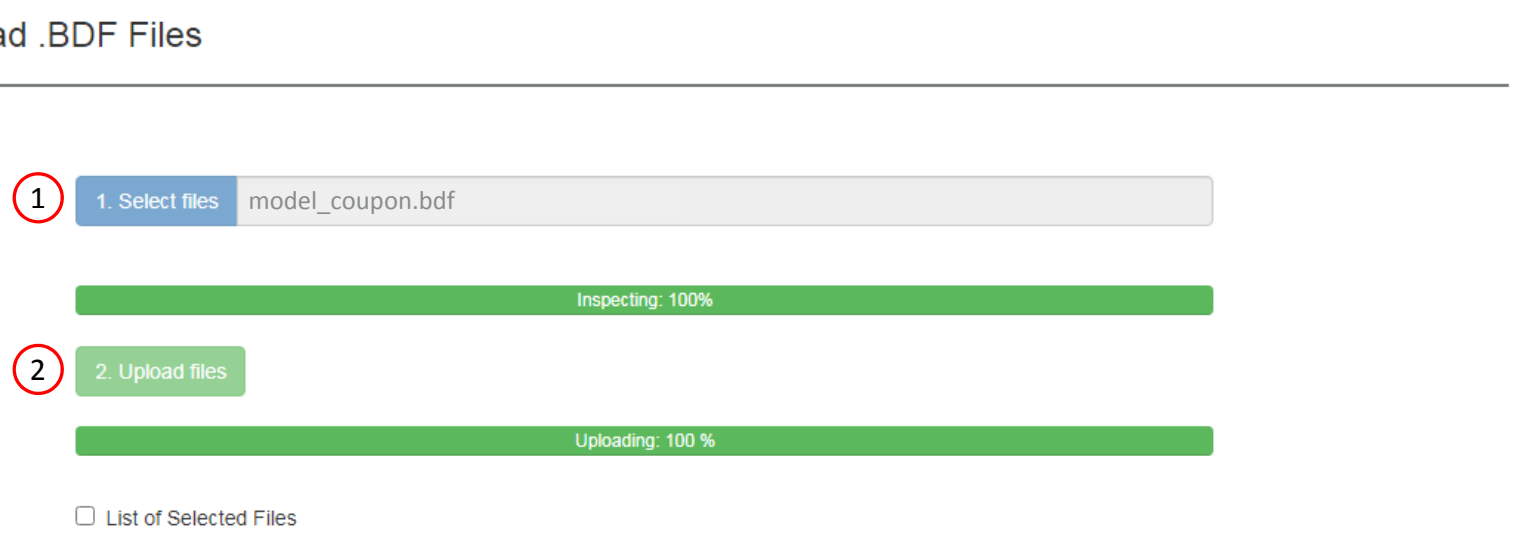
1. Click on the indicated link

- 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.

Upload BDF Files

1. Click 1. Select Files and select model_coupon.bdf
2. Click Upload Files

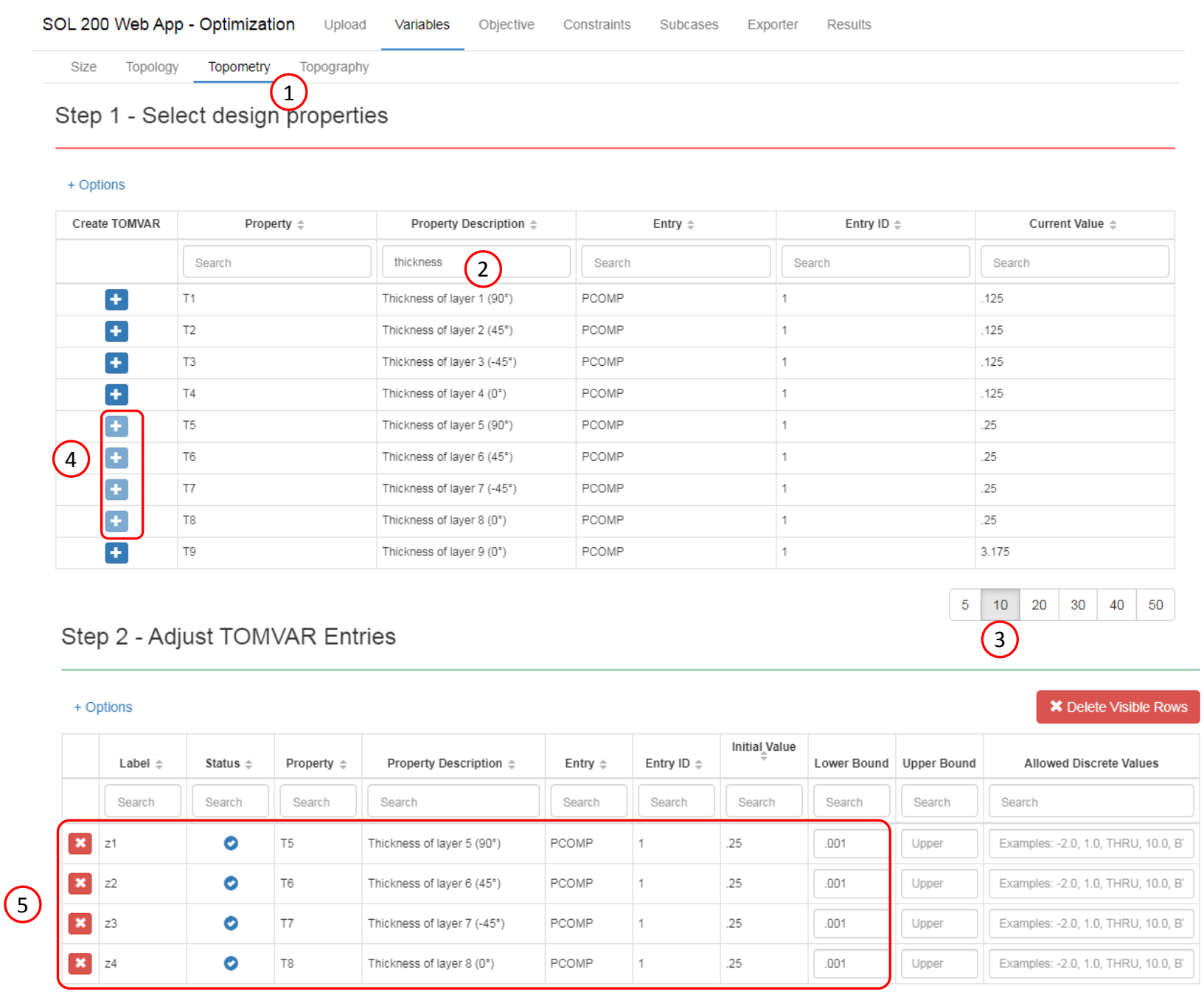
- The process starts by uploading all the necessary BDF files. The BDF files can be files of your own or files found in the Tutorials section of the User's Guide.



Variables

1. Click Topometry
2. In the search box, search for: thickness
3. Click 10 on the pagination bar
4. Click the indicated plus (+) icons to create a TOMVAR entry for layers 5, 6, 7 and 8
5. Four new TOMVAR entries have been created

- Each ply shape that will be optimized requires a TOMVAR entry. In this example, optimal ply shapes will be created for the 90°, ±45° and 0° layers, i.e. T5, T6, T7 and T8, so a total of 4 TOMVAR entries are created.
- Additional TOMVAR entries may be defined for other layers in different PCOMP entries.



TOMVAR Entries

1. The indicated TOMVAR entries have been created for the thicknesses of layers 5, 6, 7 and 8

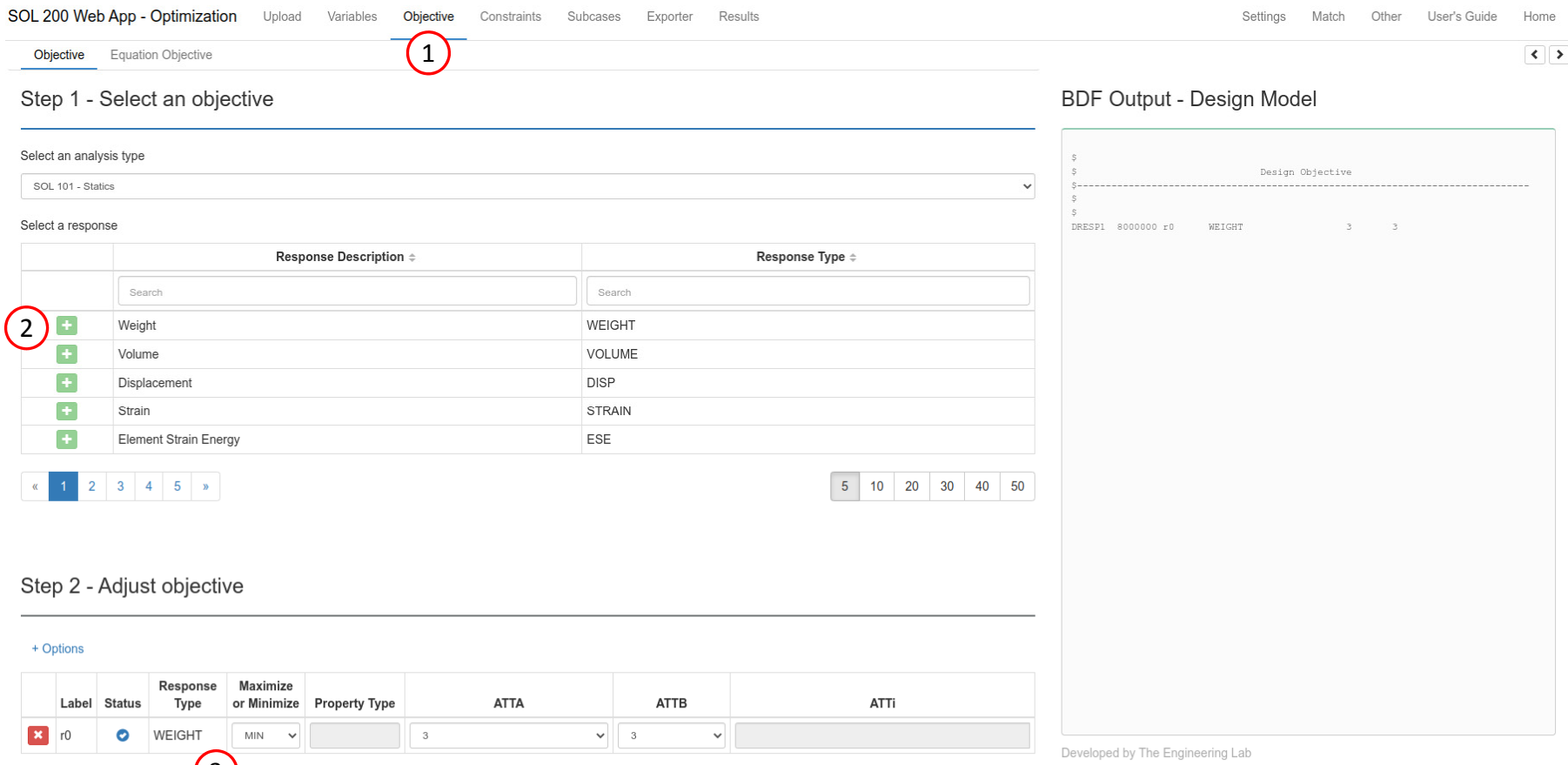
It is expected that files model.ply0005, model.ply0006, model.ply0007 and model.ply0008 are available to construct optimal ply shapes. The creation of the PLY000i files is covered in part 2 of this tutorial.

(1)

```
$TOMVAR  ID       TYPE    PID      PNAME    XINIT    XLB      XUB      DELXV
TOMVAR   3000001  PCOMP   1        T5       .25      .001
TOMVAR   3000002  PCOMP   1        T6       .25      .001
TOMVAR   3000003  PCOMP   1        T7       .25      .001
TOMVAR   3000004  PCOMP   1        T8       .25      .001
```

Objective

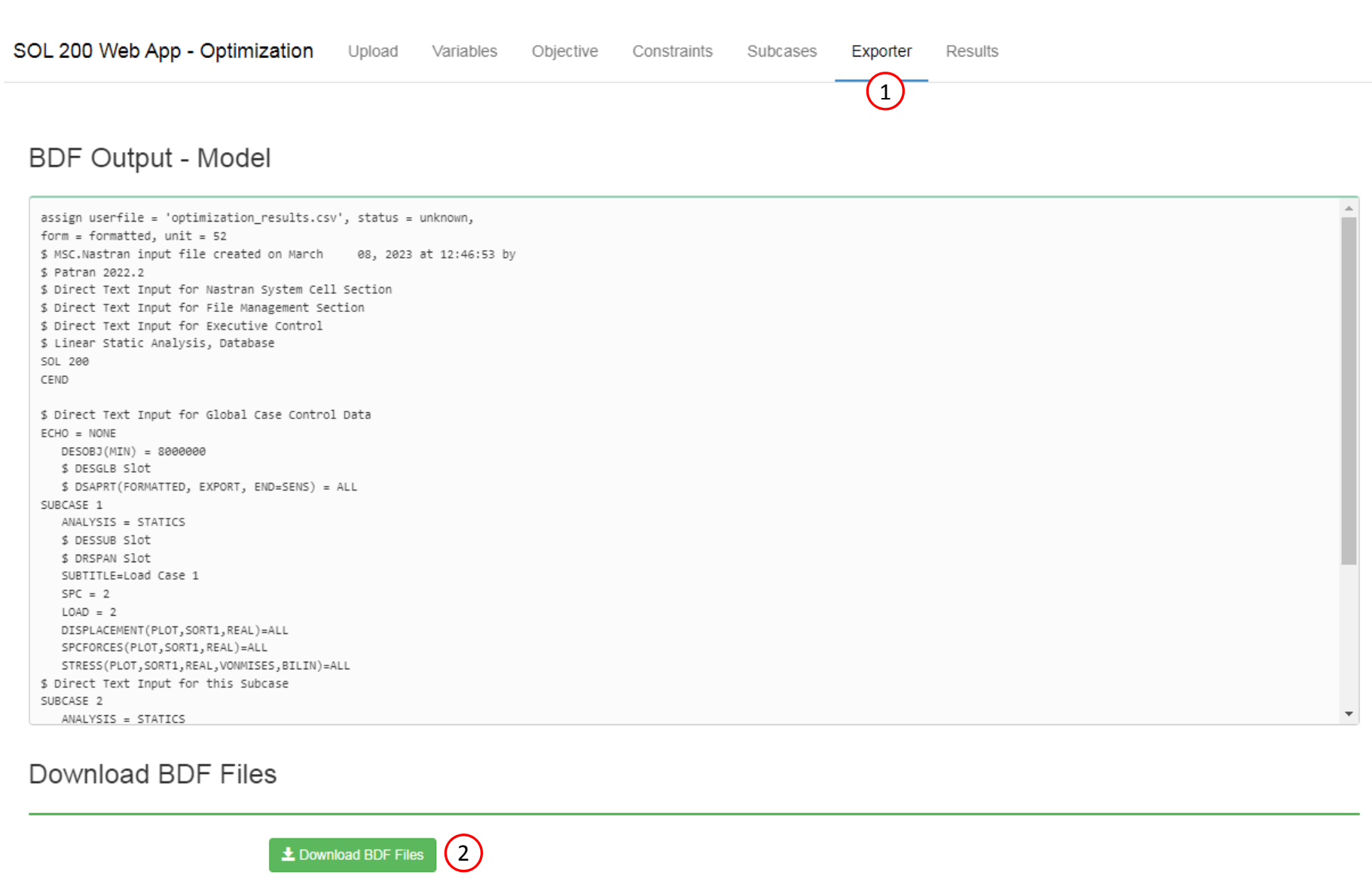
1. Click Objective
2. Click the plus (+) icon for Weight
3. An objective to minimize weight has been created



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”

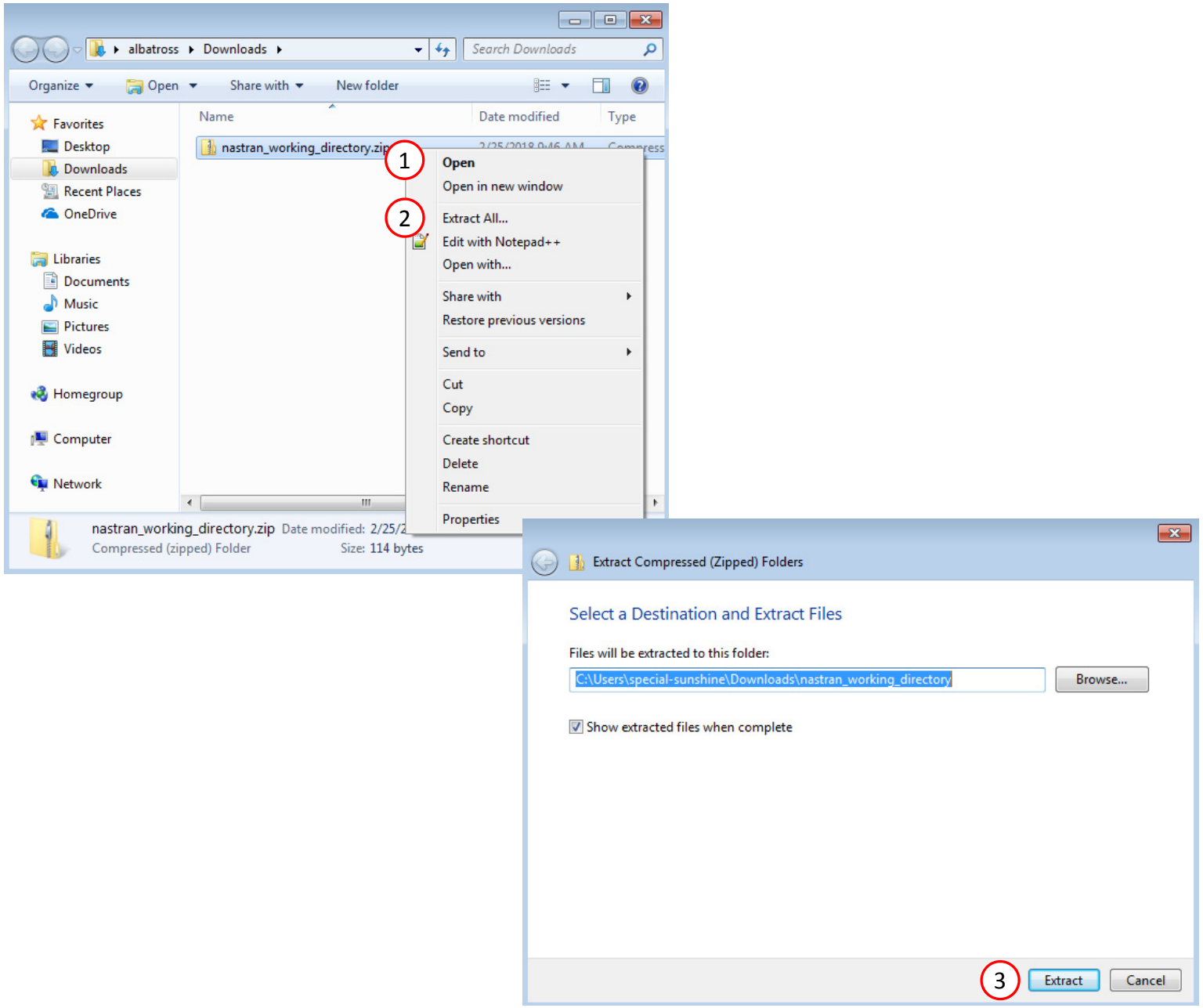


Extract the Contents of the ZIP File

A new .zip file has been downloaded

1. Right click on the file
2. Click Extract All
3. Click Extract on the following window

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



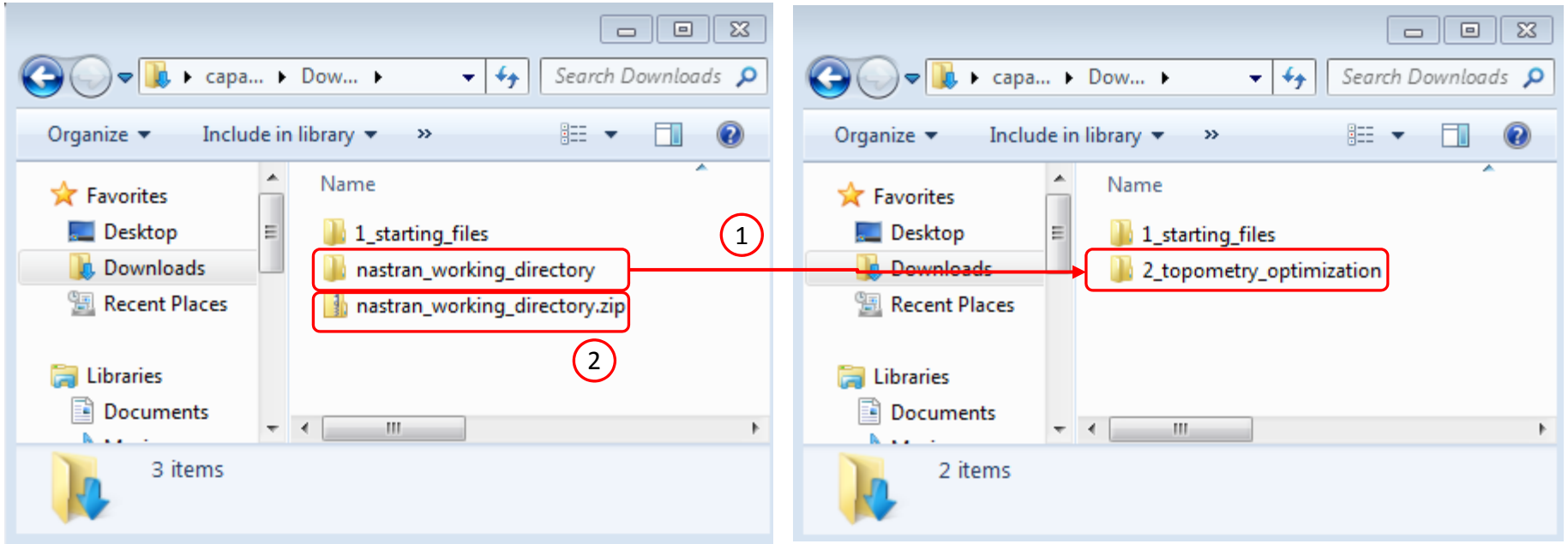
Extract the Contents of the ZIP File

1. Rename directory nastran_working_directory as 2_topometry_optimization
2. Delete the indicated ZIP file

A topometry optimization is NOT performed in this exercise. Do NOT perform a topometry optimization. The BDF files with TOMVAR entries are required by the Viewer web app in order to construct ply shapes.

This tutorial only discusses the creation of the BDF file, with TOMVAR entries, and the PLY000i files.

- Refer to the appendix to answer this question: Why is a topometry optimization skipped?

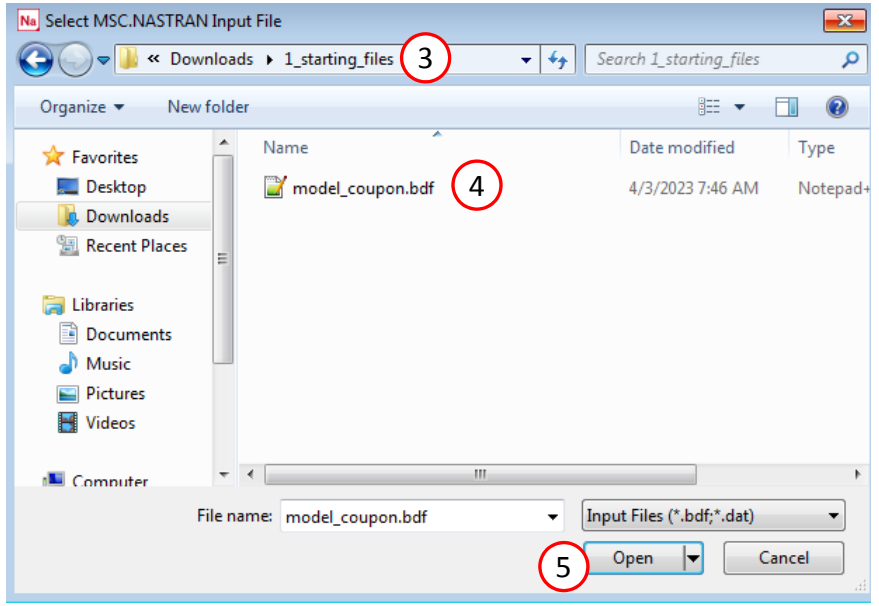


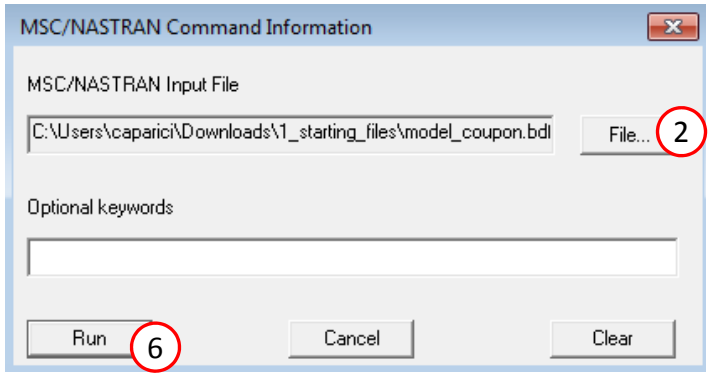
Part 2 - PLY000i Files

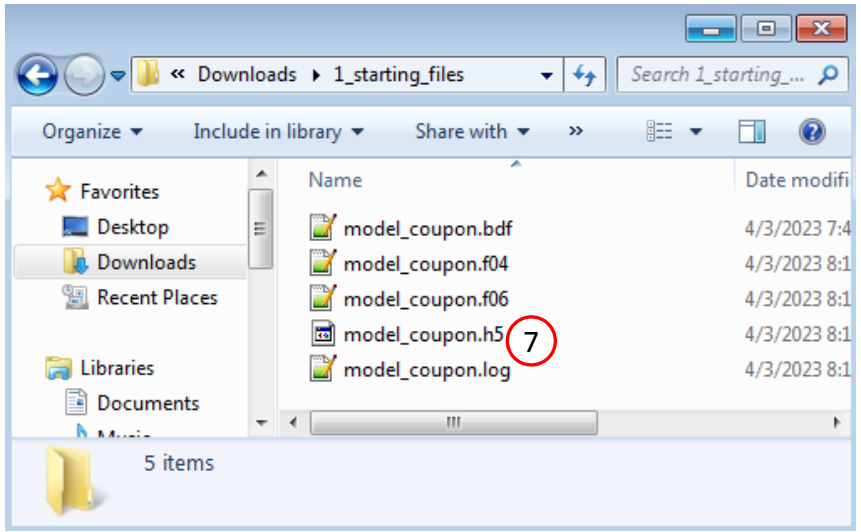
Create the H5 File

1. Double click the MSC Nastran desktop shortcut
2. Click File
3. Navigate to directory 1_starting_files
4. Select file model_coupon.bdf
5. Click Open
6. Click Run
7. The file model_coupon.h5 is now available

- The results of the statics analysis are contained in the H5, including the ply failure indices. The failure indices are required in the following steps, so the H5 file is generated.





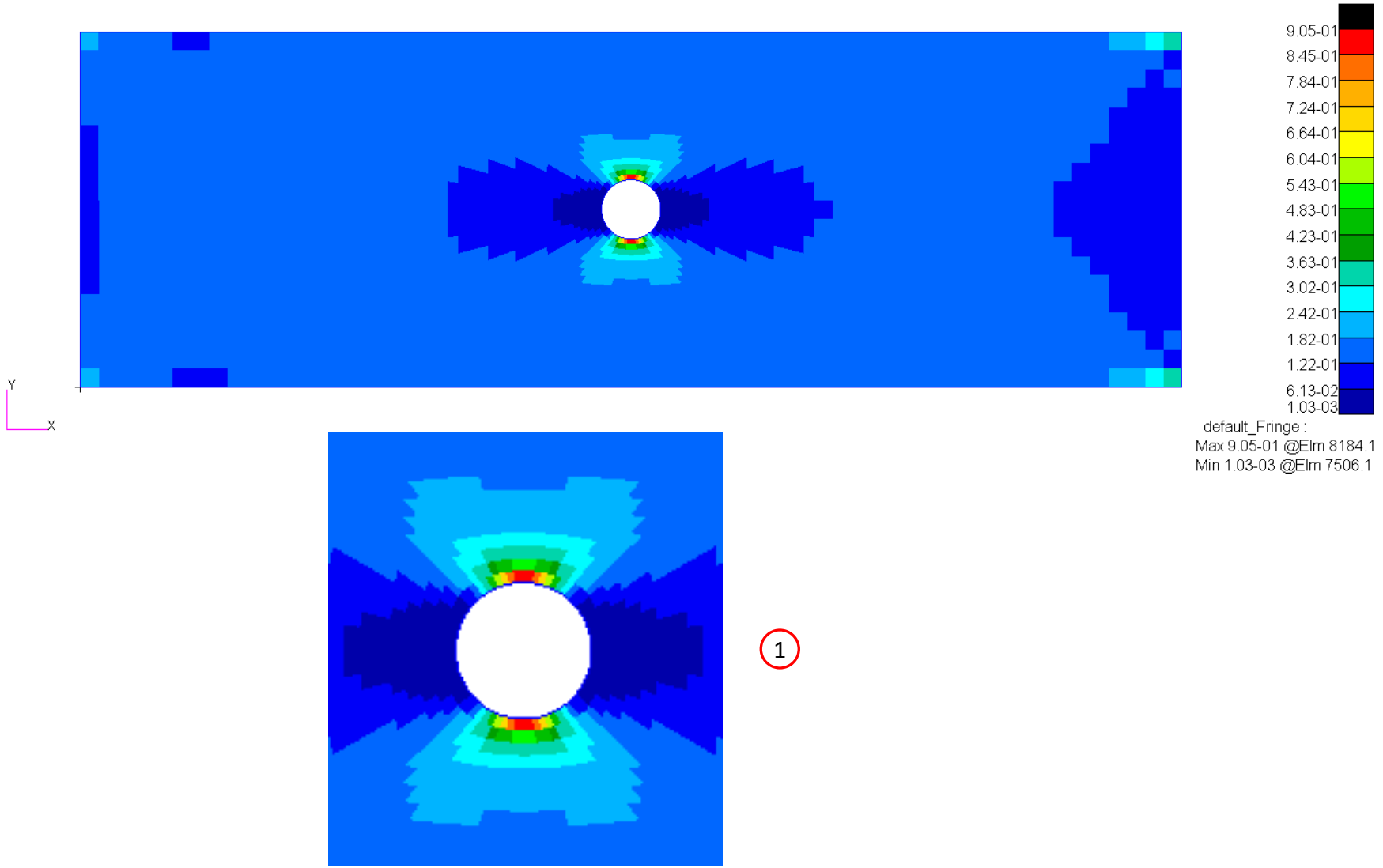


Ply Shape Strategy for Failure Indices

A strategy is necessary to create ply shapes for failure index responses.

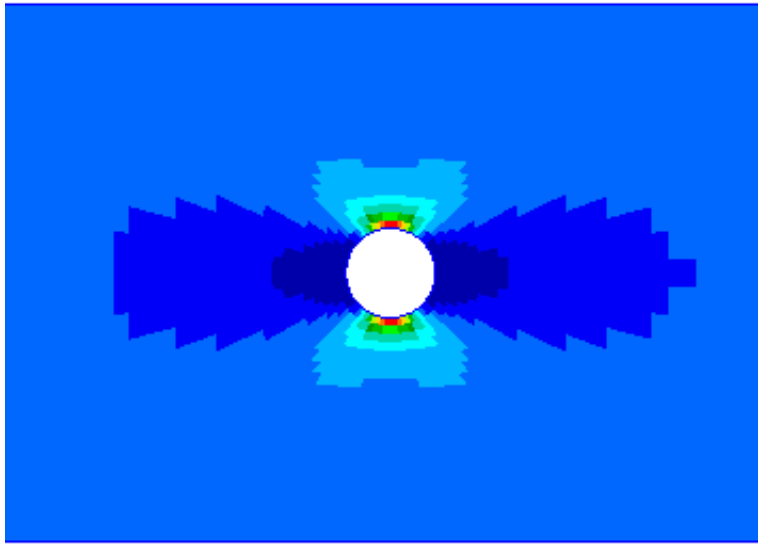
1. To the right, a plot created by Patran is displayed of failure indices for layer 1 of subcase 1. Notice that the highest failure index values are at the hole.

Failure index of layer 1, subcase 1

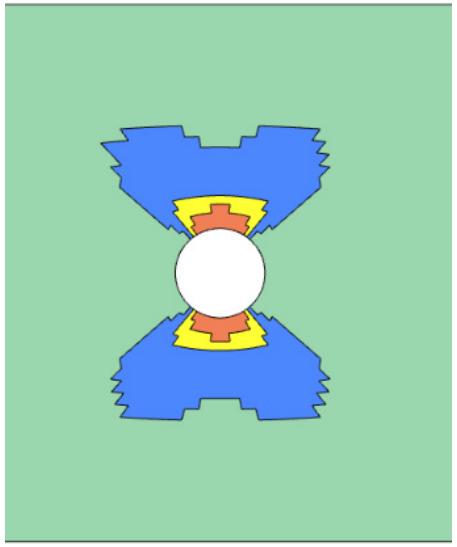


Ply Shape Strategy for Failure Indices

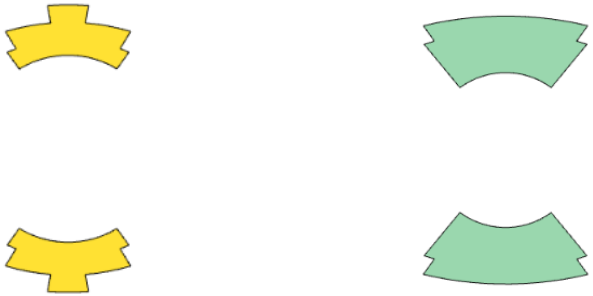
An effective strategy is to build ply shapes that follow the contours of the failure index fringe plot.



Fringe Plot: Failure indices of layer 1 for subcase 1

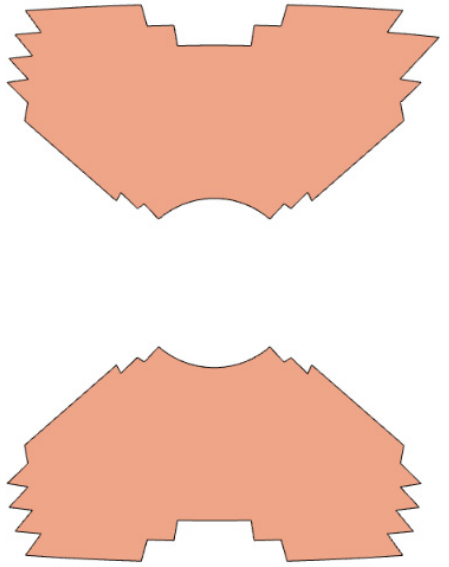


Overlapped ply shape candidates



Ply Shape Candidate 1

Ply Shape Candidate 2

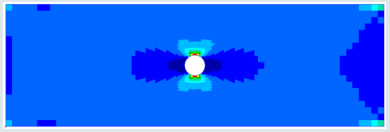
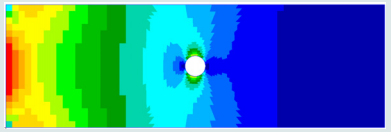
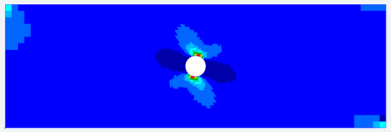
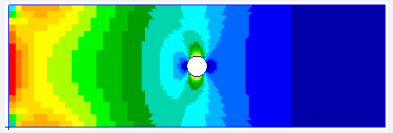
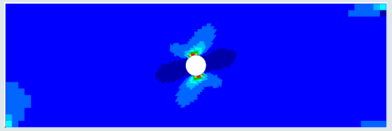
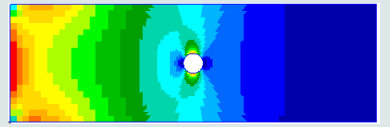
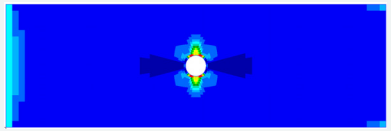
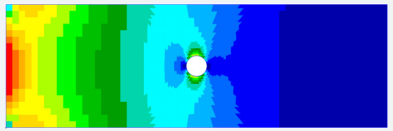
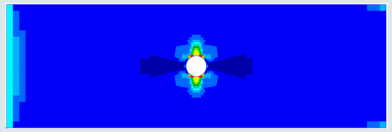
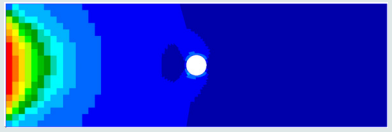
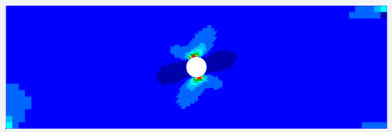
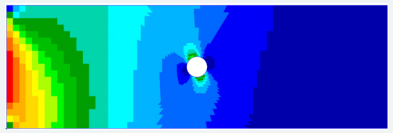
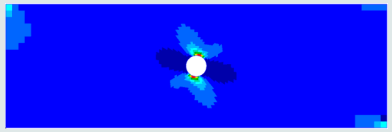
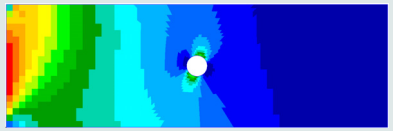
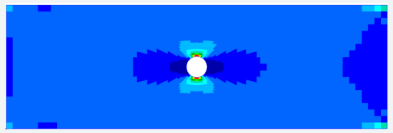
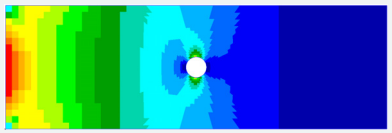


Ply Shape Candidate 3

Ply Shape Strategy for Failure Indices

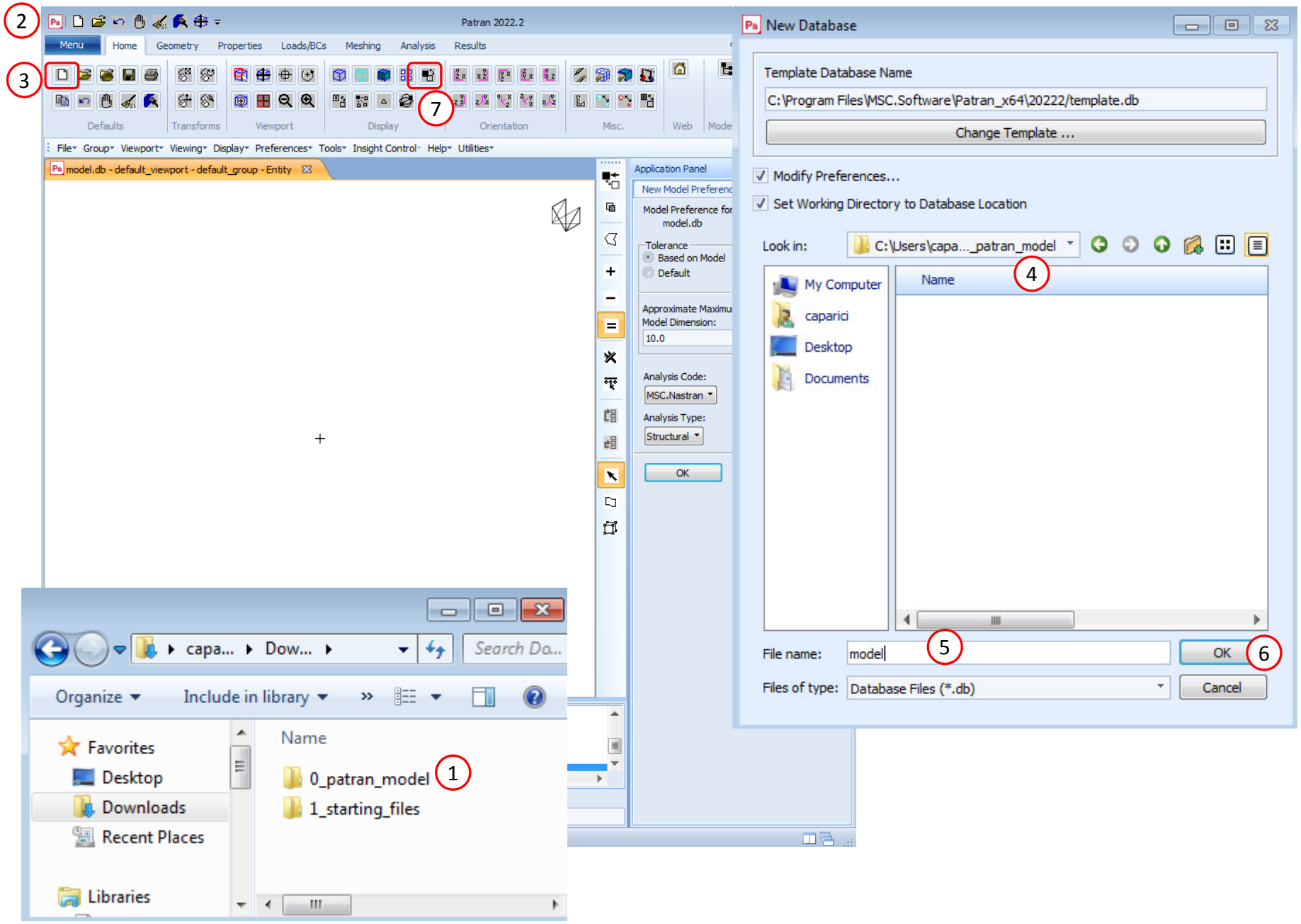
- This analysis model involves two subcases and multiple layers.
- A procedure is necessary to build ply shapes for each layer and for each subcase.

- Layers 5 and 6 are purposely ignored during this optimization exercise and are not listed in this table. Layers 5 and 6 correspond to the core of the composite and the core is not modified during this optimization procedure.

Layer	Theta	Subcase 1	Subcase 2
1	90		
2	45		
3	-45		
4	0		
15	0		
16	-45		
17	45		
18	90		

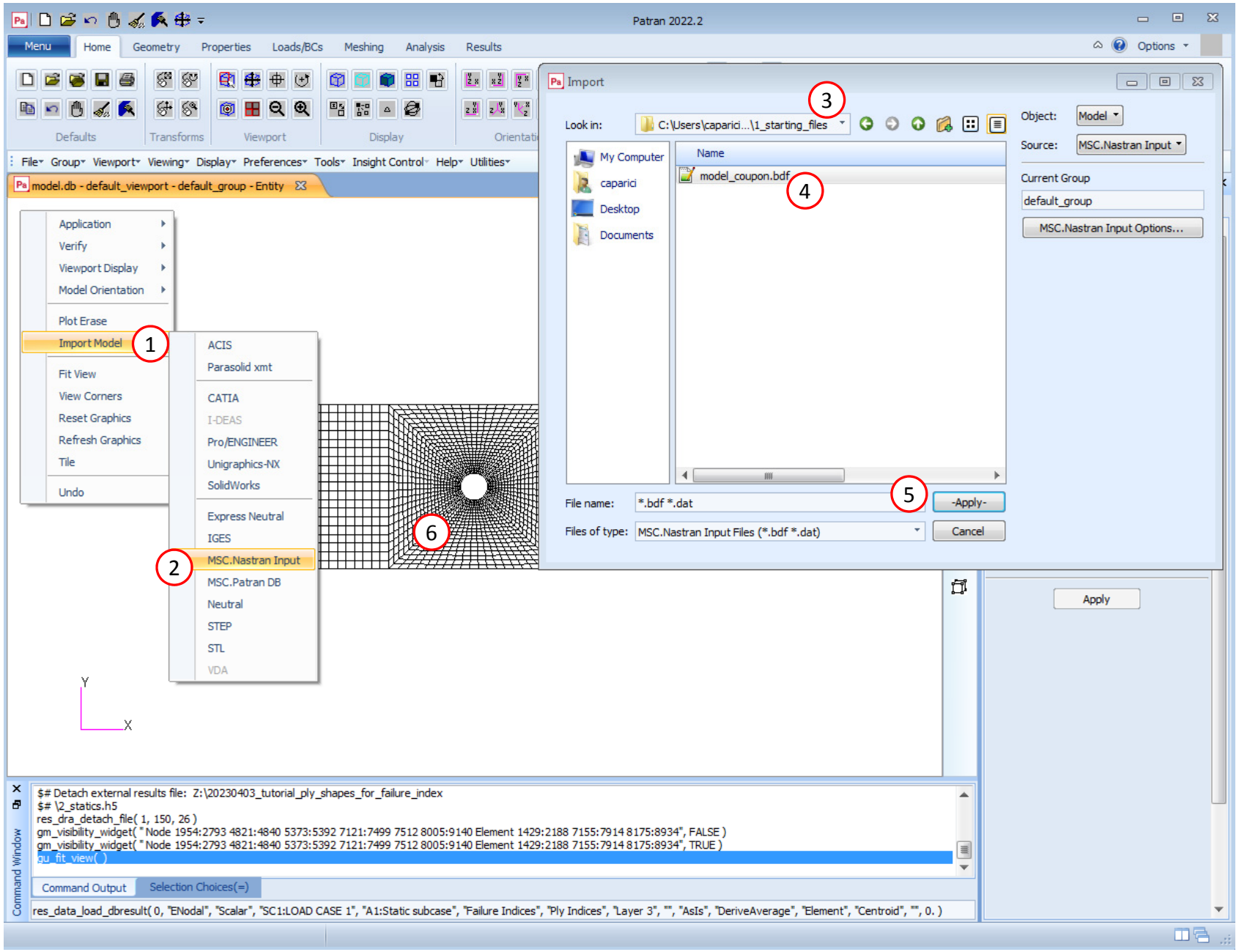
Open Patran

1. Create a new directory named 0_patran_model in your Downloads directory
2. Open Patran
3. Click New
4. Navigate to the directory 0_patran_model
5. Set File name to model
6. Click OK
7. Click the indicated icon 2 times to change the background to white



Import the BDF

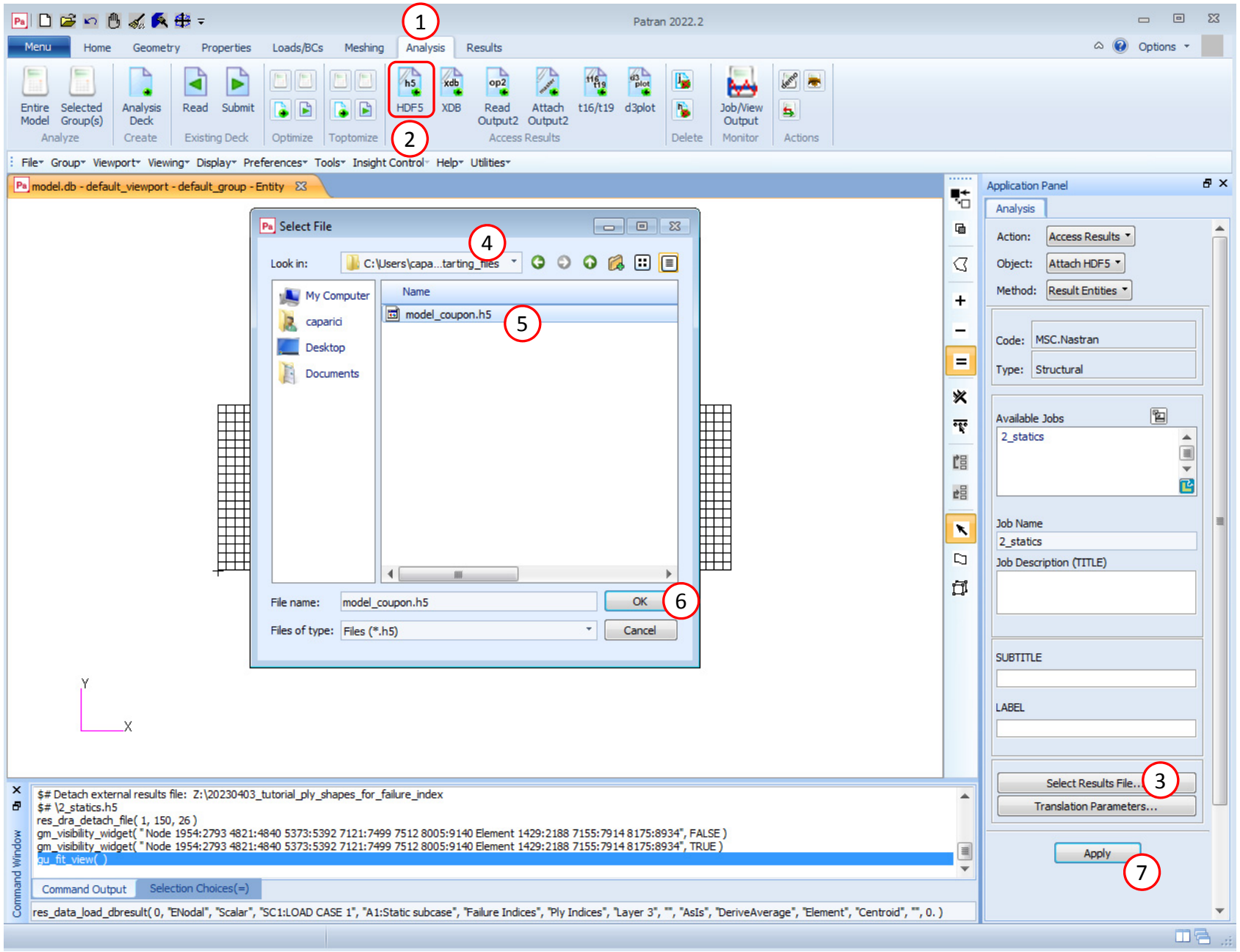
1. Right click in the viewport and click Import Model
2. Click MSC.Nastran Input
3. Navigate to directory 1_starting_files
4. Select the file model_coupon.bdf
5. Click Apply
6. The model has been imported
7. Click OK on the window Nastran Input File Summary if it is visible (not shown)



Import the Results

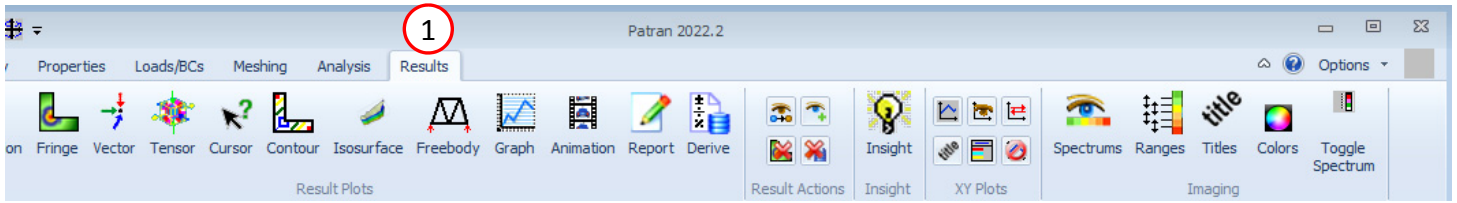
1. Click Analysis
2. Click HDF5
3. Click Select Results File
4. Navigate to 1_starting_files
5. Select model_coupon.h5
6. Click OK
7. Click Apply

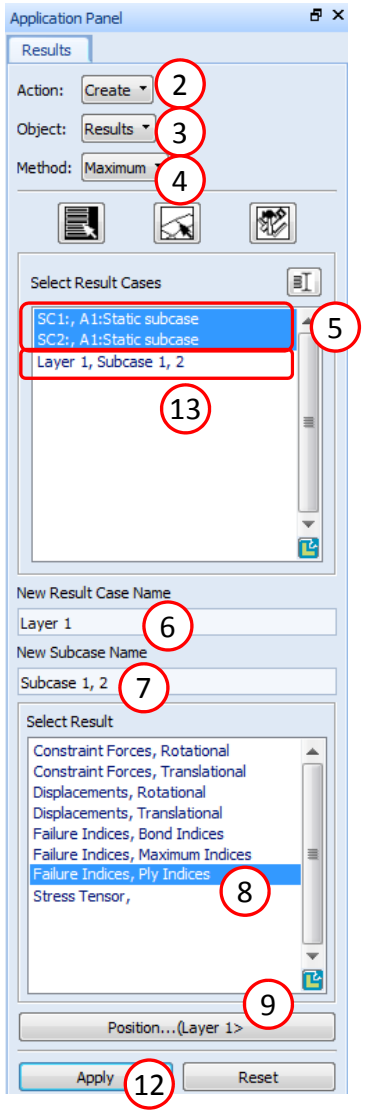
The results from the H5 file has been imported to Patran.

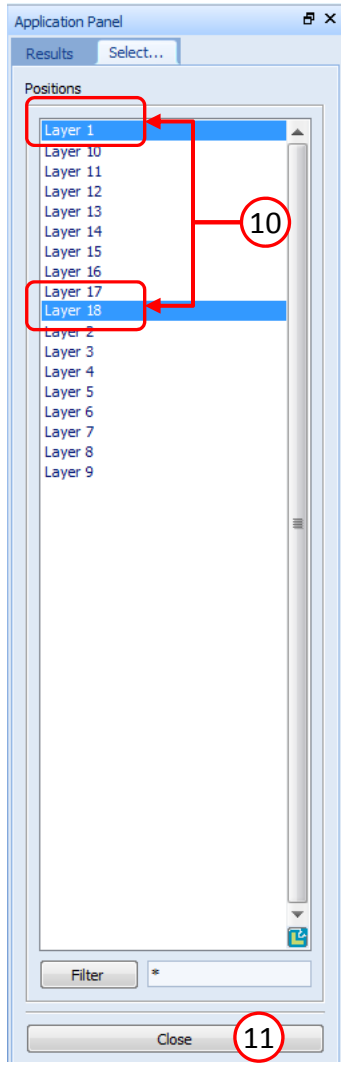


Create a New Subcase: Layer 1, Subcase 1, 2

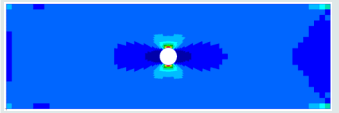
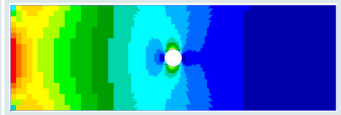
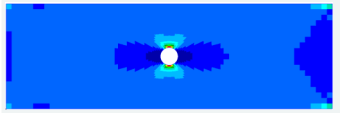
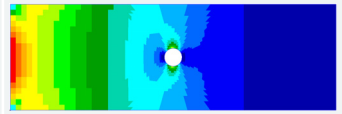
1. Click Results
2. Set Action: Create
3. Set Object: Results
4. Set Method: Maximum
5. Select both subcases
6. Set the name to Layer 1
7. Set the subcase name to Subcase 1, 2
8. Select Failure Index, Ply Indices
9. Click Position
10. Select Layer 1 and Layer 18
11. Click Close
12. Click Apply
13. A new subcase is created and is named Layer 1, Subcase 1, 2





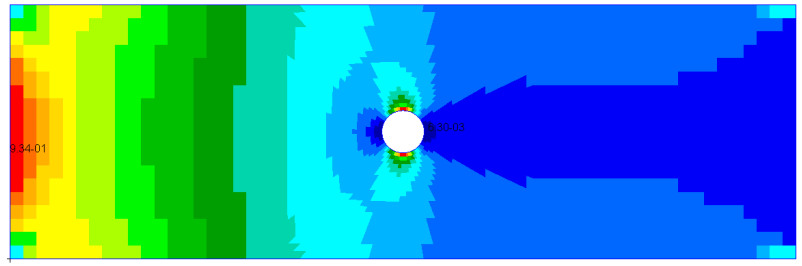


Failure Index

Layer	Subcase 1	Subcase 2
1		
18		

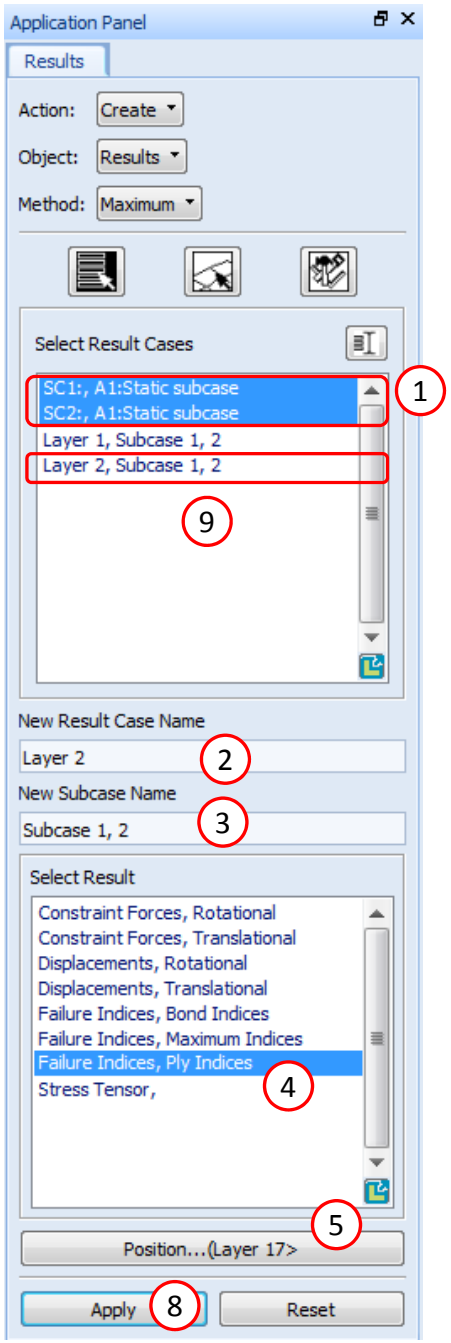
Layer 1, Subcase 1 and 2

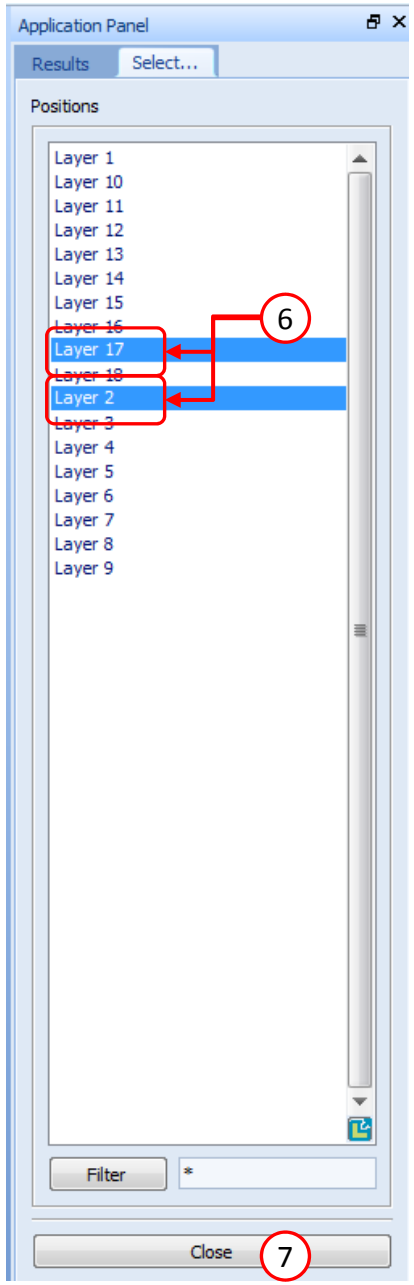
Maximum failure index of layers 1 and 10 for subcase 1 and 2



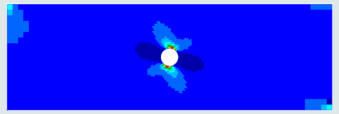
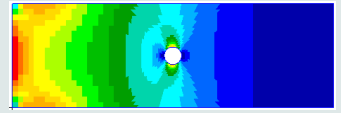
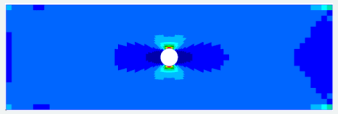
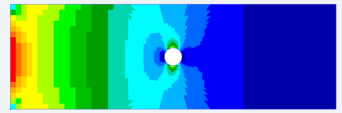
Create a New Subcase: Layer 2, Subcase 1, 2

1. Select both subcases
2. Set the name to Layer 2
3. Set the subcase name to Subcase 1, 2
4. Select Failure Index, Ply Indices
5. Click Position
6. Select Layer 2 and Layer 17
7. Click Close
8. Click Apply
9. A new subcase is created and is named Layer 2, Subcase 1, 2



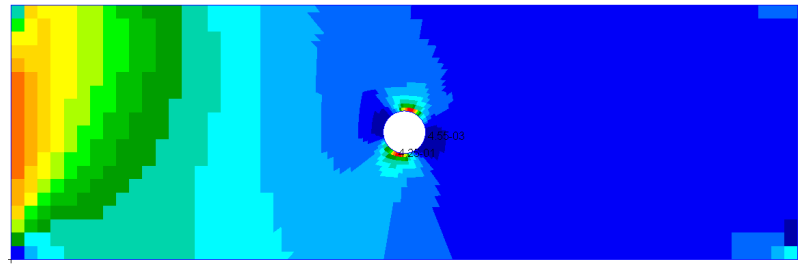


Failure Index

Layer	Subcase 1	Subcase 2
2		
17		

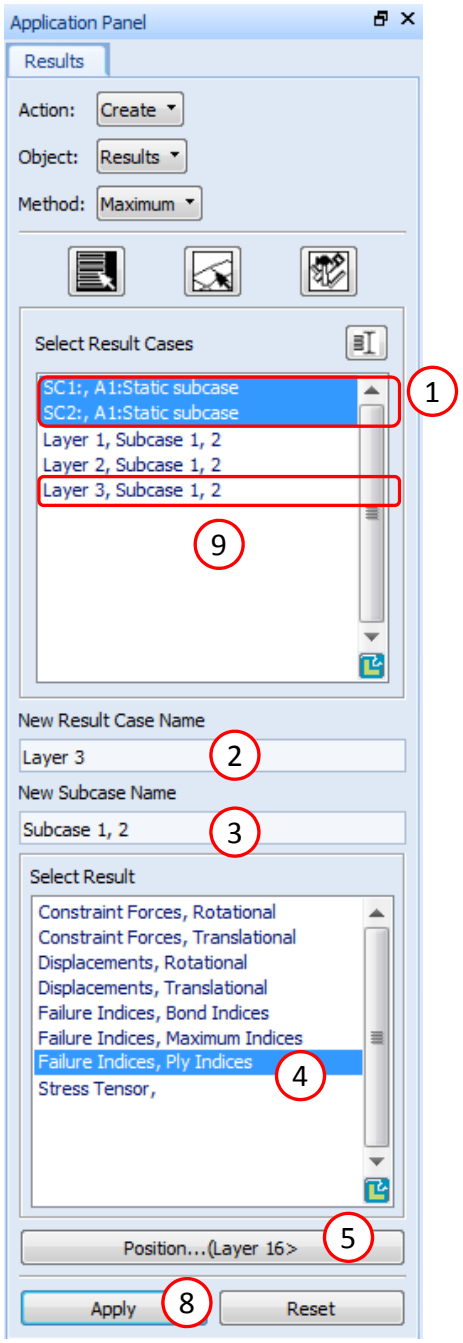
Layer 2, Subcase 1 and 2

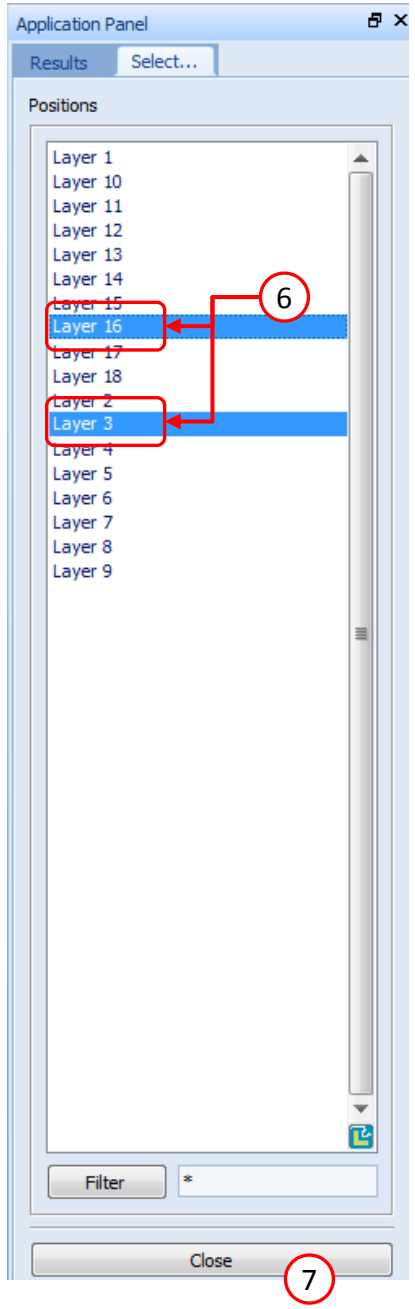
Maximum failure index of layers 2 and 9 for subcase 1 and 2



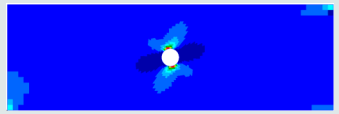
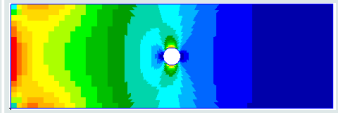
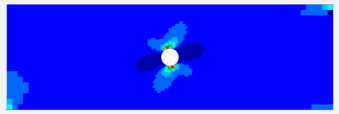
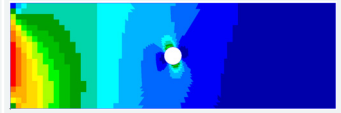
Create a New Subcase: Layer 3, Subcase 1, 2

1. Select both subcases
2. Set the name to Layer 3
3. Set the subcase name to Subcase 1, 2
4. Select Failure Index, Ply Indices
5. Click Position
6. Select Layer 3 and Layer 16
7. Click Close
8. Click Apply
9. A new subcase is created and is named Layer 3, Subcase 1, 2



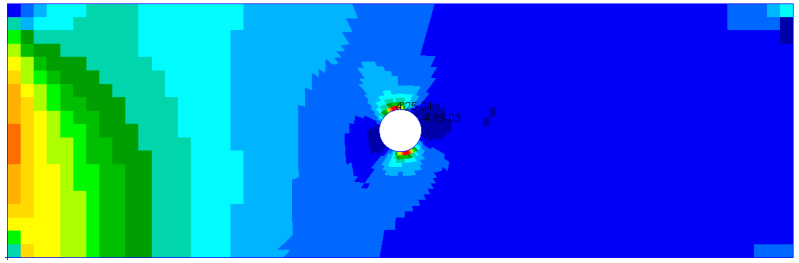


Failure Index

Layer	Subcase 1	Subcase 2
3		
16		

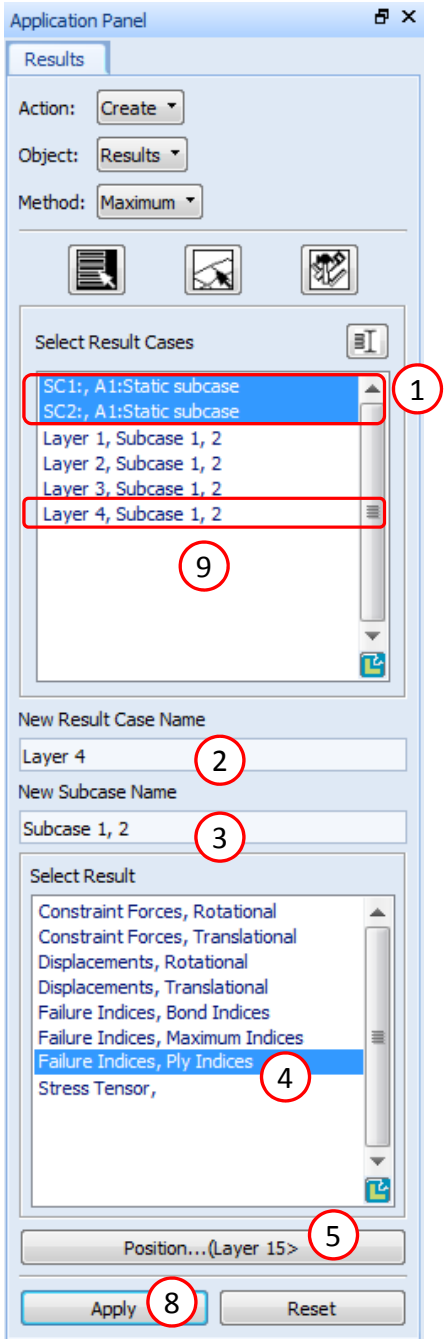
Layer 3, Subcase 1 and 2

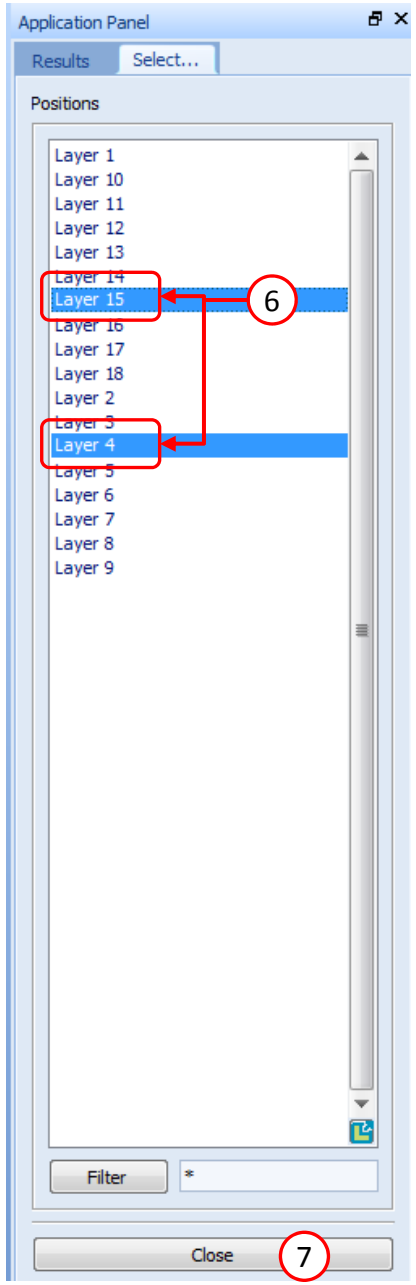
Maximum failure index of layers 3 and 8 for subcase 1 and 2



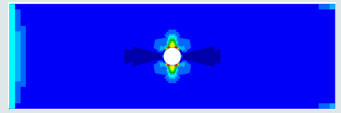
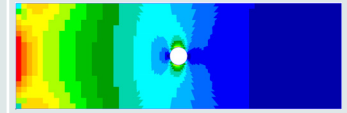
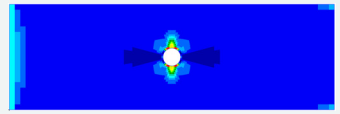
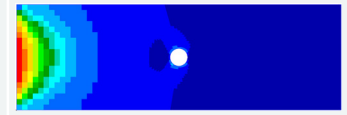
Create a New Subcase: Layer 4 Subcase 1, 2

1. Select both subcases
2. Set the name to Layer 4
3. Set the subcase name to Subcase 1, 2
4. Select Failure Index, Ply Indices
5. Click Position
6. Select Layer 4 and Layer 15
7. Click Close
8. Click Apply
9. A new subcase is created and is named Layer 4, Subcase 1, 2



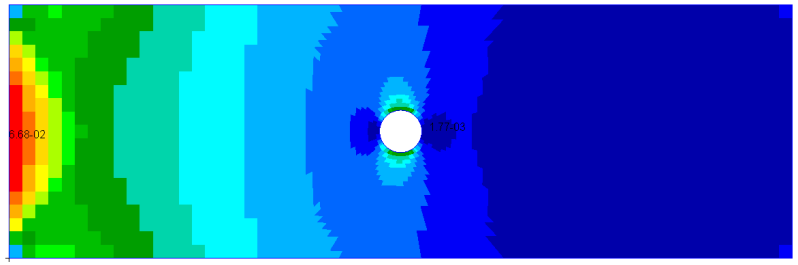


Failure Index

Layer	Subcase 1	Subcase 2
4		
15		

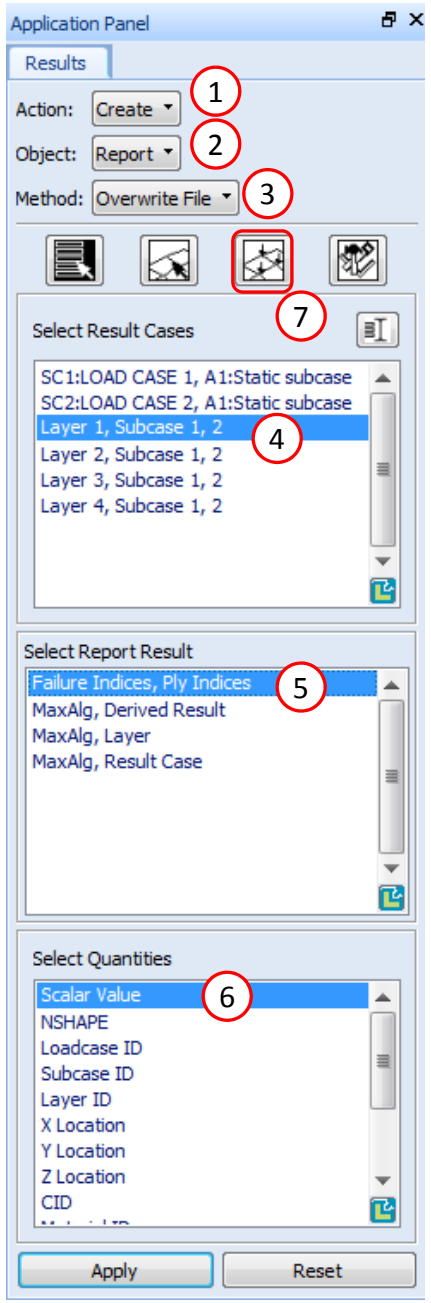
Layer 4, Subcase 1 and 2

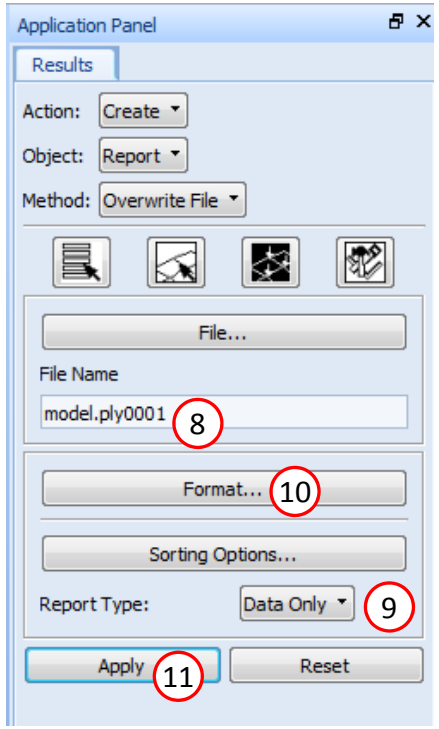
Maximum failure index of layers 4 and 7 for subcase 1 and 2

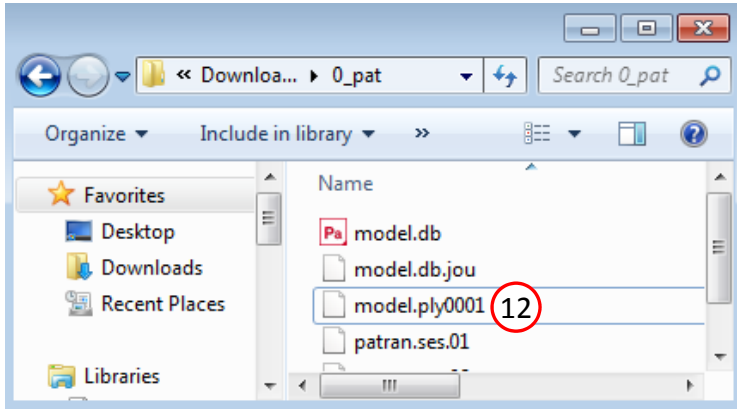


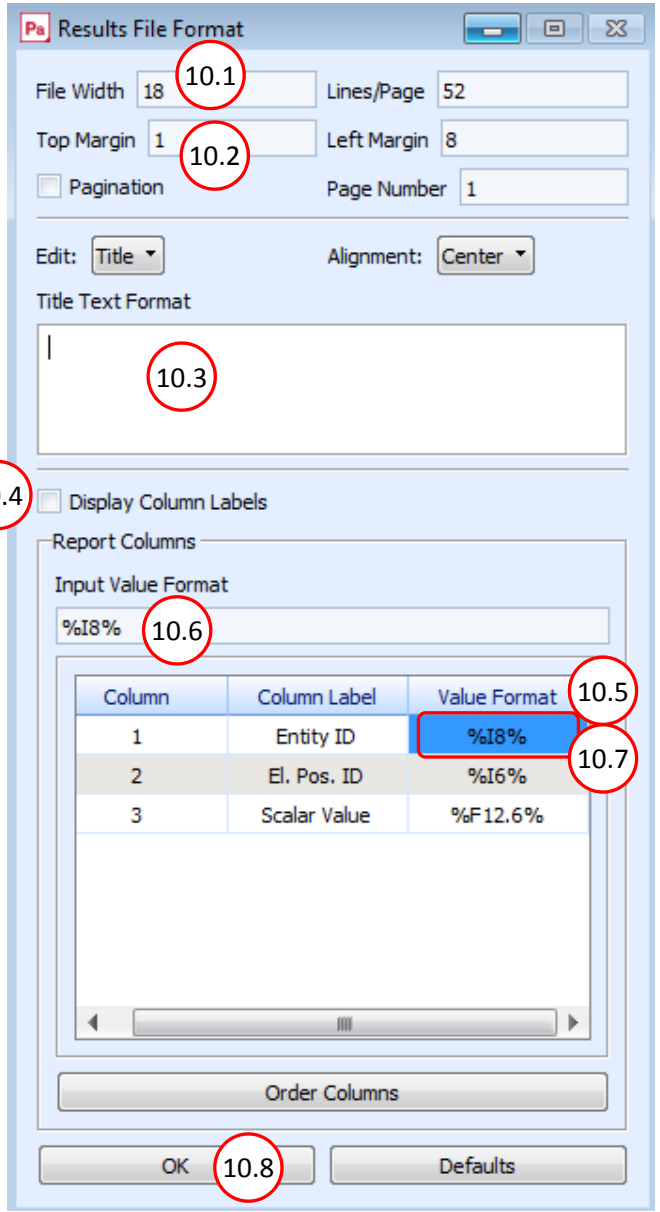
Create model.ply0001

1. Set Action: Create
2. Set Object: Report
3. Set Method: Overwrite File
4. Select Layer 1, Subcase 1, 2
5. Select Failure Indices, Ply Indices
6. Select Scalar Value
7. Click Display Attributes
8. Set File Name: model.ply0001
9. Set Report Type: Data Only
10. Click Format
    1. Set File Width: 18
    2. Top Margin: 1
    3. Set Title Text Format: blank
    4. Unmark the checkbox Display Column Labels
    5. Select the indicated cell, which previously reads: %I6%
    6. For the indicated input box, type in this text : %I8%
    7. Press Enter on the keyboard to commit the new text, the indicated cell should now read: %I8%
    8. Click OK
11. Click Apply
12. A new file model.ply0001 has been created









Create model.ply0001

1. The files .ply000i are typically created by a topometry optimization. This tutorial manually creates the .ply000i files.
2. Open file model.ply0001 in a text editor. Note that the format of the manually created mode.ply0001 is similar to the format created by a topometry optimization.

① model.ply0001 (Topometry Optimization)

model.ply0001

```
DESIGN CYCLE :    14
    1
Topometry Optimization Mat
Total number of element
    1429        0
0.1002350E-02
    1430        0
0.1002253E-02
    1431        0
0.1002049E-02
    1432        0
0.1002280E-02
    1433        0
0.1002328E-02
    1434        0
0.1002254E-02
    1435        0
0.1002217E-02
    1436        0
0.1002244E-02
    1437        0
```

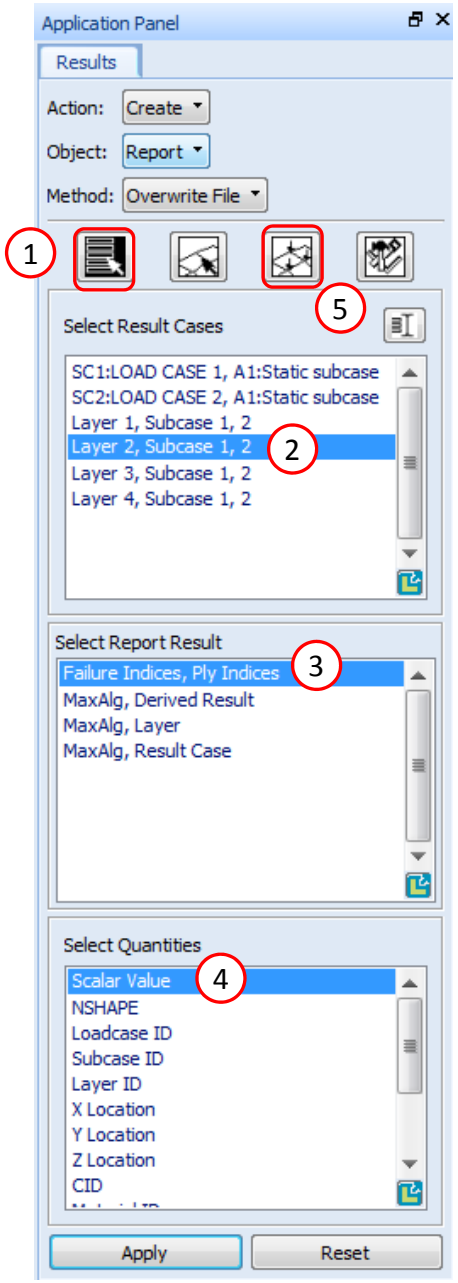
② model.ply0001

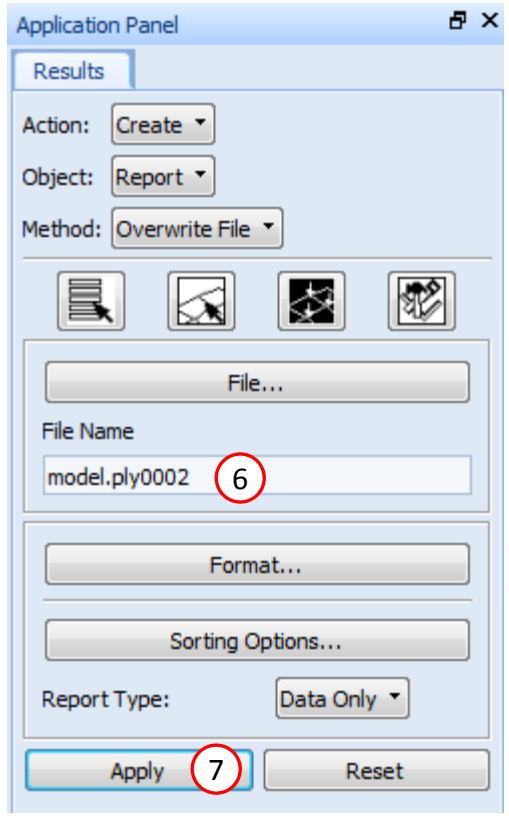
model.ply0001

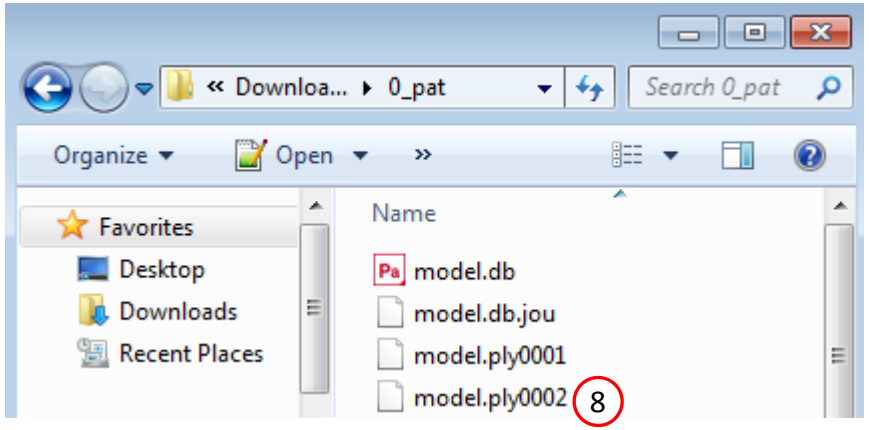
```
1
2
    1429        0
0.307122
    1430        0
0.103824
    1431        0
0.123881
    1432        0
0.120190
    1433        0
0.121350
    1434        0
0.121152
    1435        0
0.121225
    1436        0
0.121206
    1437        0
0.121206
    1438        0
```

Create model.ply0002

1. Click Select Results
2. Select Layer 2, Subcase 1, 2
3. Select Failure Indices, Ply Indices
4. Select Scalar Value
5. Click Display Attributes
6. Set File Name: model.ply0002
7. Click Apply
8. A new file model.ply0002 has been created

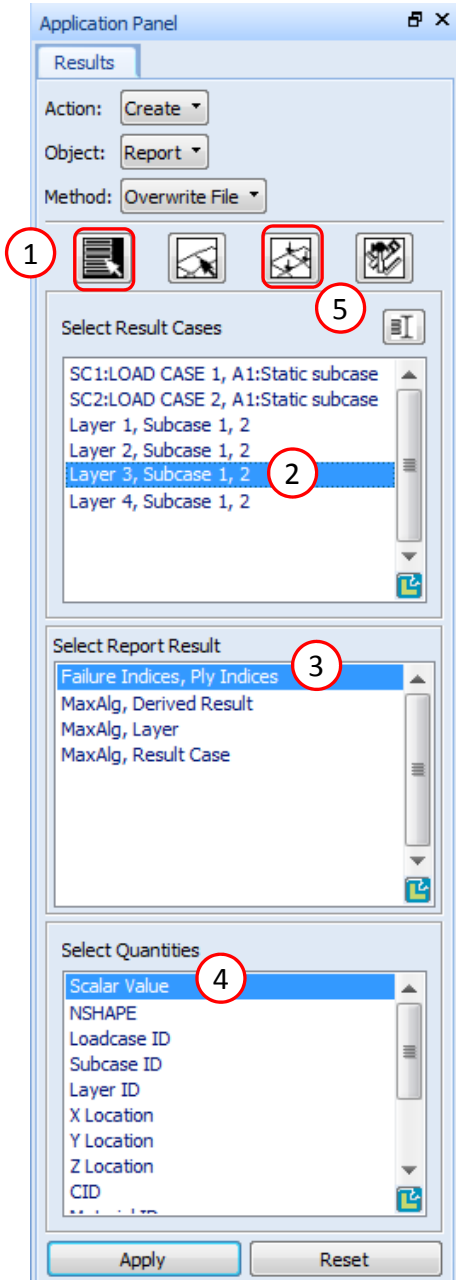


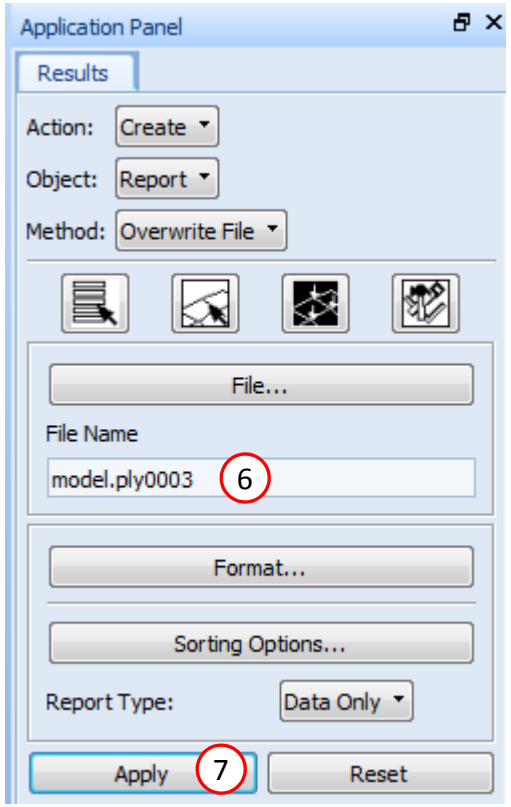


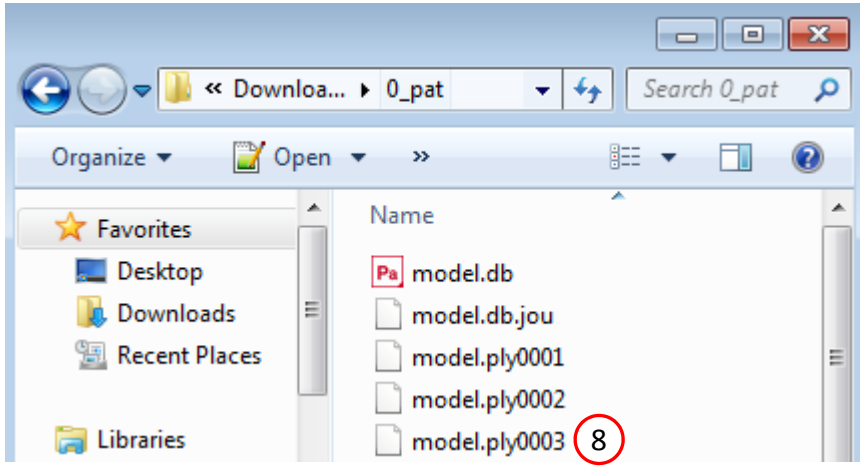


Create model.ply0003

1. Click Select Results
2. Select Layer 3, Subcase 1, 2
3. Select Failure Indices, Ply Indices
4. Select Scalar Value
5. Click Display Attributes
6. Set File Name: model.ply0003
7. Click Apply
8. A new file model.ply0003 has been created

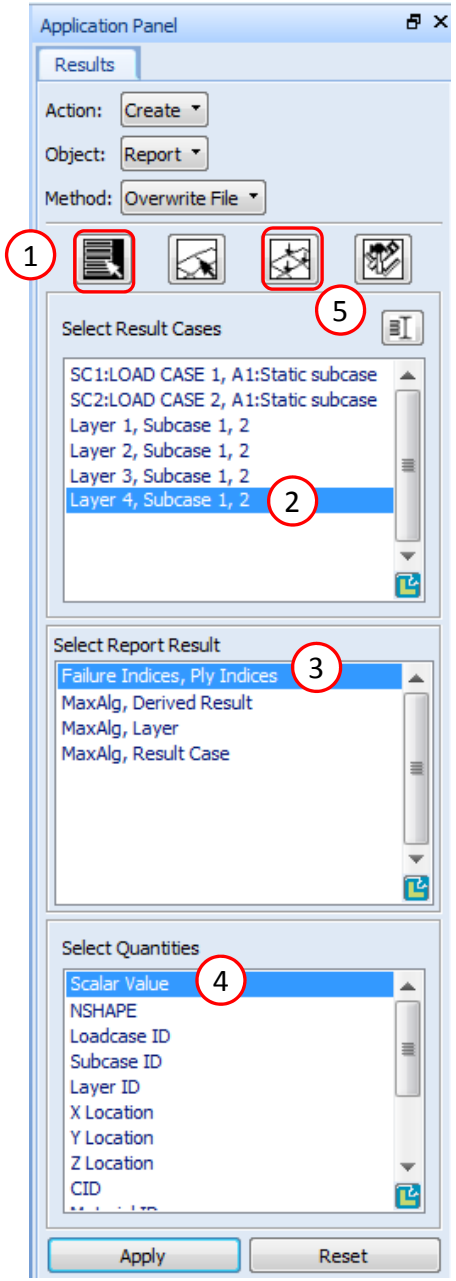


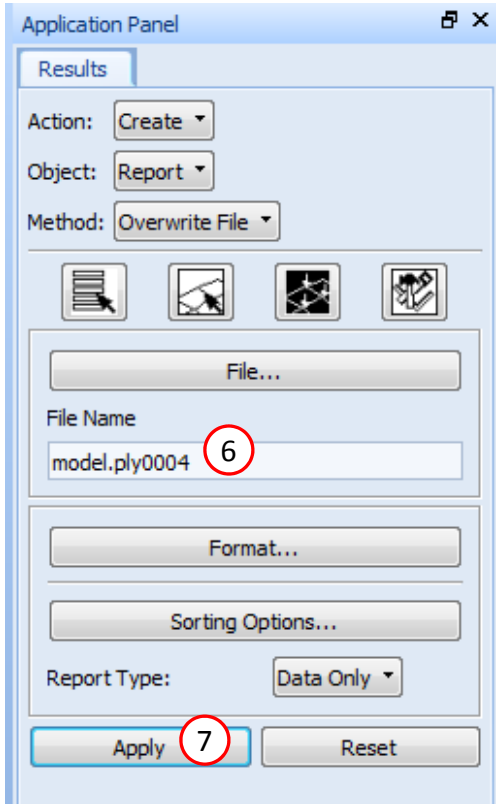


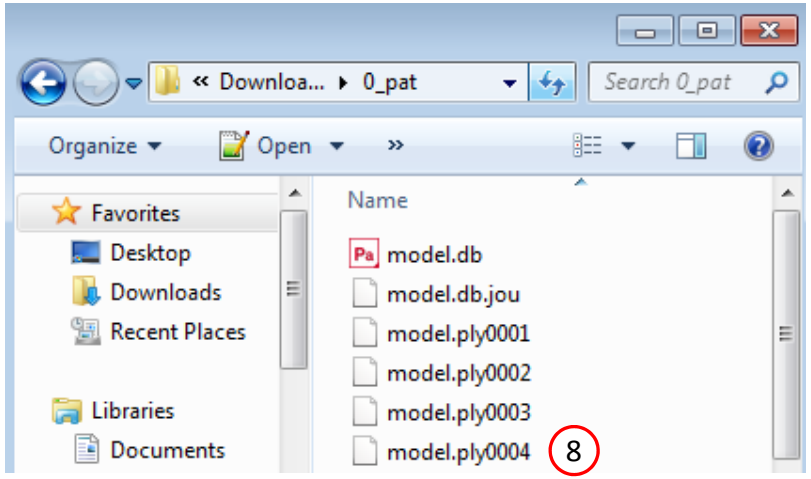


Create model.ply0004

1. Click Select Results
2. Select Layer 4, Subcase 1, 2
3. Select Failure Indices, Ply Indices
4. Select Scalar Value
5. Click Display Attributes
6. Set File Name: model.ply0004
7. Click Apply
8. A new file model.ply0004 has been created

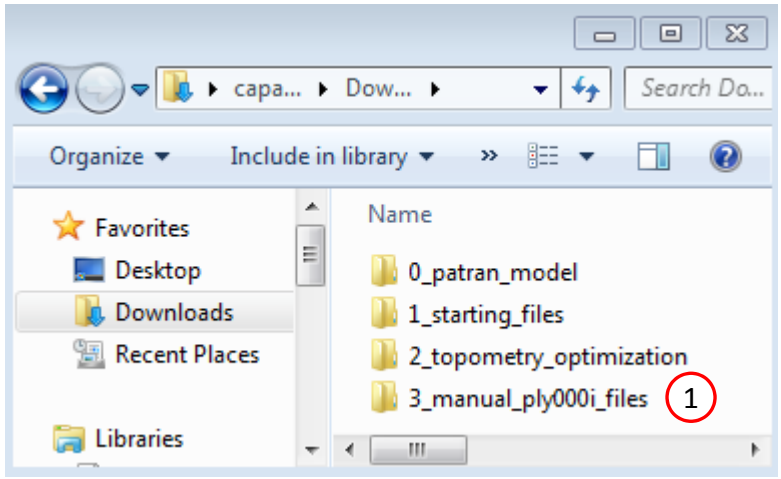


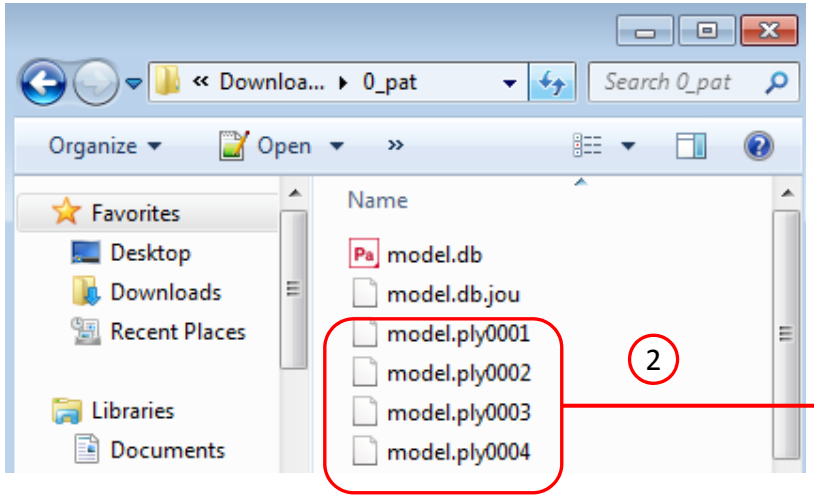


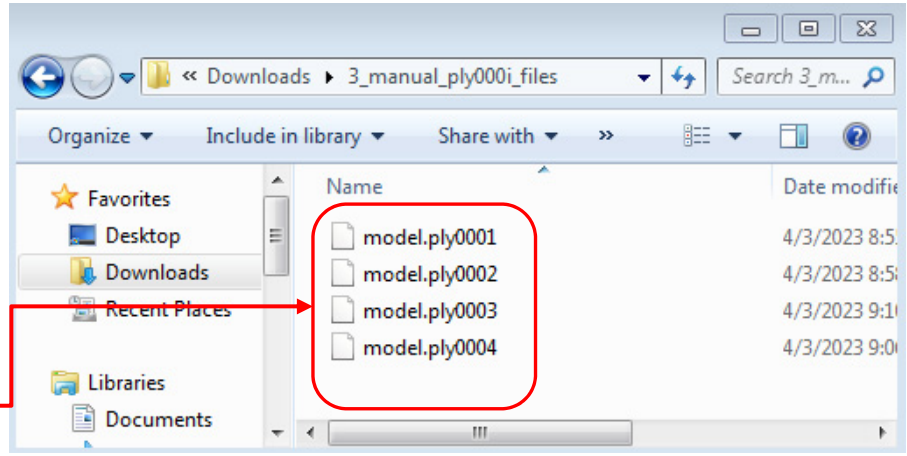


Store the PLY000i Files

1. Navigate to the Downloads directory and create a new directory named 3_manual_ply000i_files
2. Copy the PLY000i files to directory 3_manual_ply000i_files







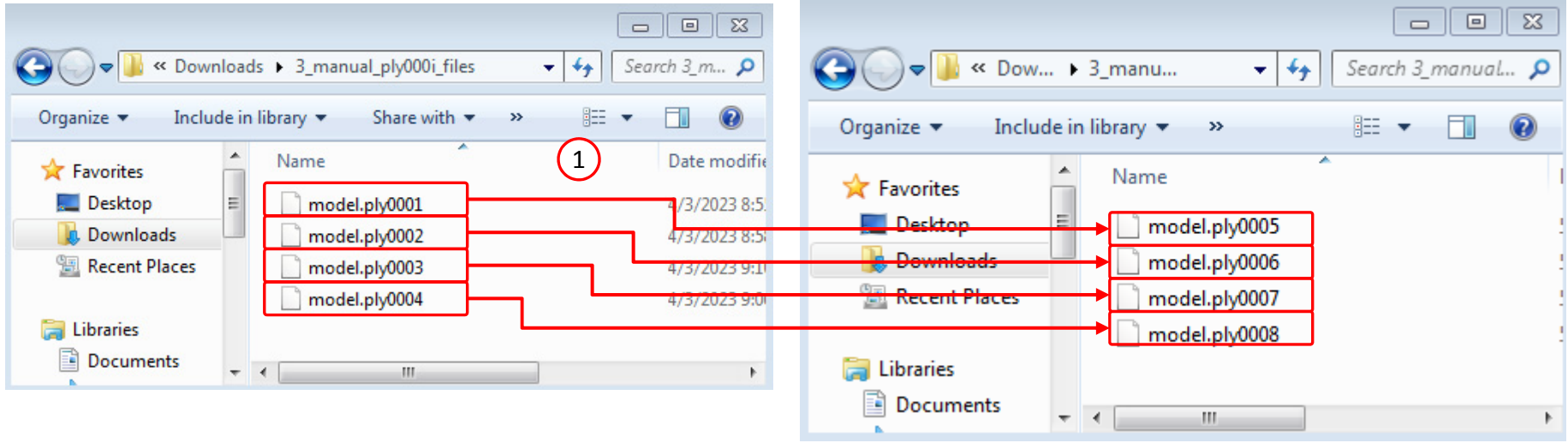
Store the PLY000i Files

1. Rename the following files
   - model.ply0001 => model.ply0005
   - model.ply0002 => model.ply0006
   - model.ply0003 => model.ply0007
   - model.ply0004 => model.ply0008
2. These file names align with the layer numbers referenced in the TOMVAR entries, e.g. T5, T6, T7 and T8.

- Layers 1-4 will remain fixed during the optimization. Only layers 5, 6, 7 and 8 will be change during this optimization procedure.

(2)

```
$TOMVAR  ID       TYPE    PID      PNAME    XINIT    XLB      XUB      DELXV
TOMVAR   3000001  PCOMP   1        T5       .25      .001
TOMVAR   3000002  PCOMP   1        T6       .25      .001
TOMVAR   3000003  PCOMP   1        T7       .25      .001
TOMVAR   3000004  PCOMP   1        T8       .25      .001
```



Inspect the PLY000i Files

1. Open each PLY000i file in a text editor and ensure the values are similar to what is shown

model.ply0005

model.ply0005

```
1
2
3       1429      0
4       0.307122
5       1430      0
6       0.103824
7       1431      0
8       0.123881
9       1432      0
10      0.120190
11      1433      0
12      0.121350
13      1434      0
14      0.121152
15      1435      0
16      0.121225
17      1436      0
18      0.121206
19      1437      0
20      0.121206
21      1438      0
```

model.ply0006

model.ply0006

```
1
2
3       1429      0
4       0.068311
5       1430      0
6       0.033003
7       1431      0
8       0.037165
9       1432      0
10      0.035959
11      1433      0
12      0.036363
13      1434      0
14      0.036402
15      1435      0
16      0.036498
17      1436      0
18      0.036520
19      1437      0
20      0.036492
21      1438      0
```

model.ply0007

model.ply0007

```
1
2
3       1429      0
4       0.128537
5       1430      0
6       0.023576
7       1431      0
8       0.032193
9       1432      0
10      0.032717
11      1433      0
12      0.034264
13      1434      0
14      0.034998
15      1435      0
16      0.035578
17      1436      0
18      0.035959
19      1437      0
20      0.036224
21      1438      0
```

model.ply0008

model.ply0008

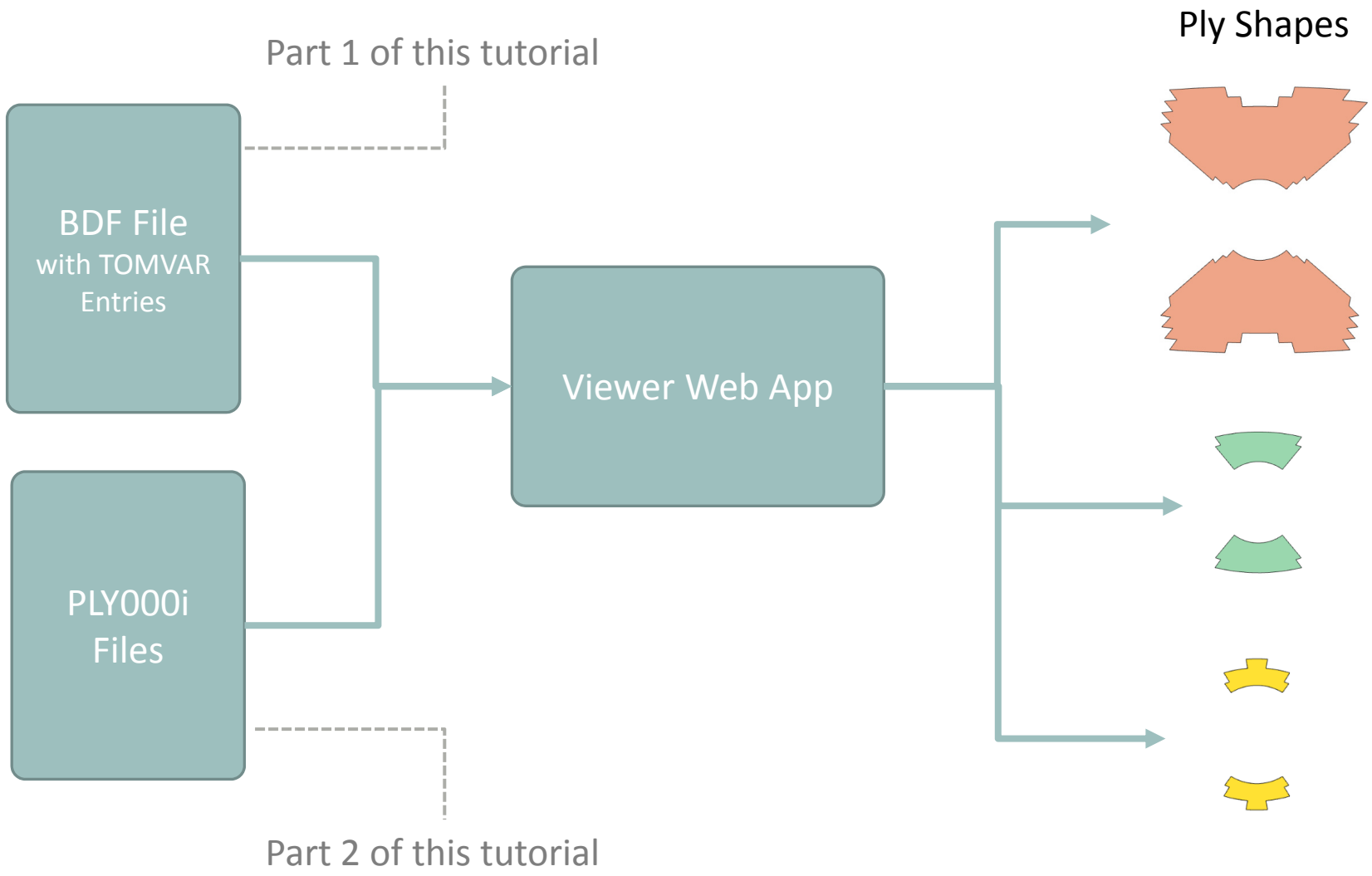
```
1
2
3       1429      0
4       0.008058
5       1430      0
6       0.003148
7       1431      0
8       0.003341
9       1432      0
10      0.003091
11      1433      0
12      0.003008
13      1434      0
14      0.002936
15      1435      0
16      0.002893
17      1436      0
18      0.002865
19      1437      0
20      0.002850
21      1438      0
```

Conclusion

A future goal is to construct a lightweight composite with optimized ply shapes.

The Viewer web app may generate new ply shapes, but first, BDF files, with TOMVAR entries, and PLY000i files must be created. This tutorial detailed how to create the BDF and PLY000i files.

In a separate tutorial, instructions are provided to upload the BDF files and PLY000i files to the Viewer web app and how to create ply shapes.



End of Tutorial

Appendix

Appendix Contents

- Comments on bulk data entries compatible with ply shape optimization
- Why is a topometry optimization skipped?
- Methods to Create PLY000i Files

Comments on bulk data entries compatible with ply shape optimization

Certain configurations of bulk data entries should be avoided in ply shape optimization or in general optimization

1. The TOMVAR entry does NOT support PCOMPG entries, so use PCOMP entries.
2. The formatting of PCOMPG and PCOMP entries are very similar. A text editor may be used to convert PCOMPG to PCOMP entries.
3. The Ti fields corresponding to the membrane thickness of the element at the grid points should NOT be used in a weight optimization. Using these fields will fix the volume of the element, which will fix the mass of the model. During the weight optimization, the mass will remain constant but the goal is to minimize the mass.
4. Use 2D element entries that do NOT use the Ti fields in a weight optimization.

NOT OK

(1)

```
PCOMPG    1                                90.      HILL
          1       101      .3755           90.       YES
          2       101      .3755           45.       YES
          3       101      .3755           -45.      YES
          4       101      .3755           0.        YES
          5       501      3.175           0.        YES
```

OK

(2)

```
PCOMP     1                                90.      HILL
          101      .3755           90.       YES
          101      .3755           45.       YES
          101      .3755           -45.      YES
          101      .3755           0.        YES
          501      3.175           0.        YES
```

NOT OK

(3)

```
CQUAD4    1429     1               2393      2374      2452      2411
                                   1.0       1.0       1.0       1.0
CQUAD4    1430     1               2411      2452      2453      2410
                                   1.0       1.0       1.0       1.0
```

OK

(4)

```
CQUAD4    1429     1               2393      2374      2452      2411
CQUAD4    1430     1               2411      2452      2453      2410
```

Why is a topometry optimization skipped?

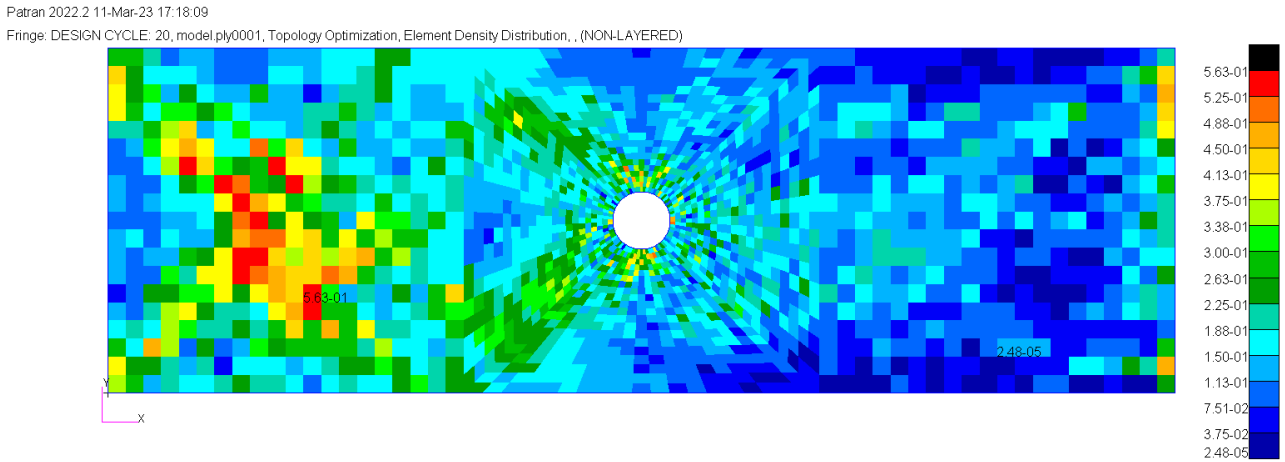
There are 2 reasons why topometry optimization is not performed.

1. Topometry optimization with failure index constraint does not yield good results. This is likely due to the many local optimization solutions that exist. One topometry optimization may yield a converged solution but is one solution of many solutions. A topometry optimization with failure index constraints is not performed. Instead, the failure index results are used to construct optimal ply shapes. The failure index results are stored in PLY000i files.

2. While a topometry optimization is not necessary, the BDF files do require TOMVAR entries to exist. For each layer that will have new optimized ply shapes, a TOMVAR entry must be defined.

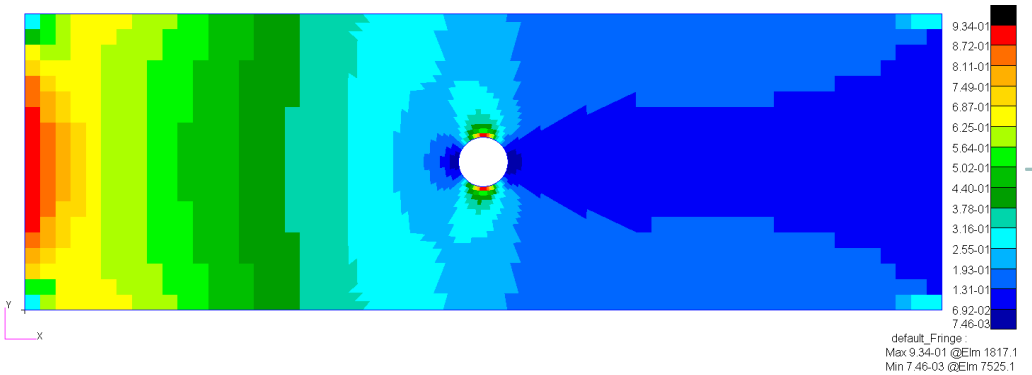
3. If global responses, such as buckling load factors or natural frequencies, are to be optimized, a topometry optimization does yield good results and should be used to optimize composites.

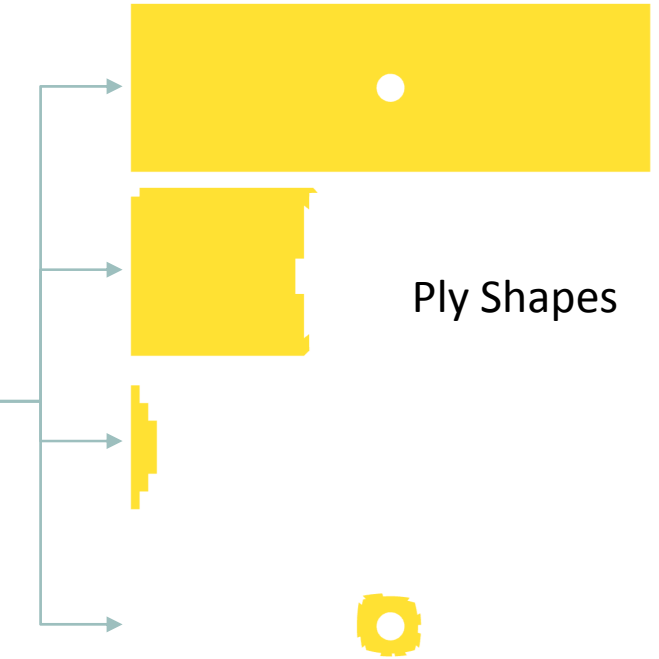
Topometry Optimization Results



Best Approach

Failure index plot of 0-degree layers for the most critical subcase(s)





Methods to Create PLY000i Files

PLY000i files are required to perform ply shape optimization. There are various methods to create PLY000i files.

1. Manual Method – Manually combine fringe plots and create PLY000i files.
2. Topometry Optimization Method – Use Topometry optimization to generate PLY000 files.
3. Hybrid Method – Combine PLY000i files from the manual method and topometry optimization.

- This tutorial employs the Manual Method

Method to Create PLY000i Files	Primary Constrained Response
Manual Method	Element Quantities: Ply Stress, Ply Strain, Failure Index or Strength Ratio
Topometry Optimization Method	Non-element Quantities: Displacements, Natural Frequencies and Buckling Load Factors
Hybrid Method	Element AND non-element quantities