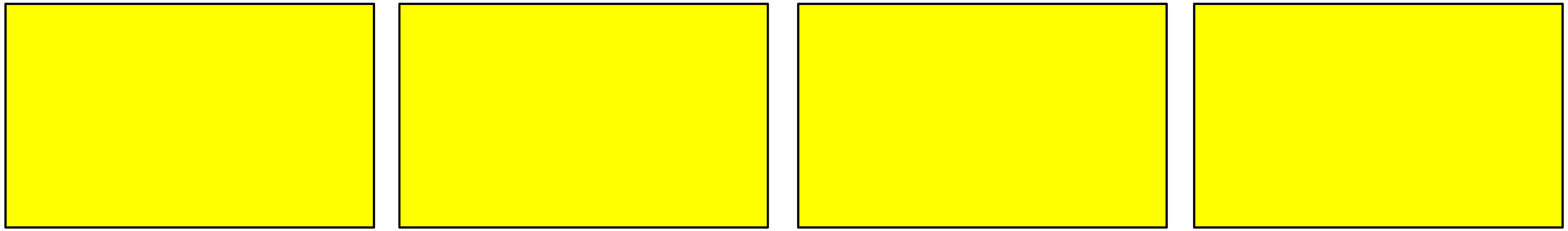
Workshop - MSC Nastran Topometry Optimization of a Composite Panel

AN MSC NASTRAN SOL 200 TUTORIAL

Goal: Use Nastran SOL 200 Optimization

Use Topometry optimization to determine ply shapes

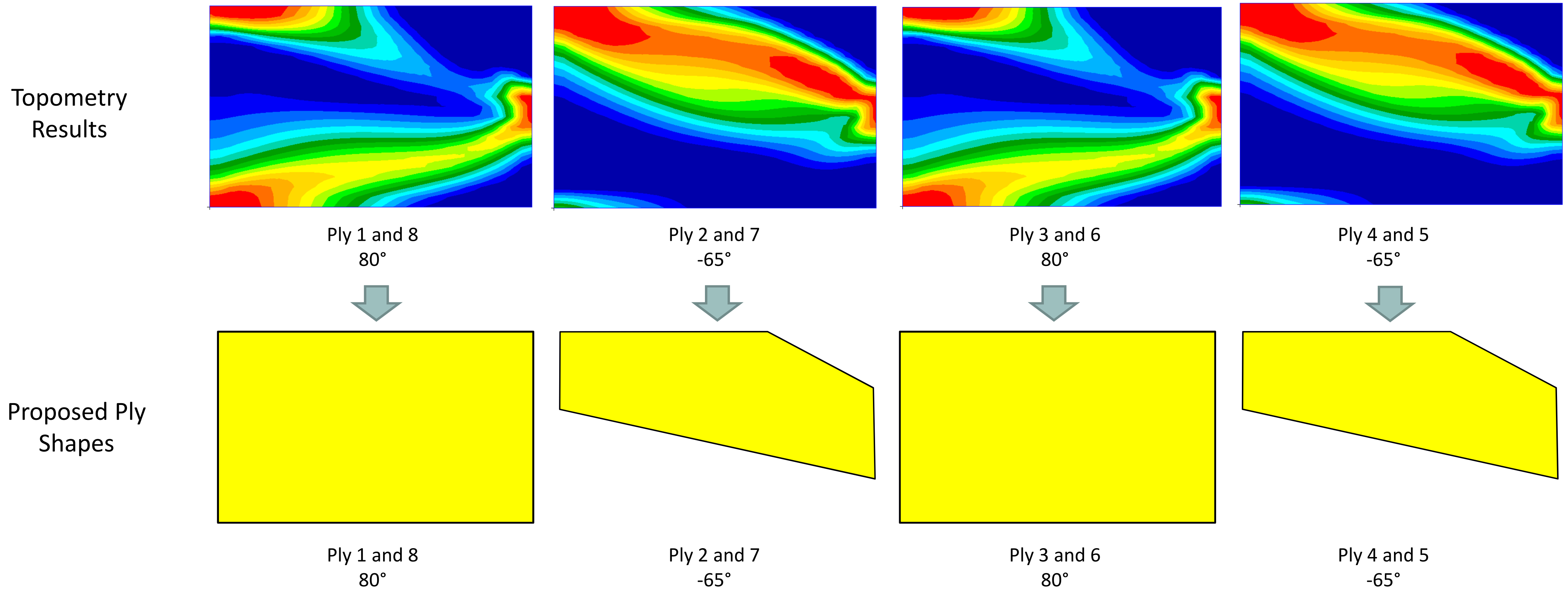
Initial Ply Shapes



Ply 1 and 8	Ply 2 and 7	Ply 3 and 6	Ply 4 and 5
80°	-65°	80°	-65°

Goal: Use Nastran SOL 200 Optimization

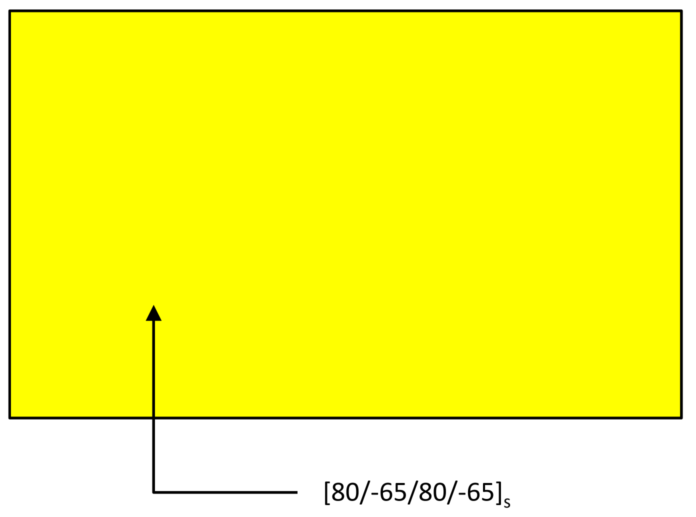
Use Topometry optimization to determine optimal ply shapes



Goal: Use Nastran SOL 200 Optimization

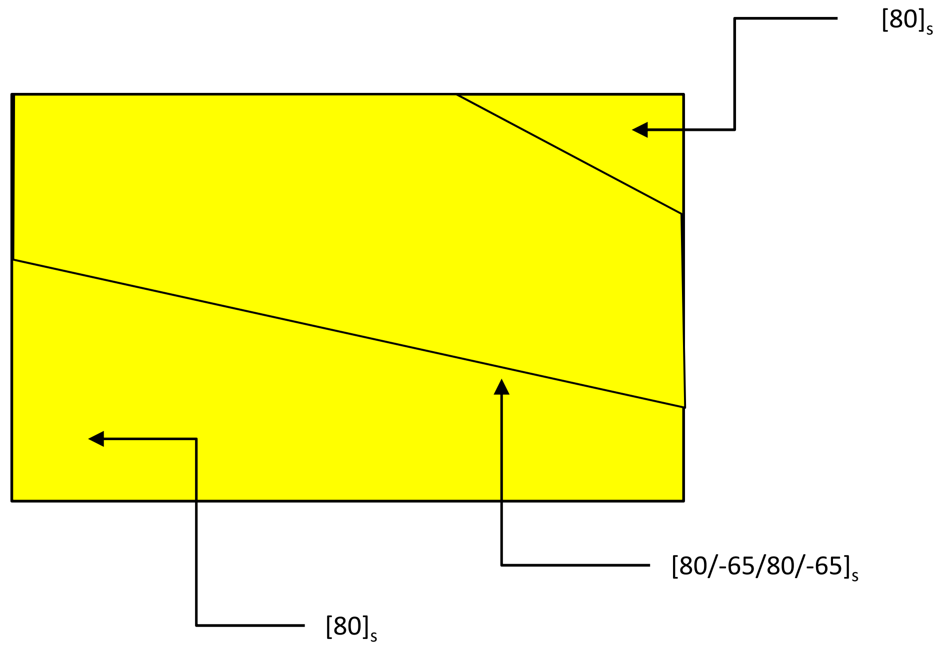
Before Optimization

- Panel of initial layup

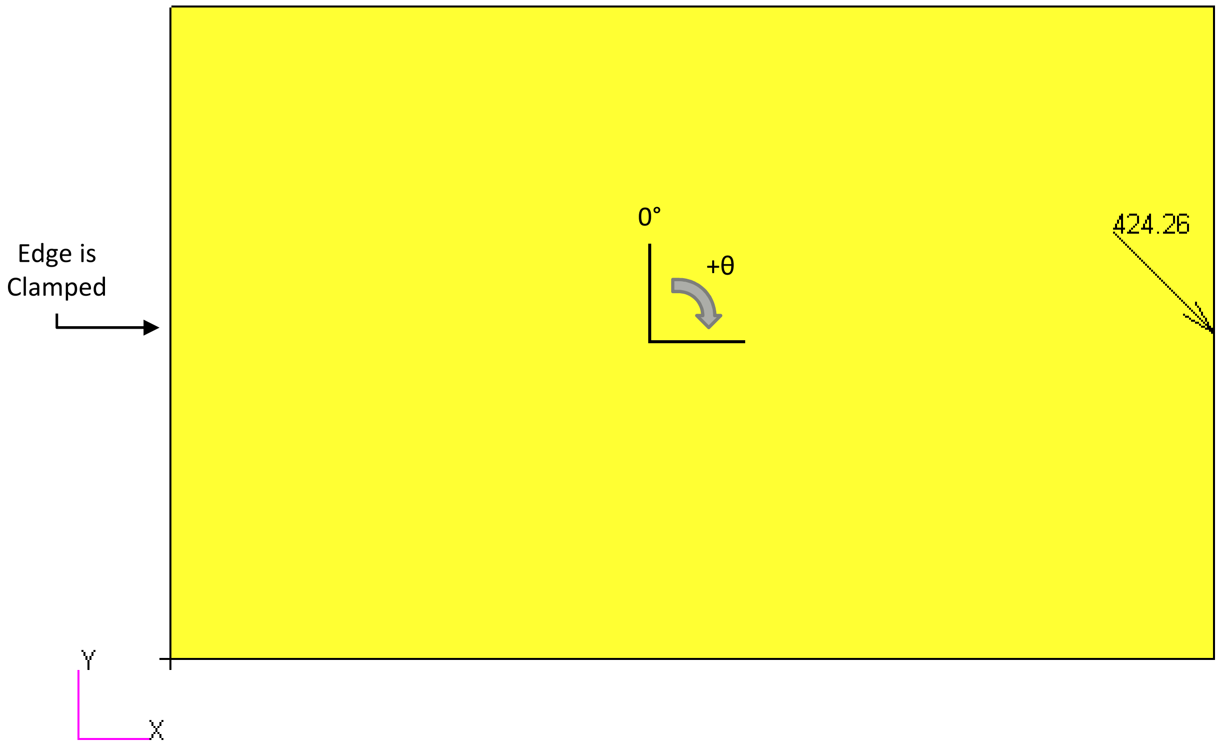


After Optimization

- Panel of updated layups
- The weight is reduced



Details of the structural model



Panel: 16in. x 10in.
Layup: $[80/-65/80/-65]_s$

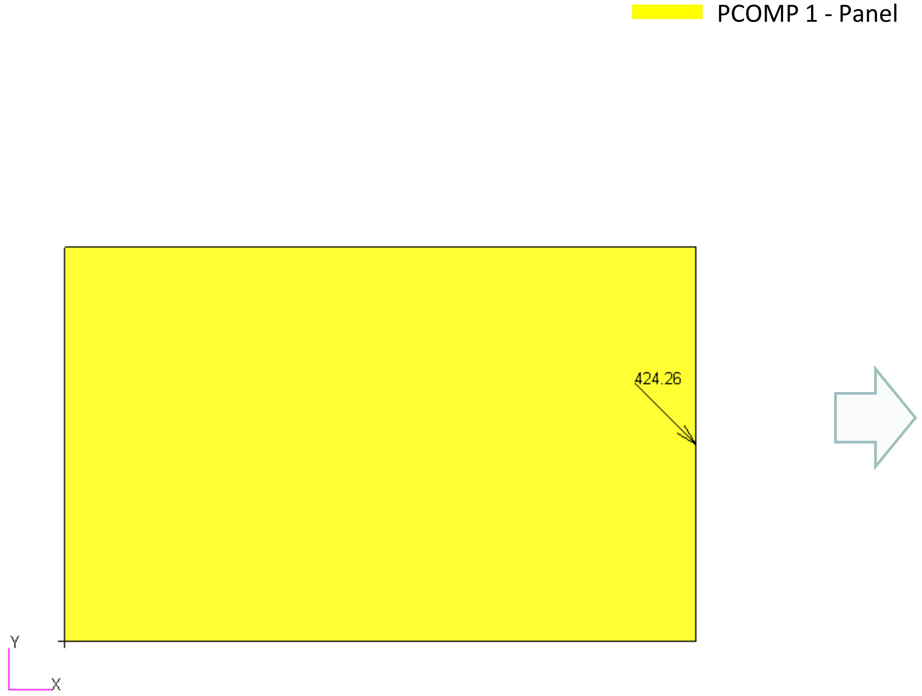
Optimization Problem Statement

Design Region (Topometry)

z1: Thickness of ply 1 and 8
z2: Thickness of ply 2 and 7
z3: Thickness of ply 3 and 6
z4: Thickness of ply 4 and 5

.001 < z1, z2, z3, z4

Variable Linking
z3 = z1
z4 = z2



Design Objective

r0: Minimize compliance
This is equivalent to maximizing stiffness

Design Constraints

r1: Weight

r1 < 38.0 (~50% of original weight 75.0)

Contact me

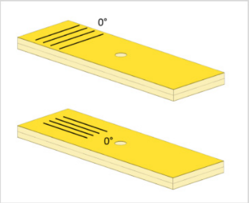
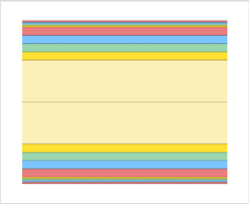
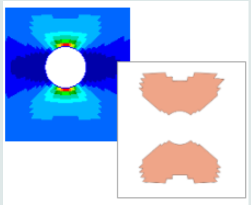
- Nastran SOL 200 training
- Nastran SOL 200 questions
- Structural or mechanical optimization questions
- Access to the SOL 200 Web App

christian@ the-engineering-lab.com

Before Continuing

Consider the New Composite Laminate Optimization Tutorials – Composite Coupon

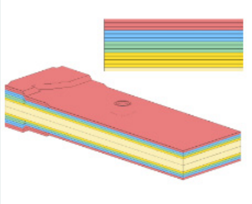
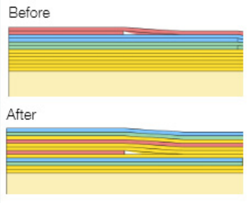
Visit the User's Guide to access the newest tutorials.

	Title and Description	PDF Tutorial	YouTube Tutorial
	**Composite Coupon – Phase A – Determination of the optimal 0° direction of a composite** The goal of this 5-phase tutorial series is to optimize a composite coupon, with a core, and produce a lightweight composite that satisfies failure index constraints. The optimal ply shapes (ply drop-offs) and ply numbers are determined for 0°, ±45°, and 90° plies. A stacking sequence optimization is performed to satisfy manufacturing requirements. One important part of optimizing composites is visualizing the composite plies. This tutorial series also demonstrates the visualization of ply drop-offs, tapered plies and core layers. This first phase involves determining the optimal 0° direction of a composite. It is best practice to align the 0° plies in the direction of the load. Not doing so will more than likely produce a suboptimal composite that is heavier than necessary. This tutorial demonstrates the use of MSC Nastran's optimizer to determine the optimal 0° direction of a composite. An optimization is performed to maximize the stiffness of the composite for multiple load cases and while varying the angle of the 0° plies. Ultimately, the best 0° direction is determined. This is the first phase in a 5-phase tutorial series.	Link	Link
	**Composite Coupon – Phase B – Baseline Ply Number Optimization** This tutorial demonstrates how to configure a basic ply number optimization of continuous plies that span the entire model. The goal of this tutorial is to demonstrate basic actions such as creating variables, a weight objective and constraints on failure index. The results of this ply number optimization serve as a baseline for future comparisons. In a subsequent tutorial, the ply shapes will be optimized to minimize weight. This is the second phase in a 5-phase tutorial series.	Link	Link
	**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.	Link	Link

Before Continuing

Consider the New Composite Laminate Optimization Tutorials – Composite Coupon, Continued

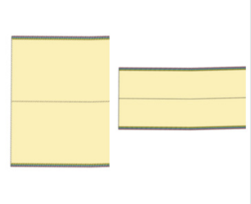
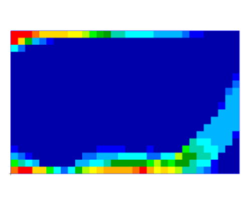
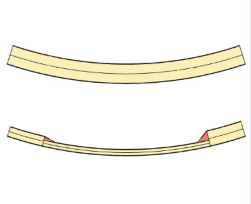
Visit the User's Guide to access the newest tutorials.

	Title and Description	PDF Tutorial	YouTube Tutorial
	**Composite Coupon – Phase D – Ply Shape and Ply Number Optimization** This tutorial details the process to build optimal ply shapes and perform a ply number optimization. The optimal ply shapes are constructed to follow the contours of the failure indices. The ply number optimization involves minimizing weight and constraining the failure indices of plies. The PLY000i files and BDF files from the previous tutorial, phase C, are used in this tutorial. This is the fourth phase in a 5-phase tutorial series.	Link	Link
	**Composite Coupon – Phase E – Stacking Sequence Optimization** This tutorial involves performing a stacking sequence optimization and is a continuation of the previous tutorial, phase D. A final statics analysis is performed to confirm the optimized composite satisfies failure index constraints. This is the fifth phase in a 5-phase tutorial series.	Link	Link

Before Continuing

Consider the New Composite Laminate Optimization Tutorials – Sandwich Composite Panel

Visit the User's Guide to access the newest tutorials.

	Title and Description	PDF Tutorial	YouTube Tutorial
	**Sandwich Composite Panel – Phase B – Baseline Core Thickness Optimization** The goal of this 3-phase tutorial series is to optimize a curved composite panel, with a core, and produce a lightweight composite that satisfies constraints on the buckling load factor. This tutorial series focuses exclusively on optimizing the thickness of the core. The methods detailed in the tutorial series are applicable to both foam and honeycomb cores. This tutorial demonstrates how to configure a basic core thickness optimization where the core has a constant thickness throughout the entire model. The goal of this tutorial is to demonstrate basic actions such as creating variables, a weight objective and constraints on the buckling load factor. The results of this core thickness optimization serve as a baseline for future comparisons. In a subsequent tutorial, the core will be allowed to have a variable thickness throughout the model and will be optimized to minimize weight. This is the first phase in a 3-phase tutorial series.	Link	Link
	**Sandwich Composite Panel – Phase C – Topometry Optimization to Determine Optimal Core Shape** This tutorial is a guide to preparing data for core shape and core thickness optimization in a subsequent tutorial. A topometry optimization is performed in this tutorial to determine the ideal thickness distribution of the core throughout the entire composite panel while satisfying constraints on the buckling load factor and minimizing weight. The results of a topometry optimization are contained in the PLY000i files and will be used to construct optimal core shapes in a subsequent tutorial. This is the second phase in a 3-phase tutorial series.	Link	Link
	**Sandwich 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.	Link	Link

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 Regions/Variables
     - Design Objective
     - Design Constraints
   - Perform optimization with Nastran SOL 200
3. Review optimization results
   - .f06
   - Topometry Optimization and Structural Results

Special Topics Covered

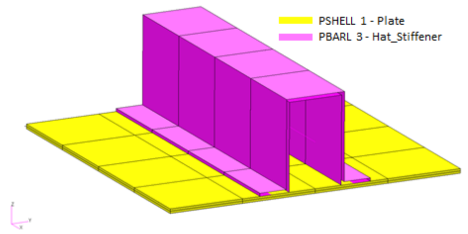
Linked Properties in Topometry Optimization – When configuring a size optimization, there is an option to link variables, i.e. one variable is dependent on the change of another variable. A similar option exists for the thickness properties on the PCOMP entry, enabling users to link ply thicknesses of a composite laminate during a topometry optimization.

SOL 200 Web App Capabilities

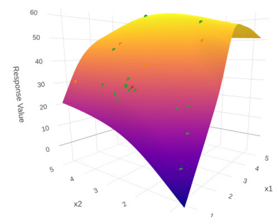
Benefits

- 200+ error validations (real time)
- Web browser accessible
- Automated creation of entries (real time)
- Automatic post-processing
- 76 tutorials

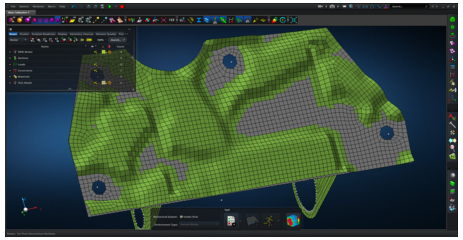
Capabilities



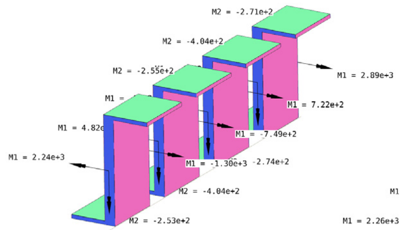
Web Apps for SOL 200
Pre/post for MSC Nastran SOL 200. Support for size, topology, topometry, topography and multi-model.



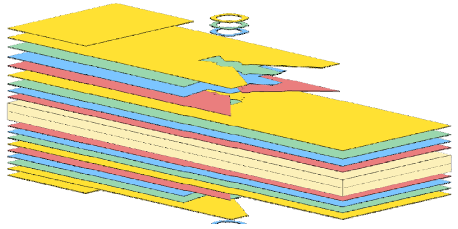
Machine Learning Web App
Bayesian Optimization for nonlinear response optimization (SOL 400)



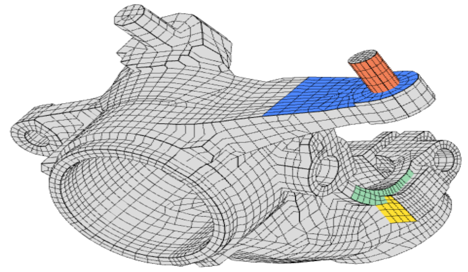
MSC Apex Post Processing Support
View the newly optimized model after an optimization



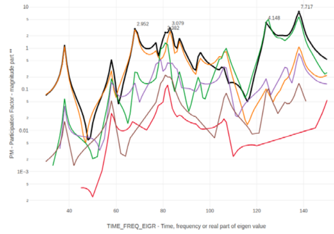
Beams Viewer Web App
Post process 1D element forces, including shear forces, moments, torque and axial forces



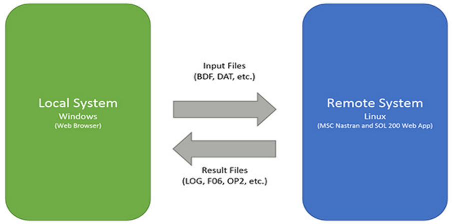
Ply Shape Optimization Web App
Spread plies optimally and generate new PCOMPG entries



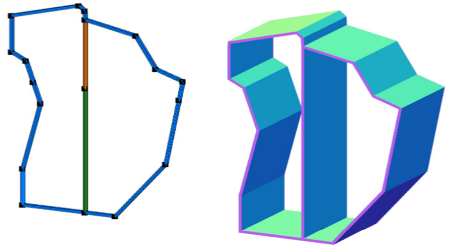
Shape Optimization Web App
Use a web application to configure and perform shape optimization.



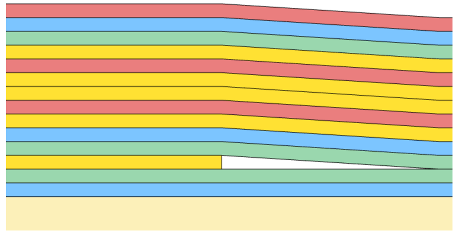
HDF5 Explorer Web App
Create XY plots using data from the H5 file



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



PBMSECT Web App
Generate PBMSECT and PBRSECT entries graphically

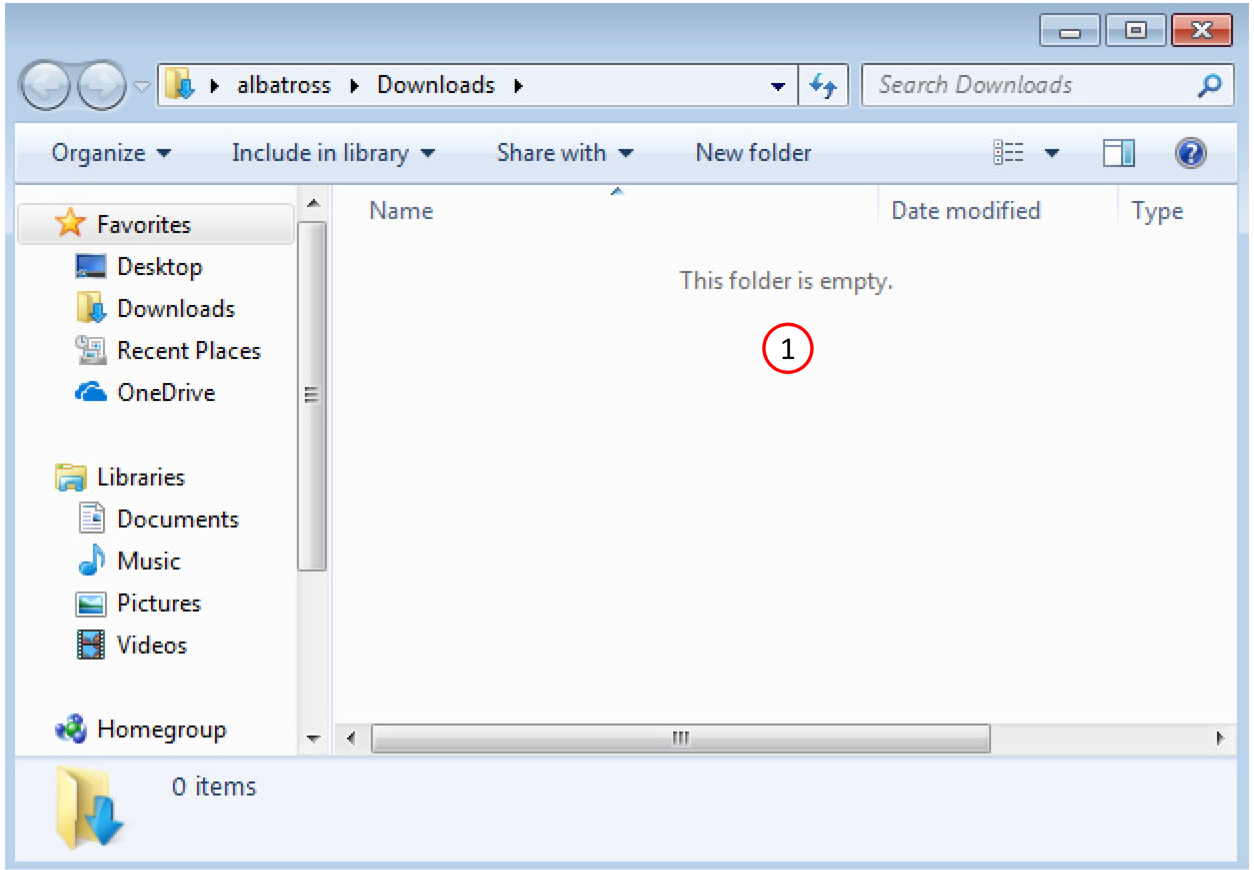


Stacking Sequence Web App
Optimize the stacking sequence of composite laminate plies

Before Starting

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

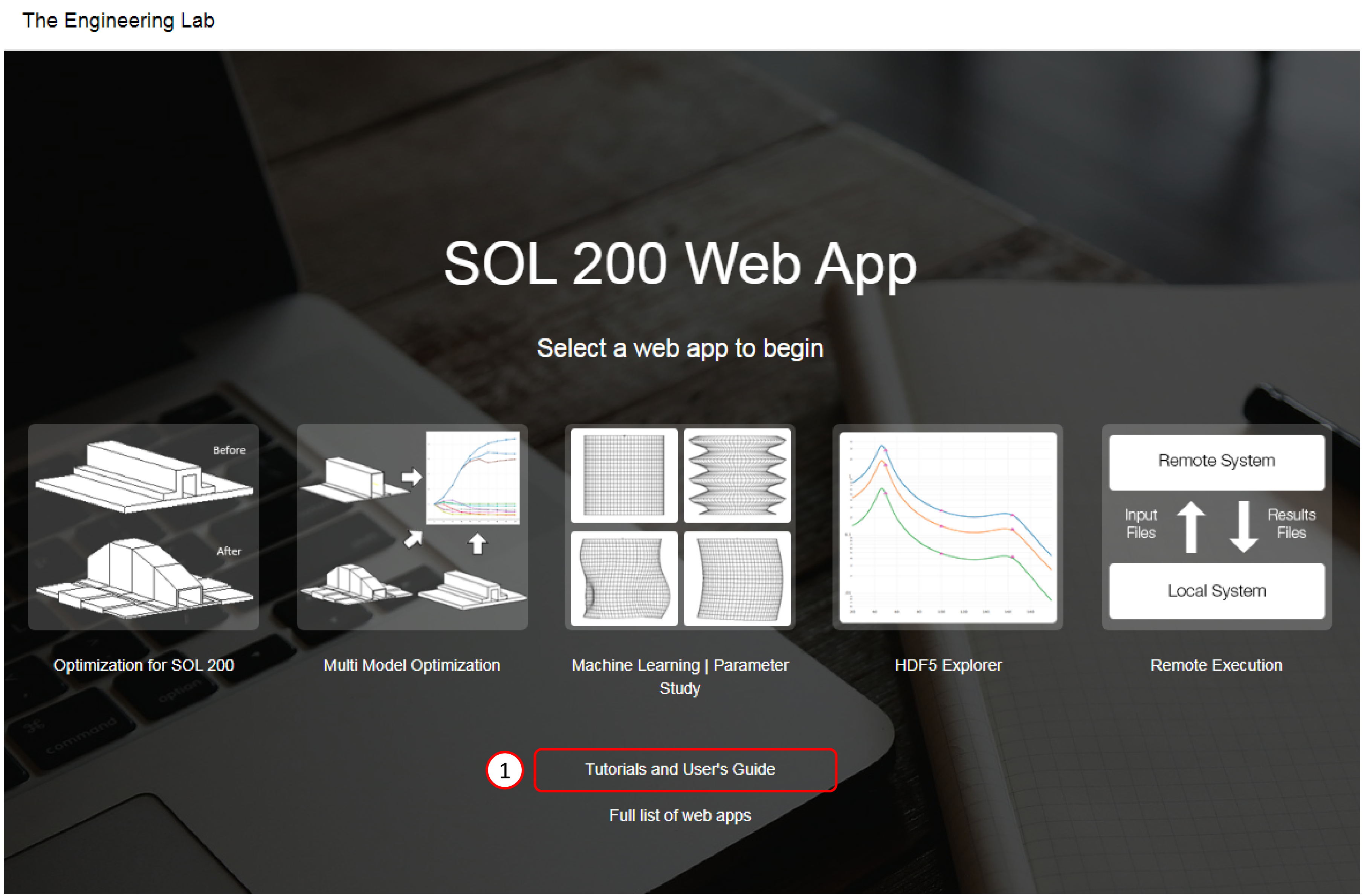
- Throughout this workshop, you will be working with multiple file types and directories such as:
    - .bdf/.dat
    - nastran_working_directory
    - .f06, .log, .pch, .h5, etc.
- To minimize confusion with files and folders, it is encouraged to start with a clean directory.



Go to the User's Guide

1. Click on the indicated link

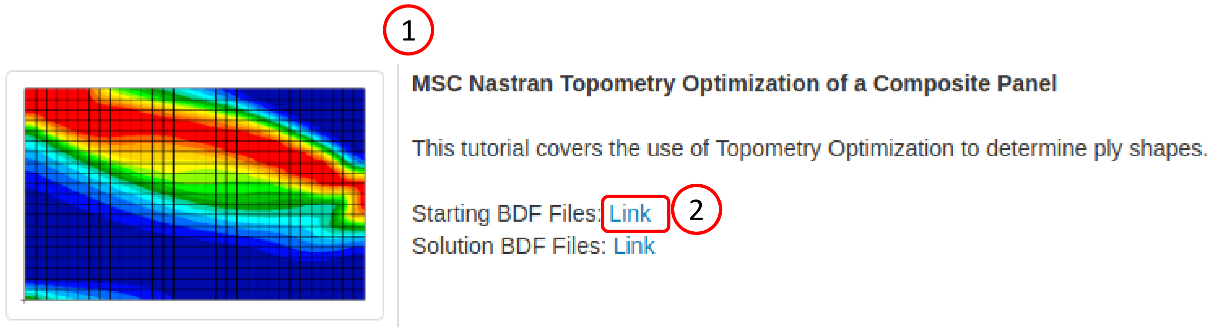
- The necessary BDF files for this tutorial are available in the Tutorials section of the User's Guide.

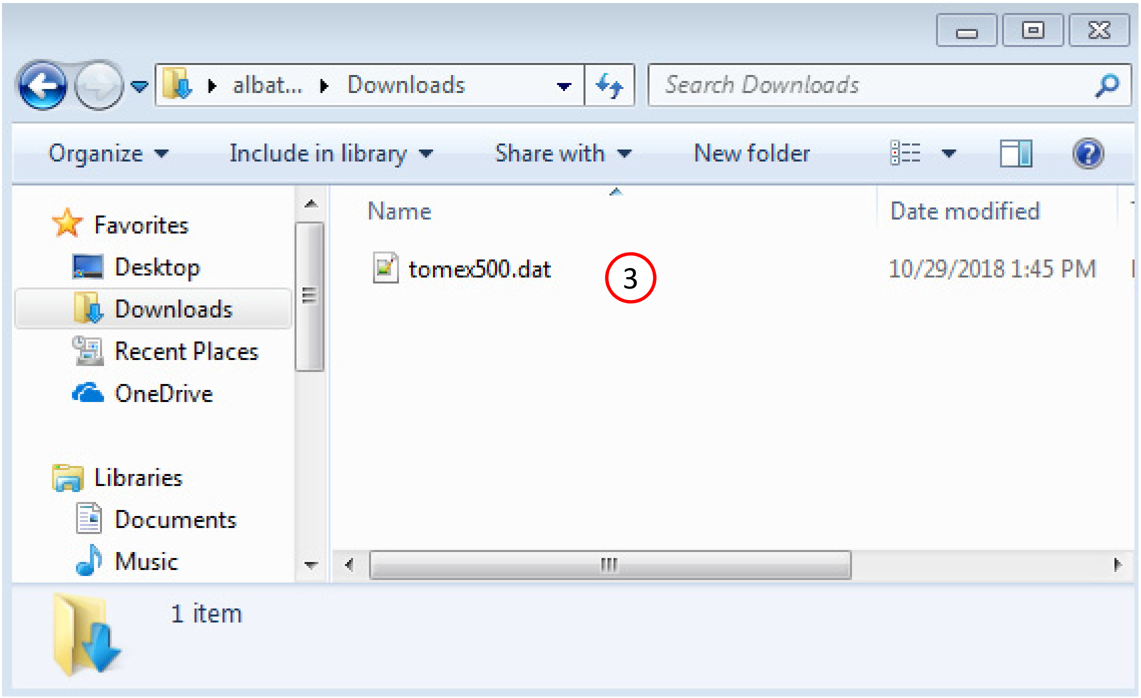


Obtain Starting Files

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.





Open the Correct Page

1. Click on the indicated link

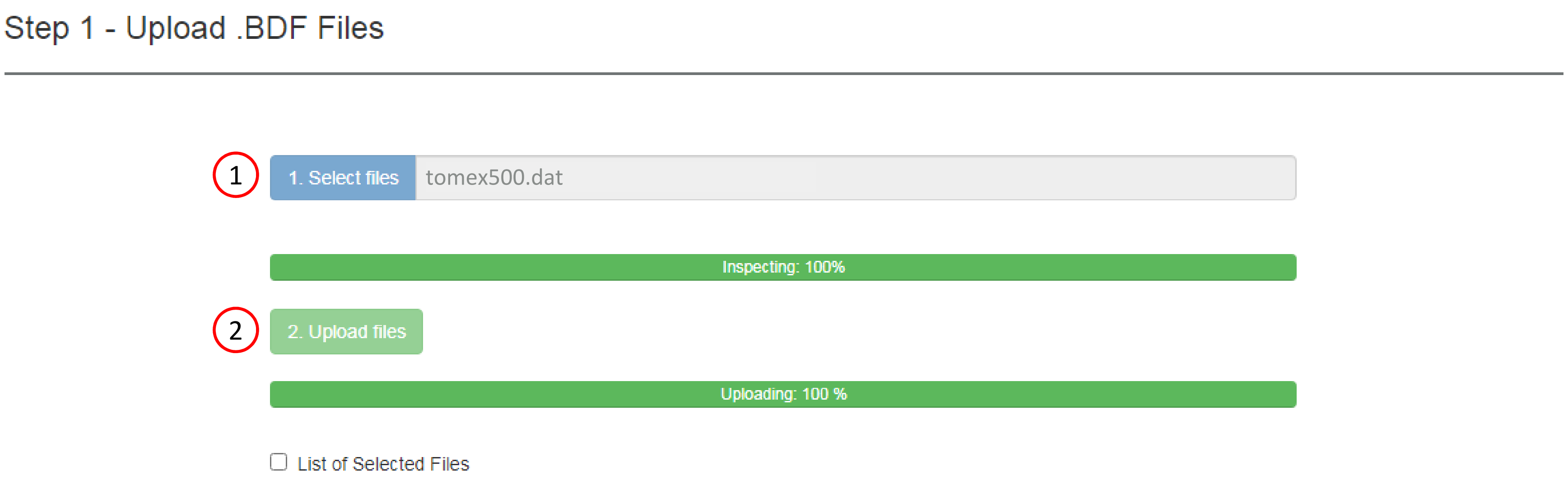
- MSC Nastran can perform many optimization types. The SOL 200 Web App includes dedicated web apps for the following:
    - Optimization for SOL 200 (Size, Topology, Topometry, Topography, Local Optimization, Sensitivity Analysis and Global Optimization)
    - Multi Model Optimization
    - Machine Learning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

The Engineering Lab

Upload BDF Files

1. Click 1. Select Files and select tomex500.dat
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.



Create Design Region

1. Click Topometry
2. In the search box, type ‘thickness’
3. Click on the plus (+) icons to set the thickness (Ti) of Plies 1-4 as Design Regions
4. Scroll to the section titled Step 2 – Adjust TOMVAR entries
5. The new Design Region is added to the table, no further edit is necessary

- Suppose the goal is to vary the thickness. In traditional Size optimization, the thickness can be a set a single design variable. With Topometry optimization, when the design region is set, each element in the region is given its own independent thickness design variable.
- If PSHELL 1 has 500 elements associated and is configured as a design region, then there will be 500 design variables created.
- Each step has hidden functionality for advanced users. The visibility is controlled by clicking +Options .
- If the property entry, e.g. PSHELL, was given a name in Patran, e.g. Car Door, the name can be shown by marking the checkbox titled Entry Name.

SOL 200 Web App - Optimization | Upload | Variables | Objective | Constraints | Subcases | Exporter | Results

Size | Topology | Topometry (1) | Topography

Step 1 - Select design properties

+ Options

Create TOMVAR	Property	Property Description	Entry	Entry ID	Current Value
	Search	thickness (2)	Search	Search	Search
+ (3)	T1	Thickness of ply	PCOMP	1	1.000
+	T2	Thickness of ply	PCOMP	1	1.000
+	T3	Thickness of ply	PCOMP	1	1.000
+	T4	Thickness of ply	PCOMP	1	1.000

5 | 10 | 20 | 30 | 40 | 50

Number of Visible Rows 5

(4) Step 2 - Adjust TOMVAR Entries

+ Options

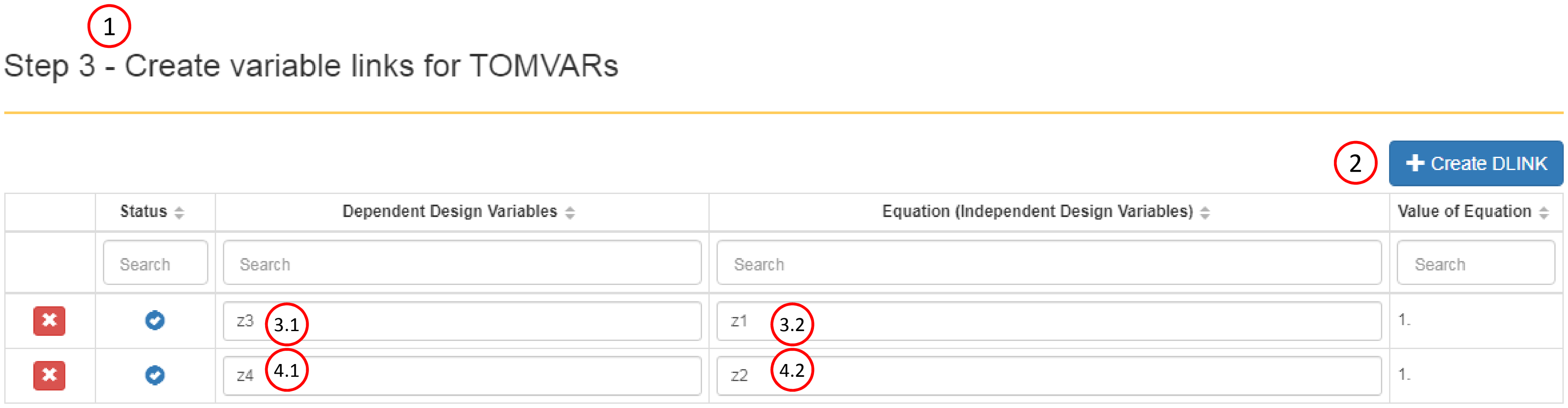
✖ Delete Visible Rows

	Label	Status	Property	Property Description	Entry	Entry ID	Initial Value	Lower Bound	Upper Bound	Allowed Discrete Values
	Search	Search	Search	Search	Search	Search	Search	Search	Search	Search
✖	z1	✔	T1	Thickness of ply	PCOMP	1	1.000	.001	Upper	Examples: -2.0, 1.0, THRU, 10.0, B'
✖	z2 (5)	✔	T2	Thickness of ply	PCOMP	1	1.000	.001	Upper	Examples: -2.0, 1.0, THRU, 10.0, B'
✖	z3	✔	T3	Thickness of ply	PCOMP	1	1.000	.001	Upper	Examples: -2.0, 1.0, THRU, 10.0, B'
✖	z4	✔	T4	Thickness of ply	PCOMP	1	1.000	.001	Upper	Examples: -2.0, 1.0, THRU, 10.0, B'

Create Design Region

1. Scroll to the section titled Step 3 – Optional – Create variable links for TOMVARs
2. Click 2 times on +Create DLINK
3. Create design variables links for the thickness of ply 1 and 3
    1. Dependent Design Variables: z3
    2. Equation: z1
4. Create design variables links for the thickness of ply 2 and 4
    1. Dependent Design Variables: z4
    2. Equation: z2

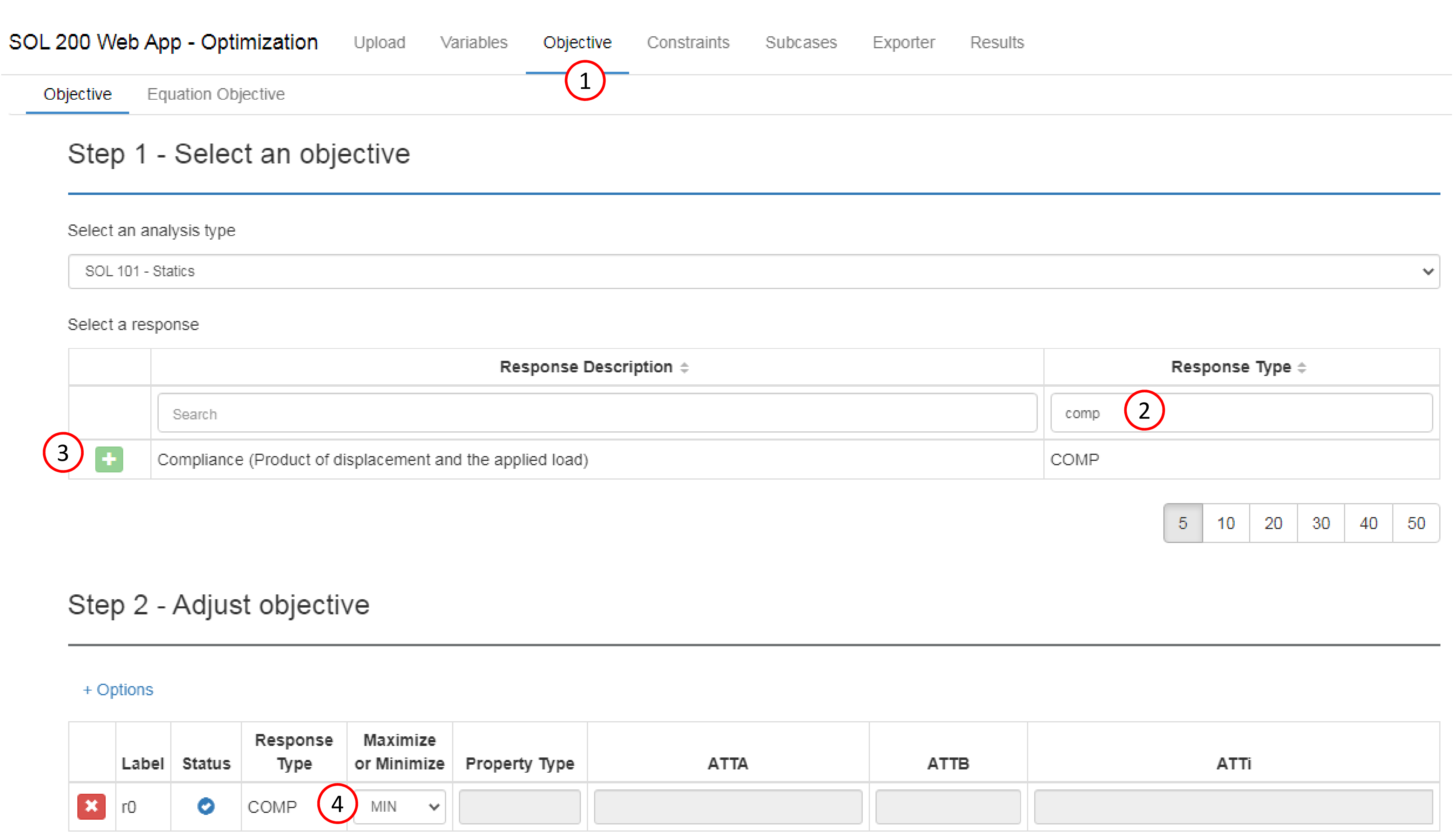
- It is important to verify the Equation is configured properly. For example, the variable z3 is initially equal to 1.0. When the Equation is configured, it should also produce an initial value of 1.0. The resulting value of the Equation is displayed on the column titled Value of Equation and can be used to validate the Equation is configured properly.



Create Design Objective

1. Click on Objective
2. Type 'comp' in the search box
3. Select the plus(+) icon for Compliance
4. The objective with label r0 is created. The objective is to minimize (MIN)

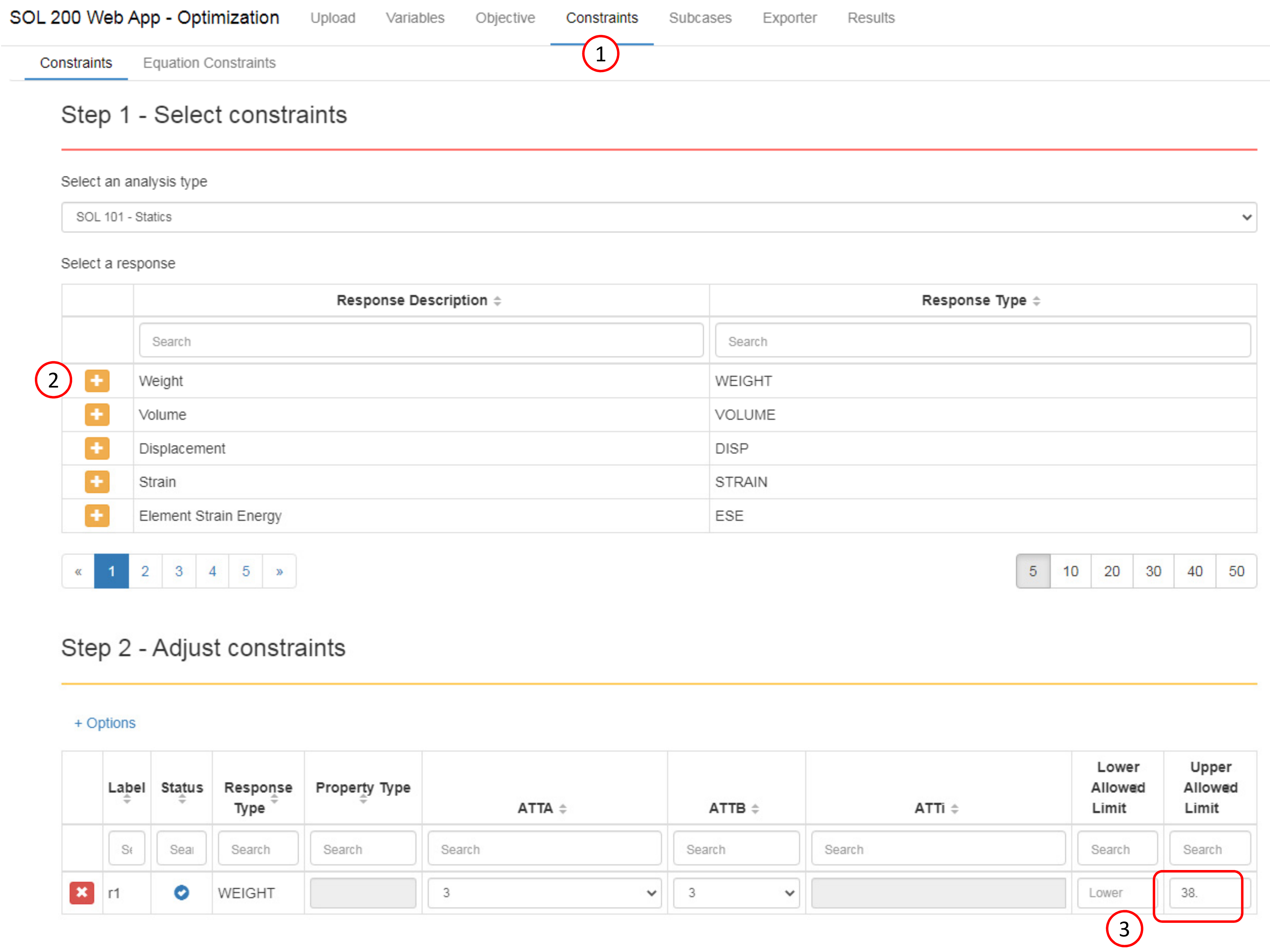
- The objective must always be a single scalar response. A response such as weight and volume are single responses and can be used as an objective. Other responses require special care when set as an objective. For example, if the objective is stress, only the stress of a single component, e.g. von Mises, of a single element, of a single load case may be used.



Create Design Constraints

1. Click Constraints
2. Click on the plus (+) icon for Weight
3. Configure the following for r1:
    - Upper Allowed Limit: 38.0

- The constraints are defined normally as would be done in a size optimization.



Configure Optimization Settings

1. Click Settings
2. Set P2 to 12 – Print constraints and responses

- The P2 setting controls the output of the following information to the F06 file: objective, constraints, responses, properties and design variables.
- This is a topometry optimization and will generate a large amount of property and design variable data in the F06 file. To make the F06 file size manageable, the design variable information is omitted by using the P2=12 option. When the results are viewed, note that the objective and constraint information is plotted, but the design variable history is not plotted due to the P2=12 option.
- If this is a combined size and topometry optimization, P2 should be set to 15. If this is a pure size optimization, P2 should be set to 15.

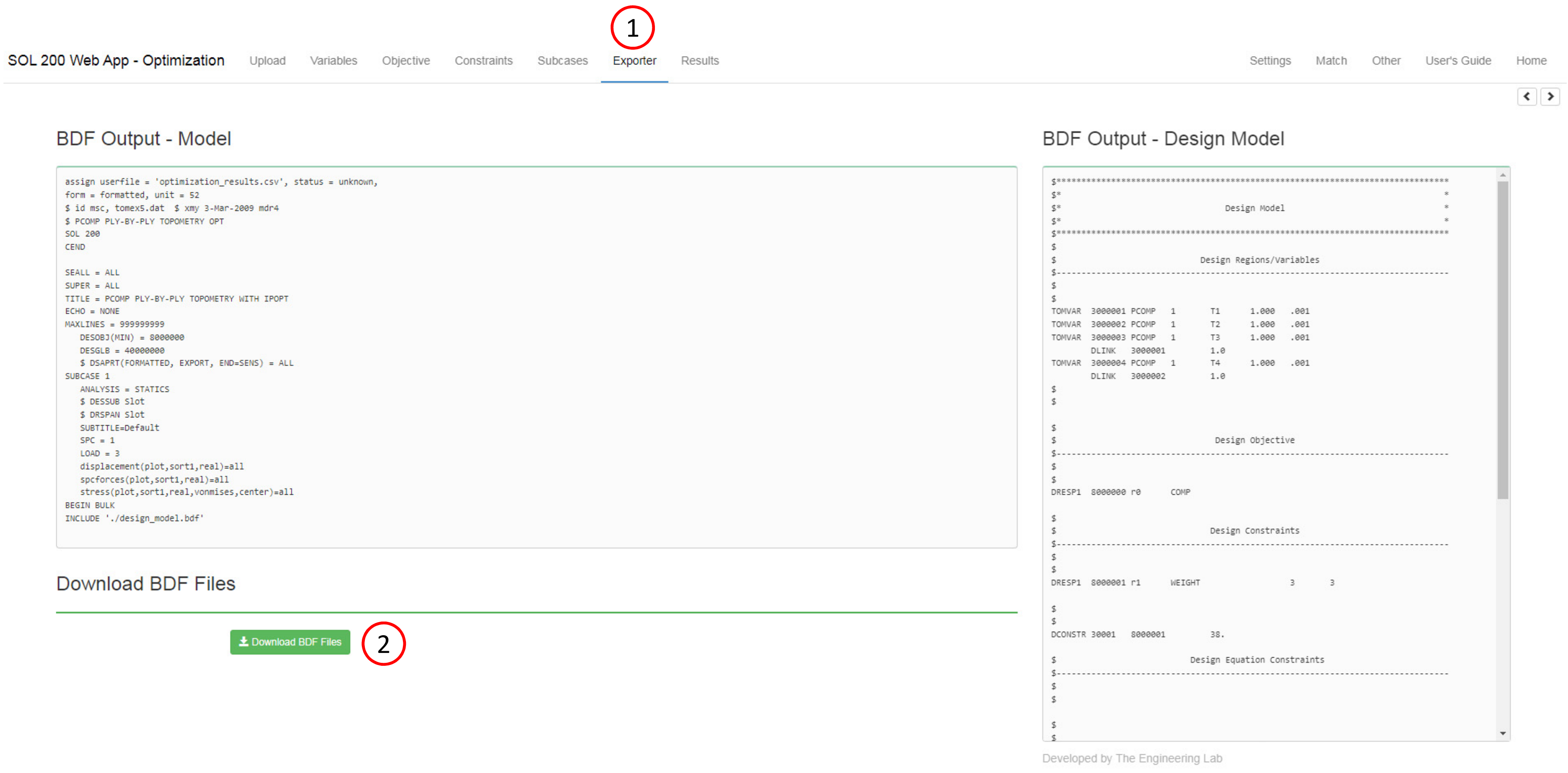
SOL 200 Web App - Optimization | Upload | Variables | Objective | Constraints | Subcases | Exporter | Results | Settings (1) | Match | Other

Optimization Settings

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

Export New BDF Files

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

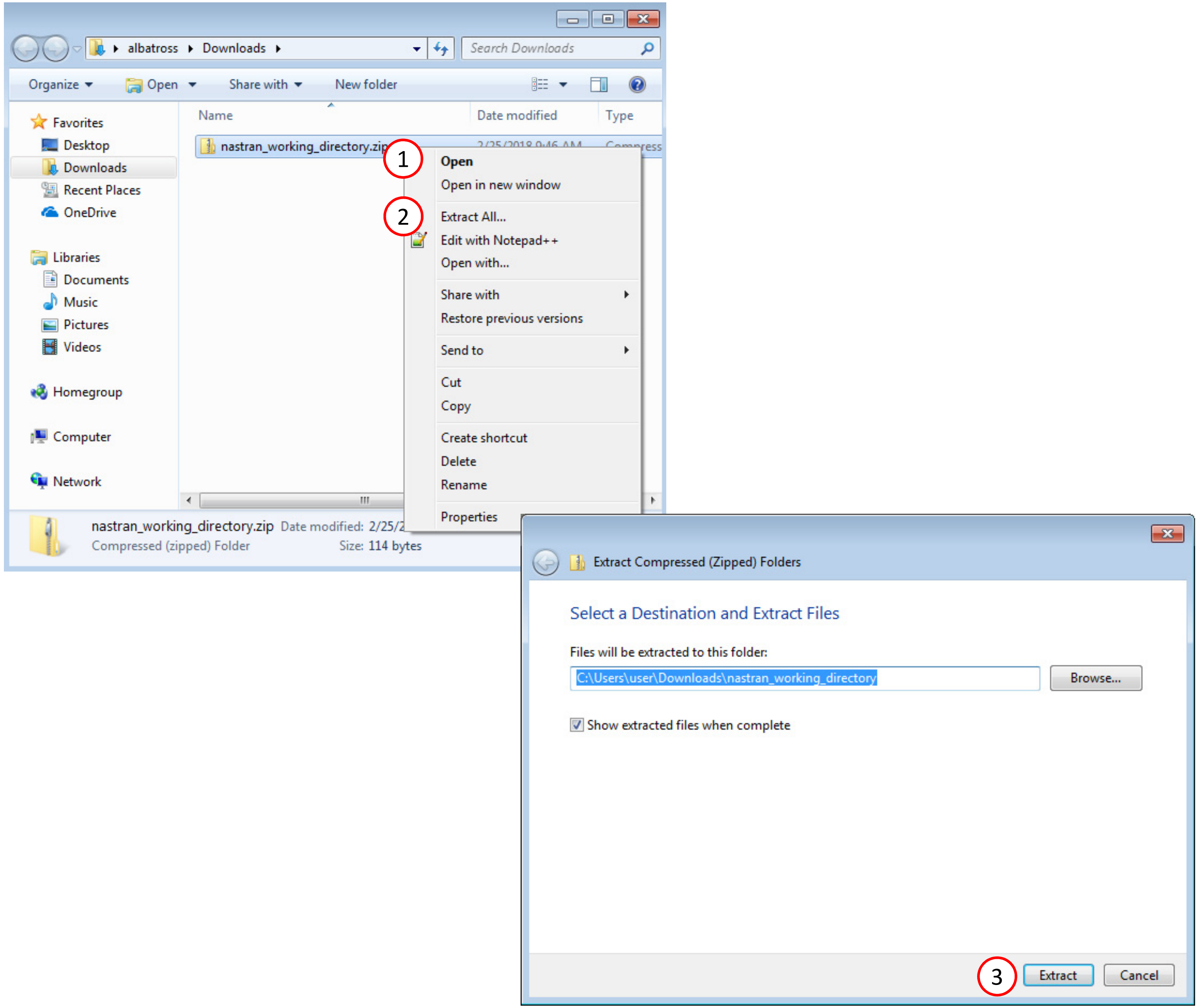


- When the download button is clicked a new file named “nastran_working_directory” is downloaded. If the file already exists in your local folder, the folder name is appended with a number, e.g. “nastran_working_directory (1).zip”

Perform the Optimization with Nastran SOL 200

1. A new .zip file has been downloaded
2. Right click on the file
3. Click Extract All
4. 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

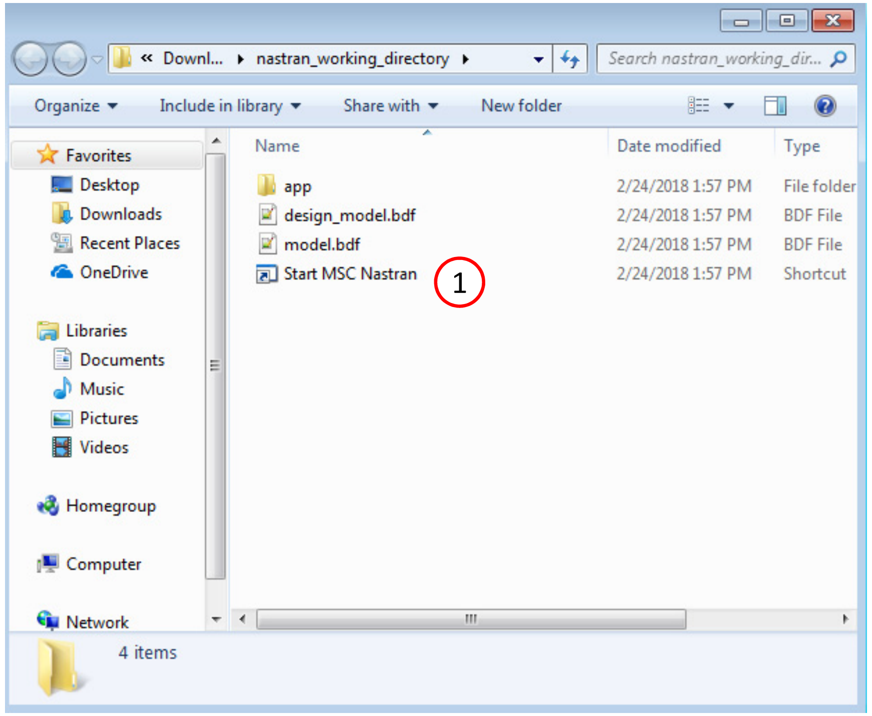
- After a successful optimization, the results will be automatically displayed as long as the following files are present: BDF, F06 and LOG.
- One can run the Nastran job on a remote machine as follows:
  1) Copy the BDF files and the INCLUDE files to a remote machine. 2) Run the MSC Nastran job on the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

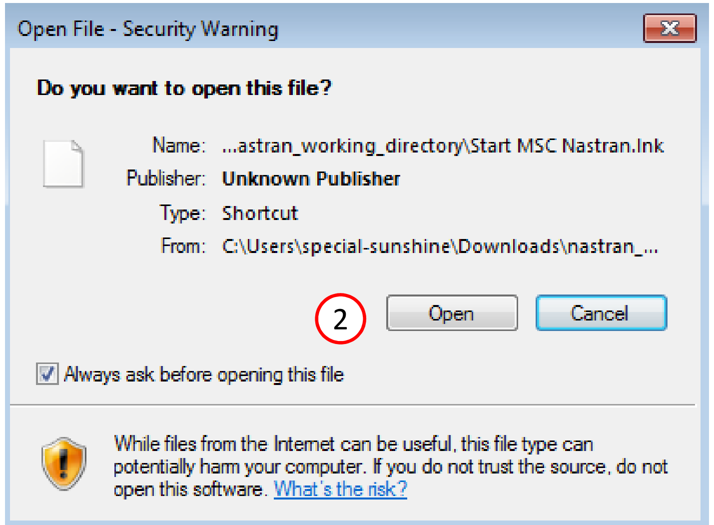
Using Linux?

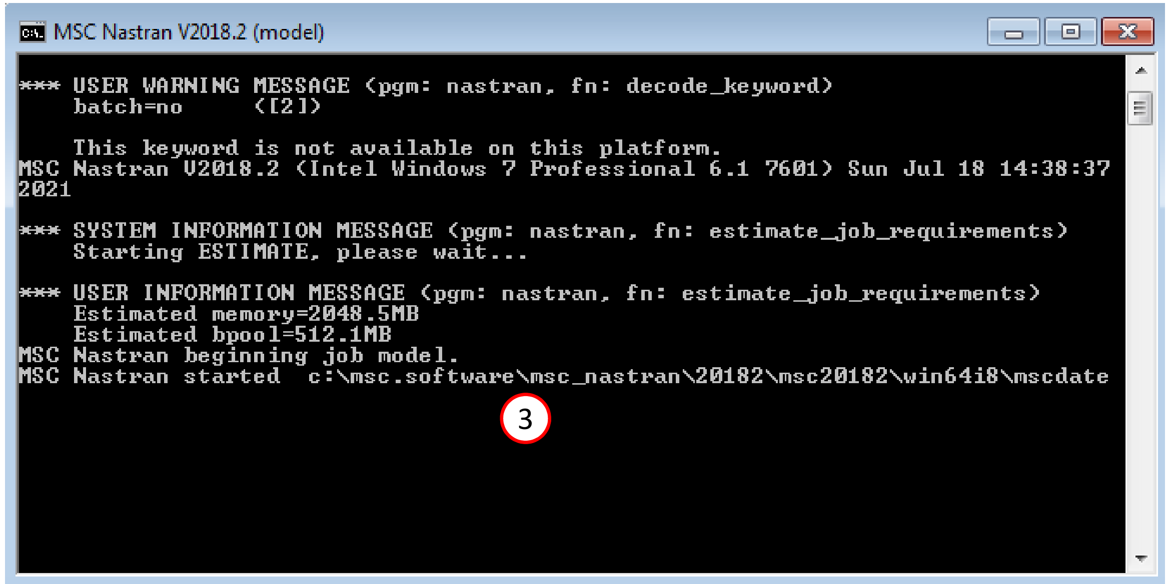
Follow these instructions:
1) Open Terminal
2) Navigate to the nastran_working_directory
   cd ./nastran_working_directory
3) Use this command to start the process
   ./Start_MSC_Nastran.sh

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 here) and design variables can be reviewed.

- Note that in a Topometry optimization, hundreds or thousands of design variables can be created. In this situation, the Design Variables are not plotted and displayed. Instead, the Objective and Normalized Constraints are displayed. It is recommended that a traditional post-processor be used to review the design variable results.

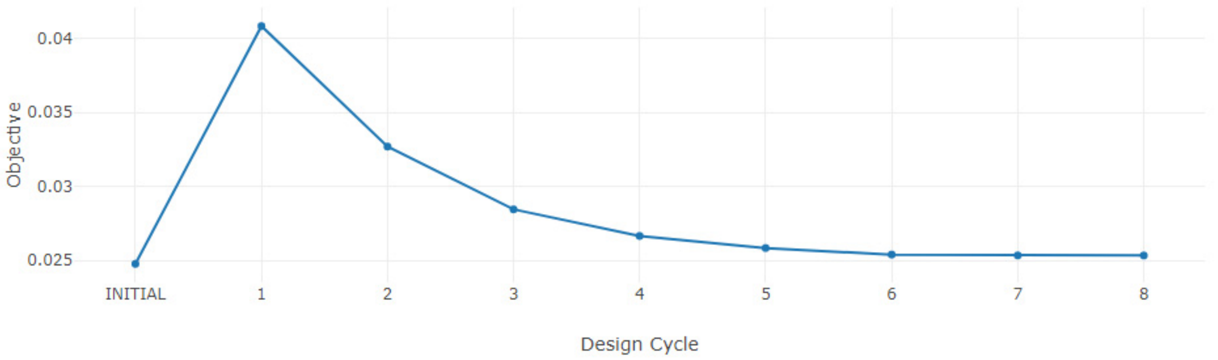
SOL 200 Web App - Local Optimization Results

Home

1 Final Message in .f06

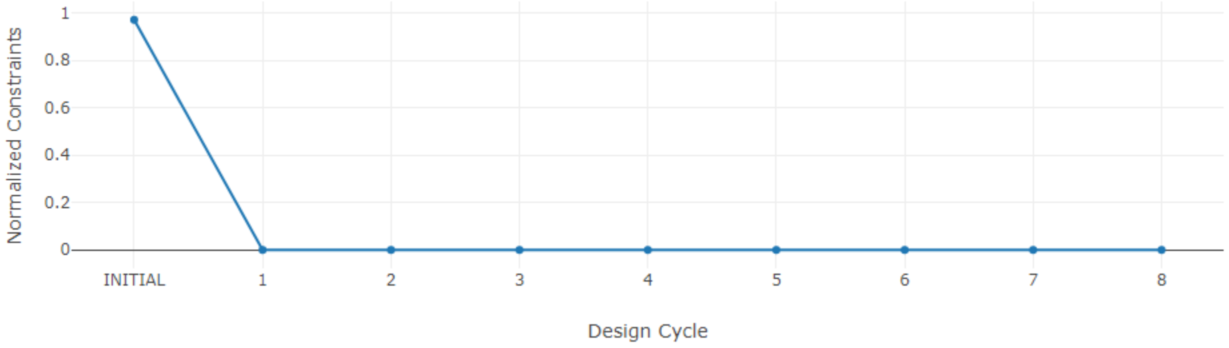
RUN TERMINATED DUE TO HARD CONVERGENCE TO AN OPTIMUM AT CYCLE NUMBER = 8.

Objective



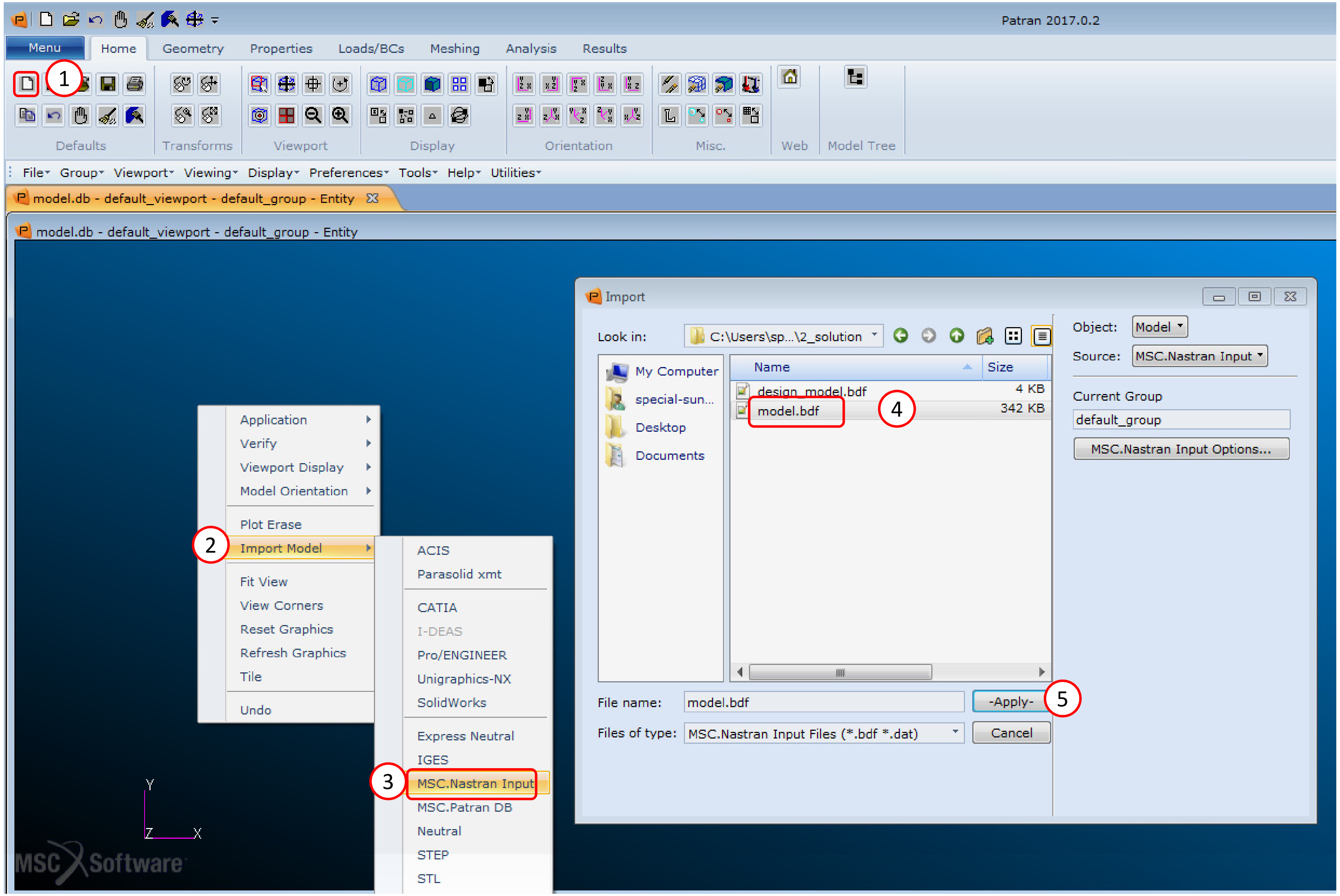
2 Normalized Constraints

+ Info



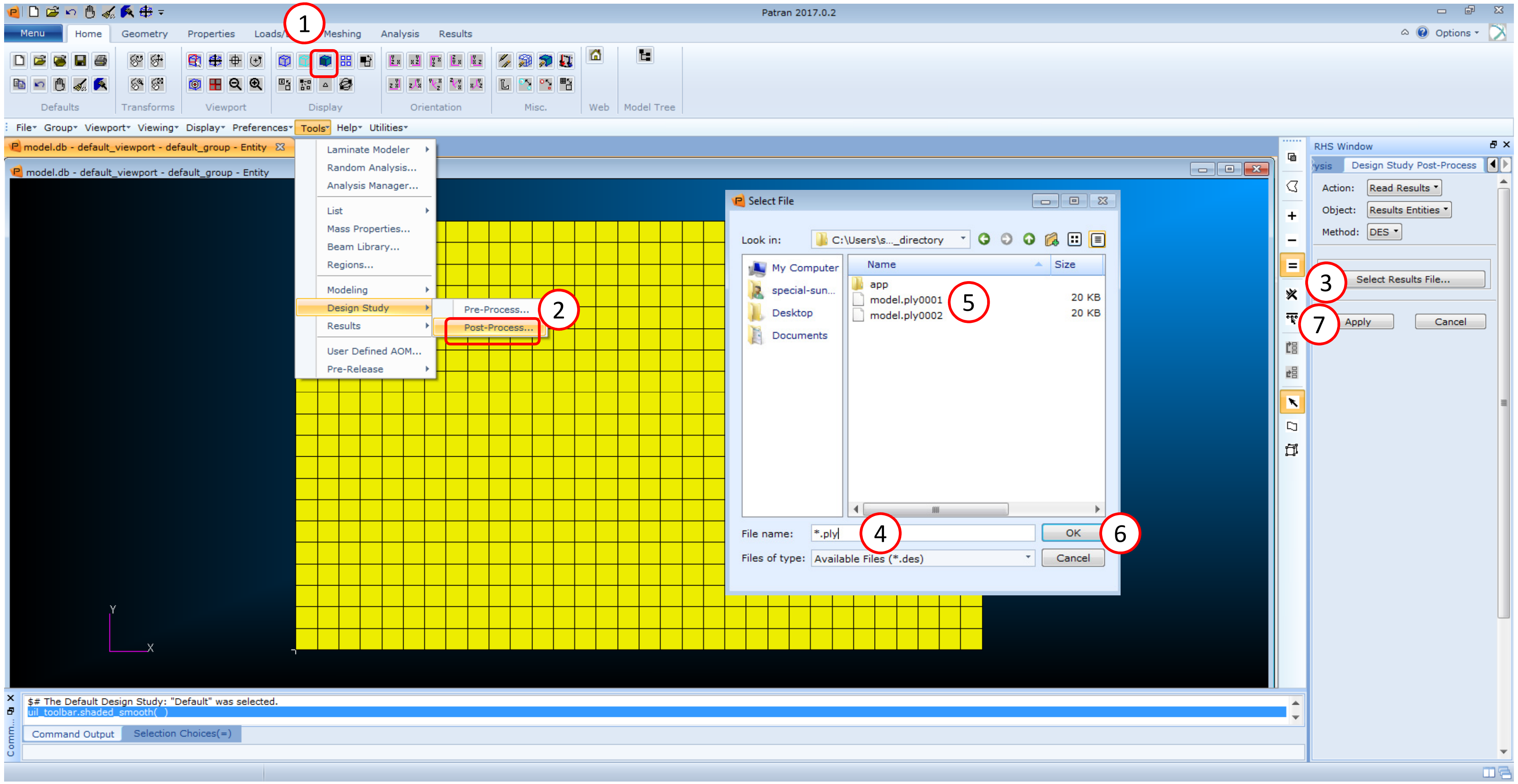
Review Optimization Results in Patran

1. Start a new Patran session
2. Right click to open a menu
3. Go to Import Model and click on MSC.Nastran Input
4. Select model.bdf (This file was used for the optimization)
5. Click Apply



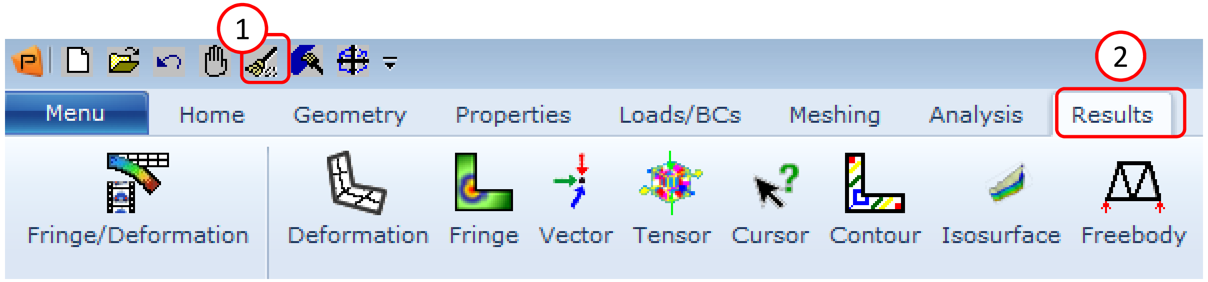
Review Optimization Results in Patran

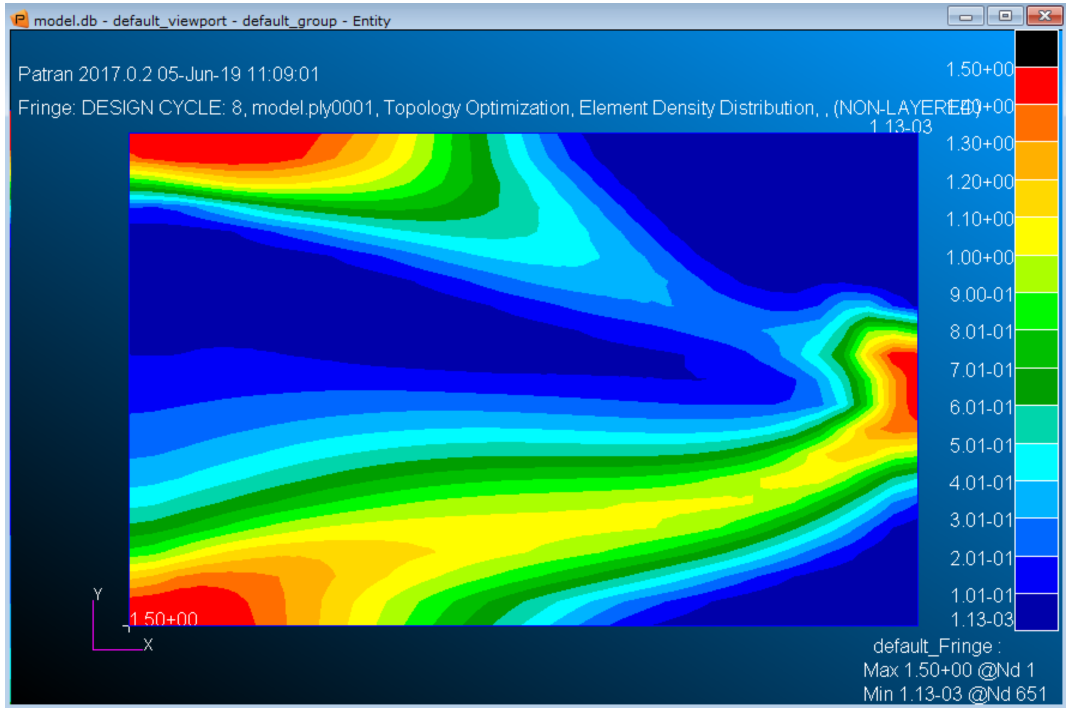
1. Click Smooth Shading
2. Go to Tools > Design Study and click on Post-Process
3. Click Select Results File
4. Type "*.ply" and press the enter key to show all the files in the folder
5. Select model.ply0001 (This file was created during the optimization)
6. Click OK
7. Click Apply
8. Repeat steps 3-7 for the following files:
    1. model.ply0002

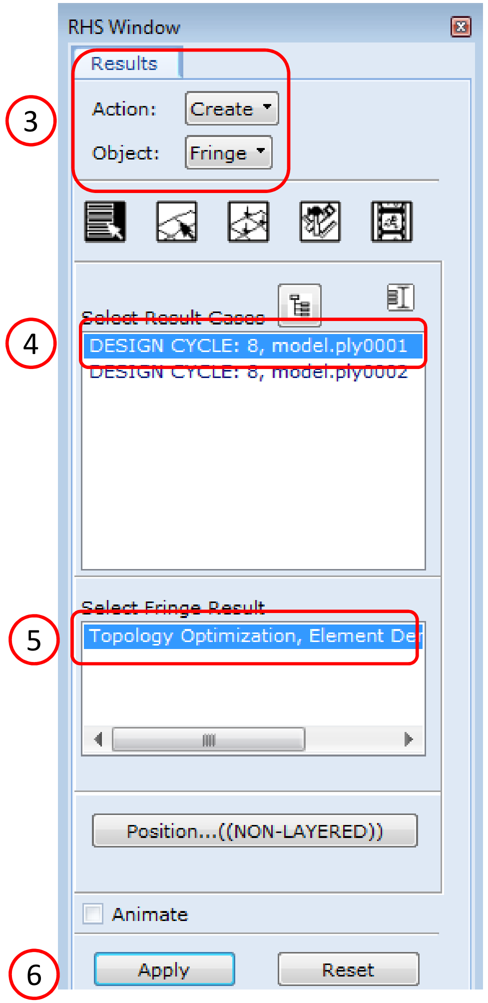


Review Optimization Results in Patran

1. Click the clear icon
2. Click Results
3. Set the following:
   - Action: Create
   - Object: Fringe
4. Select: DESIGN CYCLE: 8, model.ply0001 (The row should be highlighted blue)
5. Select Topology Optimization, Element D... (The row should be highlighted blue)
6. Click Apply
7. Repeat steps 4-6 for the following:
   - DESIGN CYCLE: 8, model.ply0002

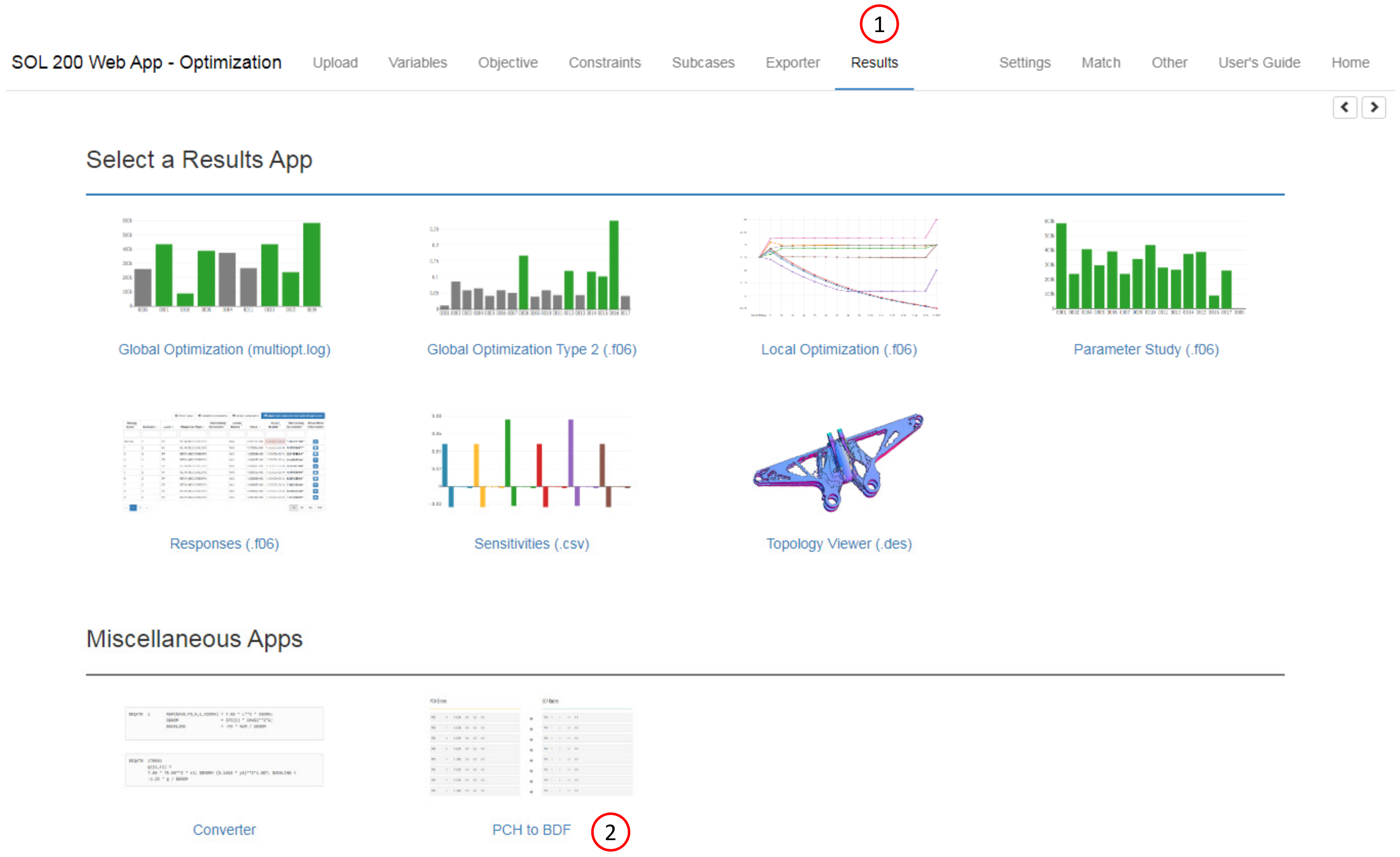






Update the Original Model

1. Click Results
2. Click PCH to BDF

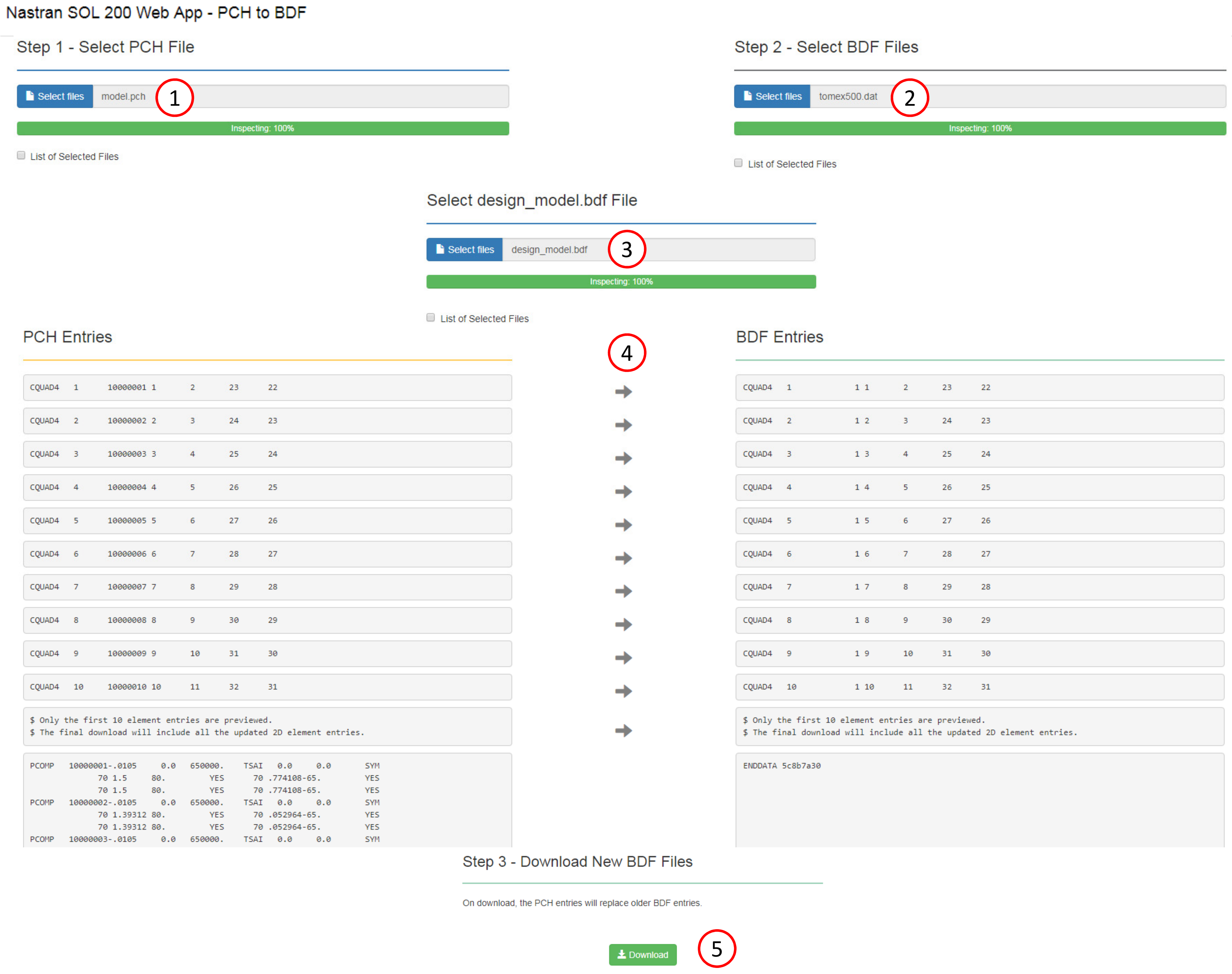


Update the Original Model

The original .bdf/.dat file has old information about the properties. The properties will be updated.

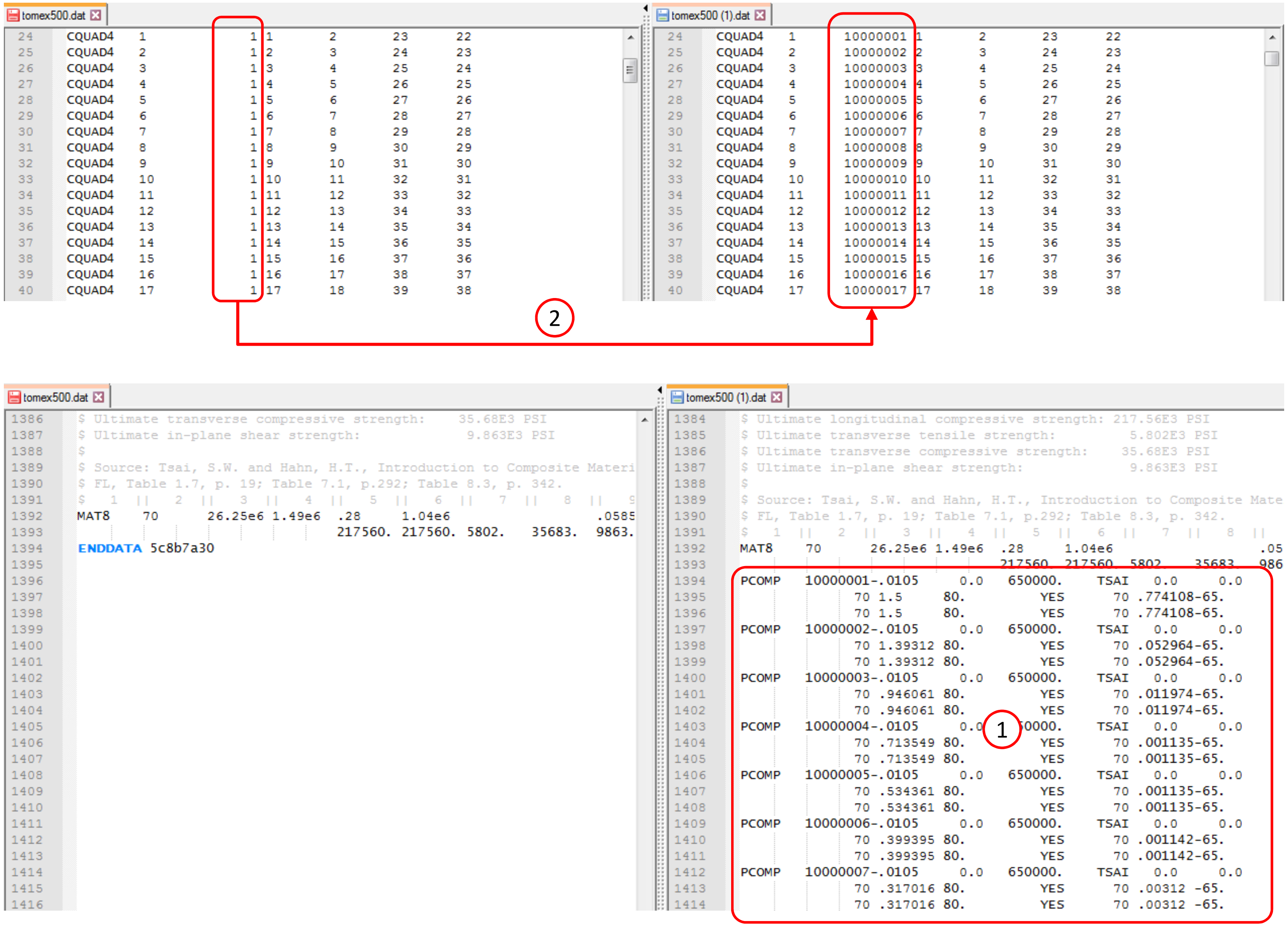
1. Select the model.pch file
2. Select the original file: tomex500.dat
3. Select the design_model.bdf file
4. A summary of updates that will be performed are shown
5. Click Download and a new updated BDF file is downloaded

In the V3.5 release, the PCH to BDF app supports updated PCOMP entries generated by a Topometry optimization. The associated 2D elements, e.g. CQUAD4, are also updated. All other properties generated by a Topometry optimization, such as PSHELL and PWELD properties are not supported. If performing Size optimization, the PCH to BDF app supports PCOMP, PSHELL and PWELD properties.



Update the Original Model

1. Since this was a topometry optimization, each element has been given its own PCOMP entry with updated thicknesses for plies 1, 2, 3 and 4. The PCH to BDF web app transfers the new PCOMP entries from the .pch file to the tomex500.dat file.
2. In addition, each CQUAD4 element must be updated to point to its new respective PCOMP entry, e.g.

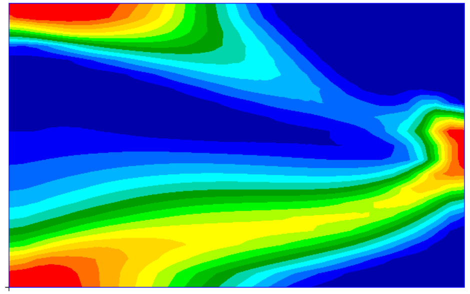


Original BDF/DAT File

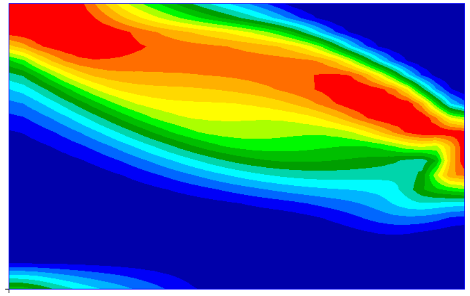
Downloaded BDF/DAT File

Results

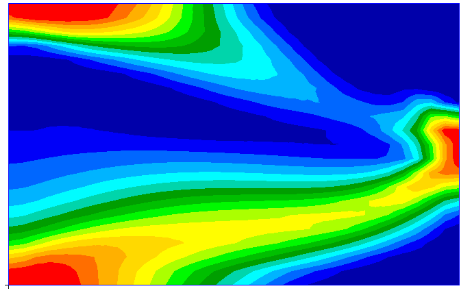
Topometry Results



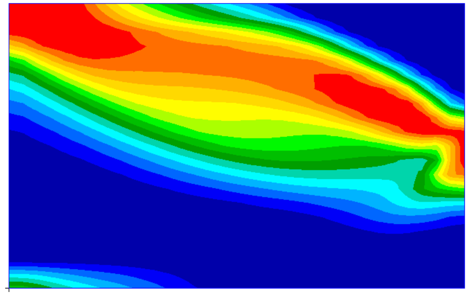
Ply 1 and 8
80°



Ply 2 and 7
-65°

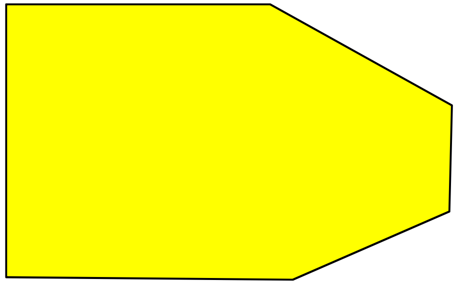


Ply 3 and 6
80°

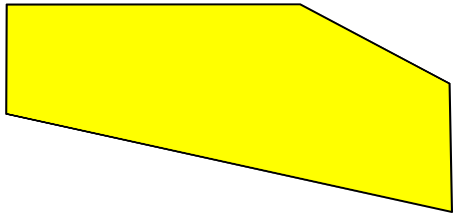


Ply 4 and 5
-65°

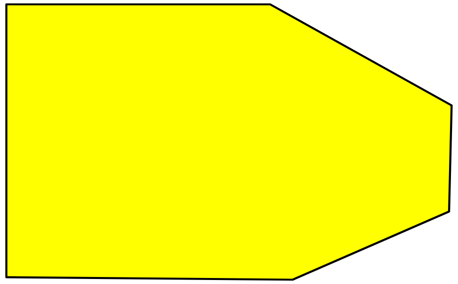
Possible Ply Shapes



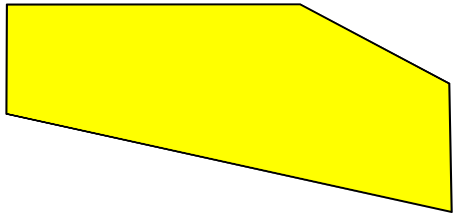
Ply 1 and 8
80°



Ply 2 and 7
-65°



Ply 3 and 6
80°

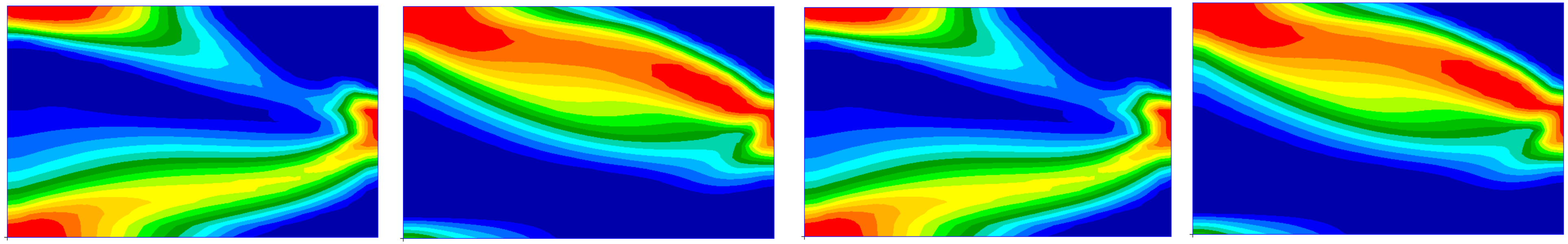


Ply 4 and 5
-65°

Results

Ply drop offs are employed for the -65 degree plies. In the interest of manufacturability, ply drop offs are not employed for the 80 degree plies.

Topometry Results



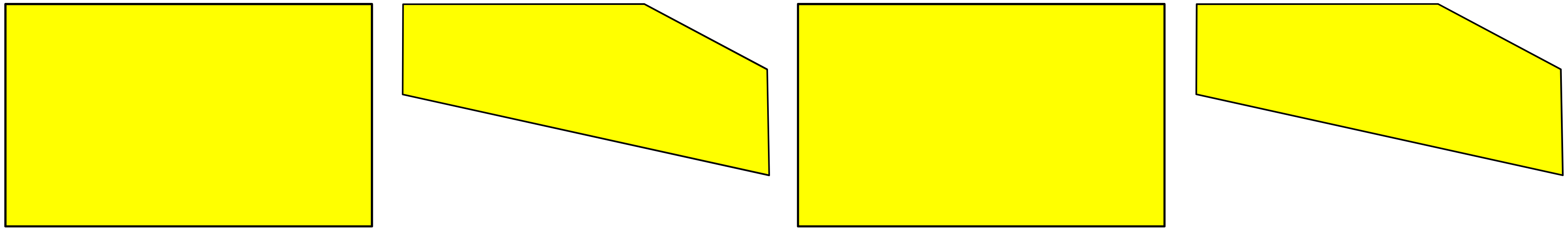
Ply 1 and 8
80°

Ply 2 and 7
-65°

Ply 3 and 6
80°

Ply 4 and 5
-65°

Proposed Ply Shapes



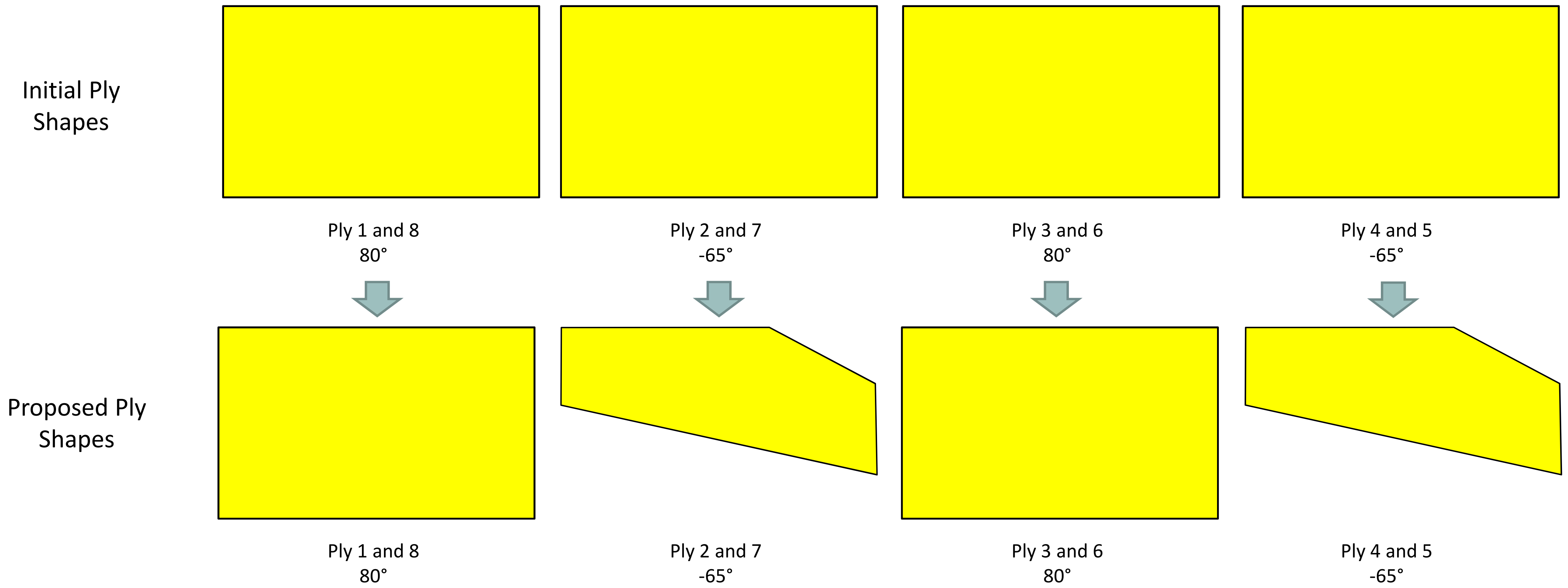
Ply 1 and 8
80°

Ply 2 and 7
-65°

Ply 3 and 6
80°

Ply 4 and 5
-65°

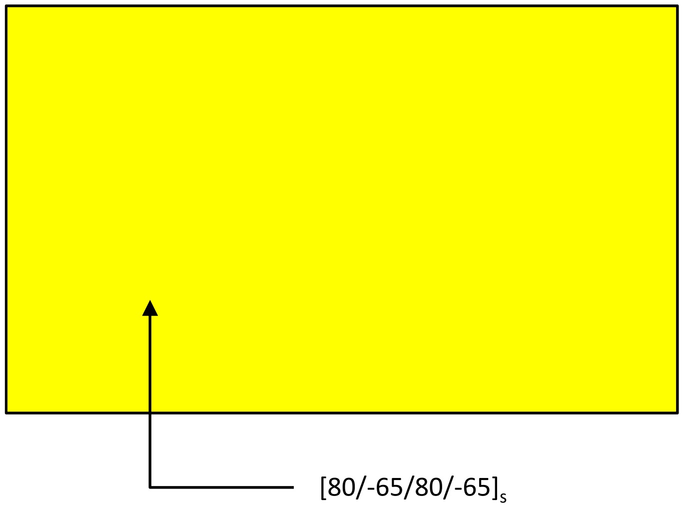
Results


Initial Ply Shapes
Ply 1 and 8
80°
Ply 2 and 7
-65°
Ply 3 and 6
80°
Ply 4 and 5
-65°
Proposed Ply Shapes
Ply 1 and 8
80°
Ply 2 and 7
-65°
Ply 3 and 6
80°
Ply 4 and 5
-65°

Results

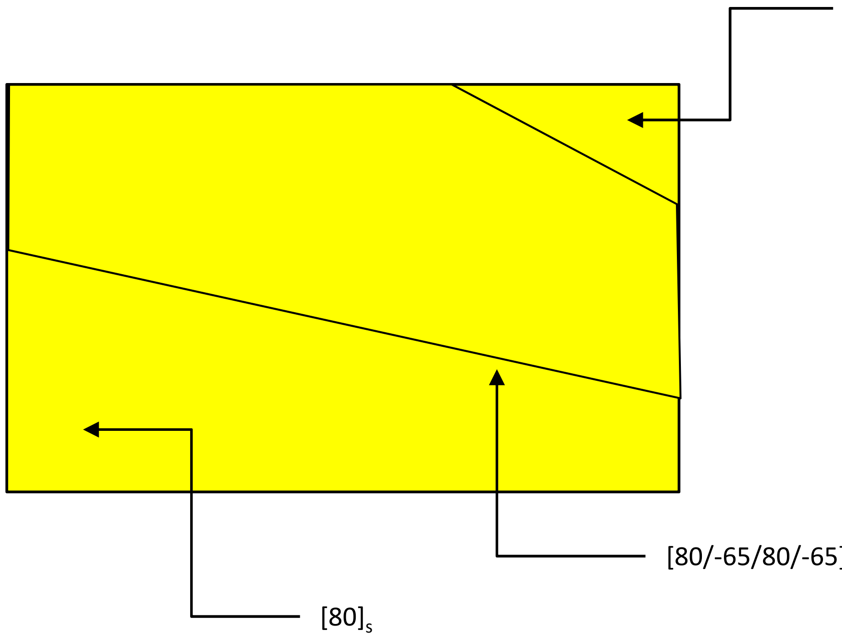
Before Optimization

- Panel of initial layup



After Optimization

- Panel of updated layups
- The weight is reduced



End of Tutorial