Workshop - Optimizing for Buckling - Twenty-Five Bar Truss

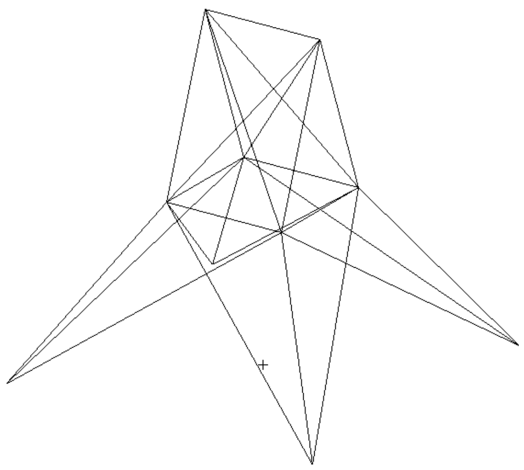
AN MSC NASTRAN SOL 200 TUTORIAL

Goal: Use Nastran SOL 200 Optimization

Optimize the weight of this truss subject to stress and buckling constraints

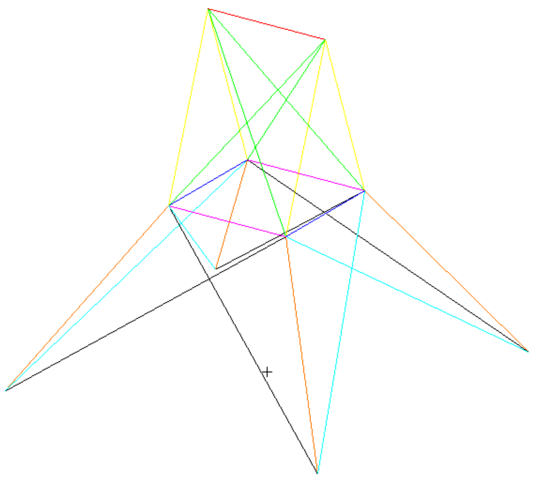
Before Optimization

- Weight: 660 slinch
- Vary member cross section areas
- Stress constraint initially violated



After Optimization

- Weight: 1007 slinch
- Stress and Buckling within limits



Details of the structural model

Twenty-Five Bar Truss, Superelement and Discrete Variable Optimization

This problem, often seen in the early design optimization literature, calls for a minimum weight structure subject to member stress, Euler buckling, and joint displacement constraints. The structure is shown in Figure 8-25. The formulation of the buckling constraints is a good example of constructing normalized constraints based on user-defined structural responses.

In addition, this problem will be substructured in order to illustrate superelement optimization and the final design will be selected from a user specified list of discrete variables.

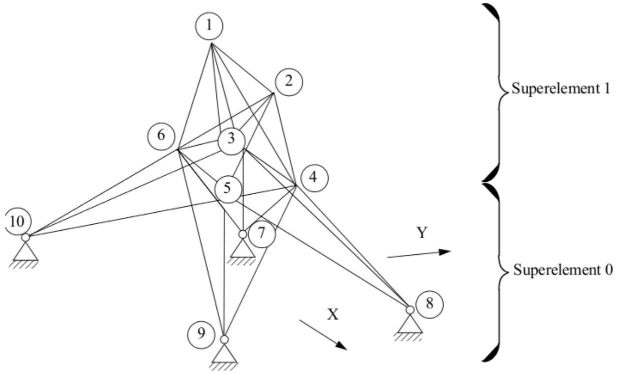


Figure 8-25 Twenty-Five Bar Truss

MSC Nastran Design Sensitivity and Optimization User's Guide
Chapter 8 - Example Problems - Twenty-Five Bar Truss,
Superelement and Discrete
Variable Optimization

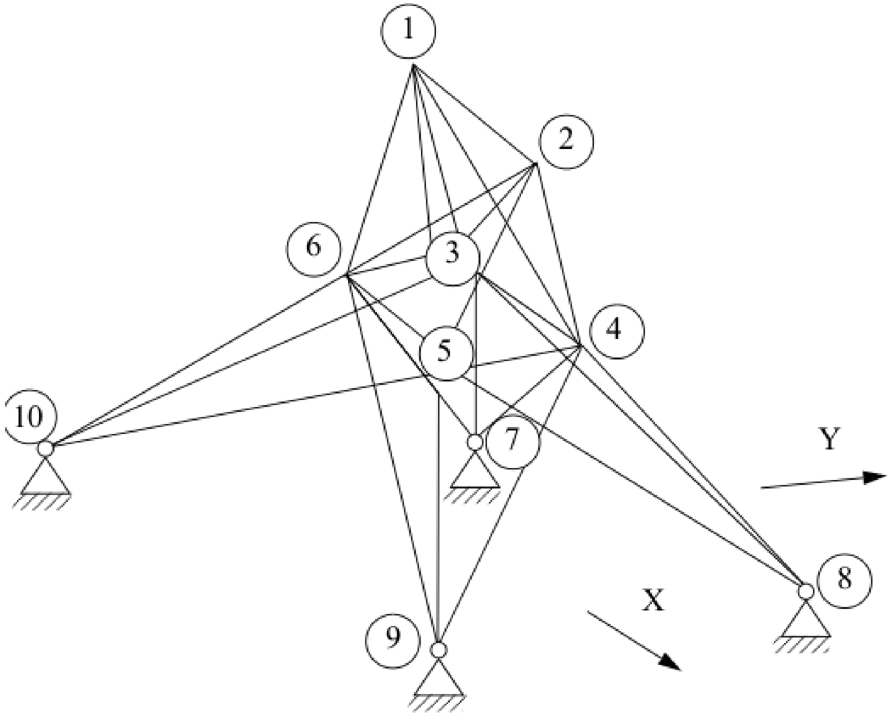


Figure 8-25 Twenty-Five Bar Truss

Optimization Problem Statement

Design Variables

y1 ---> $A1 = \frac{\pi\, y1^2}{10}$ of PROD 1

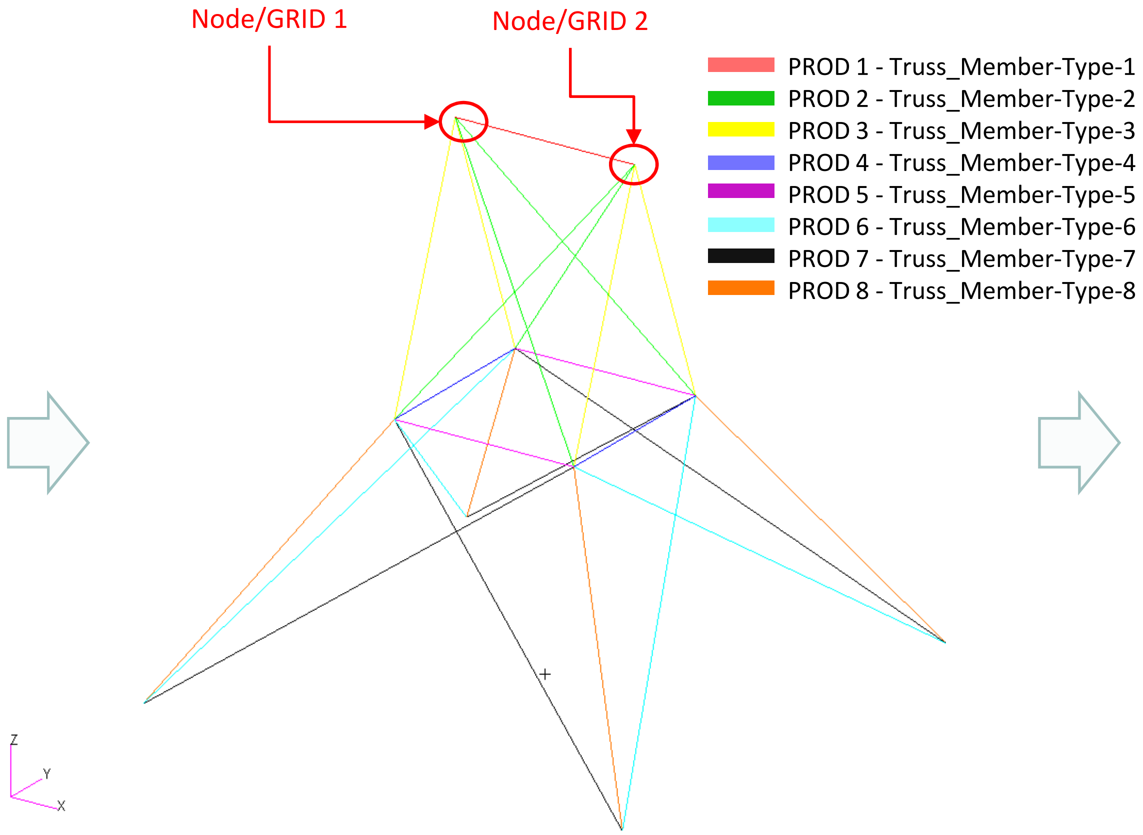
....

y8 ---> $A8 = \frac{\pi\, y8^2}{10}$ of PROD 8

yi_initial= 2.52

.01 < yi < 100.

Allowed values for design variables: .1, .5, 1.0, 2.0, … 100.



Design Objective

r0: Minimize weight

Design Constraints

r1: Axial stress of elements related to PROD 1

…

r8: Axial stress of elements related to PROD 8

-40,000 < r1, … r8 < 40,000

r9: x, y component of displacement at nodes 1 and 2

-.35 < r9 < .35

Design Constraints, Equation

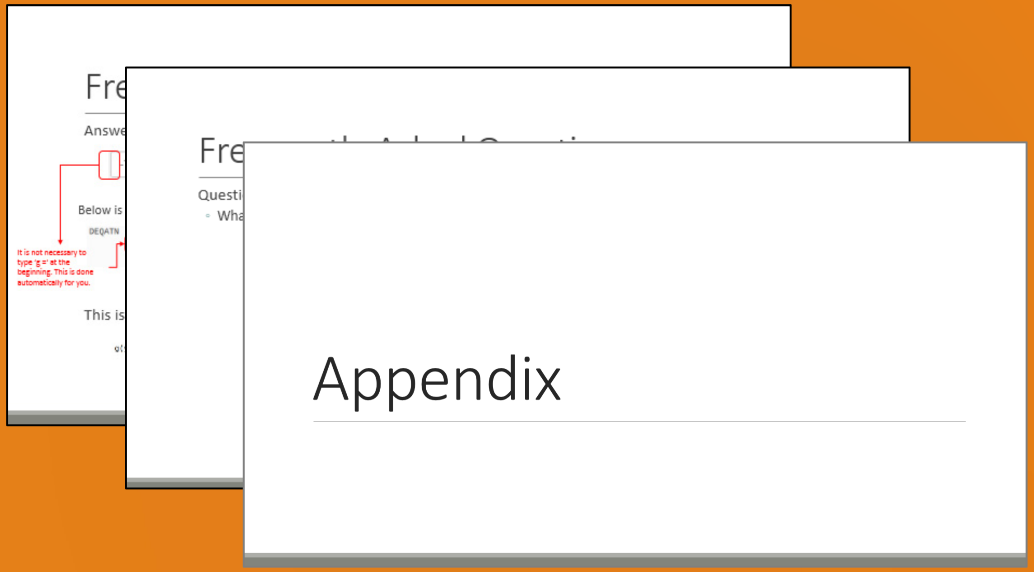
$$Ri = F_s \frac{-7.69 \cdot ri \cdot Li^2}{\pi^2 \cdot 1.0E^7 \cdot yi^2} < 1.0$$

Number	Label	L	Variable
1	r1	75.	y1
2	r2	130.5	y2
3	r3	106.8	y3
4	r4	75.	y4
5	r5	75.	y5
6	r6	181.14	y6
7	r7	181.14	y7
8	r8	133.46	y8

More Information Available in the Appendix

The Appendix includes information regarding the following:

- Frequently Asked Questions
  - What are the different ways of writing Equations for Equation Objective and Equation Constraints?
  - What does this message mean:
    SOFT FEASIBLE DISCRETE DESIGN OBTAINED?



Contact me

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

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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
     - Design Constraints
   - Perform optimization with Nastran SOL 200
3. Plot the Optimization Results
4. Update the original model with optimized parameters

Special Topics Covered

Automatically Creating Hundreds of Design Variables - It may be the case that hundreds of design variables must be created. The Web App features a capability to automatically create and configure hundreds of design variables. Design variable lower and upper limits and discrete values can also be automatically set. This tutorial discusses the process of automatically creating multiple design variables.

Creating Hundreds of Equation Driven Parameters - Certain parameters of the Finite Element Model may need to be adjusted as certain design variables change. For example, as the thickness of a plate changes, an attached stiffener's offset will depend on the thickness. This tutorials describes the process for automatically generating dozens or hundreds of these equation driven parameters.

Discrete Values for Design Variables - This example has a requirement where the design variables can only take on specific values. Instead of an optimization solution where the values may be 45.23423 or 15.90234, the use of Discrete Values will allow specific values to be obtained such as 45.0 or 16.0. This tutorial showcases a feature to specify specific values that can be taken by the design variables.

Equation Driven Constraints - MSC Nastran includes a list of quantities that can be set as objectives or constraints. In addition, custom user defined equations may be specified and be set as objectives or constraints. This tutorial details the process in defining custom equations.

SOL 200 Web App Capabilities

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

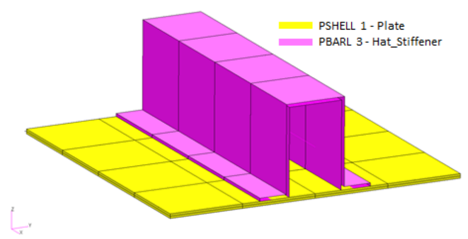
Compatibility

- 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.

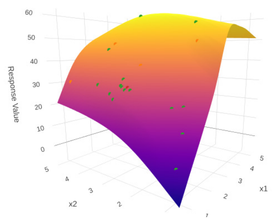
Benefits

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

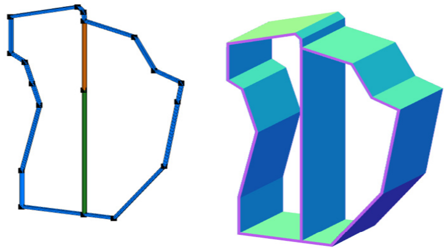
Web Apps



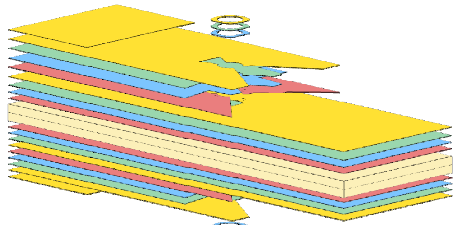
Web Apps for MSC Nastran SOL 200
Pre/post for MSC Nastran SOL 200. Support for size, topology, topometry, topography, multi-model optimization.



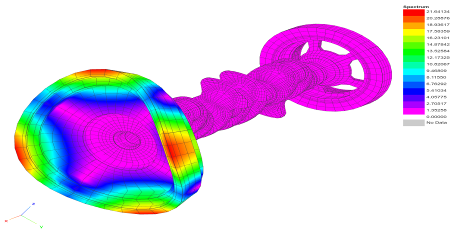
Machine Learning Web App
Bayesian Optimization for nonlinear response optimization (SOL 400)



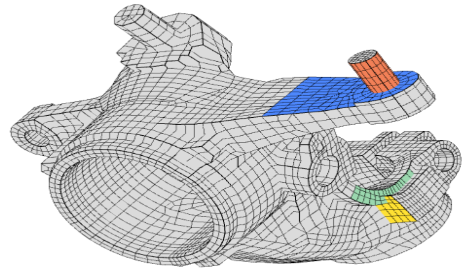
PBMSECT Web App
Generate PBMSECT and PBRSECT entries graphically



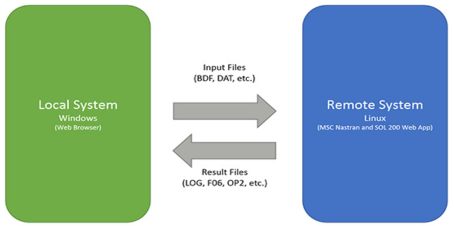
Ply Shape Optimization Web App
Optimize composite ply drop-off locations, and generate new PCOMPG entries



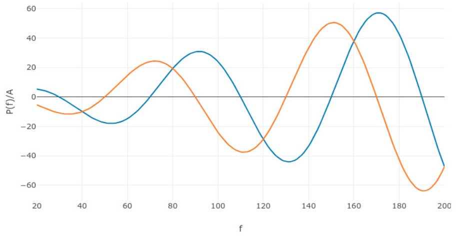
Post-processor Web App
View MSC Nastran results in a web browser on Windows and Linux



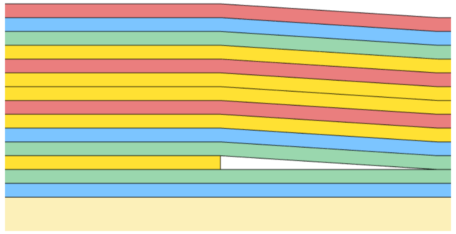
Shape Optimization Web App
Use a web application to configure and perform shape optimization.



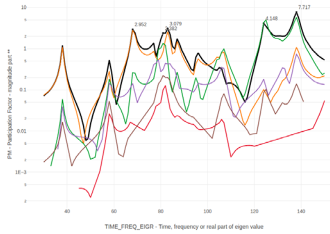
Remote Execution Web App
Run MSC Nastran jobs on remote Linux or Windows systems available on the local network



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



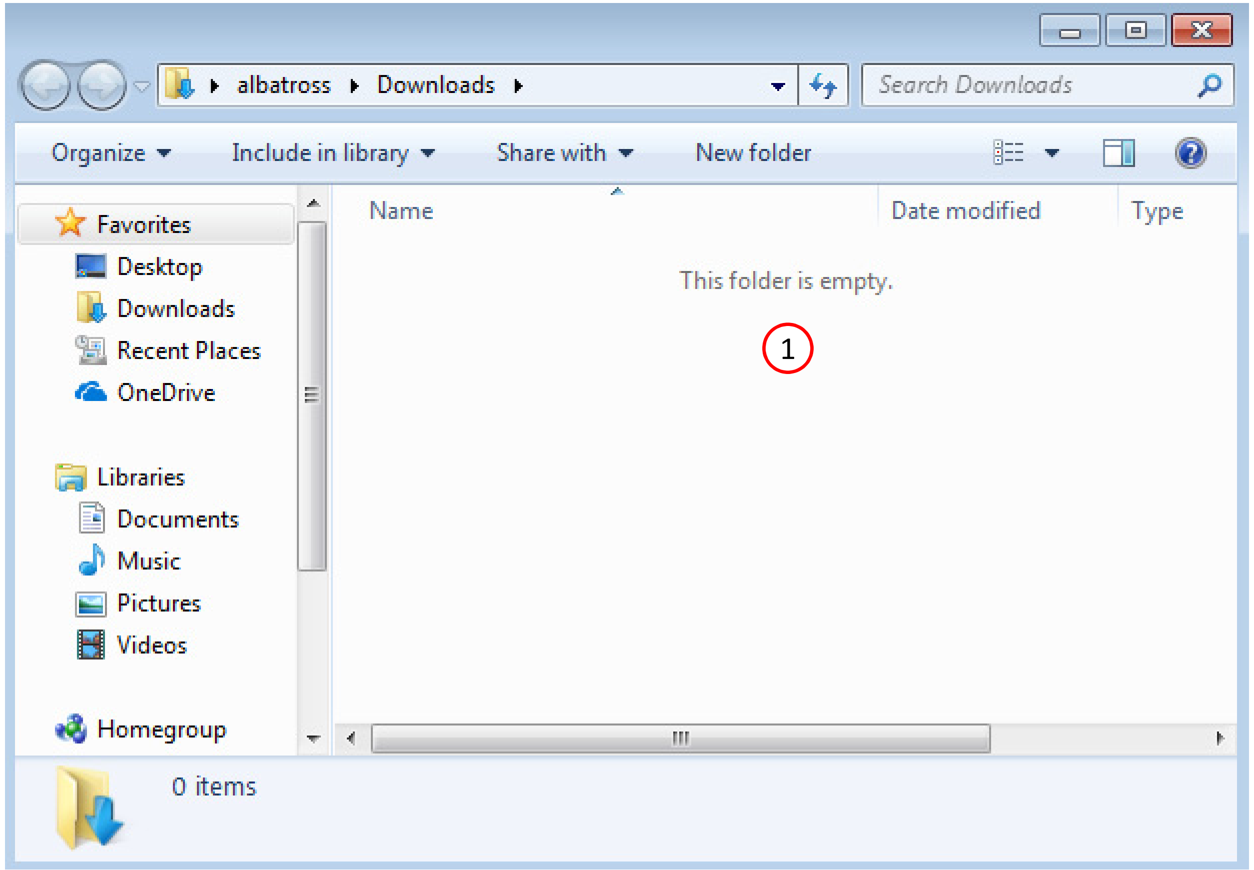
Stacking Sequence Web App
Optimize the stacking sequence of composite laminate plies



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

Before Starting

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

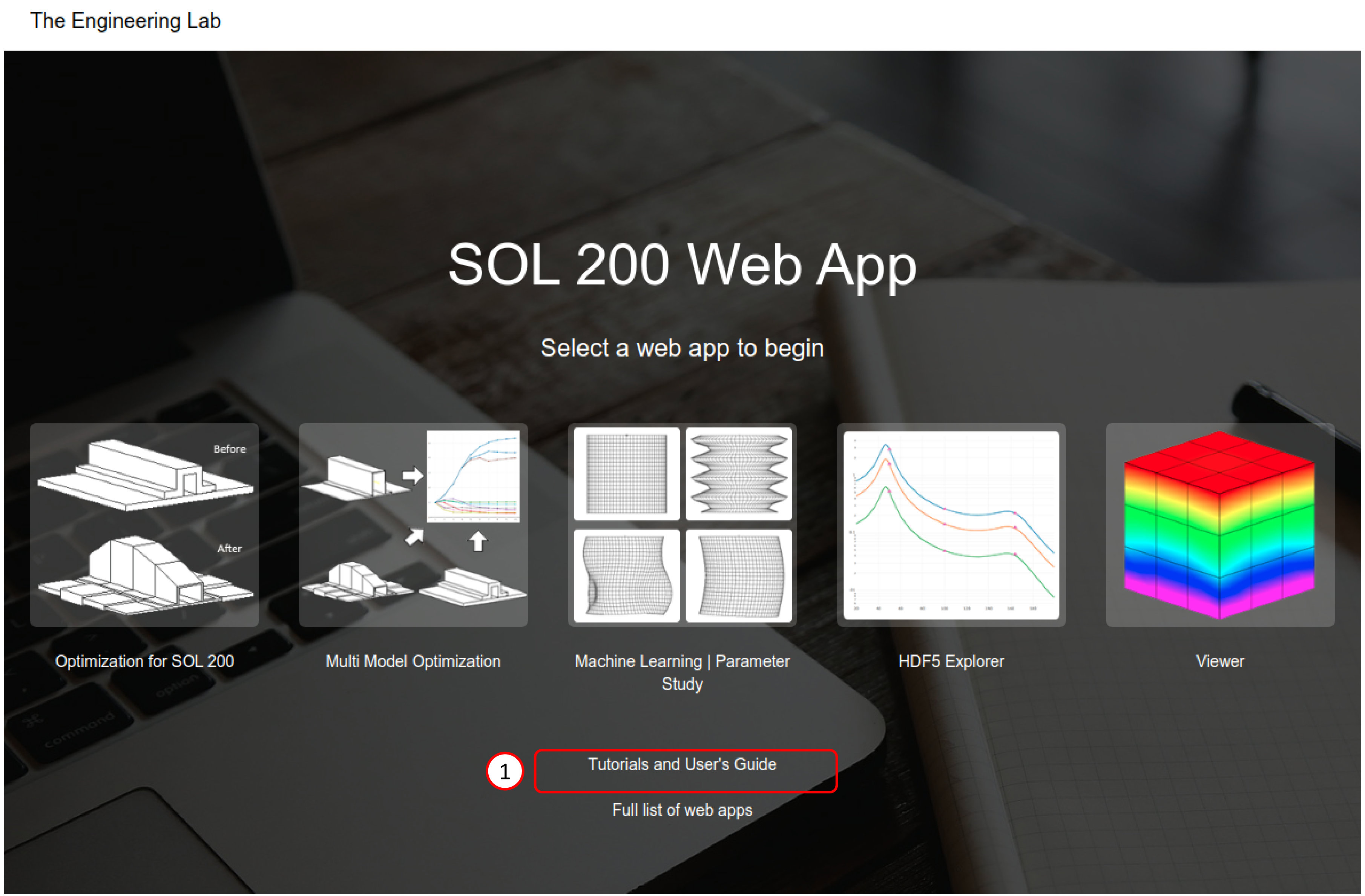


- Throughout this workshop, you will be working with multiple file types and directories such as:
  - .bdf/.dat
  - nastran_working_directory
  - .f06, .log, .pch, .h5, etc.
- To minimize confusion with files and folders, it is encouraged to start with a clean directory.

Go to the User's Guide

1. Click on the indicated link

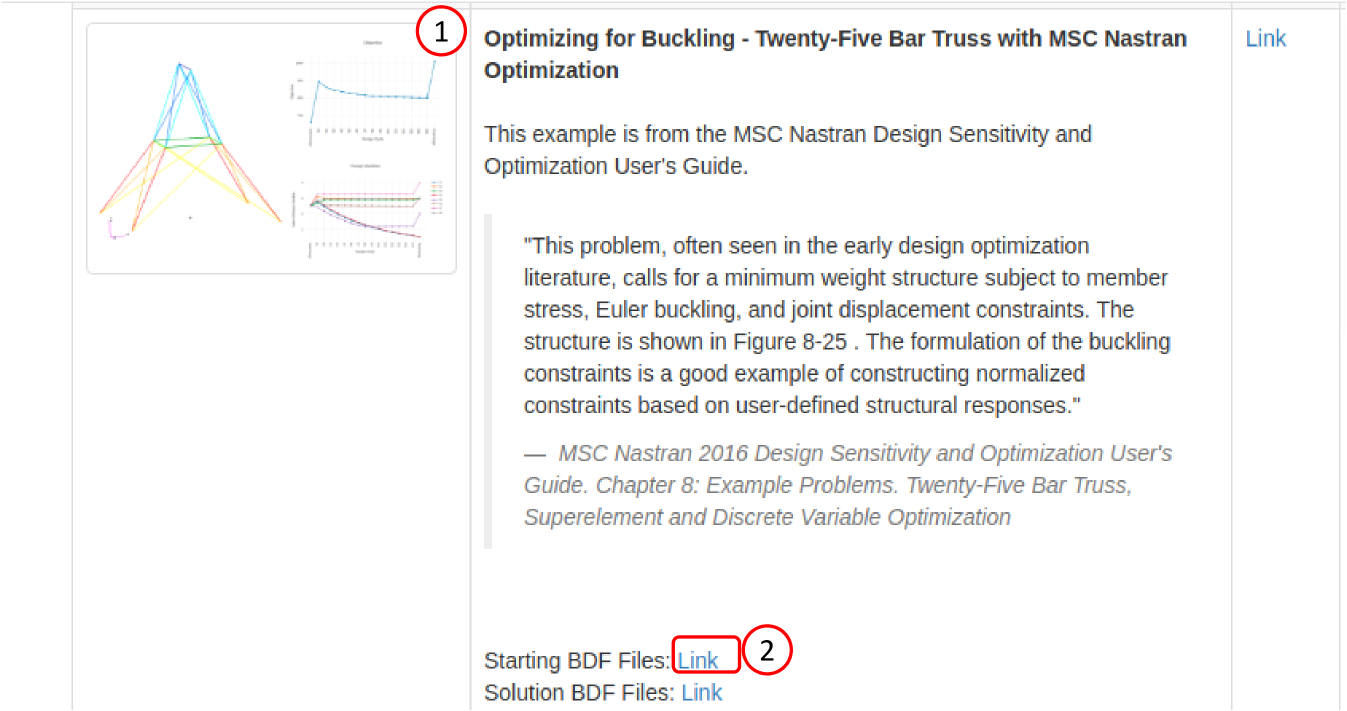
- The necessary BDF files for this tutorial are available in the Tutorials section of the User's Guide.

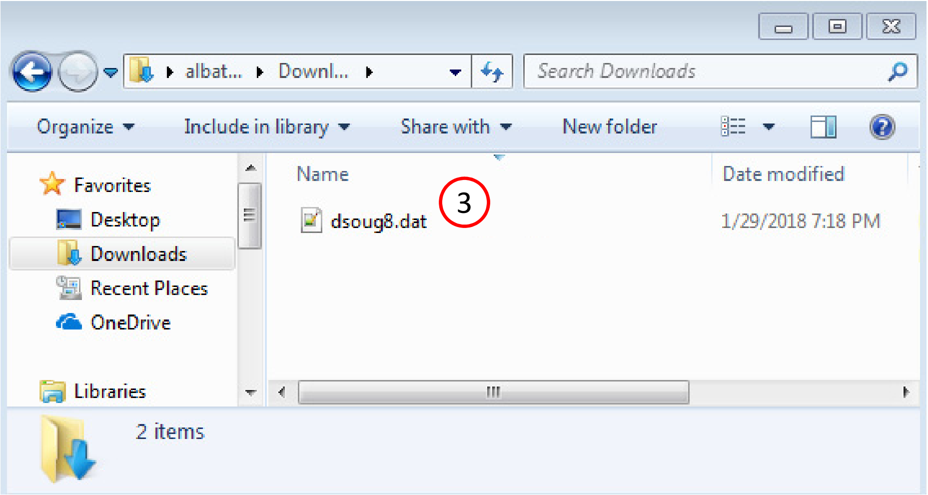


Obtain Starting Files

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

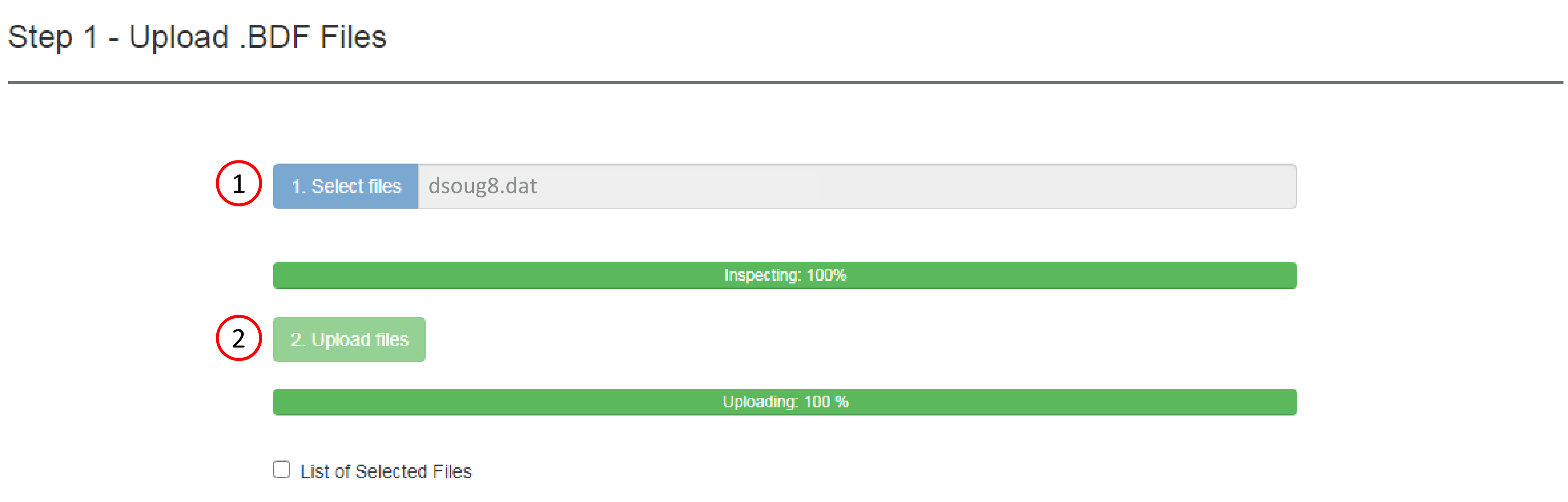
1. Click on the indicated link

- 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 dsoug8.dat
2. Click Upload Files

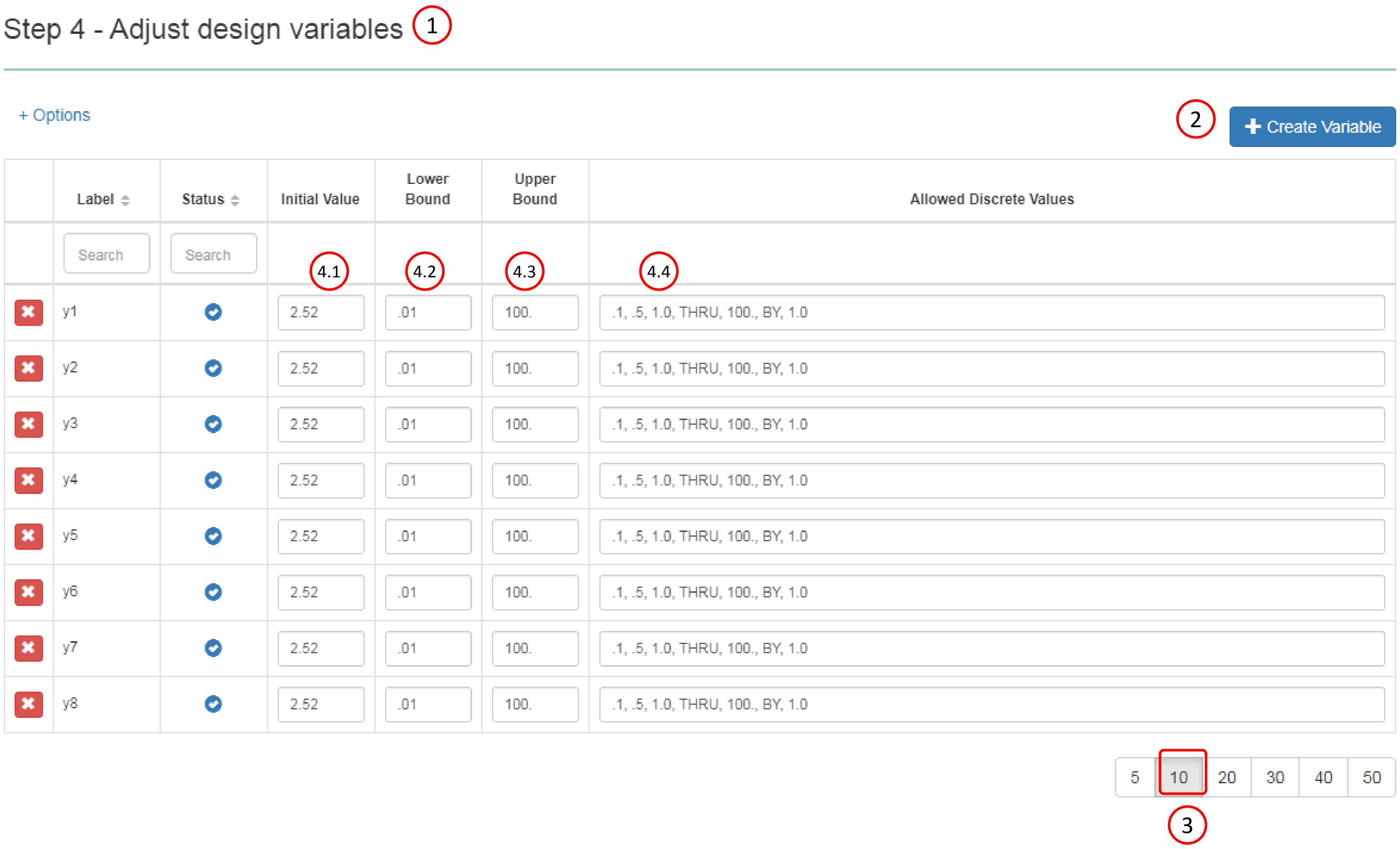


- The process starts by uploading all the necessary BDF files. The BDF files can be files of your own or files found in the Tutorials section of the User’s Guide.

Create Design Variables

1. Scroll to section: Step 4 - Adjust design variables
2. Click Create Variable 8 times
3. Click 10 on the pagination bar and this will display 10 rows
4. For each variable, use the following values:
   - Initial Value: 2.52
   - Lower Bound: .01
   - Upper Bound: 100.
   - Allowed Discrete Values: .1, .5, 1.0, THRU, 100., BY, 1.0

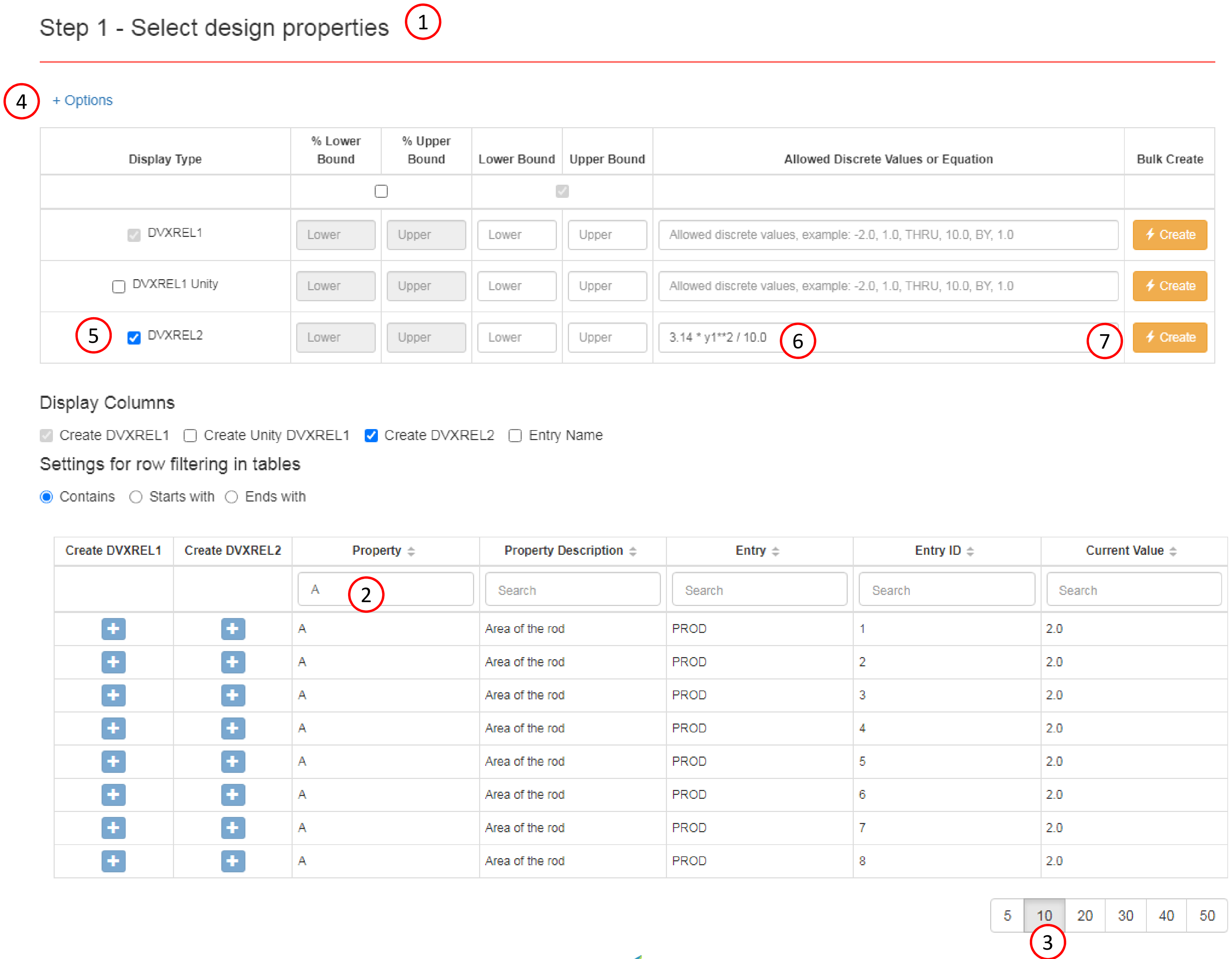
- 8 DESVAR entries are created and configured to use the following discrete values: .1, .5, 1.0, 2.0, 3.0, …., 99.0, 100.0



Create Design Variables

1. Scroll to the section: Step 1 – Select design properties
2. In the search box, type ‘A’
3. Select 10 in the pagination bar
4. Click on + Options
5. Check the DVXREL2 checkbox
6. Type in this equation: 3.14 * y1**2 / 10.0
7. Click on Create

- There are 2 methods to create the 8 DVPREL2 entries: Click each blue plus icon, which requires 8 mouse clicks, OR click the yellow Create icon, which requires 1 mouse click. The second method has an additional benefit because the equation defining the relationship can be configured for all 8 properties.



Create Design Variables

1. Scroll to section: Step 5 - Adjust DVXREL2
2. Click 10 on the pagination bar
3. For each row, change the y1 to yi. Examples:
    - y1 for P1
    - y2 for P2
    - y3 for P3
    - …
    - y8 for P8

- 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.

Step 5 - Adjust DVXREL2 (1)

✖ Delete Visible Rows

+ Options

	Label	Status	Property	Property Description	Entry	Entry ID	Initial Value	Lower Bound	Upper Bound	Equation
	Search	Search	Search	Search	Search	Search	Search	Search	Search	Search
✖	P1		A	Area of the rod	PROD	1	2.0	.001	Maximum	3.14 * y1**2 / 10.0
✖	P2		A	Area of the rod	PROD	2	2.0	.001	Maximum	3.14 * y2**2 / 10.0
✖	P3		A	Area of the rod	PROD	3	2.0	.001	Maximum	3.14 * y3**2 / 10.0
✖	P4		A	Area of the rod	PROD	4	2.0	.001	Maximum	3.14 * y4**2 / 10.0
✖	P5		A	Area of the rod	PROD	5	2.0	.001	Maximum	3.14 * y5**2 / 10.0
✖	P6		A	Area of the rod	PROD	6	2.0	.001	Maximum	3.14 * y6**2 / 10.0
✖	P7		A	Area of the rod	PROD	7	2.0	.001	Maximum	3.14 * y7**2 / 10.0
✖	P8		A	Area of the rod	PROD	8	2.0	.001	Maximum	3.14 * y8**2 / 10.0

(3)

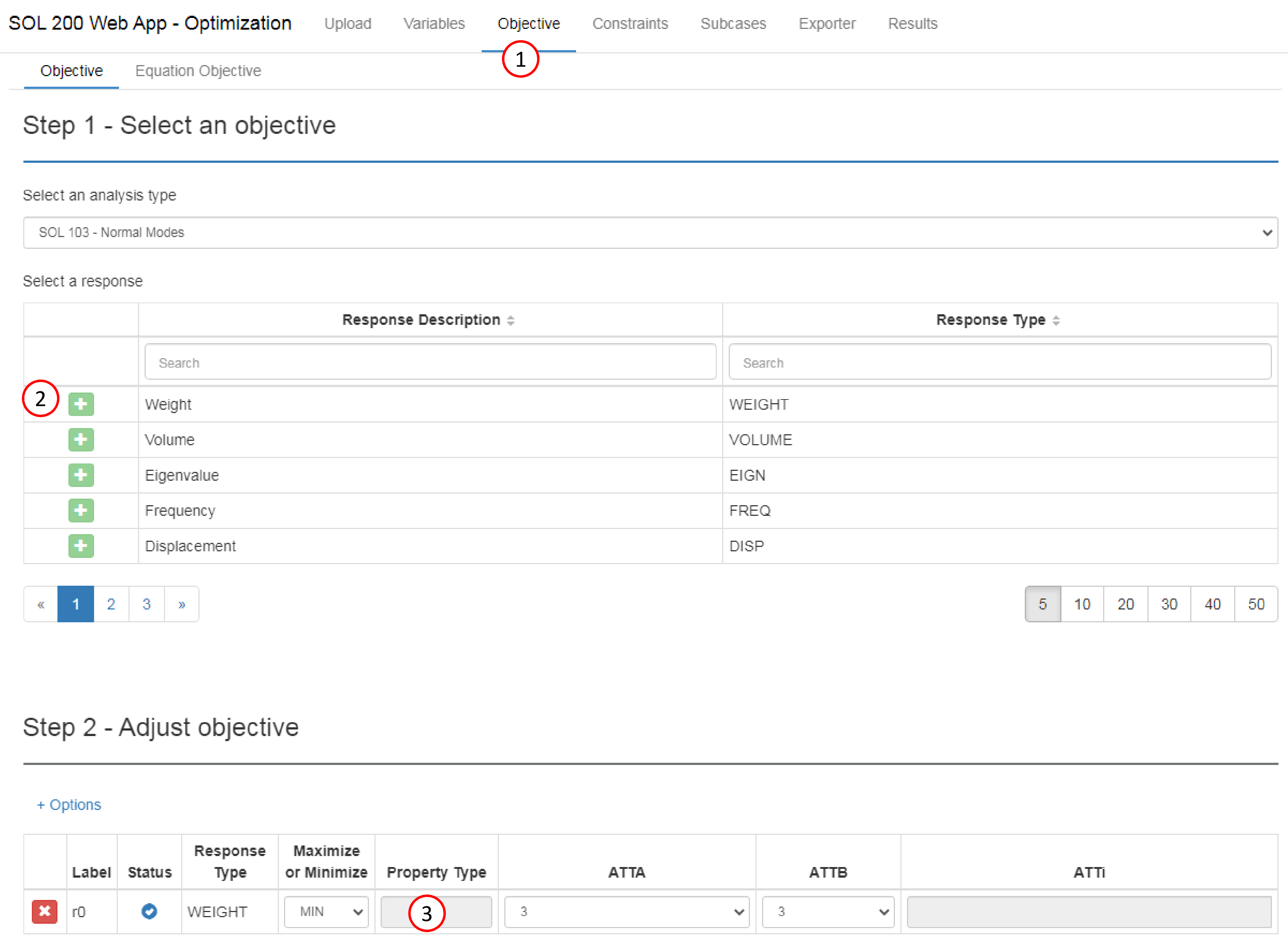
5 | 10 | 20 | 30 | 40 | 50

(2)

Create Design Objective

1. Click Objective
2. Select the plus (+) icon for weight
3. The objective has been set to minimize the weight, no further modification is necessary

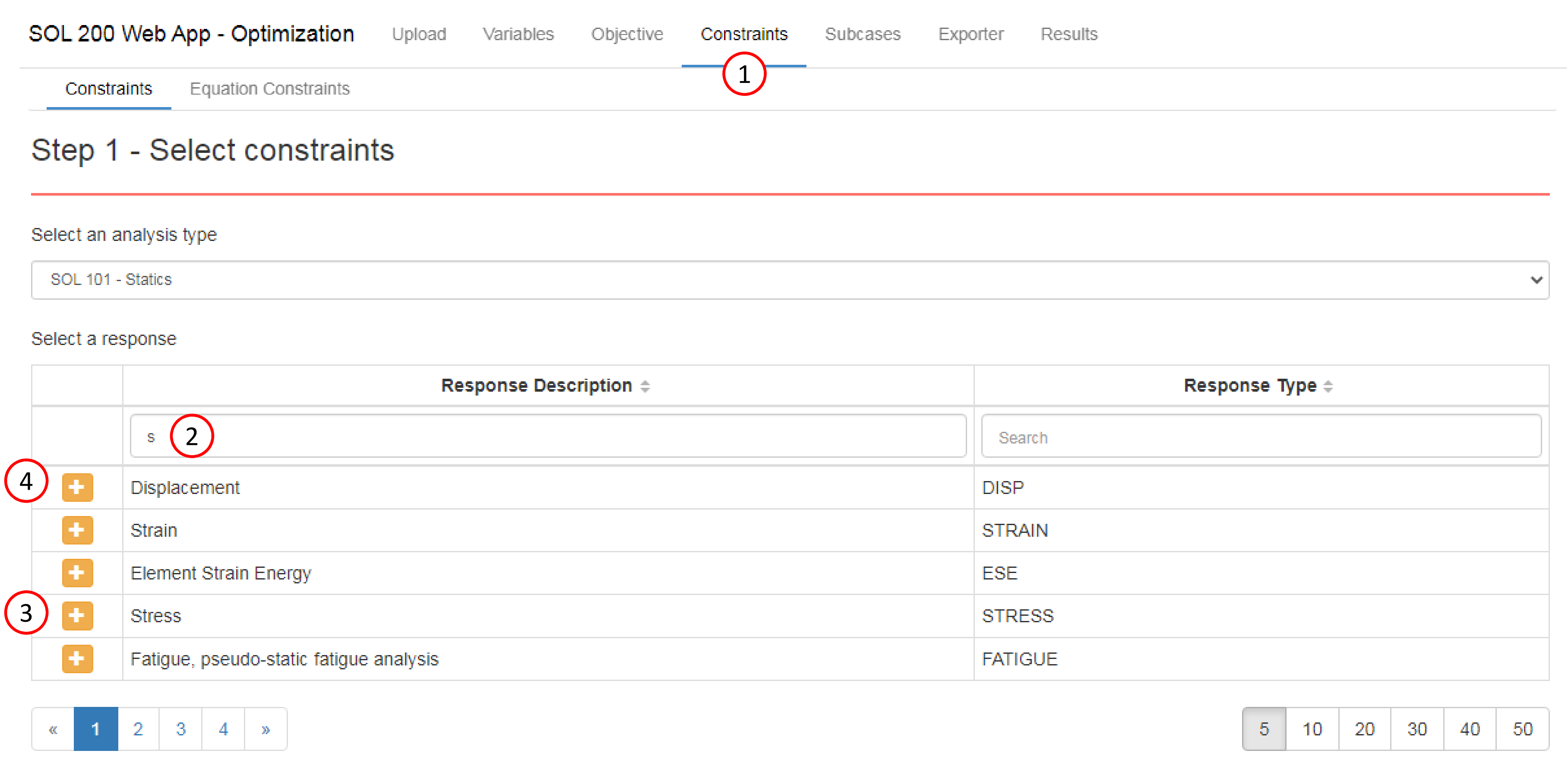
- The objective must always be a single and global response. A response such as weight and volume are single responses, are independent of load case, and can be used as an objective. Other responses require special care when set as an objective. For example, if the objective is stress, only the stress 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. In the search box, type 's'
3. Select the plus(+) icon 8 times for Stress to create 8 stress constraints
4. Select the plus(+) icon 1 time for Displacement to create 1 displacement constraint

- The search box is used to filter the tables for the Displacement and Stress responses.



Create Design Constraints

1. Click 10 on the pagination bar
2. Configure the constraints as shown to the right
   - Example: Configure the following for r1
     - Property Type: PROD
     - ATTA: 2 - Axial stress
     - ATTi: 1 (PID 1)
     - Lower Allowed Limit: -40000.
     - Upper Allowed Limit: 40000.
   - Example: Configure the following for r9
     - ATTA: 123 - T1, T2, T3
     - ATTi: 1, 2 (Nodes 1 and 2)
     - Lower Allowed Limit: -.35.
     - Upper Allowed Limit: .35.
   - Repeat the same for r2, r3, ... r8, but note that each cell will be different

- The r1 label is configured as follows: A stress constraint is created for all elements associated with the entry PROD 1, for component 2 (Axial Stress). PROD 1 has 1 element associated, so 1 stress quantity is constrained.
- The r9 label is configured as follows: The T1, T2, T3 components (x, y, z) of displacement at grid 1 and 2 are constrained. Since there are 3x2 responses, 6 responses are constrained.

Step 2 - Adjust constraints

+ Options

	Label	Status	Response Type	Property Type	ATTA	ATTB	ATTi	Lower Allowed Limit	Upper Allowed Limit
	Se	Seai	Search	Search	Search	Search	Search	Search	Search
✖	r1	✔	STRESS	PROD	2 - Axial stress		1	-40000.	40000.
✖	r2	✔	STRESS	PROD	2 - Axial stress		2	-40000.	40000.
✖	r3	✔	STRESS	PROD	2 - Axial stress		3	-40000.	40000.
✖	r4	✔	STRESS	PROD	2 - Axial stress		4	-40000.	40000.
✖	r5	✔	STRESS	PROD	2 - Axial stress		5	-40000.	40000.
✖	r6	✔	STRESS	PROD	2 - Axial stress		6	-40000.	40000.
✖	r7	✔	STRESS	PROD	2 - Axial stress		7	-40000.	40000.
✖	r8	✔	STRESS	PROD	2 - Axial stress		8	-40000.	40000.
✖	r9	✔	DISP		123 - T1, T2, T3		1, 2	-.35	.35

2

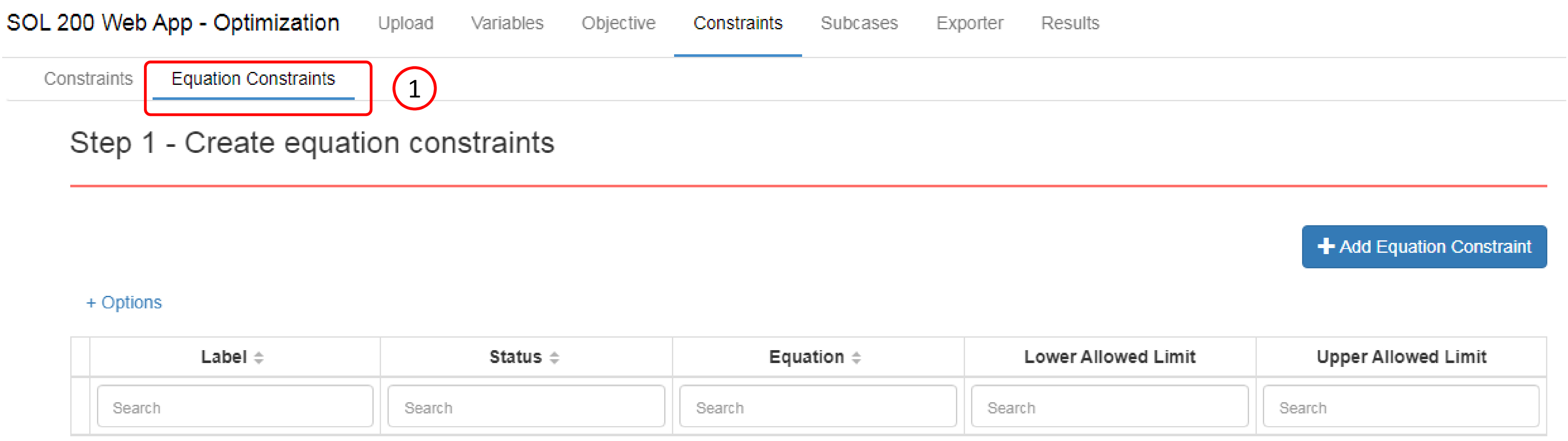
5 | 10 | 20 | 30 | 40 | 50

1

Create Design Constraints

1. Click Equation Constraints. This will make the Equation Constraints section visible and accessible

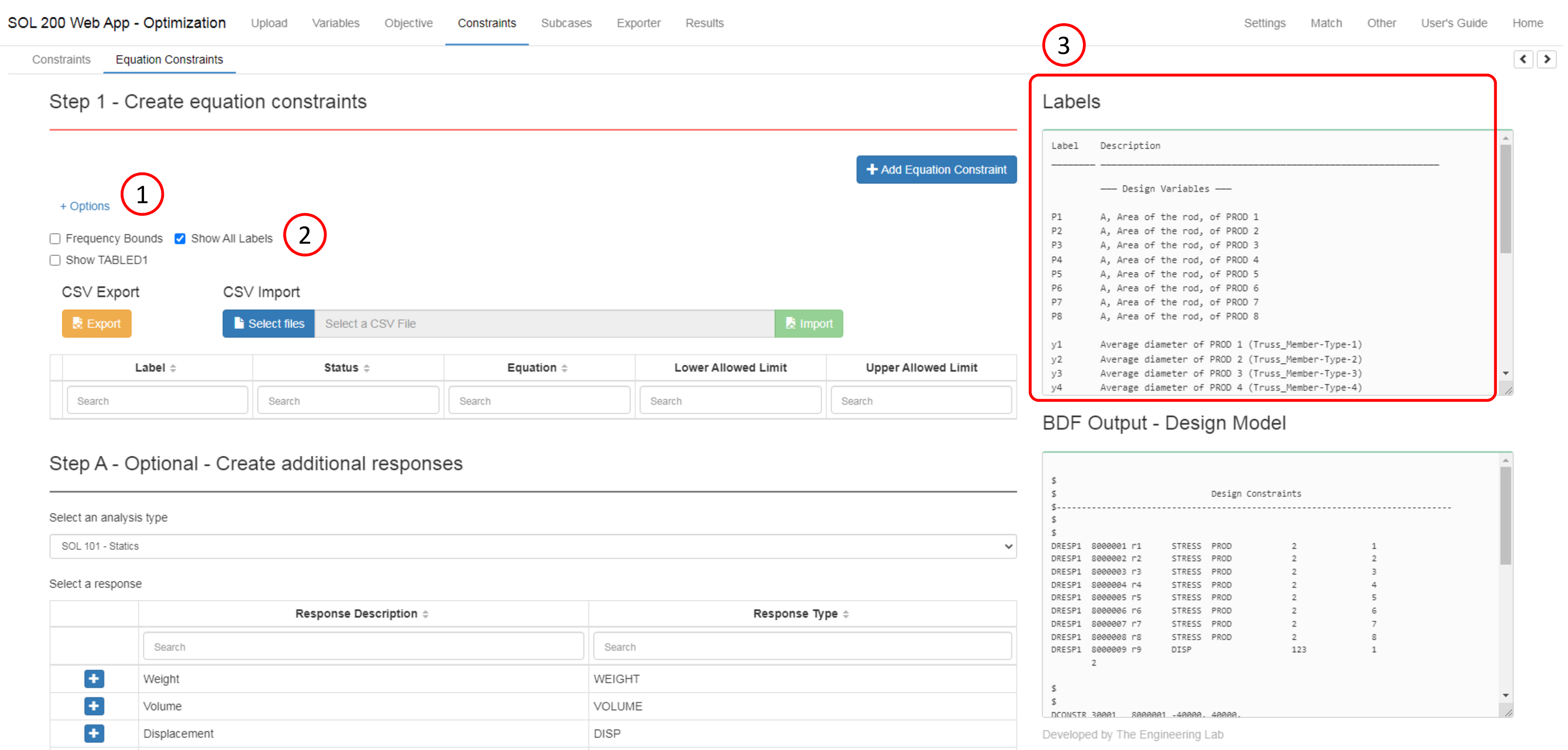
- There are 2 methods of creating a constraint.
    - Method 1 – Select a constraint from a given list of responses, e.g. Weight, Volume, etc.
    - Method 2 – Create an equation.
- This page shows the use of Method 2 to create an Equation Constraint.



Create Design Constraints

1. Click +Options
2. Mark the checkbox titled Show All Labels
3. This new section lists all the existing labels in the design model and will be used as reference to create the equation constraints

- Multiple labels are created in various locations throughout the web app. The Labels section is a single location where all the labels can be viewed.



Create Design Constraints

1. Click +Options
2. Click 8 times on +Add Equation Constraint
3. Click 10 on the pagination bar
4. Use Table 1 to type in the 8 equations for each Ri, where i = 1, 2, 3, … 8
   - Caution: Do not copy and paste the equations into the web app, sometimes PowerPoint will change the negative symbol from '-' to '–' and will be carried over if you copy and paste. Manually type in the equation instead.
5. Specify the upper bound as 1.0 for all 8 constraints

- The Equation Constraint R2 can be read as follows:
  - g = -7.69 * r2 * 130.5**2;
  - g2 = 3.14**2 * 1.0E7 * y2**2;
  - g3 = g / g2 * 1.25
    The value g3 is the value taken by the Equation Constraint.
- When typing the equation, the beginning of the equation does NOT need "g =" This is automatically inserted in the background.

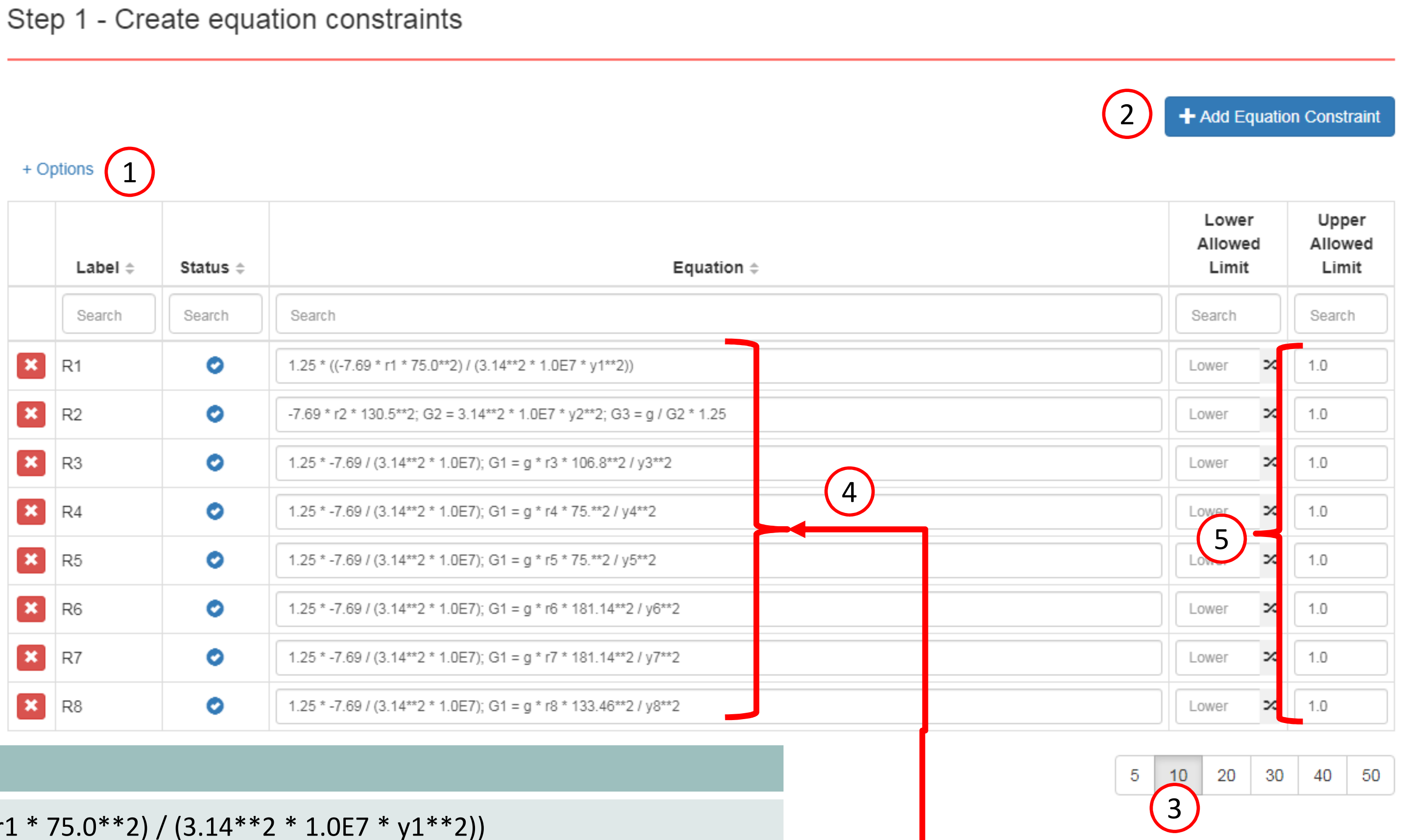


Table 1

Ri	Equation
R1	1.25 * ((-7.69 * r1 * 75.0**2) / (3.14**2 * 1.0E7 * y1**2))
R2	-7.69 * r2 * 130.5**2; g2 = 3.14**2 * 1.0E7 * y2**2; g3 = g / g2 * 1.25
R3	1.25 * -7.69 / (3.14**2 * 1.0E7); g2 = g * r3 * 106.8**2 / y3**2
R4	1.25 * -7.69 / (3.14**2 * 1.0E7); g2 = g * r4 * 75.0**2 / y4**2
R5	1.25 * -7.69 / (3.14**2 * 1.0E7); g2 = g * r5 * 75.0**2 / y5**2
R6	1.25 * -7.69 / (3.14**2 * 1.0E7); g2 = g * r6 * 181.14**2 / y6**2
R7	1.25 * -7.69 / (3.14**2 * 1.0E7); g2 = g * r7 * 181.14**2 / y7**2
R8	1.25 * -7.69 / (3.14**2 * 1.0E7); g2 = g * r8 * 133.46**2 / y8**2

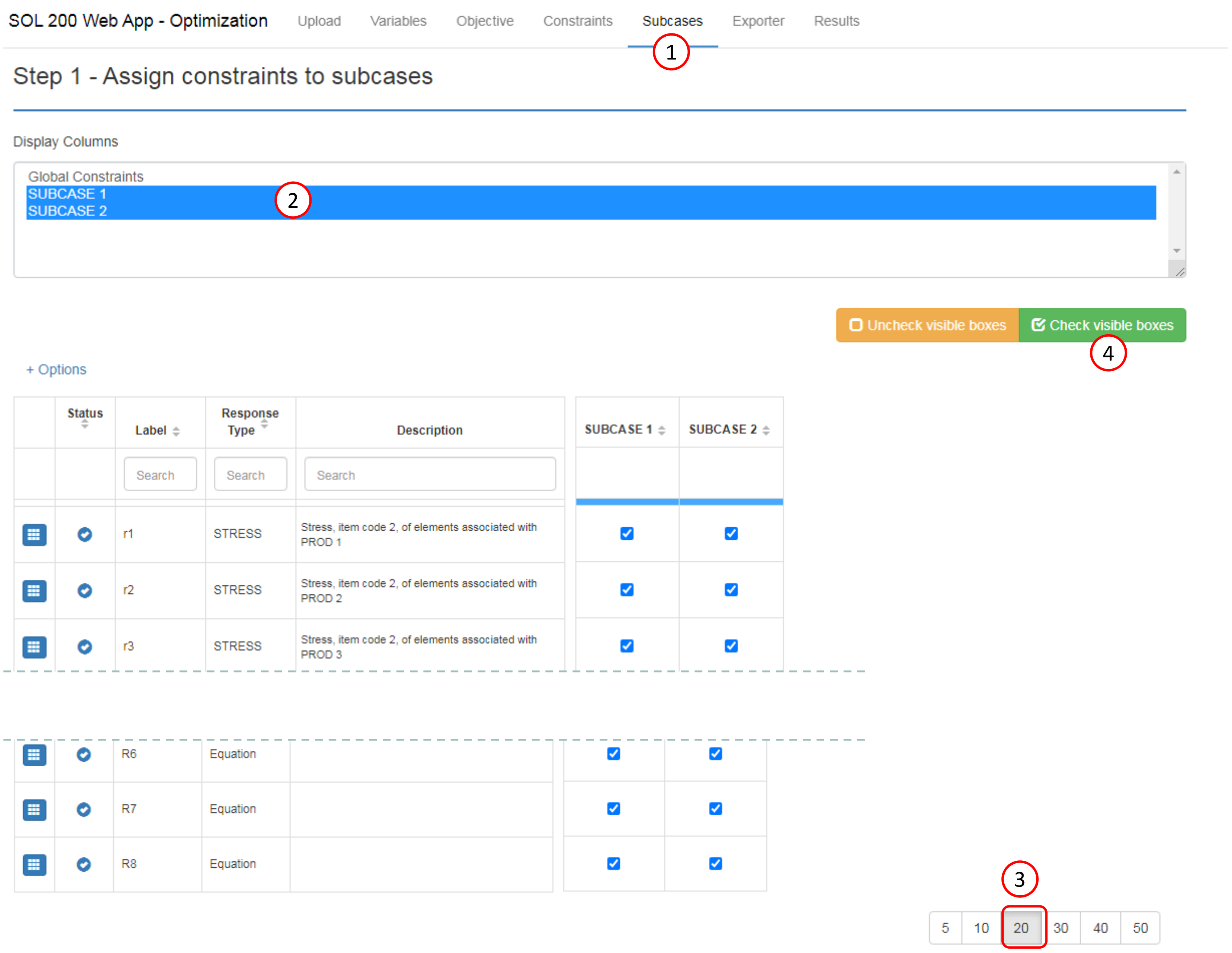
Assign Constraints to Load Cases (SUBCASES)

1. Click Subcases
2. Select only SUBCASE 1 and SUBCASE 2
3. Click 20 in the pagination bar
4. Click Check visible boxes
   - Each checkbox for the columns should be marked

- The following constraints have been applied to SUBCASE 1 and 2: r1, r2, r3, r4, r5, r6, r7, r8, r9, R1, R2, R3, R4, R5, R6, R7, R8
- When hundreds of SUBCASEs must be configured, the following options expedite the process:

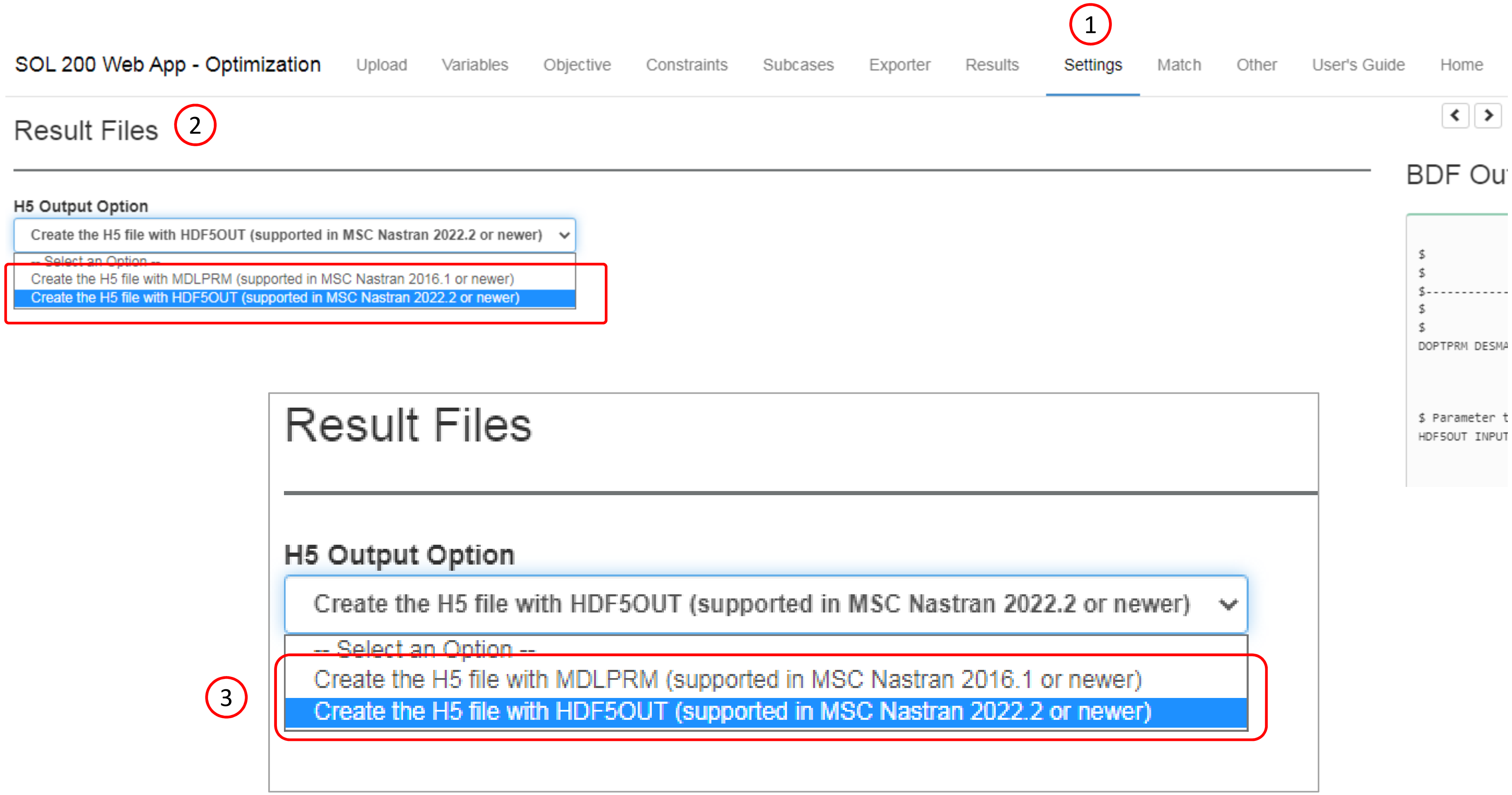
Uncheck visible boxes

Check visible boxes



Configure Settings

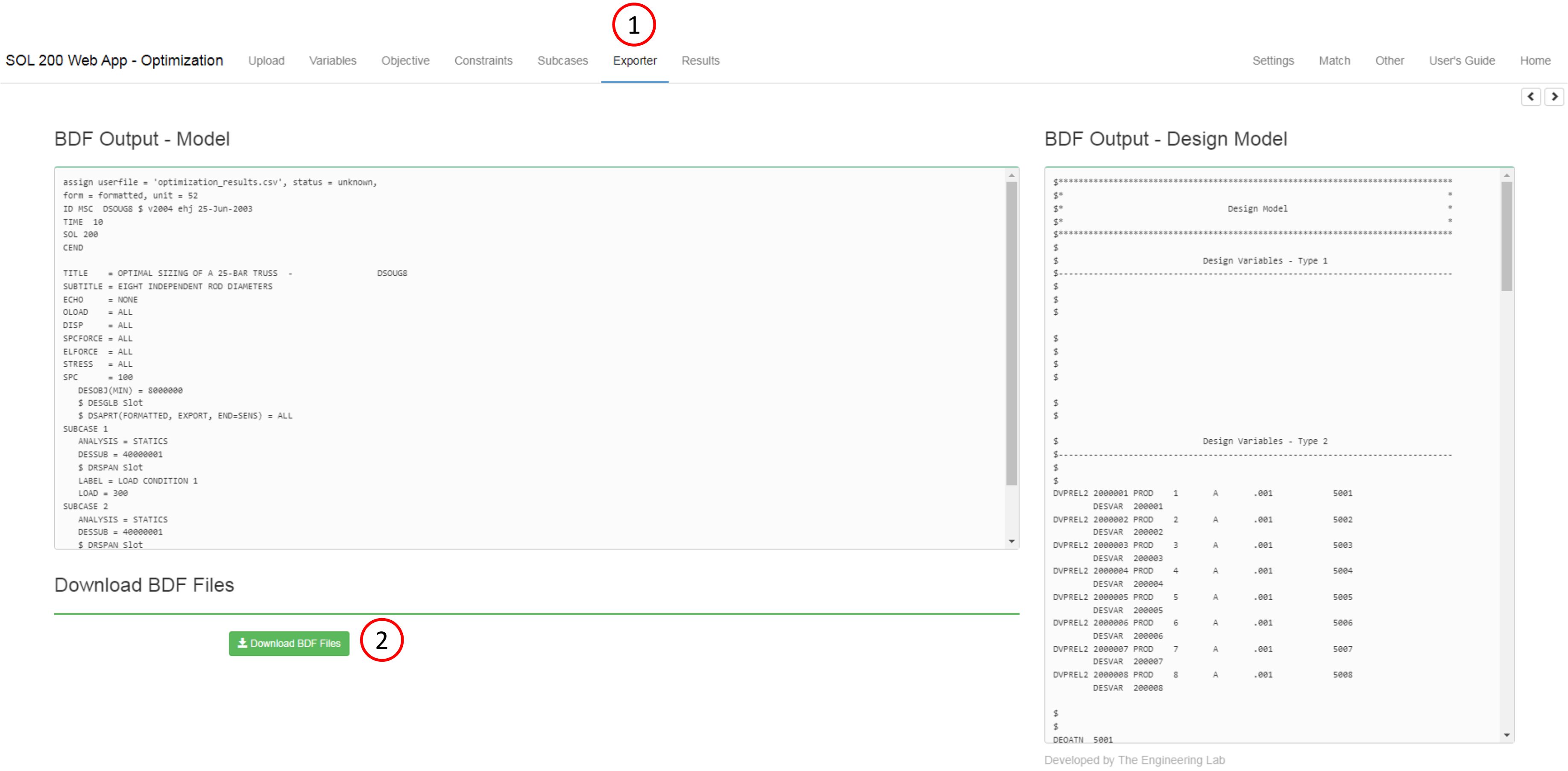
1. Click Settings
2. Scroll to section Result Files
3. Select one of the following H5 output options
    - Create the H5 file with MDLPRM
    - Create the H5 file with HDF5OUT



- The H5 file is used by the Post-processor web app to display MSC Nastran results.
- The H5 file is used by the HDF5 Explorer to create graphs (XY Plots) of MSC Nastran results.

Export New BDF Files

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

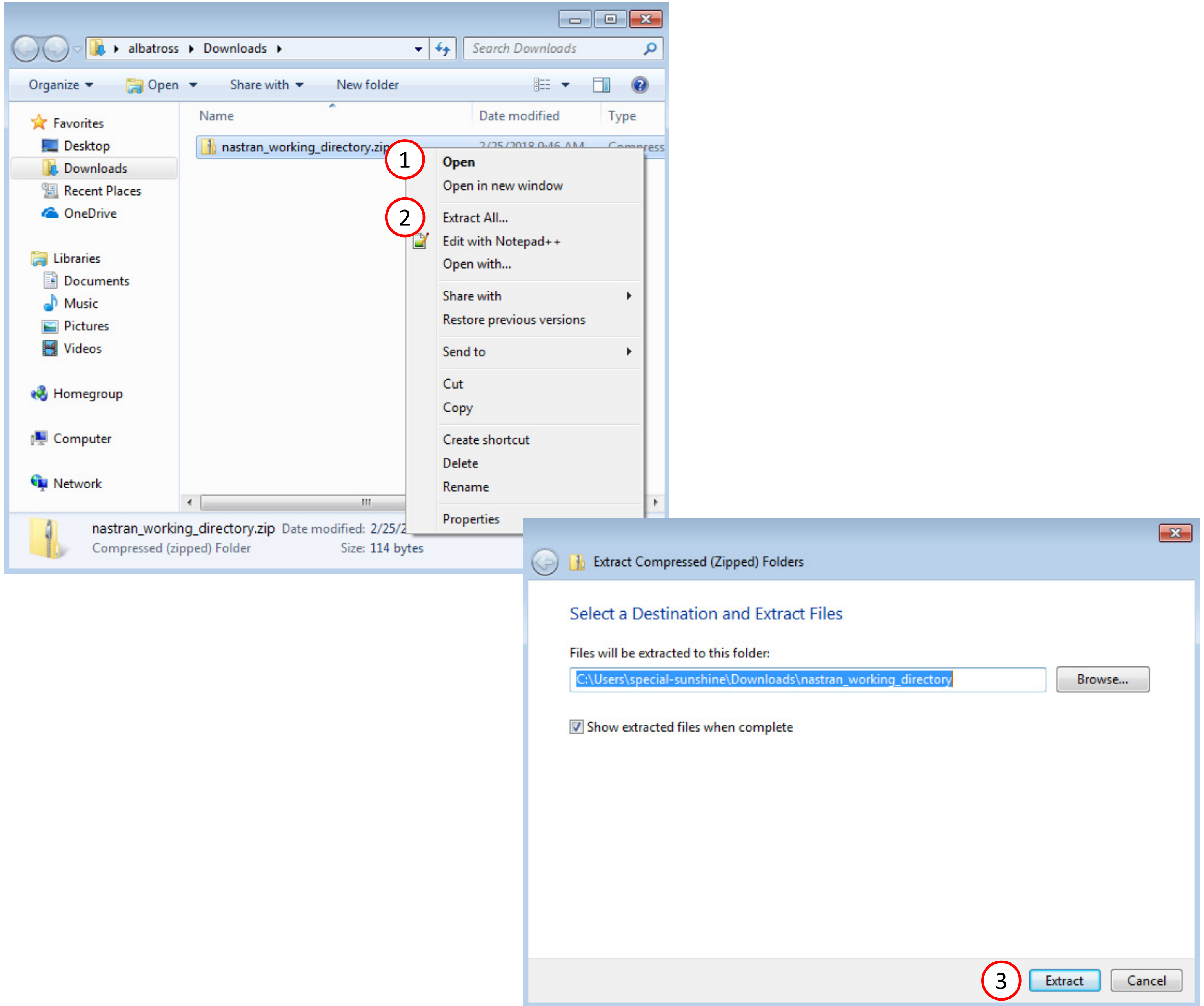


- When the download button is clicked a new file named "nastran_working_directory" is downloaded. If the file already exists in your local folder, the folder name is appended with a number, e.g. "nastran_working_directory (1).zip"

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

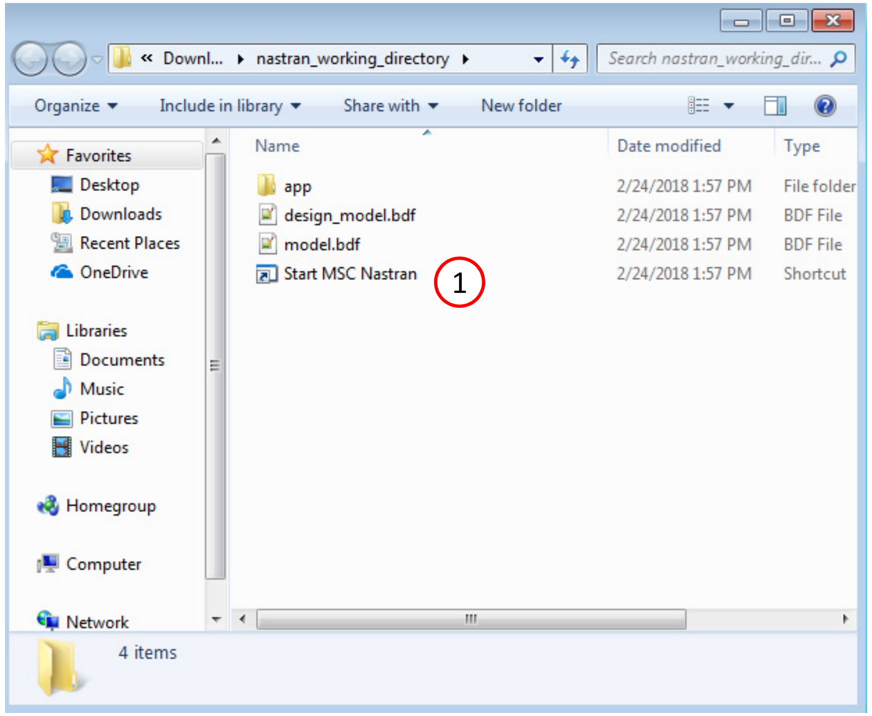
- After a successful optimization, the results will be automatically displayed as long as the following files are present: BDF, F06 and LOG.
- One can run the Nastran job on a remote machine as follows: 1) Copy the BDF files and the INCLUDE files to a remote machine. 2) Run the MSC Nastran job on the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

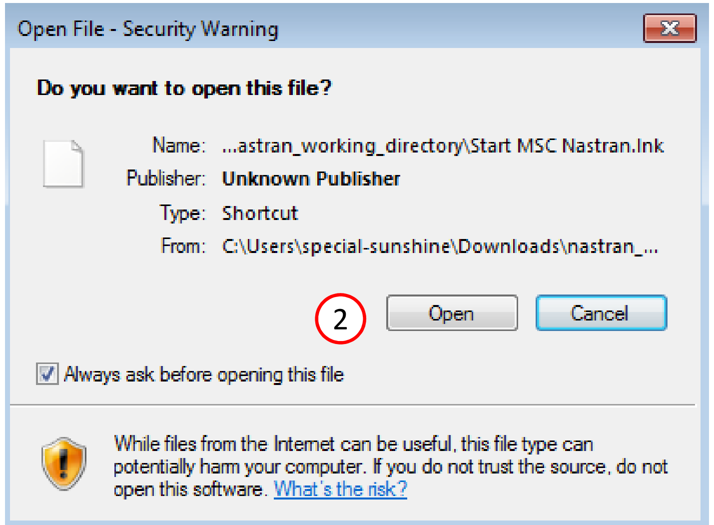
Using Linux?

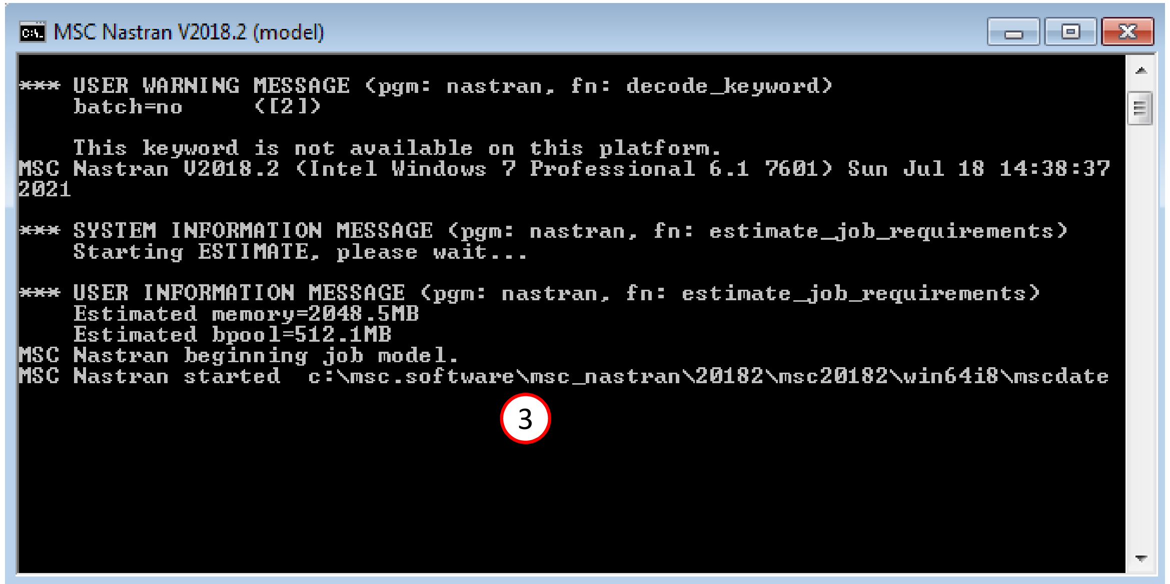
Follow these instructions:
1) Open Terminal
2) Navigate to the nastran_working_directory
cd ./nastran_working_directory
3) Use this command to start the process
./Start_MSC_Nastran.sh

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) and design variables can be reviewed.

- The reader may realize a sudden jump/change in the results after the 15D design cycle. Recall that the design variables were configured to take on allowed values. The optimization performs a regular continuous optimization for design cycles 1-15. Upon convergence, the variables are not equal to the allowed values, e.g. the variable might be 1.25, but the allowed value is either 1.0 or 2.0. A discrete process is performed after the last design cycle, in this case cycle 15D, to force the variables to be an allowed value, i.e. 1.25 becomes 1.0. As a result of this sudden change in variables, both the objective and constraints also change.
- The final message includes a second line. If this line appears, the discrete process was a success.
    - AND HARD FEASIBLE DISCRETE DESIGN OBTAINED
- If the this line appears, refer to the Appendix - What does this message mean: SOFT FEASIBLE DISCRETE DESIGN OBTAINED?
    - AND SOFT FEASIBLE DISCRETE DESIGN OBTAINED

SOL 200 Web App - Local Optimization Results

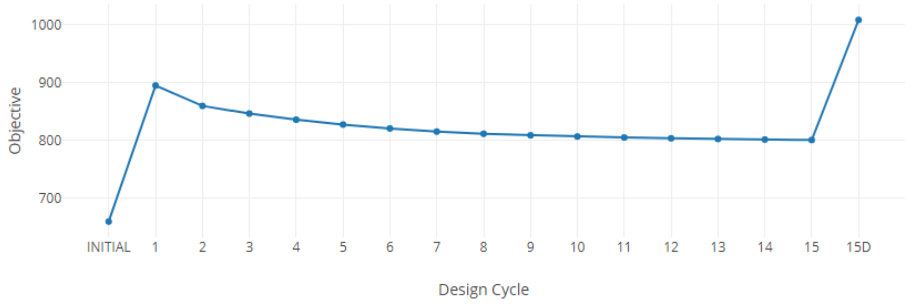
Home

Final Message in .f06

1

RUN TERMINATED DUE TO HARD CONVERGENCE TO AN OPTIMUM AT CYCLE NUMBER = 15.
AND HARD FEASIBLE DISCRETE DESIGN OBTAINED

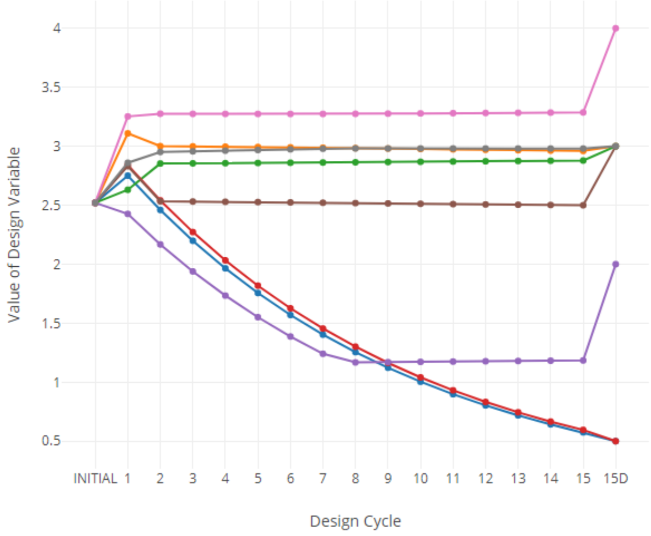
Objective



2

Design Variables

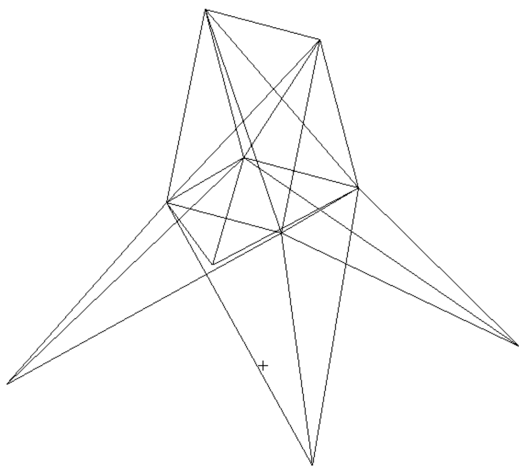
Display None | Display All



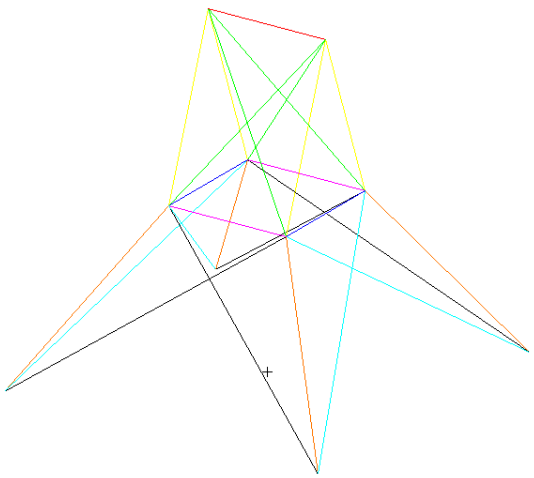
Display	Color	Label	Label Comments
☑	—	y1	Average diameter of PROD 1 (Truss_Member-Type-1)
☑	—	y2	Average diameter of PROD 2 (Truss_Member-Type-2)
☑	—	y3	Average diameter of PROD 3 (Truss_Member-Type-3)
☑	—	y4	Average diameter of PROD 4 (Truss_Member-Type-4)
☑	—	y5	Average diameter of PROD 5 (Truss_Member-Type-5)
☑	—	y6	Average diameter of PROD 6 (Truss_Member-Type-6)
☑	—	y7	Average diameter of PROD 7 (Truss_Member-Type-7)
☑	—	y8	Average diameter of PROD 8 (Truss_Member-Type-8)

Results

Initial Design
- Weight: 660 slinch
- Vary member cross section areas
- Stress constraint initially violated



Optimized Design
- Weight: 1007 slinch
- Stress and Buckling within limits



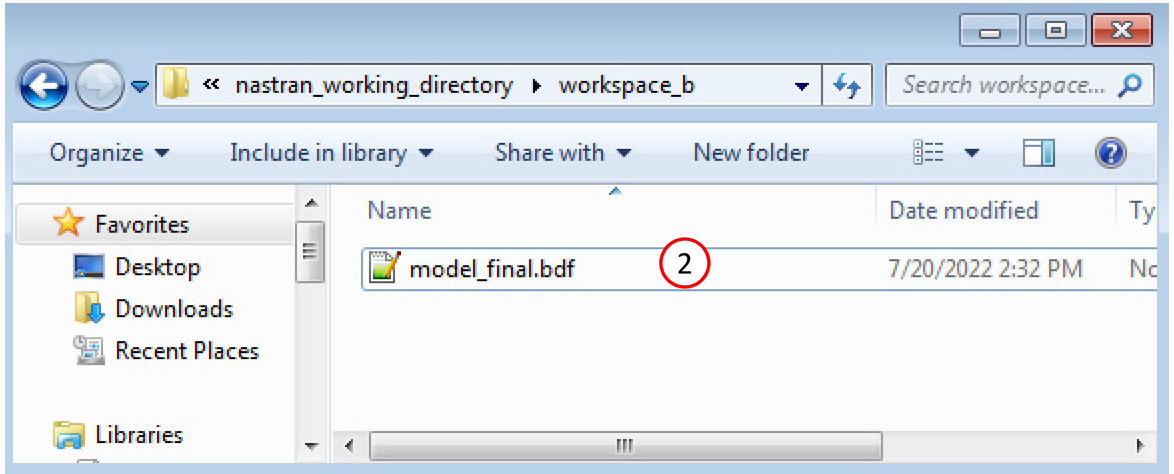
Update the Original Model

1. The original input files, e.g. DAT, BDF, etc., contains the original values for the designed properties. These original values must be updated to use the new and optimized values.

2. A new BDF file has been created in nastran_working_directory/workspace_b/model_final.bdf.

3. The file model_final.bdf is a copy of the original input files but the original values for the designed properties have been updated to use the optimized values.

- 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.



Original Input Files

```
PROD     1        1       2.0      0.0
$ Elements and Element Properties for region : Truss_Member-Type-2
PROD     2        1       2.0      0.0
$ Elements and Element Properties for region : Truss_Member-Type-3
PROD     3        1       2.0      0.0
$ Elements and Element Properties for region : Truss_Member-Type-4
PROD     4        1       2.0      0.0
$ Elements and Element Properties for region : Truss_Member-Type-5
PROD     5        1       2.0      0.0
$ Elements and Element Properties for region : Truss_Member-Type-6
PROD     6        1       2.0      0.0
$ Elements and Element Properties for region : Truss_Member-Type-7
PROD     7        1       2.0      0.0
$ Elements and Element Properties for region : Truss_Member-Type-8
PROD     8        1       2.0      0.0
```

1

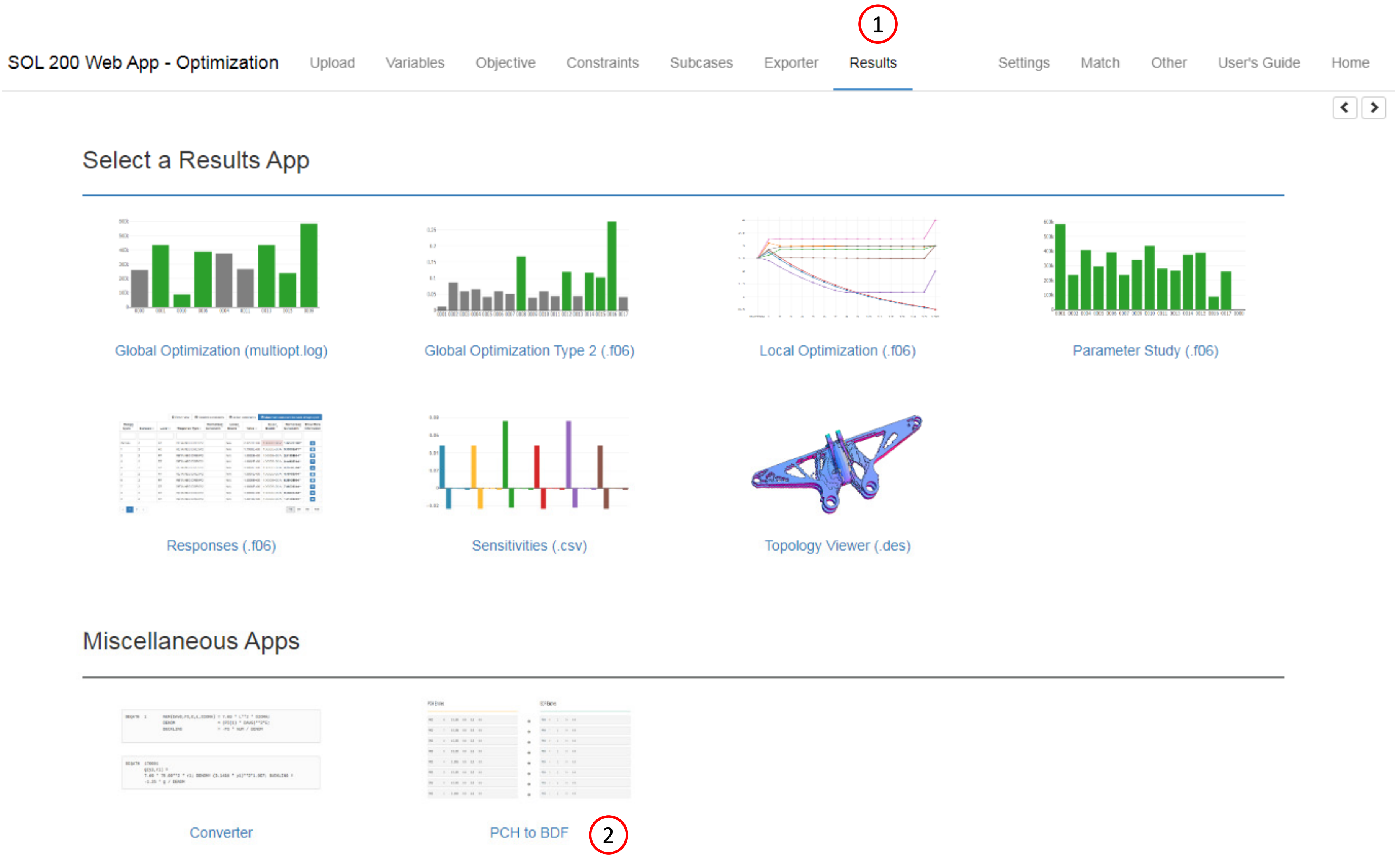
Updated BDF File (model_final.bdf)

```
PROD           1        1 .0785     0.0     0.0     0.0
$ Elements and Element Properties for region : Truss_Member-Type-2
PROD           2        1 2.826     0.0     0.0     0.0
$ Elements and Element Properties for region : Truss_Member-Type-3
PROD           3        1 2.826     0.0     0.0     0.0
$ Elements and Element Properties for region : Truss_Member-Type-4
PROD           4        1 .0785     0.0     0.0     0.0
$ Elements and Element Properties for region : Truss_Member-Type-5
PROD           5        1 1.256     0.0     0.0     0.0
$ Elements and Element Properties for region : Truss_Member-Type-6
PROD           6        1 2.826     0.0     0.0     0.0
$ Elements and Element Properties for region : Truss_Member-Type-7
PROD           7        1 5.024     0.0     0.0     0.0
$ Elements and Element Properties for region : Truss_Member-Type-8
PROD           8        1 2.826     0.0     0.0     0.0
```

3

Update the Original Model

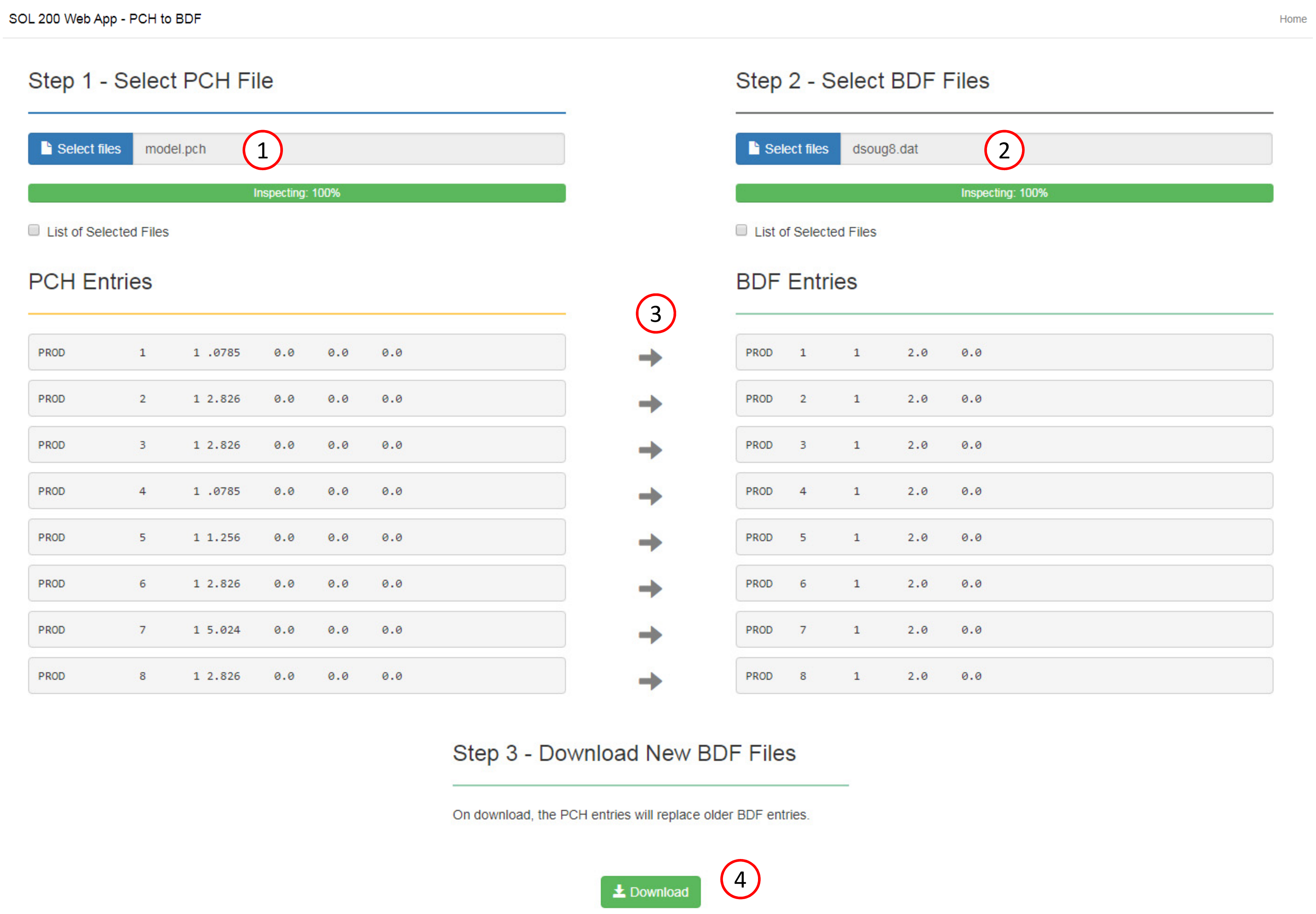
1. Click Results
2. Click PCH to BDF



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: dsoug8.dat
3. A summary of updates that will be performed are shown
4. Click Download and a new updated BDF file is downloaded



Update the Original Model

1. Note the entries have been updated with the optimized properties

dsoug8.dat

```
CROD    10      4       3       6
CROD    11      4       4       5
CROD    12      5       3       4
CROD    13      5       5       6
CROD    14      6       3       10
CROD    15      6       6       7
CROD    16      6       4       9
CROD    17      6       5       8
CROD    18      7       4       7
CROD    19      7       3       8
CROD    20      7       5       10
CROD    21      7       6       9
CROD    22      8       6       10
CROD    23      8       3       7
CROD    24      8       5       9
CROD    25      8       4       8
$
$ Elements and Element Properties for region : Truss_Member-Type-1
PROD    1       1       2.0     0.0
$ Elements and Element Properties for region : Truss_Member-Type-2
PROD    2       1       2.0     0.0
$ Elements and Element Properties for region : Truss_Member-Type-3
PROD    3       1       2.0     0.0
$ Elements and Element Properties for region : Truss_Member-Type-4
PROD    4       1       2.0     0.0
$ Elements and Element Properties for region : Truss_Member-Type-5
PROD    5       1       2.0     0.0
$ Elements and Element Properties for region : Truss_Member-Type-6
PROD    6       1       2.0     0.0
$ Elements and Element Properties for region : Truss_Member-Type-7
PROD    7       1       2.0     0.0
$ Elements and Element Properties for region : Truss_Member-Type-8
PROD    8       1       2.0     0.0
$
FORCE   300     1               1.0     1000.   10000.  -5000.
FORCE   300     2               1.0        0.   10000.  -5000.
FORCE   300     3               1.0      500.       0.      0.
FORCE   300     6               1.0      500.       0.      0.
FORCE   310     1               1.0        0.   20000.  -5000.
FORCE   310     2               1.0        0.  -20000.  -5000.
ENDDATA
$.......2.......3.......4.......5.......6.......7.......8.......9.......0
```

Original BDF/DAT File

dsoug8.dat

```
CROD    10      4       3       6
CROD    11      4       4       5
CROD    12      5       3       4
CROD    13      5       5       6
CROD    14      6       3       10
CROD    15      6       6       7
CROD    16      6       4       9
CROD    17      6       5       8
CROD    18      7       4       7
CROD    19      7       3       8
CROD    20      7       5       10
CROD    21      7       6       9
CROD    22      8       6       10
CROD    23      8       3       7
CROD    24      8       5       9
CROD    25      8       4       8
$
$ Elements and Element Properties for region : Truss_Member-Type-1
PROD           1       1 .0785     0.0     0.0     0.0
$ Elements and Element Properties for region : Truss_Member-Type-2
PROD           2       1 2.826     0.0     0.0     0.0
$ Elements and Element Properties for region : Truss_Member-Type-3
PROD           3       1 2.826     0.0     0.0     0.0
$ Elements and Element Properties for region : Truss_Member-Type-4
PROD           4       1 .0785     0.0     0.0     0.0
$ Elements and Element Properties for region : Truss_Member-Type-5
PROD           5       1 1.256     0.0     0.0     0.0
$ Elements and Element Properties for region : Truss_Member-Type-6
PROD           6       1 2.826     0.0     0.0     0.0
$ Elements and Element Properties for region : Truss_Member-Type-7
PROD           7       1 5.024     0.0     0.0     0.0
$ Elements and Element Properties for region : Truss_Member-Type-8
PROD           8       1 2.826     0.0     0.0     0.0
$
FORCE   300     1               1.0     1000.   10000.  -5000.
FORCE   300     2               1.0        0.   10000.  -5000.
FORCE   300     3               1.0      500.       0.      0.
FORCE   300     6               1.0      500.       0.      0.
FORCE   310     1               1.0        0.   20000.  -5000.
FORCE   310     2               1.0        0.  -20000.  -5000.
ENDDATA
$.......2.......3.......4.......5.......6.......7.......8.......9.......0
```

Downloaded BDF/DAT File

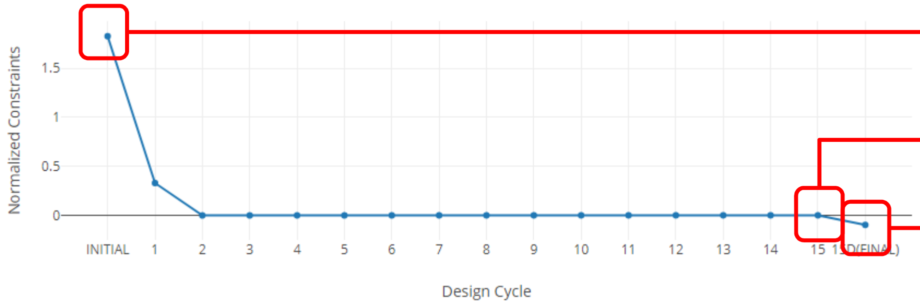
Inspection of MSC Nastran Results with the Post-processor Web App

Normalized Constraints

- All constraints are normalized. For each design cycle, the maximum normalized constraint (NC) is reported in the Normalized Constraints plot.
- The Responses web app is used to inspect the corresponding response for each maximum normalized constraint value.
    - For the initial design, the maximum NC is 1.8272 and corresponds to a factor of safety for buckling of 2.8272.
    - For design cycle 14, the maximum NC is .0011263 and corresponds to a buckling value of 1.0011.
    - For the final design, the maximum NC is -.09668 and corresponds to a buckling value of .90332. The final buckling value is well under the upper bound of 1.0. This is because the final design variables were adjusted to use the discrete values that were defined on the DDVAL entry. A variable value such as 3.28 may have been adjusted to 4. The change in variable values caused the buckling value to change from 1.0, in the previous design cycle, to 0.90, in the final design cycle.

Normalized Constraints

+ Info



SOL 200 Web App - Responses

Home

Responses

Reset view | Violated constraints | Active constraints | Maximum constraint for each design cycle

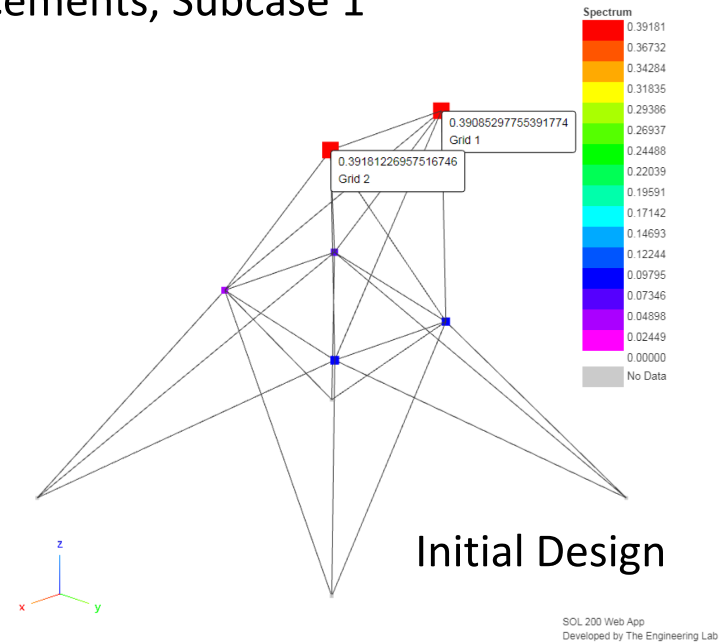
Design Cycle	Subcase	Label	Response Type	Normalized Constraint	Lower Bound	Value	Upper Bound	Normalized Constraint	Show More Information
Search	Search	Seai	Search	Search	Searc	Search	Search	Search	
INITIAL	2	R7	RETAINED DRESP2		N/A	2.8272E+00	1.0000E+00 V	1.8272E+00**	
14	2	R7	RETAINED DRESP2		N/A	1.0011E+00	1.0000E+00 A	1.1263E-03**	
FINAL - 15D(FI	2	R2	RETAINED DRESP2		N/A	9.0332E-01	1.0000E+00	-9.6680E-02**	

Post-processor Web App

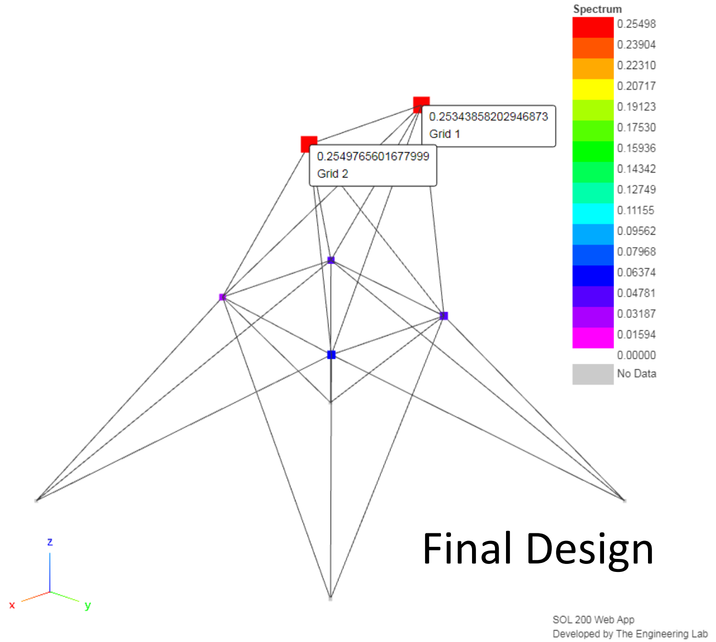
- The Post-processor web app is used to inspect the MSC Nastran results.
- The displacements are displayed. Note the displacements at grids 1 and 2 are within the bounds specified on the design constraints.

- Refer to the Post-processor web app tutorials to learn more about MSC Nastran results.

Displacements, Subcase 1

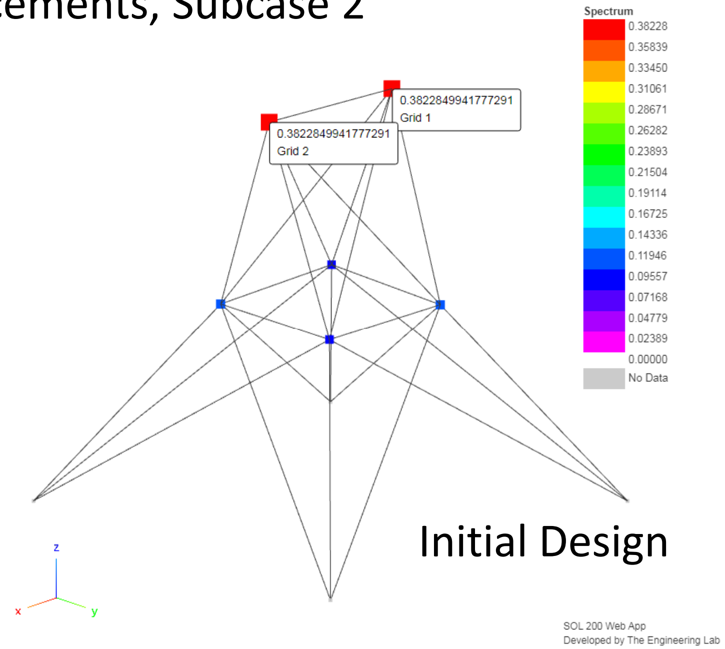


Initial Design

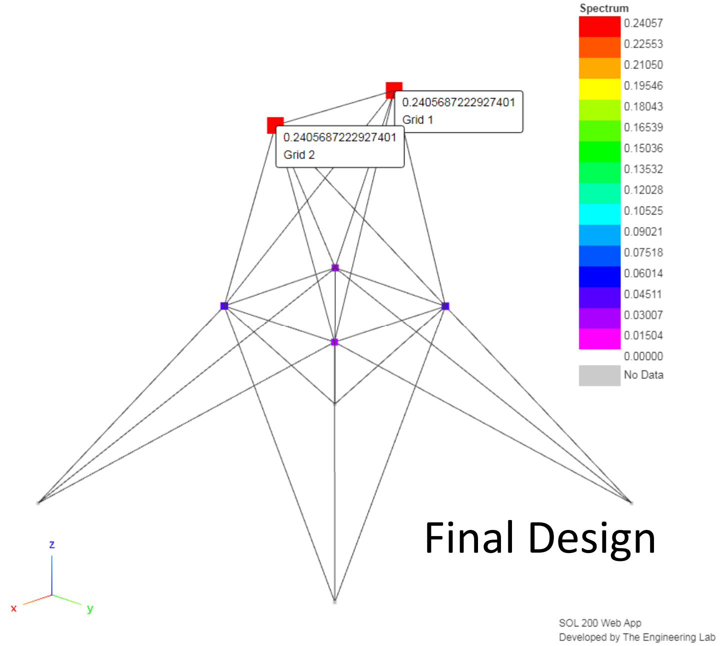


Final Design

Displacements, Subcase 2



Initial Design



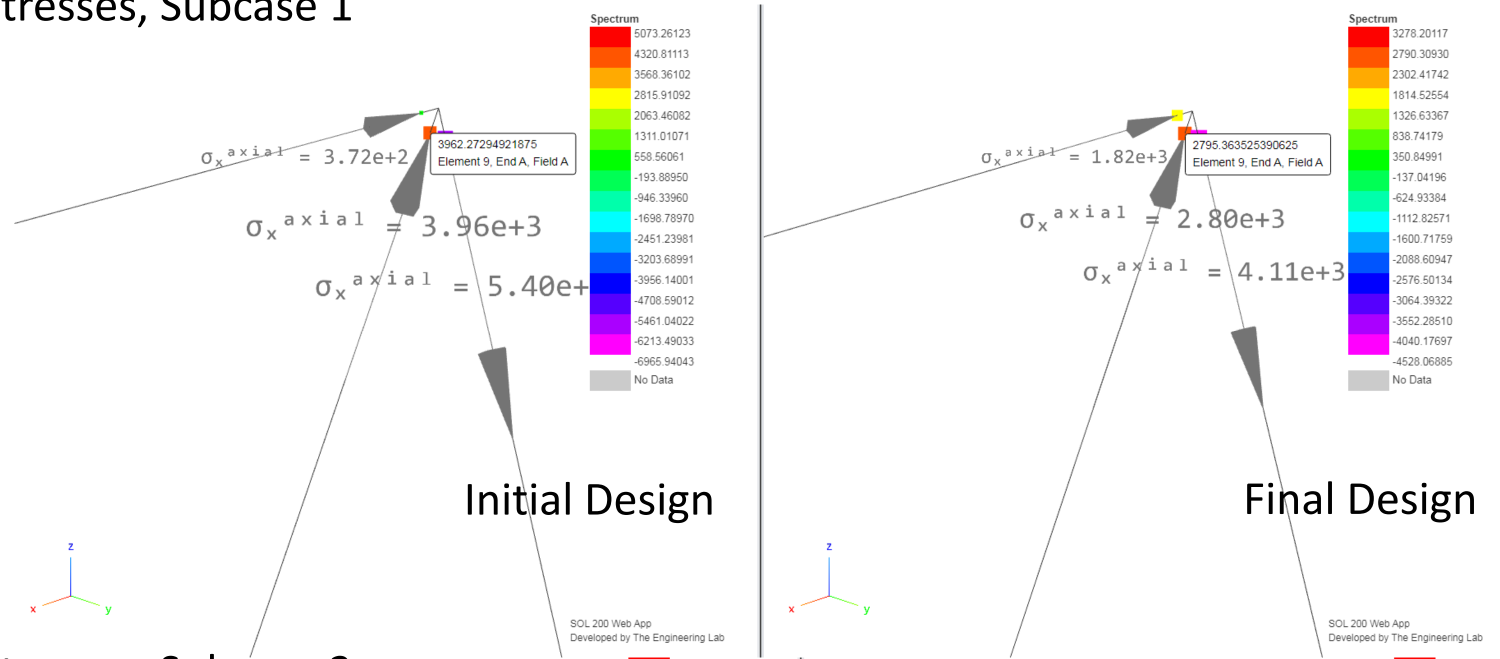
Final Design

Post-processor Web App

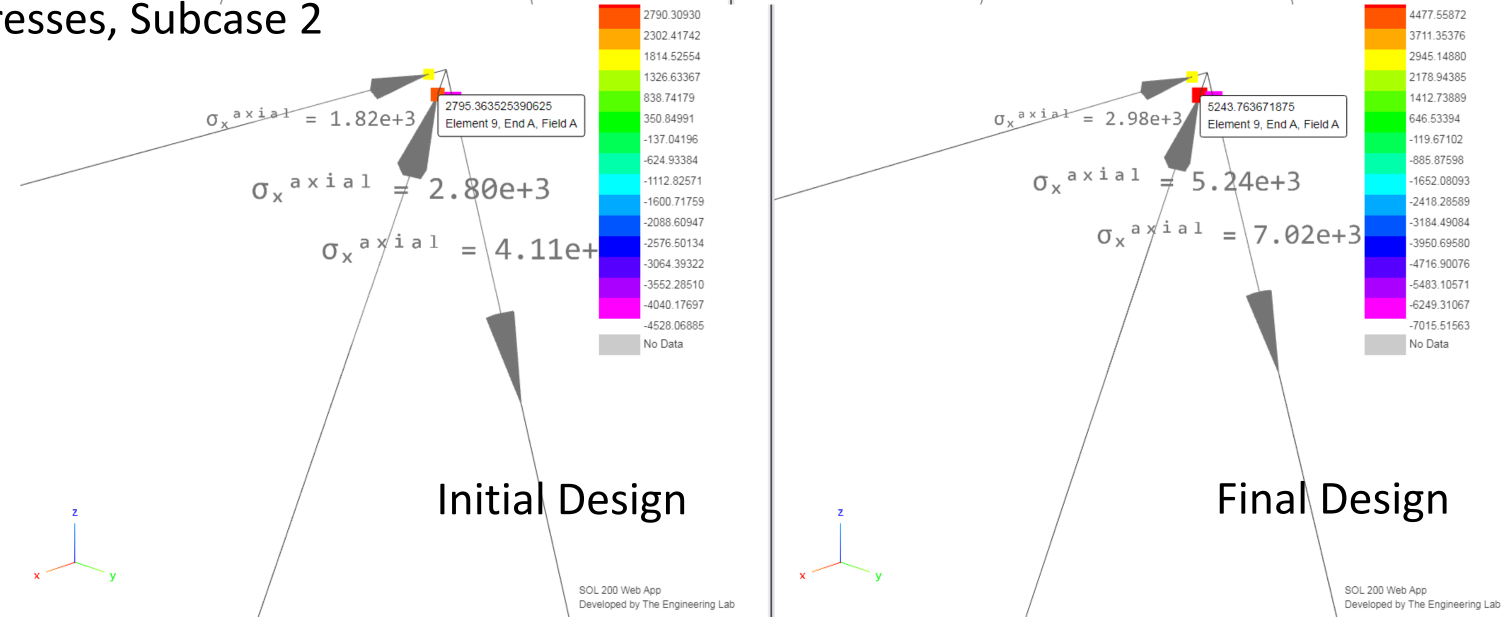
- The Post-processor web app is used to inspect the MSC Nastran results.
- The axial stresses are displayed.

- Refer to the Post-processor web app tutorials to learn more about MSC Nastran results.

Axial Stresses, Subcase 1



Axial Stresses, Subcase 2

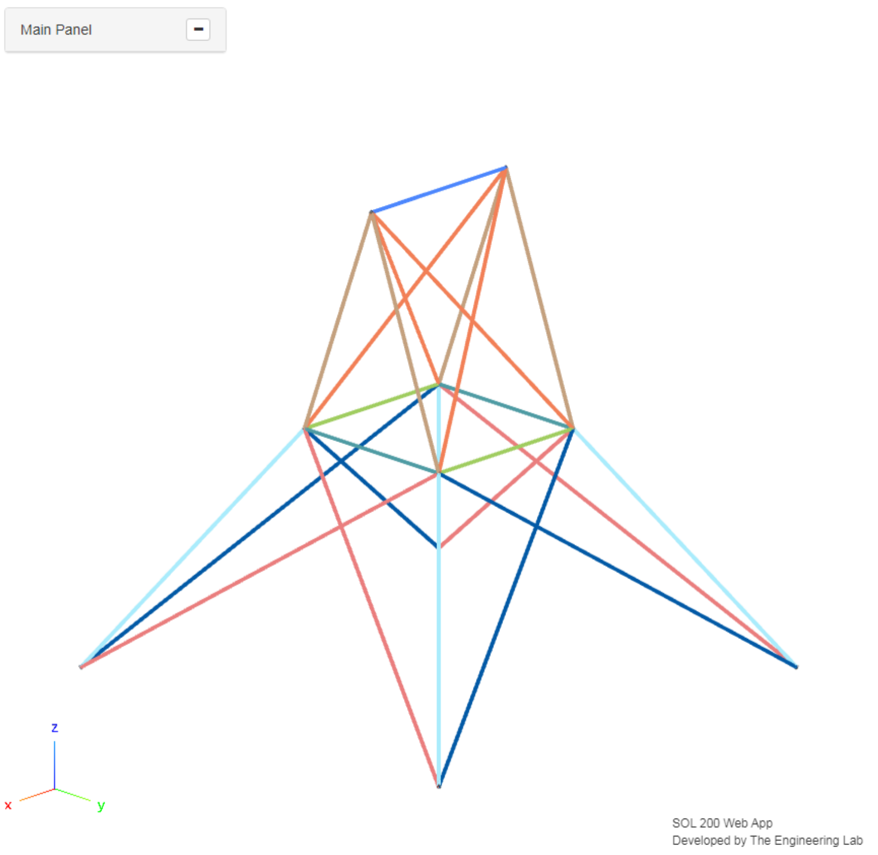


Post-processor Web App

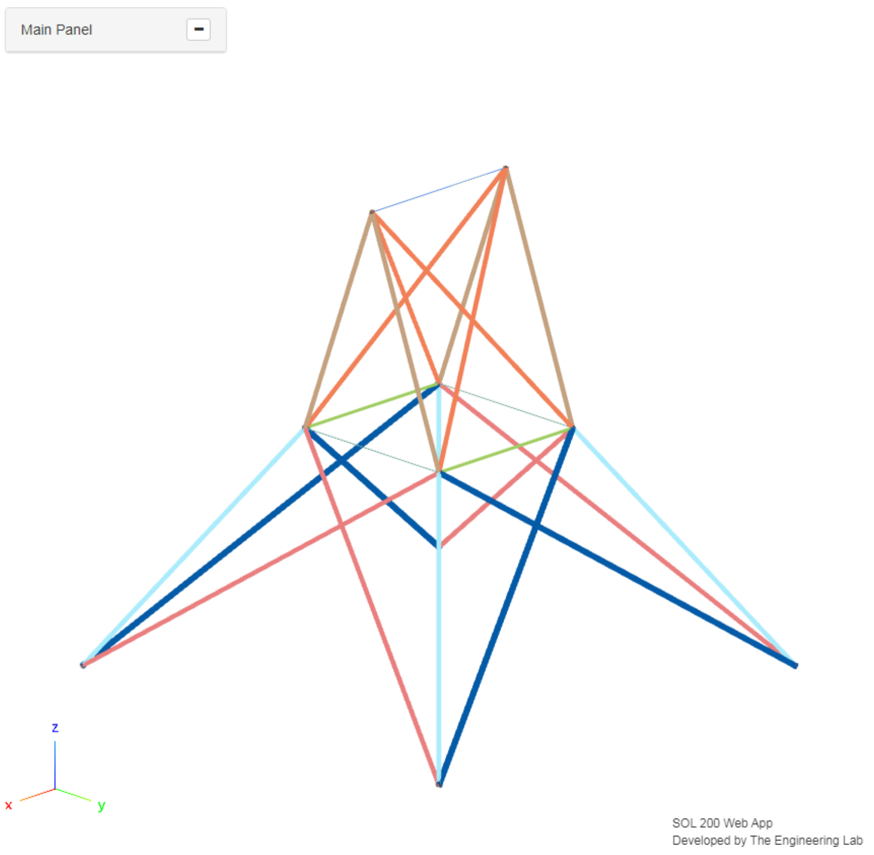
- The CROD cross sections of the initial and final design are compared.

- Refer to the Post-processor web app tutorials to learn more about MSC Nastran results.

Cross section of CROD elements



Initial Design



Final Design

End of Tutorial

Appendix

Appendix Contents

- Frequently Asked Questions
  - What are the different ways of writing Equations for Equation Objective and Equation Constraints?

Frequently Asked Questions

Question:

- What are the different ways of writing Equations for Equation Objective and Equation Constraints?
- What does this message mean: SOFT FEASIBLE DISCRETE DESIGN OBTAINED?

Frequently Asked Questions

Answer: **Single expression**

-7.69 * r1 * 75.**2 * 1.25 / (3.14**2 * 1.e7 * y1**2)

Below is the DEQATN entry that is created in the web app

```
DEQATN  170001
        g(y1,r1) =
        -7.69 * r1 * 75.**2 * 1.25 / (3.14**2 * 1.e7 * y1**2)
```

It is not necessary to type 'g =' at the beginning. This is done automatically for you.

This is how Nastran interprets the input

```
g(y1,r1) = -7.69 * r1 * 75.**2
              * 1.25 / (3.14**2 * 1.e7 * y1**2)    (eq. 1)
```

Answer: **Multiple expression**

-7.69 * r1 * 75.**2; g2 = 3.14**2 * 1.e7 * y1**2; g3 = g / g2 * 1.25;

Below is the DEQATN entry that is created in the web app

```
DEQATN  170001
        g(y1,r1) =
        -7.69 * r1 * 75.**2; g2 = 3.14**2 * 1.e7 * y1**2; g3 = g / g2 *
        1.25;
```

This is how Nastran interprets the input

```
g1(y1, r1) = -7.69 * r2 * 130.5**2;     (eq. 1)
        g2 = 3.14**2 * 1.0E7 * y2**2;   (eq. 2)
        g3 = g / g2 * 1.25;             (eq. 3)
```

The last expression is the value used by Nastran.

What does this message mean: SOFT FEASIBLE DISCRETE DESIGN OBTAINED?

Recall that the discrete process occurs after the last design cycle. The discrete process causes an apparent change, sometimes a jump, in the design variables and, consequently, the responses (objective and constraints). During the change, the constraints can remain satisfied or become violated.

The discrete process is a success if this message is reported, this indicates the constraints remained satisfied after the change: “AND HARD FEASIBLE DISCRETE DESIGN OBTAINED.”

1. This example reports “SOFT FEASIBLE DISCRETE DESIGN OBTAINED” and indicates that after the variables were adjusted to allowed values, a constraint became violated in the process. For example, the thickness at 1.125 produces a stress of 40,000 and is ok, but once the thickness is changed to 1.000, the stress becomes 40,010, thus violating the constraint.
2. When reviewing the Normalized Constraints, it is found that for 15D, the discrete process, the normalized constraint value is negative, indication of a violated constraint after the discrete process.

What does this message mean: SOFT FEASIBLE DISCRETE DESIGN OBTAINED?

To address the issue, the following can be performed to address the issue.

1. The idea is to trigger the discrete process 3-5 design cycles before the final design cycle. In this example, design cycle 13 is selected as the cycle to start the discrete process. This option is used in the design model to start the discrete process at design cycle 13.
   - DOPTPRM DISBEG 13

2. Before, this example produced cycles 13, 14, 15, 15D. With DISBEG 13, the cycles are now 13, 13D, 14, 14D, 15, 15D. The discrete process is performed after each design cycle starting at 13.

3. Since 15D resulted in a SOFT FEASIBLE DISCRETE DESIGN, the previous cycles 14D and 13D can be manually inspected. If 14D or 13D yield designs with satisfied constraints, i.e. the normalized constraint is negative, the optimum is chosen from 13D or 14D. In this example, 14D yields a design with satisfied constraints and is taken as the optimum design.

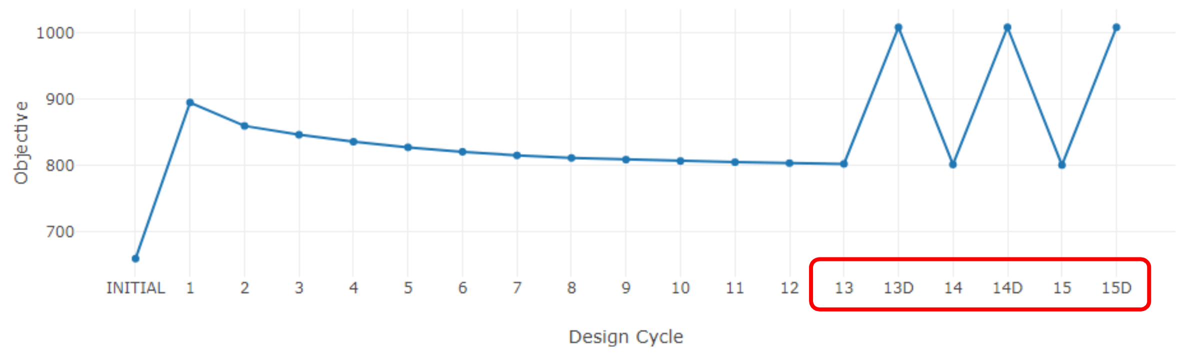
```
$
$                      Optimization Control Settings
$------------------------------------------------------------------------------
$   1  ||   2  ||   3  ||   4  ||   5  ||   6  ||   7  ||   8  ||   9  ||  10  |
$DOPTPRM PARAM1 VAL1    PARAM2  VAL2    PARAM3  VAL3    PARAM4  VAL4
DOPTPRM DESMAX  40      P1      1       P2      15      disbeg  13
```

1

Final Message in .f06

```
RUN TERMINATED DUE TO HARD CONVERGENCE TO AN OPTIMUM AT CYCLE NUMBER =      15.
AND SOFT FEASIBLE DISCRETE DESIGN OBTAINED
```

Objective



Normalized Constraints

+ Info