Workshop - Acoustic Optimization, Nastran BETA Function

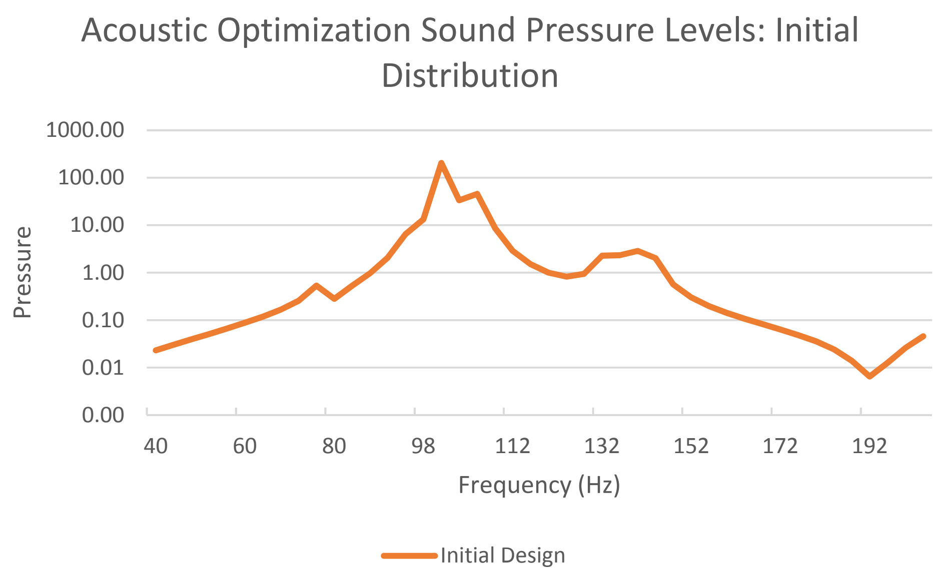
AN MSC NASTRAN SOL 200 TUTORIAL

Goal: Use Nastran SOL 200 Optimization

Minimize peak acoustic pressure without increasing the weight of the box

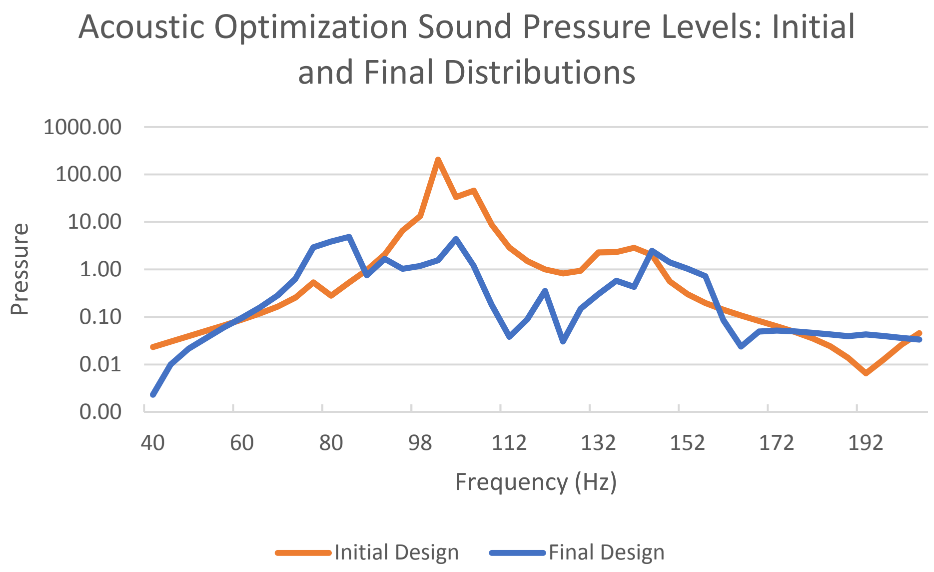
Before Optimization

- Weight: 2894



After Optimization

- Weight: 2910



MSC Nastran Design Sensitivity and Optimization User's Guide
Chapter 8 - Example Problems - Dynamic Response Optimization

Details of the structural model

Acoustic Optimization

Acoustic Optimization uses acoustic pressures as a design response. These are computed from a solution of the coupled fluid-structure interaction problem. An optimal design can thus be found based not only on a consideration of acoustic pressures, but structural responses as well.

This example considers a closed box with fluid elements on the interior. An acoustic source is located at one end of the box, with a transducer located at the opposite end. The design goal is to modify the thicknesses of the box walls such that the peak acoustic pressure at the transducer is minimized without increasing the weight of the box.

The box geometry and property groups of thicknesses to be modified are shown in Figure 8-29. Six design variables are to be related to six of these property groups (the third property group in Figure 8-29 remains fixed.) The model consists of 1000 structural elements and 2000 fluid elements.

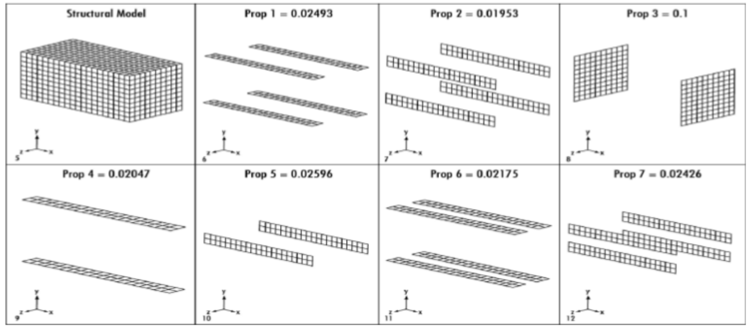
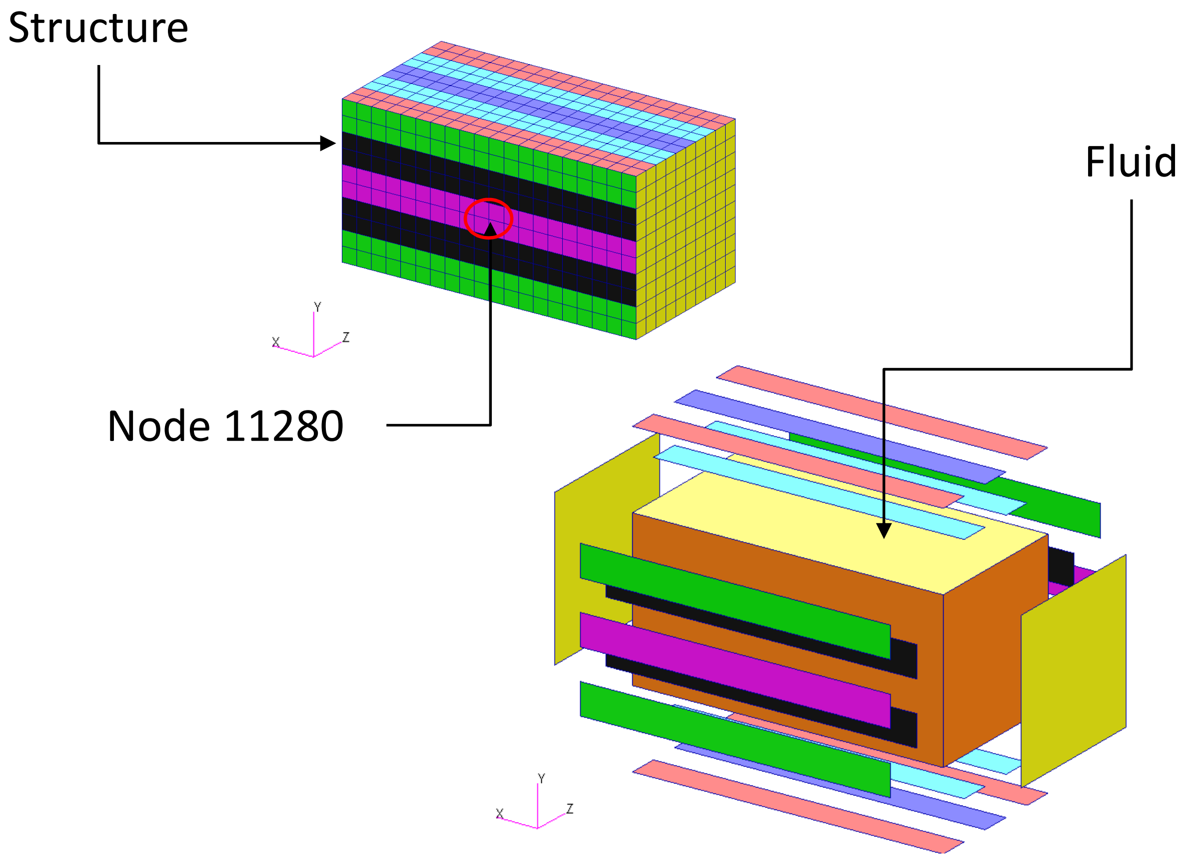


Figure 8-29 Acoustic Box Showing Portions Designed by Each Design Variable (Prop 3 is Fixed)

MSC Nastran Design Sensitivity and Optimization User's Guide
Chapter 8 - Example Problems - Acoustic Optimization



Optimization Problem Statement

Design Variables

x1: T of PSHELL 1
x2: T of PSHELL 2

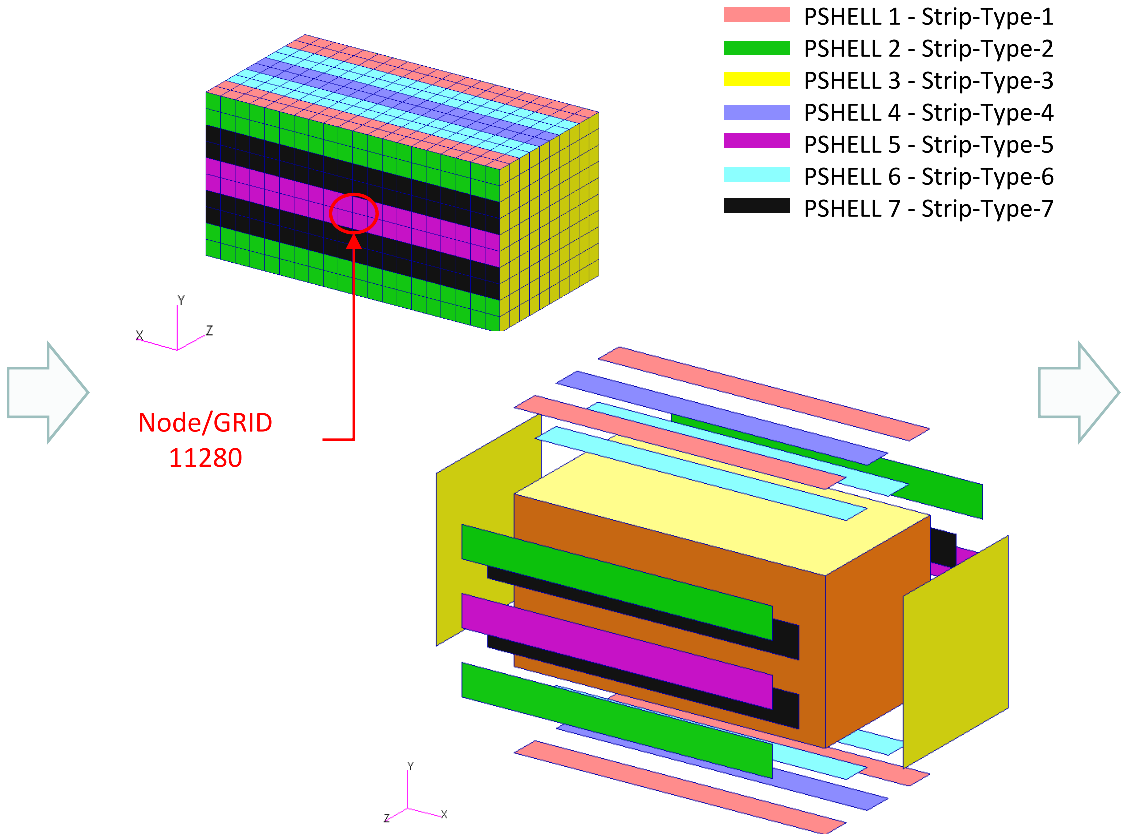
x4: T of PSHELL 4
x5: T of PSHELL 5
x6: T of PSHELL 6
x7: T of PSHELL 7

.001 < xi < 1.0

x_beta: Automatically generated by Nastran

x_beta, initial = 1.0

.001 < x_beta



Design Objective

R0: Minimize

C1 * x_beta

C1 = 1.0 (Default or if left blank)

Other Responses

b1: Pressure, x-component, at node 11280 across all forcing frequencies

Design Constraints

g: Automatically generated by Nastran

$$g = \frac{b1 - \gamma\, x_{beta}}{C3} \leq 0$$

γ is determined from the following expression. Refer to MSC Nastran manual for details regarding Beta Function and C1, C2 and C3.

$$g_{max} = \frac{b_{max} - \gamma\, x_{beta}}{C3} = C2$$

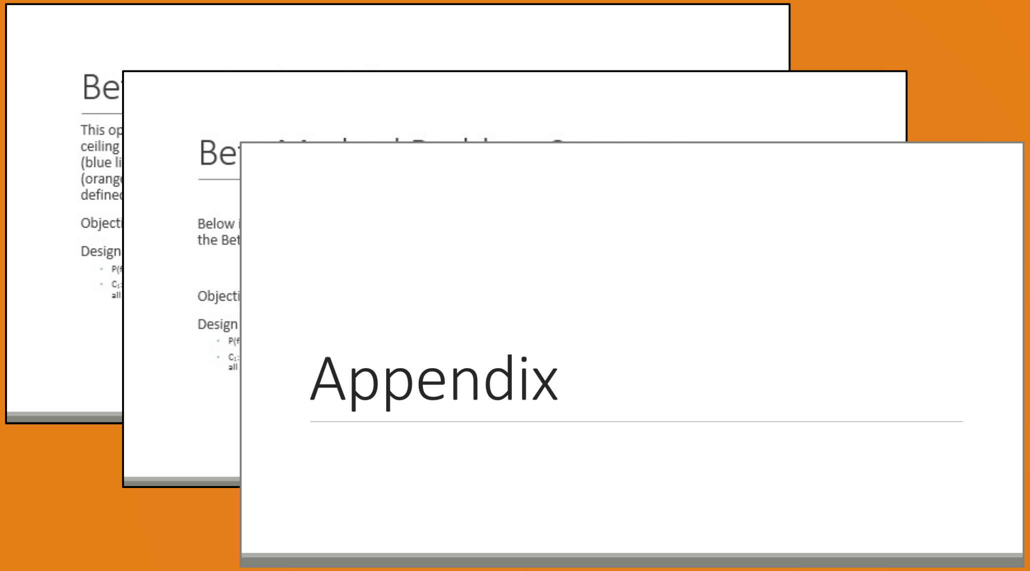
r1: Weight

2890. < r1 < 2910.

More Information Available in the Appendix

The Appendix includes information regarding the following:

- Frequently Asked Questions
  - Beta Method Problem Statement
    - Response Minimization
    - Response Maximization



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

Special Topics Covered

The BETA Function for Acoustic Optimization - MSC Nastran includes a capability known as the BETA function that reduces the work necessary to configure an Acoustic Optimization. This tutorial details how to use the BETA function for MSC Nastran SOL 200, which minimizes the work needed to define design variables, objective and constraints.

Minimize $\phi = C1\, X_\beta$

Subject to $g = \frac{\gamma X_\beta - r_j}{C3} \geq 0$

SOL 200 Web App Capabilities

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

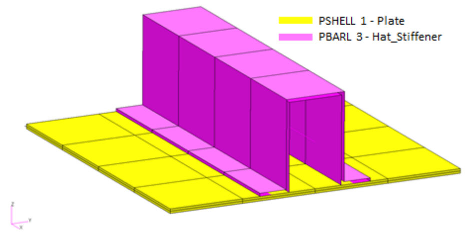
Compatibility

- 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.

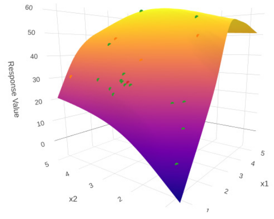
Benefits

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

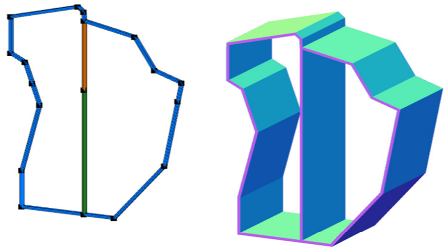
Web Apps



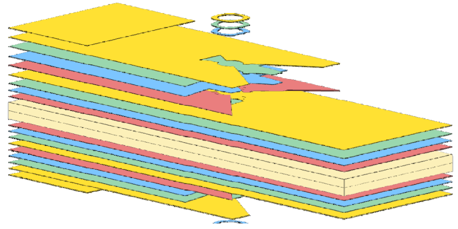
Web Apps for MSC Nastran SOL 200
Pre/post for MSC Nastran SOL 200. Support for size, topology, topometry, topography, multi-model optimization.



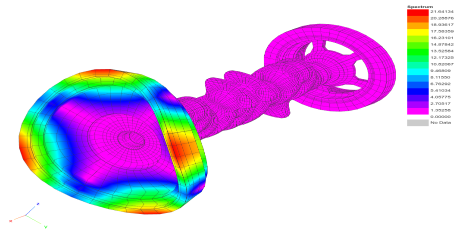
Machine Learning Web App
Bayesian Optimization for nonlinear response optimization (SOL 400)



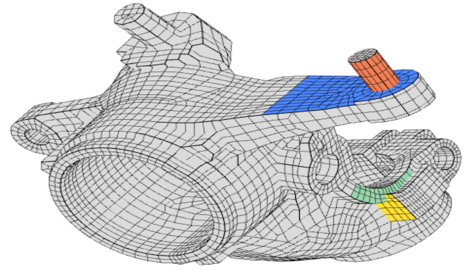
PBMSECT Web App
Generate PBMSECT and PBRSECT entries graphically



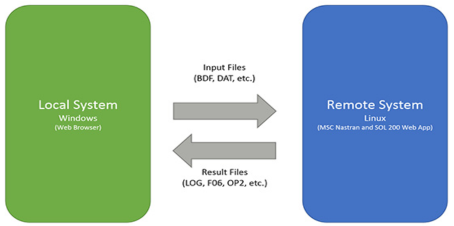
Ply Shape Optimization Web App
Optimize composite ply drop-off locations, and generate new PCOMPG entries



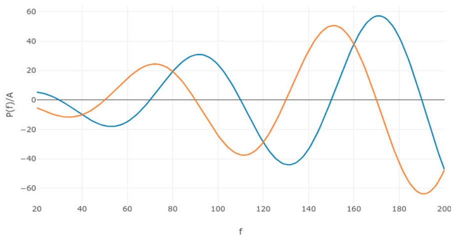
Post-processor Web App
View MSC Nastran results in a web browser on Windows and Linux



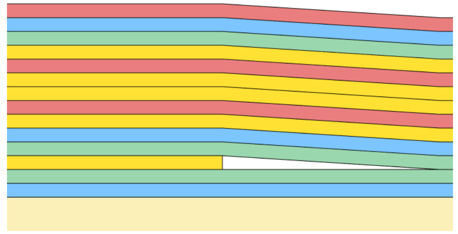
Shape Optimization Web App
Use a web application to configure and perform shape optimization.



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

Note before starting

This example was previously done, but in this version of the tutorial, the *BETA function* will be used. Below is a comparison of the steps involved. When the BETA function is used, Nastran will automatically generate the design variable x8, the Equation Objective and necessary Equation Constraints.

Original Steps

1. Create design variables x1, x2, x4, … x7
2. Create design variable x8
3. Create Equation Objective R0
4. Create Constraints r1
5. Create Equation Constraint R1
   1. Create supporting response b1
6. Create Constrain Group 1
7. Create Constraint Group 2

Steps with the BETA function

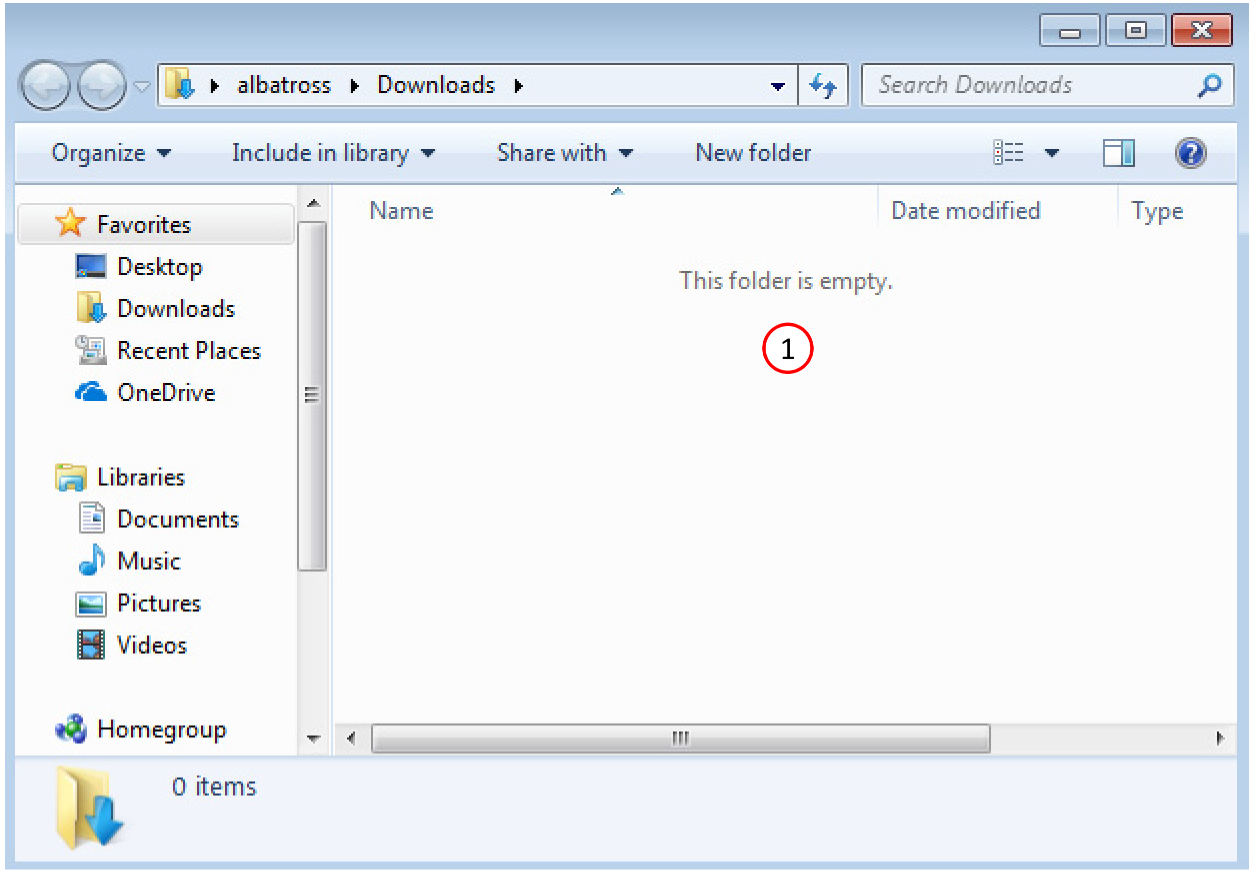
1. Create design variables x1, x2, x4, … x7
2. ~~Create design variable x8~~
3. Create Equation Objective R0 using the BETA function
4. Create Constraints r1
5. ~~Create Equation Constraint R1~~
   1. ~~Create supporting response b1~~
6. Create Constrain Group 1
7. ~~Create Constraint Group 2~~

The BETA function will trigger Nastran to automatically create the items that are crossed out

Before Starting

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

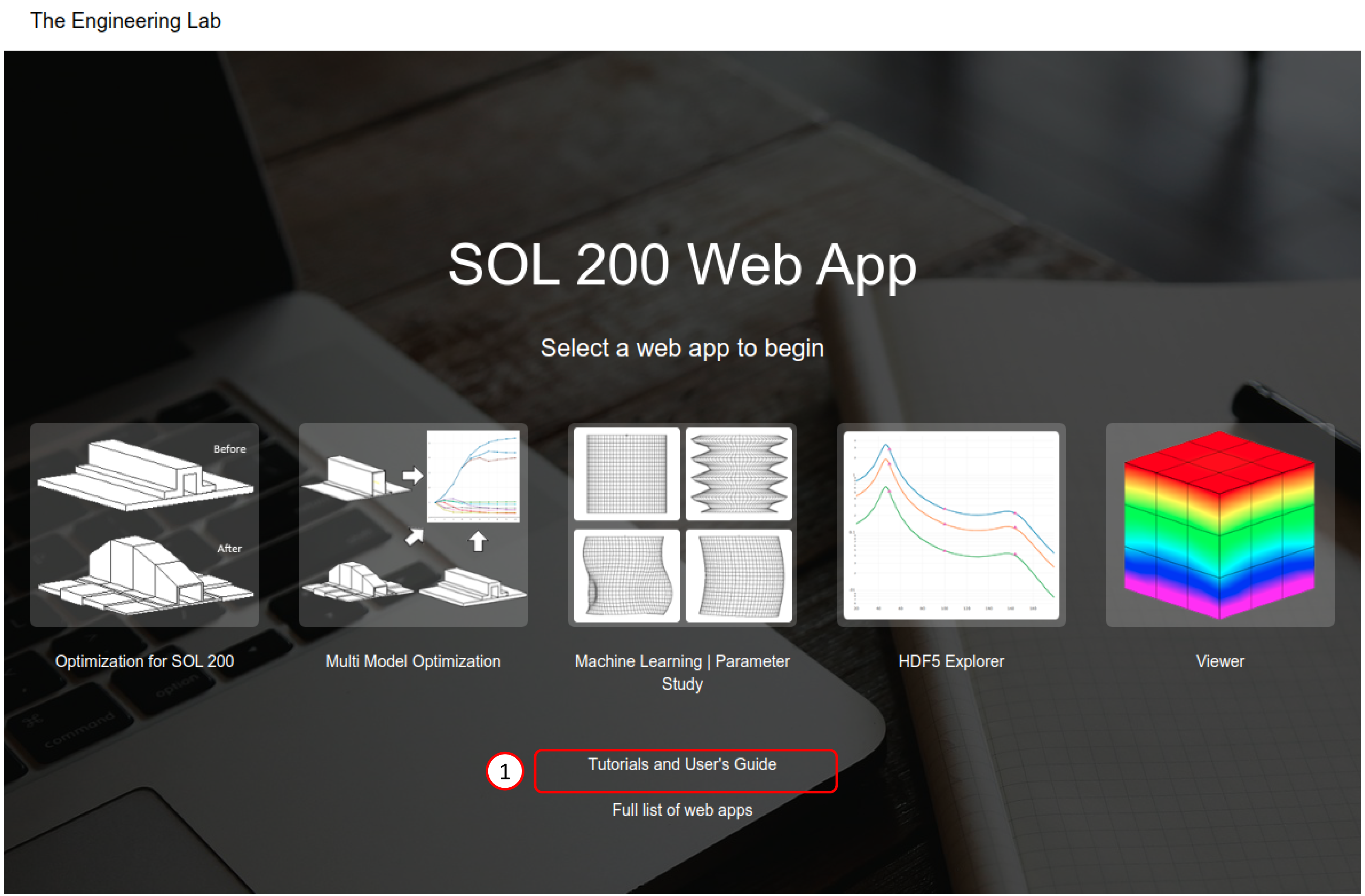
- Throughout this workshop, you will be working with multiple file types and directories such as:
    - .bdf/.dat
    - nastran_working_directory
    - .f06, .log, .pch, .h5, etc.
- To minimize confusion with files and folders, it is encouraged to start with a clean directory.



Go to the User's Guide

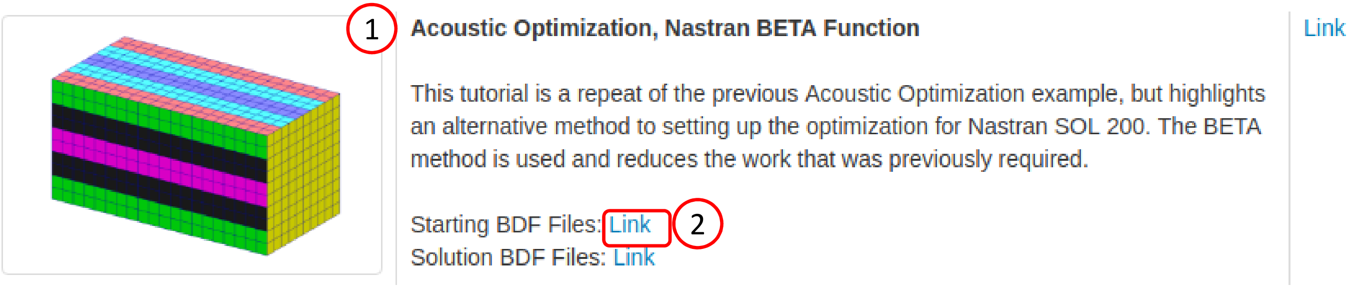
1. Click on the indicated link

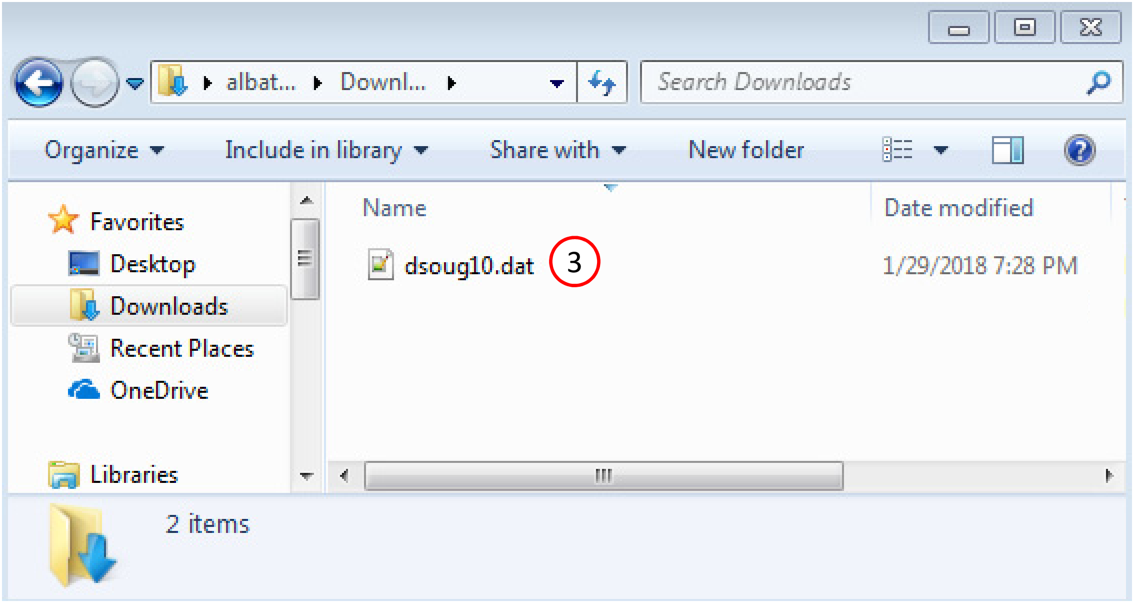
- The necessary BDF files for this tutorial are available in the Tutorials section of the User's Guide.



Obtain Starting Files

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



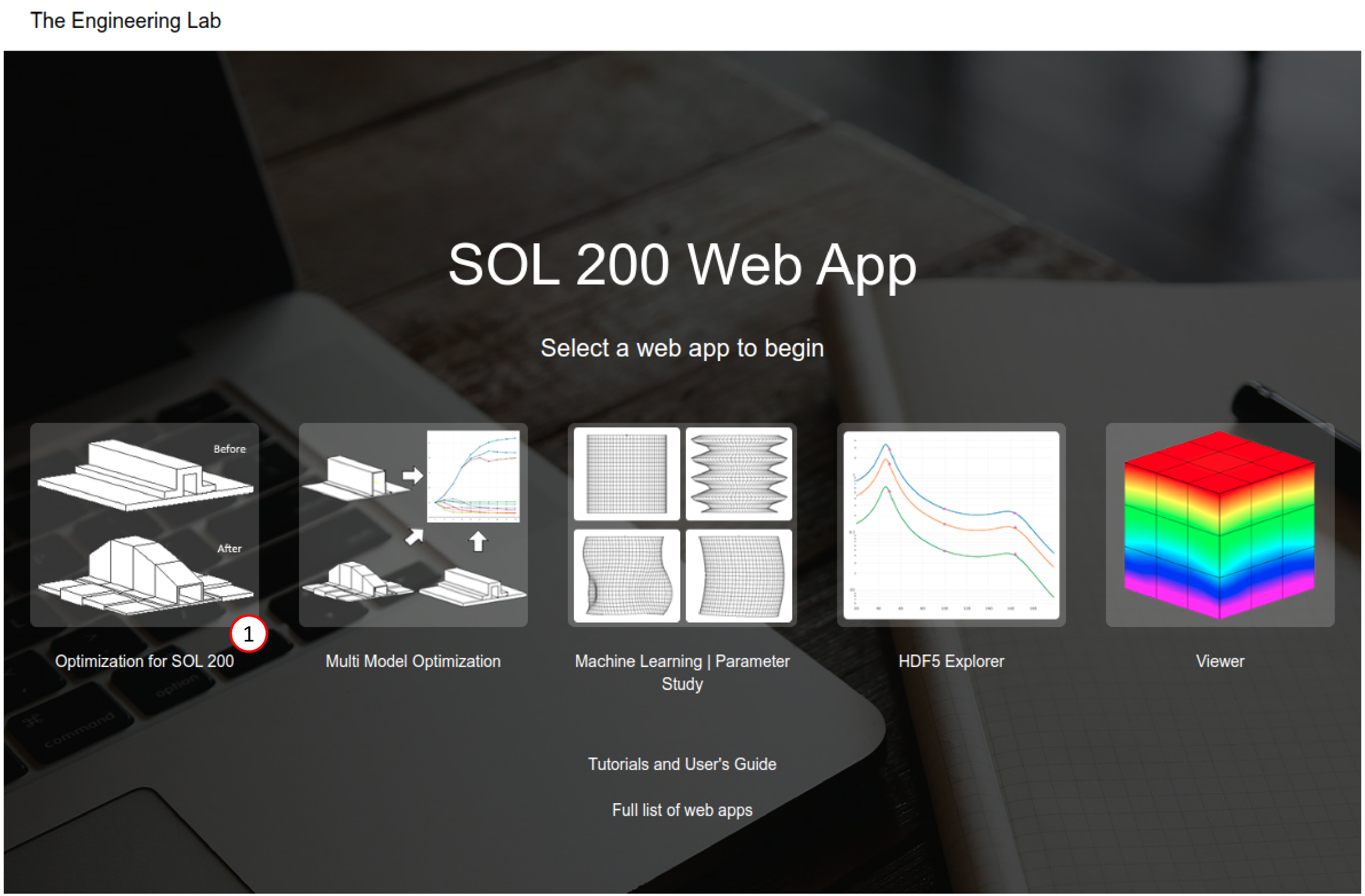


- When starting the procedure, all the necessary BDF files must be collected together.

Open the Correct Page

1. Click on the indicated link

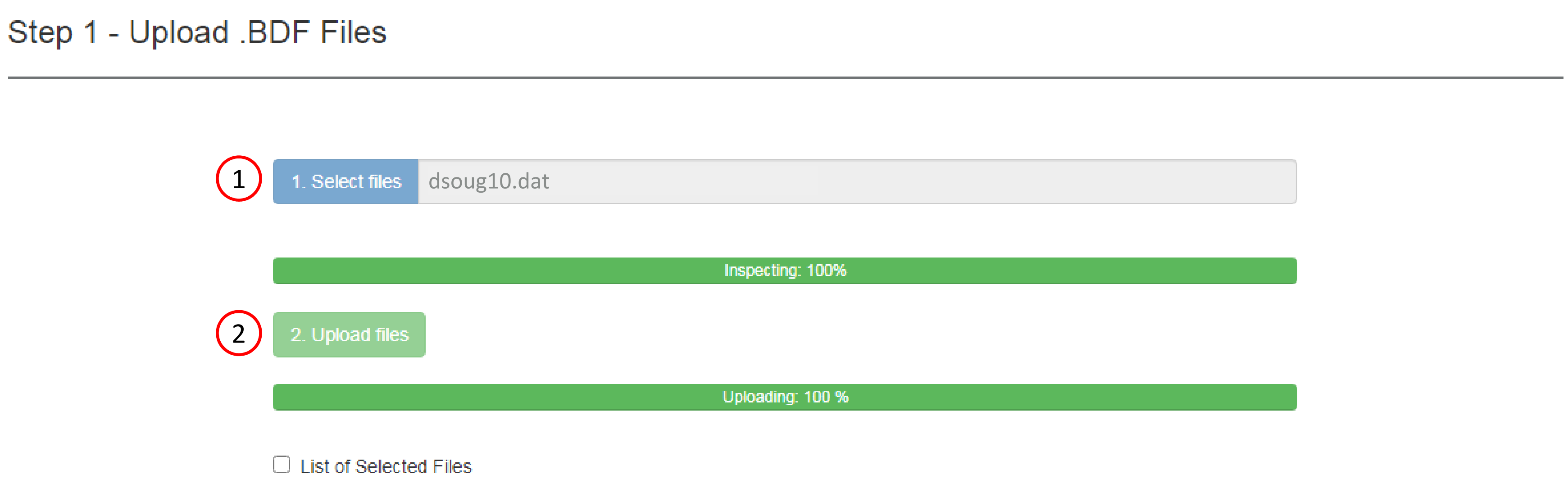
- MSC Nastran can perform many optimization types. The SOL 200 Web App includes dedicated web apps for the following:
    - Optimization for SOL 200 (Size, Topology, Topometry, Topography, Local Optimization, Sensitivity Analysis and Global Optimization)
    - Multi Model Optimization
    - Machine Learning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



Upload BDF Files

1. Click 1. Select Files and select dsoug10.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.

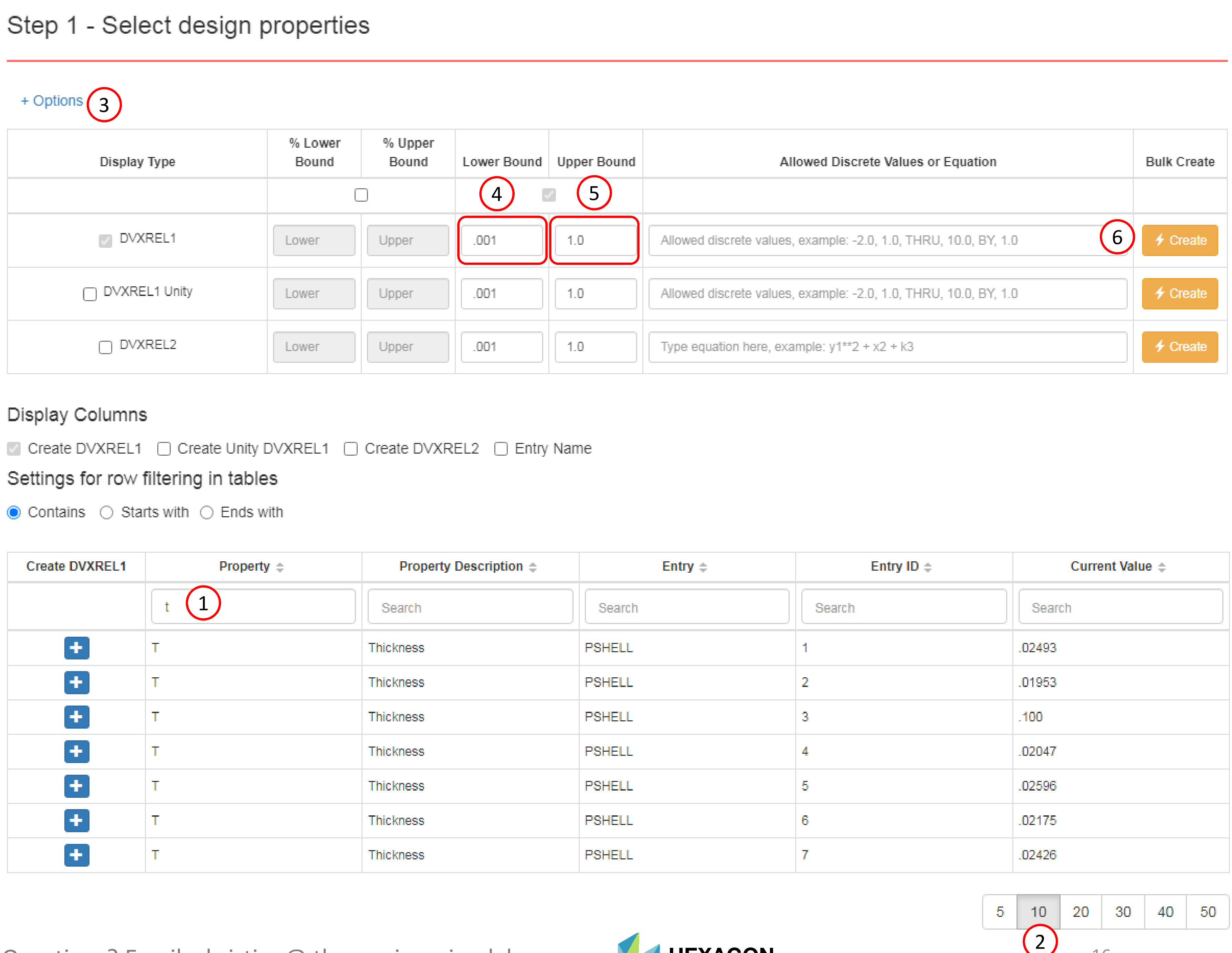


Create Design Variables

1. In the search box, type 't'
2. Click 10 on the page bar
3. Click + Options
4. Set the lower bound to .001
5. Set the upper bound to 1.0
6. Click Create

This will set all visible properties as design variables

- There are 2 methods to create the 7 design variables: Click each blue plus icon, which requires 7 mouse clicks, OR click the yellow Create icon, which requires 1 mouse click.
- 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.



Create Design Variables

1. Click on 10 as shown to display all design variables
2. Delete design variable x3 by clicking the x icon

- In some instances, the optimizer will vary a positive design variable and make it negative, e.g. a thickness of .08 becomes -.01 in a weight minimization optimization. Certain properties, such as thickness or beam cross sections should never be negative. The lower bound in this example is set to .001 to avoid a negative variable during the optimization.

Step 2 - Adjust design variables

✖ Delete Visible Rows

+ Options

	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
✖	x1	✔	T	Thickness	PSHELL	1	.02493	.001	1.0	Examples: -2.0, 1.0, THRU, 10.0,
✖	x2	✔	T	Thickness	PSHELL	2	.01953	.001	1.0	Examples: -2.0, 1.0, THRU, 10.0,
2 ✖	~~x3~~	~~✔~~	~~T~~	~~Thickness~~	~~PSHELL~~	~~3~~	~~.100~~	~~.001~~	~~1.0~~	Examples: -2.0, 1.0, THRU, 10.0,
✖	x4	✔	T	Thickness	PSHELL	4	.02047	.001	1.0	Examples: -2.0, 1.0, THRU, 10.0,
✖	x5	✔	T	Thickness	PSHELL	5	.02596	.001	1.0	Examples: -2.0, 1.0, THRU, 10.0,
✖	x6	✔	T	Thickness	PSHELL	6	.02175	.001	1.0	Examples: -2.0, 1.0, THRU, 10.0,
✖	x7	✔	T	Thickness	PSHELL	7	.02426	.001	1.0	Examples: -2.0, 1.0, THRU, 10.0,

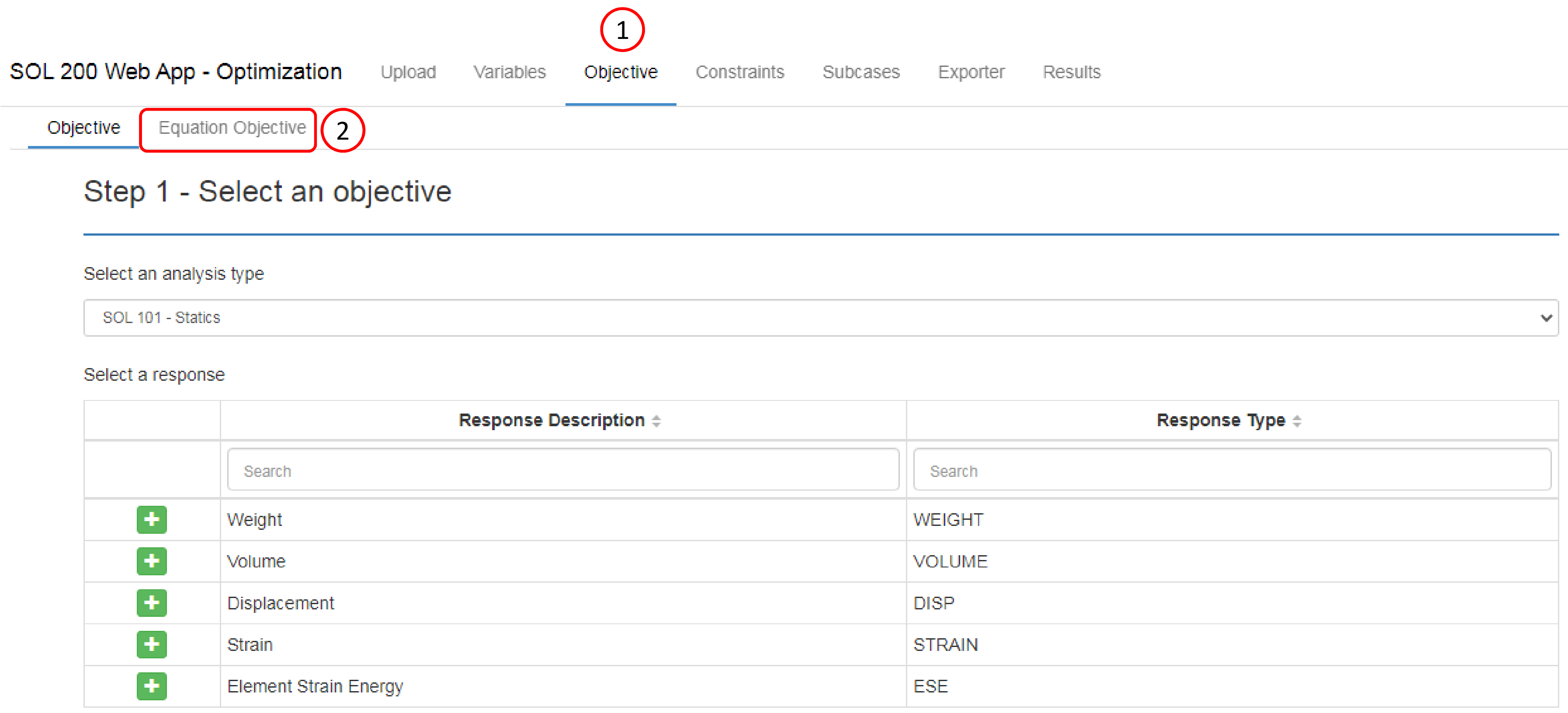
5 | 10 | 20 | 30 | 40 | 50

1

Create Design Objective

1. Click on Objective
2. Click on Equation Objective

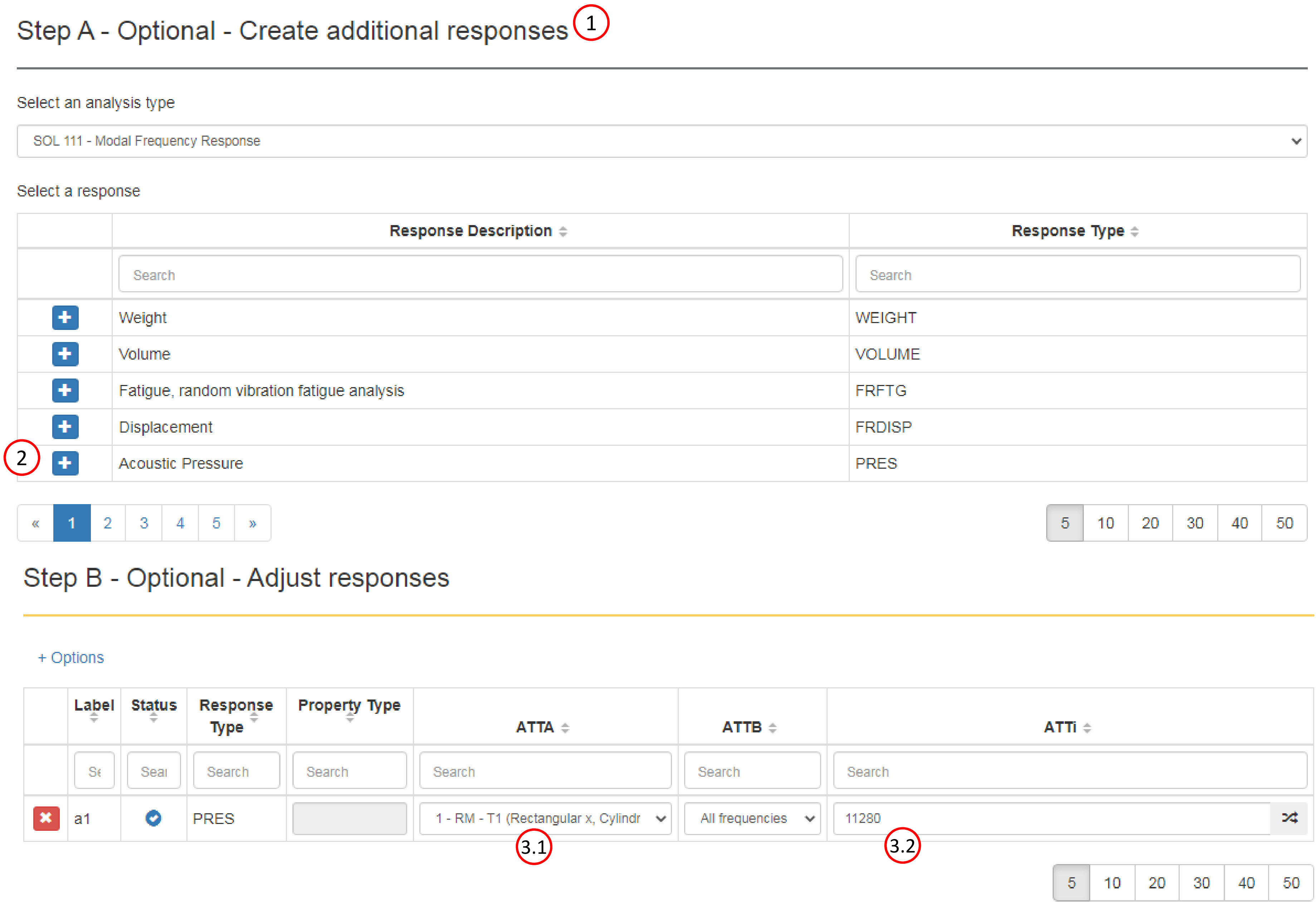
- There are 2 methods of setting an objective.
    - Method 1 – Select a objective from a given list of responses, e.g. Weight, Volume, etc.
    - Method 2 – Create an equation.
- This example uses Method 2 for the objective.



Create Design Objective

1. Scroll to Step A – Optional - Create additional responses
2. Click the plus (+) icon for Acoustic Pressure
3. Configure the following for a1
   1. ATTA: 1 - RM - T1 (Rectangular …
   2. ATTi: 11280 (node 11280)

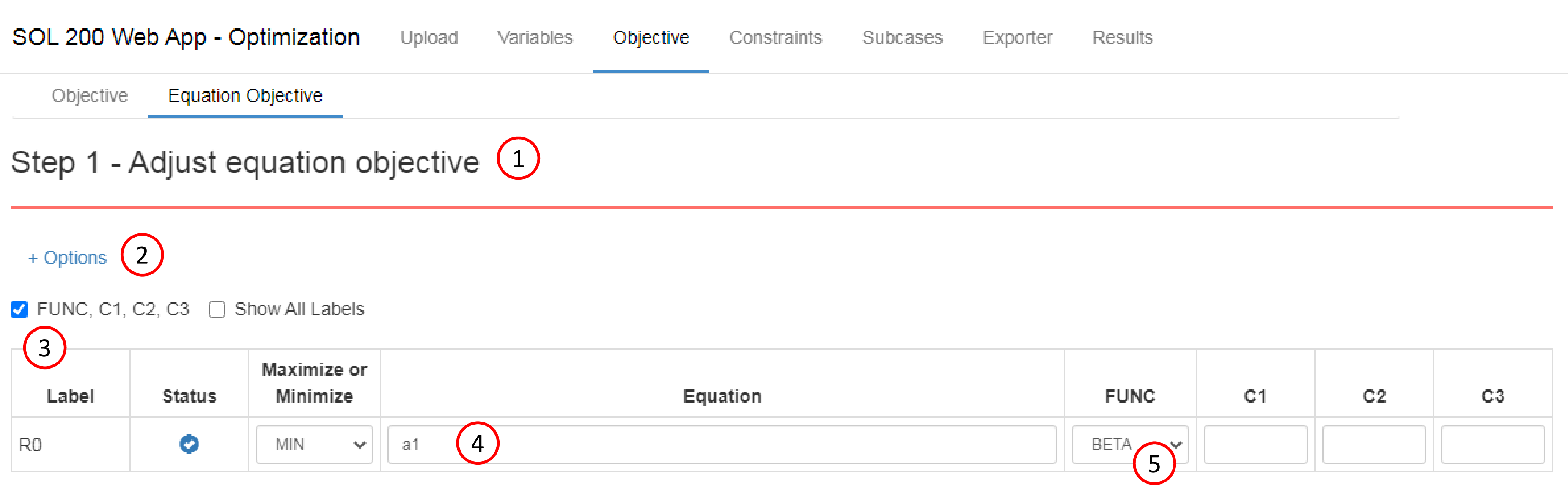
- The label a1 represents the pressure at each forcing frequency for grid 11280. There are 44 forcing frequencies, so a1 represents 44 acoustic pressures.



Create Design Objective

1. Scroll to section Step 1 - Adjust equation objective
2. Click + Options
3. Mark the checkbox for FUNC, METHOD, C1, C2, C3
4. Type in a1
5. Set the FUNC as BETA

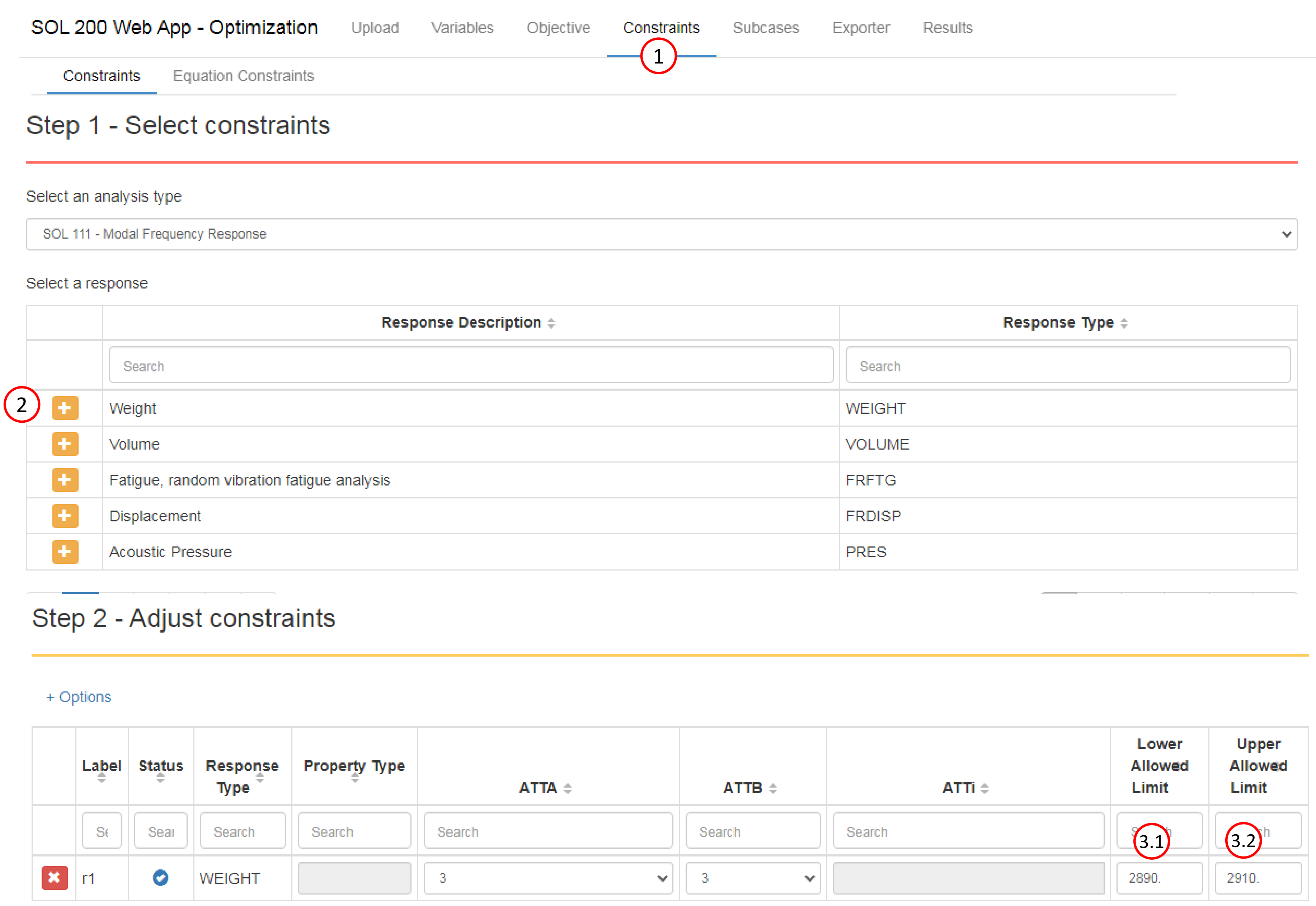
- Traditionally, the Beta Method requires the explicit creation of an Equation Objective, e.g. R0 = 250. * y0, and an Equation Constraints, e.g. R1 = 250. * y0 - b1 + 100. When the FUNC=BETA option is used, MSC Nastran automatically generates the Equation Objective and Equation Constraint internally.



Create Design Constraints

1. Click Constraints
2. Click the plus (+) icon for Weight
3. Configure the following for constraint r1
    1. Lower Allowed Limit: 2890.
    2. Upper Allowed Limit: 2910.

- For some optimization scenarios, the weight is allowed to vary only a small amount. For this example, the weight is only allowed to vary +/-10 relative to the original values of 2900. This is achieved by setting the lower bound to 2890 and the upper bound to 2910.

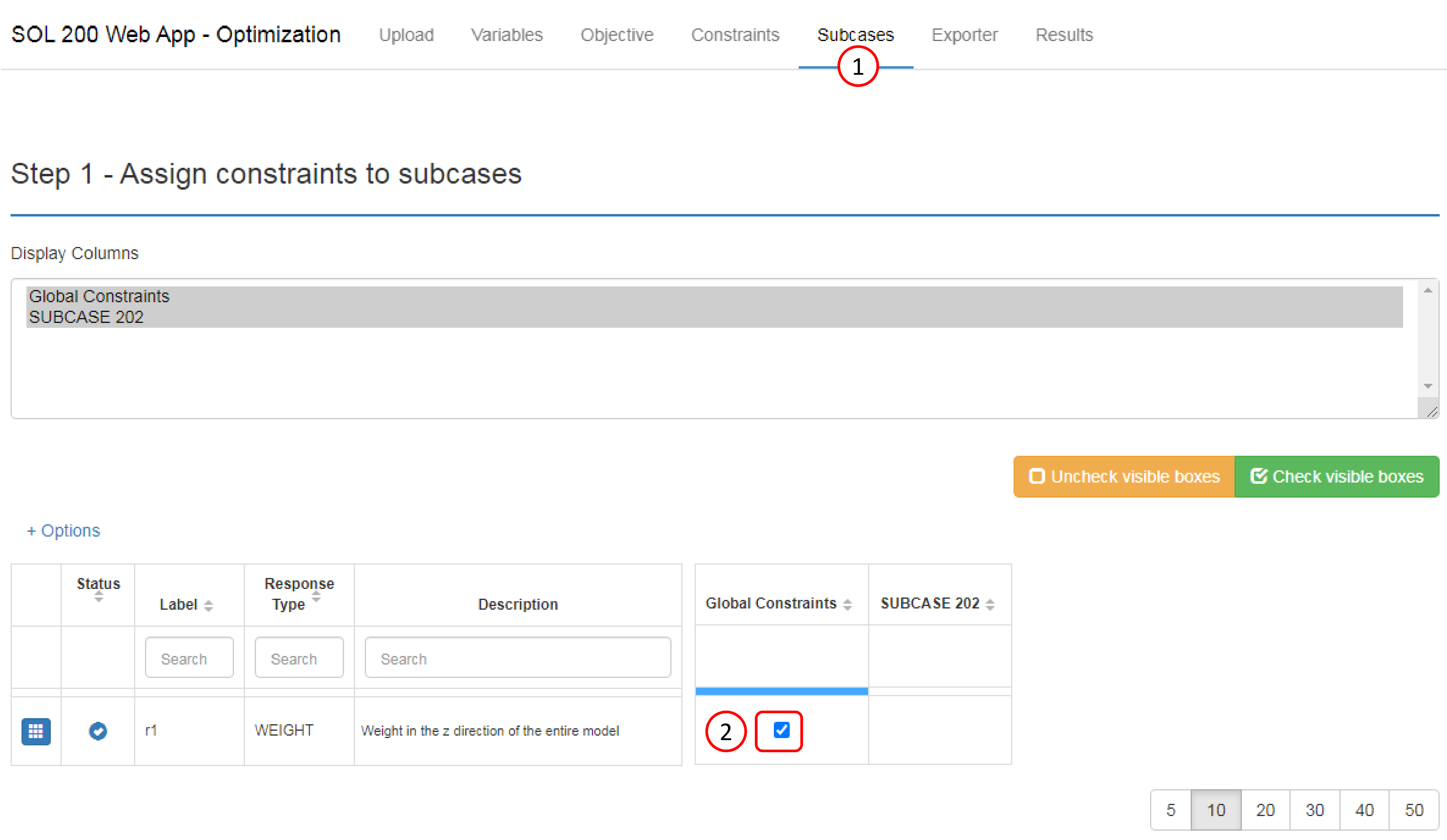


Assign Constraints to Load Cases (SUBCASES)

1. Click Subcases
2. Mark the checkbox

r1 or the Volume is applied as a Global Constraint

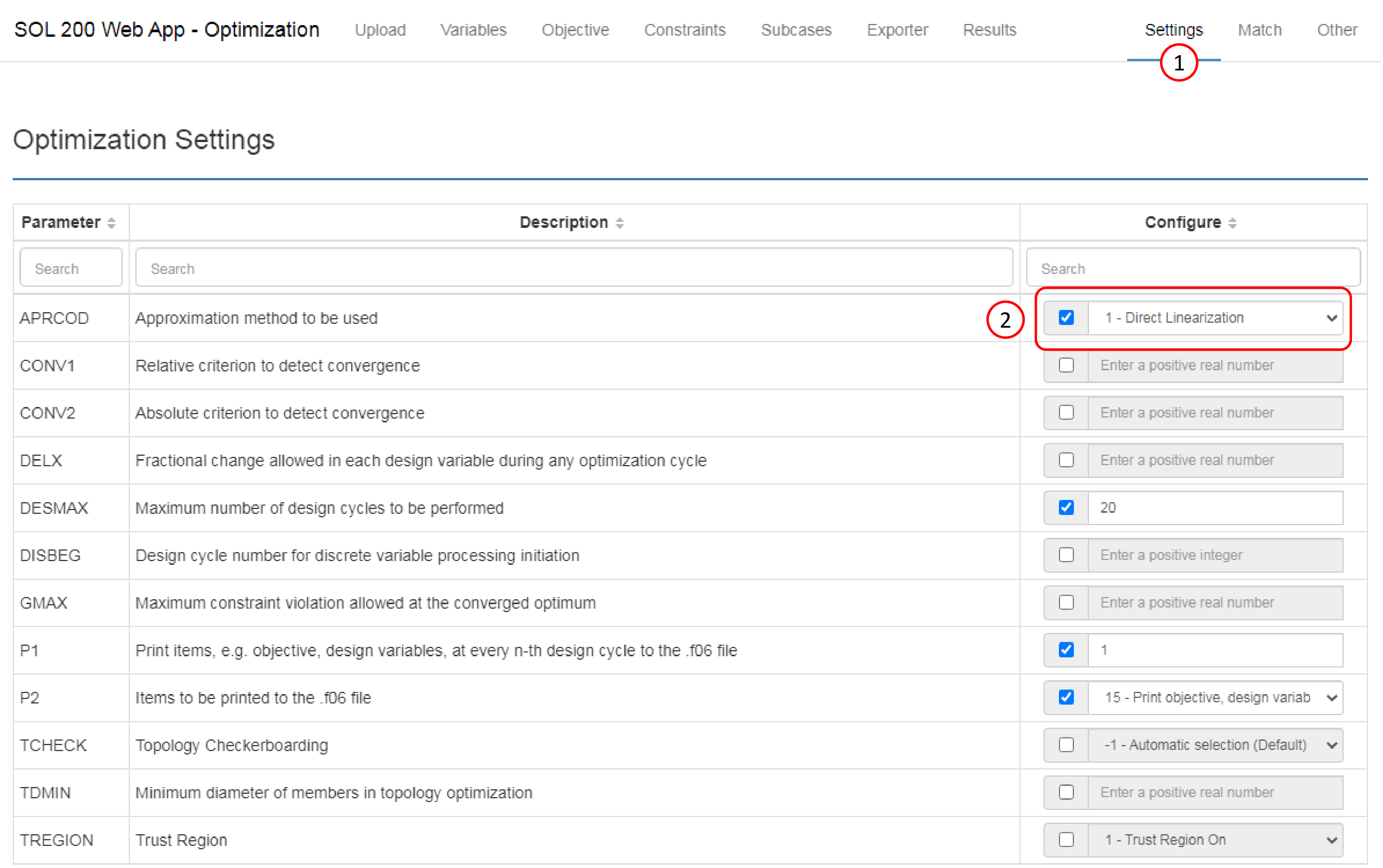
- There are 2 types of responses: Global and Subcase Dependent responses. Global responses are the same regardless of subcase and examples include volume, weight, etc. Subcase Dependent responses vary across subcases. For example, stress or strain will vary from subcase to subcase.
- In this example, weight is a global response, therefore, the weight constraint is assigned as a Global Constraint.



Configure Settings

1. At the top right hand corner, click on Settings

2. Ensure the following checkboxes are marked and the respective values match as shown in the image to the right

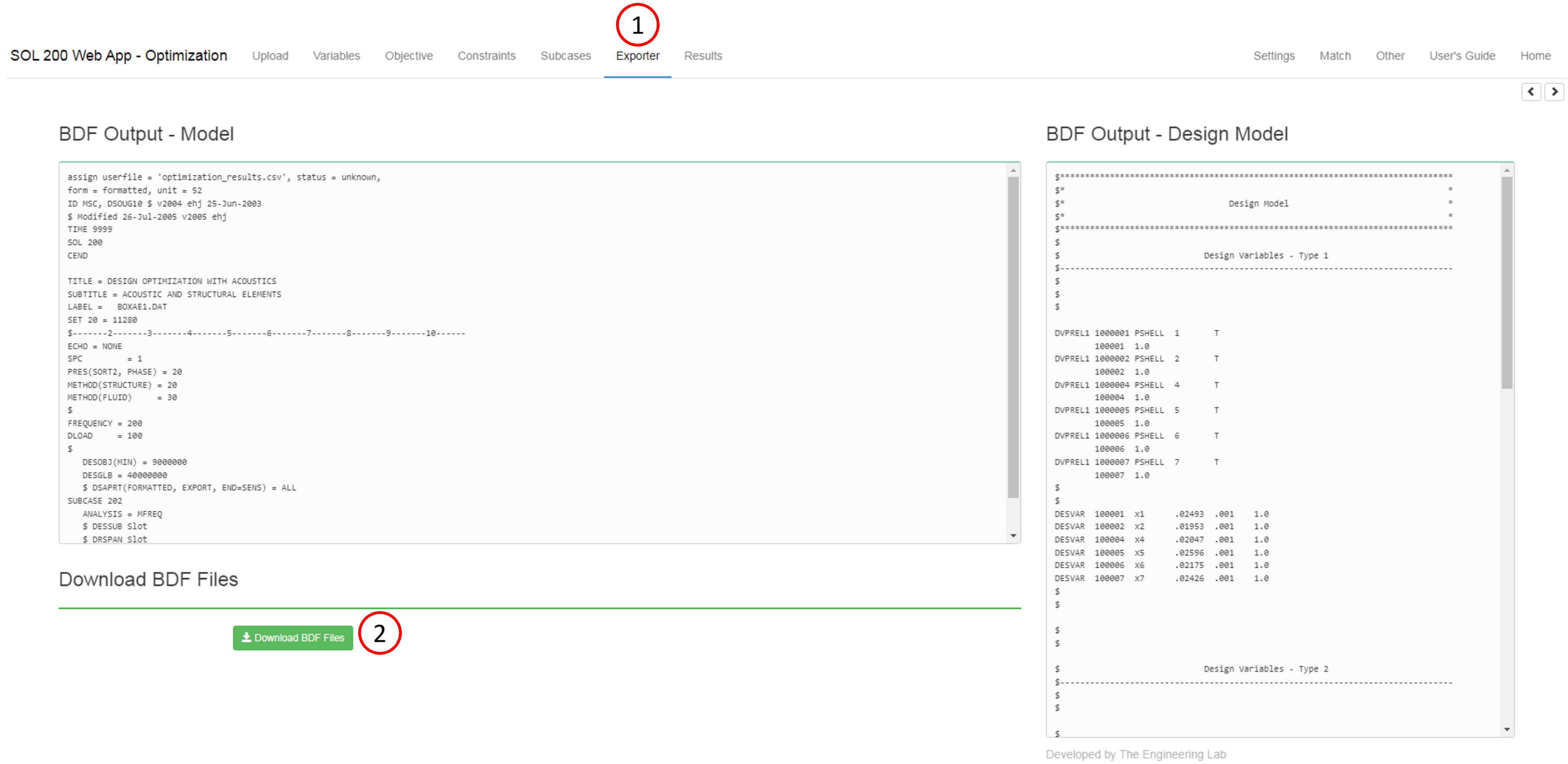


Parameter	Description	Configure
APRCOD	Approximation method to be used	☑ 1 - Direct Linearization
CONV1	Relative criterion to detect convergence	☐ Enter a positive real number
CONV2	Absolute criterion to detect convergence	☐ Enter a positive real number
DELX	Fractional change allowed in each design variable 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	☑ 15 - Print objective, design variab
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

- When APRCOD=2, the optimization converges in 29 design cycles. When APRCOD=1, the optimization converges in 11 design cycles. APRCOD=1 is used since the optimization converges in fewer design cycles.
- Per the MSC Nastran Design Sensitivity and Optimization User's Guide, the Direct Linearization method for Approximation is often useful for dynamic response optimization.

Export New BDF Files

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

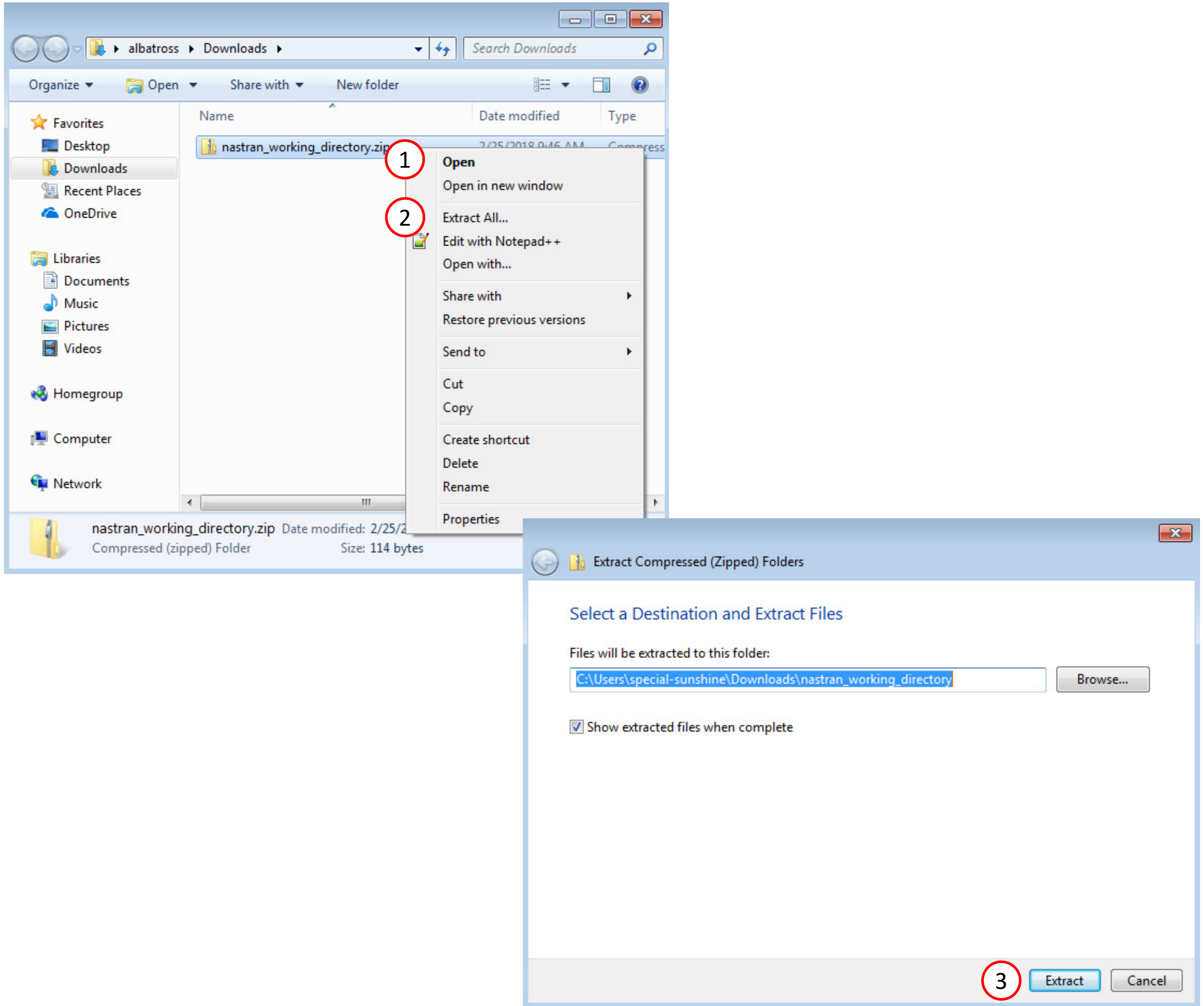


- When the download button is clicked a new file named “nastran_working_directory” is downloaded. If the file already exists in your local folder, the folder name is appended with a number, e.g. “nastran_working_directory (1).zip”

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

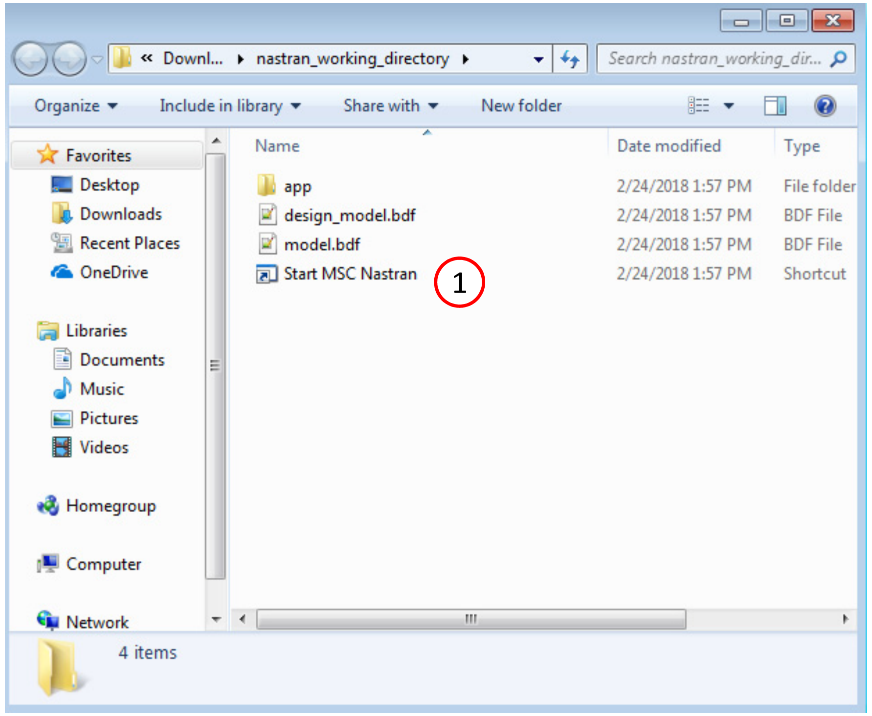
- After a successful optimization, the results will be automatically displayed as long as the following files are present: BDF, F06 and LOG.
- One can run the Nastran job on a remote machine as follows:
  1) Copy the BDF files and the INCLUDE files to a remote machine. 2) Run the MSC Nastran job on the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

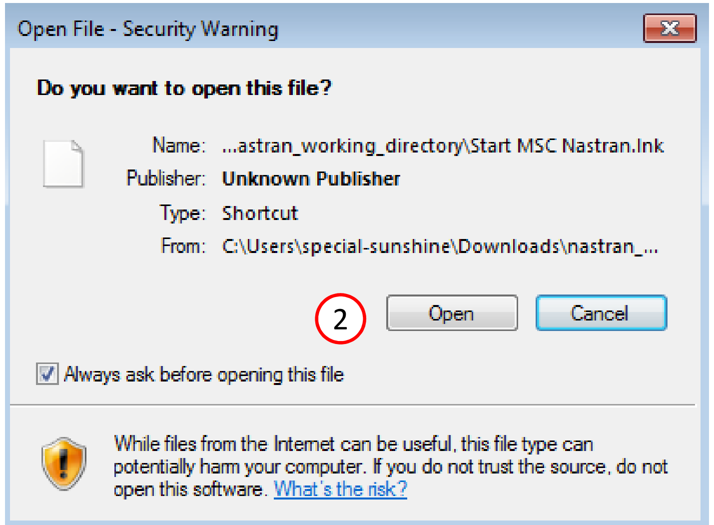
Using Linux?

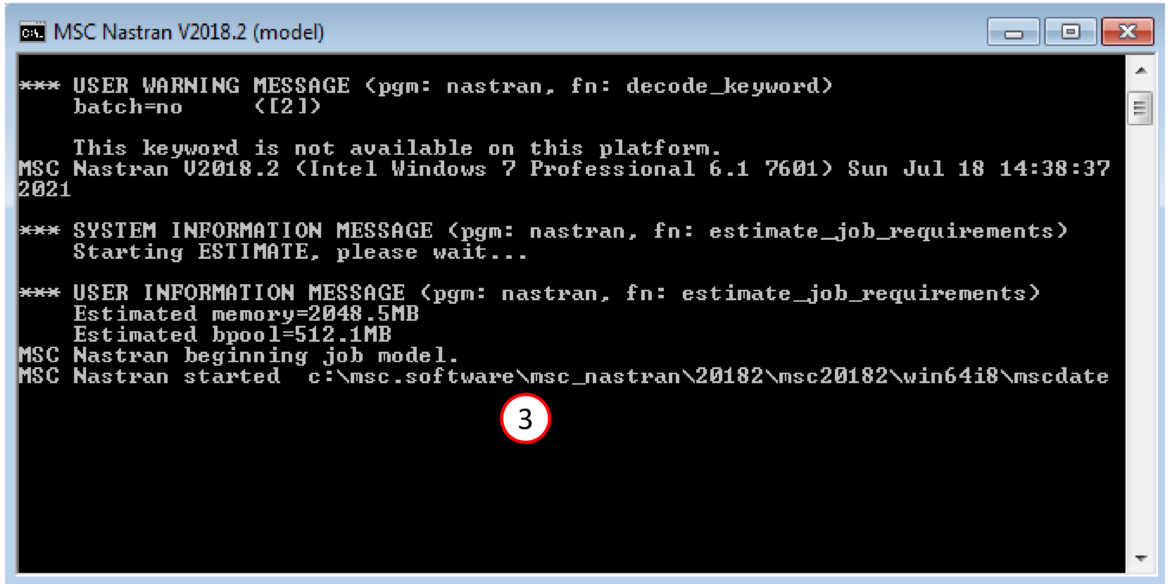
Follow these instructions:
1) Open Terminal
2) Navigate to the nastran_working_directory
   cd ./nastran_working_directory
3) Use this command to start the process
   ./Start_MSC_Nastran.sh

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.

- After an optimization, the results will be automatically displayed as long as the following files are present: BDF, F06 and LOG.
- Note that as the objective is minimized the peaks of the pressure response are being minimized across each forcing frequency.

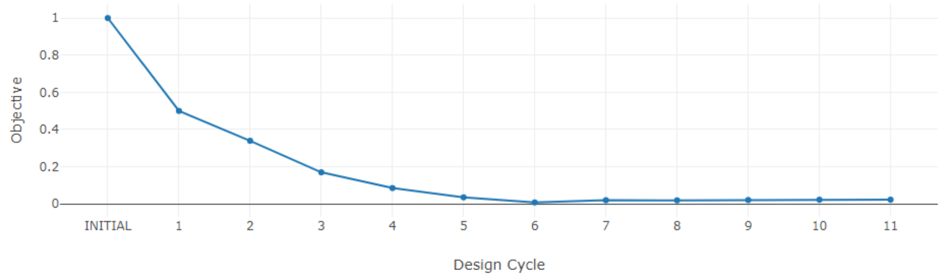
SOL 200 Web App - Local Optimization Results   Home

Final Message in .f06

1

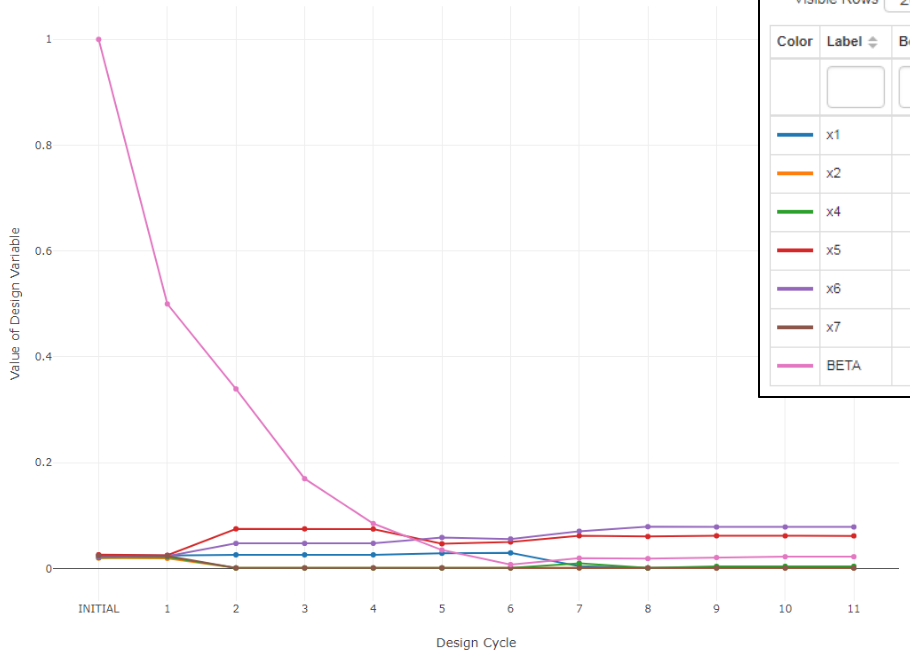
RUN TERMINATED DUE TO HARD CONVERGENCE TO AN OPTIMUM AT CYCLE NUMBER =   11.

Objective



2

Design Variables



Visible Rows 20 | Reset view | Un-bookmark | Bookmark

Color	Label	Bookmark	Label Comments
		—	
	x1		T, Thickness, of PSHELL 1 (Strip-Type-1)
	x2		T, Thickness, of PSHELL 2 (Strip-Type-2)
	x4		T, Thickness, of PSHELL 4 (Strip-Type-4)
	x5		T, Thickness, of PSHELL 5 (Strip-Type-5)
	x6		T, Thickness, of PSHELL 6 (Strip-Type-6)
	x7		T, Thickness, of PSHELL 7 (Strip-Type-7)
	BETA		

Review Dynamic Results

1. If “Start MSC Nastran“ is used and MSC Nastran 2016 or newer is used, the HDF5 Explorer will be opened and a plot will automatically be created.
2. The Plots Browser contains a list of the plots that have been created
3. Click the indicated image

- Use the navigation bar at the top of the web app to navigate between the following sections
    - Acquire Dataset
    - Plots Browser
    - Combine Plots
    - Last Plot Added

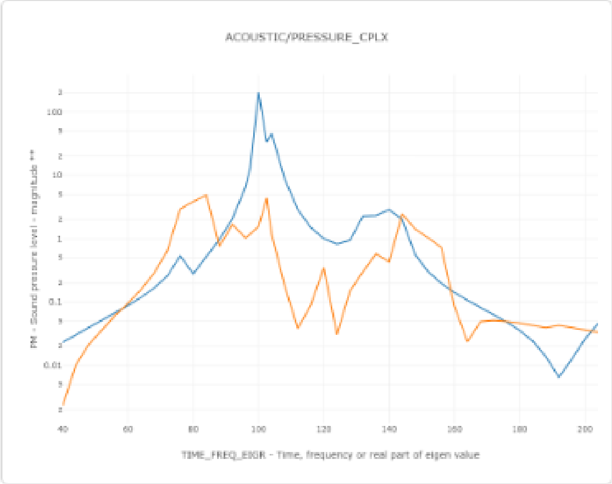
1

SOL 200 Web App - HDF5 Explorer   Acquire Dataset   Plots Browser   Combine Plots   Last Plot Added

Plots Browser

2

ACOUSTIC/PRESSURE_CPLX

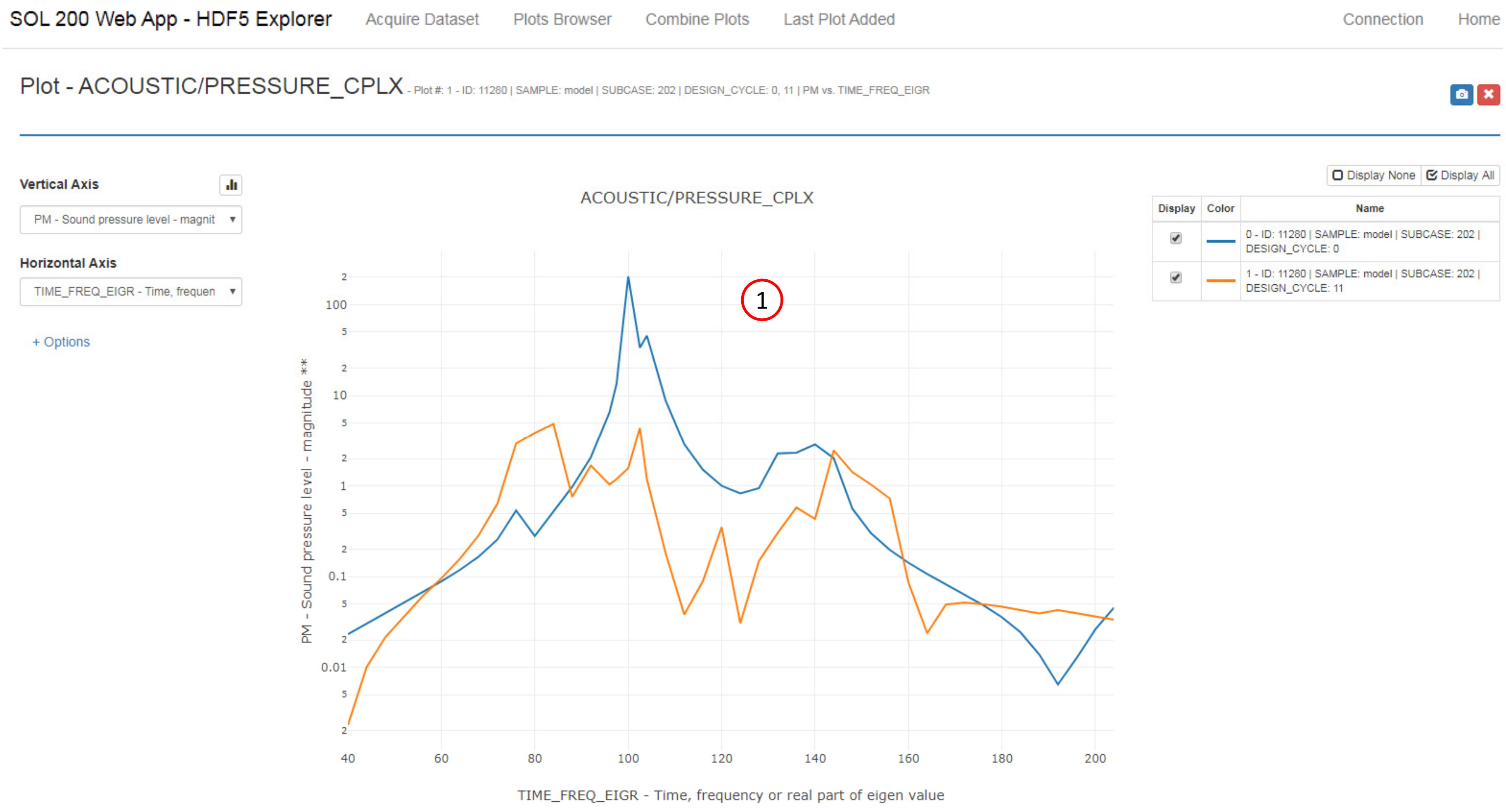


Plot #: 1 - ID: 11280 | SAMPLE: model | SUBCASE: 202 | DESIGN_CYCLE: 0, 11 | PM vs. TIME_FREQ_EIGR

3

Review Dynamic Results

1. The plot contains the INITIAL and FINAL values of the dynamic response.

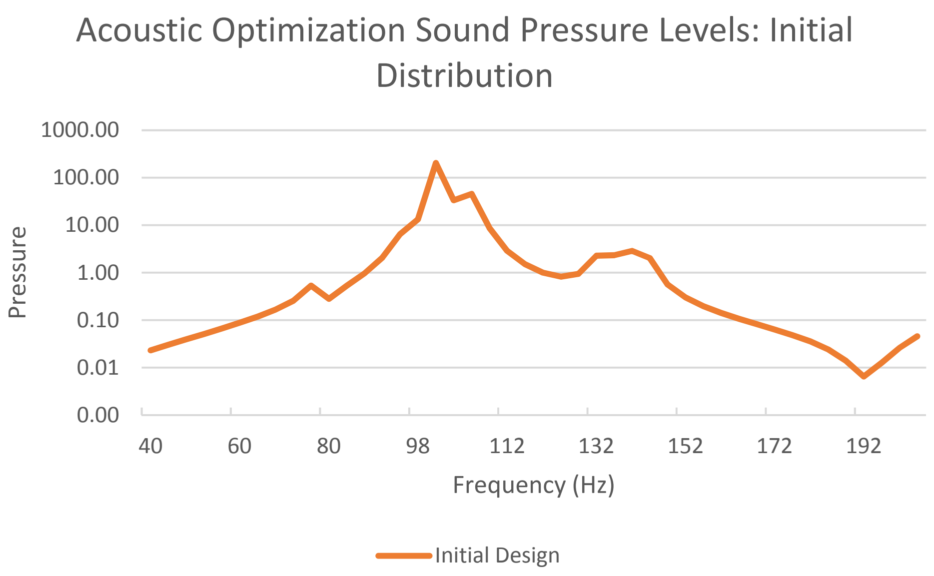


- From the plot, the FINAL pressure curve in orange is lower than the INITIAL pressure curve in blue. The optimization was successful.

Results

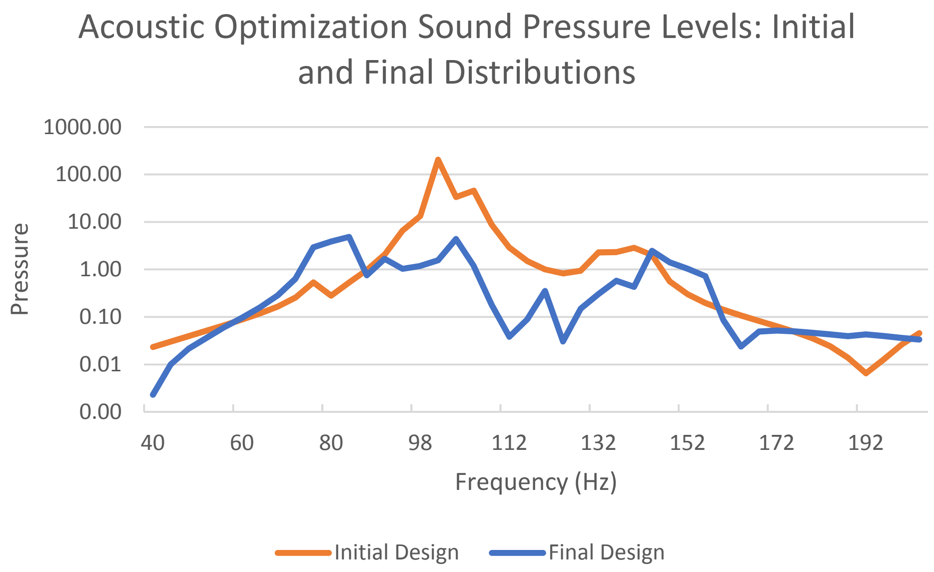
Before Optimization

- Weight: 2894



After Optimization

- Weight: 2910

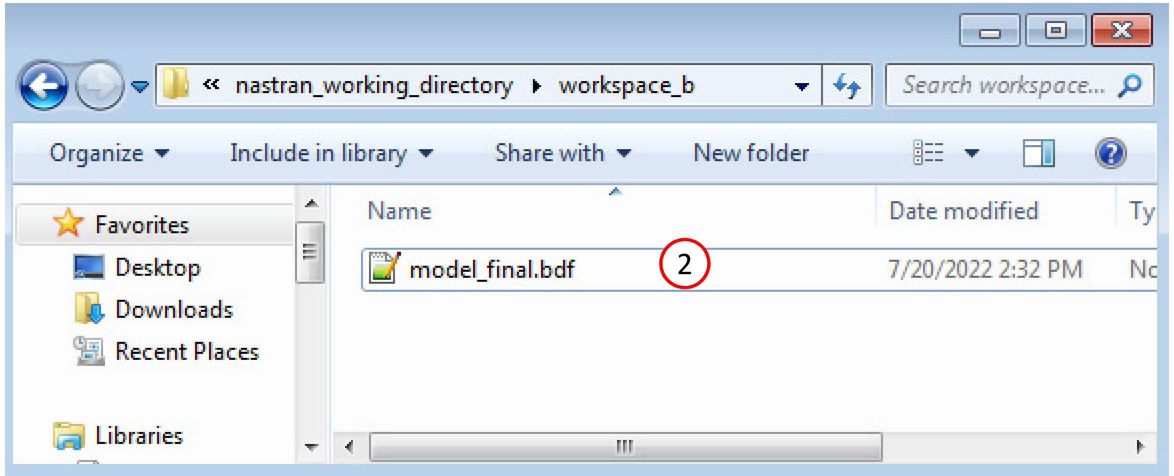


MSC Nastran Design Sensitivity and Optimization User's Guide
Chapter 8 - Example Problems - Dynamic Response Optimization

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

1

```
PSHELL  1       1       .02493  1
$ Elements and Element Properties for region : Strip-Type-2
PSHELL  2       1       .01953  1
$ Elements and Element Properties for region : Strip-Type-3
PSHELL  3       1       .100    1
$ Elements and Element Properties for region : Strip-Type-4
PSHELL  4       1       .02047  1
$ Elements and Element Properties for region : Strip-Type-5
PSHELL  5       1       .02596  1
$ Elements and Element Properties for region : Strip-Type-6
PSHELL  6       1       .02175  1
$ Elements and Element Properties for region : Strip-Type-7
PSHELL  7       1       .02426  1
$
GRID    1               0.0     0.0     0.0
GRID    2               2.      0.0     0.0
GRID    3               2.      0.0     1.
GRID    4               0.0     0.0     1.
GRID    5               0.0     1.      0.0
```

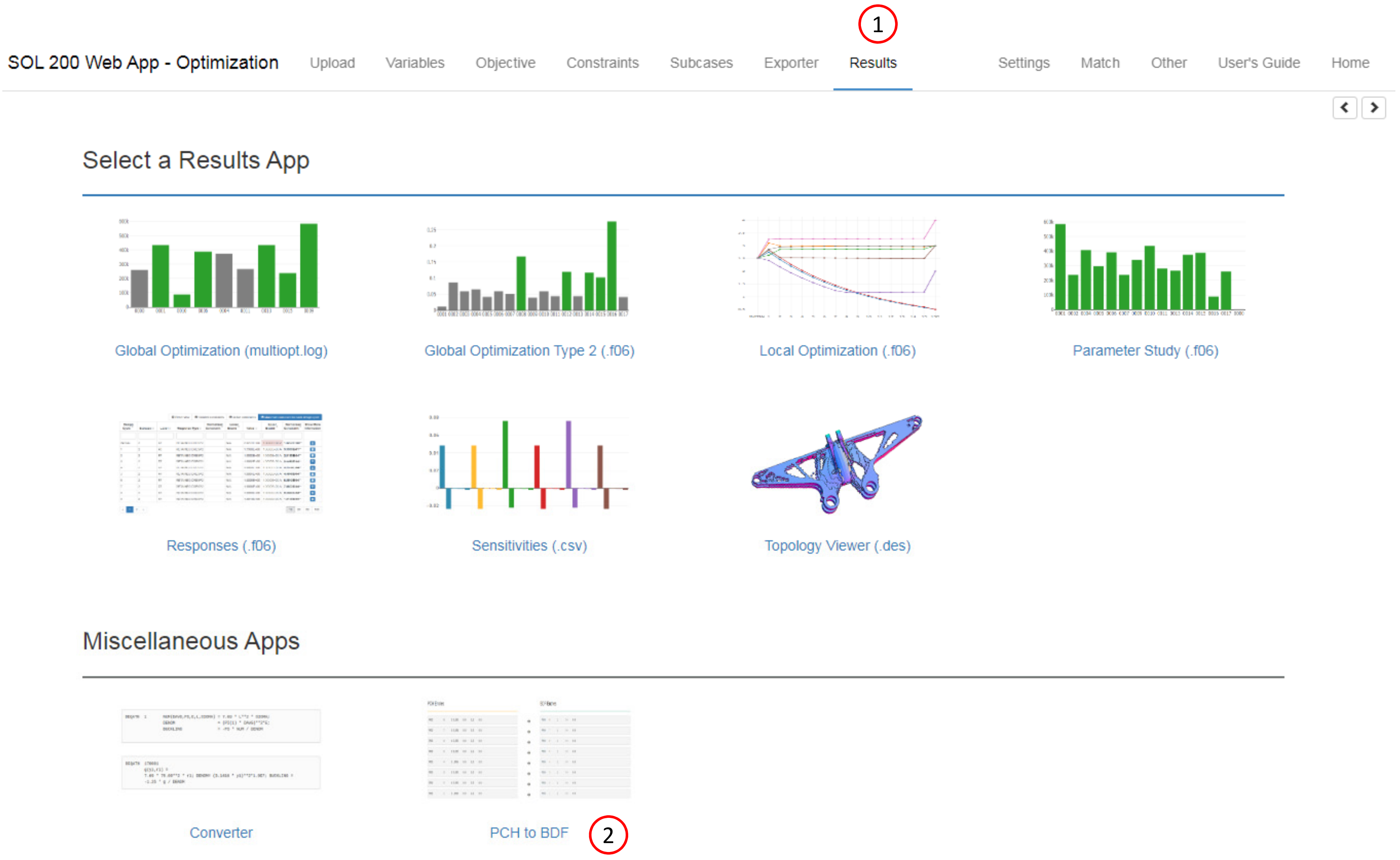
Updated BDF File (model_final.bdf)

3

```
PSHELL         1       1 .001055       1     1.0               0 .833333     0.0
                               0
$ Elements and Element Properties for region : Strip-Type-2
PSHELL         2       1 .001018       1     1.0               0 .833333     0.0
                               0
$ Elements and Element Properties for region : Strip-Type-3
PSHELL  3        1        .100     1
$ Elements and Element Properties for region : Strip-Type-4
PSHELL         4       1 .004094       1     1.0               0 .833333     0.0
                               0
$ Elements and Element Properties for region : Strip-Type-5
PSHELL         5       1 .061583       1     1.0               0 .833333     0.0
                               0
$ Elements and Element Properties for region : Strip-Type-6
PSHELL         6       1 .078398       1     1.0               0 .833333     0.0
                               0
$ Elements and Element Properties for region : Strip-Type-7
PSHELL         7       1 .001          1     1.0               0 .833333     0.0
                               0
```

Update the Original Model

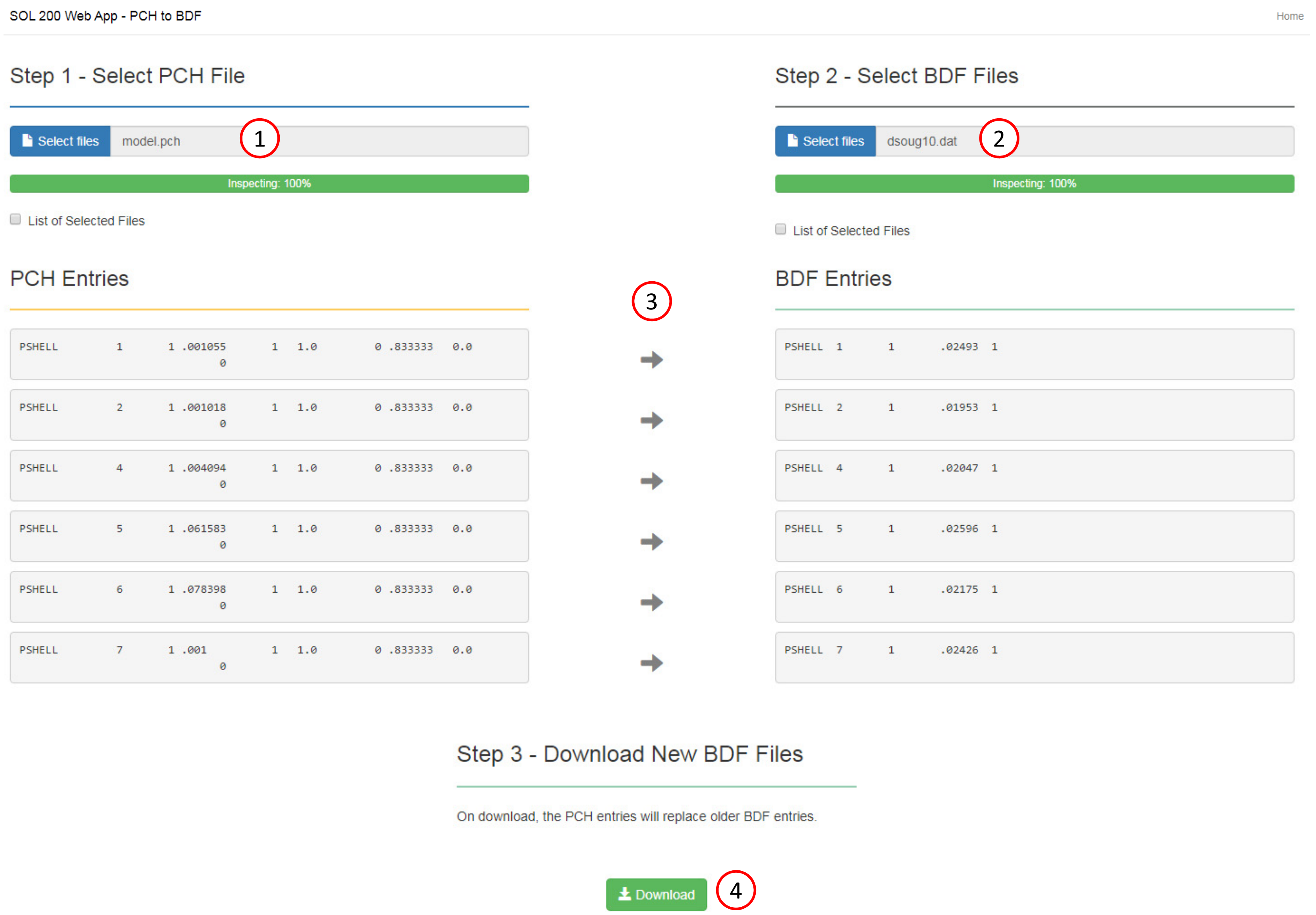
1. Click Results
2. Click PCH to BDF



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: dsoug10.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

dsoug10.dat

```
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$        STRUCTURAL MODEL
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$ Elements and Element Properties for region : Strip-Type-1
PSHELL  1       1       .02493  1
$ Elements and Element Properties for region : Strip-Type-2
PSHELL  2       1       .01953  1
$ Elements and Element Properties for region : Strip-Type-3
PSHELL  3       1       .100    1
$ Elements and Element Properties for region : Strip-Type-4
PSHELL  4       1       .02047  1
$ Elements and Element Properties for region : Strip-Type-5
PSHELL  5       1       .02596  1
$ Elements and Element Properties for region : Strip-Type-6
PSHELL  6       1       .02175  1
$ Elements and Element Properties for region : Strip-Type-7
PSHELL  7       1       .02426  1
$
GRID    1               0.0     0.0     0.0
GRID    2               2.      0.0     0.0
GRID    3               2.      0.0     1.
GRID    4               0.0     0.0     1.
GRID    5               0.0     1.      0.0
```

Original BDF/DAT File

dsoug10.dat

```
$
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$        STRUCTURAL MODEL
$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
$
$ Elements and Element Properties for region : Strip-Type-1
PSHELL         1       1 .001055       1    1.0            0 .833333    0.0
                               0
$ Elements and Element Properties for region : Strip-Type-2
PSHELL         2       1 .001018       1    1.0            0 .833333    0.0
                               0
$ Elements and Element Properties for region : Strip-Type-3
PSHELL  3       1       .100    1
$ Elements and Element Properties for region : Strip-Type-4
PSHELL         4       1 .004094       1    1.0            0 .833333    0.0
                               0
$ Elements and Element Properties for region : Strip-Type-5
PSHELL         5       1 .061583       1    1.0            0 .833333    0.0
                               0
$ Elements and Element Properties for region : Strip-Type-6
PSHELL         6       1 .078398       1    1.0            0 .833333    0.0
                               0
$ Elements and Element Properties for region : Strip-Type-7
PSHELL         7       1 .001          1    1.0            0 .833333    0.0
                               0
```

Downloaded BDF/DAT File

1

End of Tutorial

Appendix

Appendix Contents

- Frequently Asked Questions
  - Beta Method Problem Statement
    - Response Minimization
    - Response Maximization

Derivation of the Optimization Problem Statement for the Beta Method, Response Minimization

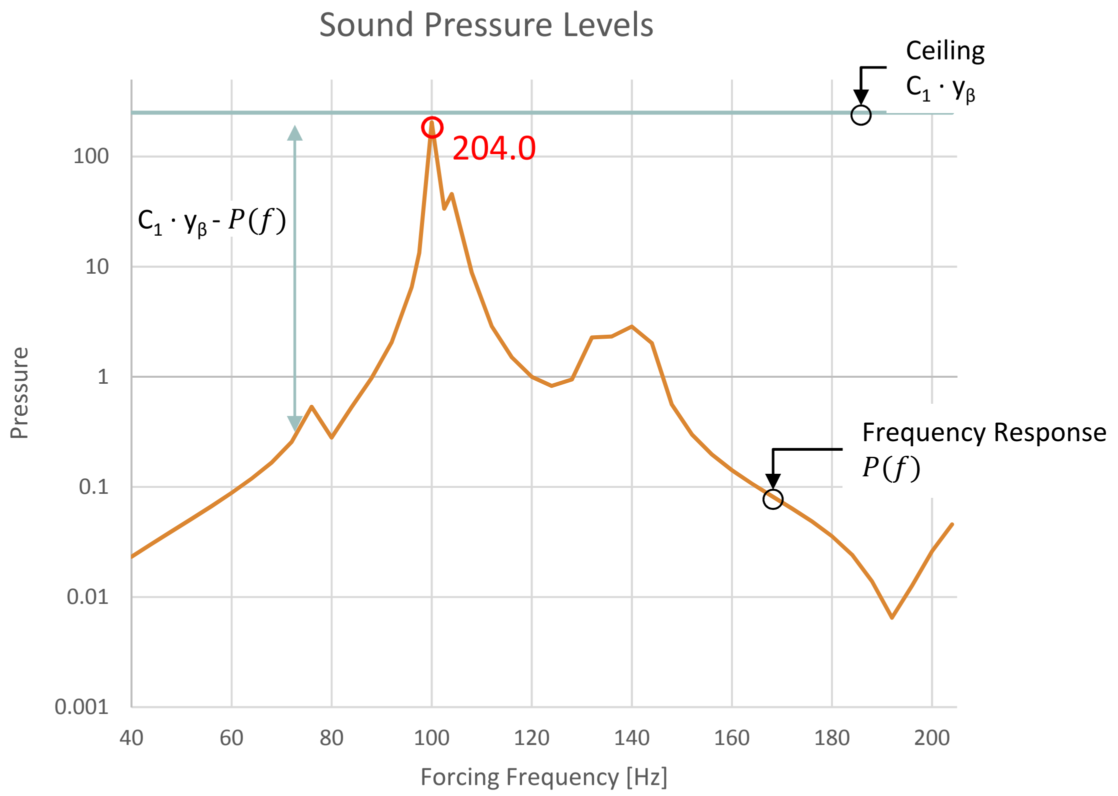
Prerequisites:

- The initial value of variable y_β is 1.0
- $P(f)$ represents the frequency response (For example, the response is Pressure vs. Frequency)

Derivation:

1. The ceiling ($C1 \cdot y_\beta$) should always be taller than the response $P(f)$ and is expressed via this inequality
   $P(f) < C1 \cdot y_\beta$
2. The expression is re-organized as:
   $0.0 < C1 \cdot y_\beta - P(f)$
3. The bound is 0.0, and optimizers do not like using 0.0 for the bounds, so an offset of 1000.0 is used. The expression is now
   $\underline{1000.0 < C1 \cdot y_\beta - P(f) + 1000.0}$

- **How is C1 determined?** C1 is chosen such that the ceiling is greater than all points of the response. This ensures the optimization starts as a feasible design.
  - Find the max peak of the response (Pressure vs Frequency)
  - Add a small delta to the max peak and this is your C1
  - For example, if your max peak is 204.0, then C1 can be 205, 206, 207, …. For example, C1=210 is chosen.

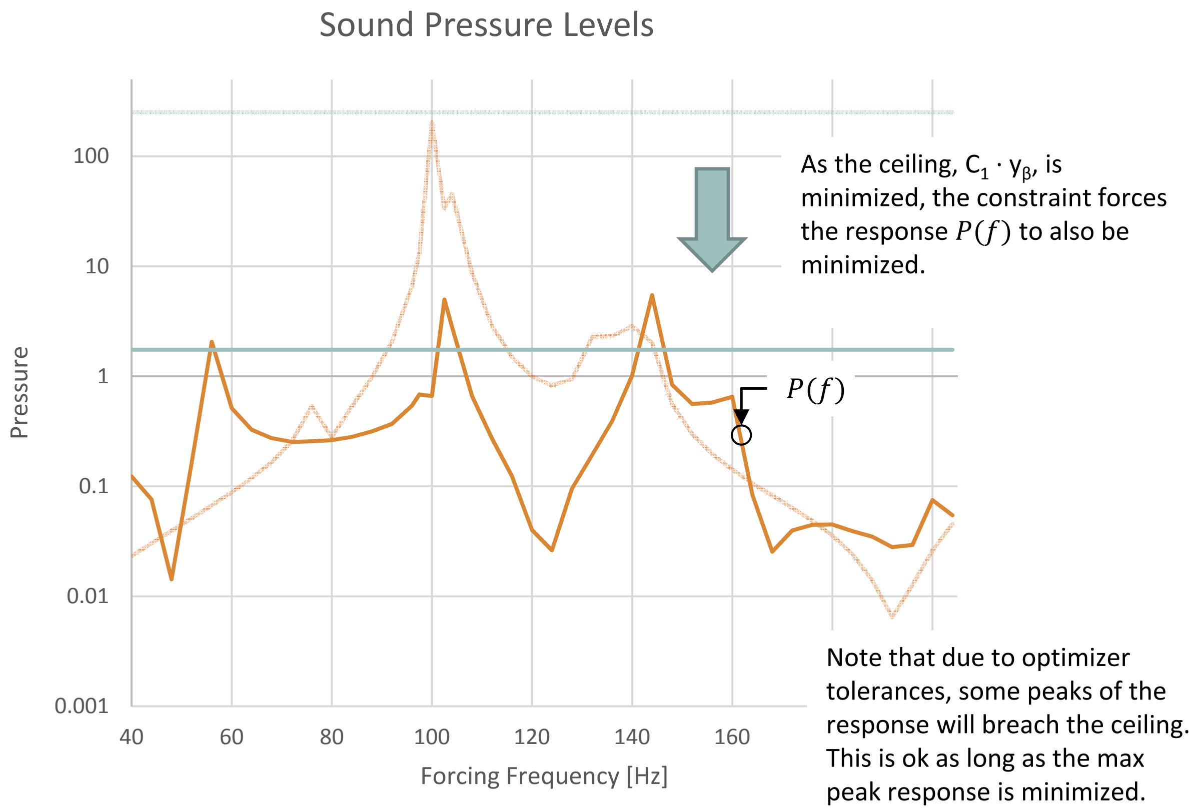


Derivation of the Optimization Problem Statement for the Beta Method, Response Minimization

The optimization problem statement is now as follows:

- Variable:
  - y_β : The initial value is 1.0. The bound can be .0001 < y_β
- Objective:
  - Minimize C1 · y_β
  - i.e. minimize the ceiling
- Constraints:
  - 1000.0 < C1 · y_β - $P(f)$ + 1000.0
    - $P(f)$ represents the frequency response (For example, the response is Pressure vs. Frequency)
  - i.e. as the ceiling is minimized, require the response $P(f)$ to be under the ceiling

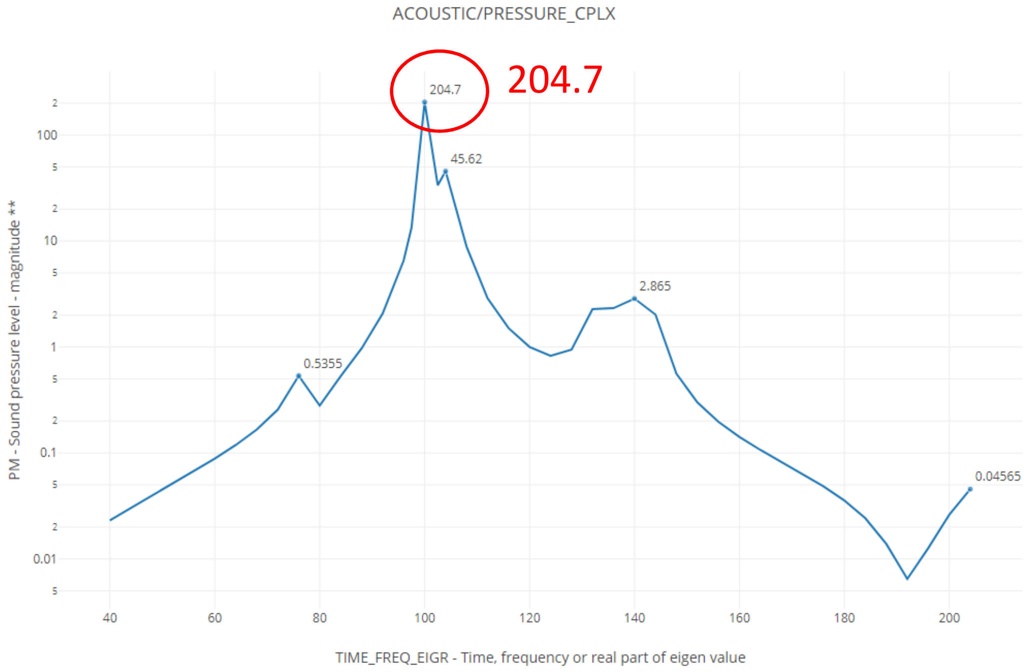
This optimization method can be seen as a moving ceiling scenario. The objective is to minimize the ceiling (blue line), while the constraint ensures the response curve (orange) remains under the ceiling.



Example of Beta Method with Multiple Responses and Subcases

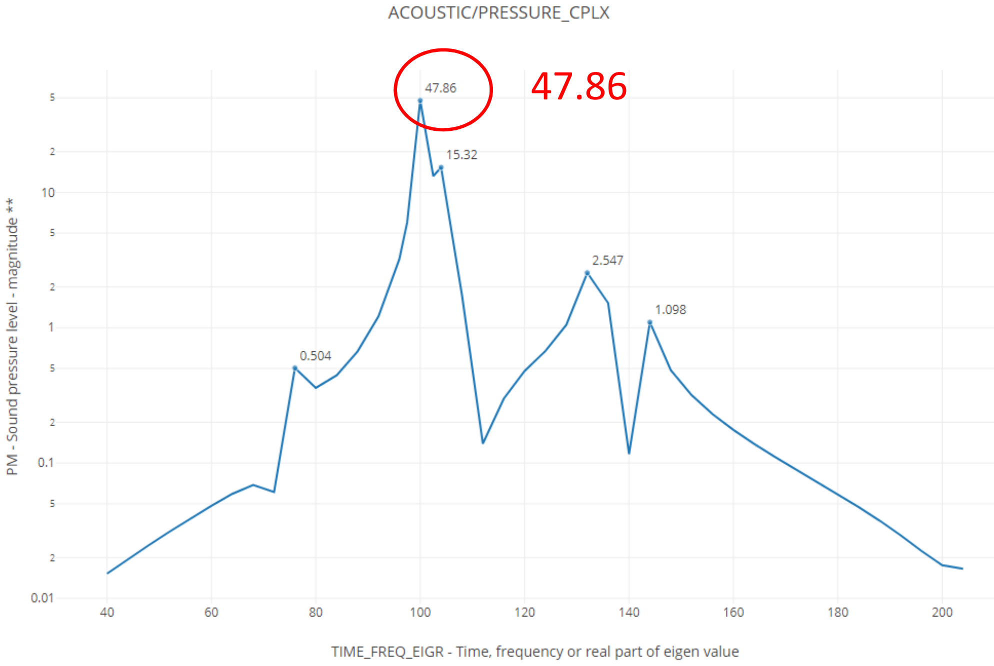
SUBCASE 1 – NODE 11280

THE MAX PEAK IS 204.7, SO C1 SHOULD BE GREATER. YOU CAN USE 205, 206, … FOR MY EXAMPLE, I PICK **C1=210.**



SUBCASE 2 – NODE 11329

THE MAX PEAK IS 47.86, SO C1 SHOULD BE GREATER. YOU CAN USE 50, 51, 52, … FOR MY EXAMPLE, I PICK **C1=50.**

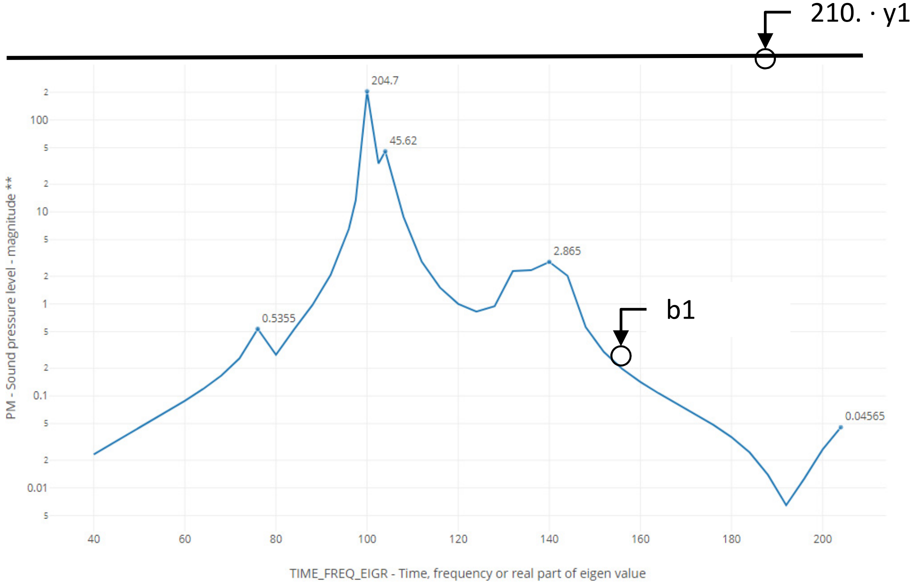


Example of Beta Method with Multiple Responses and Subcases, Continued - Constraints

SUBCASE 1 – NODE 11280

R1: 1000.0 < **210.** · y1 – b1 + *1000.0*

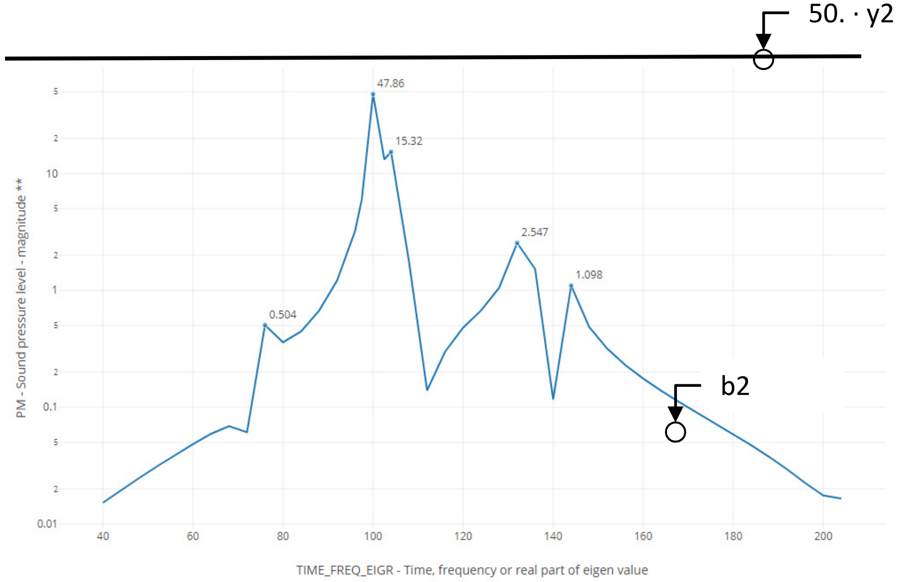
b1: The response (Pressures vs. Frequency) of node 11280, subcase 1



SUBCASE 2 – NODE 11329

R2: 1000.0 < **50.** · y2 – b2 + *1000.0*

b2: The response (Pressures vs. Frequency) of node 11329, subcase 2



Example of Beta Method with Multiple Responses and Subcases, Continued - Final Optimization Problem Statement and Subcase Configuration

The combined problem statement is

Variable:

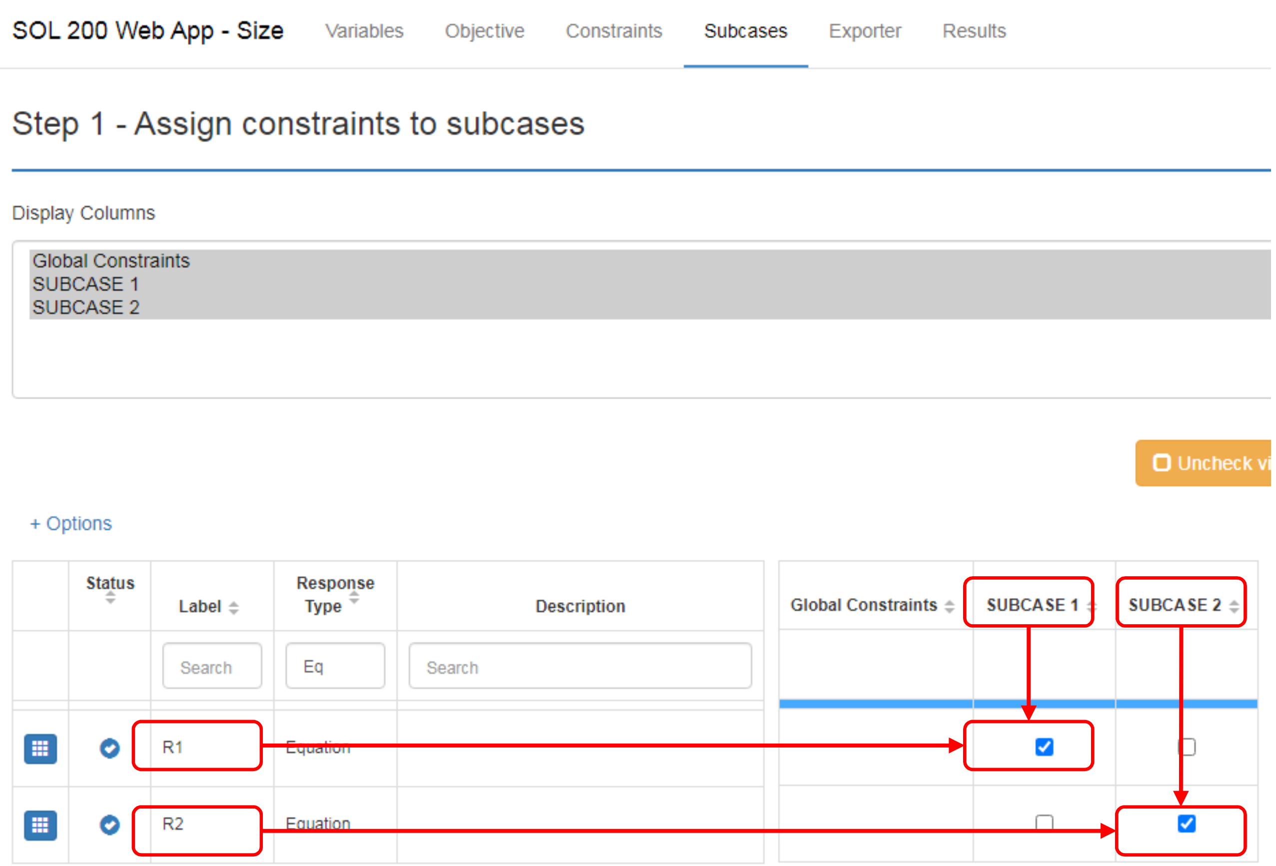
- y1: The initial value is 1.0. The bound can be .0001 < y1
- y2: The initial value is 1.0. The bound can be .0001 < y2

Objective:

- Minimize: $210. \cdot y1 + 80. \cdot y2$

Constraints:

- R1: $1000.0 < 210. \cdot y1 - b1 + 1000.0$
- R2: $1000.0 < 50. \cdot y2 - b2 + 1000.0$
- R1 and R2 are assigned to SUBCASE 1 and 2, respectively
- The web app is used to assign constraint, see the image to the right.

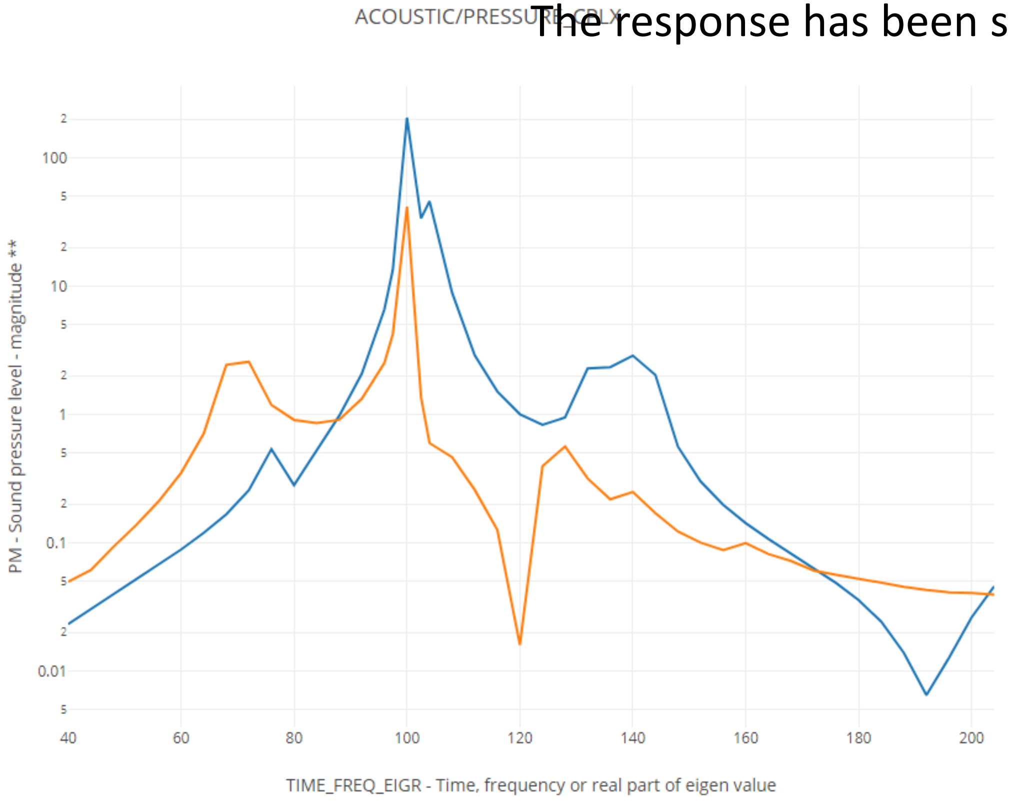


Example of Beta Method with Multiple Responses and Subcases, Continued - Responses After Optimization

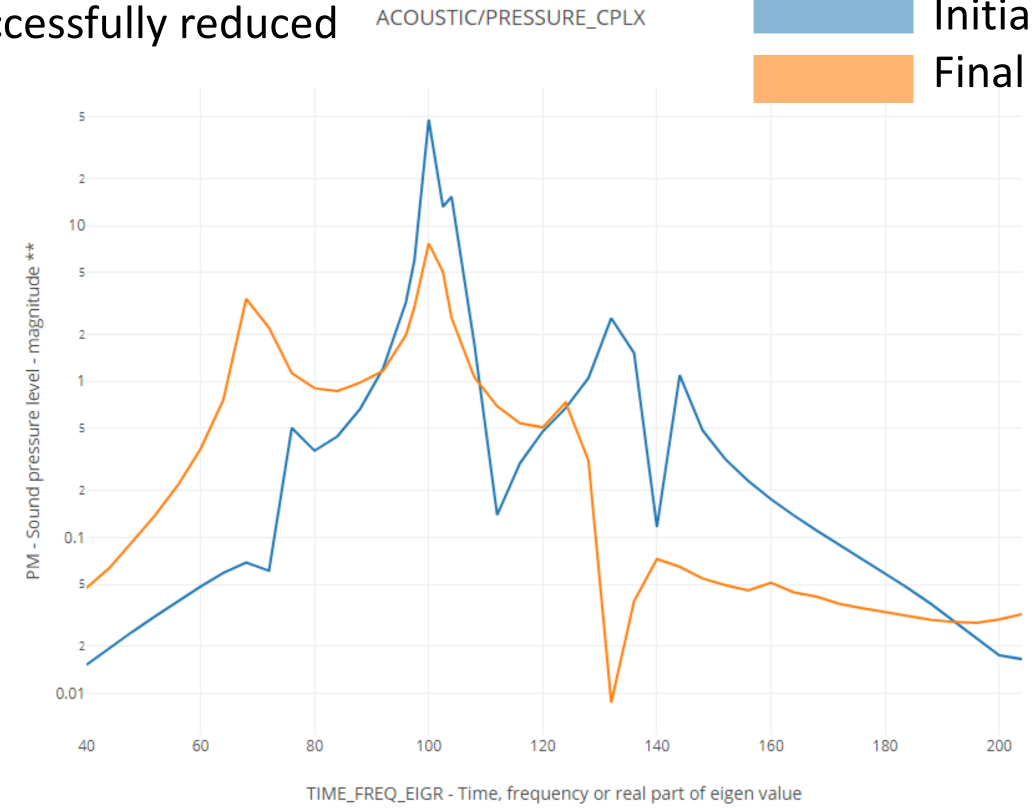
The response has been successfully reduced

Initial

Final



Node 11280, Subcase 1



Node 11329, Subcase 2

Derivation of the Optimization Problem Statement for the Beta Method, Response Maximization

The same beta method may be used to maximize a response.

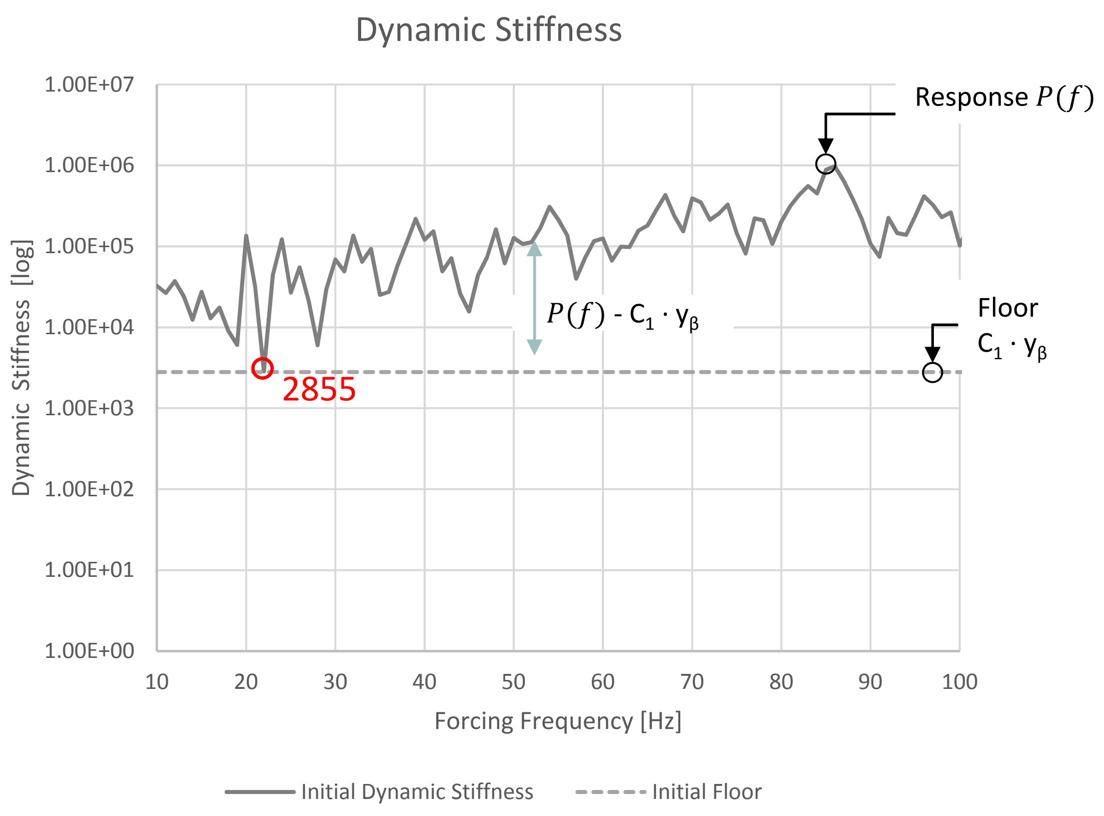
Prerequisites:

- The initial value of variable y_β is 1.0
- $P(f)$ represents the frequency response (For example, the response is Dynamic Stiffness vs. Frequency)

Derivation:

1. The response $P(f)$ should always be taller than the floor (C1 · y_β) and is expressed via this inequality
   $C1 \cdot y_\beta < P(f)$
2. The expression is re-organized as:
   $0.0 < P(f) - C1 \cdot y_\beta$
3. The bound is 0.0, and optimizers do not like using 0.0 for the bounds, so an offset of 1000.0 is used. The expression is now
   $\underline{1000.0 < P(f) - C1 \cdot y_\beta + 1000.0}$

- **How is C1 determined?** C1 is chosen such that the floor is less than all points of the response. This ensures the optimization starts as a feasible design.
  - Find the minimum of the response (Dynamic Stiffness vs Frequency)
  - Subtract a small delta to the minimum and this is your C1
  - For example, if your minimum is 2855, then C1 can be 2854, 2853, 2852, …. For example, C1=2800 is chosen.

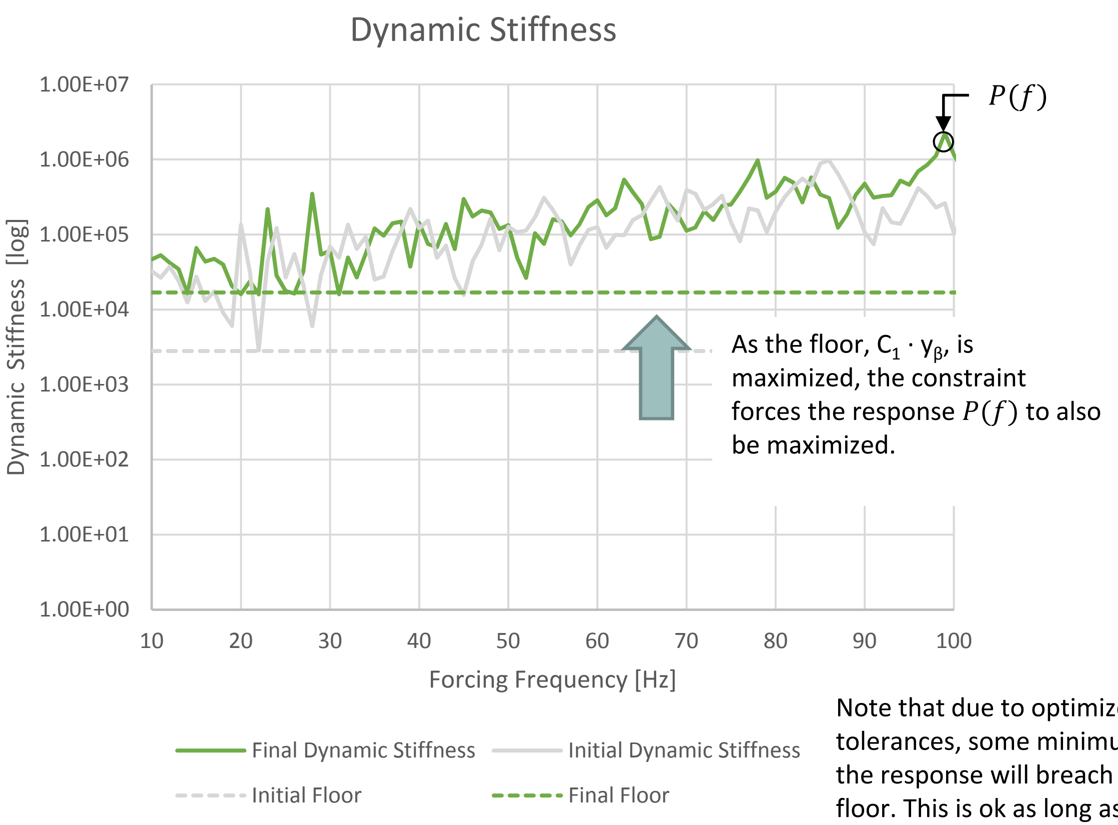


Derivation of the Optimization Problem Statement for the Beta Method, Response Maximization

The optimization problem statement is now as follows:

- Variable:
  - y_β : The initial value is 1.0. The bound can be .0001 < y_β
- Objective:
  - Maximize C1 · y_β
  - i.e. maximize the floor
- Constraints:
  - 1000.0 < $P(f)$ - C1 · y_β + 1000.0
    - $P(f)$ represents the frequency response (For example, the response is Dynamic Stiffness vs. Frequency)
  - i.e. as the floor is maximized, require the response $P(f)$ to be above the floor

This optimization method can be seen as a moving floor scenario. The objective maximizes the floor (dotted line), while the constraint ensures the response curve (solid green/gray) remains above the floor.



Note that due to optimizer tolerances, some minimums of the response will breach the floor. This is ok as long as the minimum response is maximized.