Workshop - Model Matching, Frequency Response

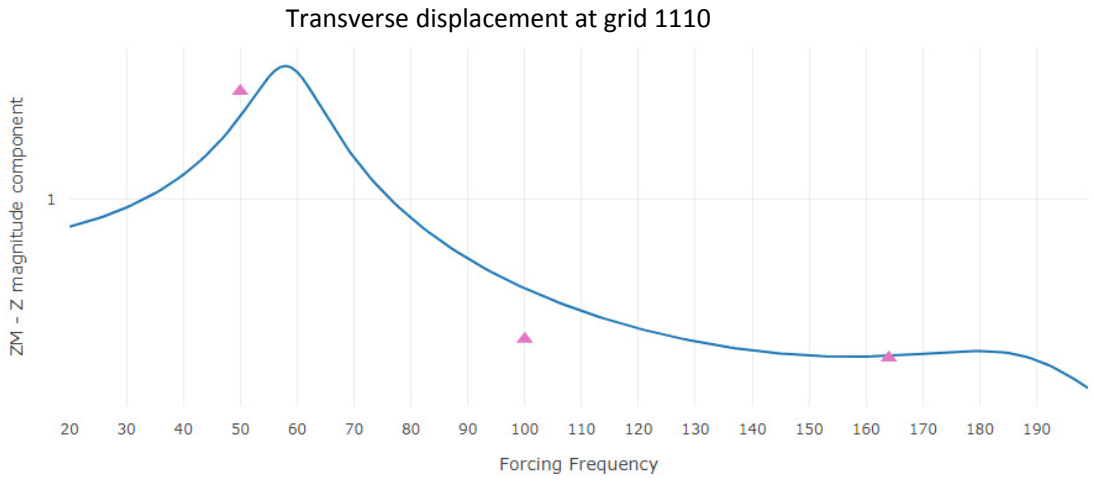
AN MSC NASTRAN SOL 200 TUTORIAL

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

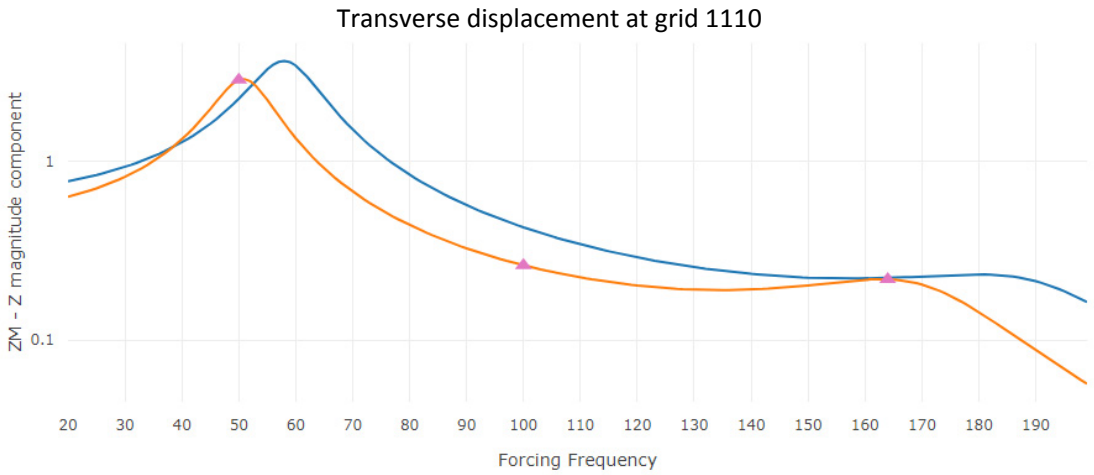
Goal: Use Nastran SOL 200 Optimization

Correlate Experiment and FEA Results

Before Optimization



After Optimization



INITIAL FEA Results
FINAL FEA Results
Experiment/ Target Values

Details of the structural model

Dynamic Response Optimization

This example demonstrates structural optimization when the structural loads are frequency dependent. The system considered is a flat rectangular plate clamped on three edges and free along the fourth, as shown in Figure 8-21. The problem investigates minimization of the mean square response of the transverse displacement at the midpoint of the free edge, while constraining the volume of the structure (and hence, weight) to be equal to that of the initial design. A pressure loading with an amplitude of $1.0\ lb_f/in^2$ is applied across a frequency range of 20.0 to 200.0 Hz. A small amount of frequency-dependent modal damping has also been included.

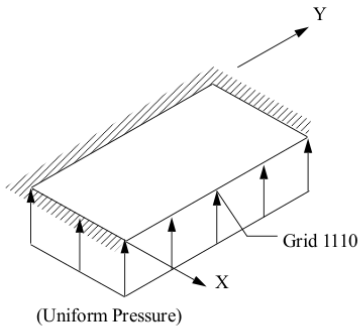
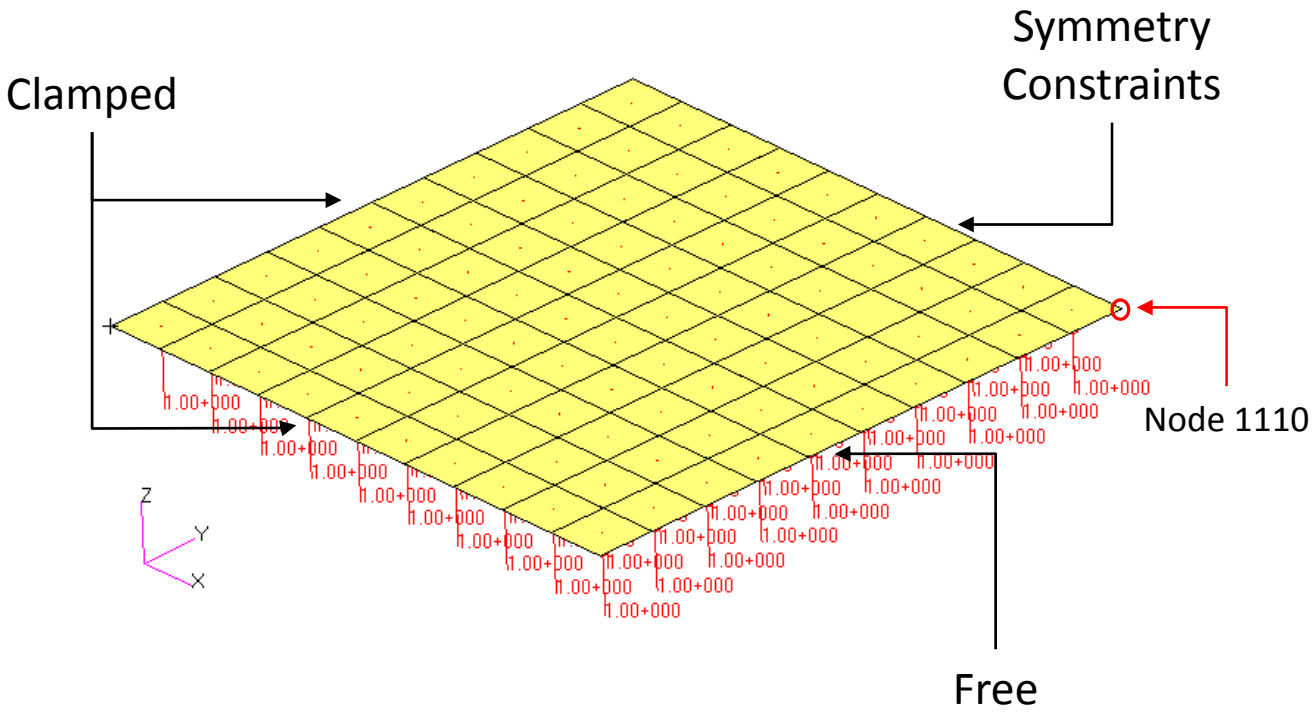


Figure 8-21 Pressure-Loaded Flat Plate

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



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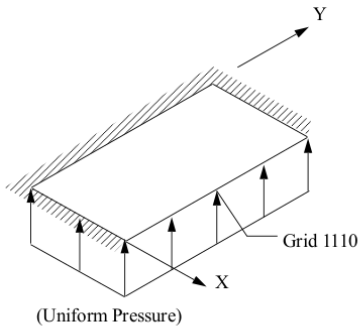
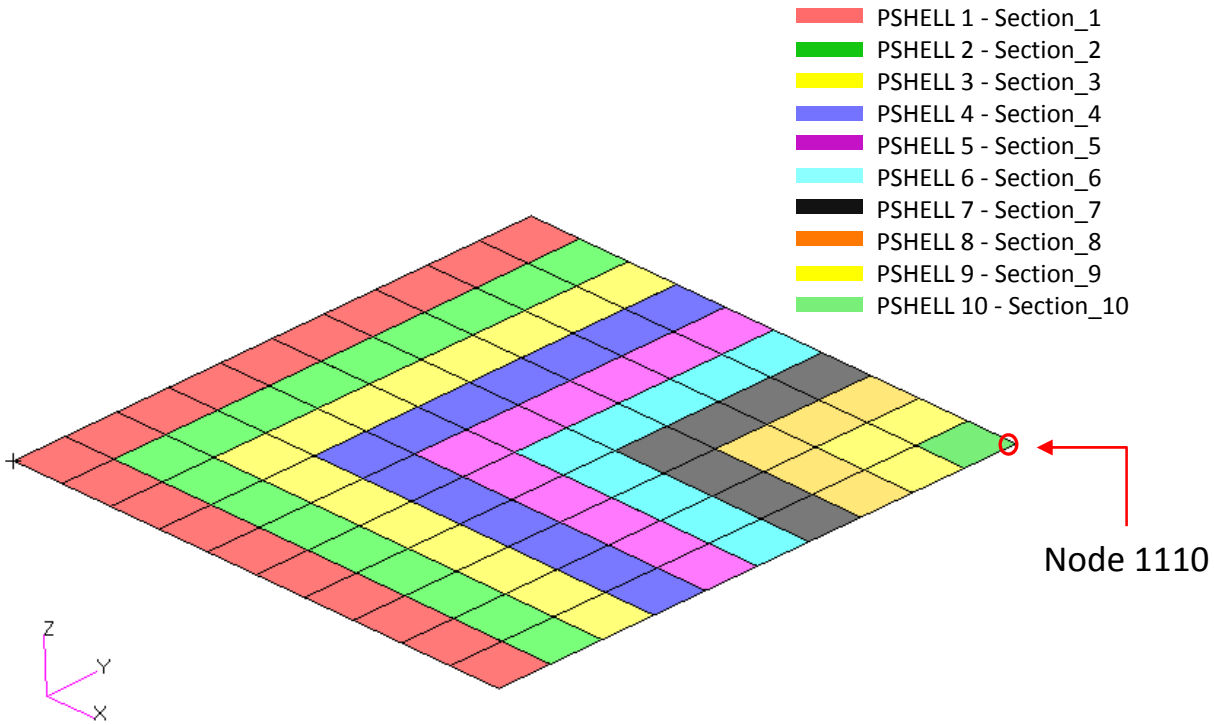


Figure 8-21 Pressure-Loaded Flat Plate

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



Optimization Problem Statement

Design Variables

x1: T of PSHELL 1
x2: T of PSHELL 2
x3: T of PSHELL 3
x4: T of PSHELL 4
x5: T of PSHELL 5
x6: T of PSHELL 6
x7: T of PSHELL 7
x8: T of PSHELL 8
x9: T of PSHELL 9
x10 : T of PSHELL 10

.01 < xi < 1.0

Design Objective, Equation

R0: Minimize

$$\left(\frac{b1 - 2.8384}{2.8384}\right)^2 + \left(\frac{b2 - 0.2613}{0.2613}\right)^2 + \left(\frac{b3 - 0.2182}{0.2182}\right)^2$$

SUBCASE 1

- b1: RM - T3 component of displacement at grid 1110 at frequency 50. Hz
- b2: RM - T3 component of displacement at grid 1110 at frequency 100. Hz
- b3: RM - T3 component of displacement at grid 1110 at frequency 164. Hz

Design Constraints

r1: Volume 7.99 < r1 < 8.01

Design Constraints, Equation

SUBCASE 1

$R1 = \left(\frac{b4 - 0.488338}{0.488338}\right)^2$ R1 < .01

$R2 = \left(\frac{b5 - .018219}{.018219}\right)^2$ R2 < . 01

$R3 = \left(\frac{b6 - 0.1845}{0.1845}\right)^2$ R3 < . 01

$R4 = \left(\frac{b7 - 0.022128}{0.022128}\right)^2$ R4 < . 01

$R5 = \left(\frac{b8 - 0.279055}{0.279055}\right)^2$ R5 < . 01

- b4: RM - T3 component of displacement at grid 605 at frequency 50. Hz
- b5: RM - T3 component of displacement at grid 605 at frequency 84. Hz
- b6: RM - T3 component of displacement at grid 605 at frequency 171. Hz
- b7: RM - T3 component of displacement at grid 1105 at frequency 97. Hz
- b8: RM - T3 component of displacement at grid 1105 at frequency 173. Hz

SUBCASE 2

$R6 = \left(\frac{b9 - 1.58019}{1.58019}\right)^2$ R6 < .01

$R7 = \left(\frac{b10 - 0.140642}{0.140642}\right)^2$ R7 < . 01

$R8 = \left(\frac{b11 - 0.124761}{0.124761}\right)^2$ R8 < . 01

- b9: RM - T3 component of displacement at grid 1110 at frequency 50. Hz
- b10: RM - T3 component of displacement at grid 1110 at frequency 100. Hz
- b11: RM - T3 component of displacement at grid 1110 at frequency 164. Hz

SUBCASE 3

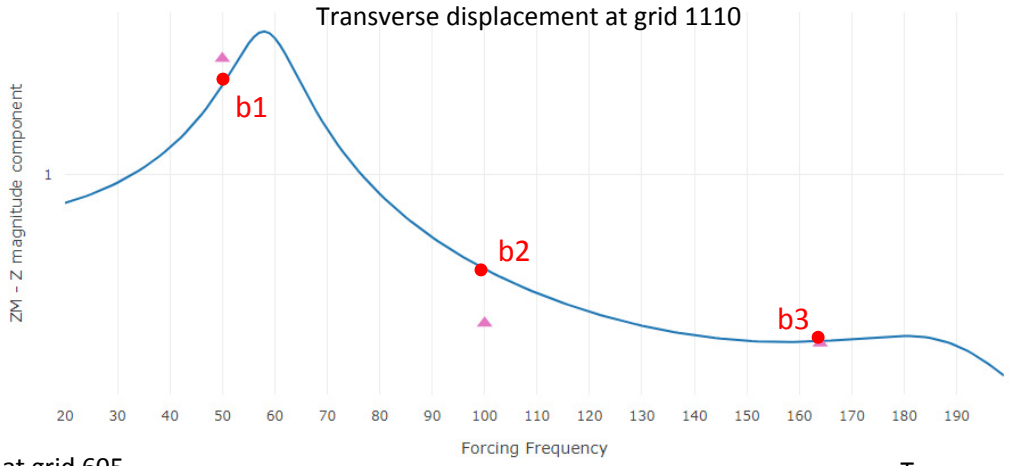
$R9 = \left(\frac{b12 - 0.522618}{0.522618}\right)^2$ R9 < .01

$R10 = \left(\frac{b13 - 0.048008}{0.048008}\right)^2$ R10 < . 01

$R11 = \left(\frac{b14 - 0.042346}{0.042346}\right)^2$ R11 < . 01

- b12: RM - T3 component of displacement at grid 1110 at frequency 50. Hz
- b13: RM - T3 component of displacement at grid 1110 at frequency 100. Hz
- b14: RM - T3 component of displacement at grid 1110 at frequency 164. Hz

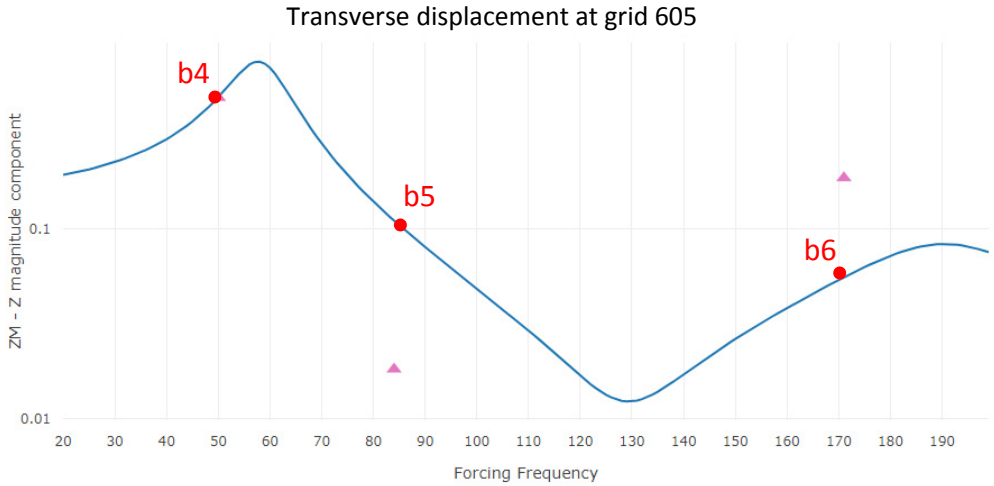
Optimization Problem Statement Continued

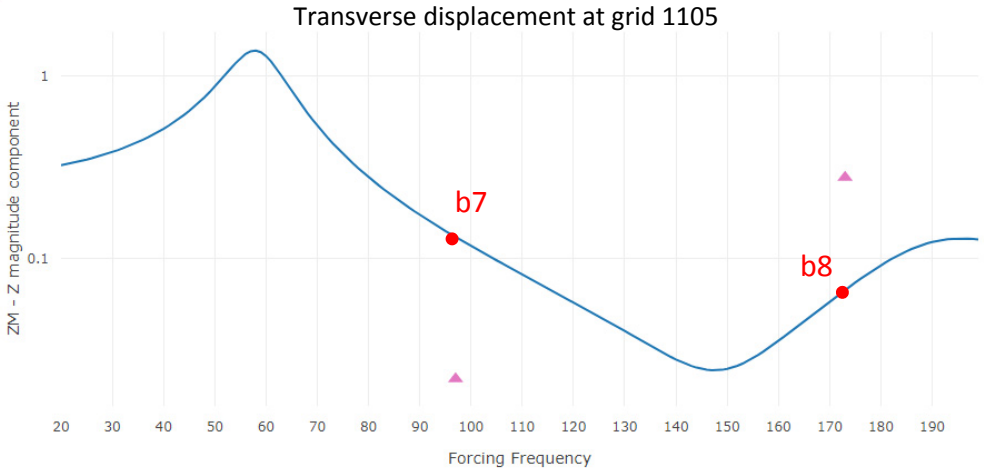


INITIAL FEA Results

Experiment/ Target Values

The plots on this page are for Subcase 1.

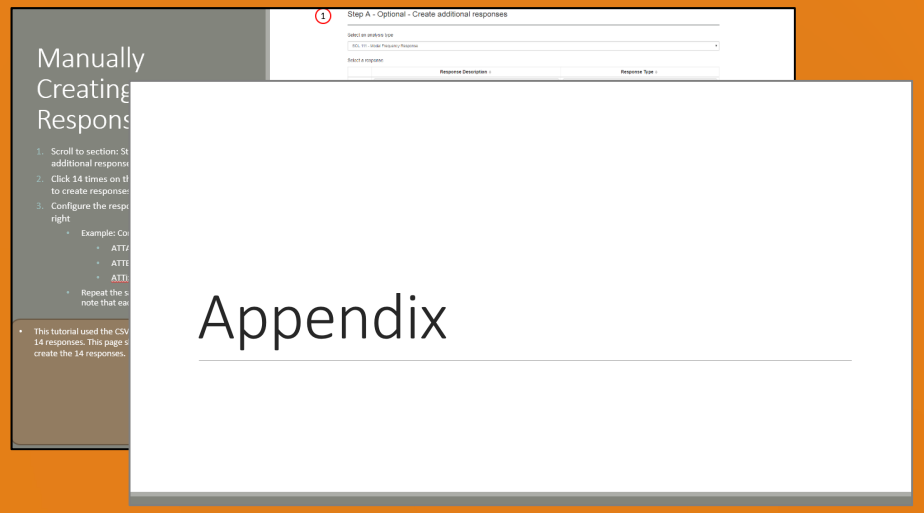




More Information Available in the Appendix

The Appendix includes information regarding the following:

- Manually Creating Responses
- How is error defined in this tutorial?



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

PART A

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.

Model Matching - The SOL 200 Web App features a single table where the model matching problem can be defined. In the background, the necessary objective and constraints are automatically generated. In addition, plots comparing the initial, final and target values are auto generated.

Multi Subcase - Model matching is to be performed across multiple subcases. The necessary steps and configuration is outlined in this tutorial to perform model matching across multiple subcases.

SOL 200 Web App Capabilities

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

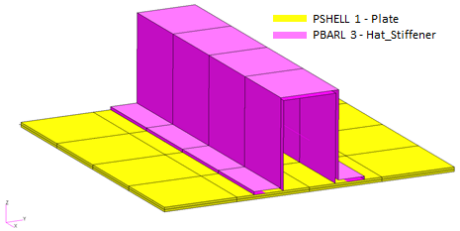
Compatibility

- 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.

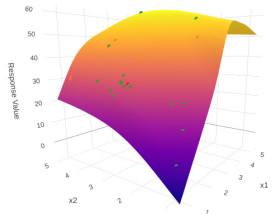
Benefits

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

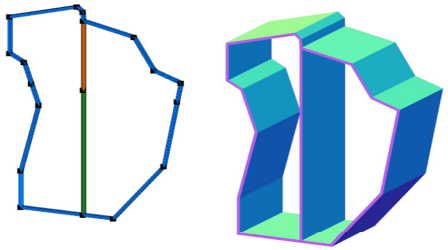
Web Apps



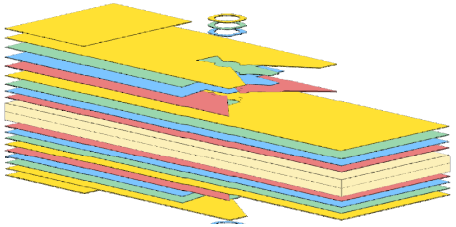
Web Apps for MSC Nastran SOL 200
Pre/post for MSC Nastran SOL 200. Support for size, topology, topometry, topography, multi-model optimization.



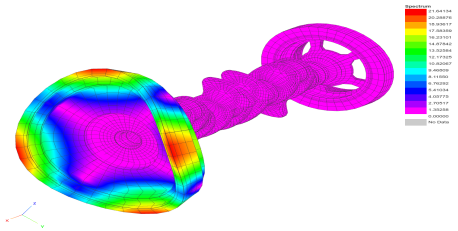
Machine Learning Web App
Bayesian Optimization for nonlinear response optimization (SOL 400)



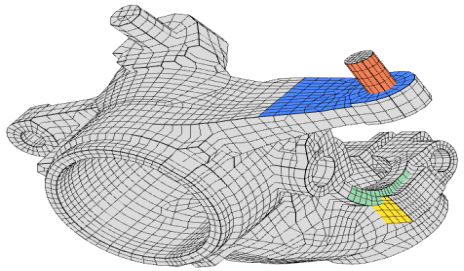
PBMSECT Web App
Generate PBMSECT and PBRSECT entries graphically



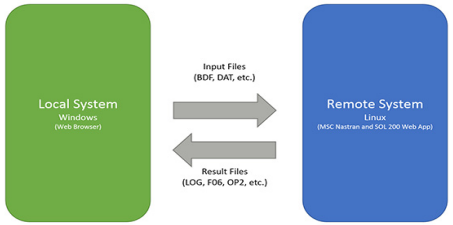
Ply Shape Optimization Web App
Optimize composite ply drop-off locations, and generate new PCOMPG entries



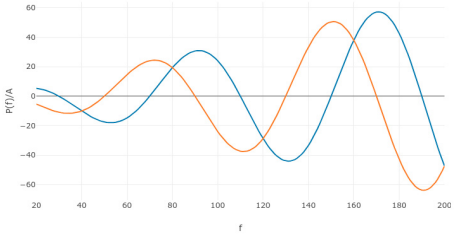
Post-processor Web App
View MSC Nastran results in a web browser on Windows and Linux



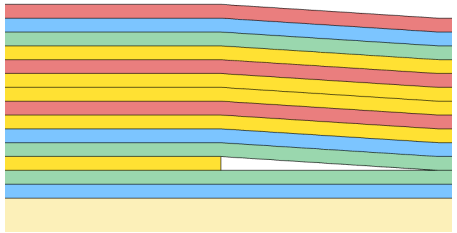
Shape Optimization Web App
Use a web application to configure and perform shape optimization.



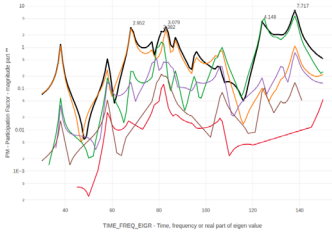
Remote Execution Web App
Run MSC Nastran jobs on remote Linux or Windows systems available on the local network



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



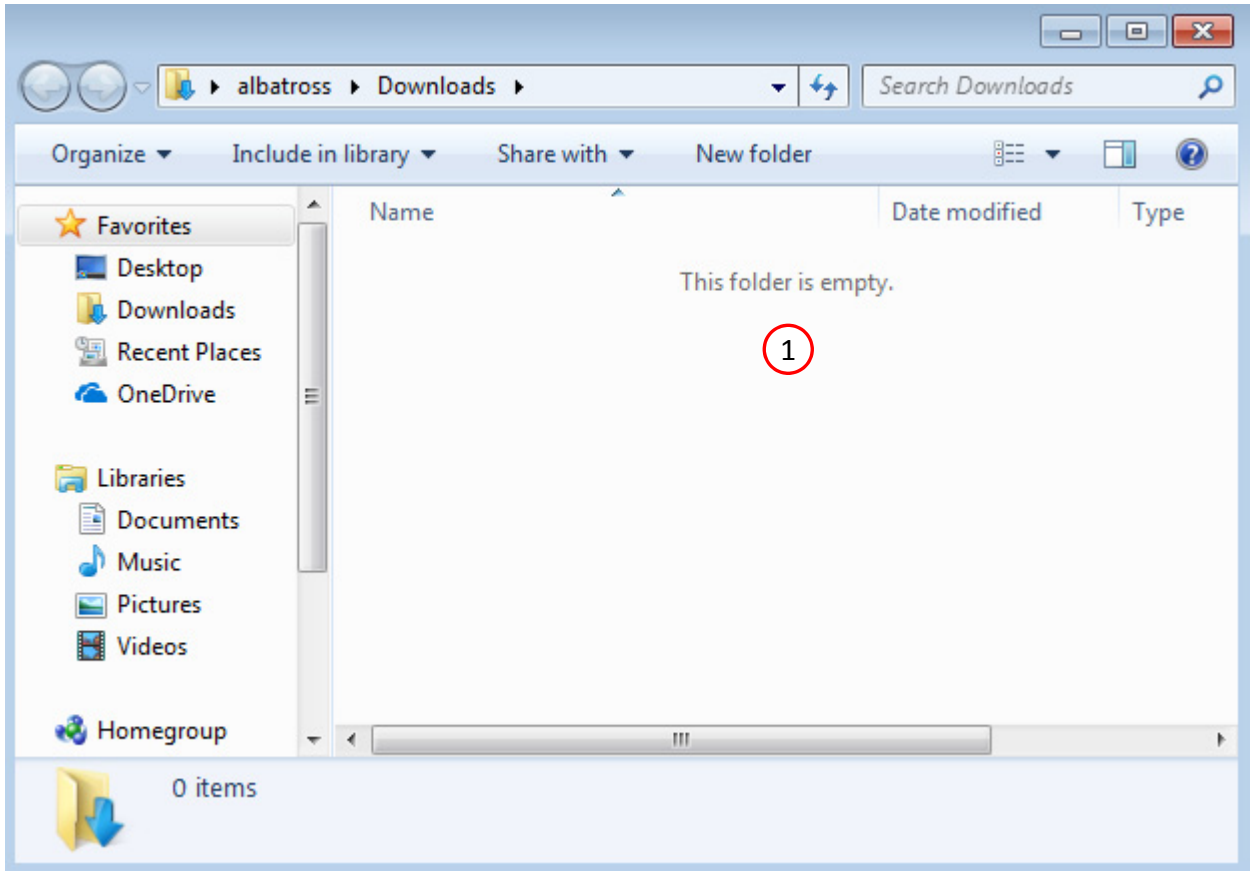
Stacking Sequence Web App
Optimize the stacking sequence of composite laminate plies



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

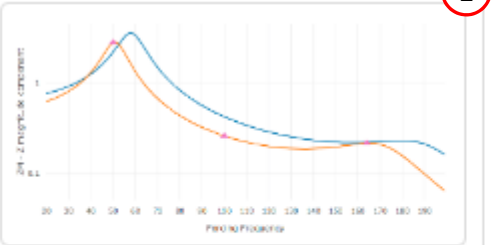
1. Click on the indicated link

- 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.



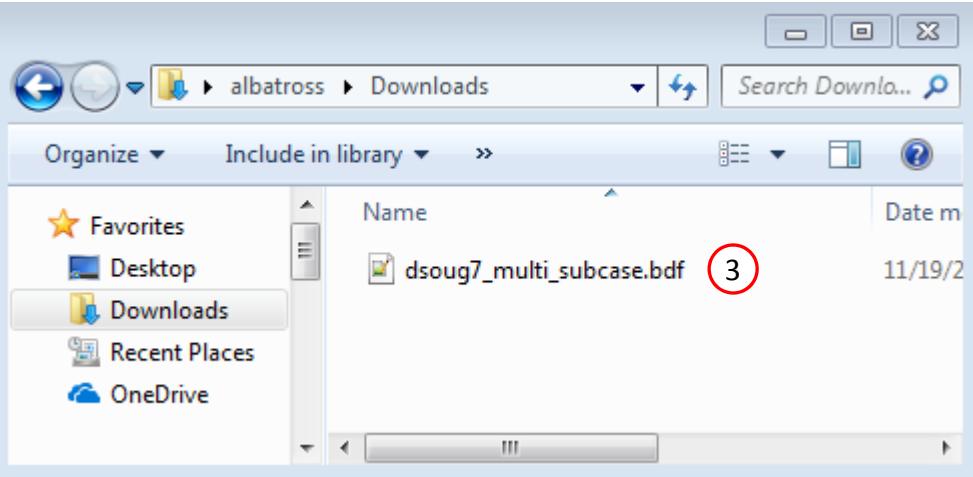
1

Model Matching, Frequency Response Analysis

A frequency response analysis has been performed, but the results do not match experimental results.

This tutorial discusses the model matching procedure in order to correlate Finite Element Analysis and test results.

Starting BDF Files: Link 2
Solution BDF Files: Link



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.

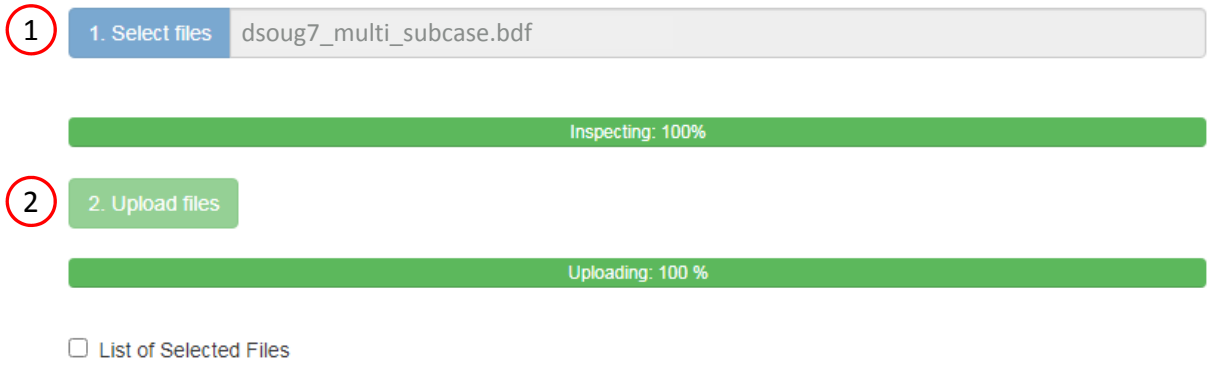
The Engineering Lab

Upload BDF Files

1. Click 1. Select Files and select dsoug7_multi_subcase.bdf
2. Click Upload Files

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

Step 1 - Upload .BDF Files



Create Design Variables

1. In the search box, type ‘t’
2. Click 10 on the pagination bar
3. Click on + Options
4. Set the Lower Bound to .01
5. Set the Upper Bound to 1.0
6. Click Create

- There are 2 methods to create the 10 design variables: Click each blue plus icon, which requires 10 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.

Step 1 - Select design properties

3 + Options

Display Type	% Lower Bound	% Upper Bound	Lower Bound	Upper Bound	Allowed Discrete Values or Equation	Bulk Create
	☐		☑			
☑ DVXREL1	Lower	Upper	.01 (4)	1.0 (5)	Allowed discrete values, example: -2.0, 1.0, THRU, 10.0, BY, 1.0 (6)	Create
☐ DVXREL1 Unity	Lower	Upper	.01	1.0	Allowed discrete values, example: -2.0, 1.0, THRU, 10.0, BY, 1.0	Create
☐ DVXREL2	Lower	Upper	.01	1.0	Type equation here, example: y1**2 + x2 + k3	Create

Display Columns

☑ Create DVXREL1 ☐ Create Unity DVXREL1 ☐ Create DVXREL2 ☐ Entry Name

Settings for row filtering in tables

◉ Contains ○ Starts with ○ Ends with

Create DVXREL1	Property	Property Description	Entry	Entry ID	Current Value
	t (1)	Search	Search	Search	Search
+	T	Thickness	PSHELL	1	.08
+	T	Thickness	PSHELL	2	.08
+	T	Thickness	PSHELL	3	.08
+	T	Thickness	PSHELL	4	.08
+	T	Thickness	PSHELL	5	.08
+	T	Thickness	PSHELL	6	.08
+	T	Thickness	PSHELL	7	.08
+	T	Thickness	PSHELL	8	.08
+	T	Thickness	PSHELL	9	.08
+	T	Thickness	PSHELL	10	.08

2

5 | 10 | 20 | 30 | 40 | 50

Create Design Variables

1. Click 10 on the pagination bar
2. 10 design variables (x1 - x10) have been created and correspond to the 10 different thicknesses

- 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 .01 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	.08	.01	1.0	Examples: -2.0, 1.0, THRU, 10.0,
✖	x2	✔	T	Thickness	PSHELL	2	.08	.01	1.0	Examples: -2.0, 1.0, THRU, 10.0,
✖	x3	✔	T	Thickness	PSHELL	3	.08	.01	1.0	Examples: -2.0, 1.0, THRU, 10.0,
✖	x4	✔	T	Thickness	PSHELL	4	.08	.01	1.0	Examples: -2.0, 1.0, THRU, 10.0,
✖	x5	✔	T	Thickness	PSHELL	5	.08	.01	1.0	Examples: -2.0, 1.0, THRU, 10.0,
✖	x6	✔	T	Thickness	PSHELL	6	.08	.01	1.0	Examples: -2.0, 1.0, THRU, 10.0,
✖	x7	✔	T	Thickness	PSHELL	7	.08	.01	1.0	Examples: -2.0, 1.0, THRU, 10.0,
✖	x8	✔	T	Thickness	PSHELL	8	.08	.01	1.0	Examples: -2.0, 1.0, THRU, 10.0,
✖	x9	✔	T	Thickness	PSHELL	9	.08	.01	1.0	Examples: -2.0, 1.0, THRU, 10.0,
✖	x10	✔	T	Thickness	PSHELL	10	.08	.01	1.0	Examples: -2.0, 1.0, THRU, 10.0,

2

5 | 10 | 20 | 30 | 40 | 50

1

Create Design Constraints

1. Click Constraints
2. Click the plus (+) icon for Volume
3. Configure the following for constraint r1
    1. Lower Allowed Limit: 7.99
    2. Upper Allowed Limit: 8.01

- It may be desired to keep a certain response constant during the optimization. For example, the goal may be to preserve the volume of the original design. This is best addressed by creating a constraint where the lower and upper bound are slightly less and greater, than the original response. In this example, you may be tempted to use a lower bound of 8 and an upper bound of 8, but this is not advisable. The better option is to use 7.99 and 8.01 for the lower and upper bound, respectively.

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

Constraints | Equation Constraints

Step 1 - Select constraints

Select an analysis type

SOL 111 - Modal Frequency Response

Select a response

	Response Description	Response Type
	Search	Search
+	Weight	WEIGHT
(2) +	Volume	VOLUME
+	Fatigue, random vibration fatigue analysis	FRFTG
+	Displacement	FRDISP
+	Acoustic Pressure	PRES

« 1 2 3 4 5 » 5 10 20 30 40 50

Step 2 - Adjust constraints

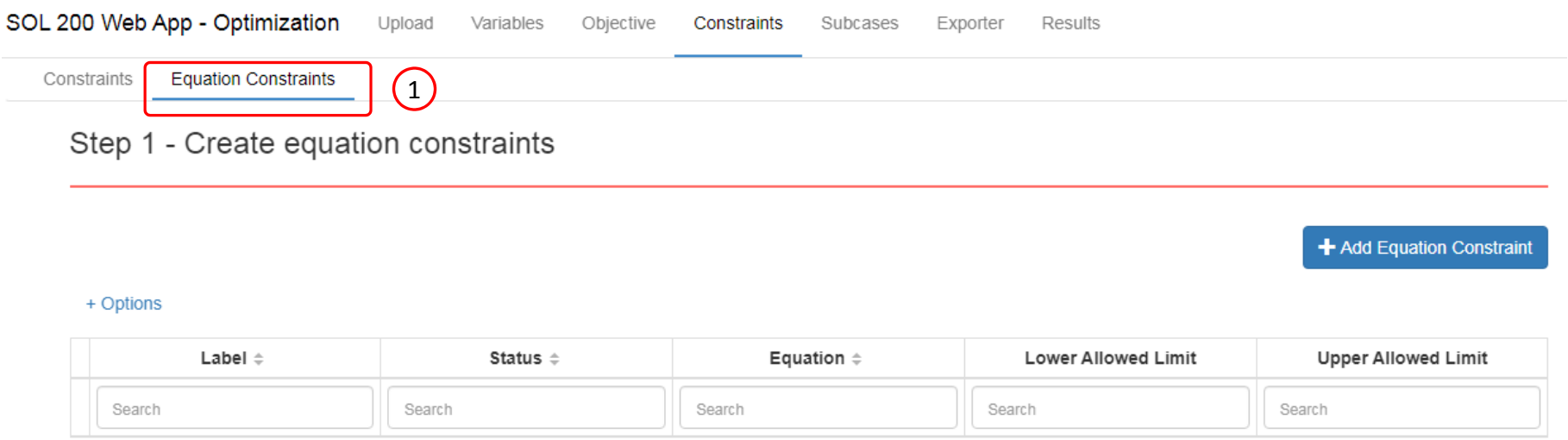
+ Options

	Label	Status	Response Type	Property Type	ATTA	ATTB	ATTi	Lower Allowed Limit	Upper Allowed Limit
	Se	Sear	Search	Search	Search	Search	Search	(3.1)	(3.2)
✖	r1	✔	VOLUME					7.99	8.01

Create Responses

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

- The responses that are used for model matching must be defined. The response can be defined in the table titled “Step A – Optional – Create additional responses.” This table is accessible by first turning on the Equation Constraint section by marking the checkbox “Step 3 ….”



Create Responses

1. Scroll to section: Step A - Optional - Create additional responses
2. Click 1 time on the Displacement response to create responses: b1
3. Configure the responses as shown to the right

- Example: Configure the following for b1
  - ATTA: 3 – RM –T3
  - ATTB: 50. (50 Hz)
  - ATTi: 1110 (grid/node 1110)

- In this example, there are 14 responses to match. One response, b1, is created here. On the next page, CSV and Excel is used to create the other 13 responses. Refer to the Appendix on how to create the 13 responses manually.

Step A - Optional - Create additional responses (1)

Select an analysis type

SOL 111 - Modal Frequency Response

Select a response

	Response Description	Response Type
	Search	Search
+	Weight	WEIGHT
+	Volume	VOLUME
+	Fatigue, random vibration fatigue analysis	FRFTG
(2) +	Displacement	FRDISP
+	Acoustic Pressure	PRES

« 1 2 3 4 5 »

5 10 20 30 40 50

Step B - Optional - Adjust responses

+ Options

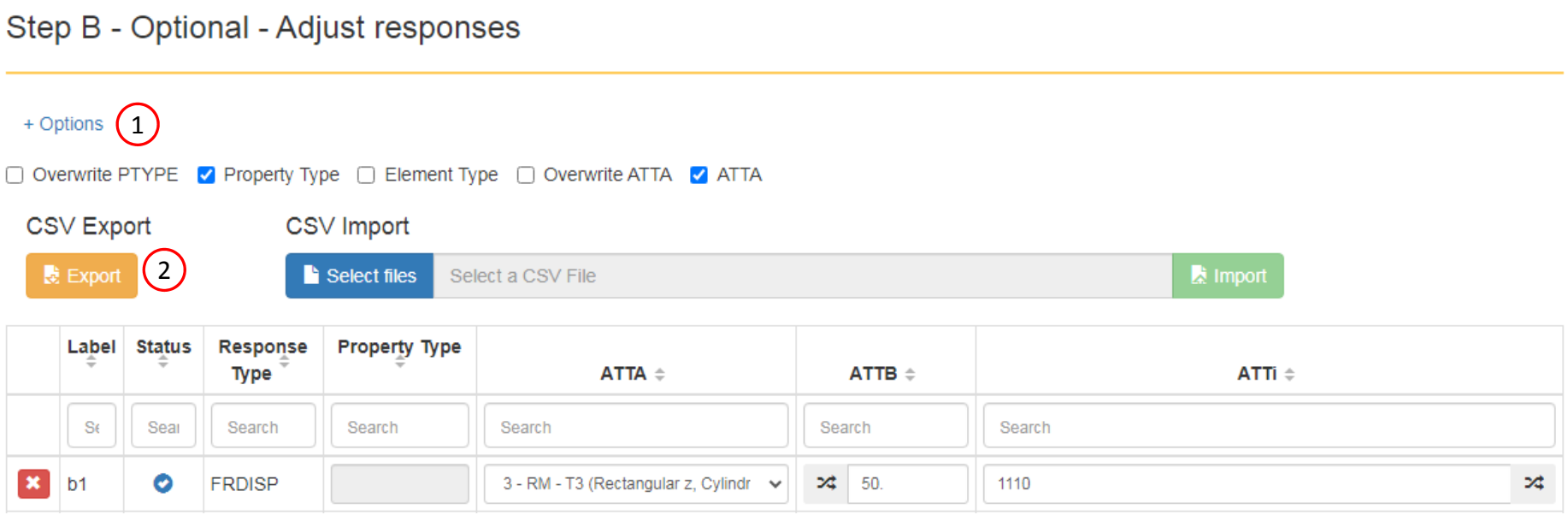
	Label	Status	Response Type	Property Type	ATTA	ATTB	ATTi
	Se	Sear	Search	Search	Search	Search	Search
✖	b1	✔	FRDISP		3 - RM - T3 (Rectangular z, Cylindr	50.	1110

(3)

CSV Change of Responses

1. Click +Options
2. Click Export

- Once Export is clicked, a CSV file is downloaded.
- When using the CSV Export capability, it is best to first create and configure one response that serves as an example for other responses that will be created.

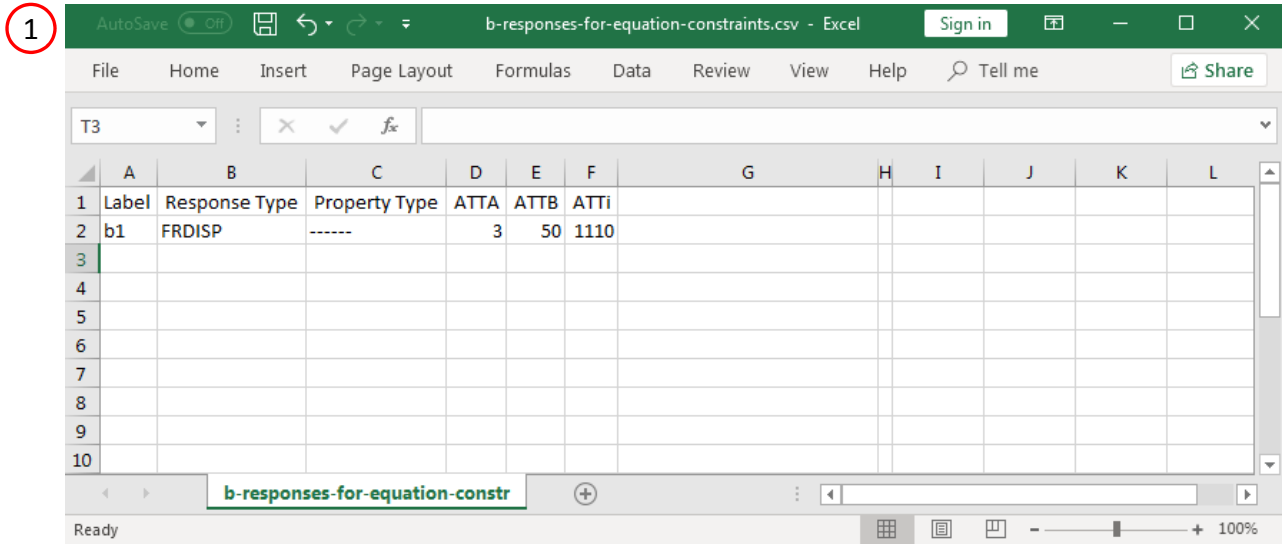


CSV Change of Responses

In the following steps, this will be done:

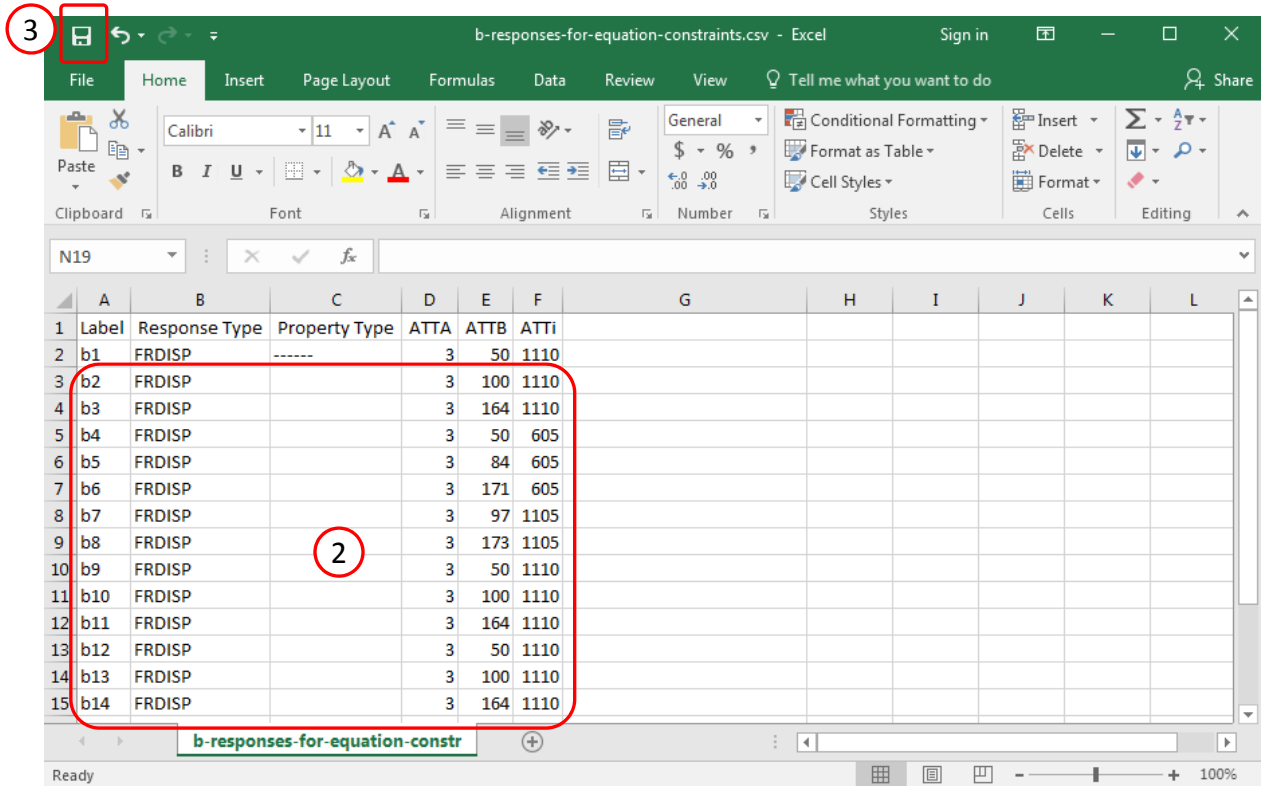
1. Open the downloaded file in Excel
2. Create 13 new rows and make the indicated changes
3. Save the file

Before



Label	Response Type	Property Type	ATTA	ATTB	ATTi
b1	FRDISP	------	3	50	1110

After



Label	Response Type	Property Type	ATTA	ATTB	ATTi
b1	FRDISP	------	3	50	1110
b2	FRDISP		3	100	1110
b3	FRDISP		3	164	1110
b4	FRDISP		3	50	605
b5	FRDISP		3	84	605
b6	FRDISP		3	171	605
b7	FRDISP		3	97	1105
b8	FRDISP		3	173	1105
b9	FRDISP		3	50	1110
b10	FRDISP		3	100	1110
b11	FRDISP		3	164	1110
b12	FRDISP		3	50	1110
b13	FRDISP		3	100	1110
b14	FRDISP		3	164	1110

CSV Change of Responses

1. Select the .csv file that was modified on the previous slide.
2. Click Import.
3. A summary of changes are shown.

- The necessary 14 responses are now available in the web app.
- MSC Nastran has strict formatting requirements. For example, characters such as !, @, # are not valid for input fields on bulk data entries. Excel has no formatting rules for MSC Nastran, so care must be taken to ensure the formatting is MSC Nastran friendly. On CSV import, a summary is reported indicating all the changes or errors encountered.

Step B - Optional - Adjust responses

+ Options

☐ Overwrite PTYPE ☑ Property Type ☐ Element Type ☐ Overwrite ATTA ☑ ATTA

CSV Export

Export

CSV Import

1 Select files b-responses-for-equation-constraints.csv Import 2 CSV imported

3 Summary of successful updates. All other data untouched.

Label	Field	Previous Value	New Value
Created b2			
Created b3			
Created b4			
Created b5			
Created b6			
Created b7			
Created b8			
Created b9			
Created b10			

	Label	Status	Response Type	Property Type	ATTA	ATTB	ATTi
	Se	Sear	Search	Search	Search	Search	Search
✖	b1	✔	FRDISP		3 - RM - T3 (Rectangular z, Cylindr	50.	1110
✖	b2	✔	FRDISP		3 - RM - T3 (Rectangular z, Cylindr	100.	1110
✖	b3	✔	FRDISP		3 - RM - T3 (Rectangular z, Cylindr	164.	1110
✖	b4	✔	FRDISP		3 - RM - T3 (Rectangular z, Cylindr	50.	605
✖	b5	✔	FRDISP		3 - RM - T3 (Rectangular z, Cylindr	84.	605

« 1 2 3 »

5 10 20 30 40 50

CSV Change of Responses

1. Click +Options
2. Click 20 to list at most 20 rows.

- Since this example has only 14 responses, only 14 rows are displayed.

Step B - Optional - Adjust responses

+ Options (1)

	Label	Status	Response Type	Property Type	ATTA	ATTB	ATTi
	Se	Sear	Search	Search	Search	Search	Search
	b1		FRDISP		3 - RM - T3 (Rectangular z, Cylindr	50.	1110
	b2		FRDISP		3 - RM - T3 (Rectangular z, Cylindr	100.	1110
	b3		FRDISP		3 - RM - T3 (Rectangular z, Cylindr	164.	1110
	b4		FRDISP		3 - RM - T3 (Rectangular z, Cylindr	50.	605
	b5		FRDISP		3 - RM - T3 (Rectangular z, Cylindr	84.	605
	b6		FRDISP		3 - RM - T3 (Rectangular z, Cylindr	171.	605
	b7		FRDISP		3 - RM - T3 (Rectangular z, Cylindr	97.	1105
	b8		FRDISP		3 - RM - T3 (Rectangular z, Cylindr	173.	1105
	b9		FRDISP		3 - RM - T3 (Rectangular z, Cylindr	50.	1110
	b10		FRDISP		3 - RM - T3 (Rectangular z, Cylindr	100.	1110
	b11		FRDISP		3 - RM - T3 (Rectangular z, Cylindr	164.	1110
	b12		FRDISP		3 - RM - T3 (Rectangular z, Cylindr	50.	1110
	b13		FRDISP		3 - RM - T3 (Rectangular z, Cylindr	100.	1110
	b14		FRDISP		3 - RM - T3 (Rectangular z, Cylindr	164.	1110

5 10 20 30 40 50

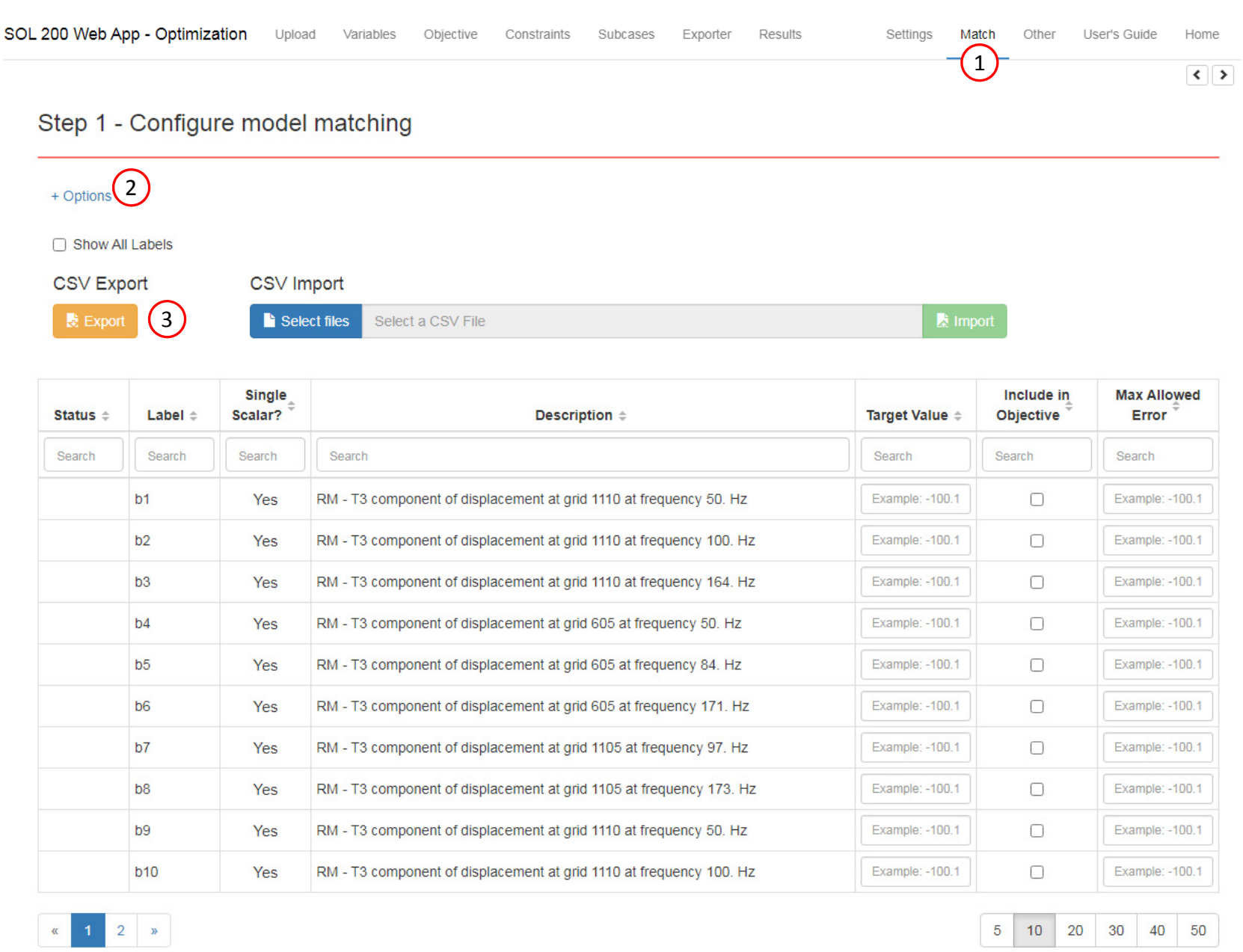
(2)

Configure Model Matching

1. Click Match
2. Click + Options
3. Click Export

A new CSV file is downloaded. Open the file in Excel.

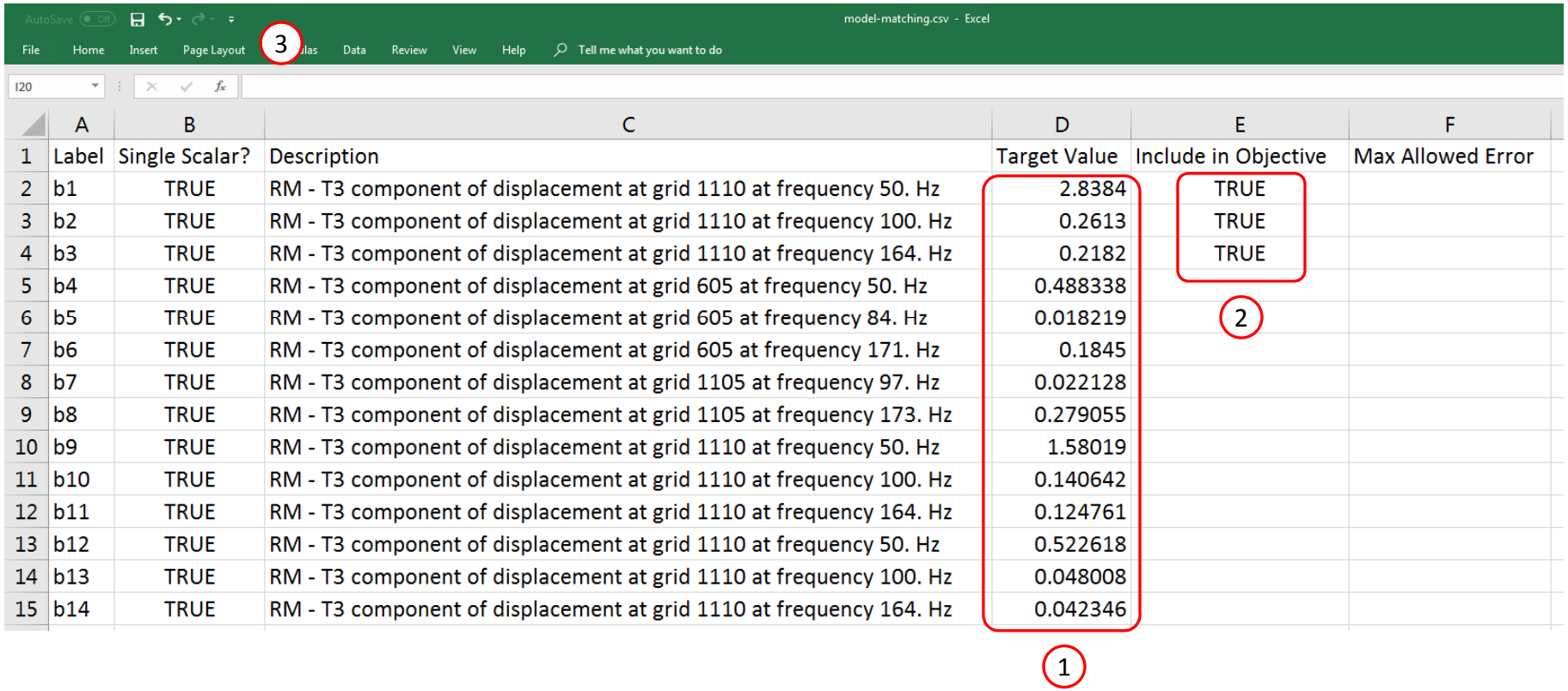
- There are 2 methods to specify model matching data, e.g. target values, include in objective, allowed errors.
  - Method 1 – Supply the data directly in the web app
  - Method 2 – Use Excel and CSV to supply the data.
- This example will use Method 2.



Configure Model Matching

1. Add the indicated Target Values
2. Set the value to TRUE for the indicated cells
3. Click Save

- Excel is used to modify the CSV file and supply information for the target values, include in objective and allowed errors.
- If a label has TRUE for “Include in Objective,” then the error will be minimized in the objective.
- If a label has a value for “Max Allowed Error,” then the error will be constrained to be less than the max allowed error.
- If the Target Value is provided, but both the “Include in Objective” and “Max Allowed Error” cells are both blank, upon import to the web app, a default value of .01 will be used for “Max Allowed Error.”
- A label can be set for both “Include in Objective” and “Max Allowed Error.”



	A	B	C	D	E	F
1	Label	Single Scalar?	Description	Target Value	Include in Objective	Max Allowed Error
2	b1	TRUE	RM - T3 component of displacement at grid 1110 at frequency 50. Hz	2.8384	TRUE	
3	b2	TRUE	RM - T3 component of displacement at grid 1110 at frequency 100. Hz	0.2613	TRUE	
4	b3	TRUE	RM - T3 component of displacement at grid 1110 at frequency 164. Hz	0.2182	TRUE	
5	b4	TRUE	RM - T3 component of displacement at grid 605 at frequency 50. Hz	0.488338		
6	b5	TRUE	RM - T3 component of displacement at grid 605 at frequency 84. Hz	0.018219		
7	b6	TRUE	RM - T3 component of displacement at grid 605 at frequency 171. Hz	0.1845		
8	b7	TRUE	RM - T3 component of displacement at grid 1105 at frequency 97. Hz	0.022128		
9	b8	TRUE	RM - T3 component of displacement at grid 1105 at frequency 173. Hz	0.279055		
10	b9	TRUE	RM - T3 component of displacement at grid 1110 at frequency 50. Hz	1.58019		
11	b10	TRUE	RM - T3 component of displacement at grid 1110 at frequency 100. Hz	0.140642		
12	b11	TRUE	RM - T3 component of displacement at grid 1110 at frequency 164. Hz	0.124761		
13	b12	TRUE	RM - T3 component of displacement at grid 1110 at frequency 50. Hz	0.522618		
14	b13	TRUE	RM - T3 component of displacement at grid 1110 at frequency 100. Hz	0.048008		
15	b14	TRUE	RM - T3 component of displacement at grid 1110 at frequency 164. Hz	0.042346		

Configure Model Matching

1. Select the CSV file that has been updated and saved
2. Click Import
3. A summary of changes is shown
4. The table has been updated to match the data in the CSV file

- If a target value is specified, then one of the following must be set: Include in Objective or Max Allowed Error. When a CSV is uploaded, if neither of these options are set, the Max Allowed Error is automatically set to .01. This value can be modified.
- Labels configured for Include in Objective are added to the Equation Objective. Labels configured with Max Allowed Error have corresponding Equation Constraints. Refer to the Equation Objective and Equation Constraint sections. A label can be set for both Include in Objective and Max Allowed Error.

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

Step 1 - Configure model matching

+ Options

Show All Labels

CSV Export

Export

1

CSV Import

Select files | model-matching.csv | Import

2

CSV imported

3

Summary of successful updates. All other data untouched.

Label	Field	Previous Value	New Value
b1	Target Value		2.8384
b1	Include in Objectiv...		true
b2	Target Value		0.2613
b2	Include in Objectiv...		true
b3	Target Value		0.2182
b3	Include in Objectiv...		true
b4	Target Value		0.488338
b4	Max Allowed Error		.01 (Auto inserted)
b5	Target Value		0.018219

Status	Label	Single Scalar?	Description	Target Value	Include in Objective	Max Allowed Error
Search	Search	Search	Search	Search	Search	Search
✓	b1	Yes	RM - T3 component of displacement at grid 1110 at frequency 50. Hz	2.8384	☑	Example: -100.1
✓	b2	Yes	RM - T3 component of displacement at grid 1110 at frequency 100. Hz	0.2613	☑	Example: -100.1
✓	b3	Yes	RM - T3 component of displacement at grid 1110 at frequency 164. Hz	0.2182	☑	Example: -100.1
✓	b4	Yes	RM - T3 component of displacement at grid 605 at frequency 50. Hz	0.488338	☐	.01
✓	b5	Yes	RM - T3 component of displacement at grid 605 at frequency 84. Hz	0.018219	☐	.01
✓	b6	Yes	RM - T3 component of displacement at grid 605 at frequency 171. Hz	0.1845	☐	.01
✓	b7	Yes	RM - T3 component of displacement at grid 1105 at frequency 97. Hz	0.022128	☐	.01
✓	b8	Yes	RM - T3 component of displacement at grid 1105 at frequency 173. Hz	0.279055	☐	.01
✓	b9	Yes	RM - T3 component of displacement at grid 1110 at frequency 50. Hz	1.58019	☐	.01
✓	b10	Yes	RM - T3 component of displacement at grid 1110 at frequency 100. Hz	0.140642	☐	.01

4

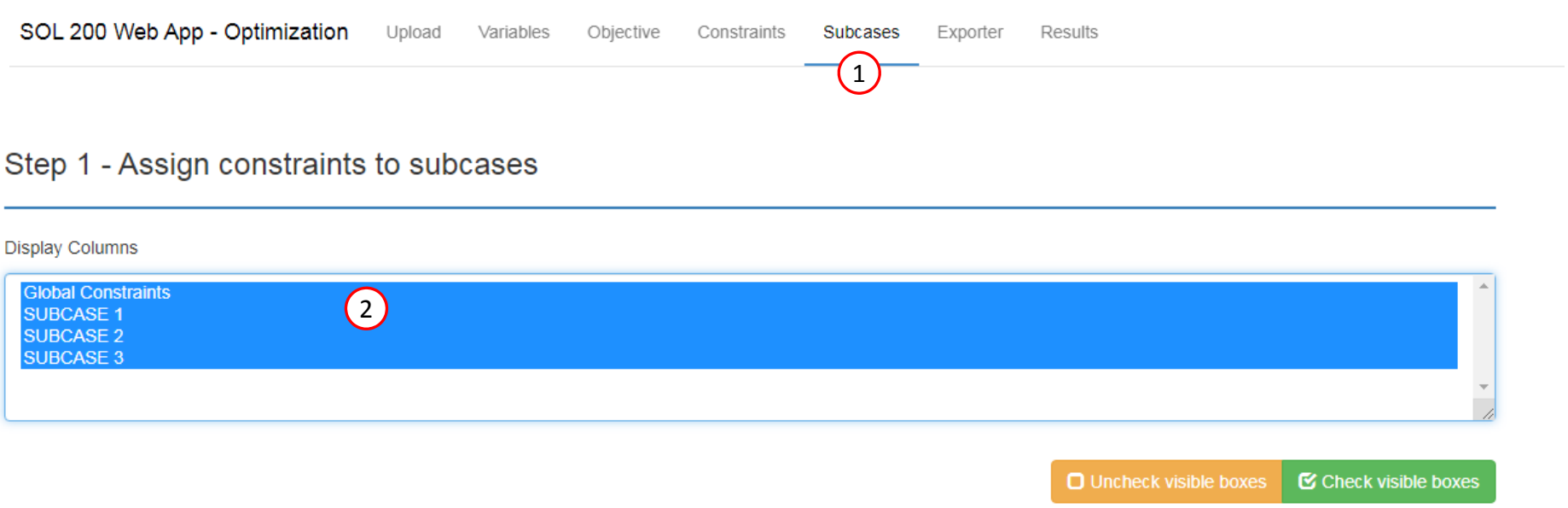
« 1 2 »

5 10 20 30 40 50

Assign Constraints to Load Cases (SUBCASES)

1. Click Subcases
2. Select all the Subcases to display the corresponding columns in the table

- This example involves multiple subcases. Model matching will be performed across different subcases.



Assign Constraints to Load Cases (SUBCASES)

1. Click 20 on the pagination bar
2. Assign r1 as a Global Constraint
3. This tutorial performs model matching for multiple subcases. The constraints must be assigned to the subcases accordingly.
3. Model matching for labels b4, b5, b6, b7 and b8 belong to SUBCASE 1. Mark the indicated checkboxes.
4. Model matching for labels b9, b10, b11 belong to SUBCASE 2. Mark the indicated checkboxes.
5. Model matching for labels b12, b13, b14 belong to SUBCASE 3. Mark the indicated checkboxes.

- Note that the labels R1, R2, …., may not necessarily be identical to the image on this page. Refer to the labels b4, b5, b6, …, in the Description column to assign the constraints.

+ Options

	Status	Label	Response Type	Description	Global Constraints	SUBCASE 1	SUBCASE 2	SUBCASE 3
		Search	Search	Search				
		r1	VOLUME	Volume of entire model	☑			
		R1	Equation	The least square difference between analysis result b4 and target value 0.488338.		☑	☐	☐
		R2	Equation	The least square difference between analysis result b5 and target value 0.018219.		☑	☐	☐
		R3	Equation	The least square difference between analysis result b6 and target value 0.1845.		☑	☐	☐
		R4	Equation	The least square difference between analysis result b7 and target value 0.022128.		☑	☐	☐
		R5	Equation	The least square difference between analysis result b8 and target value 0.279055.		☑	☐	☐
		R6	Equation	The least square difference between analysis result b9 and target value 1.58019.		☐	☑	☐
		R7	Equation	The least square difference between analysis result b10 and target value 0.140642.		☐	☑	☐
		R8	Equation	The least square difference between analysis result b11 and target value 0.124761.		☐	☑	☐
		R9	Equation	The least square difference between analysis result b12 and target value 0.522618.		☐	☐	☑
		R10	Equation	The least square difference between analysis result b13 and target value 0.048008.		☐	☐	☑
		R11	Equation	The least square difference between analysis result b14 and target value 0.042346.		☐	☐	☑

5 10 20 30 40 50

1 2 3 4 5

Assign Constraints to Load Cases (SUBCASES)

1. Scroll to section: Step B - Optional - Configure DRSPAN for equation objective and constraints
2. Configure DRSPAN such that labels b1, b2, b3 are sourced form SUBCASE 1

- Each subcase will yield different displacement frequency responses. The equation objective R0 is dependent on labels b1, b2 and b3, any of which can come from subcase 1, 2 or 3. The DRPSAN option is used to specify the subcase in which each label is sourced from.
- In this example, the equation objective is dependent on b1 from subcase 1, b2 from subcase 1 and b3 from subcase 1.

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

1

Step B - Optional - Configure DRSPAN for equation objective and constraints

+ Info

Label	Status	Configure SUBCASEs of Equation Inputs
Search	Search	
R0		R0 (b1 SUBCASE 1 ,b2 SUBCASE 1 ,b3 SUBCASE 1 ,)

2

R0		R0 (b1 SUBCASE 1 , b2 SUBCASE 1 , b3 SUBCASE 1 ,)

Export New BDF Files

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

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

1

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

BDF Output - Model

```
assign userfile = 'optimization_results.csv', status = unknown,
form = formatted, unit = 52
ID MSC  DSOUG7 $ v2004 ehj 25-Jun-2003
TIME 200
SOL 200
CEND

SET 30001 = 7000001, 7000002, 7000003
TITLE = Synthesis of Responses across Different Frequencies: DSOUG7
ECHO   = NONE
SET 10 = 1110
$                          ANALYSIS AS WELL AS SENSITIVITY ANALYSIS
   DESOBJ(MIN) = 9000000
   DESGLB = 40000000
   $ DSAPRT(FORMATTED, EXPORT, END=SENS) = ALL
subcase 1
   ANALYSIS = MFREQ
   DESSUB = 40000001
   DRSPAN = 30001
SPC          = 100
DLOAD        = 700
FREQ         = 740
METHOD       = 500
sdamping   = 2000
output
 disp(plot,phase) = ALL
subcase 2
   ANALYSIS = MFREQ
   DESSUB = 40000002
```

Download BDF Files

Download BDF Files

2

BDF Output - Design Model

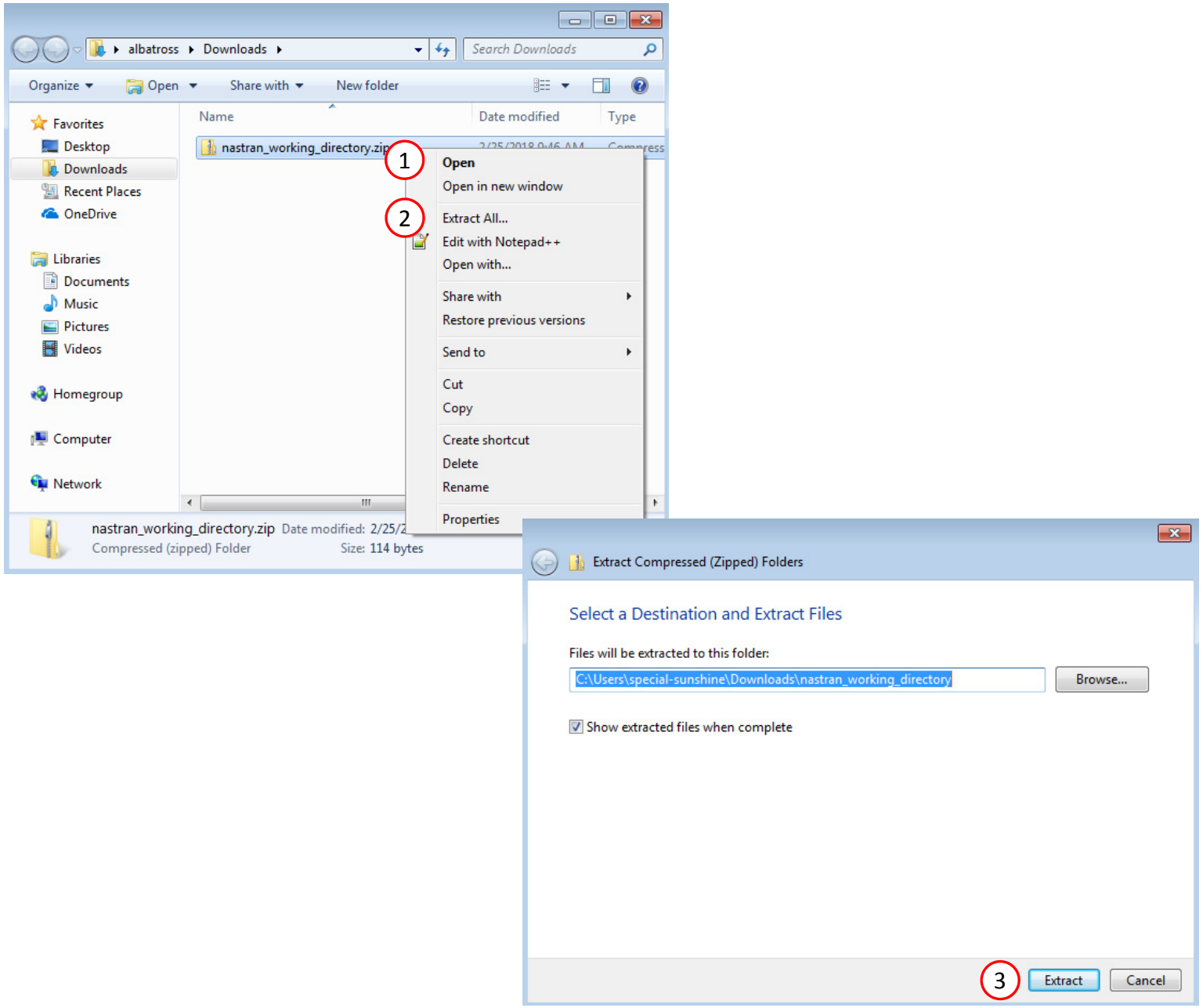
```
$*************************************************************************
$*                                                                       *
$*                            Design Model                               *
$*                                                                       *
$*************************************************************************
$
$                          Design Variables - Type 1
$-----------------------------------------------------------------------
$
$
$

DVPREL1 1000001 PSHELL  1       T
        100001  1.0
DVPREL1 1000002 PSHELL  2       T
        100002  1.0
DVPREL1 1000003 PSHELL  3       T
        100003  1.0
DVPREL1 1000004 PSHELL  4       T
        100004  1.0
DVPREL1 1000005 PSHELL  5       T
        100005  1.0
DVPREL1 1000006 PSHELL  6       T
        100006  1.0
DVPREL1 1000007 PSHELL  7       T
        100007  1.0
DVPREL1 1000008 PSHELL  8       T
        100008  1.0
DVPREL1 1000009 PSHELL  9       T
        100009  1.0
DVPREL1 1000010 PSHELL  10      T
        100010  1.0
$
$
DESVAR  100001  X1      .08     .01     1.
DESVAR  100002  X2      .08     .01     1.
DESVAR  100003  X3      .08     .01     1.
DESVAR  100004  X4      .08     .01     1.
DESVAR  100005  X5      .08     .01     1.
DESVAR  100006  X6      .08     .01     1.
DESVAR  100007  X7      .08     .01     1.
DESVAR  100008  X8      .08     .01     1.
DESVAR  100009  X9      .08     .01     1.
DESVAR  100010  X10     .08     .01     1.
```

Developed by The Engineering Lab

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

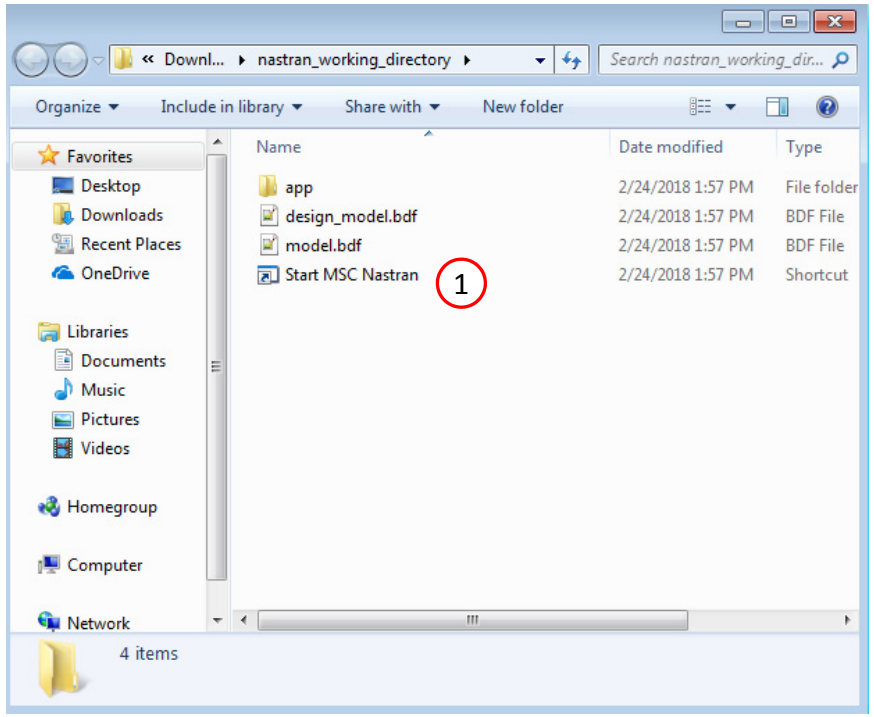
- After a successful optimization, the results will be automatically displayed as long as the following files are present: BDF, F06 and LOG.
- One can run the Nastran job on a remote machine as follows:
  1) Copy the BDF files and the INCLUDE files to a remote machine. 2) Run the MSC Nastran job on the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

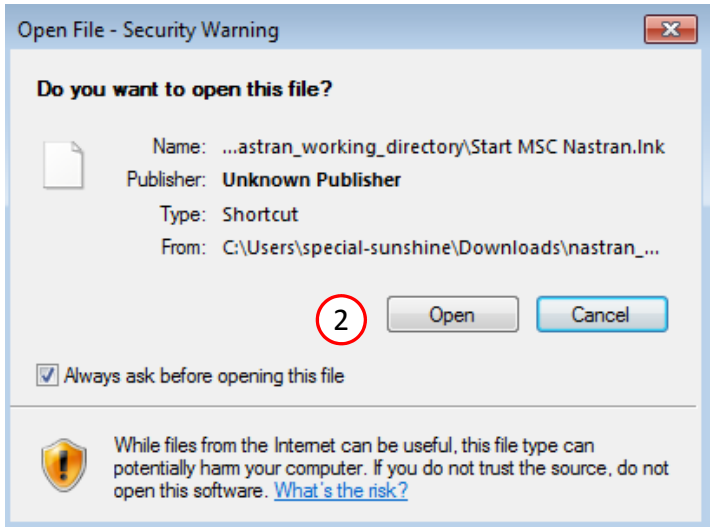
Using Linux?

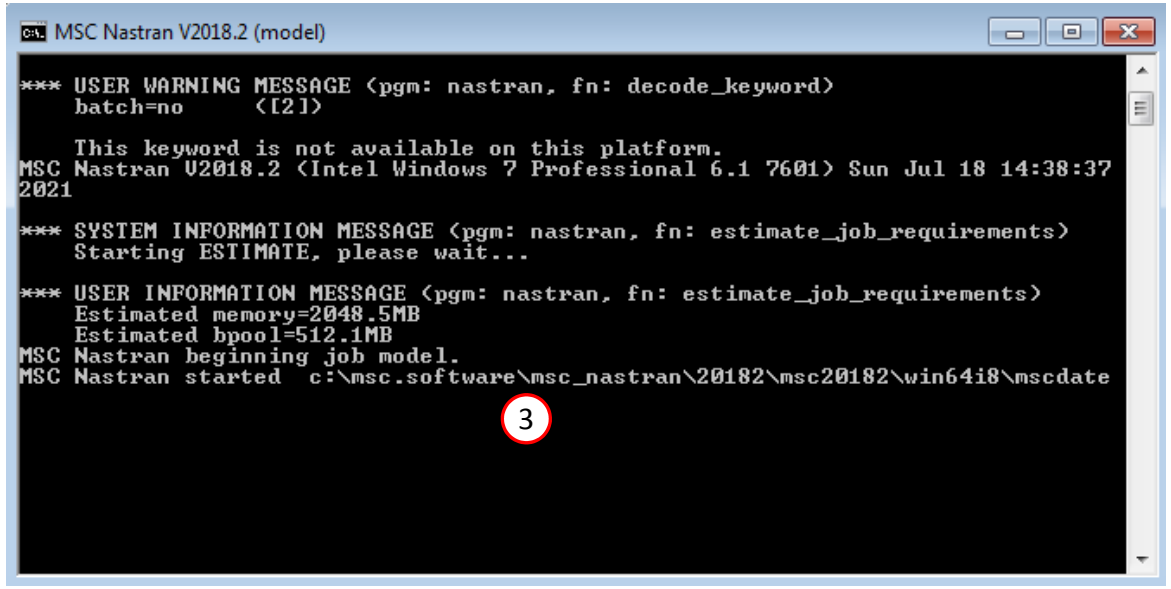
Follow these instructions:
1) Open Terminal
2) Navigate to the nastran_working_directory
   cd ./nastran_working_directory
3) Use this command to start the process
   ./Start_MSC_Nastran.sh

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. The final value of objective, normalized constraints and design variables (not shown) can be reviewed.

- When performing model matching, the final message in the F06 file may be one of the following messages:
  - RUN TERMINATED DUE TO HARD CONVERGENCE TO AN OPTIMUM
  - RUN TERMINATED DUE TO MAXIMUM NUMBER OF DESIGN CYCLES
  - RUN TERMINATED DUE TO HARD CONVERGENCE TO A BEST COMPROMISE INFEASIBLE DESIGN AT CYCLE NUMBER
- It is important to carefully interpret the final results to determine if the model matching was a success. For this example, the model matching was a success for the following reasons:
  - The objective, which is the error, is minimized as desired
  - The max normalized constraint is close to or less than 0.0
  - The Model Matching bar charts on the next page show good correlation
  - The Response vs. Frequency plots on later pages show good correlation
- If this optimization were repeated, setting the DESMAX, or maximum number of cycles, to a value of 10 will allow the optimizer to terminate sooner.

SOL 200 Web App - Local Optimization Results

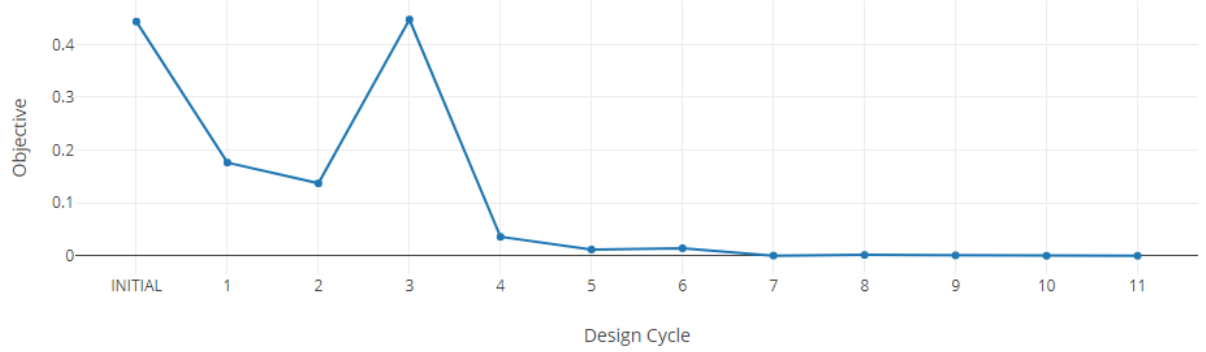
Home

Final Message in .f06

1

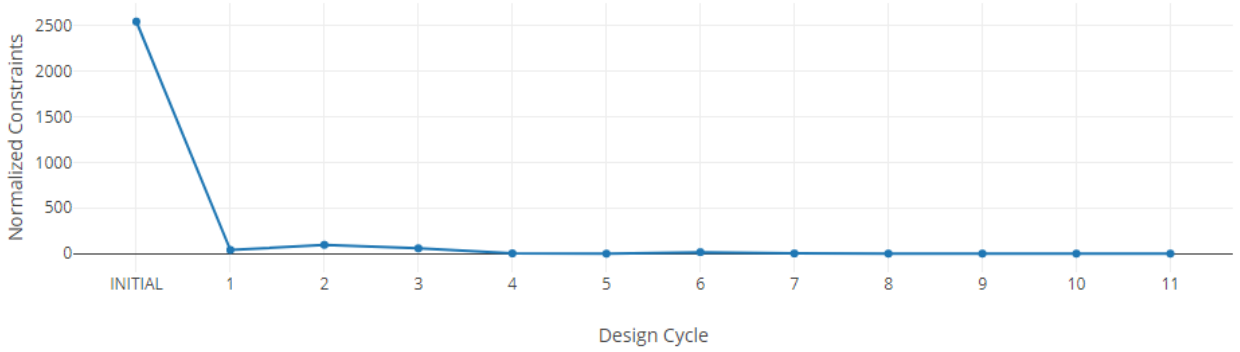
```
RUN TERMINATED DUE TO HARD CONVERGENCE TO A BEST COMPROMISE INFEASIBLE DESIGN AT CYCLE NUMBER =      11.
```

Objective



Normalized Constraints

+ Info



Review Optimization Results

1. If “Start MSC Nastran” was used, bar charts will automatically be generated.
2. These charts can be used to compare the initial and final values of the responses and the target values.

- The Bar Charts report 3 values for each response/label: The original/initial value, the final value after optimization and the target value.
- If the bars for both final and target values are equally leveled, the indicates an exact correlation.

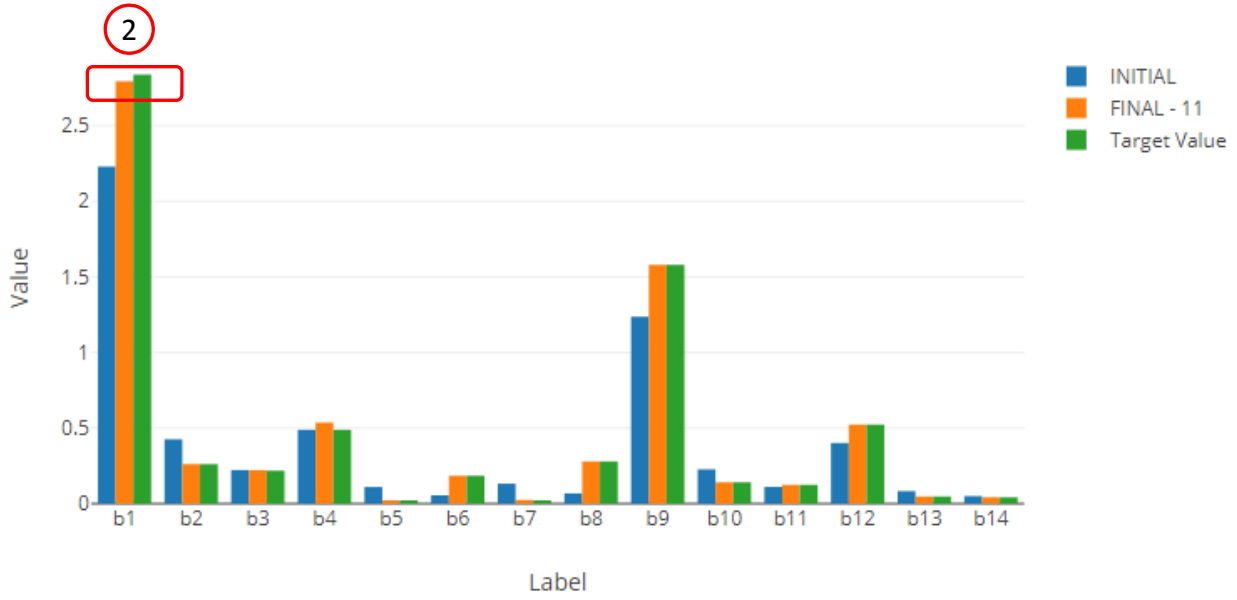
SOL 200 Web App - Responses - Model Matching

Home

Model Matching Bar Charts

1

2



Select a response

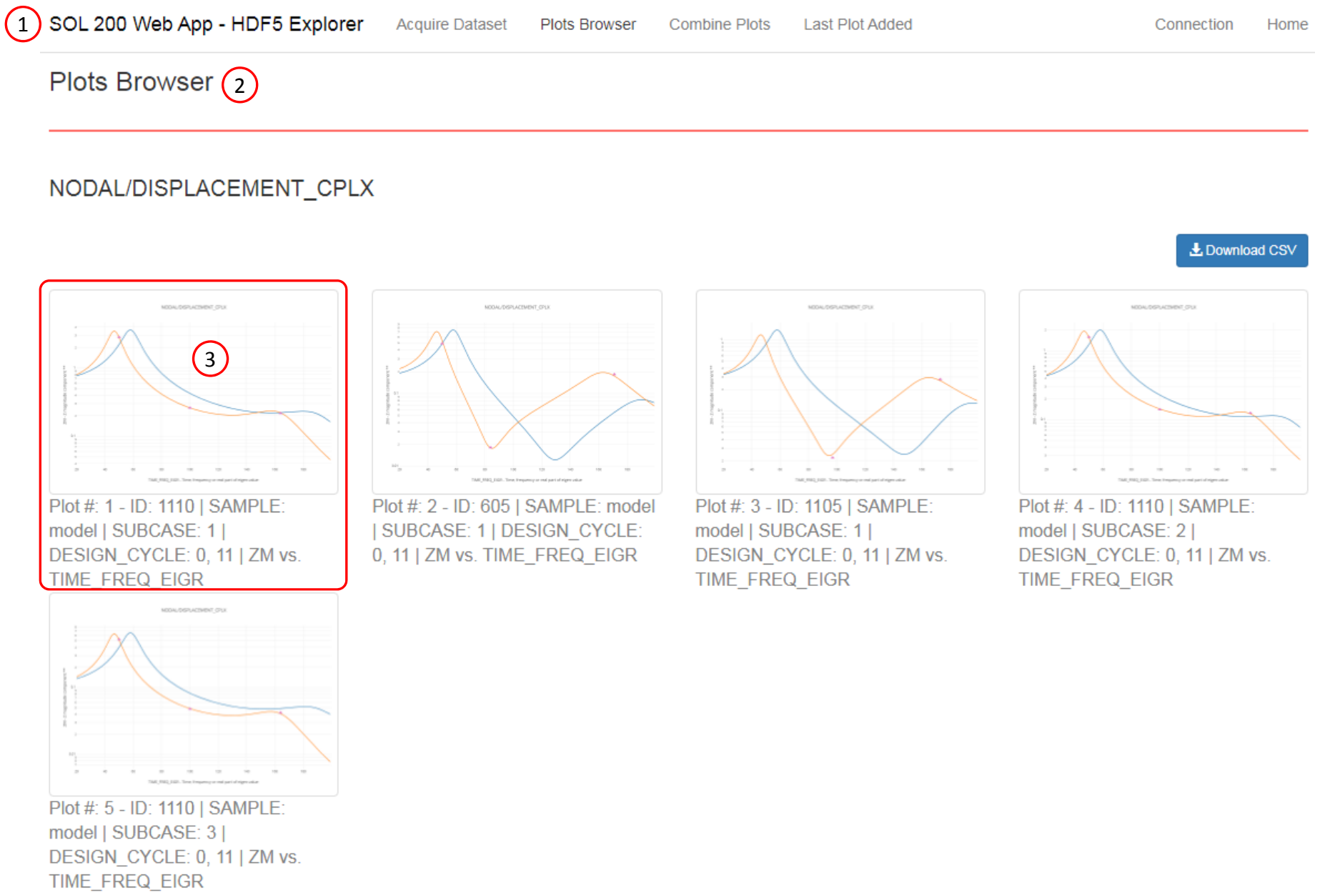
b1
b2
b3
b4
b5
b6
b7
b8
b9
b10

Design Cycle	b1	b2	b3	b4
	RM - T3 component of displacement at grid 1110 at frequency 50. Hz	RM - T3 component of displacement at grid 1110 at frequency 100. Hz	RM - T3 component of displacement at grid 1110 at frequency 164. Hz	RM - T3 at grid 6
INITIAL	2.2289E+00	4.2585E-01	2.2228E-01	4.8834E
FINAL - 11	2.7953E+00	2.6159E-01	2.2136E-01	5.3634E
Target Value	2.8384E+0	2.6130E-1	2.1820E-1	4.8834E

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

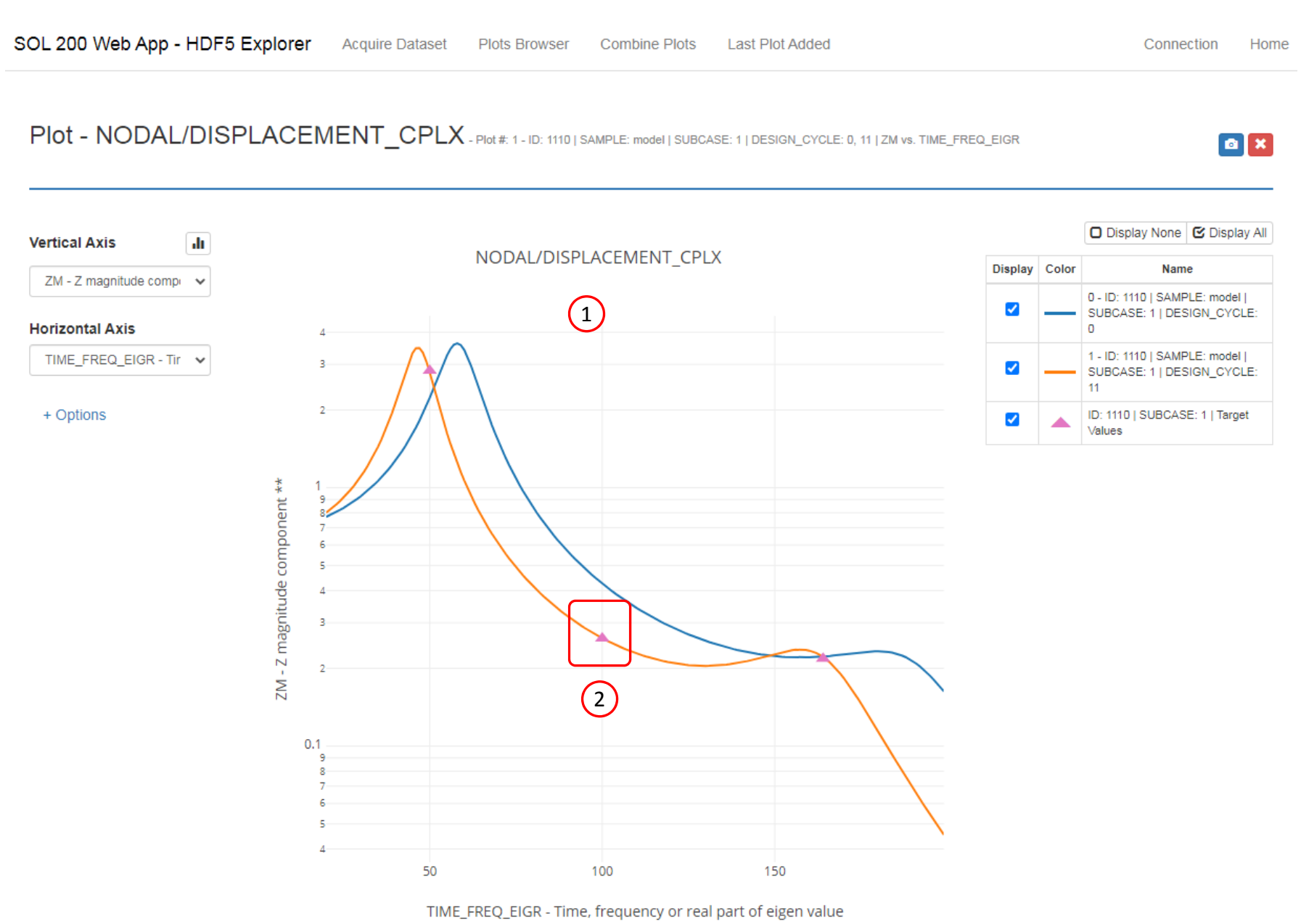
- Use the navigation bar at the top of the web app to navigate between the following sections
  - Acquire Dataset
  - Plots Browser
  - Combine Plots
  - Last Plot Added



Review Dynamic Results

1. The plot contains the INITIAL and FINAL values of the dynamic response.
2. The target values are shown by triangle markers. It is shown that the final displacement curve correlates to the target values.

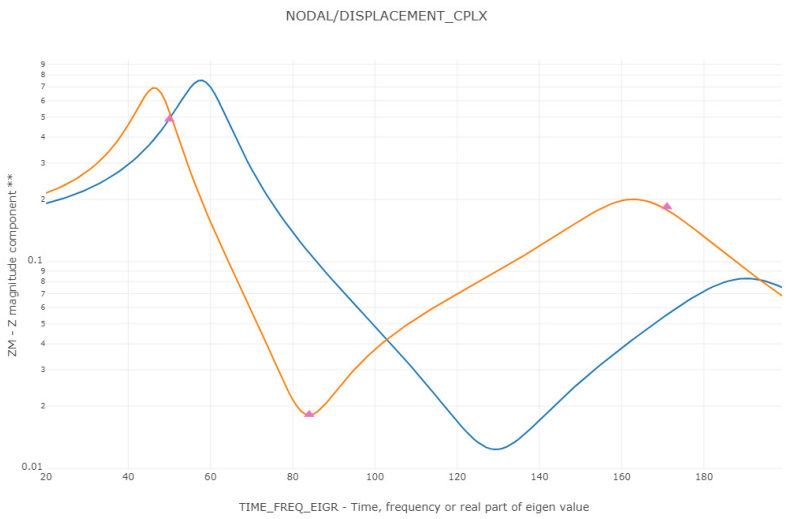
- The HDF5 Explorer is useful for creating plots of frequency response analysis results and can be used in non-optimization scenarios.



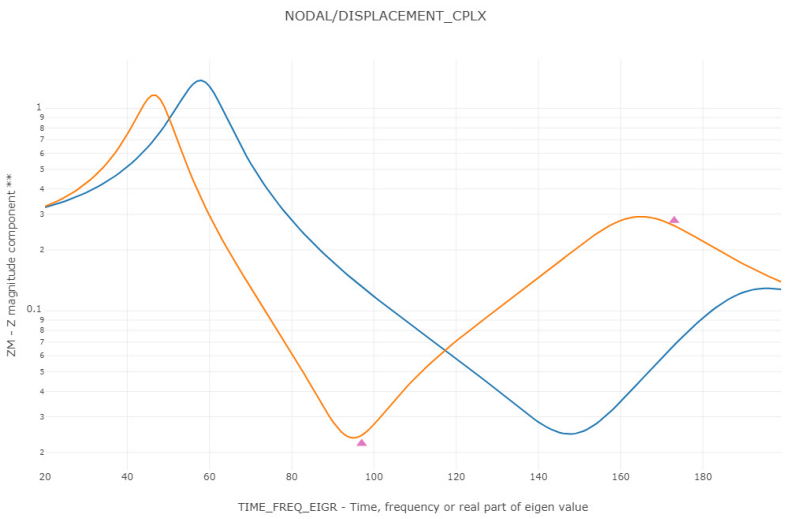
Results
Subcase 1

INITIAL FEA Results
FINAL FEA Results
Experiment/ Target Values

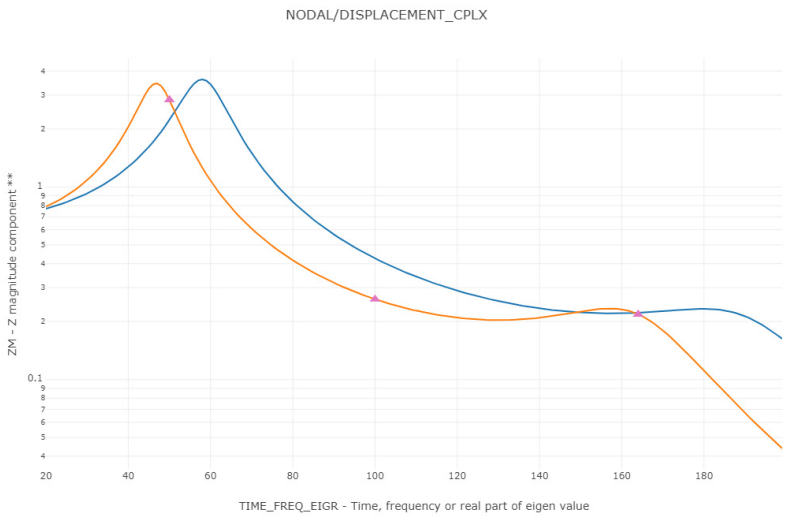
Transverse displacement at grid 605



Transverse displacement at grid 1105

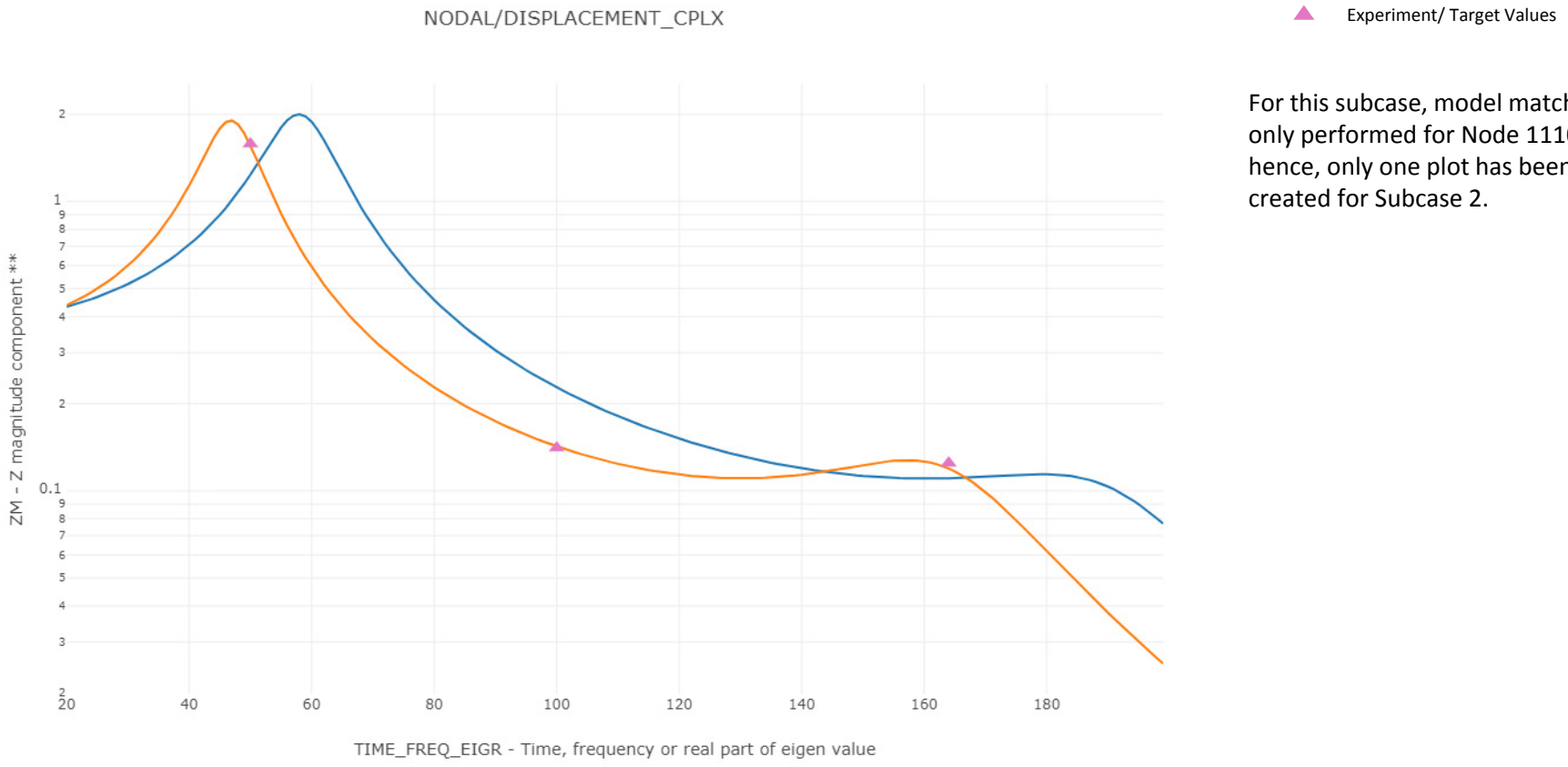


Transverse displacement at grid 1110



Results
Subcase 2

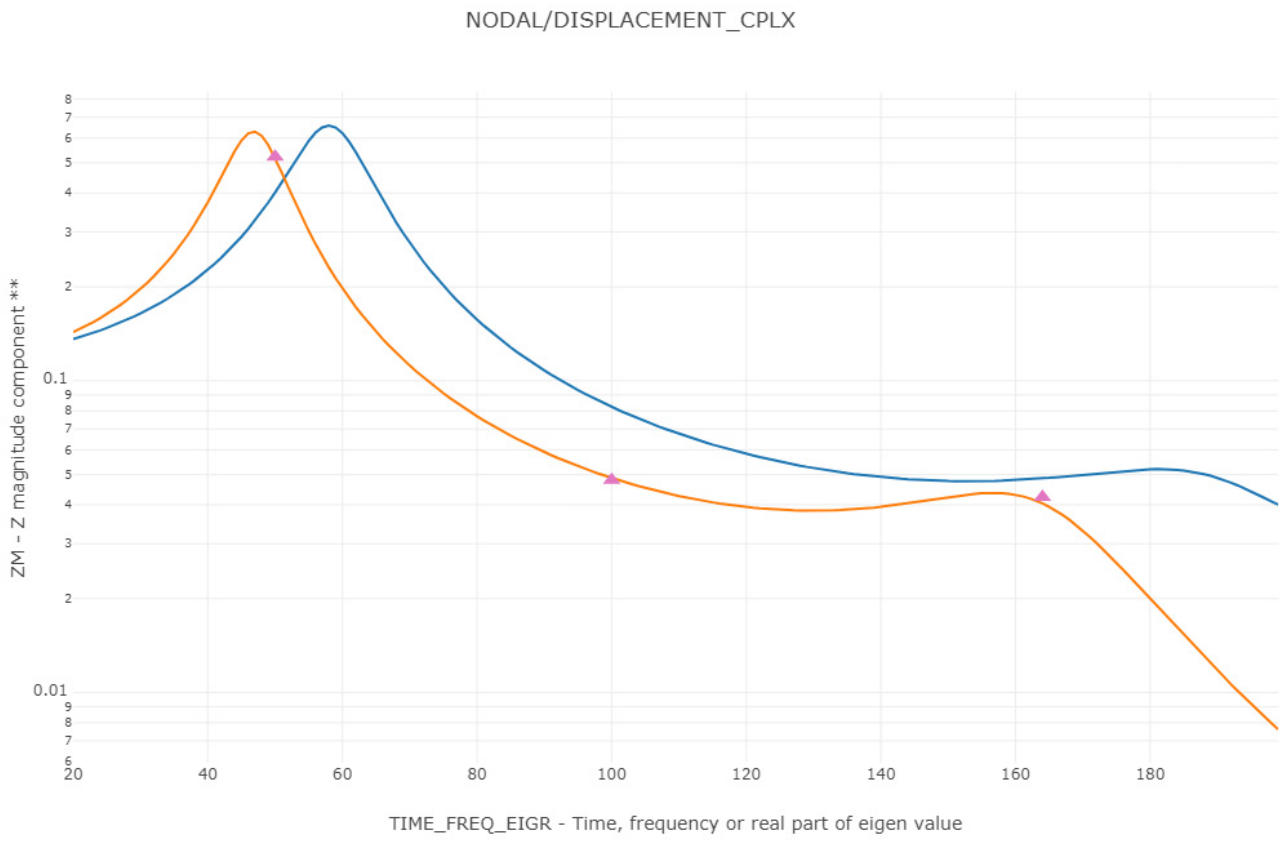
Transverse displacement at grid 1110



For this subcase, model matching is only performed for Node 1110, hence, only one plot has been created for Subcase 2.

Results
Subcase 3

Transverse displacement at grid 1110



INITIAL FEA Results
FINAL FEA Results
Experiment/ Target Values

For this subcase, model matching is only performed for Node 1110, hence, only one plot has been created for Subcase 3.

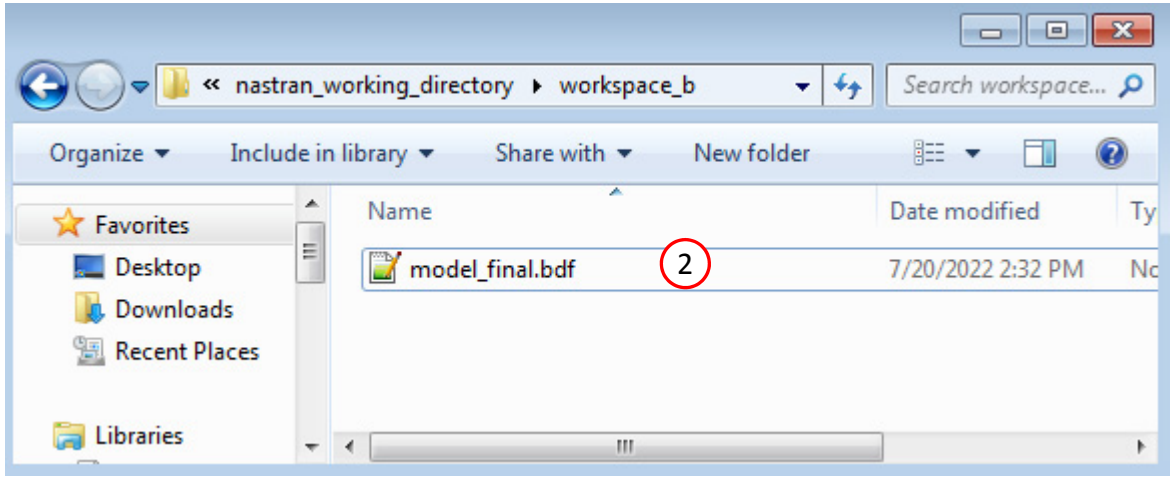
Update the Original Model

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

```
$ Elements and Element Properties for region : Section_1
PSHELL  1       150     .08     150
$ Elements and Element Properties for region : Section_2
PSHELL  2       150     .08     150
$ Elements and Element Properties for region : Section_3
PSHELL  3       150     .08     150
$ Elements and Element Properties for region : Section_4
PSHELL  4       150     .08     150
$ Elements and Element Properties for region : Section_5
PSHELL  5       150     .08     150
$ Elements and Element Properties for region : Section_6
PSHELL  6       150     .08     150
$ Elements and Element Properties for region : Section_7
PSHELL  7       150     .08     150
$ Elements and Element Properties for region : Section_8
PSHELL  8       150     .08     150
$ Elements and Element Properties for region : Section_9
PSHELL  9       150     .08     150
$ Elements and Element Properties for region : Section_10
PSHELL  10      150     .08     150
RLOAD1  700     730                     800
RLOAD1  701     740                     801
RLOAD1  702     750                     802
SPC1    100     246     1101    1102    1103    1104    1105    1106
        1107    1108    1109
SPC1    100     246     1110
SPC1    100     123456  100     101     102     103     104     105
        106     107     108     109     110     200     300     400
        500     600     700     800     900     1000    1100
TABDMP1 2000
```

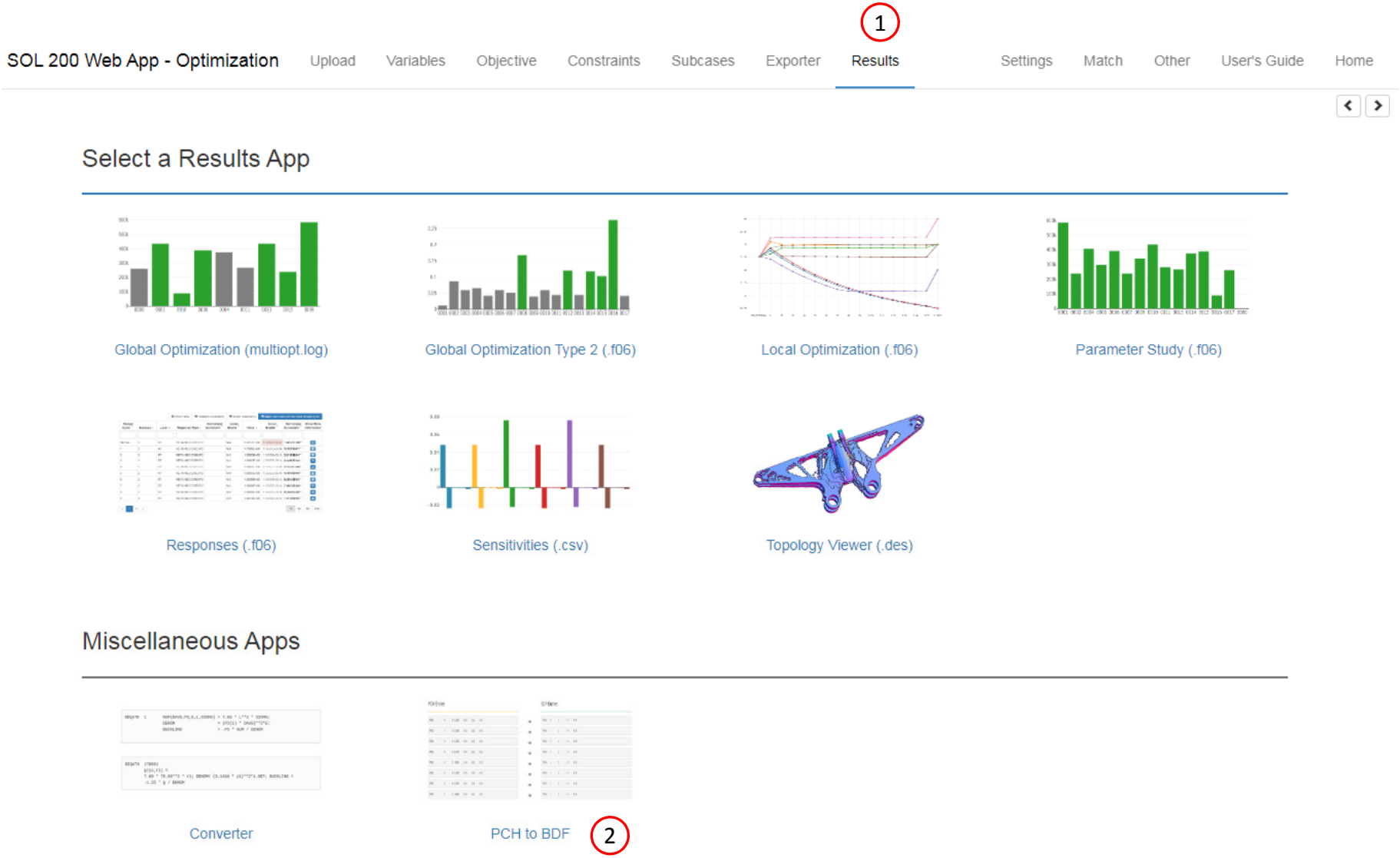
Updated BDF File (model_final.bdf)

3

```
$ Elements and Element Properties for region : Section_1
PSHELL          1     150 .118409     150   1.0         0 .833333   0.
                                  0
$ Elements and Element Properties for region : Section_2
PSHELL          2     150 .07019      150   1.0         0 .833333   0.
                                  0
$ Elements and Element Properties for region : Section_3
PSHELL          3     150 .040908     150   1.0         0 .833333   0.
                                  0
$ Elements and Element Properties for region : Section_4
PSHELL          4     150 .058417     150   1.0         0 .833333   0.
                                  0
$ Elements and Element Properties for region : Section_5
PSHELL          5     150 .047482     150   1.0         0 .833333   0.
                                  0
$ Elements and Element Properties for region : Section_6
PSHELL          6     150 .077489     150   1.0         0 .833333   0.
                                  0
$ Elements and Element Properties for region : Section_7
PSHELL          7     150 .098516     150   1.0         0 .833333   0.
                                  0
$ Elements and Element Properties for region : Section_8
PSHELL          8     150 .120287     150   1.0         0 .833333   0.
                                  0
$ Elements and Element Properties for region : Section_9
PSHELL          9     150 .167569     150   1.0         0 .833333   0.
                                  0
$ Elements and Element Properties for region : Section_10
PSHELL         10     150 .234747     150   1.0         0 .833333   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: dsoug7_multi_subcase.bdf
3. A summary of updates that will be performed are shown
4. Click Download and a new updated BDF file is downloaded

SOL 200 Web App - PCH to BDF

Home

Step 1 - Select PCH File

1 Select files model.pch

Inspecting: 100%

List of Selected Files

PCH Entries

```
PSHELL        1     150 .118409     150   1.0        0 .833333   0.0
                                0
PSHELL        2     150 .07019      150   1.0        0 .833333   0.0
                                0
PSHELL        3     150 .040908     150   1.0        0 .833333   0.0
                                0
PSHELL        4     150 .058417     150   1.0        0 .833333   0.0
                                0
PSHELL        5     150 .047482     150   1.0        0 .833333   0.0
                                0
PSHELL        6     150 .077489     150   1.0        0 .833333   0.0
                                0
PSHELL        7     150 .098516     150   1.0        0 .833333   0.0
                                0
PSHELL        8     150 .120287     150   1.0        0 .833333   0.0
                                0
PSHELL        9     150 .167569     150   1.0        0 .833333   0.0
                                0
PSHELL       10     150 .234747     150   1.0        0 .833333   0.0
                                0
```

3

Step 2 - Select BDF Files

2 Select files dsoug7_multi_subcase.bdf

Inspecting: 100%

List of Selected Files

BDF Entries

```
PSHELL  1      150     .08     150
PSHELL  2      150     .08     150
PSHELL  3      150     .08     150
PSHELL  4      150     .08     150
PSHELL  5      150     .08     150
PSHELL  6      150     .08     150
PSHELL  7      150     .08     150
PSHELL  8      150     .08     150
PSHELL  9      150     .08     150
PSHELL  10     150     .08     150
```

Step 3 - Download New BDF Files

On download, the PCH entries will replace older BDF entries.

Download 4

Update the Original Model

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

dsoug7_multi_subcase.bdf

```
$ Elements and Element Properties for region : Section_1
PSHELL  1       150     .08     150
$ Elements and Element Properties for region : Section_2
PSHELL  2       150     .08     150
$ Elements and Element Properties for region : Section_3
PSHELL  3       150     .08     150
$ Elements and Element Properties for region : Section_4
PSHELL  4       150     .08     150
$ Elements and Element Properties for region : Section_5
PSHELL  5       150     .08     150
$ Elements and Element Properties for region : Section_6
PSHELL  6       150     .08     150
$ Elements and Element Properties for region : Section_7
PSHELL  7       150     .08     150
$ Elements and Element Properties for region : Section_8
PSHELL  8       150     .08     150
$ Elements and Element Properties for region : Section_9
PSHELL  9       150     .08     150
$ Elements and Element Properties for region : Section_10
PSHELL  10      150     .08     150
RLOAD1  700     730                     800
RLOAD1  701     740                     801
RLOAD1  702     750                     802
SPC1    100     246     1101    1102    1103    1104    1105    1106
        1107    1108    1109
SPC1    100     246     1110
SPC1    100     123456  100     101     102     103     104     105
        106     107     108     109     110     200     300     400
        500     600     700     800     900     1000    1100
TABDMP1 2000
```

Original BDF/DAT File

1

dsoug7_multi_subcase.bdf

```
$ Elements and Element Properties for region : Section_1
PSHELL          1     150 .118409     150   1.0         0 .833333   0.
                                      0
$ Elements and Element Properties for region : Section_2
PSHELL          2     150 .07019      150   1.0         0 .833333   0.
                                      0
$ Elements and Element Properties for region : Section_3
PSHELL          3     150 .040908     150   1.0         0 .833333   0.
                                      0
$ Elements and Element Properties for region : Section_4
PSHELL          4     150 .058417     150   1.0         0 .833333   0.
                                      0
$ Elements and Element Properties for region : Section_5
PSHELL          5     150 .047482     150   1.0         0 .833333   0.
                                      0
$ Elements and Element Properties for region : Section_6
PSHELL          6     150 .077489     150   1.0         0 .833333   0.
                                      0
$ Elements and Element Properties for region : Section_7
PSHELL          7     150 .098516     150   1.0         0 .833333   0.
                                      0
$ Elements and Element Properties for region : Section_8
PSHELL          8     150 .120287     150   1.0         0 .833333   0.
                                      0
$ Elements and Element Properties for region : Section_9
PSHELL          9     150 .167569     150   1.0         0 .833333   0.
                                      0
$ Elements and Element Properties for region : Section_10
PSHELL         10     150 .234747     150   1.0         0 .833333   0.
                                      0
```

Downloaded BDF/DAT File

End of Tutorial

Appendix

Appendix Contents

- Manually Creating Responses
- How is error defined in this tutorial?

Manually Creating Responses

1. Scroll to section: Step A - Optional - Create additional responses
2. Click 14 times on the Displacement response to create responses: b1, b2, …, b14
3. Configure the responses as shown to the right
   - Example: Configure the following for b1
     - ATTA: 3 – RM –T3
     - ATTB: 50. (50 Hz)
     - ATTi: 1110 (grid/node 1110)
   - Repeat the same for b2 through b14 but note that each row will be different

- This tutorial used the CSV and Excel method to create all 14 responses. This page shows the process to manually create the 14 responses.

1

Step A - Optional - Create additional responses

Select an analysis type

SOL 111 - Modal Frequency Response

Select a response

2

	Response Description	Response Type
	Search	Search
+	Weight	WEIGHT
+	Volume	VOLUME
+	Fatigue, random vibration fatigue analysis	FRFTG
+	Displacement	FRDISP
+	Acoustic Pressure	PRES

Step B - Optional - Adjust responses

+ Options

3

	Label	Status	Response Type	Property Type	ATTA	ATTB	ATTi
	Search	Search	Search	Search	Search	Search	Search
×	b1	✓	FRDISP		3 - RM - T3 (Rectangular z, Cylindr	50.	1110
×	b2	✓	FRDISP		3 - RM - T3 (Rectangular z, Cylindr	100.	1110
×	b3	✓	FRDISP		3 - RM - T3 (Rectangular z, Cylindr	164.	1110
×	b4	✓	FRDISP		3 - RM - T3 (Rectangular z, Cylindr	50.	605
×	b5	✓	FRDISP		3 - RM - T3 (Rectangular z, Cylindr	84.	605
×	b6	✓	FRDISP		3 - RM - T3 (Rectangular z, Cylindr	171.	605
×	b7	✓	FRDISP		3 - RM - T3 (Rectangular z, Cylindr	97.	1105
×	b8	✓	FRDISP		3 - RM - T3 (Rectangular z, Cylindr	173.	1105
×	b9	✓	FRDISP		3 - RM - T3 (Rectangular z, Cylindr	50.	1110
×	b10	✓	FRDISP		3 - RM - T3 (Rectangular z, Cylindr	100.	1110
×	b11	✓	FRDISP		3 - RM - T3 (Rectangular z, Cylindr	164.	1110
×	b12	✓	FRDISP		3 - RM - T3 (Rectangular z, Cylindr	50.	1110
×	b13	✓	FRDISP		3 - RM - T3 (Rectangular z, Cylindr	100.	1110
×	b14	✓	FRDISP		3 - RM - T3 (Rectangular z, Cylindr	164.	1110

5 10 20 30 40 50

How is error defined in this tutorial?

There are 2 methods to define the error.

- Method A requires the use of both the lower and upper bound.
- Method B requires only the use of the upper bound.

Method A and Method B are equivalent. Method A requires both the upper and lower bound to specified, but Method B requires only the specification of an upper bound. Method B is used in this tutorial.

Let

$$\text{Error} = \frac{b1 - Target}{Target}$$

Method A

$$\text{Lower Bound} < \frac{b1 - Target}{Target} < \text{Upper Bound}$$

- $b1$: Response from FEA
- $Target$: Value from experiment
- Lower Bound: -.1 or -10%
- Upper Bound: +.1 or +10%
    - The error is allowed to be between -.1 and +.1 (Equivalently between -10% and +10%)

Method B

$$\left(\frac{b1 - Target}{Target}\right)^2 < \text{Upper Bound}$$

- $b1$: Response from FEA
- $Target$: Value from experiment
- Upper Bound: $.1^2 = .01$
    - In this method, the expression is now the error squared. The max allowed error is +/-.1 but can be expressed with one bound, i.e. $\text{error}^2 < .1^2 = .01$.