Workshop - Multi Model Optimization

AN MSC NASTRAN SOL 200 TUTORIAL
Goal: Minimize the weight of three different models of different analyses under constraints

In the structure design, it is necessary to perform design optimization using multi-models (MMO: Multi-Model Optimization) that combines two or more related optimization tasks into a single combined optimization task. The benefits are as follows:

A: Allows users to have different models that differ in their topology or in their analyses that are created to satisfy different analysis needs with proper models

B: Allows users to design the variants of vehicles or airplane with shared parts or components

C: Help users to get the best trade-off solutions using one combined optimization task rather than get different so-called optimized results from different optimization tasks
Optimization Problem Statements
Separate Design Models: Independent Design Variables, Objectives and Design Constraints

**Model 1 - m_stress**

Analysis: Statics
Objective: Minimize Weight
Constraints:
- r1: von Mises of stress, at z1, for PSHELL 1, 7
- r2: von Mises of stress, at z2, for PSHELL 1, 7
- r3: von Mises of stress, at z1, for PSHELL 3, 8
- r4: von Mises of stress, at z2, for PSHELL 3, 8
- r5: von Mises of stress, at z1, for PSHELL 8, 9, 10
- r6: von Mises of stress, at z2, for PSHELL 8, 9, 10
Variables: x1, x2, x3, x4, x5, x6, x7, x8, x9, x10

**Model 2 - m_modes**

Analysis: Modes
Objective: Minimize Weight
Constraints:
- r1: Natural frequency of mode 1, 25Hz < r1
- r2: Natural frequency of mode 2, 30Hz < r2
Settings: Mode tracking is used
Variables: x1, x2, x3, x4, x5, x6, x7, x8, x9, x10 and x11

**Model 3 - m_storsp**

Analysis: Statics
Objective: Minimize Weight
Constraints:
- r1: Displacement, y component, of node 19998
  - .15 < r1 < .15
Equation Constraint:
- R1: 1000 * 2958.4 / b1 (Effective BIW Rotational Stiffness)
  - SE13 < R1 < SE14
b1: Displacement, 4th component, of node 19998
Variables: x1, x2, x3, x4, x5, x6, x7, x8, x9, x10 and x11

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Optimization Problem Statements
Separate Design Models: Results

Model 1 - m_stress
Objective

Model 2 - m_modes
Objective

Model 3 - m_storsp
Objective

Variables

Model 1 - m_stress
Objective

Model 2 - m_modes
Objective

Model 3 - m_storsp
Objective

Variables
Separate Optimizations Tasks Without MMO

With separate optimizations for each model, different values for the variables are achieved. For example, the thickness of the door, x8, is different after each optimization. There are 3 different values for the door thickness: .55, .40 and .50.

<table>
<thead>
<tr>
<th>Design Model</th>
<th>Without MMO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model 1</td>
<td>✔</td>
</tr>
<tr>
<td>Model 2</td>
<td>✔</td>
</tr>
<tr>
<td>Model 3</td>
<td>✔</td>
</tr>
</tbody>
</table>

**Objective**
- Minimize Weight

**Constraints**
- Constraints of Model 1: ✔
- Constraints of Model 2: ✔
- Constraints of Model 3: ✔

**Variables**

| x1 | ✔ | 1.7 | ✔ | .30 | ✔ | 3.50 |
| x2 | ✔ | .45 | ✔ | .65 | ✔ | 1.05 |
| x3 | ✔ | .30 | ✔ | .10 | ✔ | 1.05 |
| x4 | ✔ | .35 | ✔ | .55 | ✔ | .550 |
| x5 | ✔ | .45 | ✔ | .65 | ✔ | 1.05 |
| x6 | ✔ | .55 | ✔ | .15 | ✔ | .850 |
| x7 | ✔ | .90 | ✔ | .25 | ✔ | 3.50 |
| x8 | ✔ | .55 | ✔ | .40 | ✔ | .500 |
| x9 | ✔ | .45 | ✔ | .95 | ✔ | .700 |
| x10| ✔ | .40 | ✔ | .20 | ✔ | .350 |
| x11| ✔ | .55 | ✔ | .850 |
Optimization Problem Statements
Multi-model Optimization: Merged Design Model

Model 1 - m_stress
Analysis: Statics
Constraints:
- r1: von Mises of stress, at z1, for PSHELL 1, 7
- r2: von Mises of stress, at z2, for PSHELL 1, 7
- r3: von Mises of stress, at z3, for PSHELL 3, 8
- r4: von Mises of stress, at z4, for PSHELL 3, 8
- r5: von Mises of stress, at z5, for PSHELL 8, 9, 10
- r6: von Mises of stress, at z6, for PSHELL 8, 9, 10

Objective: Minimize Weight

Variables: x1, x2, x3, x4, x5, x6, x7, x8, x9, x10 and x11

Model 2 - m_modes
Analysis: Modes
Constraints:
- r1: Natural frequency of mode 1, 25Hz < r1
- r2: Natural frequency of mode 2, 30Hz < r2
Settings:
- Mode tracking is used

Model 3 - m_storsp
Analysis: Statics
Constraints:
- r1: Displacement, y component, of node 19998
  - .15 < r1 < .15
Equation Constraint:
- R1: 1000 * 2958.4 / b1 (Effective BIW Rotational Stiffness)
  - 5E13 < R1 < 5E14
- b1: Displacement, 4th component, of node 19998

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Optimization Problem Statements
Merged Design Model: Linked Variables

Variables Links
- For the design variables having the same IDs from two or more models, they are optimized as shared variables and indicated as "linked." The shared variables must have the same labels, lower/upper bounds, etc. across several models or all models. Attention is needed to make sure the shared design variables are used for the same physical properties/parts across different models.
- For the design variables existing only in one model, they are unique variables to that specific model and indicated as "not linked."
- Refer to Part B for the details of corrections if there are conflicting in the definition of the design variables across models.

<table>
<thead>
<tr>
<th>Color</th>
<th>Label</th>
<th>Description</th>
<th>Entry Name</th>
<th>Bounds</th>
<th>m_stress</th>
<th>m_modes</th>
<th>m_storsp</th>
<th>Is variable linked?</th>
</tr>
</thead>
<tbody>
<tr>
<td>✔✔✔</td>
<td>x1</td>
<td>T of PSHELL 1</td>
<td>floor_roll</td>
<td>.1 &lt; xi &lt; 10.</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>Linked</td>
</tr>
<tr>
<td>✔✔✔</td>
<td>x2</td>
<td>T of PSHELL 2</td>
<td>frame</td>
<td>.1 &lt; xi &lt; 10.</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>Linked</td>
</tr>
<tr>
<td>✔✔✔</td>
<td>x3</td>
<td>T of PSHELL 3</td>
<td>floor</td>
<td>.1 &lt; xi &lt; 10.</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>Linked</td>
</tr>
<tr>
<td>✔✔✔</td>
<td>x4</td>
<td>T of PSHELL 4</td>
<td>spoiler</td>
<td>.1 &lt; xi &lt; 10.</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>Linked</td>
</tr>
<tr>
<td>✔✔✔</td>
<td>x5</td>
<td>T of PSHELL 5</td>
<td>front_mount</td>
<td>.1 &lt; xi &lt; 10.</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>Linked</td>
</tr>
<tr>
<td>✔✔✔</td>
<td>x6</td>
<td>T of PSHELL 6</td>
<td>engine_walls</td>
<td>.1 &lt; xi &lt; 10.</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>Linked</td>
</tr>
<tr>
<td>✔✔✔</td>
<td>x7</td>
<td>T of PSHELL 7</td>
<td>front_panel</td>
<td>.1 &lt; xi &lt; 10.</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>Linked</td>
</tr>
<tr>
<td>✔✔✔</td>
<td>x8</td>
<td>T of PSHELL 8</td>
<td>doors_skin</td>
<td>.1 &lt; xi &lt; 10.</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>Linked</td>
</tr>
<tr>
<td>✔✔</td>
<td>x9</td>
<td>T of PSHELL 9</td>
<td>roof</td>
<td>.1 &lt; xi &lt; 10.</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>Linked</td>
</tr>
<tr>
<td>✔✔</td>
<td>x10</td>
<td>T of PSHELL 10</td>
<td>back_panel</td>
<td>.1 &lt; xi &lt; 10.</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>Linked</td>
</tr>
<tr>
<td>✔✔</td>
<td>x11</td>
<td>T of PSHELL 11</td>
<td>windows</td>
<td>.1 &lt; xi &lt; 10.</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>Linked</td>
</tr>
</tbody>
</table>

T is for thickness
Optimization Problem Statements
Merged Design Model: Results

Model 1 - m_stress
Model 2 - m_modes
Model 3 - m_storsp

Objective: Minimize Weight

Variables: x1, x2, x3, x4, x5, x6, x7, x8, x9, x10 and x11
Comparison Without and With MMO

With MMO, a single optimization is performed across multiple models. Single values for the design variables are achieved.

For example, the thickness of the door, x8, is a single value of .525.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Without MMO</th>
<th>With MMO</th>
</tr>
</thead>
<tbody>
<tr>
<td>x1</td>
<td>✓ 1.7</td>
<td>✓ .30</td>
</tr>
<tr>
<td>x2</td>
<td>✓ .45</td>
<td>✓ .65</td>
</tr>
<tr>
<td>x3</td>
<td>✓ .30</td>
<td>✓ .10</td>
</tr>
<tr>
<td>x4</td>
<td>✓ .35</td>
<td>✓ .55</td>
</tr>
<tr>
<td>x5</td>
<td>✓ .45</td>
<td>✓ .65</td>
</tr>
<tr>
<td>x6</td>
<td>✓ .55</td>
<td>✓ .15</td>
</tr>
<tr>
<td>x7</td>
<td>✓ .90</td>
<td>✓ .25</td>
</tr>
<tr>
<td>x8</td>
<td>✓ .55</td>
<td>✓ .40</td>
</tr>
<tr>
<td>x9</td>
<td>✓ .45</td>
<td>✓ .95</td>
</tr>
<tr>
<td>x10</td>
<td>✓ .40</td>
<td>✓ .20</td>
</tr>
<tr>
<td>x11</td>
<td>✓ .55</td>
<td>✓ .850</td>
</tr>
</tbody>
</table>
More Information Available in the Appendix

The Appendix includes information regarding the following:

- Manually Configuring Multi Model Optimization
- Model Conversion for All Models
- Constructing the Merged Objective
- Linking Variables
- Constructing the MMO.xml File
- Why are DELX and CONV2 used in the DOPTPRM entry (Optimization Settings)?
Contact me

• Nastran SOL 200 training
• Nastran SOL 200 questions
• Structural optimization questions
• Access to the MSC Nastran SOL 200 Web App

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Tutorial

PART A
Tutorial Overview

Part A
1. Perform a multi model optimization with 3 models

Part B
1. Repeat Part A
2. Add a new model, but the model has errors that must be corrected
3. Correct the errors
4. Complete a multi model optimization

Special Topics Covered

Multi Model Optimization (MMO) – MMO is the process of optimizing multiple design models concurrently.

Merged Objective - Each design model’s objective, or selected objectives, can be combined into one merged objective and a multi model optimization may be performed. This example only considers only 1 objective for the merged objective.

Linked Variables – Design variables in separate models that should be treated as the same design variable must be linked. For example, as shown below, the design variables in separate models A and B must be linked.
- Variable x1 - Model A - Corresponding to thickness of Panel 1 in model A
- Variable x1 - Model B - Corresponding to thickness of Panel 1 in model B
MSC Nastran SOL 200 Web App

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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.

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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.
Obtain Starting Files

1. Right click on the zip file
2. Select Extract All...
3. Click Extract
4. The starting files are now available in a folder

- The starting files for this tutorial are contained in a ZIP file and must be extracted as shown.
MSC Nastran SOL 200 Web App

Select a web app to begin

- Size and Topometry Optimization
- Topology Optimization
- Global Optimization
- Multi Model Optimization

The web app also features the HDF5 Explorer, a web application to extract results from the H5 file type.

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Upload BDF Files

1. Click Add Model
2. Click Select Files
3. Navigate to this folder: 1_starting_files_1_m_stress
4. Select the BDF files found in the folder
5. Click Open

- This multi model optimization example involves 3 separate models. The first model is uploaded to the web app.

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Upload BDF Files

1. Click Add Model
2. Click Select Files
3. Navigate to this folder: `1_starting_files_2_m_modes`
4. Select the BDF files found in the folder
5. Click Open

• The second model is uploaded to the web app.
Upload BDF Files

1. Click Add Model
2. Click Select Files
3. Navigate to this folder: 1_starting_files_3_m_storps
4. Select the BDF files found in the folder
5. Click Open
6. The cautionary message can be ignored
7. Click Upload Files
8. Click Upload Files
9. Click Upload Files

- The third model is uploaded to the web app.
- Multi model optimization involves handling multiple BDF files, and in the process the same BDF files may be uploaded inadvertently. In this example, model 2 and 3 share the BDF file: fcar_struct.bdf and a cautionary message is displayed regarding the same uploaded BDF file. The cautionary message can be ignored for this example but should be considered in all other examples.

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Modify MMO Task

1. Find the section titled Models in Multi Model Optimization (MMO) Task

2. Note the names of each model have been automatically generated

- The model names can be customized as shown on the next slide.
Modify MMO Task

Rename the models

1. Mark the Options checkbox
2. For the 1st model (Column 1), change the model name from m_model to m_stress
3. For the 2nd model (Column 2), change the model name from m_model2 to m_modes
4. For the 3rd model (Column 3), change the model name from m_model3 to m_storsp

The merged objective will only consider the weight of model m_stress in this workshop.

5. Mark the checkbox of the 1st model (Column 1)

- The model names are limited to 8 characters.
- Marking the “Preview” checkbox will show all data changes based on the user’s selections for the MMO job settings.

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Modify MMO Task

1. Unmarking “Show only invalid” box under Linked Variables will show all linked or unlinked variables.

- In the event red status markers are visible, the design variables for the models must be modified for compatibility. Refer to Part B of this tutorial for the details regarding variable corrections.
Modify MMO Task

1. Scrolling down the page, one can see the Merged Objective which is included in the first model of the MMO job.

2. Settings for the Merged Model is also generated automatically and it will be output as MMO.XML for the MMO job run.

- This Merged Objective and Settings for Merged Model are auto generated by the MMO Web App. It is highly recommended that this data not be hand edited.
- More details regarding the changes on this page are covered in the Appendix, section Manually Configuring Multi Model Optimization.
- The same section also discusses the validations performed for Linked Variables.

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Export New BDF Files

1. Find the section titled Download Files
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”

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Perform the Optimization with Nastran SOL 200

A new .zip file has been downloaded

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

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

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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, HS 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

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Status

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.

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Review Optimization Results

After MSC Nastran is finished, the results will be automatically uploaded.

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

- For all three models involved in the multi model optimization, it can be seen that a single result for the objective and design variables has been obtained and all the design constraints have been satisfied.
Tutorial

PART B
Open the Correct Page

1. Click on the indicated link

- The Multi Model Optimization (MMO) app is used for this part of the tutorial

MSC Nastran SOL 200 Web App

Select a web app to begin

- Size and Topometry
- Topology
- Multi Model
- Parameter Study

Tutorials are available in the User's Guide

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Import Existing MMO Files

1. Mark the checkbox titled Import Existing MMO XML File
2. Click Select files
3. Open the directory nastran_working_directory
4. Select the MMO.xml file
5. Click Open

• The files from a previous MMO configuration can be re-uploaded to the MMO web app. This page shows the start of the re-upload process by uploading the XML file.
Import Existing MMO Files

1. Click Select files
2. Select all the BDF files
3. Click Open
4. Click Import

The re-upload process continues by selecting all the BDF files and uploading.
Add a 4\textsuperscript{th} model

1. Click Add Model
2. Click Select files
3. Navigate to this directory: 1\_starting\_files\_3\_m\_storsp\_bad
4. Select the BDF files found in the folder
5. Click Open
6. Click Upload files

- The previous MMO task and its settings have been imported.
- A new 4\textsuperscript{th} model will be added. The new model is identical to m\_storsp, but has variable discrepancies that will prevent a successful Multi Model Optimization. The following steps discuss how to resolve such variable discrepancies.
Export New BDF Files

1. Find the section titled Download BDF Files.

2. Errors have been detected in the newly added model. Click Jump to section to inspect.

- The purpose of this part of the tutorial is demonstrate the procedure to take in the event a model is uploaded to the MMO web app, but has errors that must be fixed. The validations and status messages are available throughout the MMO web app, and the most significant validation is visible in the Download BDF Files section.

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Review Linked Variables

There are 2 visible errors and 1 unlinked variable

1. Unmark the checkbox titled Show only invalid

2. For linked variable x2, 2 errors have been found:
   1. The upper bound of the 4th model (200.) is different from the other models (10.).
   2. The DDVAL ID of the 4th model (2001) is different form the other models (2002).

3. Model 4 (Column 4) has a variable labeled x300 (not shown). In this example, x300 and x3 correspond to the same structural property in their respective models. Therefore, x300 should be linked to x3.

• Always check the status icons in each section of the web app. Red status markers indicate an error that will fail a multi model optimization. Blue status markers indicate the setting is valid.
• Errors found in the Linked Variables section require additional modifications to resolve. The purpose of this part of the tutorial is to demonstrate the process to correct issues found in the Linked Variables section.
Open the Correct Page

1. Click on the indicated link

- In order to address the 2 visible errors and 1 unlinked variable detected in the 4th model in the MMO web app, currently named “m_model” in the last step, the 4th model must be taken to the Size web app and modified.

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Upload BDF Files

1. Click 1. Select Files
2. Navigate to this folder: 1_starting_files_3_m_storps_bad
3. Select all the BDF files found in the directory
4. Click Open
5. Click Upload Files

- The process starts by uploading all the necessary BDF files.
### Modify Design Variables

1. **Find the section titled Step 3 – Adjust design variables**
2. **Click Options**
3. **Click Export**

- For the \( x_2 \) variable, the Upper Bound and Allowed Values must be modified.
- For the \( x_3 \) variable, the Label must be modified.
- The Upper Bound and Allowed Values can be modified directly within the web app, but Label changes can only be done via exporting a CSV file and modifying the CSV file in Excel. The CSV file containing the variables is downloaded.

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Modify Design Variables

1. Open the newly downloaded CSV file titled x-design-variables.csv

2. For design variable x2, make the following changes:
   1. Change the upper bound as shown:
      2. After: 10
   2. Change the Allowed Values as shown
      1. Before: .05, THRU, 7.0, BY, .05
      2. After: .05, THRU, 7.0, BY, .050

3. For design variable x300, change the label as shown:
   1. Before: x300
   2. After: x3

4. Click the save icon

   • Recall the model configuration in the MMO web app. Model 1 and 2 (m_stress and m_modes), have the following configuration:
     • For x2, the Upper Bound is 10 and the Allowed Values are .05, THRU, 7.0, BY, .050
     • For x3, this corresponds to the thickness of PSHELL 3.
   • The 4th model’s x2 variable does not match, but as shown on this page, the values are changed to correct the difference. Also, x300 corresponds to the thickness of PSHELL 3 and should be changed to x3. If x300 is left unchanged, the multi model optimization will change x300 and x3 separately, resulting in different values for the thickness of PSHELL 3. When x300 is changed to x3, x3 of Model 4 then becomes linked to variable x3 in Models 1 and 2 in the MMO configuration.
Modify Design Variables

1. Click Select Files and select x-design-variables.csv
2. Click Import

The following changes have occurred and address the 2 visible errors and 1 unlinked variable that were shown in the MMO App.

3. The upper bound is now equal to 10.

4. In regards to the Allowed Values for x2. By making the entry unique for the Allowed Values of x2 the generated DDVAL ID is now 2002 and is unique from the other DDVAL IDs of 2001.

5. The design variable x3 is now the same as the other models. Since the label matches the other labels, x3 is now linked with the other x3 variables.

- Some may notice that there is a trailing zero in the Allowed Values, i.e. .050:.05, THRU, 7.0, BY, .050 The goal of the extra 0 is to make the to make the entire string unique from the other allowed values. This triggers the web app to create a unique DDVAL entry with identification number of 2002. Multi Model Optimization requires that linked variable’s (DESVAR and DDVAL entries) entries are identical across models. With this change, all x2 variables point to the same DDVAL 2002 entry.
Export New BDF Files

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

• To ensure this new design model yields the same solution as before, the updated BDF files are downloaded and an optimization is performed.
Perform the Optimization with Nastran SOL 200

A new .zip file has been downloaded

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

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

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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, HS 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 +x ./nastran_working_directory

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**Status**

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.

---

### Nastran SOL 200 Web App - Status

<table>
<thead>
<tr>
<th>Name</th>
<th>Status of Job</th>
<th>Design Cycle</th>
<th>RUN TERMINATED DUE TO</th>
</tr>
</thead>
<tbody>
<tr>
<td>model.bdf</td>
<td>Running</td>
<td>None</td>
<td></td>
</tr>
</tbody>
</table>

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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.

- This model has been previously optimized. In the last few steps, changes to the design variables have been done, but the optimization results should be identical to the optimization results before modification. Ensure the results are the same.
- This new design model, found in nastran_working_directory (1), has the necessary corrections in order to successfully add this design model to the MMO task.

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Open the MMO Web App

Open the existing MMO Web App

1. Click the red x to remove the 4th model. Recall that this model has errors and will not be used.

- The old 4th model is removed. This model contained the inconsistent variables x2 and x300.
Add a 4th Model

1. Click Add Model
2. Click Select Files
3. Navigate to this folder: nastran_working_directory (1)
4. Select the BDF files found in the folder
5. Click Open
6. Click Upload Files

• The new 4th model is added. This model was modified in the Size web app and is contained in the folder named nastran_working_directory (1).
Review Linked Variables

1. Note the 2 errors for x2 from before:
   1. The upper bound of the 4th model (200.) is different from the other models (10.).
   2. The DDVAL ID of the 4th model (2001) is different from the other models (2002).

2. Note that x3 was unlinked before:
   1. Each model varies Thickness (T) of PSHELL 3. The 1st and 2nd model have x3 for the T of PSHELL 3. The 4th model has x300 for the T of PSHELL3 and this label must be changed to x3 so the variable is linked with the other models.

3. After taking the 4th model, and updating the design model using the Size Web App and the CSV file, the errors have been resolved and a blue checkbox is shown for variable x2 and x3.

- The original purpose of this part of the tutorial was to demonstrate the process to correct issues found in the Linked Variables section. As shown in the New View, the status markers for x2 and x3 are blue, meaning the variables are properly configured.
Modify MMO Task

1. Find the section titled Models in Multi Model Optimization (MMO) Task
2. Mark the Options checkbox
3. For the 4th model (Column 4), change the model name to m_stors2
4. Click the red x to remove the 3rd model.

- Only the following 3 models should be included:
  - m_stress
  - m_modes
  - m_stors2
- Four models should not be included since the 3rd model and the 4th model are the same.
Export New BDF Files

1. Find the section titled Download Files
2. Click on Download BDF Files
3. Extract the contents of the .zip file and click Start MSC Nastran to begin the optimization (Not Shown)

• 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”
Review Optimization Results

After MSC Nastran is finished, the results will be automatically uploaded.

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

- It should be noted that the results from Part A should match the results from this part, Part B (shown right).
- The main purpose in Part B is to show the procedure to make corrections when one finds any problem in some of the multiple models for MMO job run.

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End of Tutorial
Appendix
The Appendix includes information regarding the following:

- Manually Configuring Multi Model Optimization
- Model Conversion for All Models
- Constructing the Merged Objective
- Linking Variables
- Constructing the MMO.xml File
- Why are DELX and CONV2 used in the DOPTPRM entry (Optimization Settings)?
Appendix Contents

- Manually Configuring Multi Model Optimization
  - Model Conversion for All Models
  - Constructing the Merged Objective
  - Linking Variables
  - Constructing the MMO.xml File
- Why are DELX and CONV2 used in the DOPTPRM entry (Optimization Settings)?
Manually Configuring Multi Model Optimization
Best Practice

For best results, each separate design model must already run successfully, for one or more design cycles, in MSC Nastran before including in Multi Model Optimization.
Manually Configuring Multi Model Optimization

The process is done in 4 steps:

1. Model Conversion for All Models
2. Constructing the Merged Objective
3. Linking Variables
4. Constructing the MMO.xml File

The MMO Web App automates these steps and no hand editing is necessary.
Manually Configuring Multi Model Optimization

MODEL CONVERSION FOR ALL MODELS
Model 1

BEFORE (MODEL.BDF)

```plaintext
assign userfile = 'optimization_results.csv', status = new, form = formatted, unit = 52

DIAG 8,15 $ Print Matrix & Table Trailers in .004
SOL 200
CEND
TITLE = B2W No Windows Inertia Relief 18 Attach dof
ECHO=SORT(EXCEPT GRID,CQUAD4,CTRIA3,CHEXA,CPENTA,CTETRA)
$ Output Control
$ ------------------------
$ DISPL(FROMT), EXPRT, END-SENS) = ALL
SUBCASE 10
ANALYSIS = STATICS
DESSUB = 40000013
$ Output Subcase
SUBTITLE = Front Left Interior Pillar Z
LOAD = 123
SUBCASE 33
ANALYSIS = STATICS
DESSUB = 40000033
$ Output Subcase
SUBTITLE = Center Left Pillar Z
LOAD = 133
SUBCASE 53
ANALYSIS = STATICS
DESSUB = 40000053
$ Output Subcase
SUBTITLE = Rear Left Pillar Z
LOAD = 153

DELETE BDF

INCLUDE '.\design_model.bdf'
```

AFTER (M_STRESS.BDF)

```plaintext
assign userfile = 'm_stress.csv', status = UNKNOWN, form = formatted, unit = 52

DIAG 8,15 $ Print Matrix & Table Trailers in .004
SOL 200
CEND
TITLE = B2W No Windows Inertia Relief 18 Attach dof
ECHO=SORT(EXCEPT GRID,CQUAD4,CTRIA3,CHEXA,CPENTA,CTETRA)
$ Output Control
$ ------------------------
$ DISPL(FROMT), EXPRT, END-SENS) = ALL
SUBCASE 10
ANALYSIS = STATICS
DESSUB = 40000013
$ Output Subcase
SUBTITLE = M_Stress
SUBCASE 33
ANALYSIS = STATICS
DESSUB = 40000033
$ Output Subcase
SUBTITLE = Front Left Interior Pillar Z
LOAD = 123
SUBCASE 53
ANALYSIS = STATICS
DESSUB = 40000053
$ Output Subcase
SUBTITLE = Center Left Pillar Z
LOAD = 133
SUBCASE 93
ANALYSIS = STATICS
DESSUB = 40000093
$ Output Subcase
SUBTITLE = Rear Left Pillar Z
LOAD = 153

DELETE BDF

INCLUDE '.\design_model_m_stress.bdf'
INCLUDE '.\design_model_m00.bdf'
```
Model 2

**BEFORE (MODEL.BDF)**

```plaintext
assign userfile = 'optimization_results.csv', status = new, form = formatted, unit = 52

DIAG 8,15 % Print Matrix & Table Trailers in .054
SOL 200
CEND
TITLE = BIW Static Torsion Tests
ECHO=SORT(EXCEPT GRID,CQUAD4,CTRIA3,CHEXA,CPENTA,CTETRA)
SET 1 = 19998
DISP = 1
STRESS(PLOT) = ALL
EIG(PLOT) = ALL
SPCF = ALL

SPC = 6
0
ESDOF3(MIN) = 8000000
$ DUMP plot
$ DUMP(export) = ALL
$ EXPORT(formatted, export, end-send) = ALL
SUBCASE 1
ANALYSIS = MODES
ESDSUB = 40000001
$ No output list
$ Subcase name: Default
$ SUBTITLE=Default
METHOD = 1
VECTOR(SORTI,REAL) = ALL
SPCFORCES(SORT2,REAL) = ALL
NODF=800
BEGIN BULK
INCLUDE './design_model1.bdf'

```  

**AFTER (M_MODES.BDF)**

```plaintext
assign userfile = 'm_modes.csv', status = unknown, form = formatted, unit = 52

DIAG 8,15 % Print Matrix & Table Trailers in .054
SOL 200
CEND
TITLE = BIW Static Torsion Tests
ECHO=SORT(EXCEPT GRID,CQUAD4,CTRIA3,CHEXA,CPENTA,CTETRA)
SET 1 = 19998
DISP = 1
STRESS(PLOT) = ALL
EIG(PLOT) = ALL
SPCF = ALL

SPC = 6
0
ESDOF3(MIN) = 8000000
$ DUMP M/M
$ DUMP = M/Modes
SUBCASE 1
ANALYSIS = M/Modes
ESDSUB = 40000001
$ DUMP Plot
$ Subcase name: Default
$ SUBTITLE=Default
METHOD = 1
VECTOR(SORTI,REAL) = ALL
SPCFORCES(SORT2,REAL) = ALL
NODF=800
BEGIN BULK
INCLUDE './design_model1.m_modes.bdf'
```
Model 3

BEFORE (MODEL.BDF)

```plaintext
assign userfile = 'optimisation_results.csv', status = new, form = formatted, unit = 82
DIA 8.15
SOL 200
CEND

TITLE = BW Static Torsion Tests
ECHO=SORT(EXCEPT GRID,CQUAD4,CTRIA3,CHEXA,CPENTA,CHETRI)
SET 1 = 19999
DISP = 1
VISC(PLOT) = ALL
STRESS(PLOT) = ALL
ESE(PLOT) = ALL
SPC = ALL

5

DESOBJ(MIN) = 8000000
DEFOBJ(DEFINED, EXPORT, END-STATUS) = ALL

SUBCASE 10
ANALYSIS = STATICS
DESSUB = 10000020
DESFIL = S
SUBTITLE = Rear Transverse Force -Y 1000 N
LOAD = 102

SUBCASE 40
ANALYSIS = STATICS
DESSUB = 10000040
DESFIL = S
SUBTITLE = Rear Torsion X 1000 N-mm
LOAD = 104

BEGIN BDF
INCLUDE '../design_model.bdf'
```

AFTER (M_STORSP.BDF)

```plaintext
assign userfile = 'n_storsp.csv', status = UNKNOWN, form = formatted, unit = 82
DIA 8.15
SOL 200
CEND

TITLE = BW Static Torsion Tests
ECHO=SORT(EXCEPT GRID,CQUAD4,CTRIA3,CHEXA,CPENTA,CHETRI)
SET 1 = 19999
DISP = 1
VISC(PLOT) = ALL
STRESS(PLOT) = ALL
ESE(PLOT) = ALL
SPCF = ALL

SPC = 6

5

DESOBJ(MIN) = 8000000
DEFOBJ(DEFINED, EXPORT, END-STATUS) = ALL

SUBCASE 10
ANALYSIS = STATICS
DESSUB = 10000020
DESFIL = S
SUBTITLE = Rear Transverse Force -Y 1000 N
LOAD = 102

SUBCASE 40
ANALYSIS = STATICS
DESSUB = 10000040
DESFIL = S
SUBTITLE = Rear Torsion X 1000 N-mm
LOAD = 104

BEGIN BDF
INCLUDE '../design_model.m_storsp.bdf'
```

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Manually Configuring Multi Model Optimization

CONSTRUCTING THE MERGED OBJECTIVE
Merged Objective

A new file named design_model_mmo.bdf is created

This file contains a DRESP2 entry with ID=5000000

This file is auto generated by the MMO Web App. It is highly recommended that this file not be hand edited.

DRESP2  5000000  R0  570000
DTABLE  c1  c2  c3
DRESP1  8000000  8000000  8000000
DEQATN  570000
\[ g(c1, c2, c3, r1, r2, r3) = c1 \times r1 + c2 \times r2 + c3 \times r3 \]
DTABLE  c1  1.0  c2  0.0  c3  0.0

design_model_mmo.bdf
Merged Objective

The edit on the next slide happens only to the first model when the checkbox is marked.

In this example, \( m_{\text{stress}} \) is the 1\textsuperscript{st} model.
Only the first model is edited

BEFORE (M_STRESS.BDF)

```
assign userfile = 'getinformation_results.csv', status = new,
form = formatted, unit = 52

DIAG 8.15 $ Print Matrix & Table Trailers in .F04

SOL 200

CEND

TITLE = BIW No Windows Inertia Relief 18 Attach dof
ECHO=SORT(EXCEPT GRID,COUAD4,CTRIA3,CHEXA,CPENTA,CTETRA)
# Output Control

$                        

DISP(PLOT) = ALL
STRESS(PLOT) = ALL
ESEQ(PLOT) = ALL

DESJOB(WIN) = 8000000

END DATA

SUBCASE 10

ANALYSIS = STATICS
DESSUB = 40000013

SUBTITLE = Front Left Interior Pillar Z
LOAD = 133

SUBCASE 33

ANALYSIS = STATICS
DESSUB = 40000033

SUBTITLE = Center Left Pillar Z
LOAD = 133

SUBCASE 53

ANALYSIS = STATICS
DESSUB = 40000053

SUBTITLE = Rear Left Pillar Z
LOAD = 133

BEGIN BULK
INCLUDE './design_model_m_stress.bdf'
```

AFTER (M_STRESS.BDF)

```
assign userfile = 'm_stress.csv', status = UNKNOWN, form = formatted, unit = 62

DIAG 8.15 $ Print Matrix & Table Trailers in .F04

SOL 200

CEND

TITLE = BIW NO Windows Inertia Relief 18 Attach dof
ECHO=SORT(EXCEPT GRID,COUAD4,CTRIA3,CHEXA,CPENTA,CTETRA)
# Output Control

$                        

DISP(PLOT) = ALL
STRESS(PLOT) = ALL
ESEQ(PLOT) = ALL

DESJOB(WIN) = 5000000

DESSUB = m_stress

SUBCASE 10

ANALYSIS = STATICS
DESSUB = 40000013

SUBTITLE = Front Left Interior Pillar Z
LOAD = 133

SUBCASE 33

ANALYSIS = STATICS
DESSUB = 40000033

SUBTITLE = Center Left Pillar Z
LOAD = 133

SUBCASE 53

ANALYSIS = STATICS
DESSUB = 40000053

SUBTITLE = Rear Left Pillar Z
LOAD = 133

BEGIN BULK
INCLUDE './design_model_m_stress.bdf'
INCLUDE './design_mode_m_stress.bdf'
```
Manually Configuring Multi Model Optimization

LINKING VARIABLES
Linking Variables

In order to Link Variables across models, the DESVAR entry must be identical in every model.

- **Linked Variables** - The following variables appear in every model and are linked: x1, x2, x3, x4, x5, x6, x7, x8, x9, x10.

- **Unlinked Variables** - The following variable appear only in one model (Model 2) and will change independently during the optimization.

---

**Model 1**
(design_model_m_stress.bdf)

**Model 2**
(design_model_m_modes.bdf)

**Model 3**
(design_model_m_storsp.bdf)

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Linking Variables

The Linked Variable section in the MMO Web App performs the validation to ensure the DESVAR entries are matching.
Linking Variables

The following fields on the DESVAR entry must be identical: XINIT, XLB, XUB. If allowable values are used, the DDVAL ID and the values on the DDVAL entry must match.

Commercial Version
The commercial version of the web app is designed to minimize the amount of information displayed. The full set of successful validations are hidden but unsuccessful validations will be fully shown to the user in red status markers.

Development Version
Below is a view of the full set of successful validations that would normally be hidden in the commercial version. This view was generated with a version of the web app only available to the developer of the web app.
An example of the comparison is shown.

Model 1
(design_model_m_stress.bdf)

Model 2
(design_model_m_modes.bdf)

Model 3
(design_model_m_storsp.bdf)
Manually Configuring Multi Model Optimization

CONSTRUCTING THE MMO.XML FILE
Constructing the MMO.xml File

A new file named MMO.xml is created

```xml
<?xml version="1.0" ?>
<rt optType="MMO" debug="no" >
  <Job name="m_stress" coef="1.0" mem="20GB" smp="1" scr="yes" blocking="0"/>
  <Job name="m_modes" coef="0.0" mem="200MB" smp="1" scr="yes" blocking="0"/>
  <Job name="m_stressp" coef="0.0" mem="200MB" smp="1" scr="yes" blocking="0"/>
  <Merge mem="200MB" smp="1" scr="yes" />
</rt>
```

MMO.xml
Constructing the MMO.xml File
Constructing the MMO.xml File

Models in Multi Model Optimization (MMO) Task

<table>
<thead>
<tr>
<th>Model</th>
<th>Status</th>
<th>Objective in MMO Task?</th>
<th>Objective Type</th>
<th>Objective Weight Coefficient</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Yes</td>
<td>ONSP</td>
<td>1.0</td>
<td></td>
</tr>
</tbody>
</table>

```xml
<xml version="1.0">
   <!-- MMO.xml -->
   <job name="m_stress" coeff="0.0" mem="200MB" smp="1" scr="yes" blocking="0"/>
   <job name="m_modes" coeff="0.0" mem="200MB" smp="1" scr="yes" blocking="0"/>
   <job name="m_stressp" coeff="0.0" mem="200MB" smp="1" scr="yes" blocking="0"/>
</xml>
```

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Constructing the MMO.xml File

Settings for Merged Model

<table>
<thead>
<tr>
<th>Option</th>
<th>Status</th>
<th>Configure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimize or Maximize Combined Objective</td>
<td>MIN</td>
<td></td>
</tr>
<tr>
<td>Memory (mem)</td>
<td></td>
<td>200MB</td>
</tr>
<tr>
<td>Number of Processors (mp)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Option for Scratch (scr)</td>
<td></td>
<td>yes</td>
</tr>
</tbody>
</table>

MMO.xml

```xml
<job name="m_stress" coef="1.0" mem="200MB" smp="1" scr="yes" blocking="0"/>
<job name="m_modes" coef="8.0" mem="200MB" smp="1" scr="yes" blocking="0"/>
<job name="m_stress" coef="1.0" mem="200MB" smp="1" scr="yes" blocking="0"/>
</rc>
```
Constructing the MMO.xml File

Model 1 (m_stress.bdf)

assign userfile="m_stress.csv", status=unknown, form=formatted, unit=52

BEGIN

SUBCASE 13
ANALYSIS = STATICS
DESSUB = 0
BEGIN_print
SUBTITLE = Front Left Interior Pillar Z
LOAD = 12
SUBCASE 33
ANALYSIS = STATICS
DESSUB = 0
BEGIN_print
SUBTITLE = Center Left Pillar Z
LOAD = 13
SUBCASE 53
ANALYSIS = STATICS
DESSUB = 0
BEGIN_print
SUBTITLE = Rear Left Pillar Z
LOAD = 13
BEGIN_NODE
INCLUDE './design_model_m_stress.bdf'
INCLUDE './design_model_mmo.bdf'

Settings for Merged Model

<table>
<thead>
<tr>
<th>Option</th>
<th>Status</th>
<th>Configure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimize or Maximize Combined Objective</td>
<td>MIN</td>
<td></td>
</tr>
<tr>
<td>Memory (mem)</td>
<td>200MB</td>
<td></td>
</tr>
<tr>
<td>Number of Processors (amp)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Option for Scratch (scr)</td>
<td>yes</td>
<td></td>
</tr>
</tbody>
</table>
Why are DELX and CONV2 used in the DOPTPRM entry (Optimization Settings)?
Why are DELX and CONV2 used in the DOPTPRM entry (Optimization Settings)?

1. Model 2 (m_modes) seeks to optimize a natural frequency and requires the use of Mode Tracking.

2. The DOPTPRM entry shown makes use of DELX1 and COVN2. The use of DELX and CONV2 are applicable to model 2.
Why is DELX=.1 used?

1. If DELX is not specified on the DOPTPRM entry, MSC Nastran uses the default DELX value of .5.

2. If model 2 is optimized without DELX specified, after the optimization, the F06 file reveals an error due to mode tracking failure.
Why is DELX=.1 used?

1. Further inspection of the F06 file reveals recommendations to avoid a mode tracking failure.
2. One option is to reduce the move limit DELX.
3. After using a DELX value of .1, mode tracking is successful and the optimization is able to proceed.

Large changes in design variables may cause mode tracking to fail. For model 2, a DELX value of .5 resulted in too large of variable changes for mode tracking to operate. The idea is to limit the changes of the design variables so that the modes are better tracked.
Why is CONV2=3.0 used?

The CONV2 value is adjusted so that the optimization converges sooner.

To the right, a optimization without and with CONV2=3.0 is compared. The optimization with CONV2=3.0 converges sooner.
Why is CONV2=3.0 used?

The CONV2 was determined as follows:

1. Search the F06 section for the last reported section titled HARD CONVERGENCE DECISION LOGIC.

2. The value of ABSOLUTE CHANGE IN OBJECTIVE is 1.4253E+00. A value of CONV2 greater than 1.4253 is chosen, e.g. 3.0.

Alternatively, the CONV1 setting can be used instead. The value of RELATIVE CHANGE IN OBJECTIVE is 2.2449E-03. A value of CONV1 greater than 2.2449E-03 is chosen and will result in termination due to convergence.
Use the same DOPTPRM entry in every model

1. Models 1 and 2 optimize successfully without specifying DELX and CONV2. Since this is a multi model optimization, it is required that the same DOPTPRM entry be used by all models. The DOPTPRM entry from model 2 is used in models 1 and 3.