Workshop - MSC Nastran Topometry Optimization of a Cantilever Plate

AN MSC NASTRAN SOL 200 TUTORIAL
Goal: Use Nastran SOL 200 Optimization

Before Optimization
- Mass: 19.5 kg

After Optimization
- Mass: 3.97 kg
- Vary the thickness of each element
Goal: Use Nastran SOL 200 Optimization

Before Optimization
- Mass: 19.5 kg

After Optimization
- Mass: 3.97 kg
- Vary the thickness of each element
Details of the structural model

Units: m, N, MPa

Material:
- $E: \, 200E9 \, \text{Pa}$
- $v: \, 0.3$
- $\rho: \, 7800 \, \text{kg/m}^3$

Dimensions: $1\,\text{m} \times 0.25\,\text{m} \times 0.01\,\text{m}$
Optimization Problem Statement

Design Region/Variables

\( z_1: \) Thickness \((T)\) of PSHELL 1

\(.001 < z_1\)

Design Objective

\( r_0: \) Minimize weight

Design Constraints

\( r_1: \) von Mises stress of PSHELL 1

\( r_1 < 250E6\)

\( r_2: \) Z Displacement of nodes 14, 28, 42, 56 (GRID IDs: 14, 28, 42, 56)

\( -0.01 < r_2\)
Difference Between Size and Topometry Optimization

Size Optimization
1. Select the parameter to optimize
2. One design variable (x1) is created and applies to all the elements

\[ x_1 = \text{Thickness of every element related to PSHELL 1} \]

Topometry Optimization
1. Select the parameter and design region
2. In the background, one design variable is automatically created for each element => Element-by-element optimization

\[ x_1 = \text{Thickness of element 1} \]
\[ x_{32} = \text{Thickness of element 2} \]
\[ x_{13} = \text{Thickness of element 13} \]
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
Tutorial Overview

1. Start with a .bdf or .dat file

2. Use the MSC Nastran SOL 200 Web App to:
   - Convert the .bdf file to SOL 200
   - Design Regions/Variables
   - Design Objective
   - Design Constraints
   - Perform optimization with Nastran SOL 200

3. Review optimization results
   - .f06
   - Topometry Optimization and Structural Results

Special Topics Covered

Topometry Optimization - This type of optimization assigns a design variable for each individual element.
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.

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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.

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MSC Nastran SOL 200 Web App

Select a web app to begin

Open the Correct Page

1. Click on the indicated link

- MSC Nastran can perform many optimization types. The MSC Nastran SOL 200 Web App includes dedicated web apps for the following:
  - 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 1. Select Files and select topometry_cantilever_plate.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.
Create Design Region

1. Click + Options
2. Mark the TOMVAR checkbox
3. Click on the plus (+) icon to set the thickness (T) of PSHELL 1 as a Design Region
4. Scroll to the section titled Step 7 – Adjust TOMVAR entries
5. The new Design Region is added to the table, no further edit is necessary

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

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Create Design Objective

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

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

1. Click Constraints
2. Type ‘s’ into the search bar
3. Click on the plus (+) icon for Displacement
4. Click on the plus (+) icon for Stress
5. Configure the following for r1:
   1. ATTA: 3 - T3  (Z component)
   2. ATTI: 14, 28, 42, 56  (Nodes 14, 28, 42 and 56)
   3. Lower Allowed Limit: -.01
6. Configure the following for r2:
   1. Property Type: PSHELL
   2. ATTA: 11 - von Mises
   3. ATTI: 1  (PSHELL 1)
   4. Upper Allowed Limit: 250.66

The constraints are defined normally as would be done in a size optimization.
### Configure Optimization Settings

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

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Configure</th>
</tr>
</thead>
<tbody>
<tr>
<td>APRRCD0</td>
<td>Approximation method to be used</td>
<td></td>
</tr>
<tr>
<td>CONV1</td>
<td>Relative criterion to detect convergence</td>
<td></td>
</tr>
<tr>
<td>CONV2</td>
<td>Absolute criterion to detect convergence</td>
<td></td>
</tr>
<tr>
<td>DELX</td>
<td>Fractional change allowed in each design variable during each optimization cycle</td>
<td></td>
</tr>
<tr>
<td>DESMAX</td>
<td>Maximum number of design cycles to be performed</td>
<td></td>
</tr>
<tr>
<td>DISBEG</td>
<td>Design cycle number for discrete variable processing initiation</td>
<td></td>
</tr>
<tr>
<td>GICDAX</td>
<td>Maximum constraint violation allowed at the converged optimum</td>
<td></td>
</tr>
<tr>
<td>P1</td>
<td>Print items, e.g. objective, design variables, at every n-th design cycle to the .F06 file</td>
<td></td>
</tr>
<tr>
<td>P2</td>
<td>Items to be printed to the .F06 file</td>
<td>Ø 12 - Print constraints and responses 12</td>
</tr>
<tr>
<td>TREGION</td>
<td>Trust Region</td>
<td></td>
</tr>
</tbody>
</table>

[Additional Content]

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Export  New BDF Files

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

- When the download button is clicked a new file named “nastran_working_directory” is downloaded. If the file already exists in your local folder, the folder name is appended with a number, e.g. “nastran_working_directory (1).zip”
Perform the Optimization with Nastran SOL 200

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.

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>
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 and normalized constraints can be reviewed.

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

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Review Optimization Results in Patran

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

1. Click Smooth Shading
2. Go to Tools > Design Study and click on Post-Process
3. Click Select Results File
4. Select model.des (This file was created during the optimization)
5. Click OK
6. Click Apply

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Review Optimization Results in Patran

1. Click the clear icon
2. Click Results
3. Set the following:
   1. Action: Create
   2. Object: Marker
   3. Method: Scalar
4. Select: DESIGN CYCLE: 18, model.des (The row should be highlighted blue)
5. Select Topology Optimization, Element D... (The row should be highlighted blue)
6. Click Target Entities
7. Set to Elements
8. Click Display Attributes
9. Mark the checkbox for Show Spectrum
10. Change to Model Scaled
11. Set Scale Factor to .06
12. Change Scalar Style to the shaded cube
13. Uncheck the box for Show Scalar Label
14. Click Apply

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Review Optimization Results in Patran

1. The plot shows the new thickness distribution of each element. Plot not to scale.
Results

Before Optimization
- Mass: 19.5 kg

After Optimization
- Mass: 3.97 kg
- Vary the thickness of each element
End of Tutorial