Workshop - Structural Optimization of a 3 Bar Truss, Sensitivity Analysis

AN MSC NASTRAN SOL 200 TUTORIAL
Goal: Perform a Sensitivity Analysis
Details of the Structural Model

Three-Bar Truss
A common task in design optimization is to reduce the mass of a structure subjected to several load conditions. Figure 8-1 shows a simple three-bar truss that must be built to withstand two separate loading conditions. Notice that these two loads define the same truss members, so both constraints as well as symmetries. Due to the loading symmetries, we expect the design to be symmetric as well. As an exercise, we'll show how to enforce this symmetry using design variable linking.

Figure 8-1 Three-Bar Truss
An important, but often overlooked consideration is that the optimization capability in MSC Nastran is multidisciplinary. That is, the final optimal design in the result of a simultaneous consideration of all analysis disciplines across all subcases. In this case, the optimal three-bar truss design will satisfy the load requirements for both subcases, which is to be expected. If, for example, a normal modes or buckling subcase were to be added, the resultant design would have to not only satisfy the static strength requirements, but also constraints on eigenvalues. As an exercise you may wish to try adding an eigenvalue constraint.

MSC Nastran Design Sensitivity and Optimization User's Guide
Chapter 8 - Example Problems - Three Bar Truss

20,000 lbs (Subcase 2)
20,000 lbs (Subcase 1)

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Optimization Problem Statement

Design Variables

x1: A of PROD 11
x2: A of PROD 12
x3: A of PROD 13

0.1 < x1, x2, x3 < 100.

Variable Link

x3 = x1

Design Objective

r0: Minimize weight

Design Constraints

r1: Axial stress of elements related to PROD 11, 12, 13

-15000 < r1 < 20000

r2: x and y component of displacement for node 4

-2 < r2 < 0.2
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:
   - Import a previously created SOL 200 BDF files
   - Set the web app to perform a sensitivity analysis
   - Perform sensitivity analysis with Nastran SOL 200

3. Plot the Sensitivities

Special Topics Covered

**Automatic Plots** - After a sensitivity analysis is complete and result files are created, the sensitivities may be automatically plotted by the Nastran Web App. This tutorial describes how to create these plots.
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.
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

• This example is using a previously created design model. The design model is a model that has been converted to SOL 200 and contains bulk data entries describing the optimization problem statement, e.g. variables, objective and constraints.
MSC Nastran SOL 200 Web App

Select a web app to begin

1. Size and Topometry Optimization
2. Topology Optimization
3. Global Optimization
4. Multi Model Optimization

Tutorials are available in the User’s Guide

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Upload BDF Files

1. Click 1. Select Files and select model.bdf and design_model.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.
Model Has Been Imported

Previously created SOL 200 BDF files have been imported to the web app and may be modified.

- This example is using a previously created design model. The design model is a model that has been converted to SOL 200 and contains bulk data entries describing the optimization problem statement, e.g. variables, objective and constraints.

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Configure Settings

1. At the top right hand corner, click on Settings
2. Mark the checkbox labeled Perform Sensitivity Analysis

• Sensitivity analysis computes the gradients or partial derivatives of responses with respect to design variables. For example, if the sensitivity of weight with respect to x1 is -200, then a change of 1.0 in x1 yields a change of -200 in the weight.
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 successfully complete, the results will be automatically uploaded.

1. Select any of the options to dynamically plot different sensitivities

- The sensitivities are labeled in the following form: $\frac{\partial r_{2_{SC1,2,1}}}{\partial x1}$
- This is read as the sensitivity of $r_2$ with respect to $x_1$, for subcase 1, component 2 (axial stress) of element 1.
- This sensitivity is negative, so a unit change in $x_1$ will produce a -11893 change in $r_{2_{SC1,2,1}}$

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Review Optimization Results

1. Click the column headers to sort the table
2. Note the sensitivities are immediately updated automatically

- The data displayed in the table is immediately plotted in the Bar Charts. This example has 22 sensitivity values. The table shows only 10 sensitivities, so the Bar Chart displays only 10 sensitivities.
End of Tutorial