Workshop - Vibration of a Cantilevered Beam (Turner's Problem)

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

Minimize the weight of this structure while constraining the 1st natural frequency

Before Optimization
- Weight: 19.2 lbs.
- 1st Natural Frequency: 26 Hz

After Optimization
- Weight: 6.97 lbs.
- 1st Natural Frequency: 20 Hz

MSC Nastran Design Sensitivity and Optimization User’s Guide
Chapter 8 - Example Problems - Vibration of a Cantilevered Beam (Turner’s Problem)
Details of the structural model

Vibration of a Cantilevered Beam (Turner's Problem)

This problem was originally published by M.J. Turner (see Reference 13). The problem is to design a minimum weight structure while constraining the fundamental natural frequency to be at or above 20 Hz. The beam is symmetric about Z = 0 and made up of a shear web having top and bottom caps that are modeled with rod elements. Turner's original design model consisted of piecewise linear bar cross-sectional areas and web thicknesses; however, we will just approximate this as a step function model with uniform cross-sectional rod elements and uniform thickness shear elements within each of three bays.

Figure 8-17  Cantilever Beam Vibration Model

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

**Design Variables**

- x1: A of PROD 201
- x2: A of PROD 202
- x3: A of PROD 203
  
  \[0.01 < x_1, x_2, x_3 < 100.\]

- x4: T of PSHELL 204
- x5: T of PSHELL 205
- x6: T of PSHELL 206
  
  \[0.0002 < x_4, x_5, x_6 < 2.\]

**Design Objective, Equation**

R0: Minimize \( a_1 - 90. \)

where,

- \( a_1: \) weight of entire structure

**Design Constraints**

- r1: 1st Natural frequency
  
  \[20 \text{ Hz} < r_1\]
More Information Available in the Appendix

The Appendix includes information regarding the following:
- Frequently Asked Questions
- There are thousands of properties that have been identified as designable. How can the properties best be sorted so the thicknesses can be set as design variables?
Contact me

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

christian@the-engineering-lab.com
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 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

Equation Driven Objective - MSC Nastran includes a list of quantities that can be set as objectives or constraints. In addition, custom user defined equations may be specified and be set as objectives or constraints. This tutorial details the process in defining custom equations.

Equation Objective

Minimize \( f = a1 - 90.0 \)
MSC Nastran SOL 200 Web App

Nastran SOL 200 questions? Email me: christian@the-engineering-lab.com
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.

Nastran SOL 200 questions? Email me: christian@the-engineering-lab.com
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.
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.
Upload BDF Files

1. Click 1. Select Files and select dsoug2.dat
2. Click Upload Files

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

Nastran SOL 200 questions? Email me: christian@the-engineering-lab.com
Create Design Variables

1. Type ‘A’ in the filter box
2. Click on the plus (+) icons to set the areas as design variables
3. Specify the lower bound as .01 for design variables x1, x2, and x3
4. Specify the upper bound as 100. for design variables x1, x2, and x3

• 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.

Nastran SOL 200 questions? Email me: christian@the-engineering-lab.com
Create Design Variables

1. Type ‘T’ in the filter box
2. Click on the plus (+) icons to set the thicknesses as design variables
3. Click 10 on the pagination bar
4. Specify the lower bound as .0002 for design variables x4, x5, and x6
5. Specify the upper bound as 2.0 for design variables x4, x5, and x6

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 .002 to avoid a negative variable during the optimization.
Create Design Objective

1. Click Objective
2. Click Switch to Equation Objective

- The objective must always be a single and global response. A response such as weight and volume are single responses, are independent of load case, 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.

Nastran SOL 200 questions? Email me: christian@the-engineering-lab.com
Create Design Objective

1. Scroll to section: Step A - Optional - Create additional responses
2. Click the plus (+) icon for Weight
3. A weight response a1 has been created
4. Scroll to section: Step 1 - Adjust equation objective
5. Type in this equation:
   • \( a1 - 90.0 \)
   Caution: Do not copy and paste this equation into the web app, sometimes PowerPoint will change the negative symbol from \(-\) to \(–\) and will be carried over if you copy and paste. Manually type in the equation instead.

- Suppose an analysis model is 10000 units of mass. If the design variables only impact .001 units of mass, then the sensitivities computed will be too small and the optimizer will be unable to minimize the weight. To overcome this, the objective is set to the weight of only the design regions (Total weight minus the weight of the non-design region OR \( r0 = a1 - 9999.999 \)). With this new objective, the sensitivities are better conditioned, and the optimizer can minimize the weight.
- Alternatively, the following option augments the objective so the objective reports the change/difference in the objective instead of the original objective. For example, Before: 10000 changes to 10002 After: 0 changes to 2.
  • DOPTPRM OBJMOD 1

Nastran SOL 200 questions? Email me: christian@the-engineering-lab.com
Create Design Constraints

1. Click Constraints
2. Click the plus (+) icon for Frequency
3. Configure the following for r1
   - ATTA: 1 (mode 1)
   - Lower Allowed Limit: 20.0

- The constraint r1 is read as follows: The natural frequency of mode 1 is to be greater than 20Hz.

Nastran SOL 200 questions? Email me: christian@the-engineering-lab.com
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.

Nastran SOL 200 questions? Email me: christian@the-engineering-lab.com
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 an optimization, the results will be automatically displayed as long as the following files are present: BDF, F06 and LOG.
• The flexibility described above enables an alternate method of starting MSC Nastran: 1) Move the BDF files to a remote machine. 2) Manually start MSC Nastran on the remote machine. 3) Move the BDF, F06 and LOG files to the local machine. 4) Click “Start MSC Nastran,” and the results will be automatically displayed.

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

Nastran SOL 200 questions? Email me: christian@the-engineering-lab.com
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.
Review Optimization Results

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

1. Ensure the messages shown have green checkmarks. This is indication of success. Any red icons indicate challenges.

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

- After an optimization, the results will be automatically displayed as long as the following files are present: BDF, F06 and LOG.
- The total weight of the structure is ~110 units of mass, but the Objective plot is reporting an initial mass of ~20. Recall earlier that the equation objective was set as follows: $R_0 = a_1 - 90$, where $a_1 = \sim110$. After evaluation, the initial objective is $R_0 = \sim20$.
Results

Before Optimization
- Weight: 19.2 lbs.
- 1st Natural Frequency: 26 Hz

After Optimization
- Weight: 6.97 lbs.
- 1st Natural Frequency: 20 Hz

MSC Nastran Design Sensitivity and Optimization User’s Guide
Chapter 8 - Example Problems - Vibration of a Cantilevered Beam (Turner’s Problem)
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: dsoug2.dat
3. A summary of updates that will be performed are shown
4. Click Download and a new updated BDF file is downloaded

Nastran SOL 200 questions? Email me: christian@the-engineering-lab.com
Update the Original Model

1. Note the entries have been updated with the optimized properties.
End of Tutorial
Appendix
Appendix Contents

◦ Frequently Asked Questions

◦ There are thousands of properties that have been identified as designable. How can the properties best be sorted so the thicknesses can be set as design variables?
Frequently Asked Questions

Question:
- There are thousands of properties that have been identified as designable. How can the properties best be sorted so the thicknesses can be set as design variables?
Frequently Asked Questions

Answer:

◦ There are search options available for the table
  1. Click on Options
  2. Click ‘Starts with’
  3. Type ‘T’ in the search box
  4. Click on Property to sort the table in sequential order
  5. Type into the box the number 8 to display only 8 rows

◦ Also, there is an option to create multiple design variables in one click
  6. Specify lower and upper bounds
  7. Click ‘Create’ and all the visible properties will be set as design variables

Nastran SOL 200 questions? Email me: christian@the-engineering-lab.com