Workshop - Acoustic Optimization, Nastran BETA Function

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

Minimize peak acoustic pressure without increasing the weight of the box

Before Optimization
- Weight: 2894

After Optimization
- Weight: 2910

MSC Nastran Design Sensitivity and Optimization User’s Guide
Chapter 8 - Example Problems - Dynamic Response Optimization
Details of the structural model

**Acoustic Optimization**

Acoustic Optimization uses acoustic pressures as a design response. These are computed from a solution of the coupled fluid-structure interaction problem. An optimal design can thus be found based not only on a consideration of acoustic pressures, but structural responses as well.

This example considers a closed box with fluid elements on the interior. An acoustic source is located at one end of the box, with a transducer located at the opposite end. The design goal is to modify the thicknesses of the box walls such that the peak acoustic pressure at the transducer is minimized without increasing the weight of the box.

The box geometry and property groups of thicknesses to be modified are shown in Figure 8-29. Six design variables are to be related to six of these property groups (the third property group in Figure 8-29 remains fixed.) The model consists of 1000 structural elements and 2000 fluid elements.

![Diagram of the structural model with fluid and node 11280 highlighted](image)
Optimization Problem Statement

Design Variables

x1: T of PSHELL 1
x2: T of PSHELL 2
x4: T of PSHELL 4
x5: T of PSHELL 5
x6: T of PSHELL 6
x7: T of PSHELL 7

.001 < xi < 1.0

x_beta: Automatically generated by Nastran
x_beta, initial = 1.0
.001 < x_beta

Design Objective

R0: Minimize

\[ C_1 \times x_{\beta} \]

\[ C_1 = 1.0 \] (Default or if left blank)

Other Responses

b1: Pressure, x-component, at node 11280 across all forcing frequencies

Design Constraints

\[ g = \frac{b_1 - y \times x_{\beta}}{C_3} \leq 0 \]

\[ \gamma \] is determined from the following expression. Refer to MSC Nastran manual for details regarding Beta Function and C1, C2 and C3.

\[ g_{\text{max}} = \frac{b_{\text{max}} - y \times x_{\beta}}{C_3} = C_2 \]

r1: Weight

2890. < r1 < 2910.
The Appendix includes information regarding the following:

- Frequently Asked Questions
- Beta Method Problem Statement
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

The BETA Function for Acoustic Optimization - MSC Nastran includes a capability known as the BETA function that reduces the work necessary to configure an Acoustic Optimization. This tutorial details how to use the BETA function for MSC Nastran SOL 200, which minimizes the work needed to define design variables, objective and constraints.

Minimize \( \phi = C1 \ X_\beta \)

Subject to \( g = \frac{r X_\beta - r_j}{c^3} \geq 0 \)

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

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

This example was previously done, but in this version of the tutorial, the *BETA function* will be used. Below is a comparison of the steps involved. When the BETA function is used, Nastran will automatically generate the design variable x8, the Equation Objective and necessary Equation Constraints.

**Original Steps**

1. Create design variables x1, x2, x4, ... x7
2. Create design variable x8
3. Create Equation Objective R0
4. Create Constraints r1
5. Create Equation Constraint R1
   1. Create supporting response b1
6. Create Constrainer Group 1
7. Create Constrainer Group 2

**Steps with the BETA function**

1. Create design variables x1, x2, x4, ... x7
2. Create design variable x8
3. Create Equation Objective R0 using the BETA function
4. Create Constraints r1
5. Create Equation Constraint R1
   1. Create supporting response b1
6. Create Constrainer Group 1
7. Create Constrainer Group 2

The BETA function will trigger Nastran to automatically create the items that are crossed out.
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.

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

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

Select an optimization type to begin

1. Size and Topometry
2. Topology
3. Multi Model

Tutorials are available in the User's Guide

• 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.

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

1. Click 1. Select Files and select dsoug10.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.

Step 1 - Upload .BDF Files

1. Select files  
dsoug10.dat

2. Upload files

Uploading 100 %

Identifying Design Properties: 100 % - Success!
Create Design Variables

1. In the filter box, type ‘t’
2. Click 10 on the page bar
3. Click + Options
4. Set the lower bound to .001
5. Set the upper bound to 1.0
6. Click Create

This will set all visible properties as design variables.

- There are 2 methods to create the 7 design variables:
  - Click each blue plus icon, which requires 7 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.
Create Design Variables

1. Click on 10 as shown to display all design variables

2. Delete design variable x3 by clicking the x icon

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

1. Click Objective
2. Click on Switch to Equation Objective

- There are 2 methods of setting an objective.
  - Method 1 – Select a objective from a given list of responses, e.g. Weight, Volume, etc.
  - Method 2 – Create an equation.
- This example uses Method 2 for the objective.
Create Design Objective

1. Scroll to Step A – Optional - Create additional responses
2. Click the plus (+) icon for Acoustic Pressure
3. Configure the following for a1
   1. ATTA: 1 - RM - T1 (Rectangular ...
   2. ATTi: 11280 (node 11280)

- The label a1 represents the pressure at each forcing frequency for grid 11280. There are 44 forcing frequencies, so a1 represents 44 acoustic pressures.

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

1. Scroll to section Step 1 - Adjust equation objective
2. Click + Options
3. Mark the checkbox for FUNC, METHOD, C1, C2, C3
4. Type in a1
5. Set the FUNC as BETA

Traditionally, the Beta Method requires the explicit creation of an Equation Objective, e.g. $R_0 = 250 \cdot y_0$, and an Equation Constraints, e.g. $R_1 = 250 \cdot y_0 - b_1 + 100$. When the FUNC=BETA option is used, MSC Nastran automatically generates the Equation Objective and Equation Constraint internally.

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

1. Click Constraints
2. Click the plus (+) icon for Weight
3. Configure the following for constraint r1
   1. Lower Allowed Limit: 2890.

- For some optimization scenarios, the weight is allowed to vary only a small amount. For this example, the weight is only allowed to vary +/-10 relative to the original values of 2900. This is achieved by setting the lower bound to 2890 and the upper bound to 2910.
Assign Constraints to Load Cases (SUBCASES)

1. Click Subcases
2. Mark the checkbox

r1 or the Volume is applied as a Global Constraint

- There are 2 types of responses: Global and Subcase Dependent responses. Global responses are the same regardless of subcase and examples include volume, weight, etc. Subcase Dependent responses vary across subcases. For example, stress or strain will vary from subcase to subcase.
- In this example, weight is a global response, therefore, the weight constraint is assigned as a Global Constraint.

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

1. At the top right hand corner, click on Settings
2. Ensure the following checkboxes are marked and the respective values match as shown in the image to the right

- Per the MSC Nastran Design Sensitivity and Optimization User’s Guide, the Direct Linearization method for Approximation is often useful for dynamic response optimization. Therefore, APRCOD is set to Direct Linearization.
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.

Nastran SOL 200 questions? Email me: christian@the-engineering-lab.com
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.
- Note that as the objective is minimized the peaks of the pressure response are being minimized across each forcing frequency.

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

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.

1. Use the Navigation side bar to navigate to the indicated plot.
2. The plot contains the INITIAL and FINAL values of the dynamic response.

- From the plot, the FINAL pressure curve in orange is lower than the INITIAL pressure curve in blue. The optimization was successful.
Results

Before Optimization
- Weight: 2894

After Optimization
- Weight: 2910

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

Nastran SOL 200 questions? Email me: christian@the-engineering-lab.com
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: dsoug10.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
- Beta Method Problem Statement
Beta Method Problem Statement

Below is the optimization problem statement for the Beta method.

**Objective:** Minimize $C_1 \cdot y_\beta$

**Design Constraint:** $0 < C_1 \cdot y_\beta - P(f)$

- $P(f)$: A point on the curve
- $C_1$: Arbitrarily chosen such that the product of $C_1$ and $y_\beta$ is greater than all or most of the points on the curve for the INITIAL design.
Beta Method Problem Statement

This optimization method can be seen as a moving ceiling scenario. The goal is to minimize the ceiling (blue line), while ensuring the response curve (orange) remains under the ceiling. The ceiling is defined as $C_1 \cdot y_{\beta}$.

Objective: Minimize $C_1 \cdot y_{\beta}$

Design Constraint: $0 < C_1 \cdot y_{\beta} - \text{P(f)}$

- $\text{P(f)}$: A point on the curve
- $C_1$: Arbitrarily chosen such that the product of $C_1$ and $y_{\beta}$ is greater than all or most of the points on the curve for the INITIAL design.

As the ceiling, $C_1 \cdot y_{\beta}$, is minimized, the peaks of the curve are also minimized.
Beta Method Problem Statement

For this example Acoustic Optimization Example,

- Minimize $C_1 \cdot y_\beta$
  - where,
    - $C_1 = 250$
    - $y_\beta = y_0$ = The Beta design variable with an initial value of 1.0
  - The constraint is
    - $0 < 250 \cdot y_0 - b_1$
      - $b_1$: The pressure at each forcing frequency
  - Since a bound of 0 can cause difficulties during optimization, an offset term of 100.0 is introduced. The constraint is equivalently:
    - $100.0 < 250 \cdot y_0 - b_1 + 100.0$
  - The full optimization problem statement is shown on the next slide.
Concept of Multi-Slope Beta Method

- Minimization of peak acoustic response with frequency dependent upper bounds rather than a flat upper bound as shown on the right figure.

minimize $\beta X$

Subject to $\beta X - P(f_i) - h_i \geq 0$

Again, to avoid using 0 as lower bound (division by zero), introducing a constant $K$ leading to the following constraint equation:

$$\beta X - P(f_i) - h_i + K \geq K$$
Concept of Multi-Slope Beta Method

Rearrange the frequency dependent constraints as follows:

\[ \beta X - P(f_i) + K \geq K + h_i \]

For the case of \( \beta = 100.0, K=50.0 \) and following values

<table>
<thead>
<tr>
<th>( f_i(\text{Hz}) )</th>
<th>20.0</th>
<th>80.0</th>
<th>120.0</th>
<th>160.0</th>
<th>200.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>( h_i )</td>
<td>20.0</td>
<td>0.0</td>
<td>0.0</td>
<td>20.0</td>
<td>25.0</td>
</tr>
</tbody>
</table>

The input in Nastran can be defined as follows:

DEQATN 100 OBJ(BETA) = 100.0 * X
DRESP1 1 PRESS FRDISP 1 11280
DRESP2 11 PRESBET 10
DESVAR 8
DRESP1 1
DEQATN 10 F(BETA,PRES) = 100.0 * X - PRES + 50.
DCONSTR 10 11 200
TABLED1 200
20. 70. 80. 50. 120. 50. 160. 70.
200. 75. ENDT