

13290 Evening Creek Drive S, San Diego CA 92128

Webinar: Design Sensitivity and Optimization with Simcenter Nastran and Femap

Anthony Ricciardi, ATA Engineering July 23rd, 2020



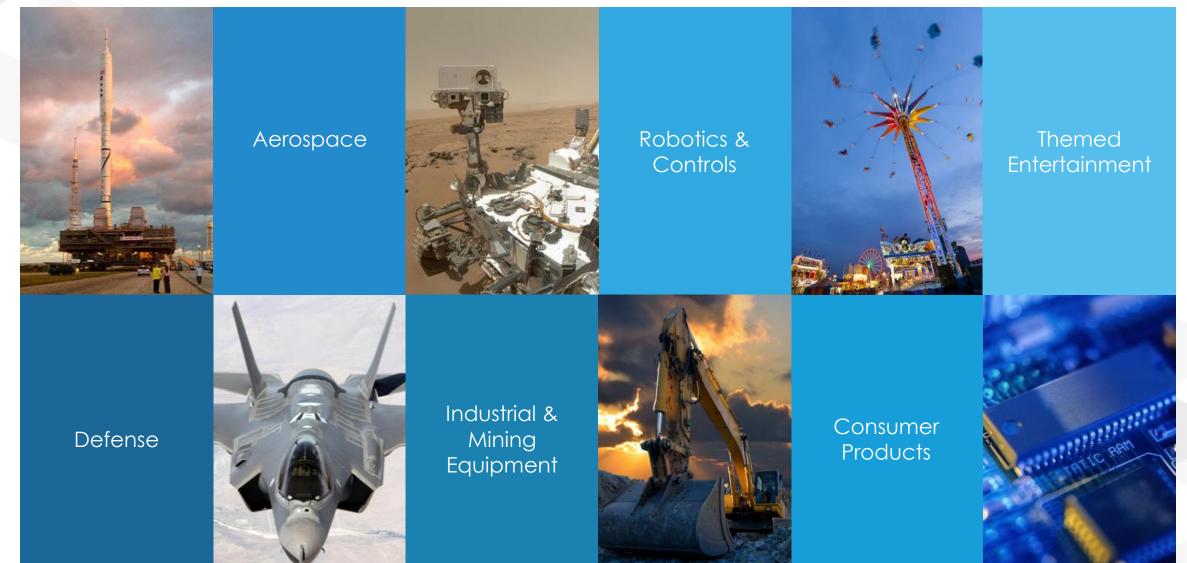


in ata-engineering

@ATAEngineering

ATA Provides High-Value Engineering Services With Expertise in Design, Analysis, and Test

ATA Engineering helps to overcome product design challenges across a range of industries



ATA is a Value-Added Reseller for Siemens Digital Industries Software

ATA offers training, free resources, and hotline support for a variety of Siemens products.



- > Siemens product lines we support include:
 - Simcenter STAR-CCM+
 - ➢ Simcenter Femap
 - Simcenter Nastran (formerly NX Nastran)
 - Simcenter 3D
 - ➢ NX CAD & CAM
 - ➤ Teamcenter
 - ➢ Solid Edge
- > Contact the hotline at 877-ATA-4CAE or

http://ata-plmsoftware.com/support

- > Developer of the official Simcenter Nastran training materials
- Preferred North American provider of Simcenter Nastran training
- > Recognized as Smart Expert Partner with validated expertise in

Femap, STAR-CCM+, and Simcenter 3D



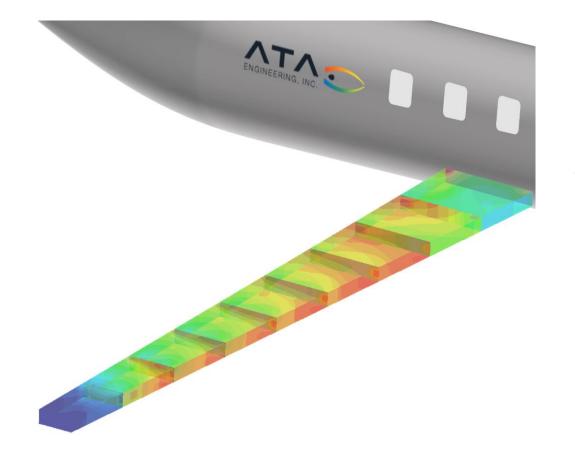


Visit Our Website for Product Information and Free Resources

www.ata-plmsoftware.com

← Support ATA × C ← → C @ www.sta-pimsoftware.com/support/		← Resources ATA × ← → C ① www.ata-pimsoftware.com/resources/?pc=NX				
		C - C Www.ata-pinsortware.com/resources/:pc-ivx		н		
PRODUCTS ABOUT EVENTS IS TRAINING SUPPORT NEWS CONTACT SEARCH TREE RESOURCE	s	SIEMENS SOLUTION PARTNER	TRAINING SUPPORT NEWS CON	TACT SEARCH FREE RESOURCES		
Support		Resources				
Support		Resources are password pr	otected. Get you	Ir password		
ATA's team of experts provide comprehensive technical support for all of the Siemens softwar we sell. Fill in the form below and one of our technical team will be in touch shortly.	re	Femap NX NX Nastran	Search Resources	Search		
Alternatively you can call us at 877-282-4223. Hours of operation (8a.m. to 8p.m. Eastern)		Whitepapers	Macros			
Your Name* Your Email*		Changing Units in an Assembly in NX PDF	Renumber Groups in NX		1 stables	
Company* Phone Number*		Assembly-Level Part Design Using Interpart Modeling in NX PDF	Check Element Quality	1		SIEMENS
Software Product*		Using Synchronous Modeling to Manipulate Solid Bodies in NX PDF	Renumber Labels in NX		Le la la	Ingenuity for life
¥		Beam Post-Processing with Cross-Section Views in NX PDF				
Please describe the issue you are having		Basic FEM Checks in NX PDF		Simcenter F	emap	
		Presentations	Other Resources	version 202		Nastran [®] , including support for monitor points and direct matrix inputs (DMIGs), as well as Ansys [®] , Abaqus [®] and LS-DYNA [®] .
Submit		Design, Analysis, and Manufacturing Success with NX PDF	On-Demand Webinar: Prin	Benefits	Summary	Simcenter Femap is now being released on a biannual schedule in the spring and the fall, which began with version
		Analysis Driven Design: Optimization of a Hexapod Isolator PDF	NX	 First implementation of synchro- nous technology for geometry modification 	Sincenter™ Prang™ software is a standalose finite element moleling para and postprocessor for engineering im- ulation and analysis. The software is CAD-independent and can import geometry from all and oxorisis in combi- ration with a wide variety of finite ele- ment analysis occurs, including the most analysis occurs, including the Modermized to Modermized to Modermized to Modermized to Modermized to Modermized to Modermized to Modermized to Modermized to Modermized to Mod	2019.1 and continues with version 2020.1. The software is now referred to as Simcenter Femap to reflect that it is a
		Workflows in NX: Product and Manufacturing Information (PMI) for Design and Analysis PDF	On-Demand Webinar: Intro	Streammer works low and reuse of previous data definitions Upgraded support for various analysis applications Features Updates to UI and preprocessing		part of the Simcenter portfolio of Siemens CAE products. For the same reason, NX ^{IM} Nastran [®] software is now Simcenter ^{IM} Nastran [®] .
		Comparison of Composite Modeling Techniques PDF	On-Demand Webinar: Best Patterning			Visualization and user interface Modernized icons All icons found throughout the user
© 2017 ATA Engineering. All rights reserved. Web Design by Eyesparks	ING.INC	Training Videos	Tutorials	Improvements to existing meshing functionality Added support for simulation entities used in more advanced solutions	The latest release provides a variety of improvements that will improve your productivity across the simulation work- flow. Model creation enhancements consist of more robust editing of geo- metric features, the ability to align geo- metric features useful for mapped	interface have been modernized to incorporate design elements utilized in commercial software applications across all industries. This includes icons on toolbars, in the menu structure, within dialog hows and in the model tree
		L			mathing, and improved deflecting capabilities for filters and letters. For mething, existing overflows have been enhanced to adver greater filter file.2019 setterments from the degles of other let- ements or weaking elements along an existing meth. There are also serveral updates to solver integration for	





13290 Evening Creek Drive S, San Diego CA 92128

Webinar: Design Sensitivity and Optimization with Simcenter Nastran and Femap

Anthony Ricciardi, ATA Engineering July 23rd, 2020





in ata-engineering

@ATAEngineering

Target Audiences and Objectives

Group	Target Audience	Objectives				
(1)	Experienced with NastranNew to optimization	 Introduce(1)/review(2) fundamentals of design sensitivity and optimization 				
(2)	 Experienced with legacy Nastran and optimization New to recent developments (~2017-2018) Topology optimization added to Simcenter Nastran starting with NX Nastran 12 Improved Femap support for optimization starting with Femap 12 	 Introduce Simcenter Nastran and Femap capabilities Demonstrate Simcenter Nastran and Femap capabilities to Reinforce your understating Help you get started 				



Outline

Design Sensitivity and Optimization with Simcenter Nastran and Femap

➤Fundamentals

Simcenter Nastran & Femap Capabilities

➤Examples

- 1. Sizing a beam cross-section
 - Graphical solution based on hand calculations
 - Femap with Simcenter Nastran solution
- 2. Topology optimization of a cantilever structure
 - \succ Sigmund 99-line topology optimization reference solution
 - \succ Femap with Simcenter Nastran solution
- 3. Sizing an aircraft wing structure using Femap with Simcenter Nastran
 - Many design variables
 - Multiple subcase types



What are Design Sensitivity and Design Optimization?

8

Design sensitivity analysis computes the rates of change of structural responses with respect to changes in design variables.

- These design variables can be used to represent shell thicknesses, beam cross sectional dimensions, etc.
- In civil engineering, we may be interested in how changes in the deflection of a bridge span can be affected by changes in the dimensions of the bridge sections.
- In automotive design, we may want to investigate changes in cabin resonant frequencies given changes in panel thicknesses.
- These rates of change (what we call derivatives in calculus) are called design sensitivities or design gradients.
- Design optimization is an automated process that uses an optimizer to generate improved designs.
 - > An optimizer implements a formal algorithm to search for the best design.
 - Gradient-based optimization algorithms use design sensitivities to guide this search process.
 - > Simcenter Nastran uses gradient-based optimization algorithms for design optimization.



Why Use Design Sensitivity and Optimization?

> Design sensitivity analysis can be used for:

- Improving understanding of how a system response changes with respect to adjustable parameters
- > Approximate/reduced-order model creation
- > Uncertainty quantification
- ➤ Gradient-based optimization

> Design optimization can be used for:

- > Producing the best design that satisfies requirements
- ➢ Performing trade-off or feasibility studies
- \succ Updating models to correlate with test data



Nastran & Femap Capabilities

Example

10

Engineering Analysis and Optimization

Physical system and design problem

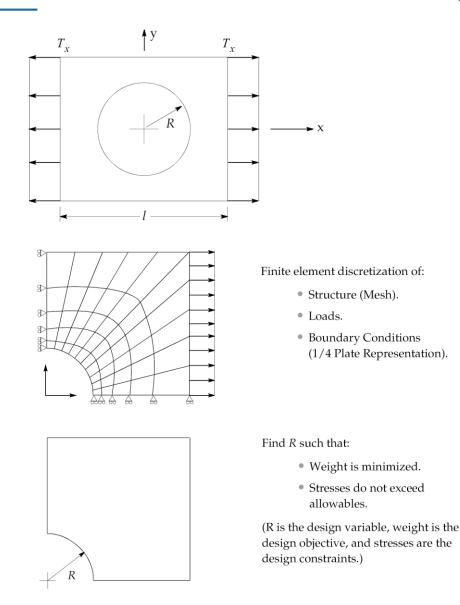
- A physical system that exists or design that will exist in reality
- Example:
 - <u>Physical system</u>: loaded flat plate with a hole
 - <u>Design problem</u>: the hole radius is to be optimized to minimize the weight of the plate while not exceeding allowable stress

Analysis model

- A mathematical idealization of a physical system
- Provides response predictions
- Parametrized by design variables for optimization

Design model

A formal statement of a the design objective, design variables, and constraints





Reference: Simcenter Nastran Design Sensitivity and Optimization User's Guide

11

Basic Optimization Problem Statement

 $f(\vec{x})$

What: Minimize the objective function:

How:Design variables:

> Design properties:

Subject to:Inequality constraints:

➤ Equality constraints:

➤ Bounds:

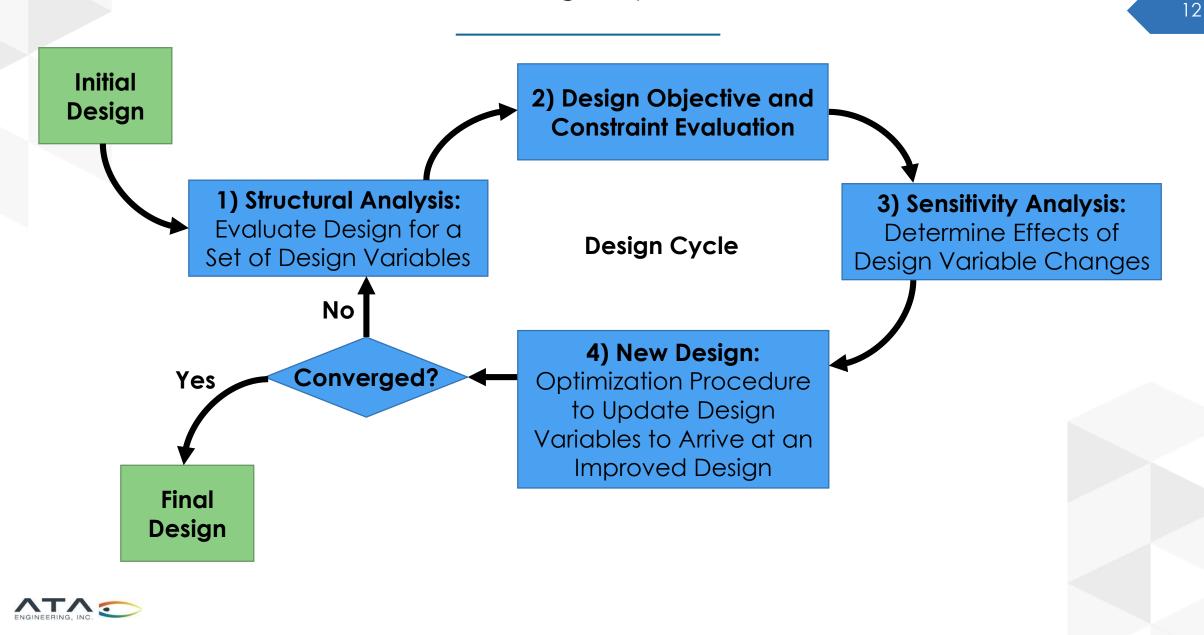
 $\vec{x} = \{x_1, x_2, \dots, x_n\}$ $\vec{p} = \{p_1(\vec{x}), p_2(\vec{x}), \dots, p_m(\vec{x})\}$

 $g_j(\vec{x}) \le 0 \quad j = 1, \dots, n_g$ $h_k(\vec{x}) = 0 \quad k = 1, \dots, n_h$ $x_i^l \le x_i \le x_i^u \quad i = 1, \dots, n$

This basic optimization problem can be solved using Simcenter Nastran. Femap and Simcenter 3D support optimization preprocessing.



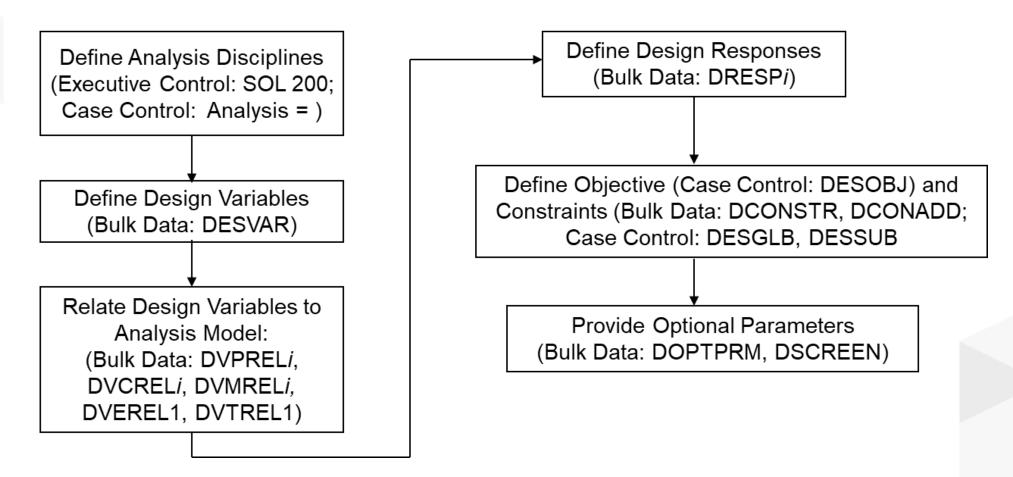
Simcenter Nastran Design Optimization Procedure



13

Simcenter Nastran Design Model Definition

(Not all capabilities shown)





Simcenter Nastran Capabilities (1)

Optimization Analysis Disciplines

Туре	Meaning			
STATICS ^{+, f}	Statics			
MODES ^{+, f}	Normal Modes			
BUCK ⁺	Buckling			
DFREQ ^{*,f}	Direct Frequency			
MFREQ ^{*,f}	Modal Frequency			
MTRAN ⁺	Modal Transient			
DCEIG [*]	Direct Complex Eigenvalue Analysis			
MCEIG*	Modal Complex Eigenvalue Analysis			
SAERO [*]	Static Aeroelasticity			
DIVERGE [*]	Static Aeroelastic Divergence			
FLUTTER [*]	Flutter			
+ Design and topology optimization				

- * Design optimization only
- f Native Femap support (DFREQ has native Femap support for design optimization only)
- Controlled using ANALYSIS=TYPE case control command.
- Can be defined at subcase level to simultaneously optimize with multiple analysis types.

Design Variables

- **DESVAR** design variables and bounds.
- **DDVAL** optional discrete variable values.
- **DLINK** design variable linking.

Design-to-Model Relations

- **DVCREL***i* Design-Variable-Connectivity RELation
- **DVMREL***i* Design-Variable-Material RELation
- **DVPREL***i* Design-Variable-Property RELation
- Basic (or type-1 entries) support linear design variable-to-property relations.
- **DEQATN** (Design EQUATION and type-2) entries can optionally be used for arbitrary relationships.
- **DVGRID**, **DVBSHAP**, and **DVSHAP** are used for shape optimization.
- **DVEREL1** automatically creates shell element thickness design variables.
- **DVTREL1** automatically creates design variables for topology optimization.



Simcenter Nastran Capabilities (2)

Design Response Quantities

- **DRESP1** supports 40 easily accessible response types:
 - CEIG, CFAILURE, CMPLNCE, CSTRAIN, CSTRESS, DISP, DWEIGHT, EIGN, ERP, ESE, FLUTTER, FORCE, FRACCL, FRDISP, FREQ, FRFORC, FRSPCF, FRSTRE, FRVELO, LAMA, PRES, PSDACCL, PSDDISP, PSDVELO, RMSACCL, RMSDISP, RMSVELO, SPCFORCE, STABDER, STRAIN, STRESS, TACCL, TDISP, TFORC, TRIM, TSPCF, TSTRE, TVELO, VOLUME, WEIGHT
 - See Simcenter Nastran Quick Reference Guide for details.
- **DRESP2** Defines arbitrary equation responses that are used for the objective and/or design constraints, or for sensitivity analysis purposes.
- **DRESP3** Defines arbitrary responses to be evaluated in an external user-supplied program.

Objective and Constraint Definitions

- Case control commands are used to specify a DRESPi entry that is the objective function and DCONSR or DCONADD entry that define constraints.
- **DCONSTR** defines design constraints, references DRESP1.
- **DCONADD** defines constraint set combination.
- Constraints can be subcase-specific.

Topology-Optimization-Specific Entries

- **DVTREL1** automatically creates design variables for topology optimization.
- **DMRLAW** controls the relation between material properties and the normalized mass density.
- **DMNCON** defines a manufacturing constraints for topology optimization.



Examples

16

Simcenter Nastran Capabilities (3)

Design Sensitivity Output

- Request output using either:
 - **DSAPRT** Case control command
 - **PARAM**, **OPTEXIT** Bulk data entry
- Various output formats supported
- Can request sensitivities only (no optimization)
 - User still needs to set up design variables and responses
 - General recommendation:
 - Define a violated constraint for each response quantity you require sensitivities for
 - Define a dummy objective function (e.g., weight)



Femap and Simcenter 3D Optimization Preprocessing

Examples

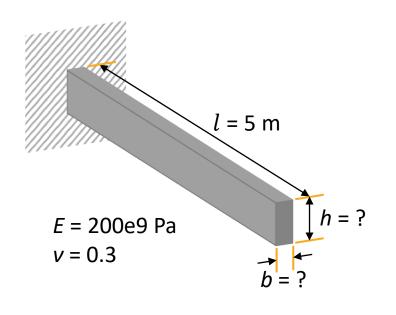
Live Femap Optimization Interface Walkthrough

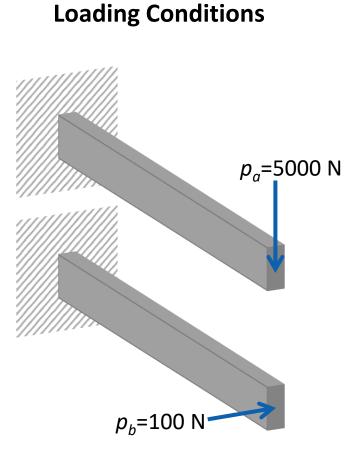




Beam Sizing Optimization

Dimensions and Properties





Problem Statement

Objective: Minimize volume

Design variables: *b*, *h*

Constraints: $\sigma \leq 200e6$ Pa (abs. due to bending) $\delta \leq 0.1$ m (abs. due do bending)

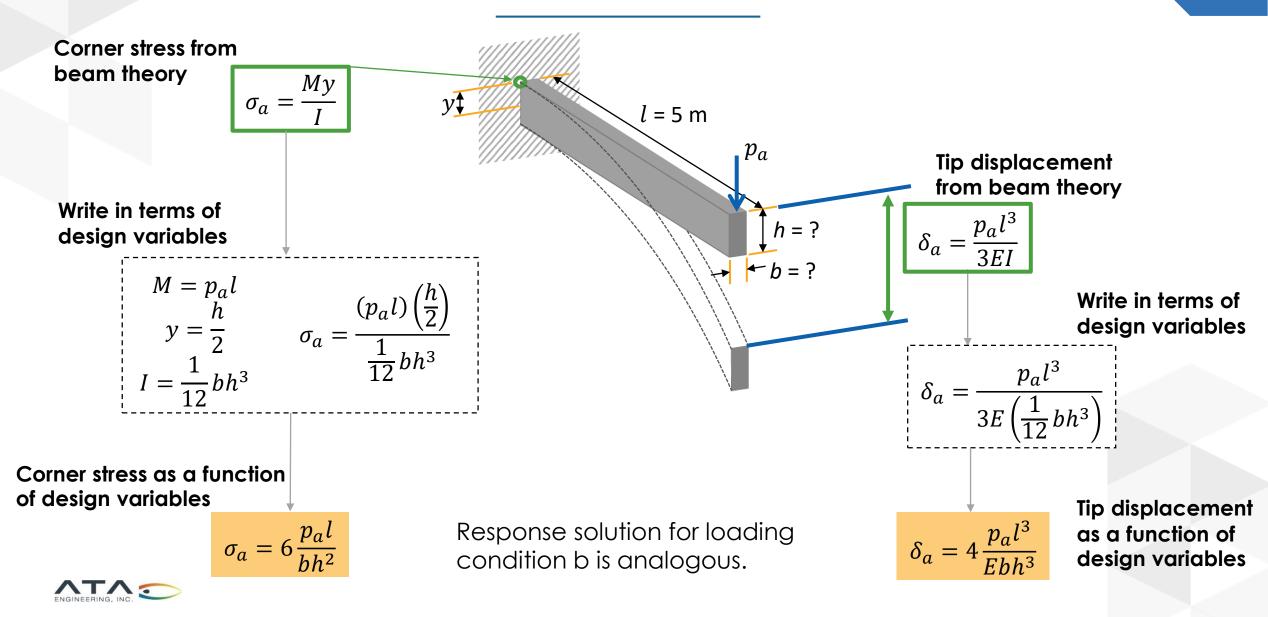
Bounds: $0.01 \text{ m} \le b \le 0.30 \text{ m}$ $0.01 \text{ m} \le h \le 0.05 \text{ m}$



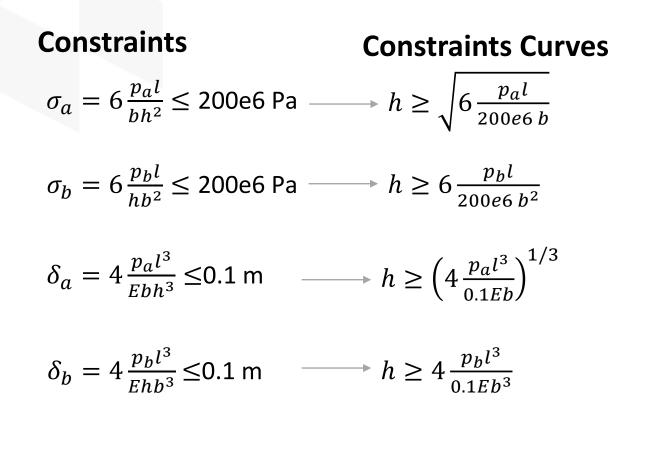
18

Examples

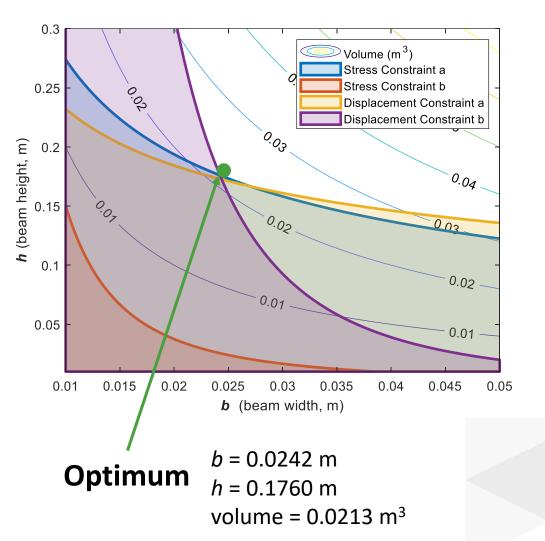
Response Solution Using Hand Calculations



Objective: minimize volume = *lbh*



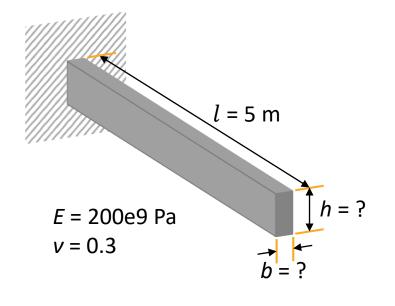


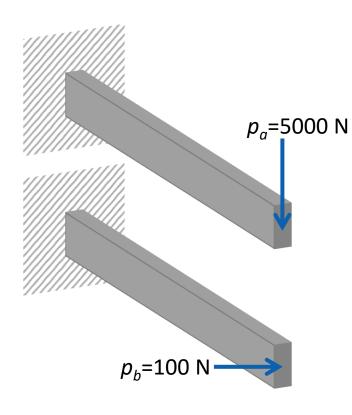


Examples

Dimensions and Properties

Loading Conditions





Problem Statement

Objective: Minimize volume

Design variables: *b*, *h*

Constraints: $\sigma \leq 200e6$ Pa (abs. due to bending) $\delta \leq 0.1$ m(abs. due do bending)

Bounds: $0.01 \text{ m} \le b \le 0.05 \text{ m}$ $0.01 \text{ m} \le h \le 0.30 \text{ m}$

Live Femap Demonstration



Examples

Topology Optimization Example

Sigmund Cantilever Beam

Ole Sigmund. "A 99 line topology optimization code written in MATLAB." Structural and Multidisciplinary Optimization 21(2), 2001, pp. 120-127).

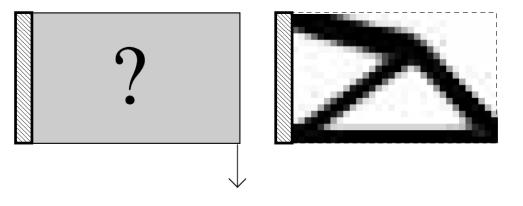
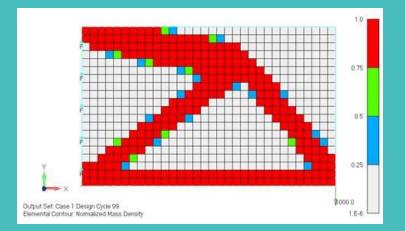


Fig. 2 Topology optimization of a cantilever beam. Left: design domain and right: topology optimized beam

```
nelx = 32; % number of elements in the horizontal direction
nely = 20; % number of elements in the horizontal direction
volfrac = 0.4;% volume fraction
top(nelx,nely,volfrac,3.0,1.5)
```

Live Femap Demonstration





Final TEL Design

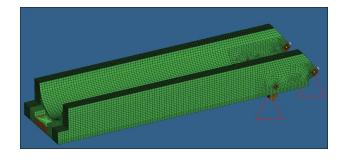
Topology Optimization Case Study

Transporter/Erector/Launcher (TEL) system for the Antares

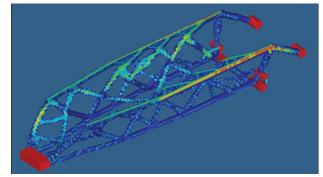
Background

- ATA Engineering and its engineering and manufacturing partner, Martinez & Turek, were selected to design, engineer, manufacture, install, and test the TEL.
- Topology optimization was used to rapidly explore topologies.

Meshed design space of strongback



Topology optimization results



http://www.ata-e.com/wp-content/uploads/2019/12/TEL-Case-Study_2020.pdf#new_tab



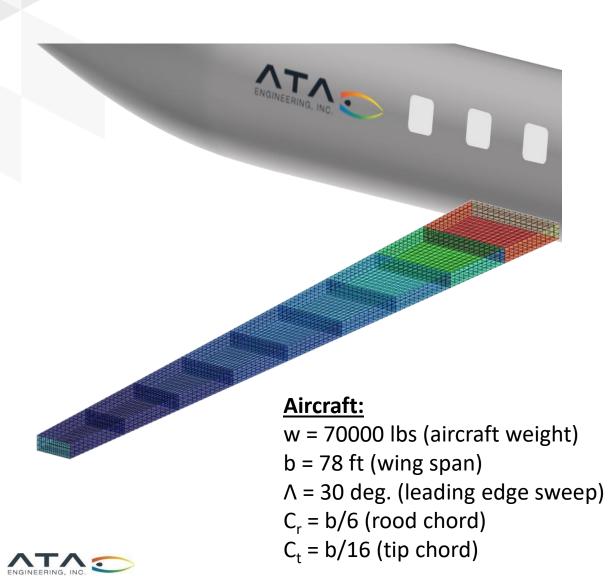


Sections: Fundamentals Nastran 8

Nastran & Femap Capabilities **Examples**

24

Sizing an Aircraft Wing Structure Using Femap With Simcenter Nastran



Problem Statement

Objective: Minimize weight

Design variables: wing skin, spar, and rib thicknesses (26 total)

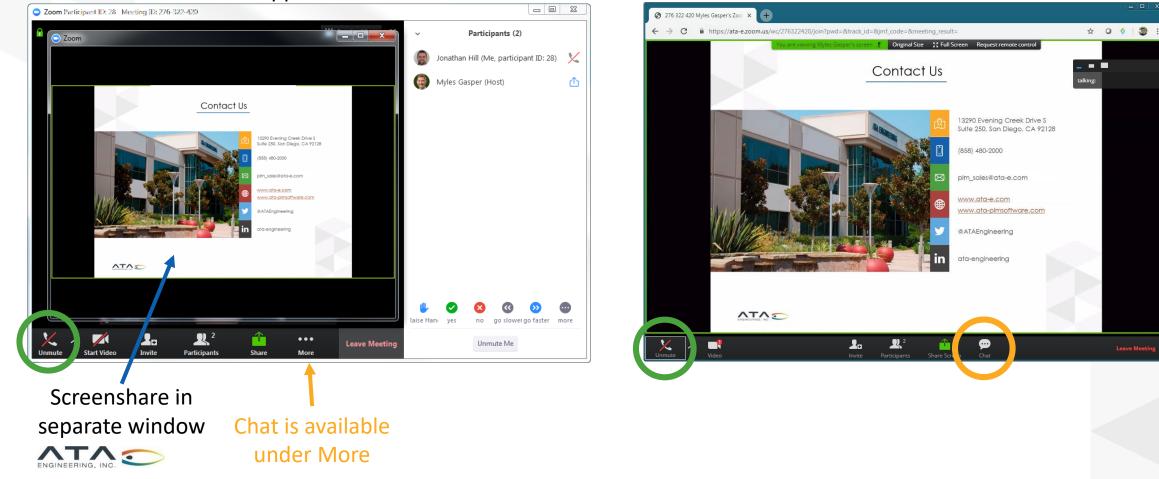
Constraints: $\sigma_{vm} \leq 30$ ksi (4.4g maneuver load) $f_1 \geq 8$ Hz

Live Femap Demonstration Optimization with 26 design variables two analysis types

Questions?

Submit questions in the chat or unmute yourself now

Zoom Application



Web Interface

Contact Us



13290 Evening Creek Drive S San Diego, CA 92128

(858) 480-2000

plm_sales@ata-e.com

www.ata-e.com www.ata-plmsoftware.com

@ATAEngineering

ata-engineering

