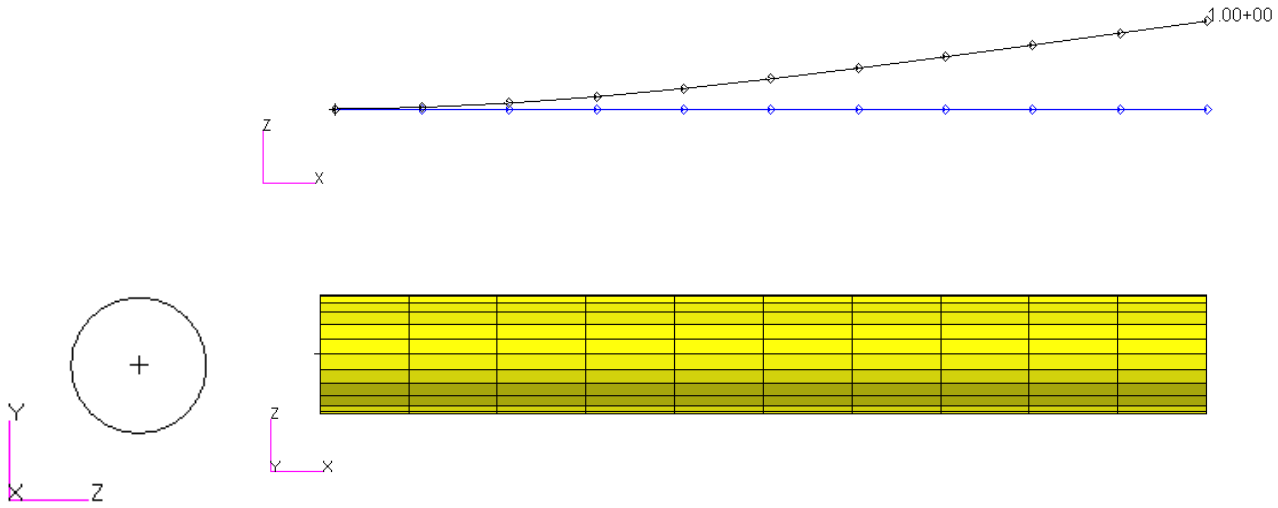
Model Matching / System Identification

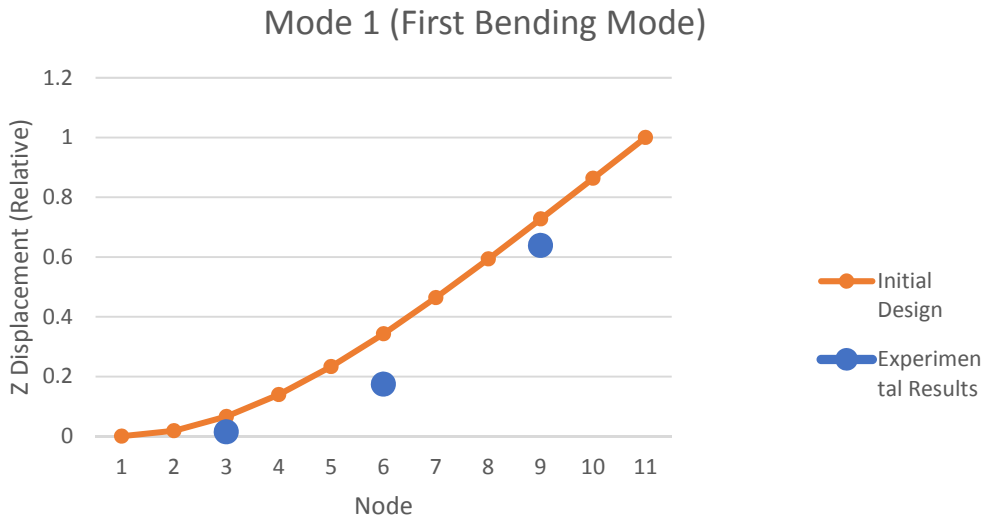
PRESENTED BY CHRISTIAN APARICIO

Questions? Email: christian@ the-engineering-lab.com

Goal: Use Nastran SOL 200 Optimization

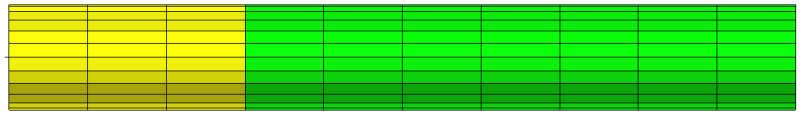
Modes analysis reveals discrepancy between FEM and experiment

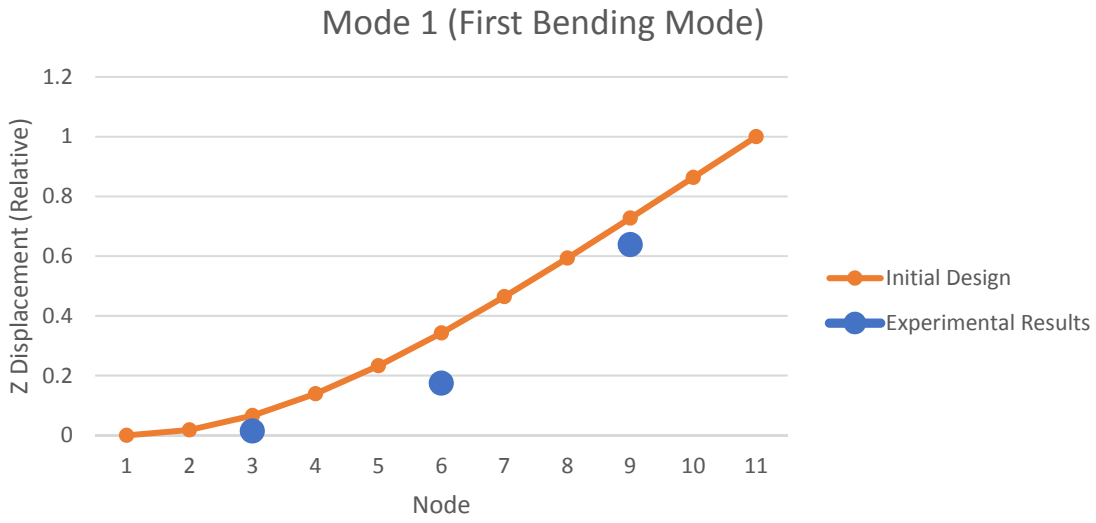




Goal: Use Nastran SOL 200 Optimization Correlate test data and analysis results

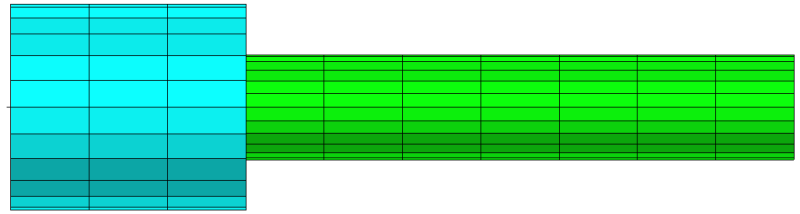
Before Optimization
Radius: 2 in

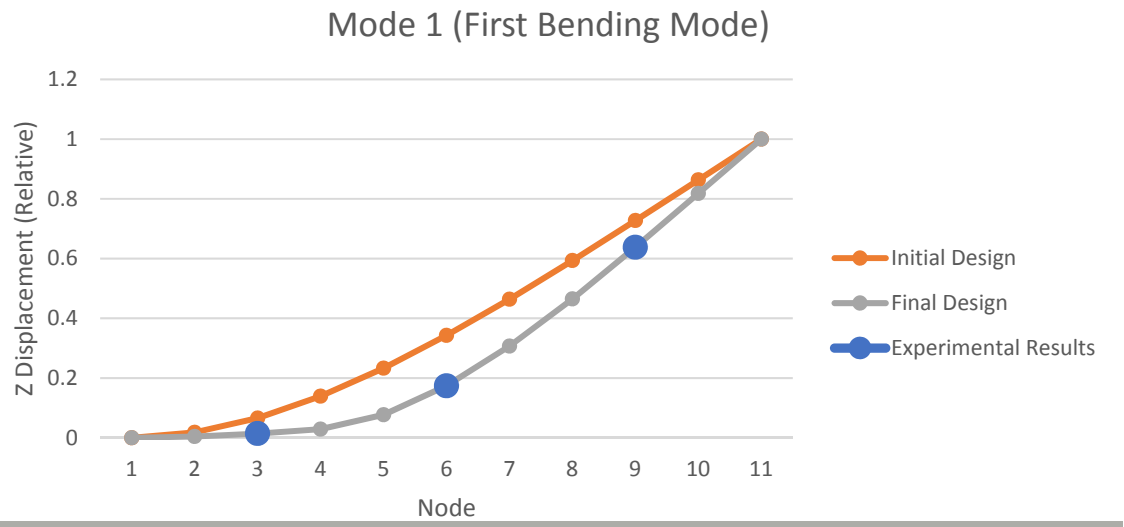




After Optimization

- Radius 3.93 in





Agenda

Details of the structural model

Optimization Problem Statement

Steps to use Nastran SOL 200 (Optimization)
- Convert a .bdf file to SOL 200
- Create:
  - Design Variables
  - Design Objective
  - Design Constraints
- Perform optimization with Nastran SOL 200

View optimization results
- Online Plotter
- Structural Results

Update the original structural model with optimized parameters

Contact me

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

christian@ the-engineering-lab.com

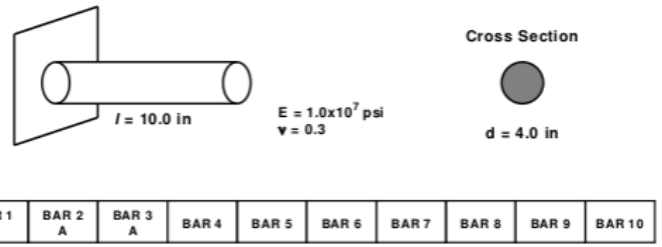
Details of the structural model

25.6.6 System Identification

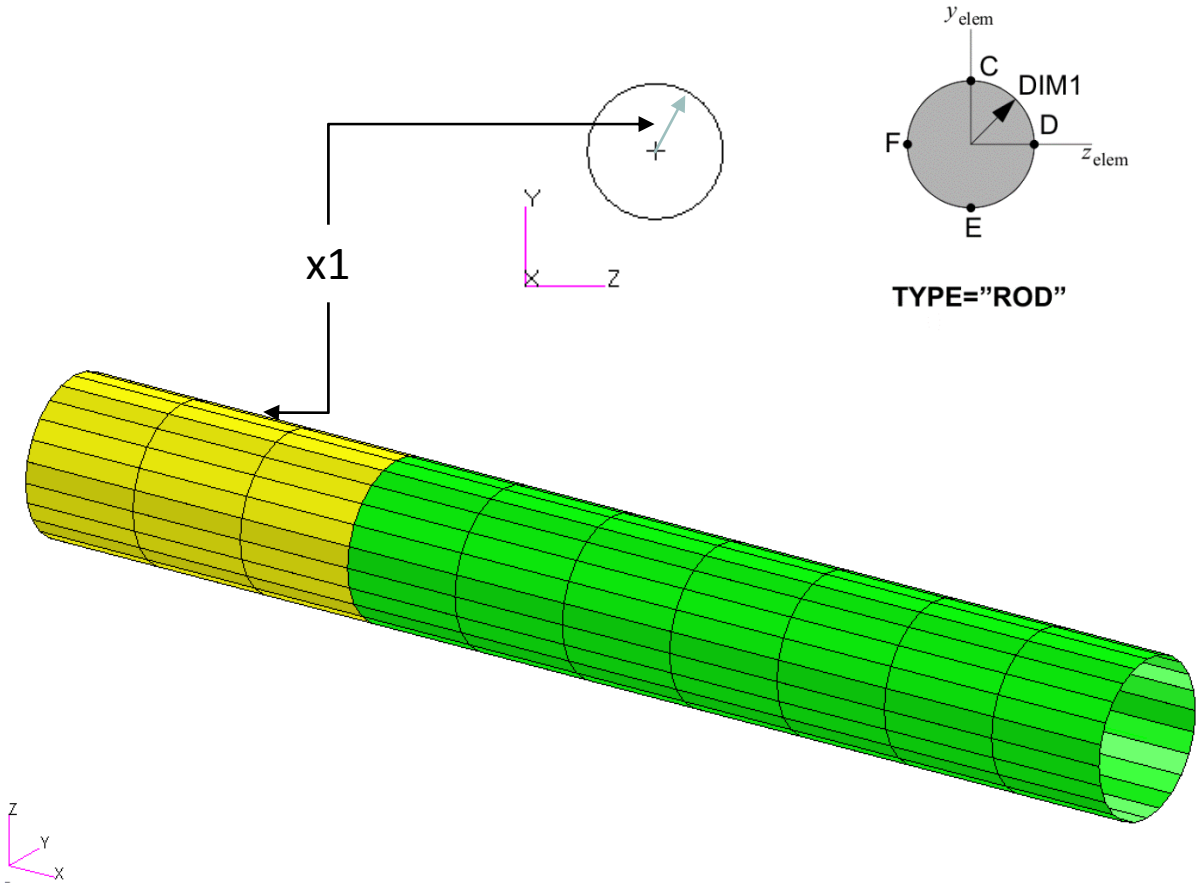
An important area of research is the tuning of finite element models to experimental test results. This is often called system identification. This example problem illustrates how optimization may be used to address these requirements. It features:

- Normal modes optimization
- Constraints on RMS error in mode shapes
- Frequency constraints
- Using an analytical response as the objective

Figure 25-13. SYSTEM ID — SIMPLE BEAM MODEL

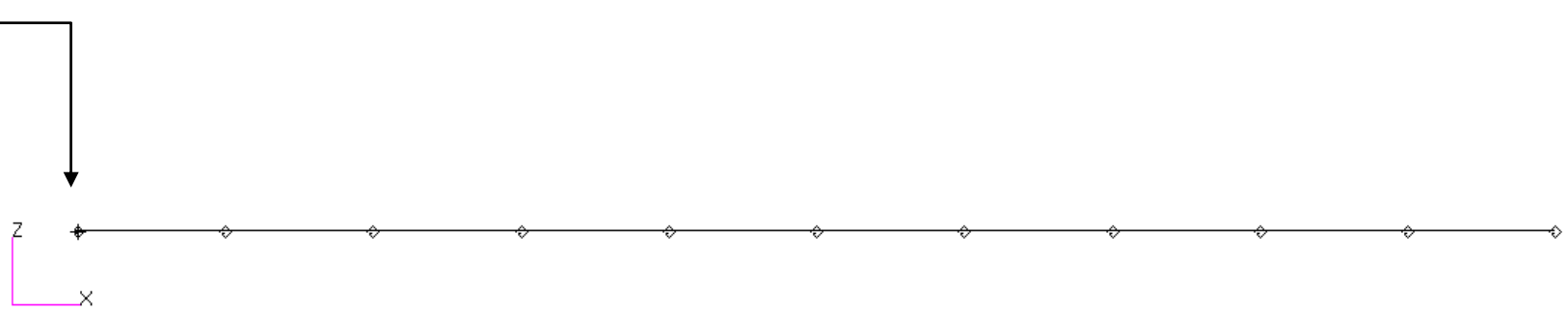


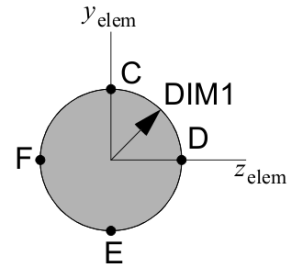
UAI/NASTRAN User's Guide for Version 20.1
Chapter 25 – MULTIDISCIPLINARY DESIGN OPTIMIZATION –
25.6.6 System Identification



Details of the structural model

Fixed





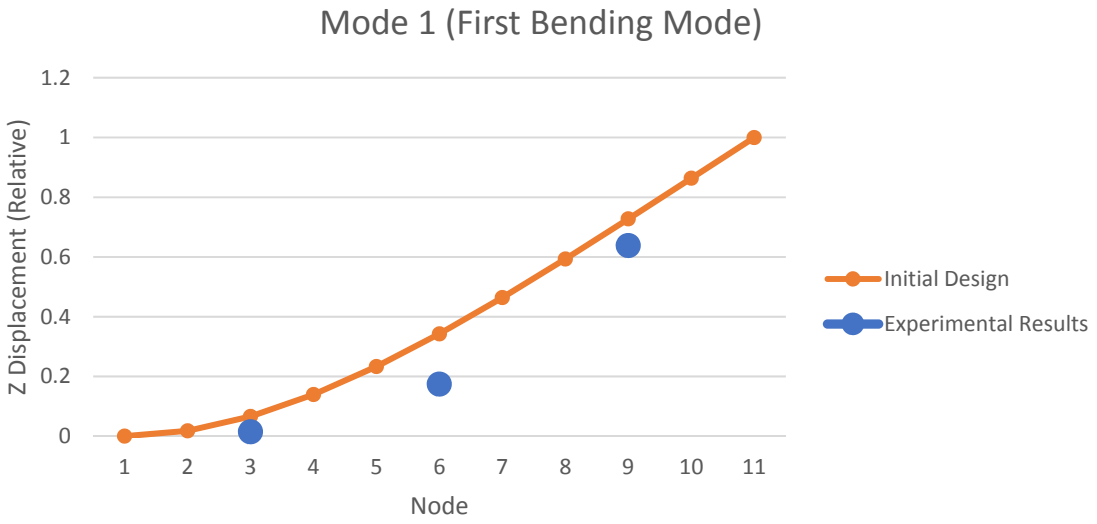
TYPE="ROD"

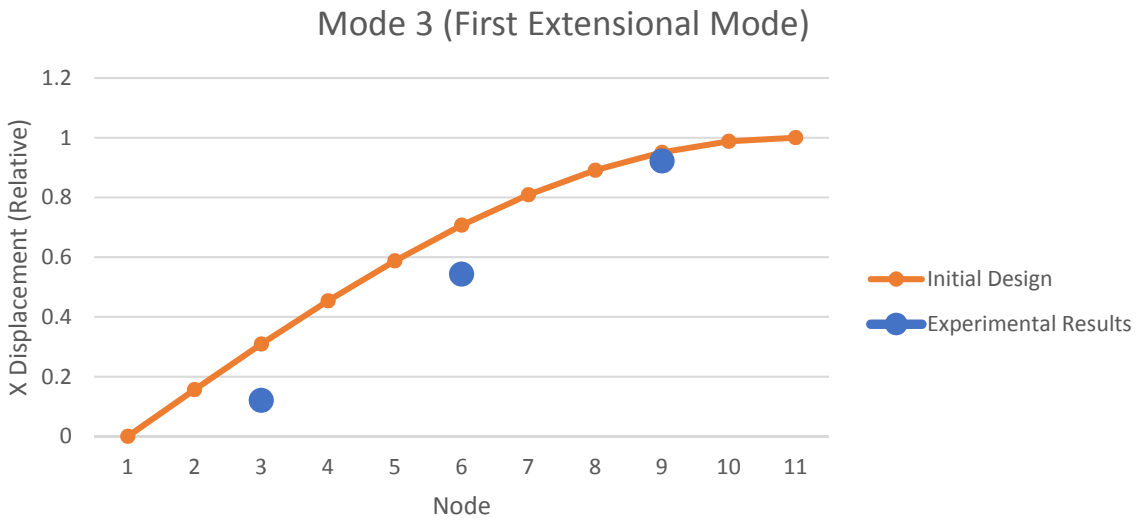
Length: 30 in

E = 1 * 10^7 psi
v = .3
Density = .01 lb_f * s^2 / in^4

Details of the structural model Experimental Results

	Mode 1			Mode 3	
Node	Component	Experimental Value		Component	Experimental Value
3	z or 3 direction	0.0143		x or 1 direction	0.1204
6	z or 3 direction	0.1741		x or 1 direction	0.5431
9	z or 3 direction	0.6381		x or 1 direction	0.9216

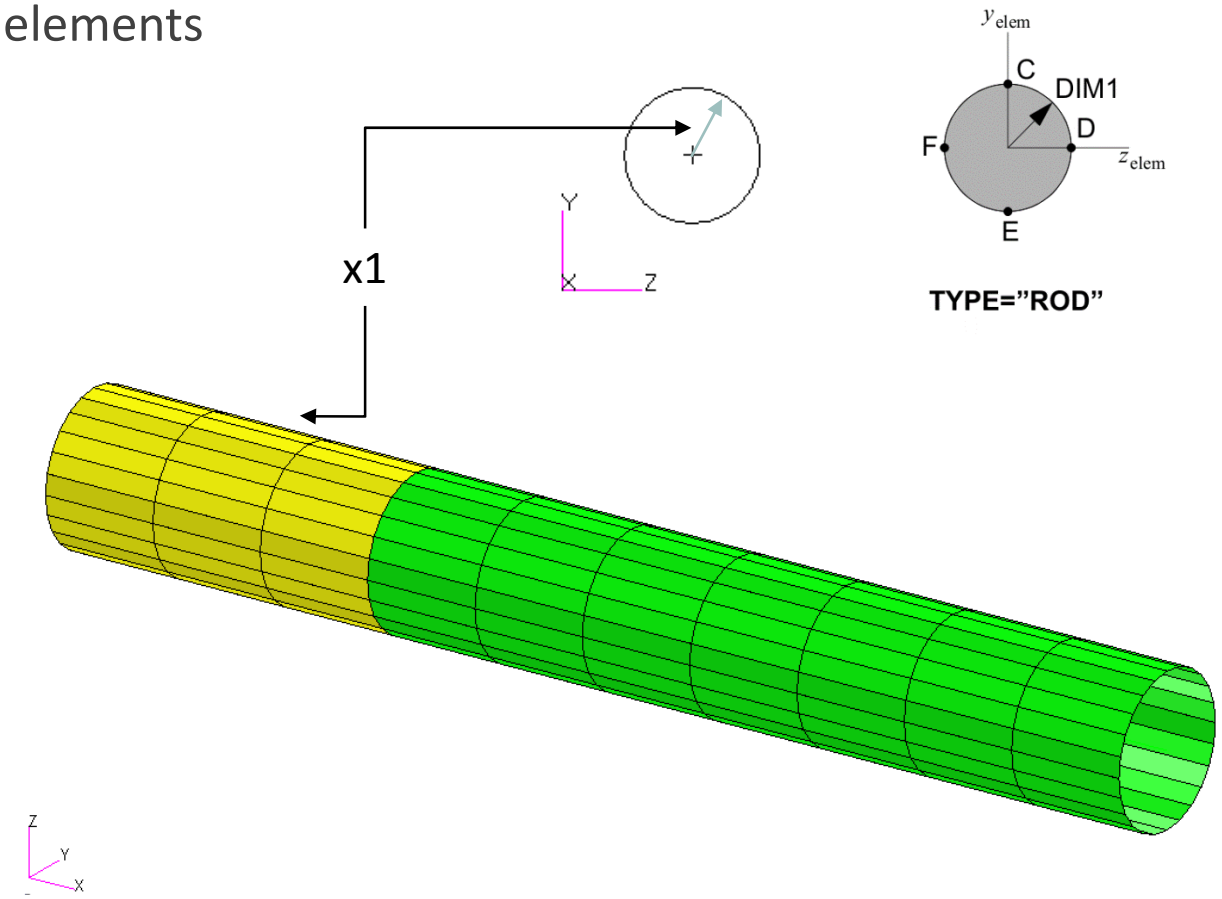




Optimization Problem Statement Design Variables

x1: Radius of cross section for first 3 elements

- .1 < x1 < 10.

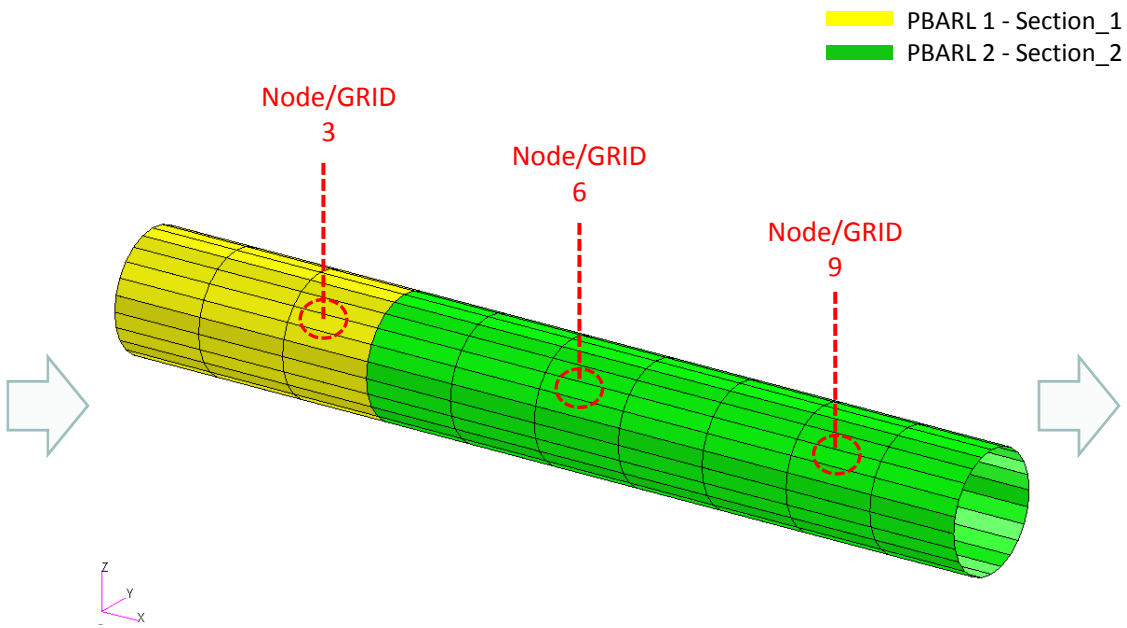


Optimization Problem Statement

Design Variables

x1: Radius of cross section (DIM1 of PBARL 1)

.1 < x1 < 10.



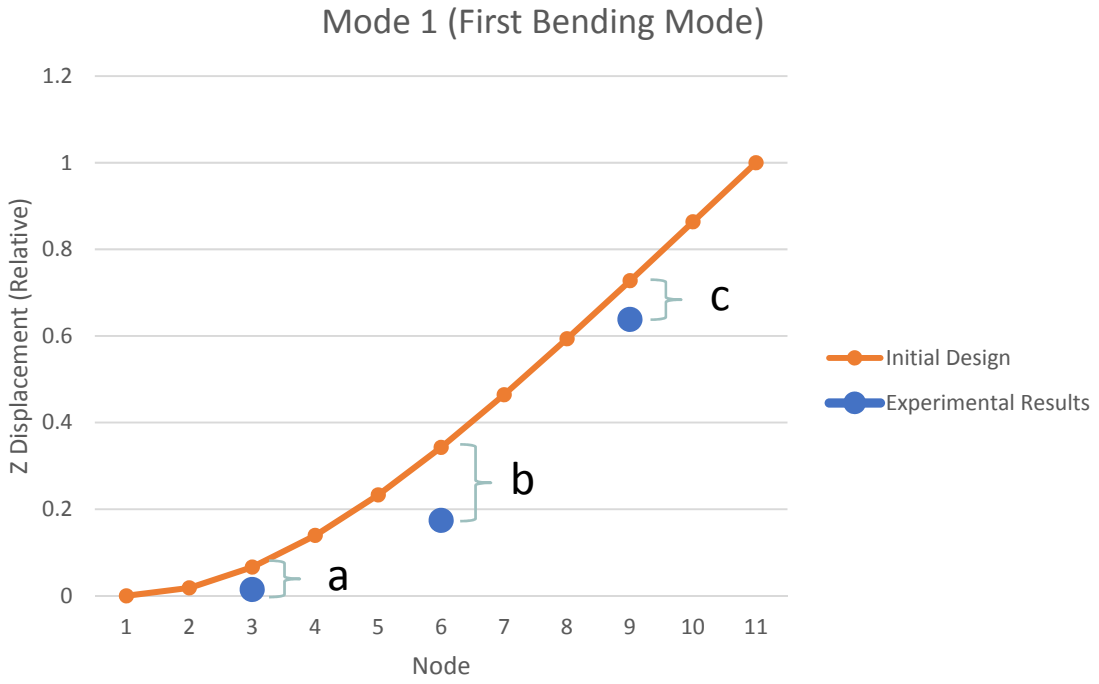
Responses (Outputs)

- Frequencies
- Mode shapes
- ….

Optimization Problem Statement Design Objective

For mode 1, minimize least squares

- Minimize R0
  - R0 = a + b + c
    - a = $(\frac{a1-.0143}{.0143})^2$
    - b = $(\frac{a2-.1741}{.1741})^2$
    - c = $(\frac{a3-.6381}{.6381})^2$
    - a1, a2, a3 are the z displacements at nodes 3, 6, 9, respectively, for mode 1

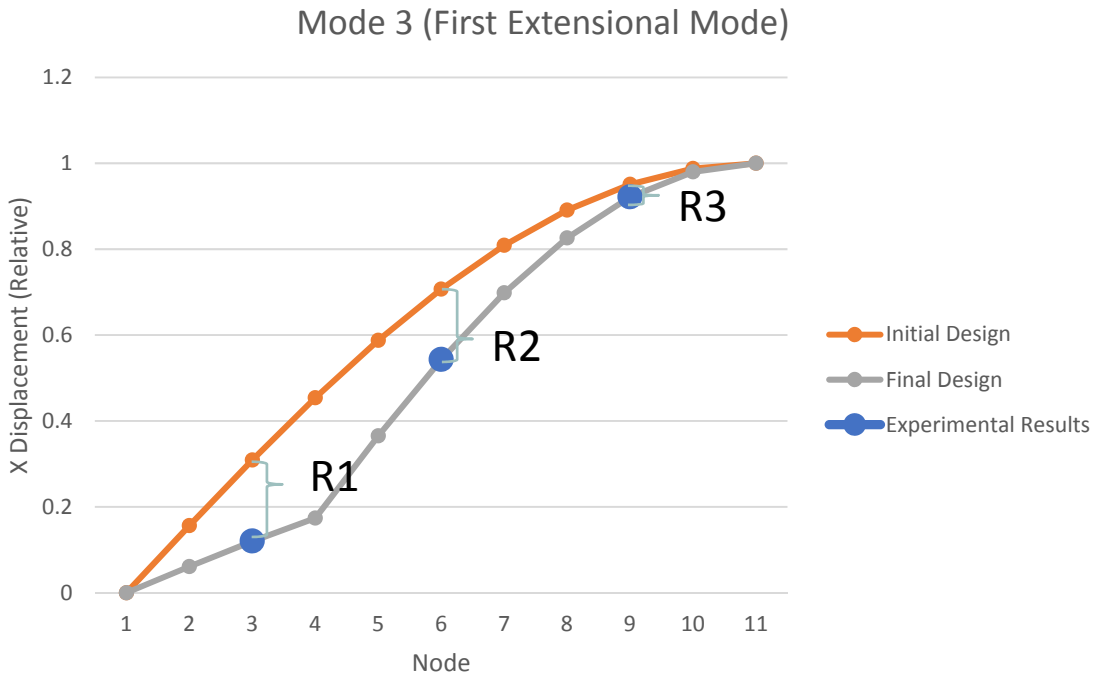


Optimization Problem Statement Design Constraint

For mode 3,

- R1 = $\left(\frac{a4-.1204}{.1204}\right)^2$ R1 < .001
- R2 = $\left(\frac{a5-.5431}{.5431}\right)^2$ R2 < .001
- R3 = $\left(\frac{a6-.9216}{.9216}\right)^2$ R3 < .001

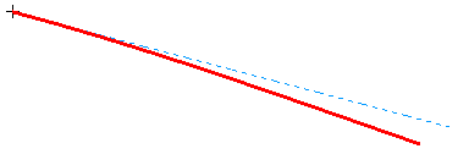
a4, a5, a6 are the x displacements at nodes 3, 6, 9, respectively, for mode 3



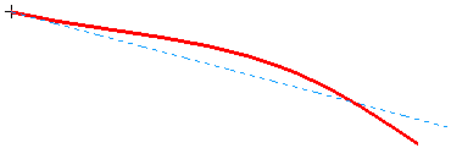
Mode Tracking

radius = 2 in.

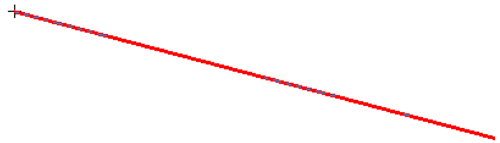
Mode 1
19Hz



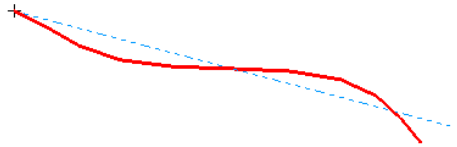
Mode 2
115Hz



Mode 3
263Hz

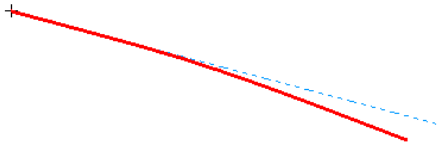


Mode 4
299Hz

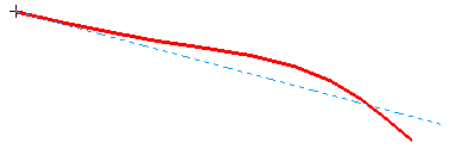


radius = 3.9 in.

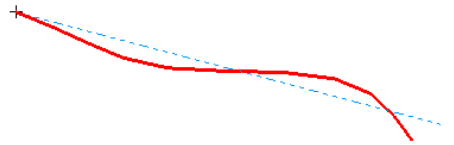
Mode 1
35Hz



Mode 2
174Hz



Mode 3
333Hz



Mode 4
334Hz

Mode Tracking

radius = 2 in.

Mode 1
19Hz

Mode 2
115Hz

Mode 3
263Hz

Mode 4
299Hz

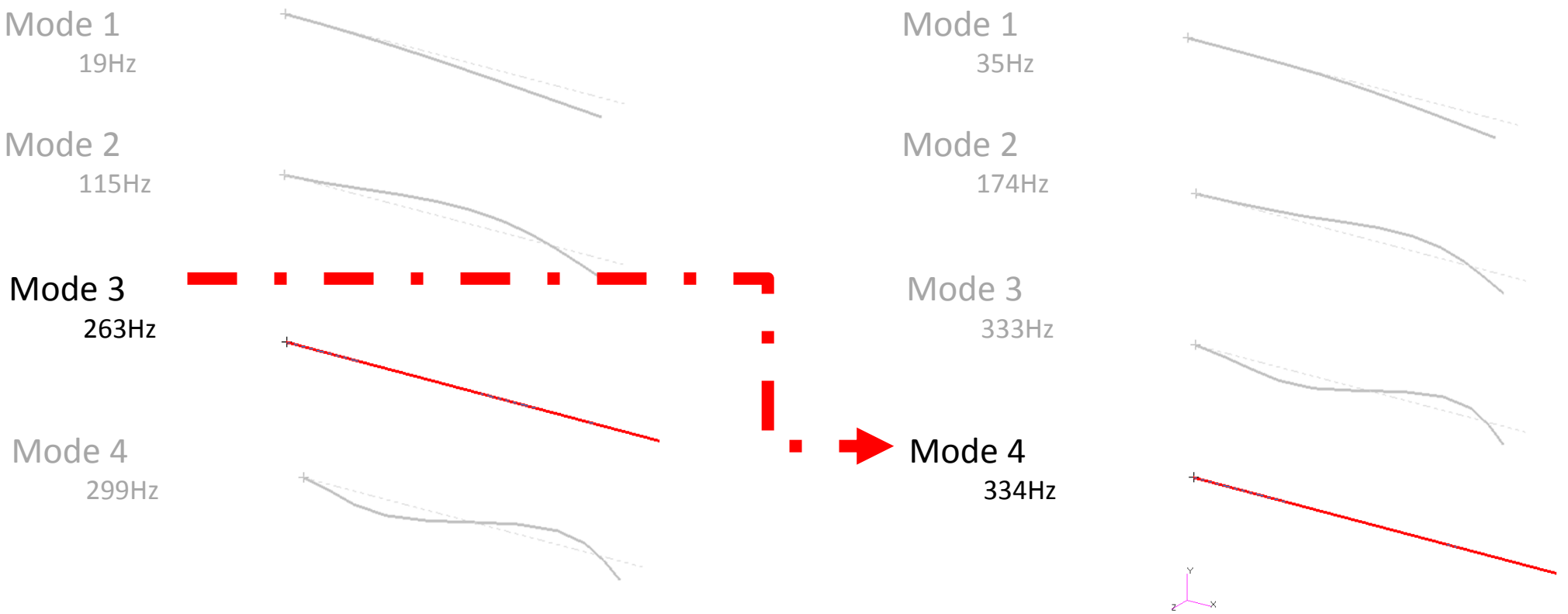
radius = 3.9 in.

Mode 1
35Hz

Mode 2
174Hz

Mode 3
333Hz

Mode 4
334Hz

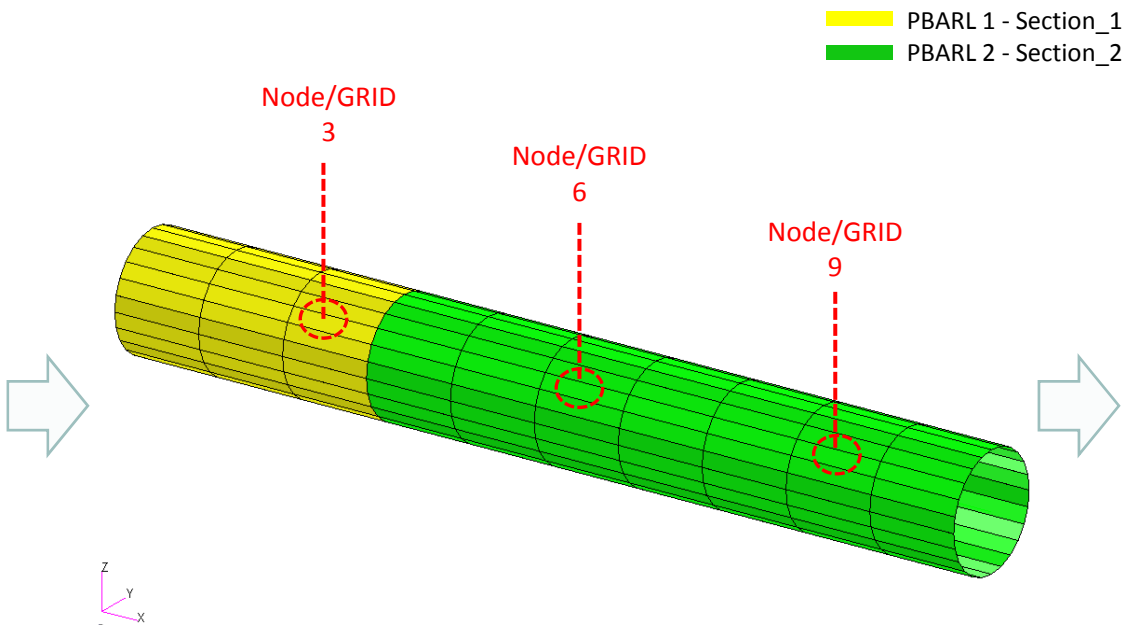


Optimization Problem Statement

Design Variables

x1: Radius of cross section (DIM1 of PBARL 1)

.1 < x1 < 10.



Design Objective, Equation

R0: Minimize

$$\left(\frac{a1-.0143}{.0143}\right)^2 + \left(\frac{a2-.1741}{.1741}\right)^2 + \left(\frac{a3-.6381}{.6381}\right)^2$$

- a1: 3rd component of relative displacement for mode 1 at grid 3
- a2: 3rd component of relative displacement for mode 1 at grid 6
- a3: 3rd component of relative displacement for mode 1 at grid 9

Design Constraints, Equation

$R1 = \left(\frac{a4-.1204}{.1204}\right)^2$ R1 < .001

$R2 = \left(\frac{a5-.5431}{.5431}\right)^2$ R2 < .001

$R3 = \left(\frac{a6-.9216}{.9216}\right)^2$ R3 < .001

- a4: 1st component of relative displacement for mode 3 at grid 3
- a5: 1st component of relative displacement for mode 3 at grid 6
- a6: 1st component of relative displacement for mode 3 at grid 9

Steps to use Nastran SOL 200 (Optimization)

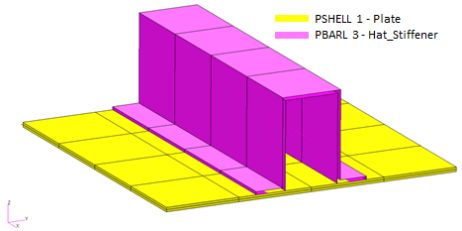
1. Start with a .bdf or .dat file
2. Use the SOL 200 Web App to:
   - Convert the .bdf file to SOL 200
     - Design Variables
     - Design Objective
     - Design Constraints
   - Perform optimization with Nastran SOL 200
3. Review optimization results
   - Online Plotter
   - Optimized structural results
4. Update the original model with optimized parameters

SOL 200 Web App Capabilities

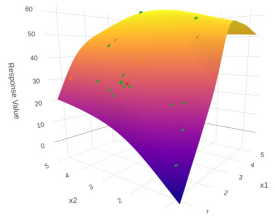
Benefits

- 200+ error validations (real time)
- Web browser accessible
- Automated creation of entries (real time)
- Automatic post-processing
- 76 tutorials

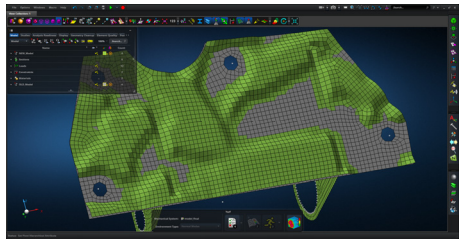
Capabilities



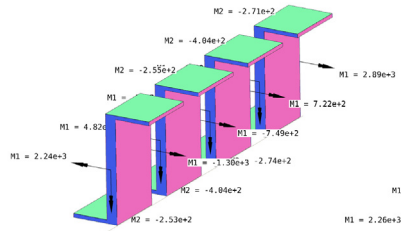
Web Apps for SOL 200
Pre/post for MSC Nastran SOL 200. Support for size, topology, topometry, topography and multi-model.



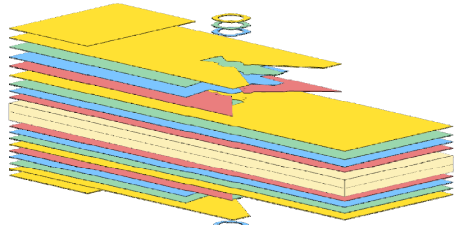
Machine Learning Web App
Bayesian Optimization for nonlinear response optimization (SOL 400)



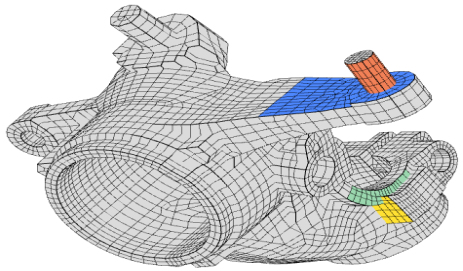
MSC Apex Post Processing Support
View the newly optimized model after an optimization



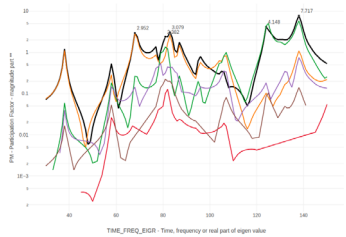
Beams Viewer Web App
Post process 1D element forces, including shear forces, moments, torque and axial forces



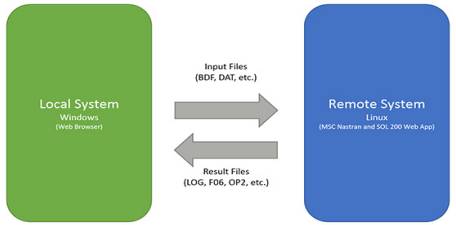
Ply Shape Optimization Web App
Spread plies optimally and generate new PCOMPG entries



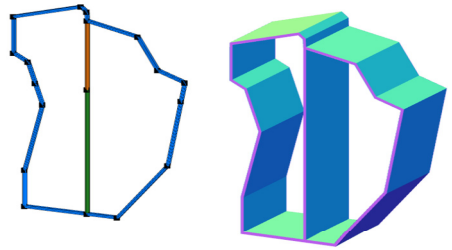
Shape Optimization Web App
Use a web application to configure and perform shape optimization.



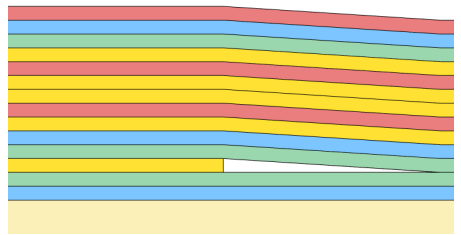
HDF5 Explorer Web App
Create XY plots using data from the H5 file



Remote Execution Web App
Run MSC Nastran jobs on remote Linux or Windows systems available on the local network



PBMSECT Web App
Generate PBMSECT and PBRSECT entries graphically



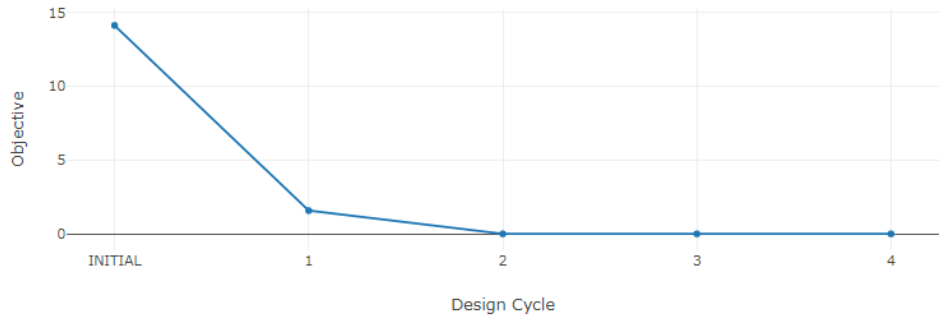
Stacking Sequence Web App
Optimize the stacking sequence of composite laminate plies

View Optimization Results
Online Plotter

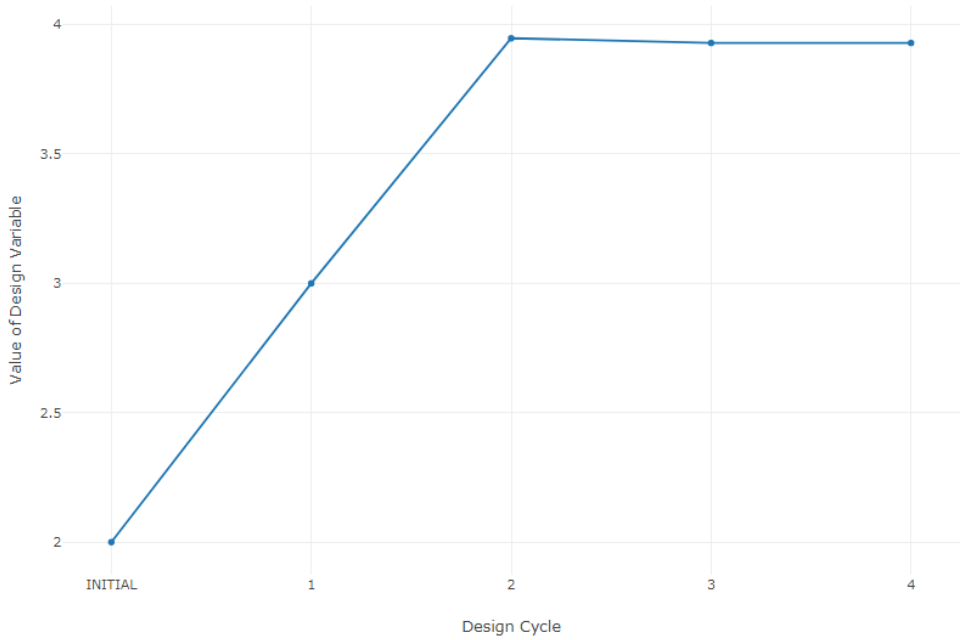
Final Message in .f06

RUN TERMINATED DUE TO HARD CONVERGENCE TO AN OPTIMUM AT CYCLE NUMBER = 4.

Objective



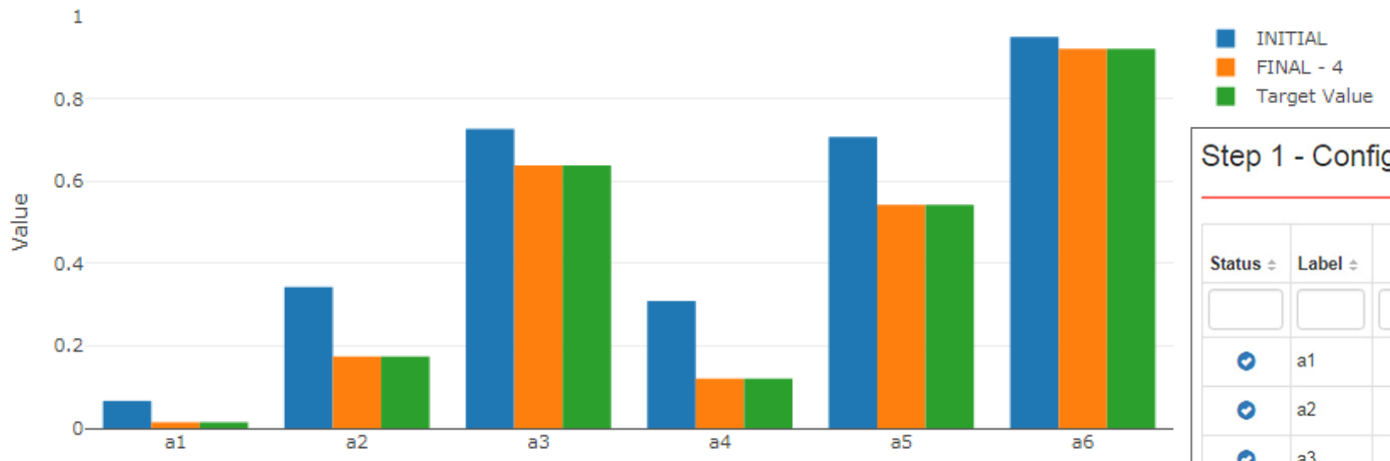
Design Variables



View Optimization Results

Comparison between FINAL and Target Values

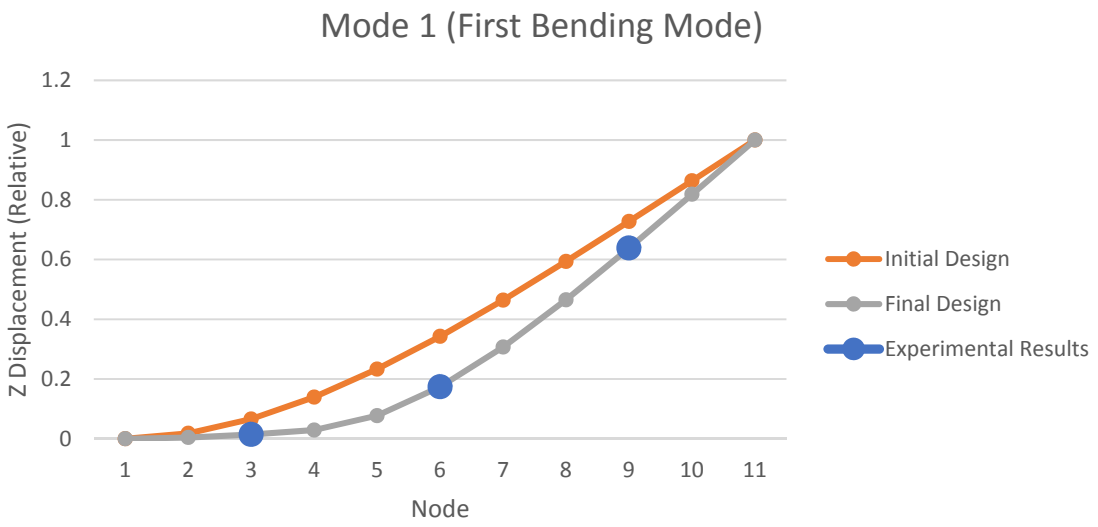
Model Matching Bar Charts

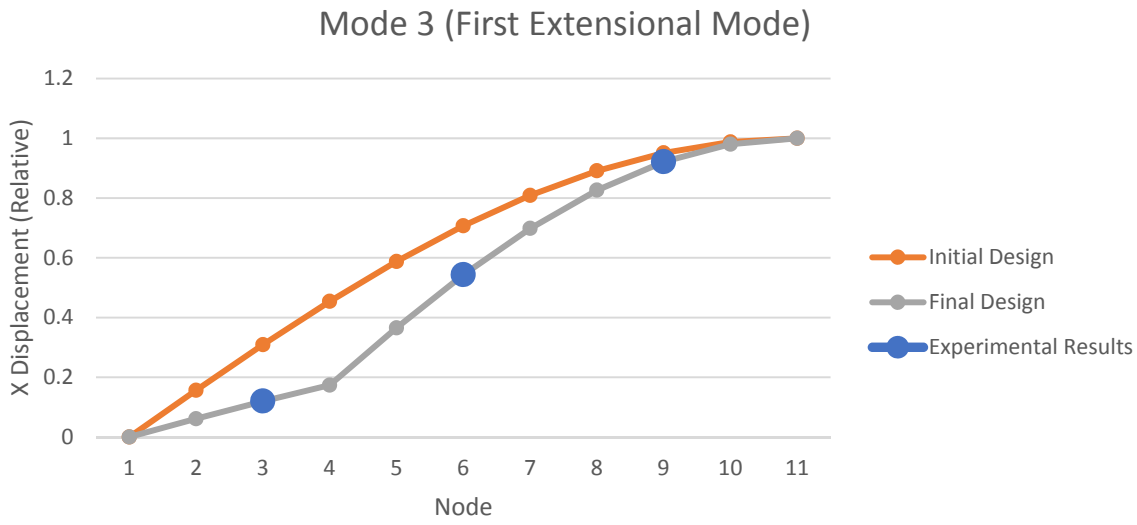


Step 1 - Configure model matching

Status	Label	Single Scalar?	Description	Target Value	Include in Objective	Max Allowed Error
✓	a1	Yes	T3 component(s) of displacement at grid 3 of mode 1	.0143	☑	Example: -100.1
✓	a2	Yes	T3 component(s) of displacement at grid 6 of mode 1	.1741	☑	Example: -100.1
✓	a3	Yes	T3 component(s) of displacement at grid 9 of mode 1	.6381	☑	Example: -100.1
✓	a4	Yes	T1 component(s) of displacement at grid 3 of mode 3	.1204	☐	.001
✓	a5	Yes	T1 component(s) of displacement at grid 6 of mode 3	.5431	☐	.001
✓	a6	Yes	T1 component(s) of displacement at grid 9 of mode 3	.9216	☐	.001

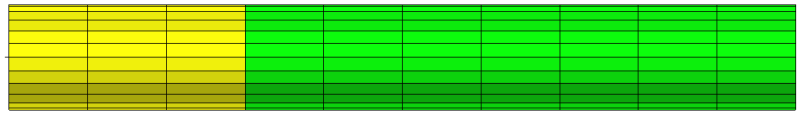
View Optimization Results
Comparison between analysis and experiment

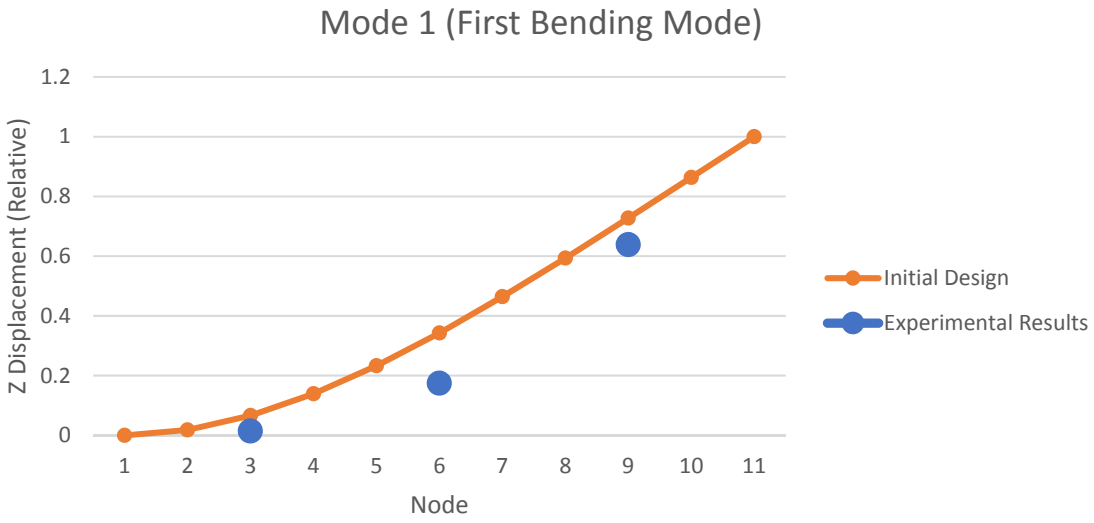




Goal: Use Nastran SOL 200 Optimization Correlate test data and analysis results

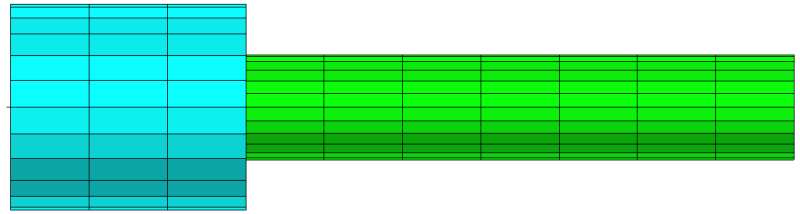
Before Optimization
Radius: 2 in

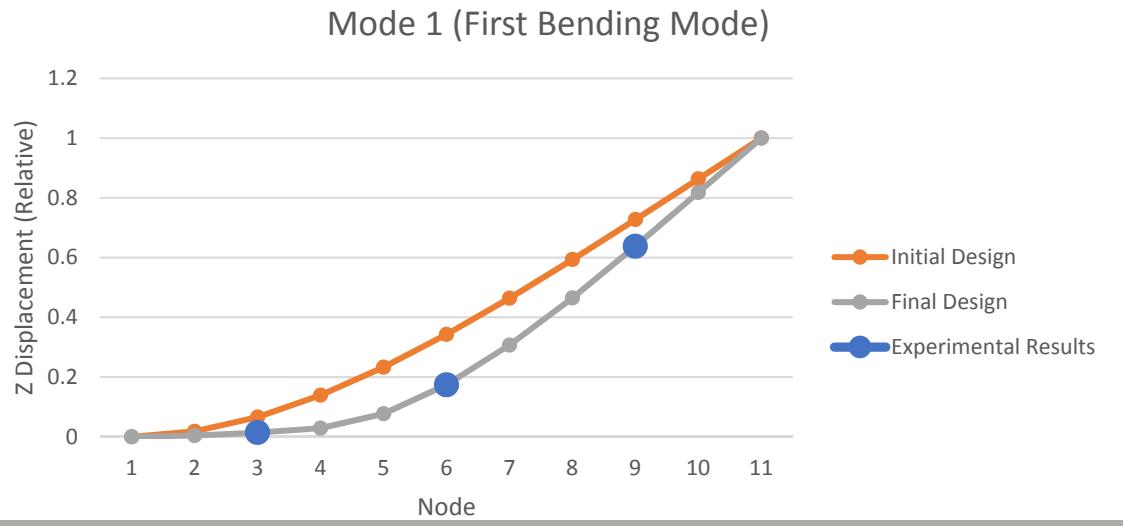




After Optimization

- Radius 3.93 in





Update the original structural model with optimized parameters

Use the .pch file

Contact me

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

christian@ the-engineering-lab.com