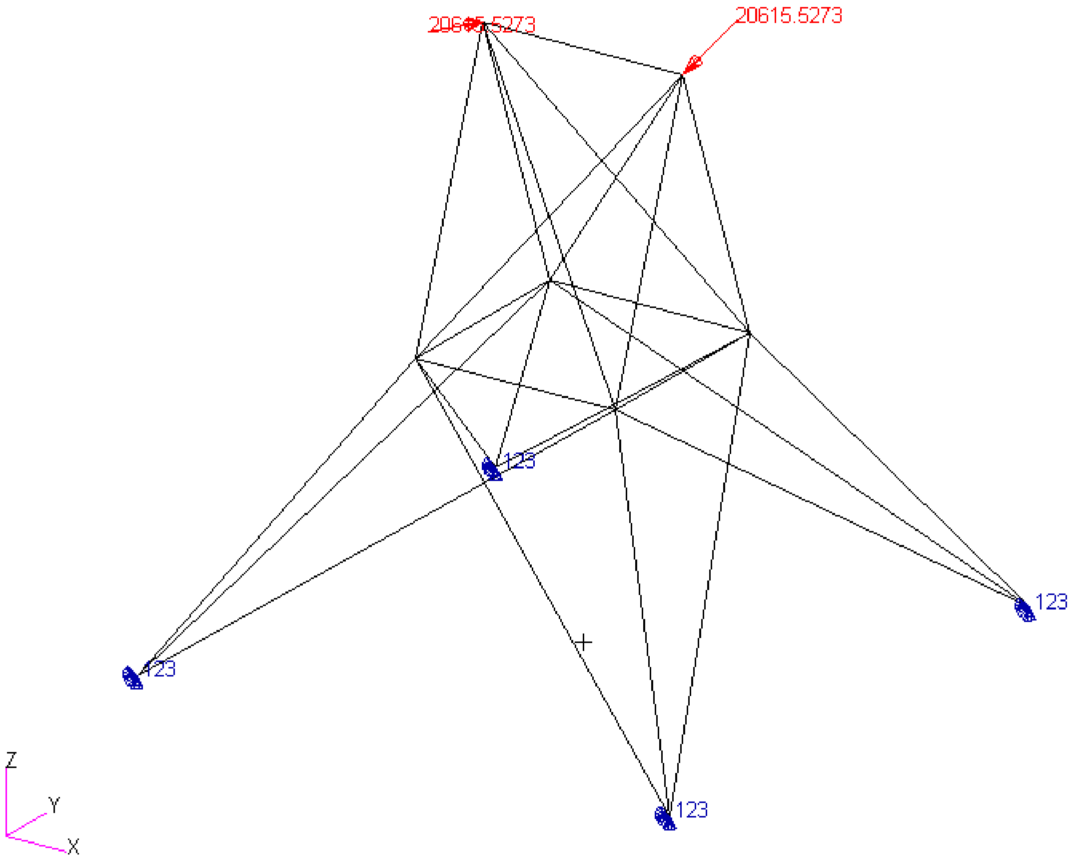
Optimizing for Buckling - Twenty-Five Bar Truss

PRESENTED BY CHRISTIAN APARICIO

Goal: Use Nastran SOL 200 Optimization

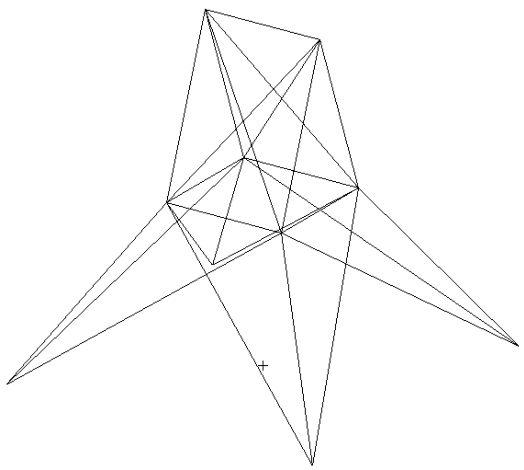


Goal: Use Nastran SOL 200 Optimization

Optimize the weight of this truss subject to stress and buckling constraints

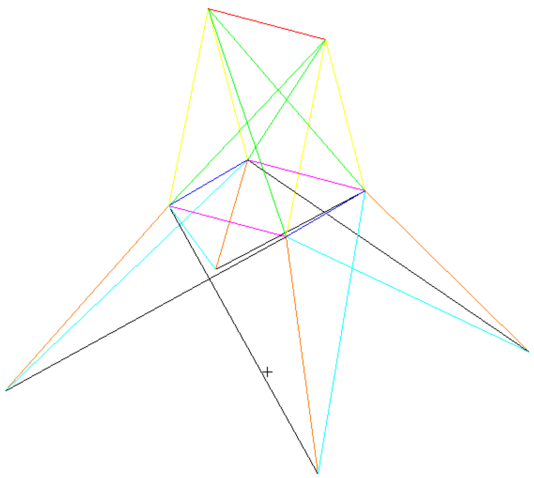
Before Optimization

- Weight: 660 slinch
- Vary member cross section areas
- Stress constraint initially violated



After Optimization

- Weight: 1007 slinch
- Stress and Buckling within limits



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

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Details of the structural model

Twenty-Five Bar Truss, Superelement and Discrete Variable Optimization

This problem, often seen in the early design optimization literature, calls for a minimum weight structure subject to member stress, Euler buckling, and joint displacement constraints. The structure is shown in Figure 8-25. The formulation of the buckling constraints is a good example of constructing normalized constraints based on user-defined structural responses.

In addition, this problem will be substructured in order to illustrate superelement optimization and the final design will be selected from a user specified list of discrete variables.

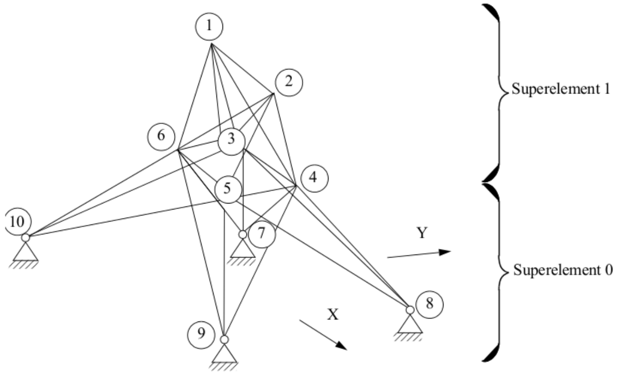


Figure 8-25 Twenty-Five Bar Truss

MSC Nastran Design Sensitivity and Optimization User's Guide
Chapter 8 – Example Problems – Twenty-Five Bar Truss,
Superelement and Discrete
Variable Optimization

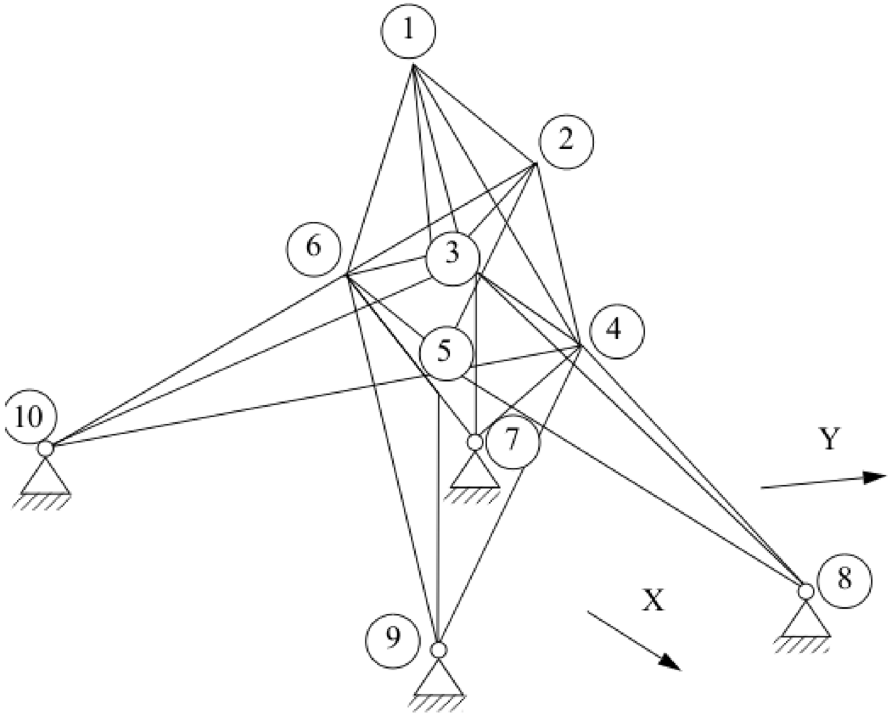


Figure 8-25 Twenty-Five Bar Truss

Optimization Problem Statement
Design Variables

$y1$: rod diameter of PROD 1

$y1$

→

Area of PROD 1

$$A = \frac{\pi \, y1^2}{10}$$

⋮

⋮

$y8$: rod diameter of PROD 8

$y8$

→

Area of PROD 8

$$A = \frac{\pi \, y8^2}{10}$$

Optimization Problem Statement
Design Variables

yi : rod diameter of PROD i

Allowed values: .1, .5, 1.0, 2.0, 3.0, … 100.

Optimization Problem Statement

Design Variables

y1 ---> $A1 = \frac{\pi \, y1^2}{10}$ of PROD 1

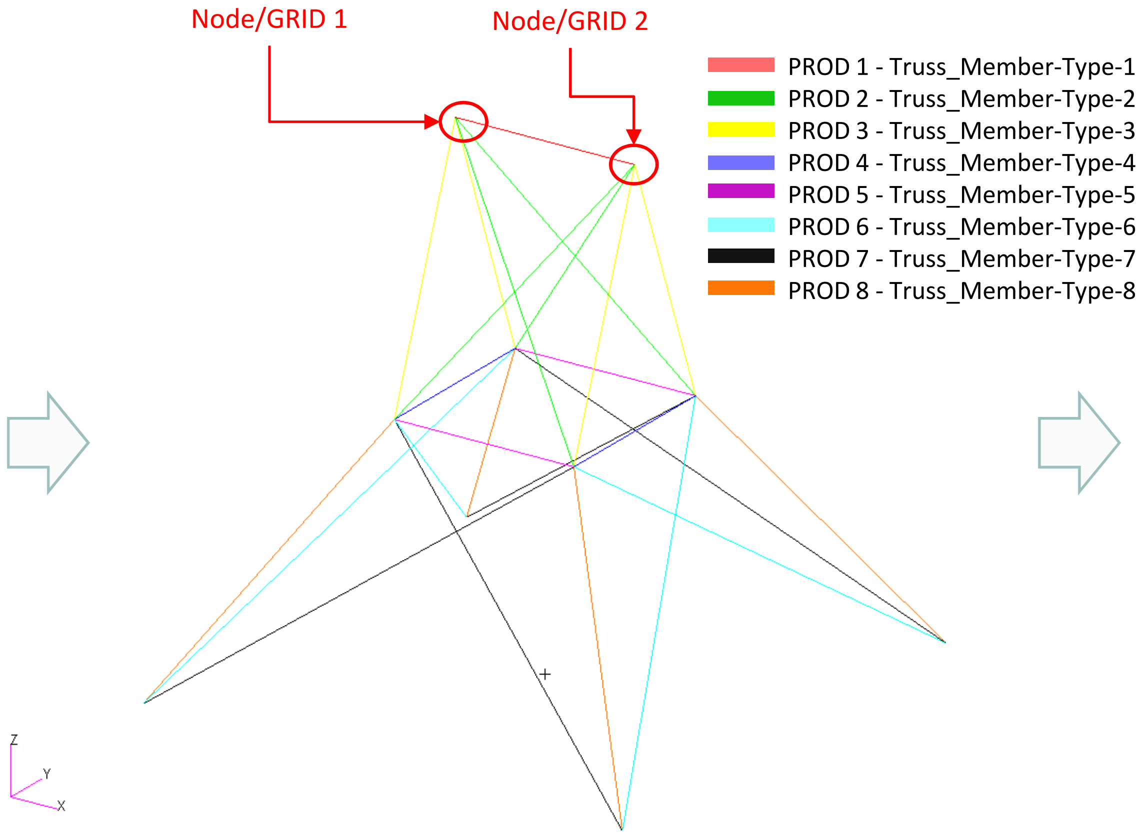
....

y8 ---> $A8 = \frac{\pi \, y8^2}{10}$ of PROD 8

yi_initial= 2.52

. 01 < yi < 100.

Allowed values for design variables: .1, .5, 1.0, 2.0, … 100.



Responses (Outputs)

- Weight
- Volume
- Displacements
- Strains
- Stresses
- ....

Optimization Problem Statement Design Objective

Design Objective

- r0: Minimize Weight

Optimization Problem Statement Design Constraints

- r1: The axial stress of PROD 1
- …
- r8: The axial stress of PROD 8
  - -40,000 < r1, … r8 < 40,000

- r9: x and y displacement of nodes 1 and 2
  - -.35 < r9 < .35

Optimization Problem Statement
Design Constraints

Design Constraints

- r1: The axial stress of PROD 1
- …
- r8: The axial stress of PROD 8

- r9: x and y displacement of nodes 1 and 2
  - -.35 < r9 < .35

Design Equation Constraints

- Buckling

$$r = \frac{F_s \sigma}{\sigma_b} = \frac{-7.69 \sigma L^2 F_s}{\pi^2 E D_{avg}^2} \leq 1.0$$

R1: buckling of PROD 1 < 1.0

$$g = 1.25 \frac{-7.69 \cdot r1 \cdot 75.^2}{3.14^2 \cdot 1.0\mathrm{E}^7 \cdot y1^2}$$

R2: buckling of PROD 2 < 1.0

$$g = -7.69 \cdot r2 \cdot 130.5^2;$$

$$g2 = 3.14^2 \cdot 1.0\mathrm{E}^7 \cdot y2^2;$$

$$g3 = 1.25 \frac{g}{g2}$$

Optimization Problem Statement
Design Constraints

Buckling

$$r = \frac{F_s \sigma}{\sigma_b} = \frac{-7.69 \sigma L^2 F_s}{\pi^2 E D_{avg}^2} \leq 1.0$$

R3 – R8: buckling of prod 3, 4, 5, … 8 < 1.0

$$g = 1.25 \frac{-7.69}{3.14^2 \cdot 1.0E^7};$$

$$g2 = g \frac{r3 \cdot 106.8^2}{y3^2}$$

Number	Label	L	Variable
1	r1	75.	y1
2	r2	130.5	y2
3	r3	106.8	y3
4	r4	75.	y4
5	r5	75.	y5
6	r6	181.14	y6
7	r7	181.14	y7
8	r8	133.46	y8

Optimization Problem Statement Design Constraint Groups

All constraints apply to load case 1 and 2

Optimization Problem Statement

Design Variables

y1 ---> $A1 = \frac{\pi\, y1^2}{10}$ of PROD 1

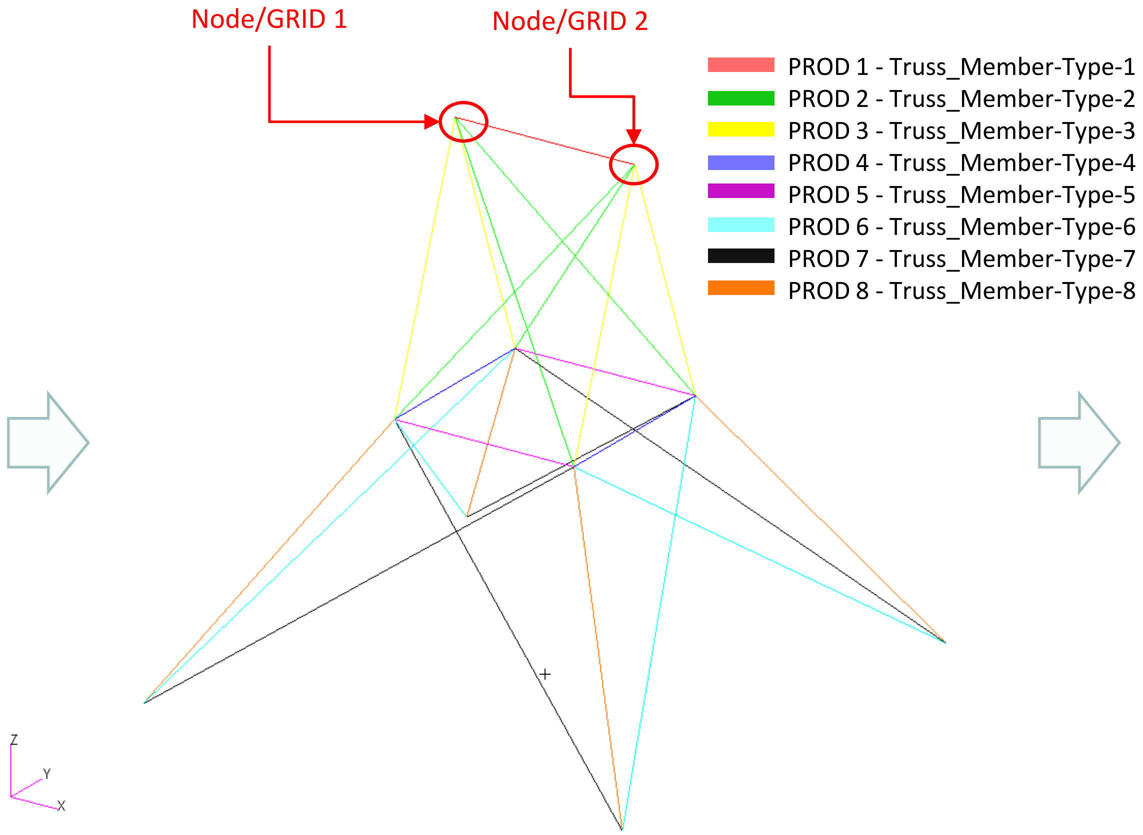
....

y8 ---> $A8 = \frac{\pi\, y8^2}{10}$ of PROD 8

yi_initial= 2.52

.01 < yi < 100.

Allowed values for design variables: .1, .5, 1.0, 2.0, … 100.



Design Objective

r0: Minimize weight

Design Constraints

r1: Axial stress of elements related to PROD 1

…

r8: Axial stress of elements related to PROD 8

-40,000 < r1, … r8 < 40,000

r9: x, y component of displacement at nodes 1 and 2

-.35 < r9 < .35

Design Constraints, Equation

$$Ri = F_s \frac{-7.69 \cdot ri \cdot Li^2}{\pi^2 \cdot 1.0E^7 \cdot yi^2} < 1.0$$

Number	Label	L	Variable
1	r1	75.	y1
2	r2	130.5	y2
3	r3	106.8	y3
4	r4	75.	y4
5	r5	75.	y5
6	r6	181.14	y6
7	r7	181.14	y7
8	r8	133.46	y8

Steps to use Nastran SOL 200 (Optimization)

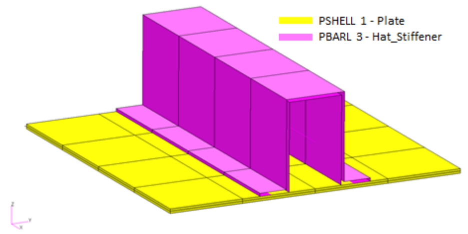
1. Start with a .bdf or .dat file
2. Use the SOL 200 Web App to:
   - Convert the .bdf file to SOL 200
     - Design Variables
     - Design Objective
     - Design Constraints
   - Perform optimization with Nastran SOL 200
3. Review optimization results
   - Online Plotter
   - Optimized structural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

SOL 200 Web App Capabilities

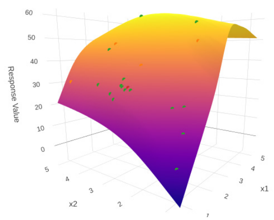
Benefits

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

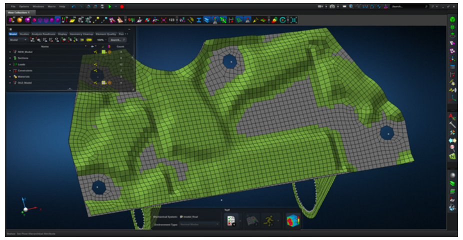
Capabilities



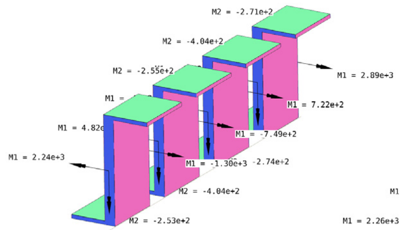
Web Apps for SOL 200
Pre/post for MSC Nastran SOL 200. Support for size, topology, topometry, topography and multi-model.



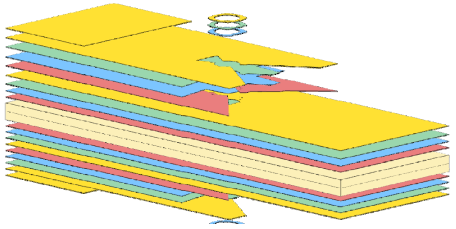
Machine Learning Web App
Bayesian Optimization for nonlinear response optimization (SOL 400)



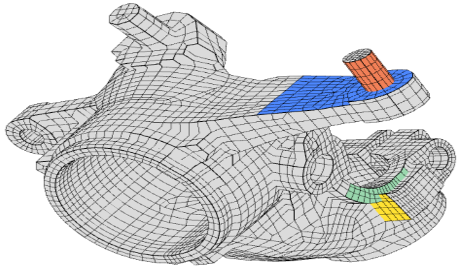
MSC Apex Post Processing Support
View the newly optimized model after an optimization



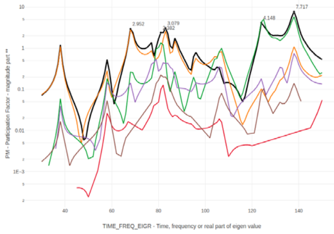
Beams Viewer Web App
Post process 1D element forces, including shear forces, moments, torque and axial forces



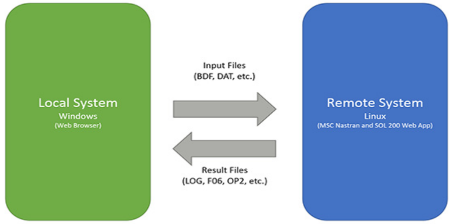
Ply Shape Optimization Web App
Spread plies optimally and generate new PCOMPG entries



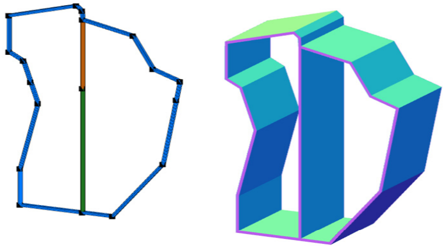
Shape Optimization Web App
Use a web application to configure and perform shape optimization.



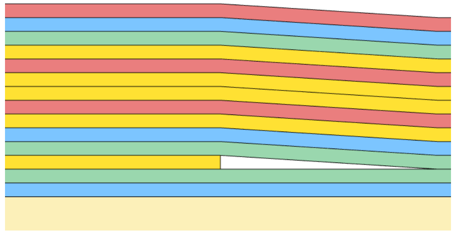
HDF5 Explorer Web App
Create XY plots using data from the H5 file



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

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RUN TERMINATED DUE TO HARD CONVERGENCE TO AN OPTIMUM AT CYCLE NUMBER =       15.
AND HARD FEASIBLE DISCRETE DESIGN OBTAINED
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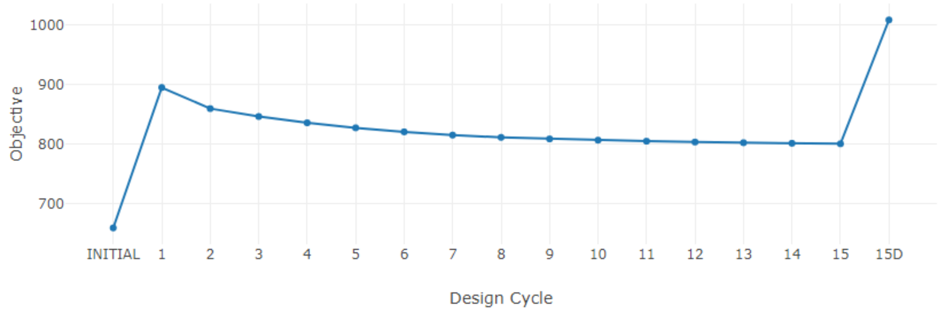
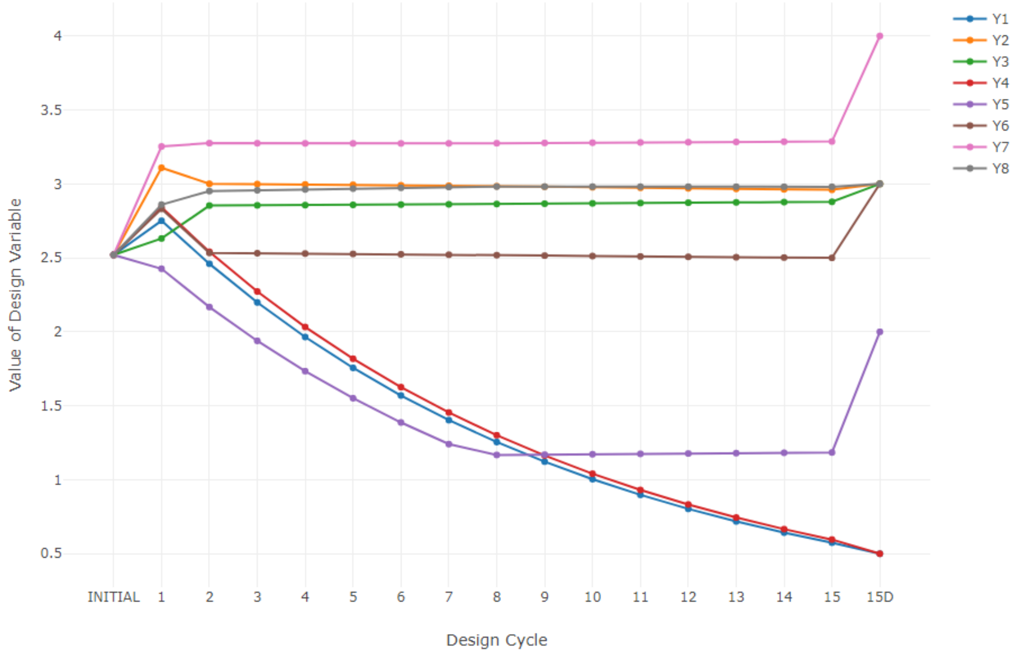
Objective

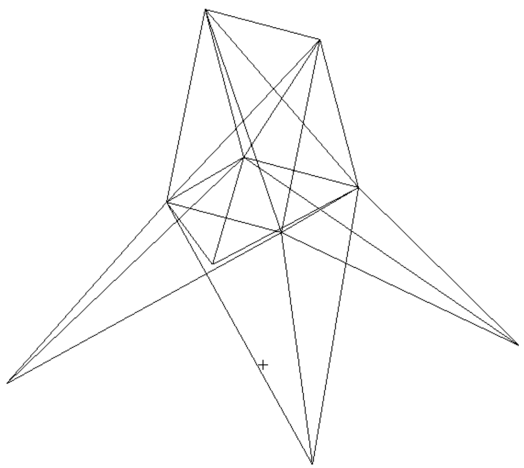


Design Variables

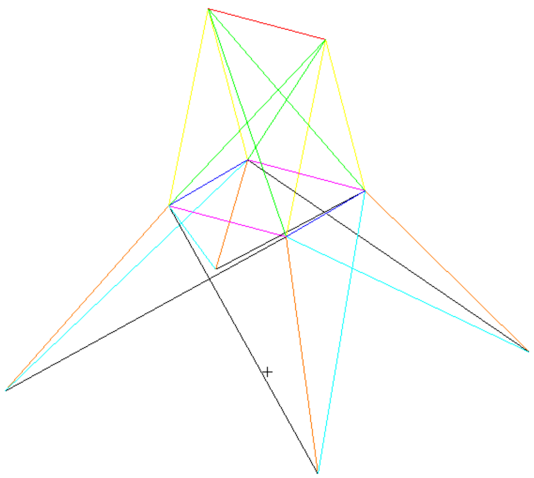


Goal: Use Nastran SOL 200 Optimization

Initial Design
- Weight: 660 slinch
- Vary member cross section areas
- Stress constraint initially violated



Optimized Design
- Weight: 1007 slinch
- Stress and Buckling within limits



Update the original structural model with optimized parameters

Use the .pch file

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