Shape Optimization

Shape Optimization is an optimization method wherein the outer boundary of the structure is modified to solve the optimization problem.

Using the finite element model, the shape is defined by the grid point locations and shape optimization modifies these locations to update the shape.

A. Points to Consider

- For simplicity, the model was reduced by removing the members identified as un-necessary in the previous analyses.
- Make sure each tube type is in a separate collector and is assigned a separate property.
- The shell welds were replaced by rigid elements to avoid mesh distortion issues.
- The base plates and welds are not part of the optimization.

Model Description for Shape Optimization

- Shape variables were defined to grow each section by 0.25" cross section in both directions.
- Morphing volumes should be created for each tube.
- Morphing of the corresponding handles (by scaling by 1.25) allows to create those shapes.
- For the gold angled tubes, the shapes can be created by freehand "move normal"(no handles defined).
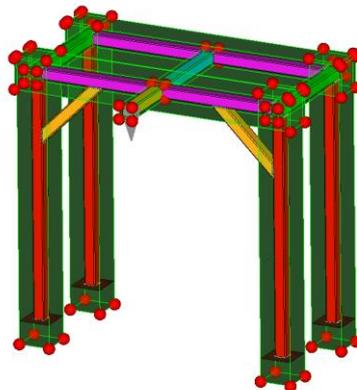
- The optimization problem should be setup as follows:
    i. Minimize mass (base plates and lump mass not included)
    ii. Displacement constraints:
        ➢ 5mm for load case 1 (2g downwards)
        ➢ 7mm for load cases 2 and 3 (1g downwards and 0.5g lateral)
- The range of the shape variables was defined between -1 and 2, so that the sections between 1.5"x1.5" and 3"x3" can be used. (original section is 2"x2")
- The gold angled tubes are not allowed to shrink to 1.5"x1.5" due to mesh distortion (0-2 range).
- The original thickness of 0.120" is maintained for all tubes.

B. Set Up

First, we will set up the domain handles and define the shapes for shape optimization.

1. Open tube-structure-shape.hm file.
2. Go to Analysis>>Optimization>>HyperMorph>>morph volumes.

| morph constraints | morph volumes | morph | morph options |
systems	domains	map to geom	
symmetry	handles	freehand	
shapes			
			return

3. You have to create morph volumes for each individual tube separately. For ease hide other components and then select the elements of single tube then click on Create.
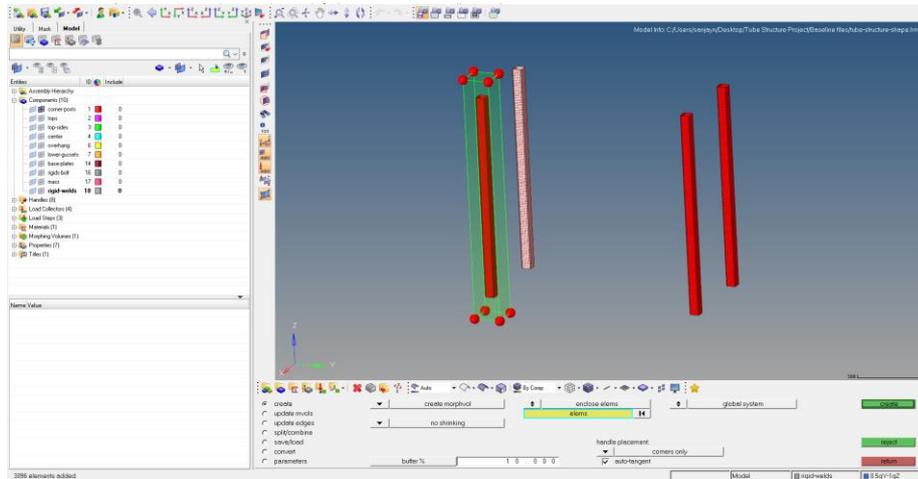
Do this for the four tubes.
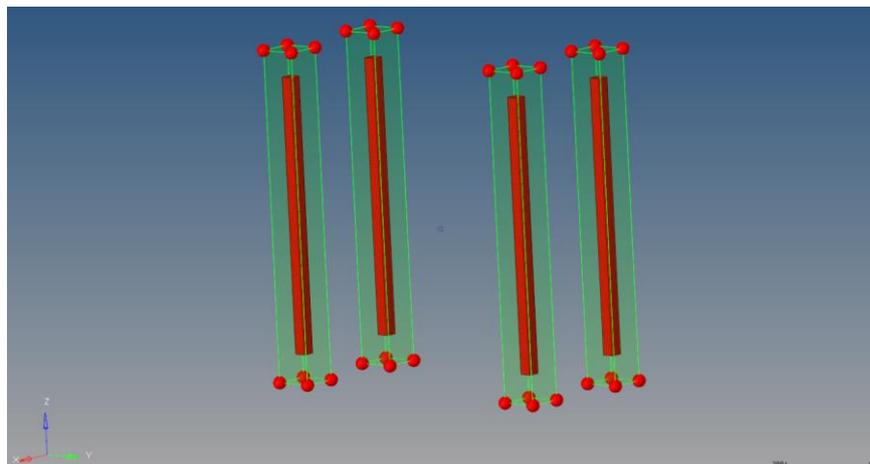
4. Now we will scale the handles one tube at a time. Go to
   Analysis>>Optimization>>HyperMorph>>morph. Select all 8 handles of only
   one tube at a time and morph the tube. Provide a value of 1.25 for X
   direction, 1.25 for Y direction and 1 for Z direction (which is axial direction of
   those tubes).
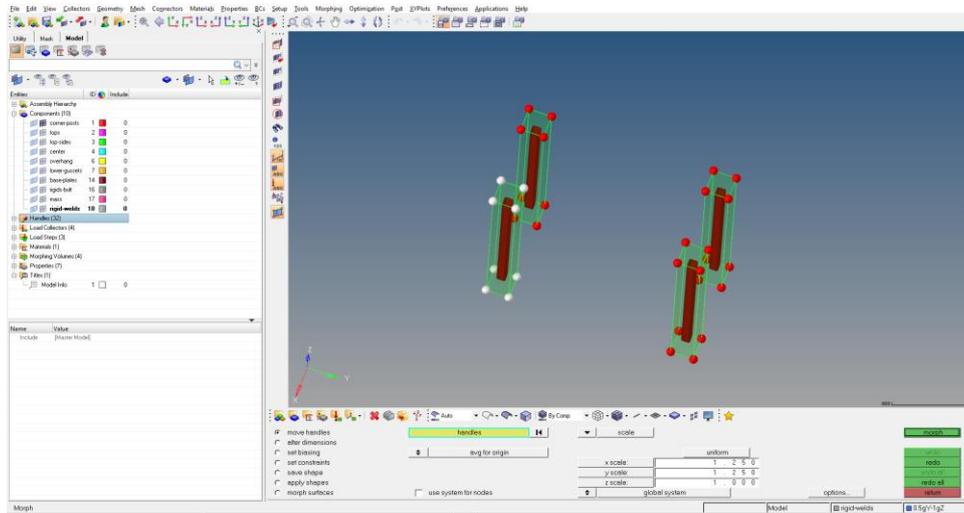
Now in the "save shape" panel, save the shape as shape_corner_posts.

After saving the shape, click on "undo all" and undo all the changes.

5. Now create a design variable for this shape. Go to

    Analysis>>optimization>>shape.

Create a new design variable "d1-corner-posts" select the shape "shape_corner posts" provide the appropriate lower bound and upper bound values and click on create.

In the model browser, now you can see a new shape and a new design Variable.
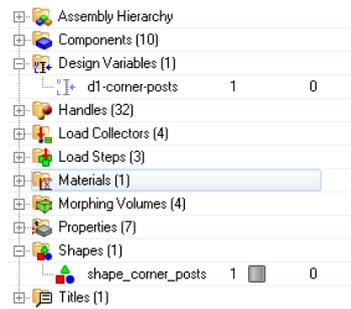
6. Repeat steps 2-5 for all the tubes (except lower gussets). Keep in mind we want to scale the size of each tube from its own center and that's why we select the handles of one tube at a time while morphing. Also keep in mind the direction of scale will be different for every component.

Scale directions are the directions which are not in direction of tube axis so it can grow in size (not length). Keep scale factor 1 for the remaining direction.

- Corner posts: scale in X and Y (shape range -1 to 2)

- Tops: scale in X and Z (shape range -1 to 2)

- Top sides: scale in Y and Z (shape range -1 to 2)

- Center: scale in Y and Z (shape range -1 to 2)

- Overhang: scale in Y and Z (shape range -1 to 2)

The shape range is the lower and upper bound values which will be used while defining the design variable.

7. After repeating steps 2-5 for all the tubes (except Lower gussets) your model browser should look like this.
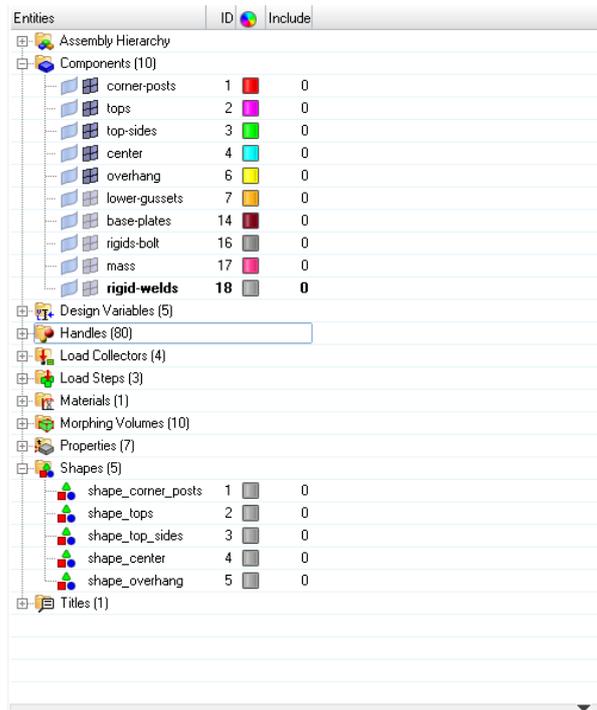
8. For the Lower gussets we will morph it along the normal. For this go to Analysis>>optimization>>HyperMorph>>freehand.
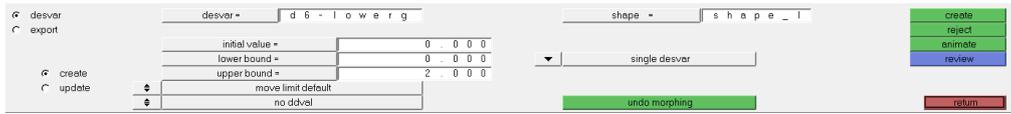

Select the "move normal" option from the drop down and select the elements for "calculate using" and "affected elements" fields. Also select the nodes for "moving nodes" field.
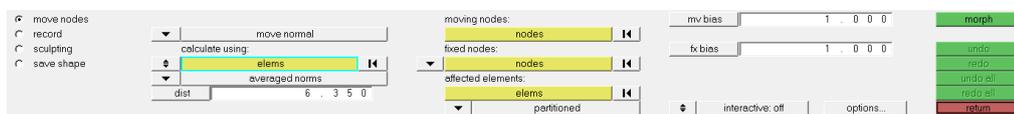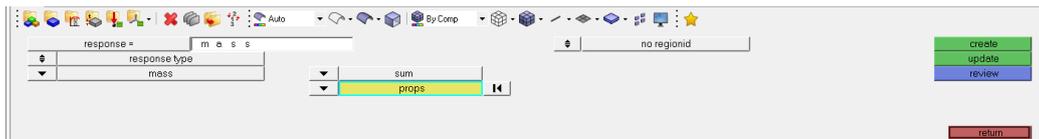

Click on morph. After this save the shape as "shape_lowergusset" and click on "undo all"

9. Create a design variable for Lower Gusset from Analysis>>optimization>>shape.
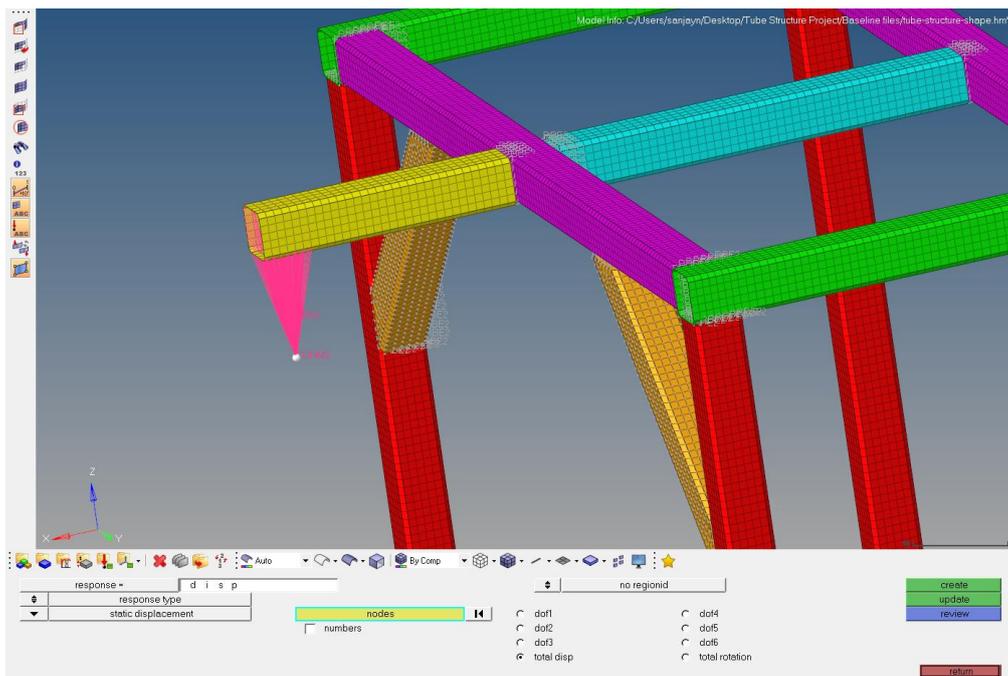
10. Now create 2 Optimization Responses:

a.   Mass Response

Select the 6 properties (base plates are not part of optimization) and click on Create.

b.   Total Displacement

Select the hanging mass node and click create

11. Now we will create Optimization Constraints for displacement for the three Load
    Steps. Go to Analysis>>optimization>>dconstraints

a. For the 2g-Z load step

Make sure to select the appropriate Load Step

b. For the 0.5gX-1gZ Load Step

c. For the 0.5gY-1gZ Load Step

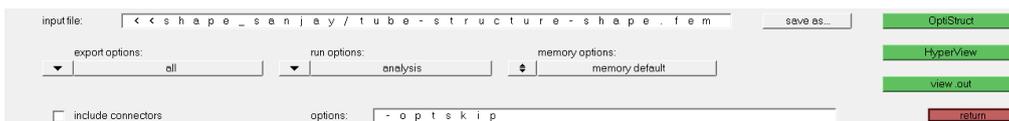12. Now we will create Objective which is to minimize the mass

Go to Analysis>>optimization>>objective

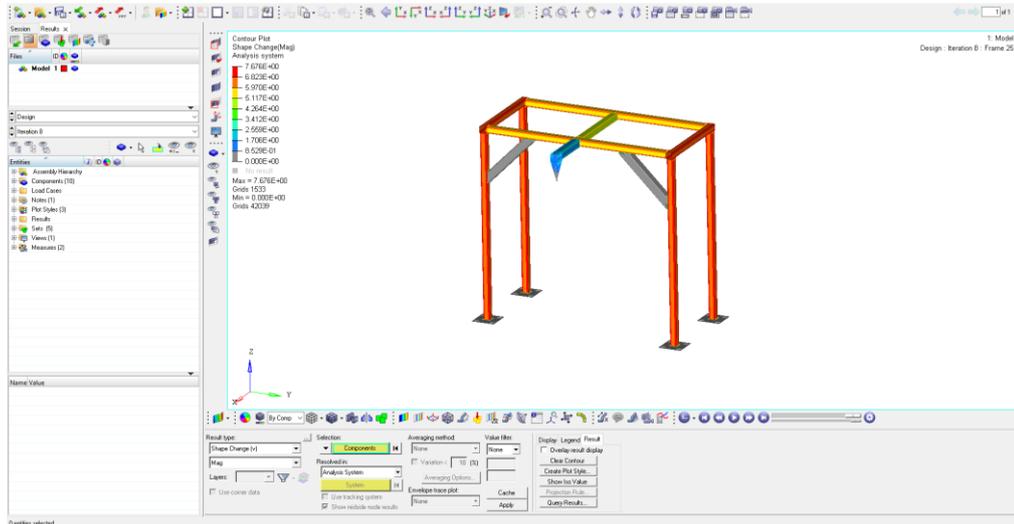Select the mass response and click on Create

C. Analysis

Finally, for the Optimization go to Analysis>>OptiStruct

Save the file first and then click on OptiStruct

D. Post-Processing

1. In HyperView, open the des.h3d file.

2. Choose the last iteration which is 8 in our case and get the Shape Change contour.

This gives us clear contour of the shape change after optimization.

3. To get the final mass of the optimized structure, open the .out file from the run directory.

4. In the .out file, go to the last iteration and check the mass.

The final mass comes out to be 28.56 Kg as compared to 59.6 Kg from the baseline structure.

E. Points from Optimization

- The results on the right show the change in section of all the members

- All displacements constraints are met and the mass is 28.56 kg (compared to 59.6 kg for the baseline).

- However, the sections obtained for the tubes are not standard, so this result is not realistic.

- Additional analysis can be conducted by adding a discrete variable for the shape and a discrete gauge optimization to this shape optimization.