Topology Optimization Case Study
Spindle Mount Design

UW Madison Topology Optimization Workshop 13-15 June 2017

The objective of this exercise is to optimize the topology of the spindle mount (see Figure 1). We will consider various phases, where in each phase, certain aspects of topology optimization such as loading conditions, mesh resolution, material selection design and manufacturing constraints will be explored.

Figure 1: Spindle assembly.

1 Modeling

Figure 2a illustrates a CAD mockup of the spindle mount assembly, while Figure 2b illustrates the forces and torques acting on the spindle. The spindle mount is restrained at the four locations illustrated. Unless otherwise stated, only the spindle mount will be optimized.

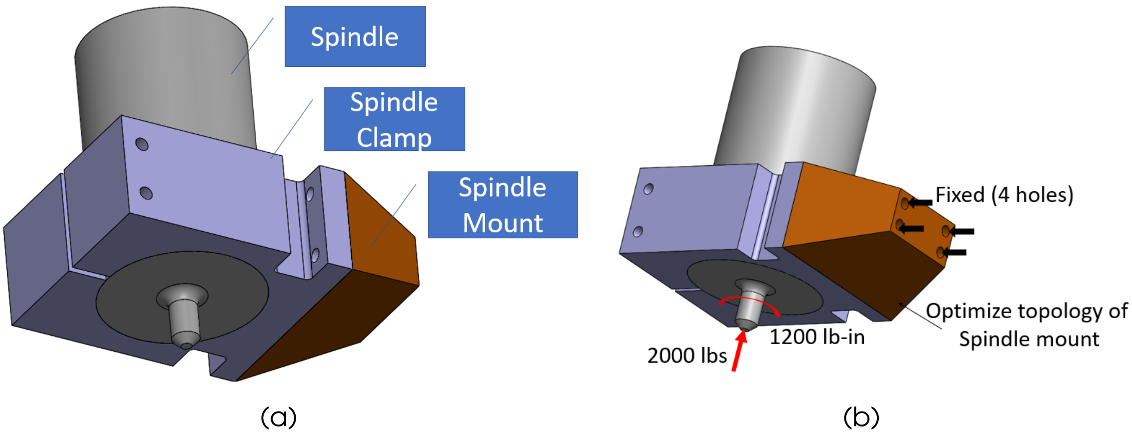

Figure 2: (a) Spindle mount, and (b) Forces, torques and restraints.

To begin with, load the project file SpindleMountProject1.prj, where the geometry, material, loading, etc. are predefined.

1.1 Geometry

The critical spindle mount dimensions are illustrated in Figure 3; the spindle mount model is provided in both SolidWorks and STL formats. All mounting holes are 0.5 inches in diameter, and the overall length is 4 inches.

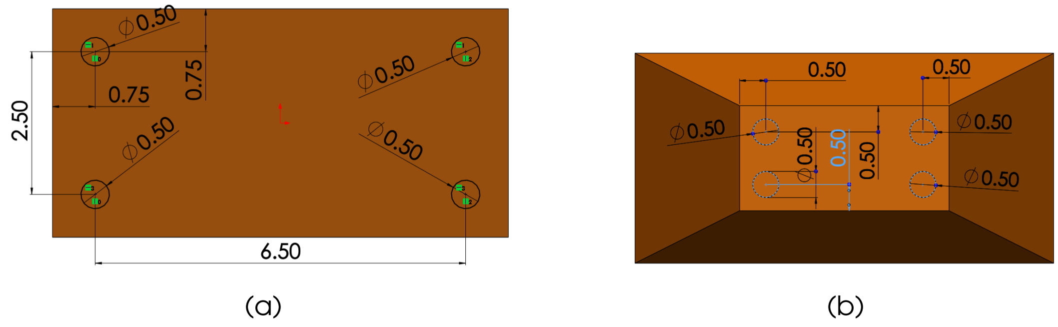

Figure 3: Critical dimensions for the spindle mount.

For force calculations, the critical dimensions for the spindle clamp are illustrated in Figure 4. Note that the spindle clamp will not be optimized, unless otherwise stated in the exercises.

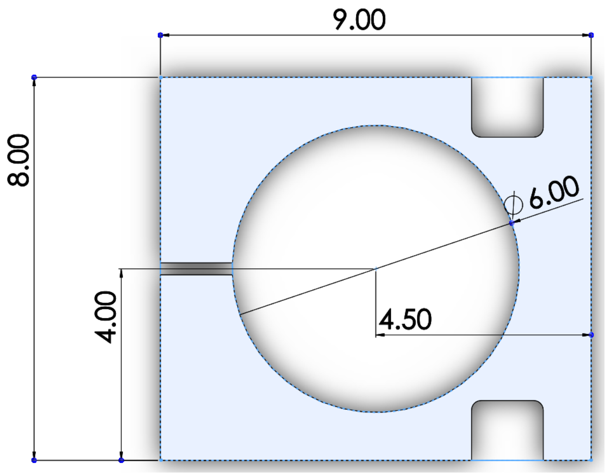

Figure 4: Critical dimensions for the spindle clamp.

1.2 Material

The material is assumed to be Aluminum 1060 (see Figure 5), with customized yield strength of 30 ksi.

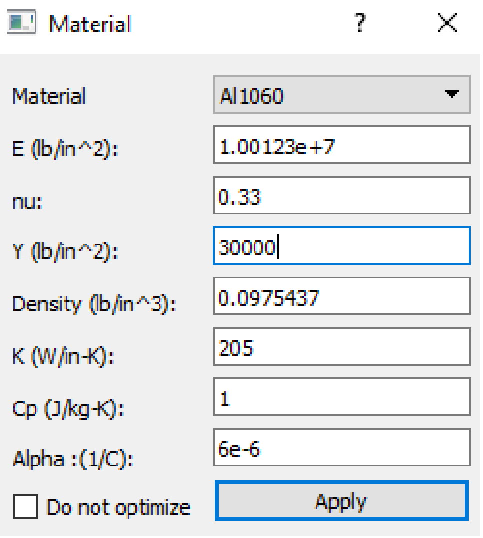

Figure 5: Aluminum 1060 material properties, with yield strength of 30 ksi.

1.3 Loading

Observe that the vertical force of 2000 lbs gets divided equally among the four mounting holes, resulting in 500 lbs per mounting hole, as illustrated in Figure 6. We have intentionally disregarded the moment due to the 2000 lb force, and the applied torque of 1200 lb-in (these are handled through the exercises below).

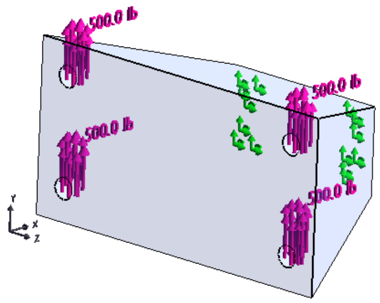

Figure 6: The 2000 lb force; the moment and torque have been disregarded.

1.4 Finite Element Analysis

Once the structural loads are defined, and material properties are specified, we can solve the FEA problem, with 100,000 elements. Figure 7 illustrates the stress distribution. Observe that the initial safety factor is 2.37.

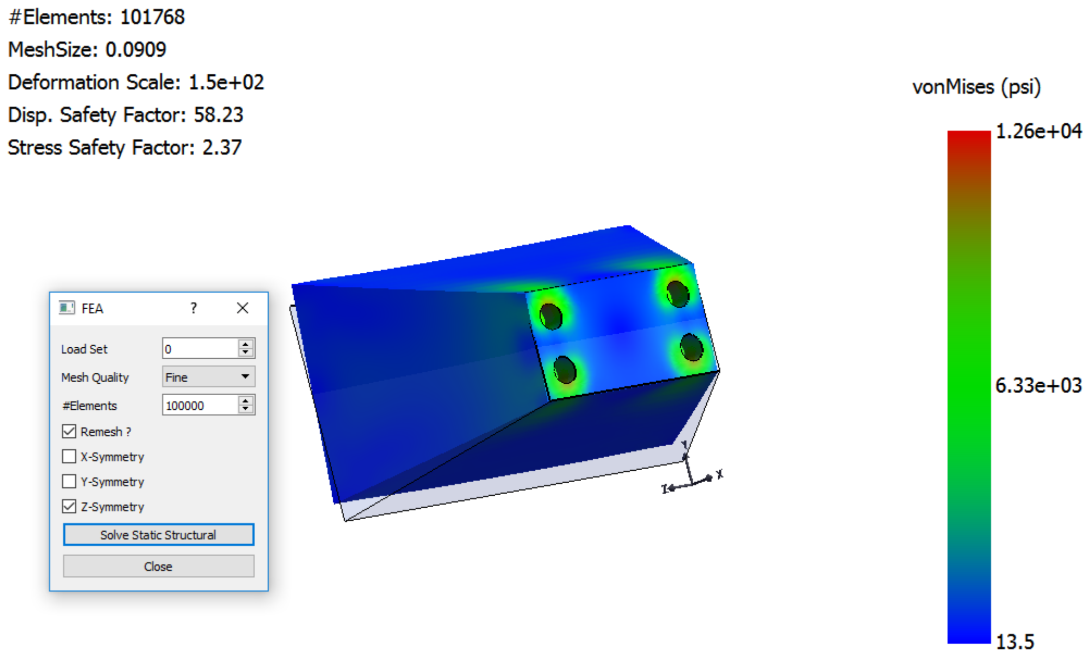

Figure 7: Stress in the initial design.

1.5 Topology Optimization

We will now optimize the spindle mount using the following constraints.

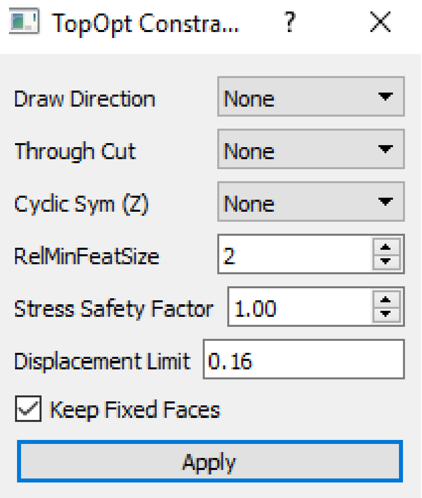

Figure 8: Topology optimization constraints.

The optimized design is illustrated in Figure 9.

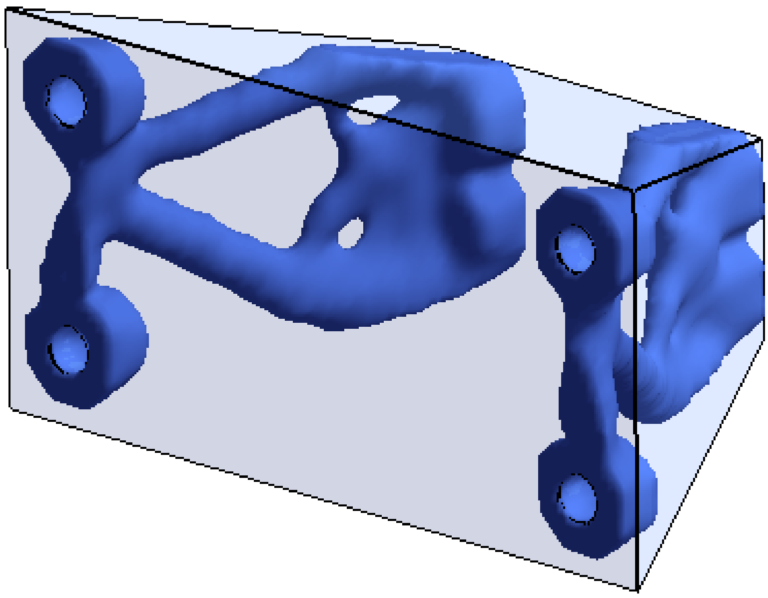

Figure 9: An optimized spindle mount with moment and torque neglected.

We will now extend this baseline problem through a few exercises.

2 Exercises

Exercise 2.1 Moment and Torque Included

Include the following into the loading calculations:

- A moment due to the $2000(lbs)$ force
- A torque of $1200(lb-in)$

Note that this will result in different forces on each of the mounting holes. Compute and apply the forces. Carry out an FEA, and find the initial safety factor. With these loads, repeat the optimization. Compare the new topology against previously computed? ■

Exercise 2.2 Effect of Mesh Resolution

Using finer meshes can result in more complex designs with thinner features. Repeat the Exercise 2.1 with 50,000 and 200,000 elements. How do the topologies compare against each other and what is the lowest volume fraction one can reach? ■

Exercise 2.3 Material Property

Replace the Al 1060 (with customized yield strength of 30 ksi) with alloy steel with yield strength of 72.5 ksi, and repeat Exercise 2.1. ■

Exercise 2.4 Manufacturing Constraints
We will now consider including multiple manufacturing constraints.

1. To control size of thin features, repeat Exercise 2.1 with 1, 3, and 4 for the RelMinFeatSize. What do you conclude from this exercise?
2. Next, repeat Exercise 2.1 by retaining the front face where the mount is attached to the spindle clamp. What do you conclude from this exercise?
3. Repeat Exercise 2.1 but impose a draw direction constraint along x direction and optimize. How does it compare against the original optimized design and why?

■

Exercise 2.5 Multi-Load Problem
The spindle mount must also be designed to handle a larger spindle. Specifically, assume that the loading is as illustrated, and the offset from the spindle axis to the mountin is 6 inches (instead of 4.5 inches; see Figure 4). The mounting holes remain the same.

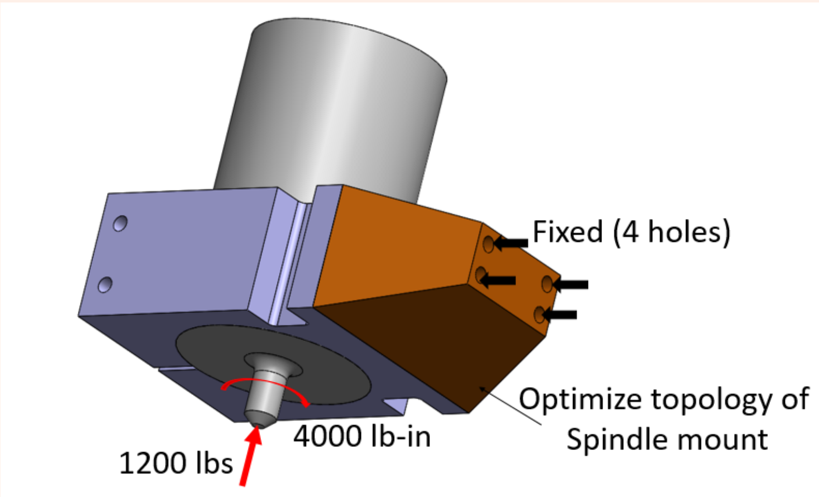

Figure 10: Second Loading Scenario.

1. Compute the loads acting on the mount due to the second load set.
2. Optimize the design considering only the second scenario. How does this compare against the one from the first load case?
3. Optimize the design considering both load sets. How does this compare against the previous designs?

■