Topology Optimization Design Challenge – Ali Kazmi

Intuitive Design

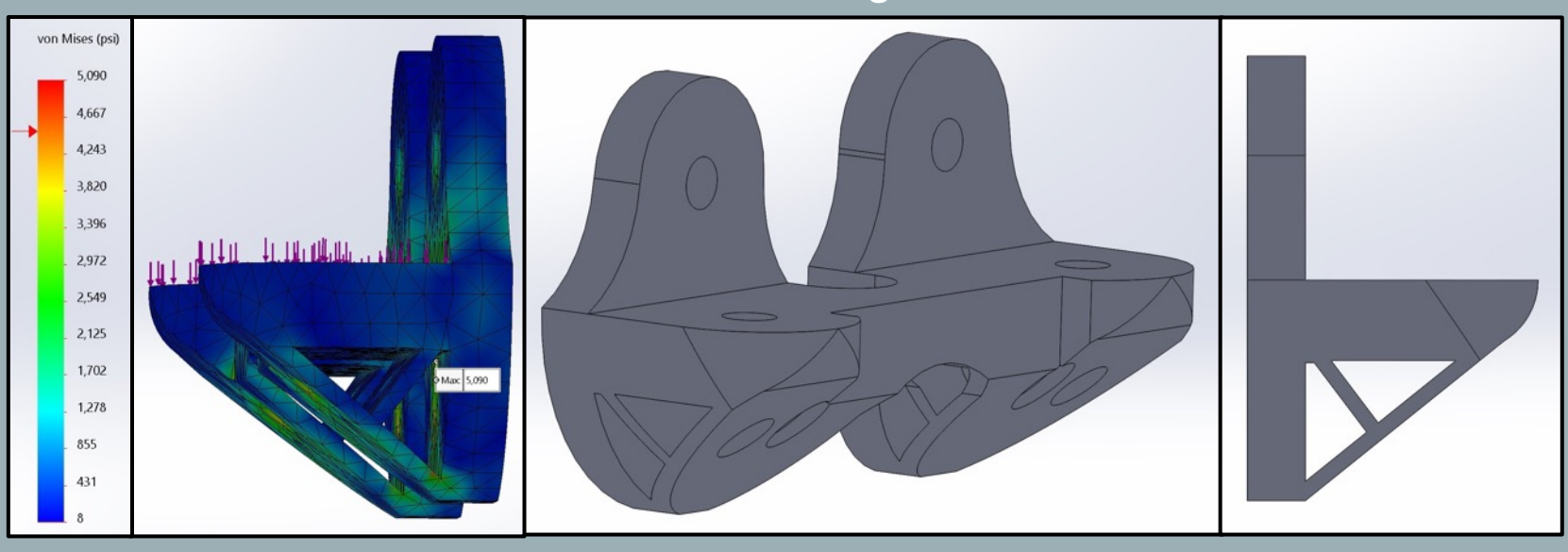

Figure 5: (Left) Stress analysis of intuitive design using Solidworks Simulation **(Middle, Right)** CAD model of intuitive design

The intuitively designed part can be seen in Figure 1 below which was a result of removing bulk material off the original model. To meet the ULA requirements, multiple iterations and adjustments were made as well as double checked using a stress analysis. As seen in Table 1 below, the intuitive design came very close to, but did not meet, the ULA criteria which seems nearly impossible for a realistic part. Either the maximum stress condition of 4500 PSI would not be met, or the maximum weight condition of 0.1 lb. would not be. Therefore, the most efficient intuitive design was made by making compromises on both ends. This resulted in a part that weights 0.17 lb. and experiences a maximum stress of 5090 PSI.

Metrics	Original Design	Intuitive Design	Top-Optimized Design	ULA Requirements
Weight	1.02 lbs	0.17 lbs	0.1 lbs	0.1 lbs
Support Mat. Weight	8 g	4 g	5 g	N/A
Max Stress	814 PSI	5090 PSI	N/A	4500 PSI
Volume	21.05 in^3	3.47 in^3	2.21 in^3	21.05 in^3

Table 1: Weight, Stress and Volume metrics for Intuitive, Topology Optimized and ULA Designs

Topology Optimized Design

Fusion 360 was used to develop the topology optimized design seen in Figure 2 (Top) on the right. Not only does the design remain within the original part volume and retain material in the ULA specified regions; it also weights just 0.1lbs by conserving nearly 90% of the original mass. This is what make this design truly unique that only a CAD software could fabricate. Figure 2 (Bottom) on the right highlights the regions preserved and the location where the 600 lb-force was applied.

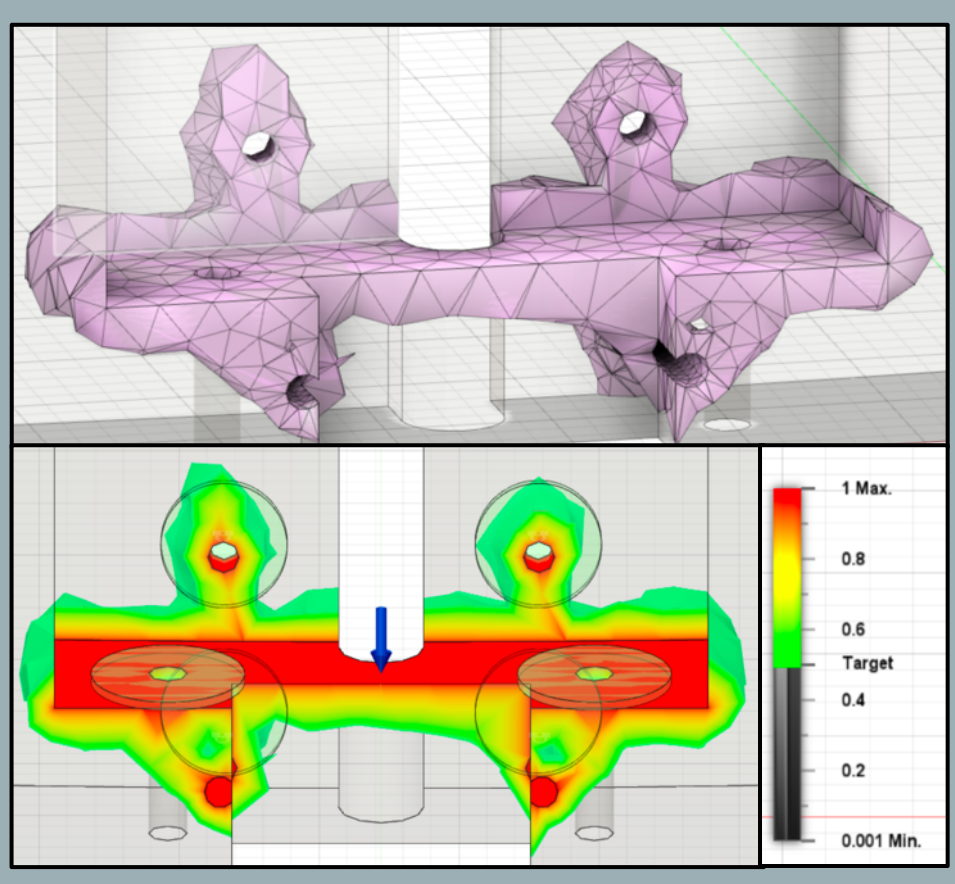

Figure 2 (Top): Mesh of Topology Optimized design using Fusion 360.
Figure 2 (Bottom): Load Analysis of Topology Optimized Design; Mass Ratio: 10.02%, Approx. Mass: 0.044 kg < 0.1lb

Manufacturability Analysis of Intuitive Design

To assess the manufacturability of the intuitive design, this paper assumed the part is to be printed on a LulzBot Taz 6 using Ultem 9085 filament. The specification of the filament are as follows: 1.75 mm diameter, 1.34 g/cm^3 density, and $75 for 250 g. Using the Cura LulzBot software, the intuitive design is expected to print without support structures in 5 hrs 15 mins, using 34 g of filament that costs $10.48 as seen in Figure 3 to the left. Meanwhile, support structures for this design will take an extra 4g of material, add an hour to the build time and cost about $1 more.

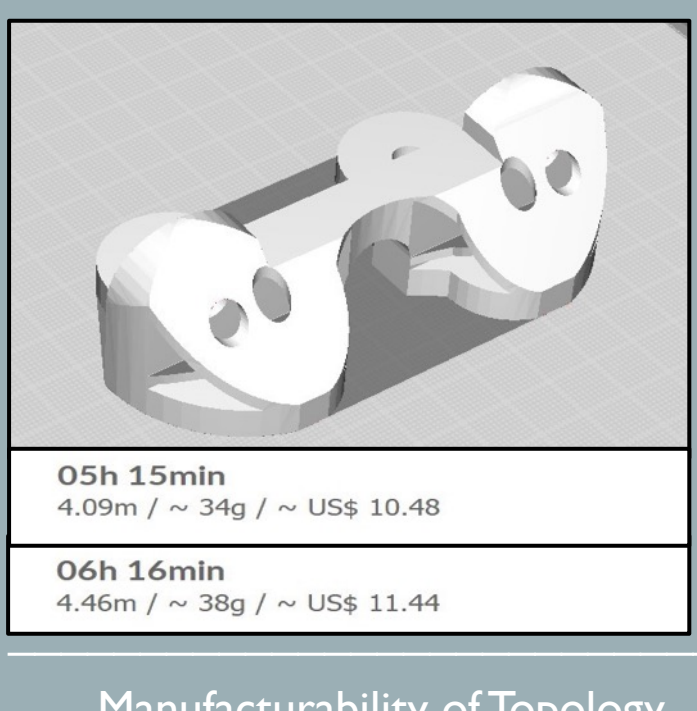

Figure 3: Build time, material usage and cost for intuitive design with and without support structures

Manufacturability of Topology Optimized Design

The manufacturability of the Autodesk Fusion 360 topology optimized design that was also assessed using the same Cura Lulzbot software. This part is expected to print without support structures in 5 hrs 21 mins, using 28 g of filament that costs $8.55 as seen in Figure 4 on the right. Meanwhile, support structures for this design will take an extra 5g of material, add about an hour and a half to the build time and cost about $1.50 more.

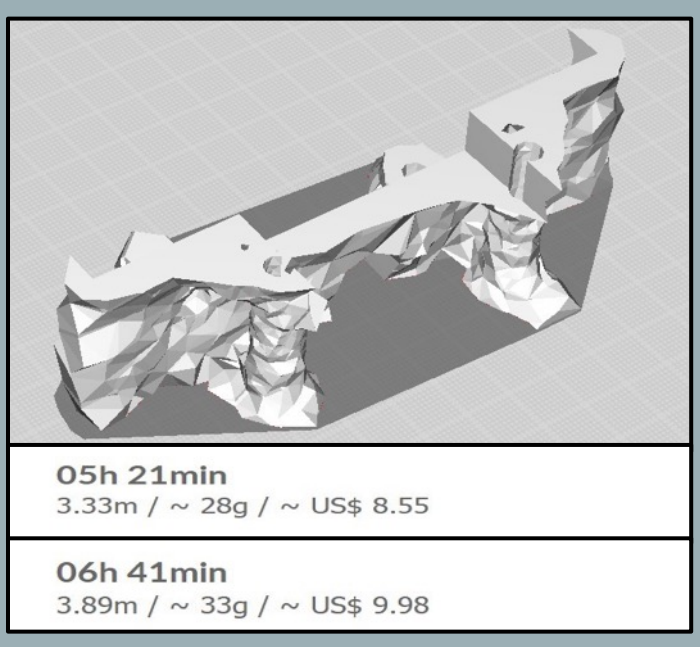

Figure 4: Build time, material usage and cost for topology optimized design with and without support structures

Design Reflection

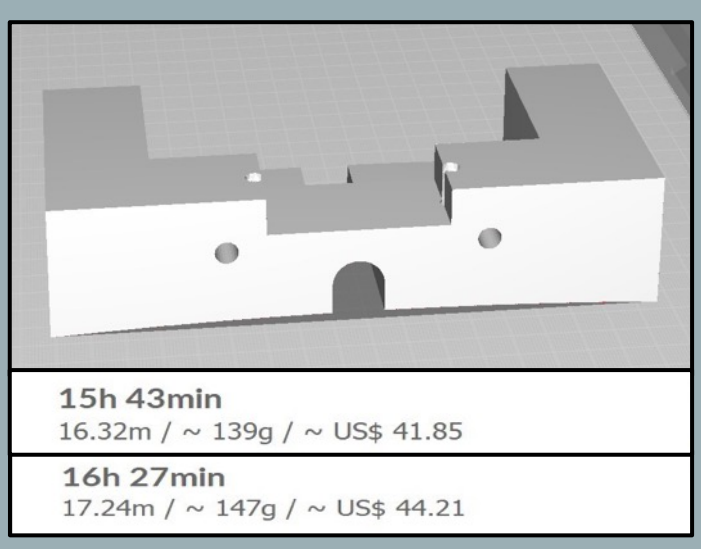

Figure 5: Build time, material usage and cost for original design with and without support structures

Both designs matched very closely in terms of build time, material and support usage; however, each design scored well in their own individual category. The intuitive design was designed with the restrictions of AM kept in mind. This meant that the design maximized the use of angles greater than 45 degrees to prevent overhanging in sections of the part. This was effectively proven to beneficial in terms of manufacturability where it was about 2% faster in printing without support materials and 7% faster with. Moreover, the intuitive design used used one less gram of support material. On the other hand, the efficiency of the computational software can truly be seen in the topology optimized design which was 18% lighter than the intuitive and 15% cheaper. Overall both the intuitive and topology optimized part did much better than the original design by using 78% less material, 50% less support structure and printing 60% faster.