Design for Manufacturing and Reliability
Assignment 4
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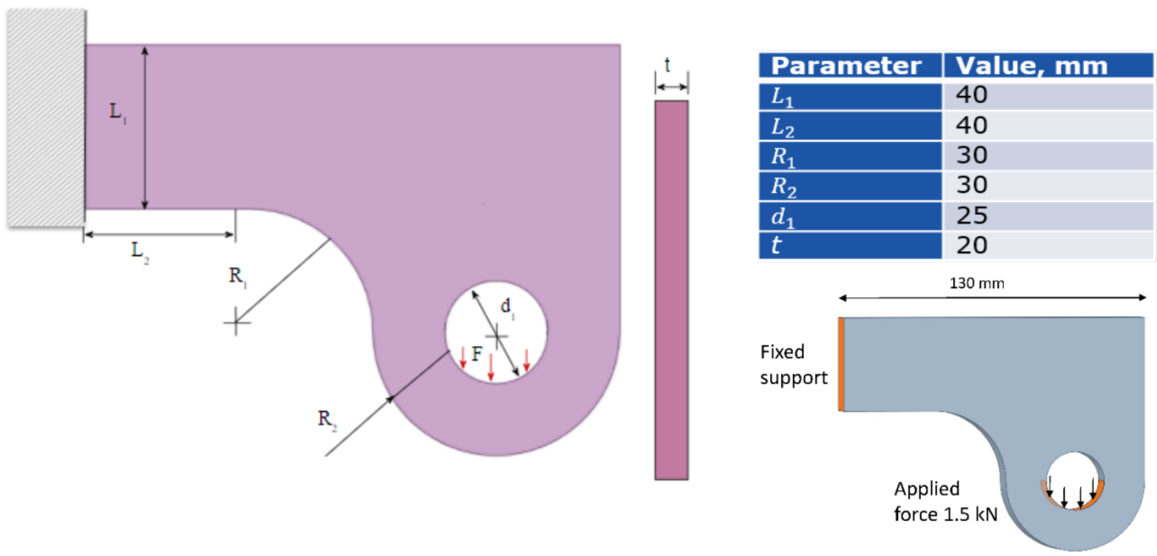
1 Introduction

This study involves a climbing hangerbracket of Ti-6Al-4V material with shape and dimensions shown in Figure 1.1. The structure is fixed at one end and loaded with a force of 1500 N.



Parameter	Value, mm
L_1	40
L_2	40
R_1	30
R_2	30
d_1	25
t	20

Figure 1.1: Initial design and loading condition of the hagning bracket.

We are to investigate the influence of the additive manufacturing on the final state of the component. This will be done by comparing the result of different operation sequences.

2 Stress-constrained topology optimization without AM constraints

First we are to perform a topology optimization of the initial design seen in figure 1.1, where the objective is to minimize the weight of the component, while satisfying the constraint of maximum allowed von Mises stress of 180 MPa. The finite element mesh size is to be 2mm, and there will be a minimum member size criteria of 5mm. The material properties of Ti-6Al-4V can be seen in table 2.1.

Property	Value
Young's Modulus (E)	111 GPa
Poisson's Ratio (ν)	0.3387
Shear Modulus (G)	0.415 GPa

Table 2.1: Material Properties of Ti-6Al-4V

A static structural study is conducted on the initial design configuration which results in the stress distribution seen in figure 2.1.

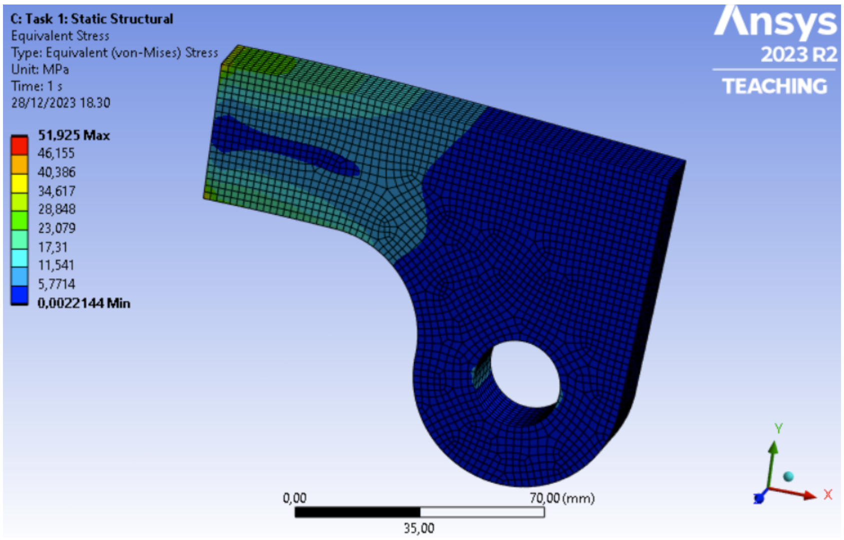


Figure 2.1: Structural analysis of the initial geometry

A structural optimization study is then conducted on this design, which optimizes the component for weight, with the constraint of maximum allowable von Mises stress of 180 MPa. The stress distribution of this result is shown in figure 2.2.

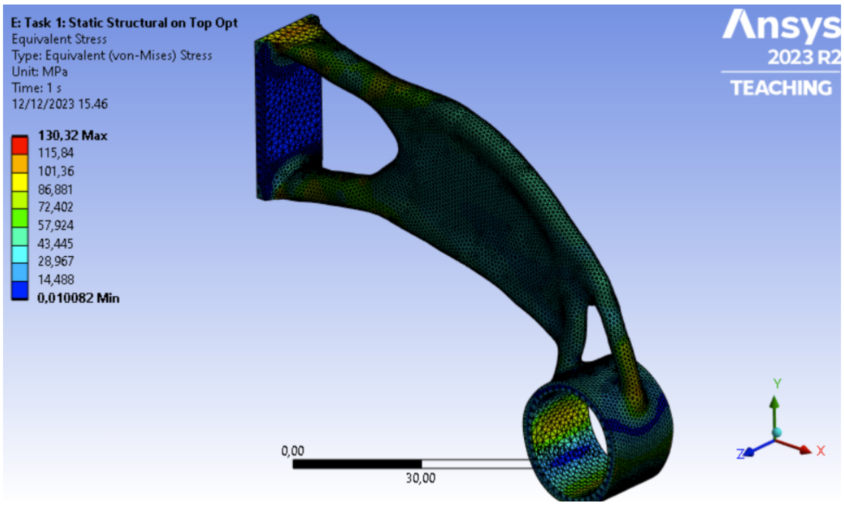


Figure 2.2: Equivalent stresses for the topology optimized geometry without AM constraints

Please note that before conducting the finite element analysis, it was necessary to 'clean up' the geometry using Ansys Spaceclaim. This step led to the mesh refinement, explaining why the mesh appears finer than depicted in Figure 2.2. It is however apparent that the stress constraint is not exceeded.

The geometry has been probed, as illustrated in Figure 2.3, specifically on its thinnest member to verify that the thickness exceeds 5 mm. Please observe the two green dots indicating the probe locations and the measurement provided at the bottom of the figure: Distance = 5.0082 mm.

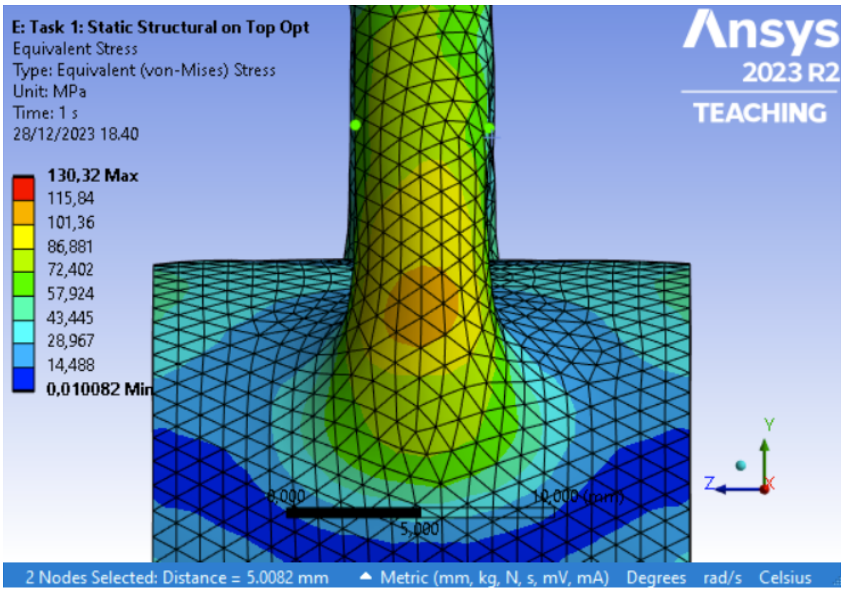


Figure 2.3: Checking the member size constraint

2.1 AM process for geometry without AM constraints

The second task uses the topology-optimized geometry (see figure 2.2) from the first task to simulate the additive manufacturing process. This is performed with a constant convection coefficient of $10^{-5}\,\mathrm{W/mm^2{\cdot}^\circ C}$ and an ambient room temperature of 22°C. Furthermore, the parameters of the selective laser melting (SLM) process simulation are given in table 2.4.

Deposition thickness [mm]	Hatch spacing [mm]	Scan speed [mm/s]	Dwell time [s]	Pre-heat temperature [°C]
0.05	0.13	1200	10	100

Figure 2.4: Parameters for the SLM process simulation

The residual stresses resulting from the intense thermal gradients induced by the SLM process are depicted in Figure 2.5.

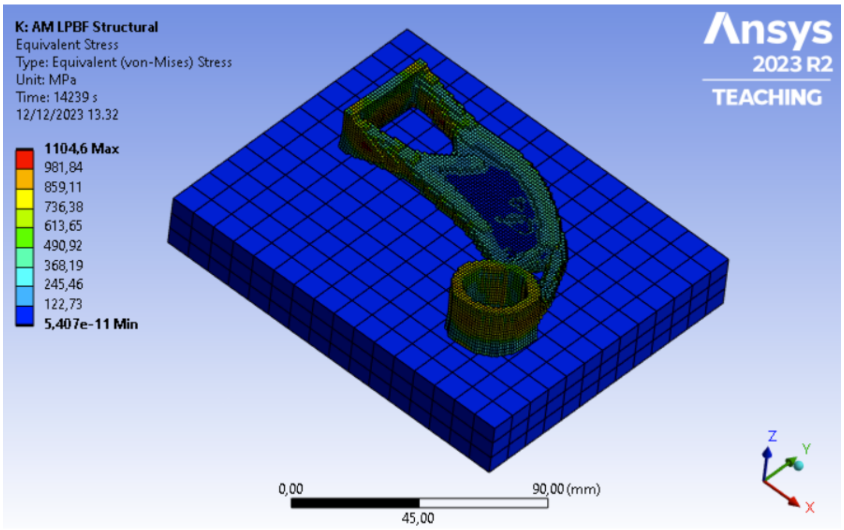


Figure 2.5: Equivalent stresses from the AM process

Significant residual stresses are anticipated in the SLM process, and some of these stresses will be partially alleviated when the object is separated from the base plate, leading to potential deformation. It is essential to note that the stresses post-removal from the base plate have not been taken into consideration.

3 Stress-constrained topology optimization with AM constraints

For the third task, topology optimization is conducted once again, following a similar approach to that of task 1 in Chapter 2. The only distinctions lie in the introduction of a 45°C overhang constraint in the z-direction (build direction) and a 10% reduction in the elastic modulus along the same direction. Given the initial elastic modulus of 111.2 GPa, a 10% decrease in the elastic modulus is calculated as follows:

$$E_{2z} = 111.2\,\mathrm{GPa} \cdot 0.9 = 100.08\,\mathrm{GPa} \tag{3.1}$$

Topology optimization is executed with identical constraints as those in the first task. Subsequently, a structural analysis is conducted on the optimized geometry, yielding the equivalent stresses illustrated in Figure 3.1.

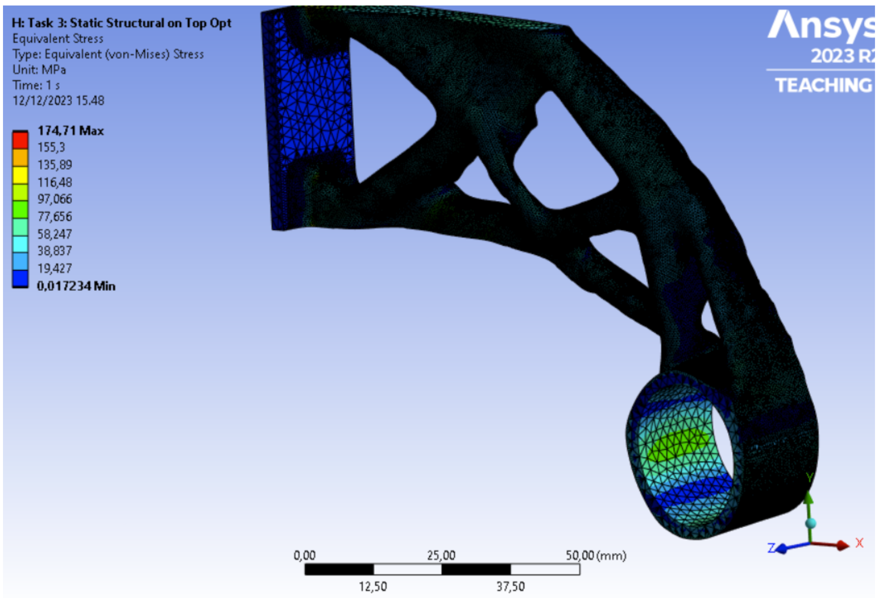


Figure 3.1: Equivalent stresses for the topology optimized geometry with AM constraints

Once again the geometry had to be 'cleaned up' in Ansys Spaceclaim.

3.1 Task 3: Revisit Task 1 Incorporating AM Constraints

Once again the AM process simulation is performed and the residual stresses computed and shown in figure 3.2.

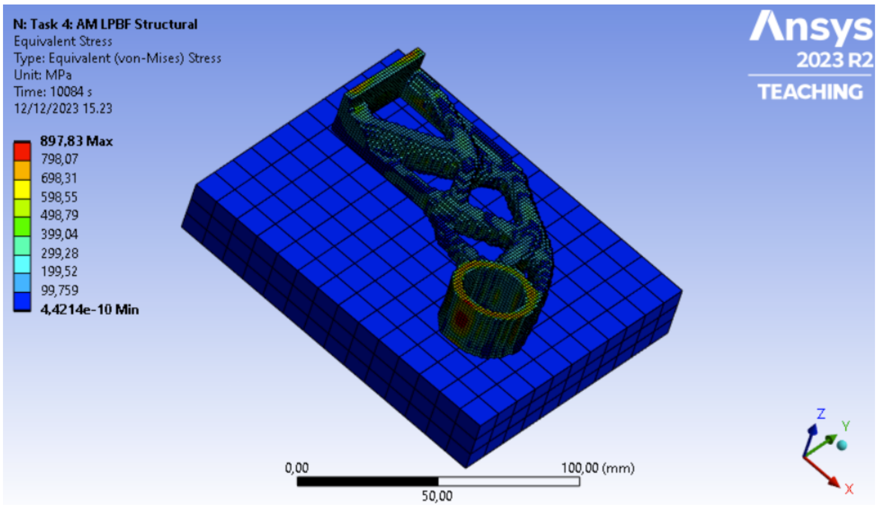


Figure 3.2: Equivalent stresses from the AM process

Not only does the overhang constraint ease the manufacturing but it also lowers the residual stresses. Compared to the results shown in figure 2.5 the maximum equivalent stress has been lowered by about 19%.