I- Shape optimization

a) Initial Simulation: Load Cases

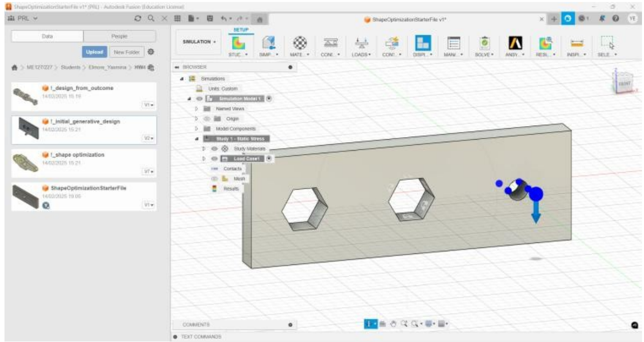
We want to design the body of a custom vise speed handle. The circular hole of the vise speed is attached to the grip, where the hand applies a downward force to tighten and an upward force to loosen. The two hexagonal holes (outer hex and inner hex) are used in order to interface with the mechanisms that we want to tighten or loosen. Therefore, we have four cases :

1) Case 1 : tighten inner hex
2) Case 2 : loosen inner hex
3) Case 3 : tighten outer hex
4) Case 4 : loosen outer hex

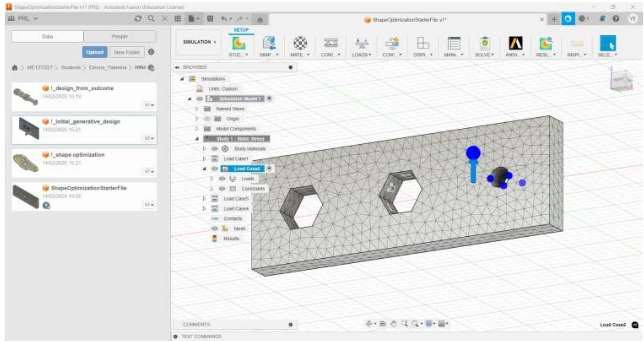
We know that the load applied to the grip can be represented as a distributed load of 3 inches long. This load is equivalent to applying a single load at a distance of 1.5 inches. We can use « remote forces » to represent that load, and the application surface chosen is the interior surface of the circular hole. We also have that for cases 1 and 2, a fixed constraint is applied to the interior surface of the inner hex, and for cases 3 and 4, a fixed constraint is applied to the interiorsurface of the outer hex.

b) Initial Simulation: Setup

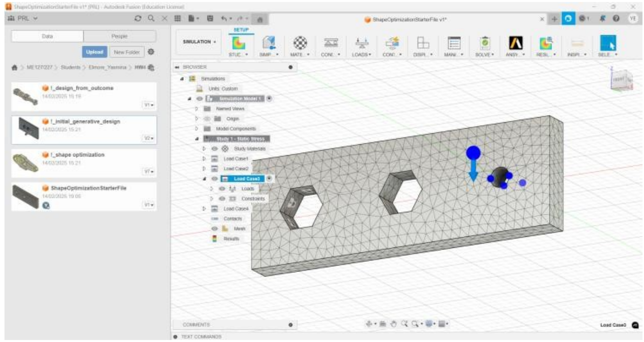
Case 1



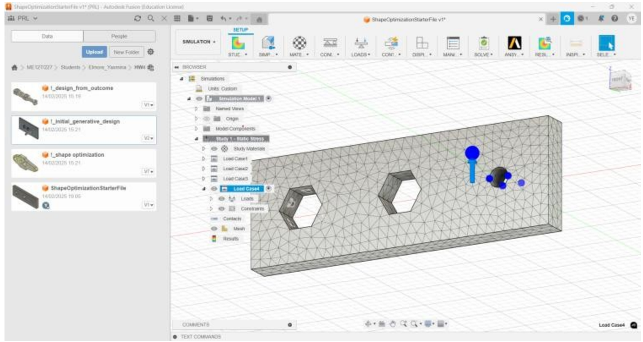
Case 2



Case 3



Case 4

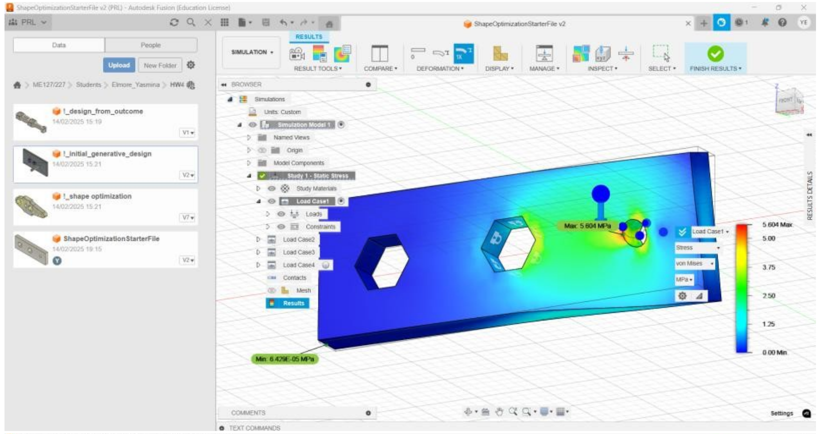


The material of the body is Aluminum 6061.
I chose a mesh of 3% (I couldn't go below 3% because my computer would stop working when I ran the simulations).
We also know that for cases 1 and 2, the applied load is 25 lb, and for cases 3 and 4, the applied load is 50 lb.

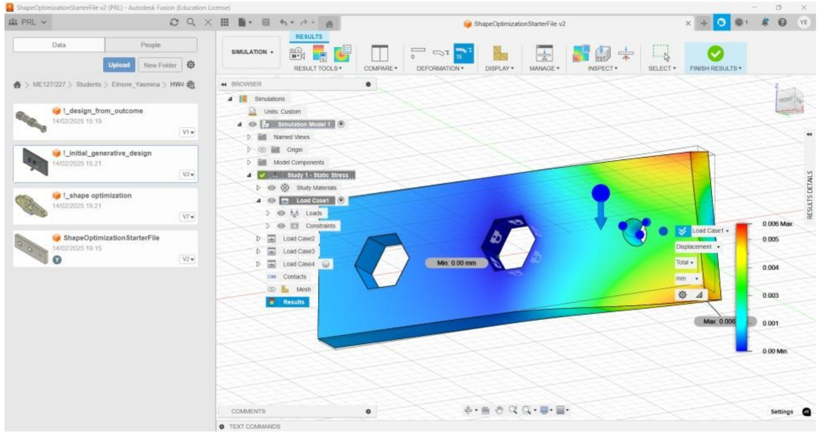
c) Initial Simulation: Results

Case 1

stress

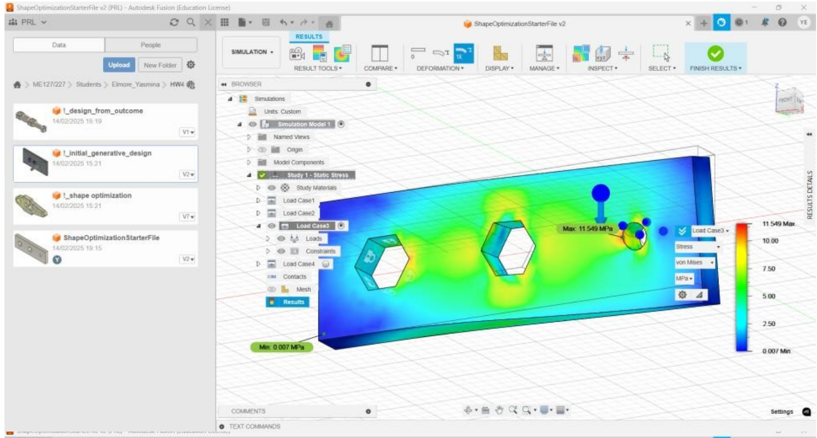


displacement

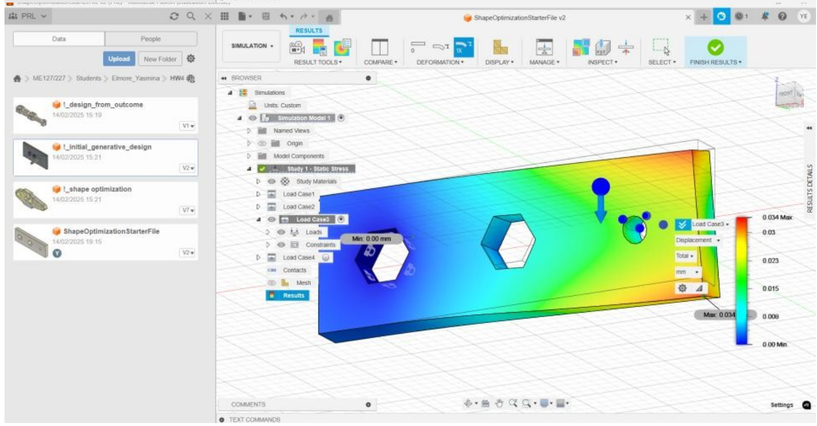


Case 3

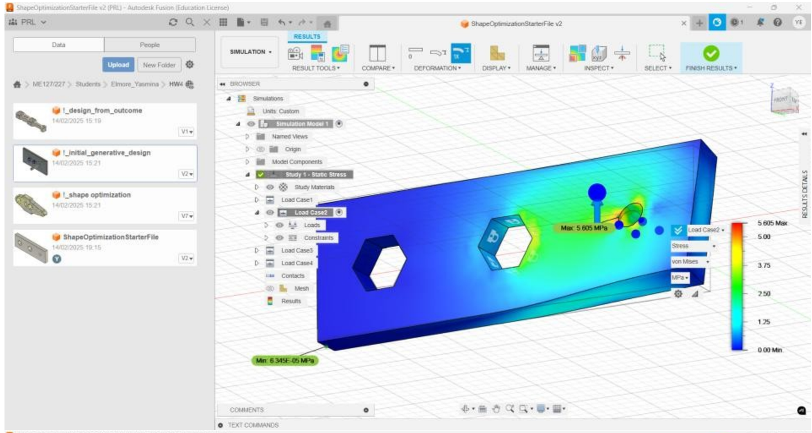
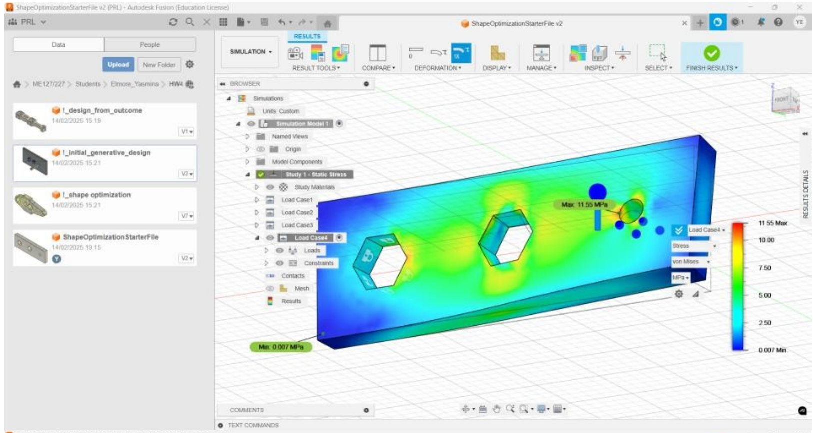
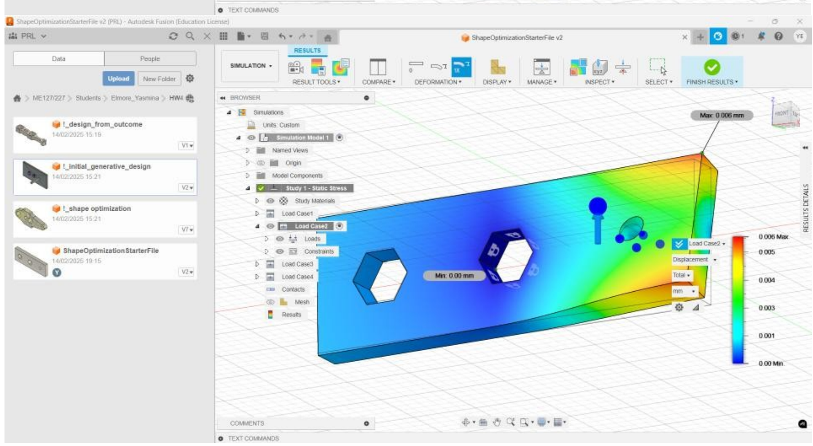
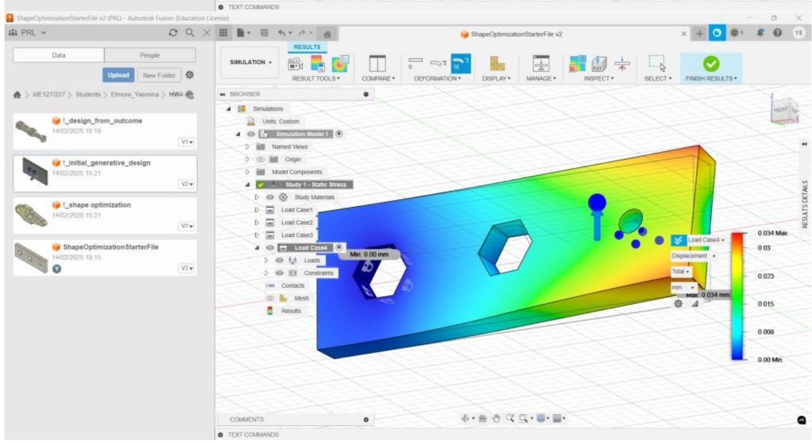
stress



displacement



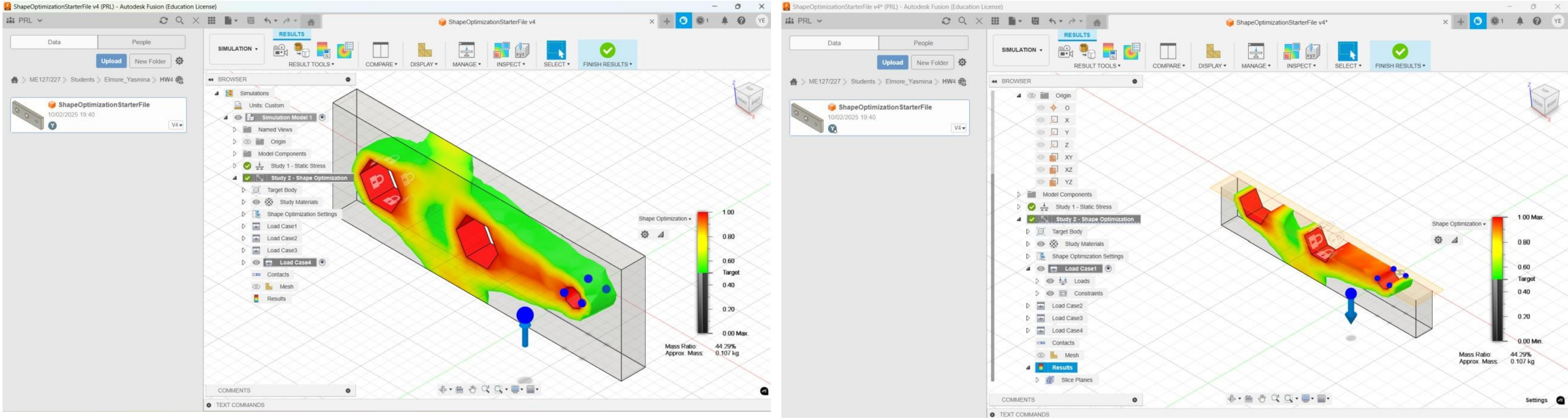
Let’s compare case 1 and case 3, for which we apply the downward load, but the fixed constraint is on the inner hex for case 1 and the outer hex for case 3. For case 1, we have a maximum stress of 5.604 MPa compared to case 3, for which we have a stress of 11.549 MPa. This means the material experiences more internal resistance in case 3, which makes sense since the applied moment is higher, leading to a greater concentration of forces inside the material. We also have a displacement of 0.006 mm for case 1 vs. 0.034 mm for case 3, which means that the material bends more in case 3.

	Case 2		Case 4
stress		stress	
displacement		displacement	

Let’s compare case 2 and case 4, for which we apply the upward load, but the fixed constraint is on the inner hex for case 2 and the outer hex for case 4. For case 2, we have a maximum stress of 5.605 MPa compared to case 4, for which we have a stress of 11.55 MPa. This means the material experiences more internal resistance in case 4, which makes sense since the applied moment is higher. We also have a displacement of 0.006 mm for case 2 vs. 0.034 mm for case 4, which means that the material bends more in case 4.

d) Shape optimization : Set up and Results

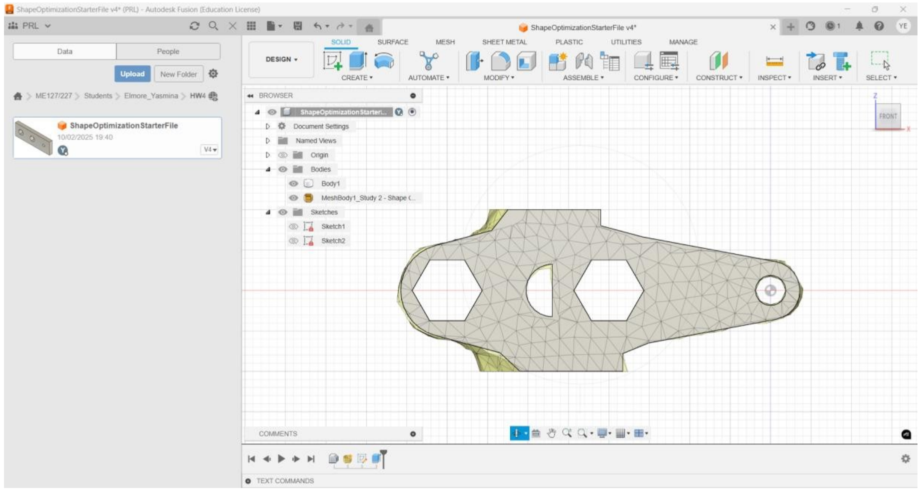
The material of the body is Aluminum 6061.
I chose a mesh of 3% (I couldn't go below 3% because my computer would stop working when I ran the simulations).
We also know that for cases 1 and 2, the applied load is 25 lb, and for cases 3 and 4, the applied load is 50 lb.



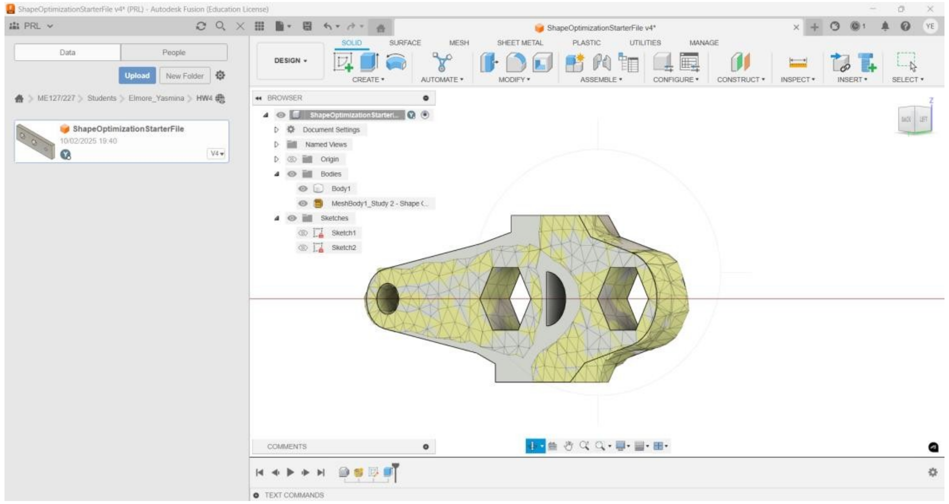
Screenshot of the optimized geometry

I obtained a mass ratio of 44.29%. However, we still need to verify that the body can prevent failure. This step will be done in the next slides.

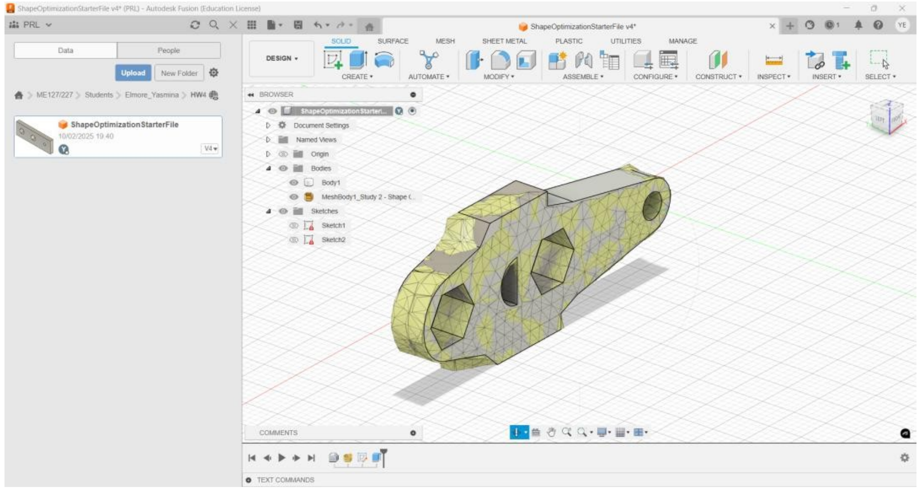
e) Shape optimization : CAD Updates



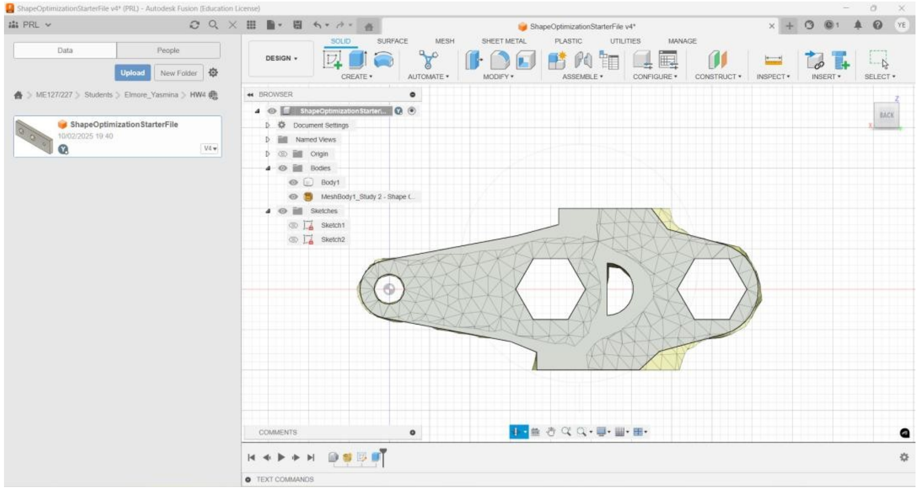
Front view of the extruded optimized body



¾ Back-side view of the extruded optimized body



3/4 front-side view of of the extruded optimized body



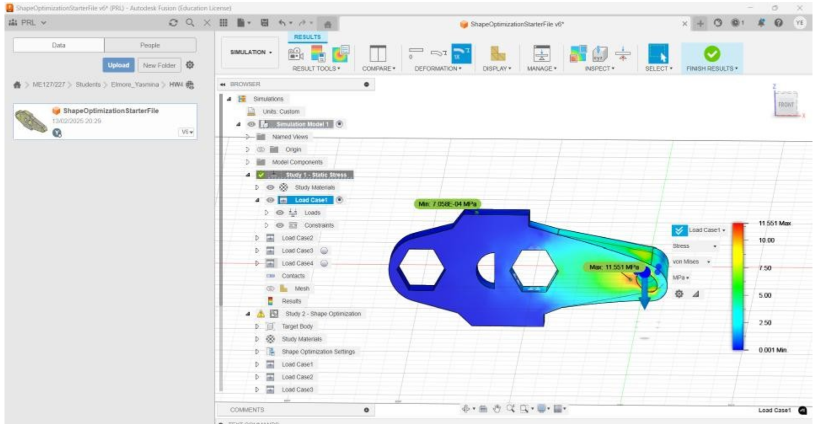
Back-side view of the extruded optimized body

I tried to remain as close as possible to the mesh and extrude the body defined by the mesh.

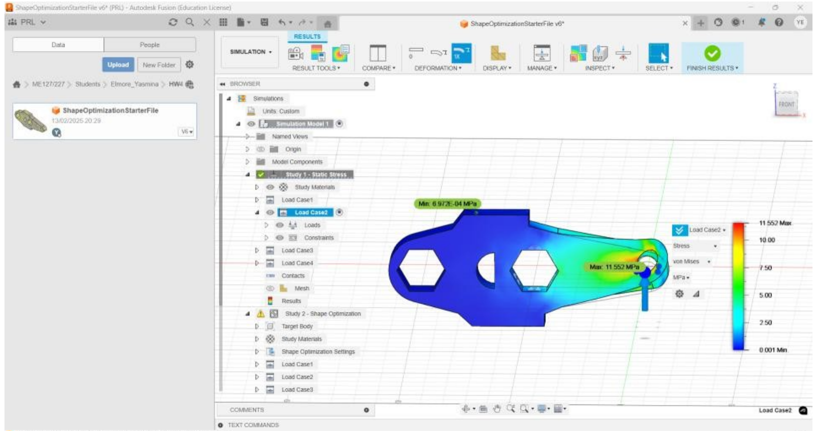
f) Shape optimization : Updated simulations and Analysis

stress

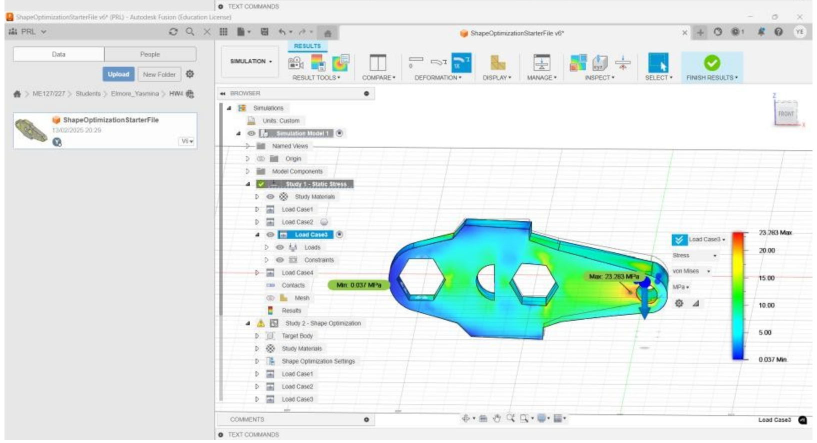
Case 1



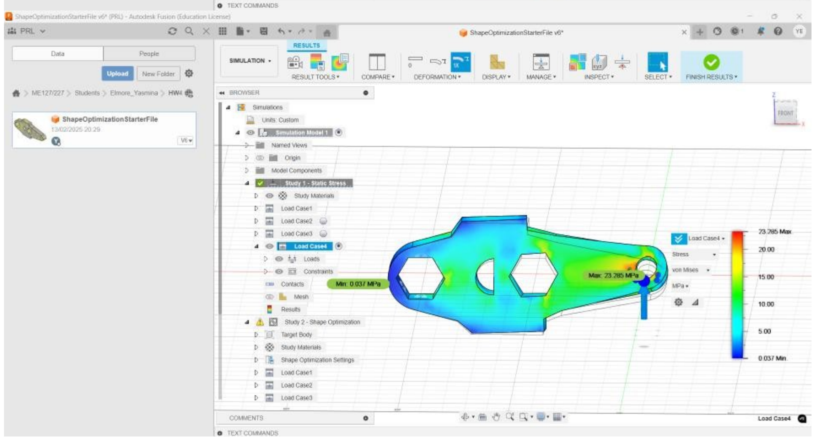
Case 2



Case 3



Case 4

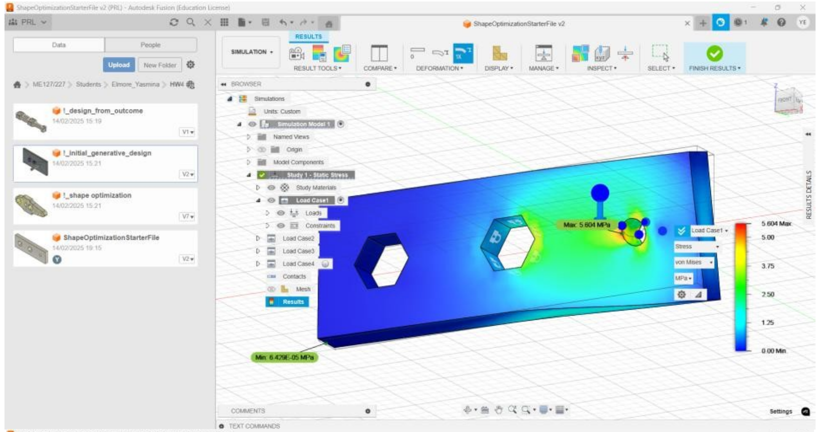


Just like in the initial configuration, if we compare case 1 and case 3, we see that the maximum stress in case 1 is lower than the maximum stress in case 3 (11.55 MPa vs. 23.26 MPa). We can see the same phenomenon for case 2 and case 4, where case 2 has a lower maximum stress than case 4 (11.56 MPa vs. 23.25 MPa).

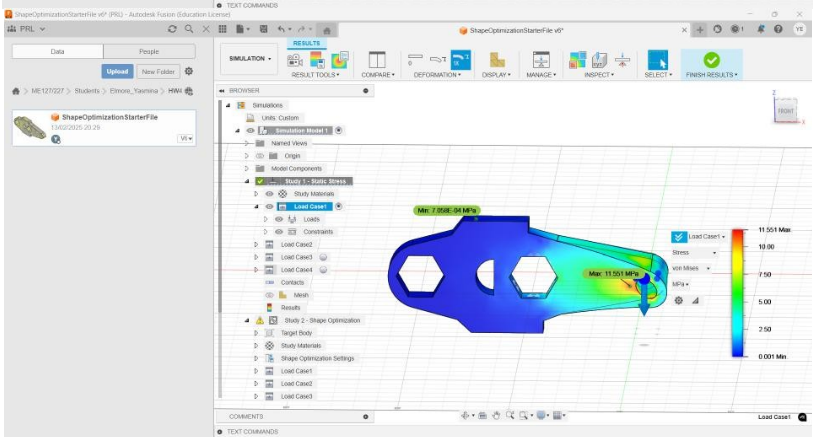
<u>**Comparison of the stress between the intial body and the shape optimized body**</u>

Case 1

Initial body

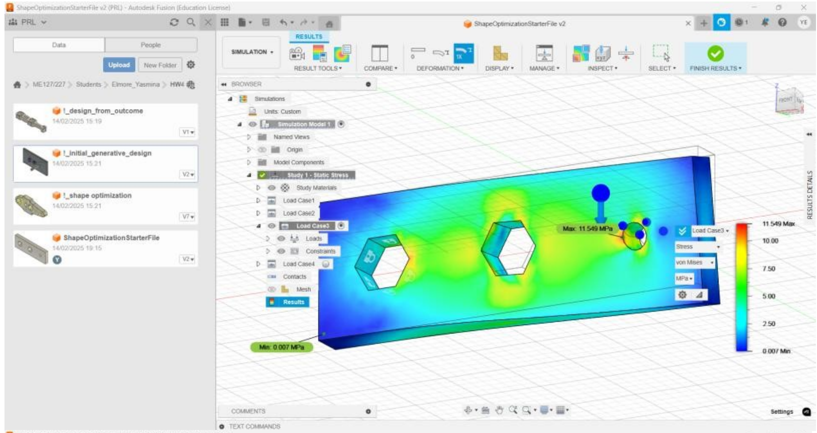


Optimized body

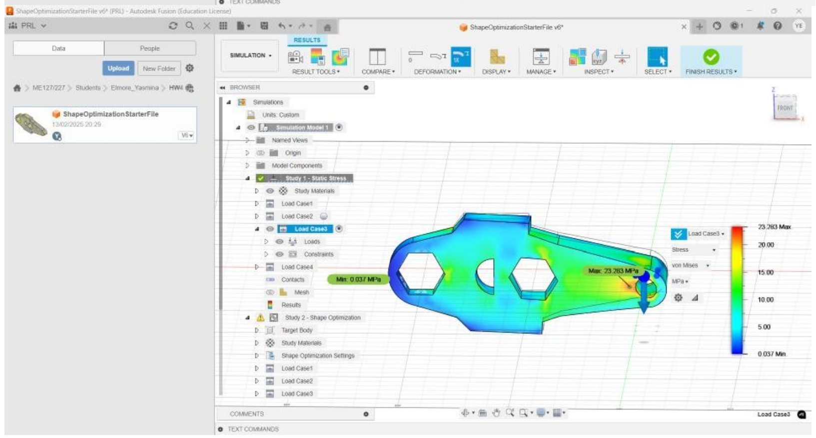


Case 3

Initial body



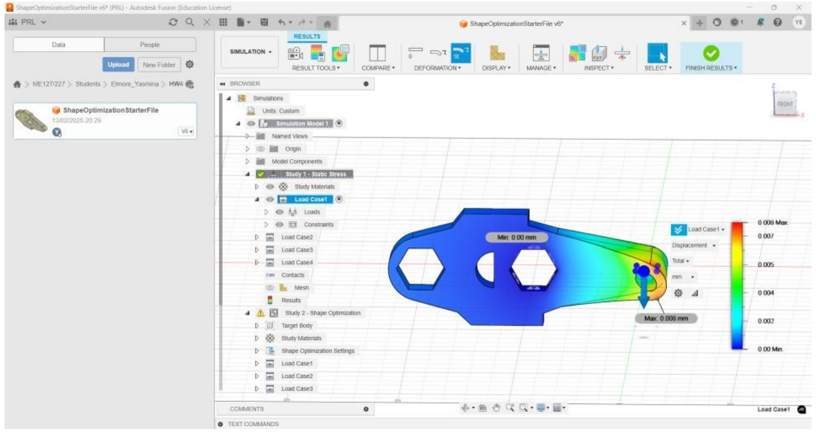
Optimized body



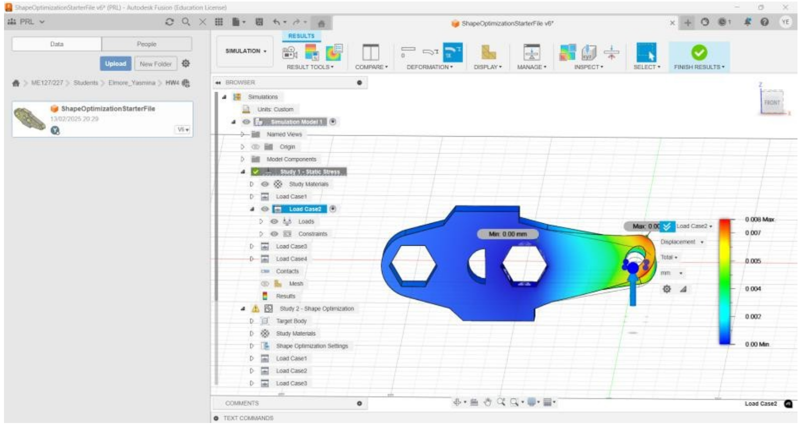
For case 1, when we compare the stress distribution in the initial body and the shape-optimized body, we observe that the maximum stress in the initial body is 5.004 MPa, compared to 11.55 MPa in the shape-optimized body. For case 3, when we compare the maximum stress, we have 11.54 MPa vs. 23.26 MPa. This can be explained by the fact that we reduced the mass around the circular hole, where we have the most stress.

displacement

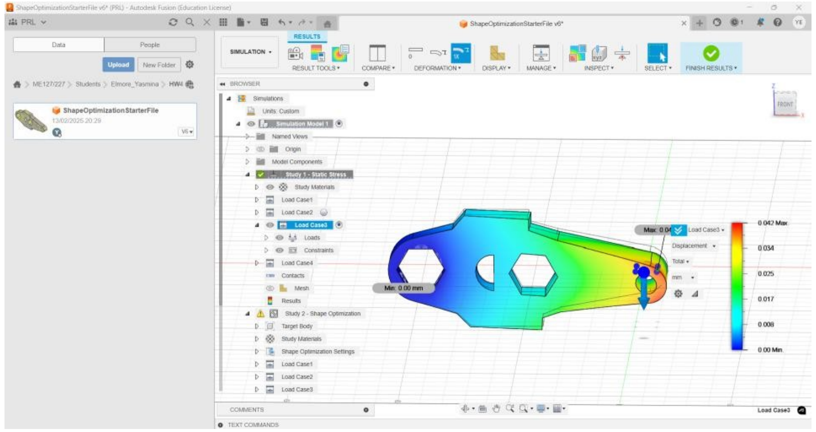
Case 1



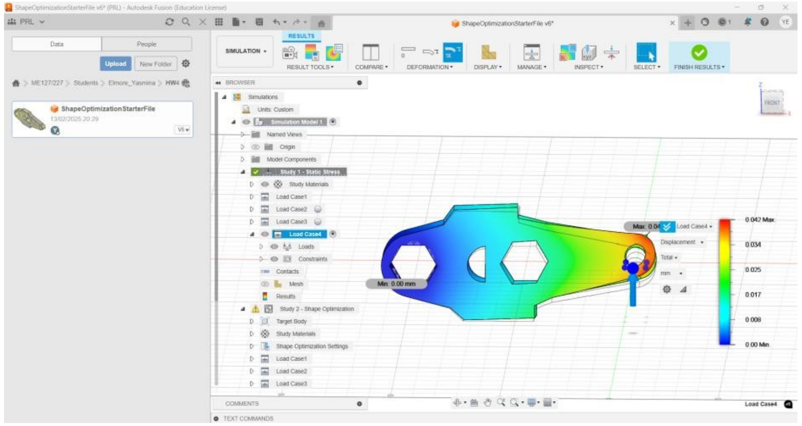
Case 2



Case 3



Case 4

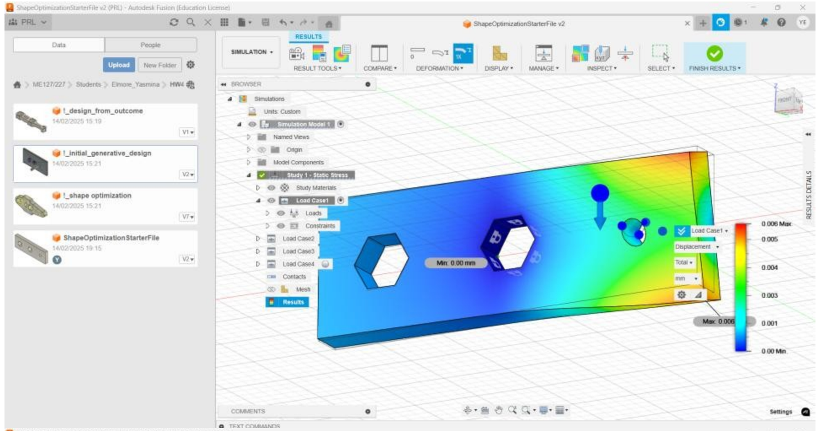


Just like in the initial configuration, if we compare case 1 and case 3, we see that the maximum displacement in case 1 is lower than the maximum displacement in case 3 (0.008 mm vs. 0.042 mm). We can see the same phenomenon for case 2 and case 4, where case 2 has a lower maximum displacement than case 4 (0.008 mm vs. 0.042 mm).

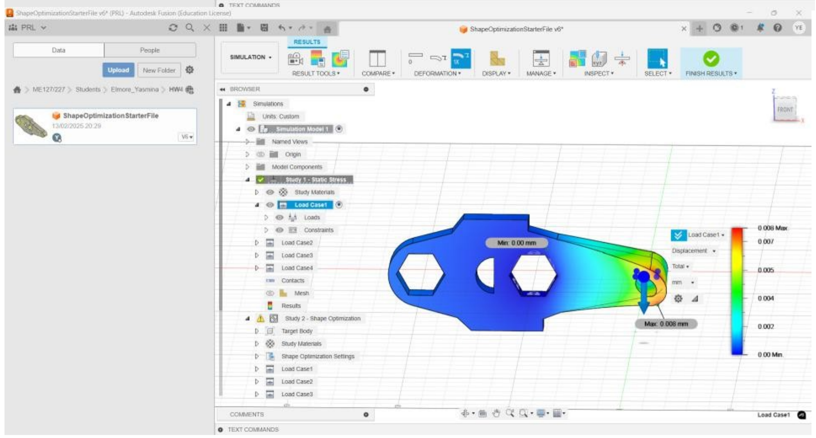
Comparison of the displacement between the intial body and the shape optimized body

Case 1

Initial body

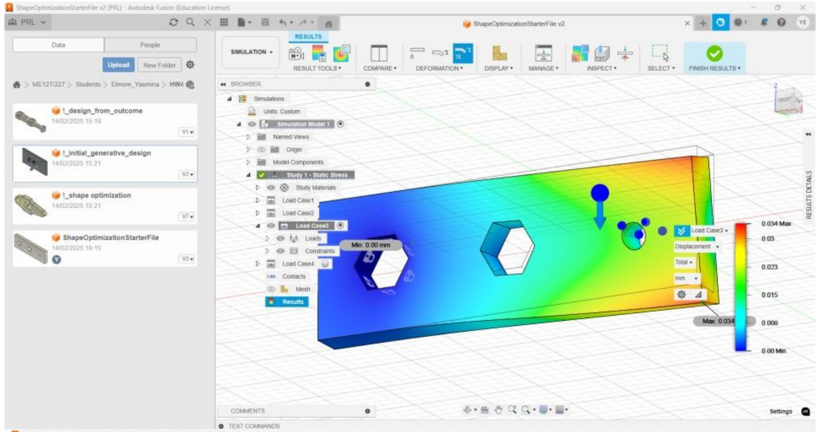


Optimized body

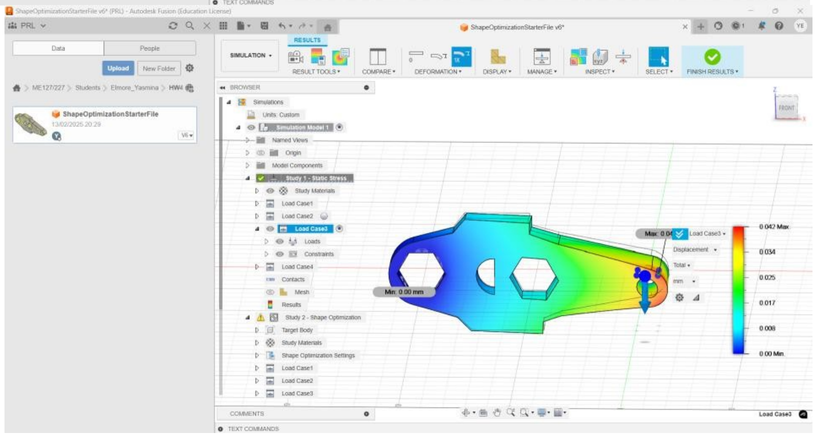


Case 3

Initial body

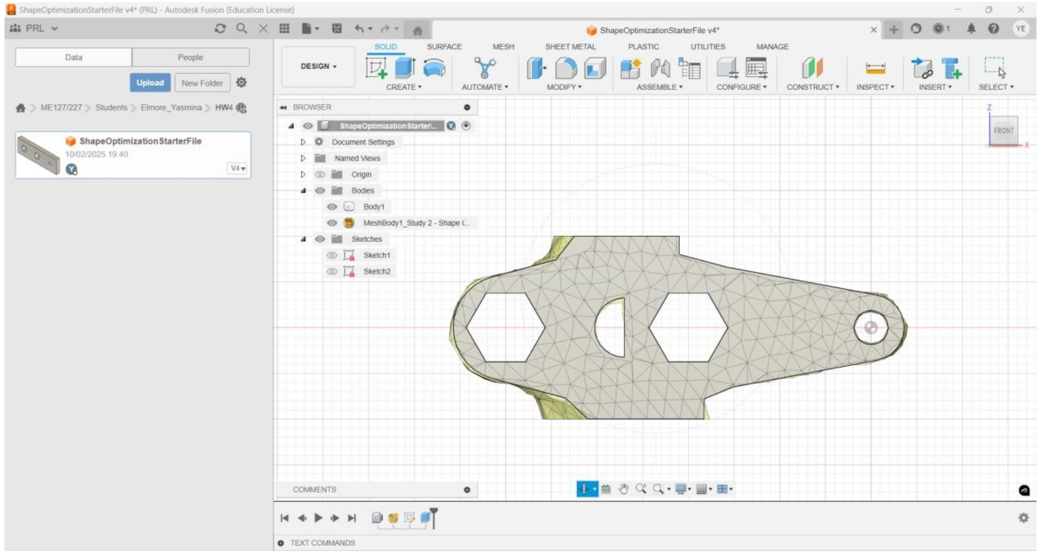


Optimized body



For case 1, when we compare the maximum displacement in the initial body and the shape-optimized body, we observe that the maximum displacement in the initial body is 0.006 mm, compared to 0.008 mm in the optimized body. For case 3, when we compare the maximum displacement, we have 0.034 mm vs. 0.042 mm. This can be explained by the fact that we reduced the mass around the circular hole.

g) Shape optimization : Conclusion



When applying shape optimization, we aim to optimize the shape of the design by:

1. reducing the amount of material used (mass reduction)
2. minimizing the maximum stress and maximum displacement.

In our case, while we do see a mass reduction of 44 %, we don’t observe a significant improvement in the reduction of the maximum stress or maximum displacement. However, the yield strength of Aluminum 6061 is above 190 MPa, which is not exceeded, so we won't have failure due to plasticity and irreversible deformation of the body.

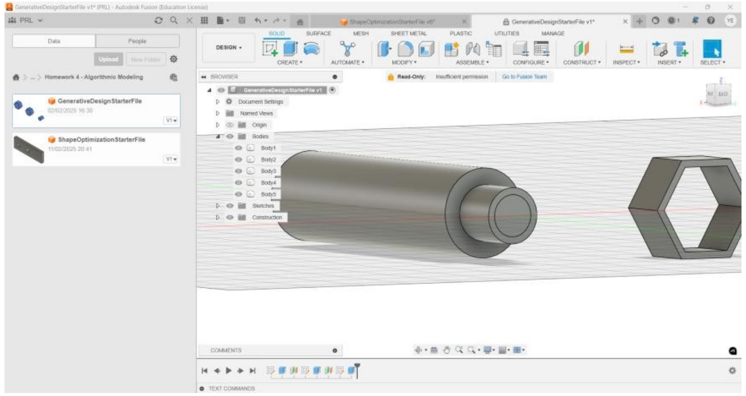
II- Generative design

a) Obstacles geometry

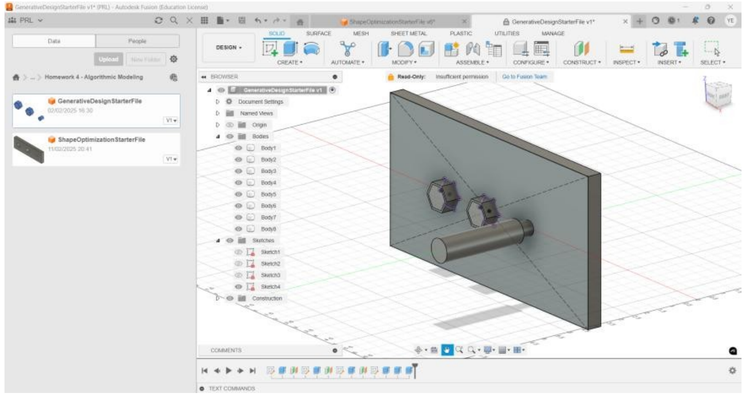
Obstacles to define:

1. The grip (handle)
2. The inside of the circular hole that should not be filled
3. The inside of the two hexagonal holes that should not be filled
4. The plane not to exceed: This plane is at the interface between the body of a custom vise speed handle and the mechanism we want to tighten. I decided to define a rectangle with a width and that is considered an obstacle.

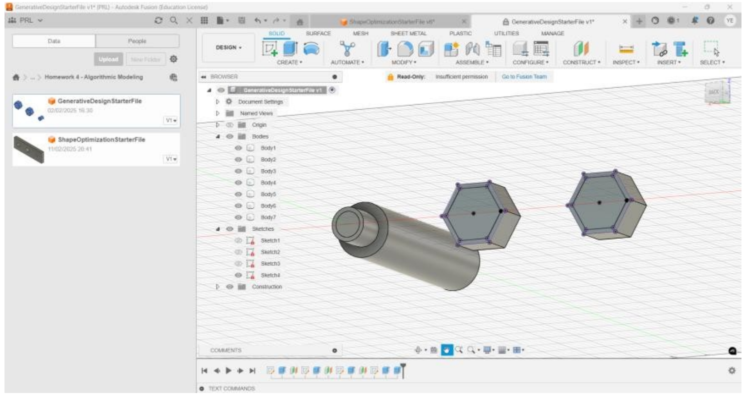
Obstacles 1 & 2



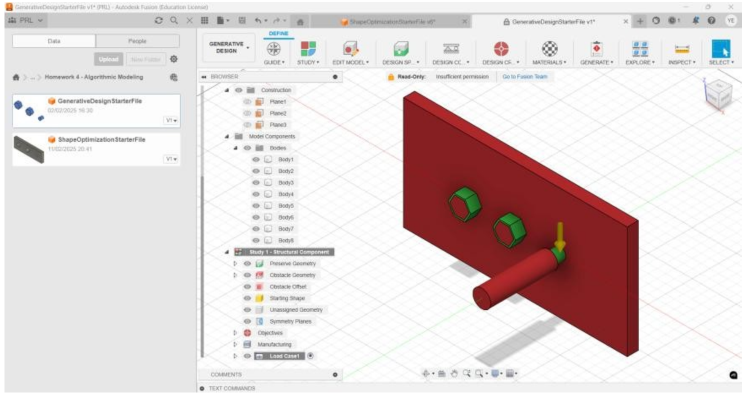
Obstacle 4



Obstacle 3



Selection of the obstacles (red)



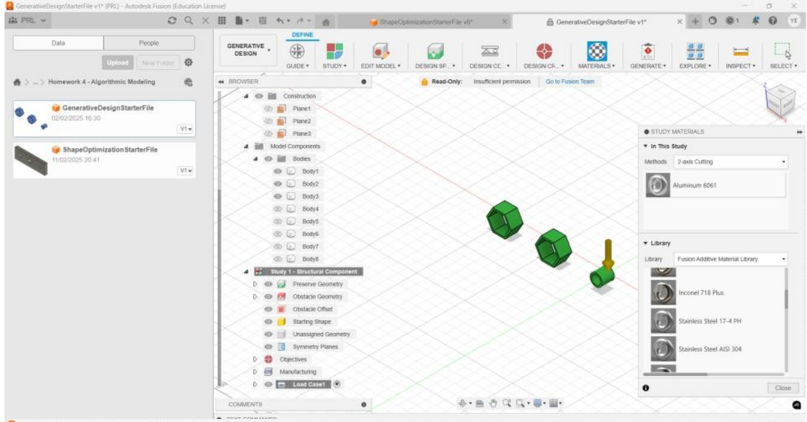
b) Set up :

For this set up, I chose :

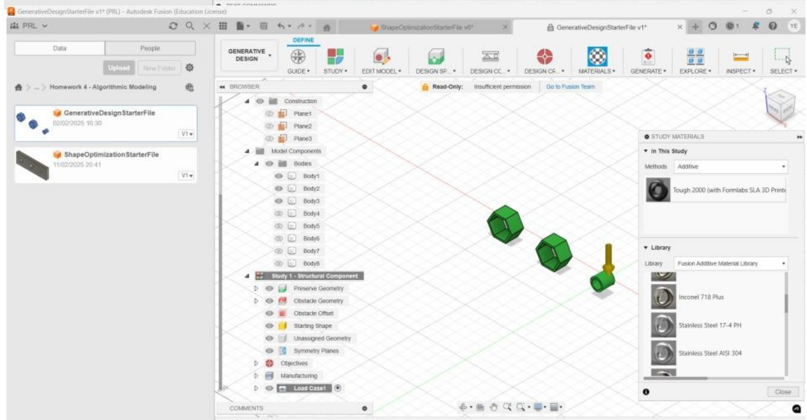
1. Tough 2000 as an additive
2. Aluminum 6061 as a 2 axis-cutting
3. Aluminum AlSi10Mg as unrestricted

I chose Tough 2000 as an additive to reinforce the material in key stress areas. I selected Aluminium 6061 for 2-axis cutting because it is compatible with milling and has high strength. Finally, I chose Aluminum AlSi10Mg as an unrestricted material to provide more flexibility. I wanted to keep Aluminium 6061 as one of the materials to compare the results obtained through generative design with those from shape optimization.

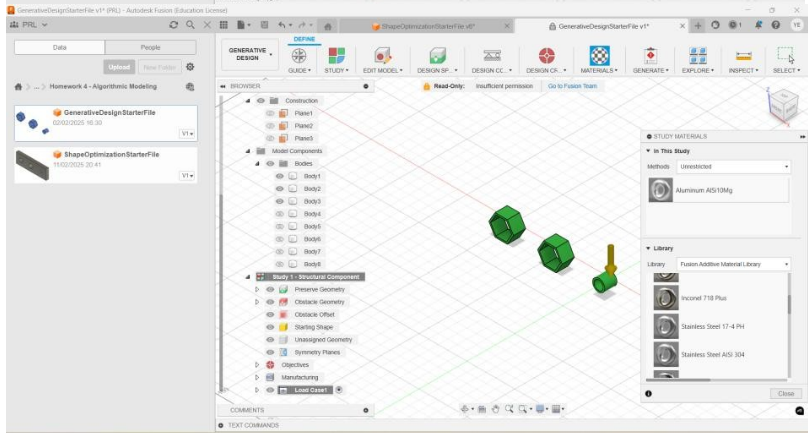
Choice for 2-axis cutting :



Choice for additive :



Choice for unrestricted :



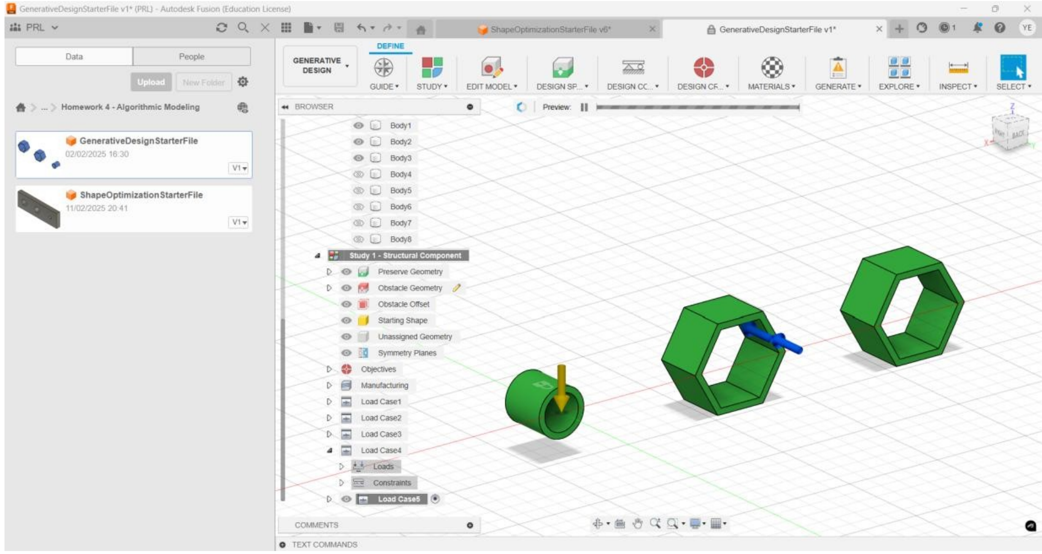
c) <u>Set up : Load cases and Improper use</u>

We apply the exact same loads as in the initial design. Hence, we have four cases:

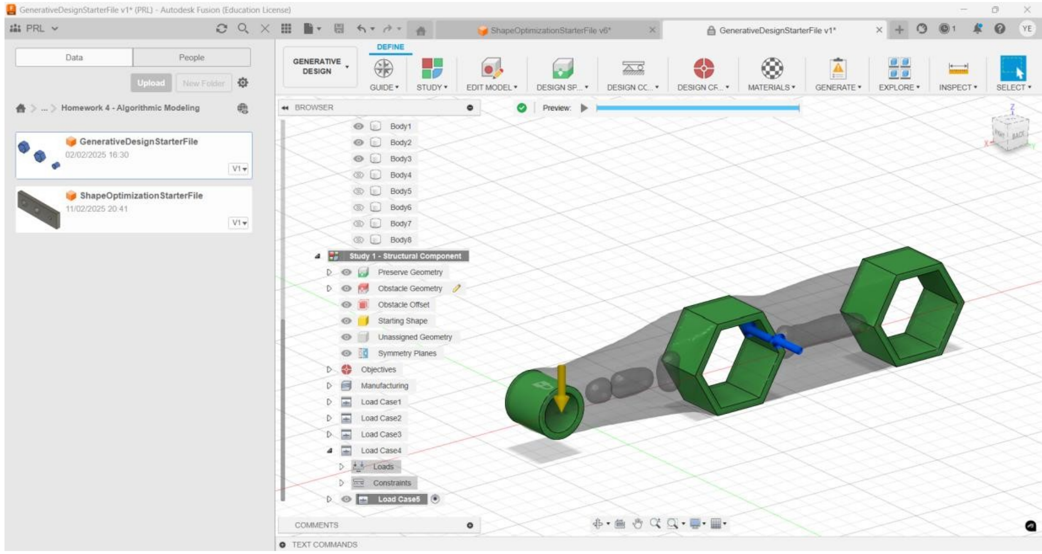
1. Case 1: Tighten inner hex
2. Case 2: Loosen inner hex
3. Case 3: Tighten outer hex
4. Case 4: Loosen outer hex

However, this time, I added one last case of improper use. Let's imagine that when the user tries to fix the inner hexagon to the tightening/loosening mechanism, he/she accidentally hits two of the edges of the inner hex. In that case, we will assume that those surfaces receive a load of 10 lb.

<u>Improper use load case :</u>



<u>Preview:</u>



d) Generative design : results and choice of the design

Study 1 - Structur... - Outcome 1
Iteration 40 (final)

Properties

Status	Converged
Generative model	Generative Model 1
Material	Aluminum 6061
Orientation	Y
Manufacturing method	2 axis cutting
Visual similarity	Ungrouped
Volume (mm^3)	13,620.026
Mass (kg)	0.037
Max von Mises stress (MPa)	135.066
Safety factor limit	2
Min safety factor	2.036
Max displacement global (mm)	0.886

For Aluminum 6061

Study 1 - Structur... - Outcome 2
Iteration 28 (final)

Properties

Status	Converged
Generative model	Generative Model 1
Material	Aluminum AlSi10Mg
Orientation	-
Manufacturing method	Unrestricted
Visual similarity	Ungrouped
Volume (mm^3)	6,643.148
Mass (kg)	0.018
Max von Mises stress (MPa)	120
Safety factor limit	2
Min safety factor	2
Max displacement global (mm)	0.545

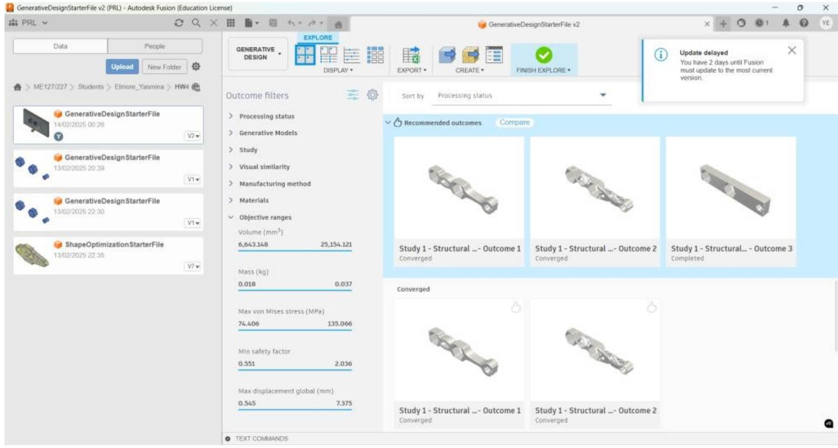
For Aluminum AlSi10Mg

Study 1 - Structur... - Outcome 3
Iteration 27 (final)

Properties

Status	Completed
Generative model	Generative Model 1
Mat...	Tough 2000 (with Formlabs SLA 3D Pri...
Orientation	Z+
Manufacturing method	Additive
Visual similarity	Ungrouped
Volume (mm^3)	25,154.121
Mass (kg)	0.029
Max von Mises stress (MPa)	74.406
Safety factor limit	2
Min safety factor	0.551
Max displacement global (mm)	7.375

For Tough 2000



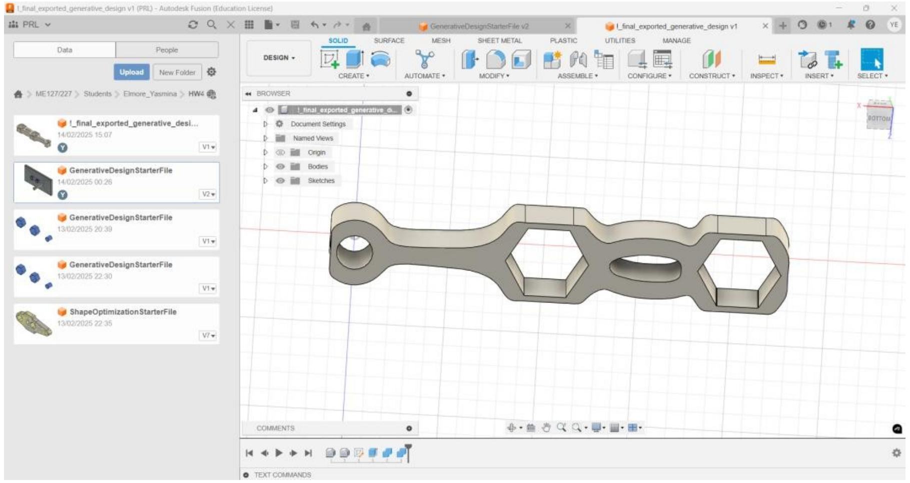
From the results, we see that Tough 2000 has a minimum safety factor of 0.551 and does not meet the required safety factor limit of 2. For Aluminum AlSi10Mg, the design is too complex for any manufacturing method and does not offer more advantages than the design with Aluminum 6061, which can be easily manufactured using a 2-axis cutting method. Hence the design chosen is 2 axis-cutting with Aluminum 6061.

d) Generative design : comparison with shape optimization

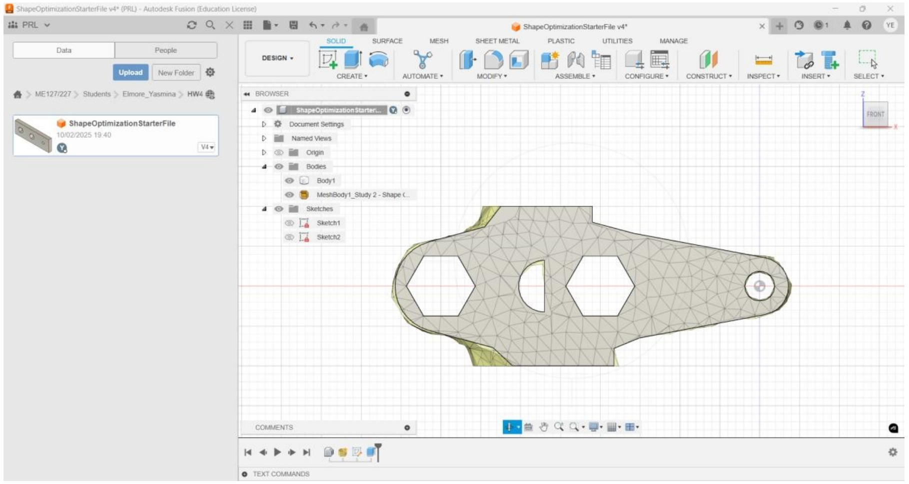
In the case of generative design, the final mass is 0.037 kg, whereas the shape optimization design has a final mass of 0.107 kg. This means that generative design achieves a greater mass reduction compared to shape optimization.

However, the maximum displacement in generative design is 0.886 mm, which is significantly higher than the 0.042 mm observed in shape optimization. Moreover, the maximum stress in generative design reaches 135 MPa vs 23.25 MPa for shape optimization.

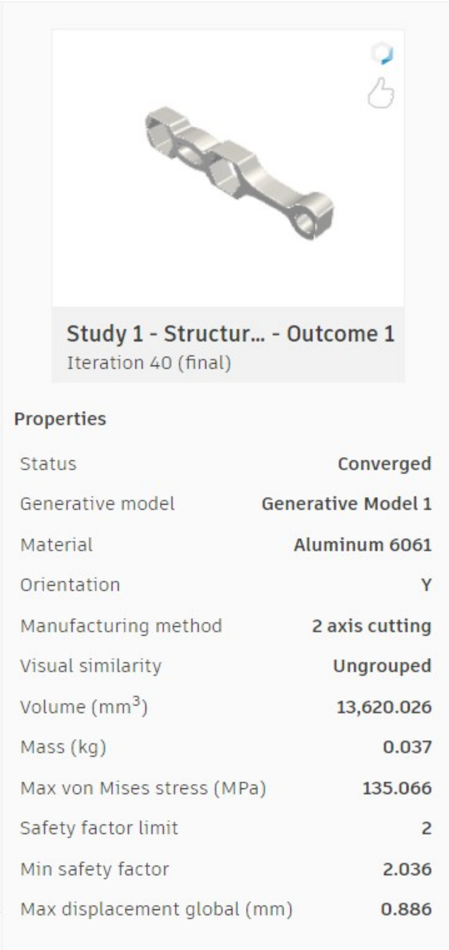
Because of the high maximum stress for the generative design, I would choose the shape optimization model.



Generative design model



Shape optimization model



Generative design model properties