Florida Institute of Technology

Spring 2025

MEE 3024 Computer-Aided Engineering

Section 1

Francesca Afruni, Elizabeth Beraducci, Kyle Kinkade

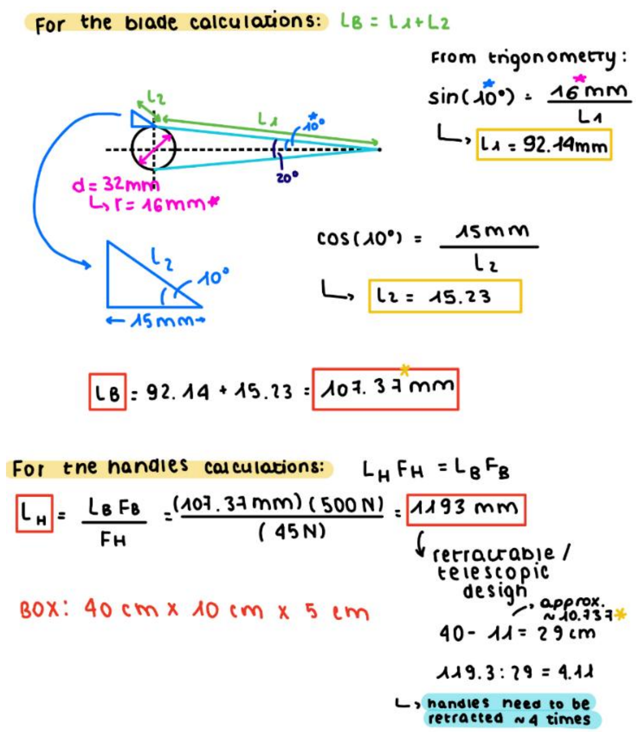
Email: fafruni2021@my.fit.edu, eberaducci2022@my.fit.edu, kkinkade2021@my.fit.edu

Project Report

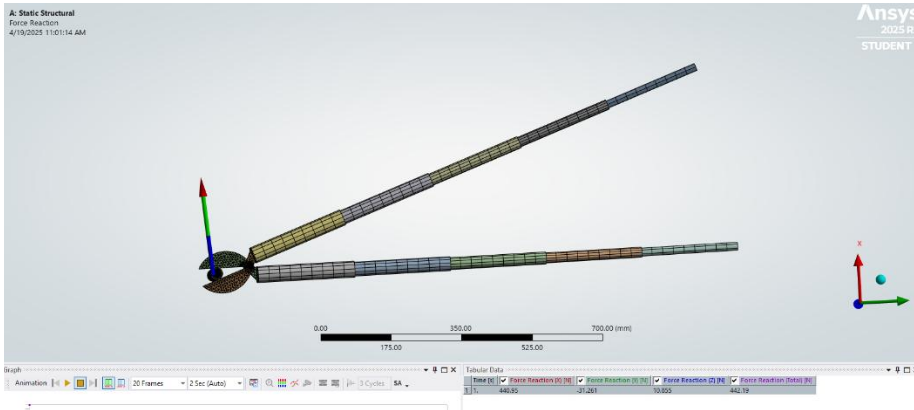
Due: April 25th 2025

Description of the Design & CAD Model with Drawings:

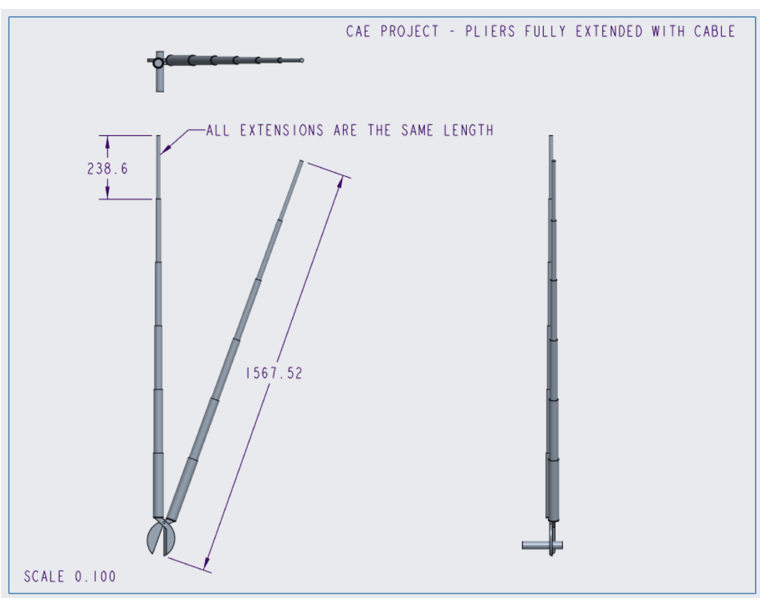
To begin the design of the cutting tool, the team began by completing a simple static analysis to ensure that the tool can produce 500N at the cutting blade when applying 45N at the handlebars. The team quickly discovered that a retractable design was necessary to remain within the 40 cm x 10 cm x 5cm size constraint while achieving the desired loads. As seen in the hand calculations below, initially, the calculations yielded that the total length of the handles would have to be divided into four sections in order to fulfill the design requirements. However, this wasn't taking into account some length that had to stay inside each extension and serve as contact. Therefore, the total length of the pliers was divided into five sections, which were 238.6 mm each. The design was based on similar extendable designs, particularly telescopes. After the length of the handles was determined, the team opted for a basic plier design with a single pin joint, of 8 mm diameter and 20 mm length, to serve as the rotating mechanism.

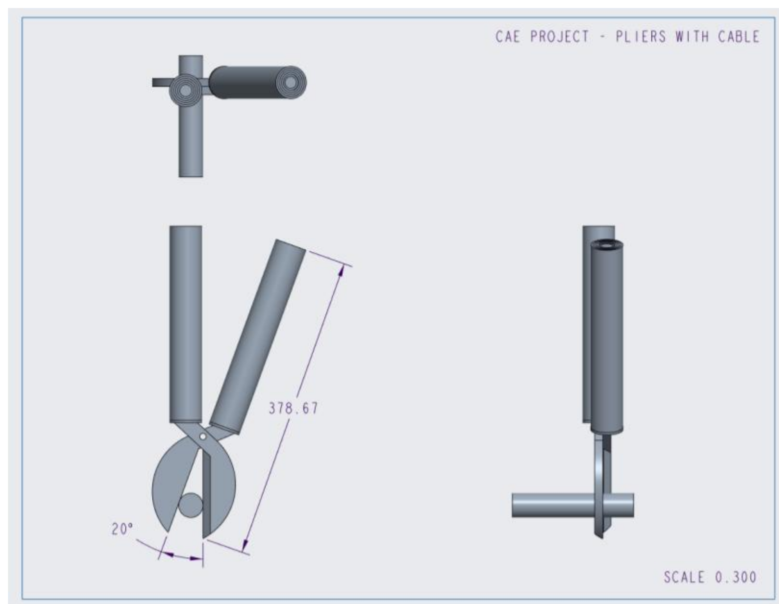


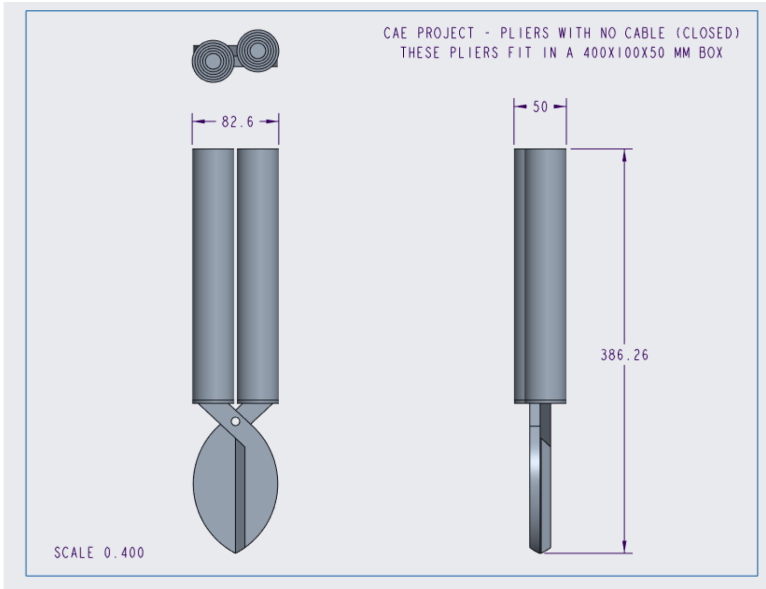
However, as can be seen in the figure below, this design did not yield the sought result in force, even though it was very close, at 442 N. Therefore, the team decided to add another extension to the design, always 238.6 mm in length, for a total of six extensions to achieve the desired result.



The following three CAD drawings show the measurements of the pliers. The first drawing shows the pliers in the fully extended configuration, with six smaller parts, each 238.6 mm, for a final total length of 1567.5 mm. The second drawing shows the design with the collapsed configuration, with a total length of 378.67 mm, while also showing that the 20-degree angle between the pliers' jaws is met while holding the 30 mm cable. Finally, the third drawing shows the necessary measurements to satisfy the 40 cm x 10 cm x 5cm box size requirements. The pliers have a height of 50 mm, a total length of 386.26 mm, and a width of 82.6 mm.







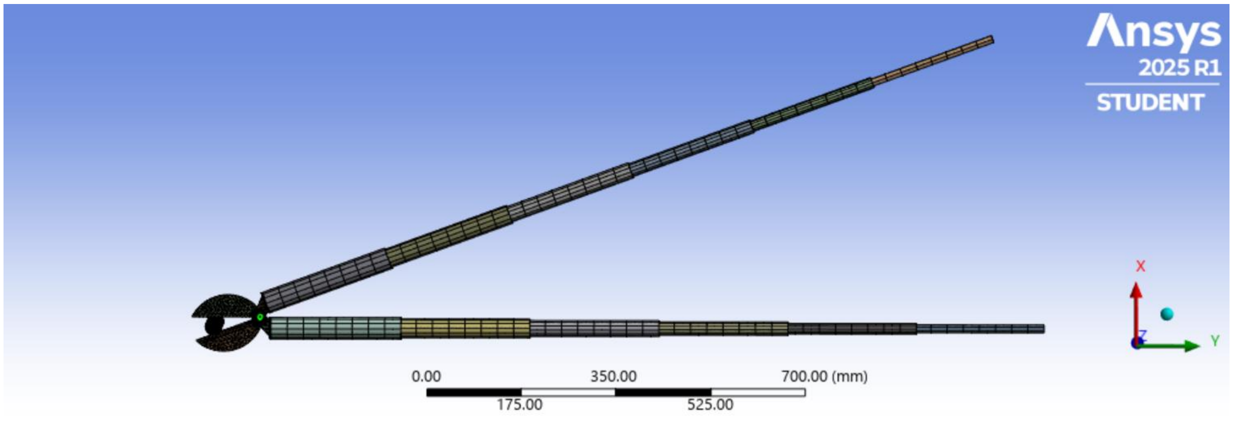
ANSYS Structural Analysis Results:

To complete the structural analysis, the CAD model was imported into a static structural problem in ANSYS. All components of the cutting tool were assigned as structural steel, and the cutting wire was designated as a copper alloy. A key part of the analysis was assigning contacts between all mechanisms to accurately model the behavior between two bodies. In this analysis, the retractable handles were given a bonded contact to ensure no separation, and no sliding were to occur. Similarly, the contact between the end of each handle to the flat base of the cutting mechanism was assigned as bonded. The pin attachment was modeled as a frictionless contact to allow smooth rotation. Finally, the wire was modeled to be bonded to the cutting blade to ensure the force was accurately transferred to the wire. A summary of the contacts are shown below.

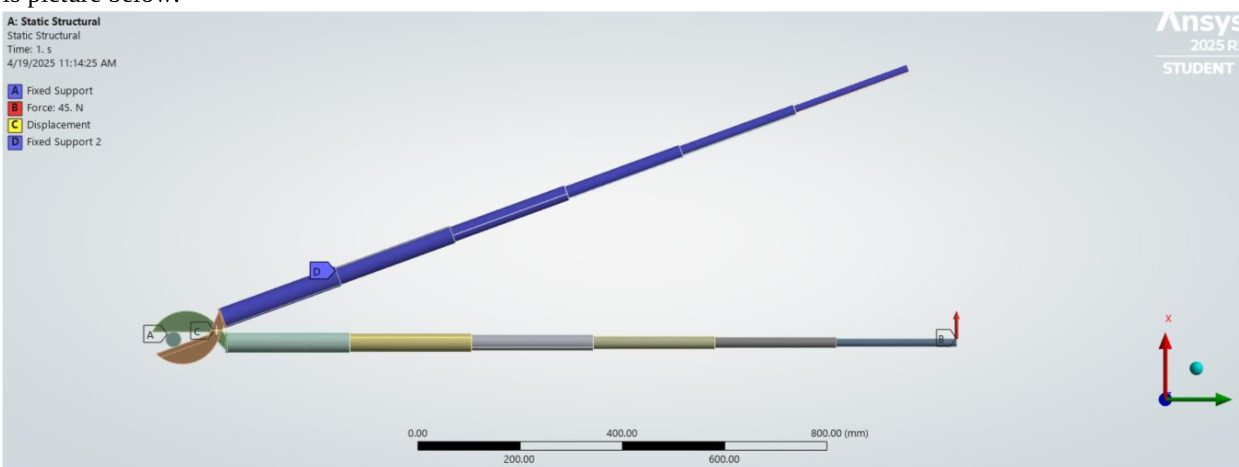
- Connections
  - Contacts
    - Bonded - PLIERS-HANDLES-ASSEMBLY_AF0_ASM|PLIERS-HANDLE-PT2|PLIERS-HANDLE-PT2 To PLIERS-HANDLES-ASSEMBLY_AF0_ASM|PLIERS-HANDLE-PT1|PLIERS-HANDLE-PT1
    - Contact Region 2
    - Bonded - PLIERS-HANDLES-ASSEMBLY_AF0_ASM|PLIERS-HANDLES-PT3|PLIERS-HANDLES-PT3 To PLIERS-HANDLES-ASSEMBLY_AF0_ASM|PLIERS-HANDLE-PT2|PLIERS-HANDLE-PT2
    - Bonded - PLIERS-HANDLES-ASSEMBLY_AF0_ASM|PLIERS-HANDLES-PT4|PLIERS-HANDLES-PT4 To PLIERS-HANDLES-ASSEMBLY_AF0_ASM|PLIERS-HANDLES-PT3|PLIERS-HANDLES-PT3
    - Bonded - PLIERS-HANDLES-ASSEMBLY|PLIERS-HANDLES-PT5|Solid To PLIERS-HANDLES-ASSEMBLY|PLIERS-HANDLES-PT4|Solid
    - Bonded - PLIERS-HANDLES-ASSEMBLY_AF1_ASM|PLIERS-HANDLE-PT2|PLIERS-HANDLE-PT2 To PLIERS-HANDLES-ASSEMBLY_AF1_ASM|PLIERS-HANDLE-PT1|PLIERS-HANDLE-PT1
    - Contact Region 7
    - Bonded - PLIERS-HANDLES-ASSEMBLY_AF1_ASM|PLIERS-HANDLES-PT3|PLIERS-HANDLES-PT3 To PLIERS-HANDLES-ASSEMBLY_AF1_ASM|PLIERS-HANDLE-PT2|PLIERS-HANDLE-PT2
    - Bonded - PLIERS-HANDLES-ASSEMBLY_AF1_ASM|PLIERS-HANDLES-PT4|PLIERS-HANDLES-PT4 To PLIERS-HANDLES-ASSEMBLY_AF1_ASM|PLIERS-HANDLES-PT3|PLIERS-HANDLES-PT3
    - Bonded - PLIERS-HANDLES-ASSEMBLY|PLIERS-HANDLES-PT5|Solid To PLIERS-HANDLES-ASSEMBLY|PLIERS-HANDLES-PT4|Solid
    - Frictionless - PLIERS-BLADE|PLIERS-BLADE To PLIERS-BLADE|PLIERS-BLADE[2]
    - Bonded - CABLE-TO-CUT|CABLE-TO-CUT To PLIERS-BLADE|PLIERS-BLADE
    - Frictionless - PIN-ATTACHMENT|PIN-ATTACHMENT To PLIERS-BLADE|PLIERS-BLADE
    - Bonded - CABLE-TO-CUT|CABLE-TO-CUT To PLIERS-BLADE|PLIERS-BLADE[2]
    - Frictionless - PIN-ATTACHMENT|PIN-ATTACHMENT To PLIERS-BLADE|PLIERS-BLADE[2]
    - Bonded - PLIERS-HANDLES-ASSEMBLY|PLIERS-HANDLES-PT6|Solid To PLIERS-HANDLES-ASSEMBLY|PLIERS-HANDLES-PT5|Solid
    - Bonded - PLIERS-HANDLES-ASSEMBLY|PLIERS-HANDLES-PT6|Solid To PLIERS-HANDLES-ASSEMBLY|PLIERS-HANDLES-PT5|Solid

After the contacts were assigned, an initial mesh was completed. To refine the mesh, the cutting mechanism was reduced to 7mm sizing, and a sweep was generated on the cylindrical pin body. The pin connection was further refined, and the wire body sizing was reduced to 3 mm. The final refined mesh can be seen below along with the statistics.

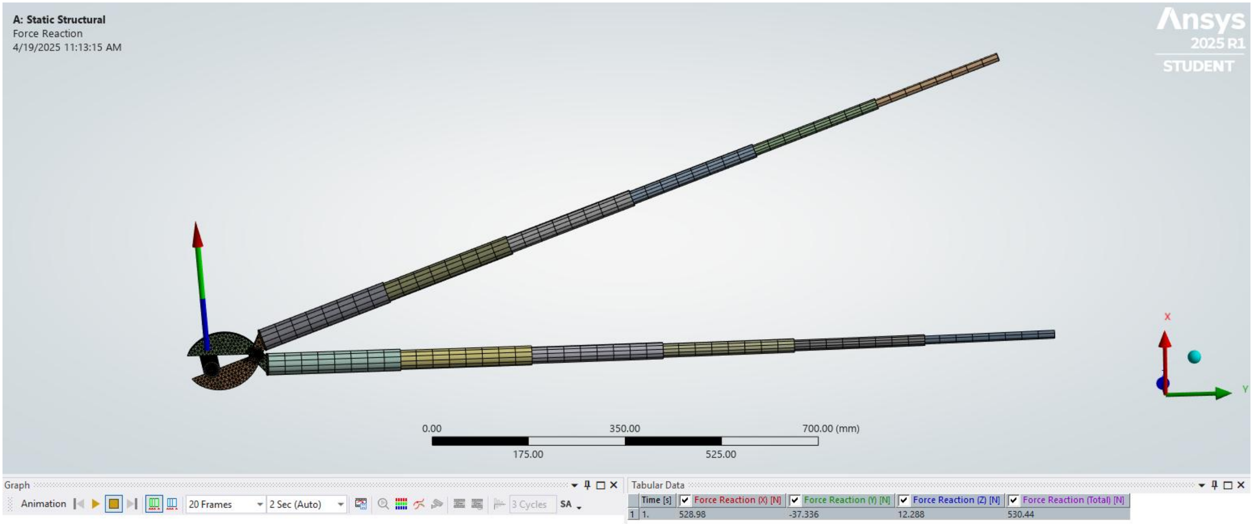
Statistics	
Nodes	57454
Elements	15566

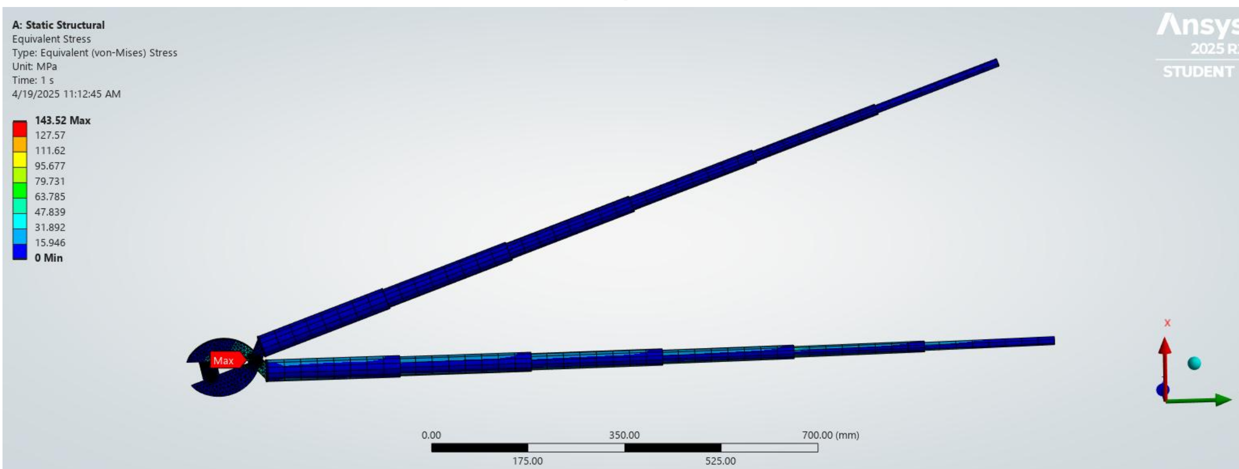


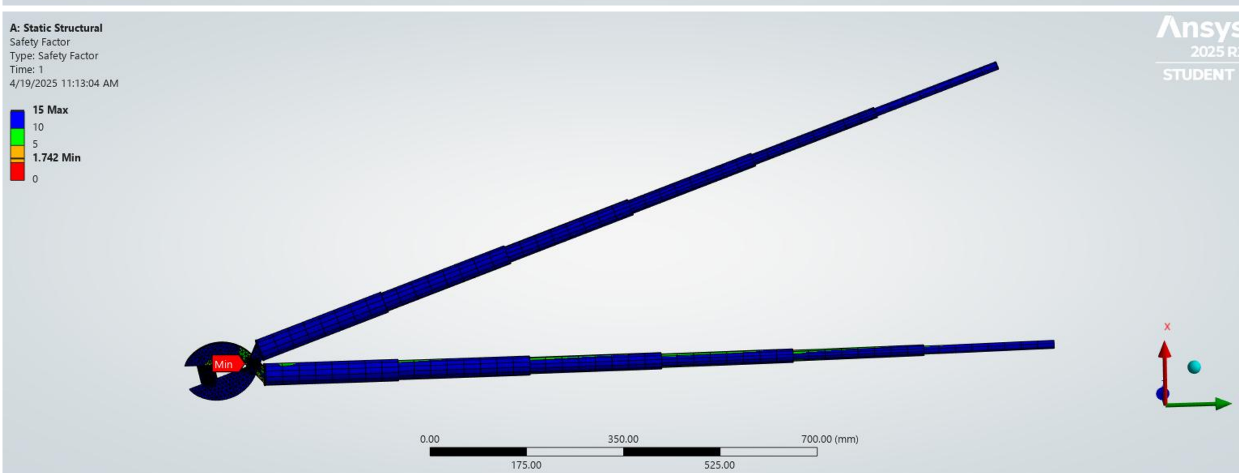
Furthermore, to accurately measure the structural loads and boundary condition reactions, a few boundary conditions need to be applied. First, the copper wire that is between the blades is fixed on one end of the faces. This is to resemble a fixed wire being cut and measure the force reaction at the support. To continue, another fixed support is applied to the top arm of the device. This is to counteract the 45 N that is applied to the bottom arm in the +X direction. Lastly, the pin that acts as a pivot point is constrained in the z-axis to keep it from sliding from between the blades. The setup is picture below.



This model was run with the purpose of validating the hand calculations for the reaction force on the wire, as well as insuring structural stability (no yielding). From the results, there was a reaction force of 530.44 N, which is more than the problem statement required. Furthermore, a max load of 143.5 MPa was applied the structure, which supplied a yield factor of safety of 1.7, meaning the design should not permanently deform or break. Below are the results.


A: Static Structural
Force Reaction
4/19/2025 11:13:15 AM
Ansys
2025 R1
STUDENT
0.00
350.00
700.00 (mm)
175.00
525.00
Graph
Animation
20 Frames
2 Sec (Auto)
3 Cycles
Tabular Data
Time [s]
Force Reaction (X) [N]
Force Reaction (Y) [N]
Force Reaction (Z) [N]
Force Reaction (Total) [N]
1 1. 528.98 -37.336 12.288 530.44


A: Static Structural
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1 s
4/19/2025 11:12:45 AM
143.52 Max
127.57
111.62
95.677
79.731
63.785
47.839
31.892
15.946
0 Min
Max
Ansys
2025 R1
STUDENT
0.00
350.00
700.00 (mm)
175.00
525.00


A: Static Structural
Safety Factor
Type: Safety Factor
Time: 1
4/19/2025 11:13:04 AM
15 Max
10
5
1.742 Min
0
Min
Ansys
2025 R1
STUDENT
0.00
350.00
700.00 (mm)
175.00
525.00

Material Cost & Weight Estimation:

As previously mentioned, all components of the cutting tool were made of structural steel, which resulted in a total mass of 6.2906 kg, which can be seen below in the table. However, this mass includes the copper cable being cut, and so after subtracting the mass of the cable, the mass of the tool is 5.404 kg. At an estimated cost of $1.10 per kg for cold-rolled coil structural steel, the price of the cutting tool would be approximately $5.95 [1].

Coordinate System: Global Coordinate System | Show Individual and Summary

Entity	Volume (mm^3)	Mass (kg)	Centroid X(mm)	Centroid Y(mm)	Centroid Z(mm)	Nodes	Elements	Body	Type
16 Bodies, Summary	7.9528e+005	6.2906	120.38	574.55	-21.534	57454	15566		
Body 1	70572	0.55399	109.27	250.52	-30.	732	96	PLIERS-HANDLES-ASSEMBLY|PLIERS-HANDLE-PT1|Solid	Solid
Body 2	61163	0.48013	190.76	474.4	-30.	732	96	PLIERS-HANDLES-ASSEMBLY|PLIERS-HANDLE-PT2|Solid	Solid
Body 3	51753	0.40626	272.25	698.28	-30.	732	96	PLIERS-HANDLES-ASSEMBLY|PLIERS-HANDLES-PT3|Solid	Solid
Body 4	42706	0.33524	353.73	922.16	-30.	732	96	PLIERS-HANDLES-ASSEMBLY|PLIERS-HANDLES-PT4|Solid	Solid
Body 5	32944	0.25861	434.98	1145.4	-30.	732	96	PLIERS-HANDLES-ASSEMBLY|PLIERS-HANDLES-PT5|Solid	Solid
Body 6	41894	0.32887	515.63	1367.	-30.	270	40	PLIERS-HANDLES-ASSEMBLY|PLIERS-HANDLES-PT6|Solid	Solid
Body 7	70572	0.55399	20.	266.26	-20.	732	96	PLIERS-HANDLES-ASSEMBLY|PLIERS-HANDLE-PT1|Solid	Solid
Body 8	61163	0.48013	20.	504.51	-20.	732	96	PLIERS-HANDLES-ASSEMBLY|PLIERS-HANDLE-PT2|Solid	Solid
Body 9	51753	0.40626	20.	742.76	-20.	732	96	PLIERS-HANDLES-ASSEMBLY|PLIERS-HANDLES-PT3|Solid	Solid

Extra Credit:

When examining stress distribution, there are several areas that can be seen on the tool which are not experiencing large loads. Additionally, the tool has a minimum factor of safety of 1.742 which is more than enough for a simple cutting tool. In an effort to minimize the cost and weight of the cutting tool, various other materials will be considered to find the best design. The first alternative considered will be stainless steel. After applying stainless steel to all components except for the wire being cut, the resulting maximum stress is 143.33 MPa with an associated minimum factor of safety of 1.4442, which confirms that this design should not experience any yielding. Additionally, by applying stainless steel, the new mass of the tool is 5.343 kg. Using the given costs of $2.7/kg from HW #7 assignment, the new price of the tool using stainless steel is $14.43. Overall, stainless steel decreased the mass of the tool but nearly doubled the cost, indicating that this is not likely the best alternative.

The next material option examined was aluminum alloy, which resulted in a total mass of 1.9097 kg. Using the provided cost from HW #7 at $1.8/kg, the cost for the aluminum alloy tool is $3.44. Furthermore, it is interesting to note that the aluminum alloy increased the minimum factor of safety to 1.9702 compared to the original minimum factor of safety of 1.742 when using structural steel. The resulting maximum stress is 142.12 MPa. These results provide confidence that the structure will not experience any yielding since the factor of safety is much greater than 1. The resulting force reaction also increased to 612.66N compared to the original 530.44N, which suggests that the structure can be reduced while still achieving the required 500N force.

The final material considered is magnesium alloy, which resulted in a total mass of 1.241 kg. At a cost of $2.12/kg, the price of the cutting tool with magnesium alloy is $2.63 [2]. This material resulted in a minimum factor of safety of 1.377 and an associated maximum stress of 140.16 MPa. Finally, the generated force reaction is 648.98 N, which confirms that the size of this tool can be further reduced, allowing for less material and less cost all while meeting the design requirements.

	Structural Steel	Stainless Steel	Aluminum Alloy	**Magnesium Alloy**
Total Cost ($)	5.95	14.43	3.44	2.63
Mass (kg)	5.404	5.343	1.9097	1.241
Minimum F.S.	1.742	1.442	1.742	1.377
Force Reaction (N)	530.44	533.53	612.66	648.98

Overall, the best material based on the above analysis should be magnesium alloy as this results in the lowest cost and mass. The tool is desired to have minimum mass in this case since it is designed to be used in space, where the greatest constraint is weight. Because the magnesium alloy generates a much larger force reaction than the required 500N, the tool can be further simplified so that it becomes more compact, lighter, and cheaper, all of which are desirable. Alternatively, the design can remain unchanged, and the force required to generate the 500 N force reaction can be minimized. Specifically, the force can be decreased to 35N, which generates a 504.7N force reaction. Additionally, the lowered force results in a new minimum factor of safety of 1.7631 with an associated maximum stress of 109.47 MPa. Overall, decreasing the required force on the handles makes the tool easier to use, which is more desirable for customers.

References

[1] Corporation, I. T. and S., "The State of Steel March 2025," Available: https://www.industrialtube.com/blog/2025/03/21/the-state-of-steel-march-2025.

[2] "Magnesium alloy AZ91D fob price today: Historical price charts of magnesium alloy AZ91D fob - shanghai metal market," *Magnesium Alloy AZ91D FOB price today | Historical price charts of Magnesium Alloy AZ91D FOB - Shanghai Metal Market* Available: https://www.metal.com/en/prices/202111190001.

<u>Francesca Afruni</u>

- Initial hand calculations
- CAD Models
- CAD Drawings

<u>Elizabeth Beraducci</u>

- Extra Credit
- Helped with initial design/CAD assembly

<u>Kyle Kinkade</u>

- CAD Assembly
- ANSYS Analysis (Non-Extra Credit)

Signed: *Francesca Afruni, Elizabeth Beraducci, Kyle Kinkade*

Email: fafruni2021@my.fit.edu, eberaducci2022@my.fit.edu, kkinkade2021@my.fit.edu