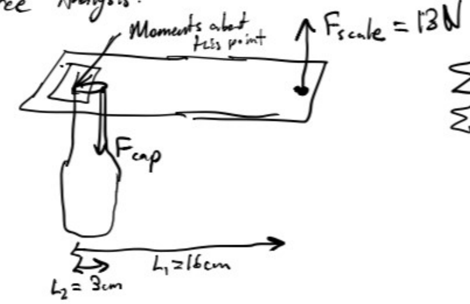
The main objective of this project was to create an adaptive design of a bottle opener that appropriately fits the needs and wants of the user. The project aimed to answer the problem statement of how one can design a bottle opener so that it is customized to the user's wants all the while making sure that the needs of the users are met, including the functionality of the bottle opener and the design constraints. This type of design is adaptive as bottle openers were pre-existing and my main objective was to make a miniscule advancement in the design of bottle openers by placing the user at the center of design, or in other words, human centered design. My human centered research process involved interviewing my user, Paula Rodriguez-Vilaboa, and asking a series of targeted questions – also known as survey – in order to fully understand the desires of my user. For the requirements/constraints of the project, the following were listed: there was a material constraint of a maximum volume of 15,000 meters cubed, a geometry constraint for the bottle opener shape of having the capability of being properly measure by a force meter, and finally having a feasible way to 3D, meaning that at least one side of the bottle opener should be flat. Another miscellaneous constraint was in the inability to choose a specific color for the bottle opener.

In terms of how my priorities inter-related, the biggest priority was for the bottle opener to not experience stress failure and buckling failure which in turn affected the priority of the size of the bottle opener my user wanted. Furthermore, the priority of keeping within the maximum volume also affected the size of the bottle opener as I had to be aware of the material constraint of the design project. This meant that the most important performance metrics were the cross-sectional area of the bottle opener being applied to the cap to determine the stress and the force required to remove the cap, or the buckling force. These metrics of stress and buckling force would then need to be compared by the ultimate tensile strength and the critical buckling force to determine whether or not my bottle opener will experience stress failure or buckling failure. Using these metrics, I was able to determine whether my bottle opener would be successful or not, but in determining further success, I defined success for my design on the degree of how much the user was satisfied with the result and the degree to which my final design met the needs and wants of my user. The following math analysis shows the stress considerations that were made and the moment balance:

Math Analysis:

Force Analysis:



$\sum F = 0$

$\sum M = 0$

$$\sum M_{reference} = 0 = F_{scale} \cdot L_1 - F_{cap} \cdot L_2$$

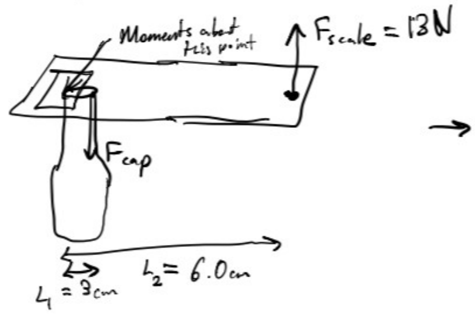
$$F_{cap.} = \frac{F_{scale} \cdot L_1}{L_2}$$

$$F_{cap} = \frac{13N \cdot 16cm}{3cm}$$

$$\boxed{F_{cap} = 69.33\ldots N}$$

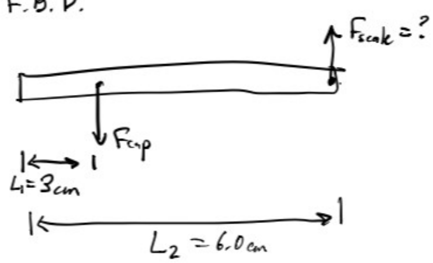
Find F_{scale} for my prototype:

$$F_{cap.} = 69.33\ldots N$$



→

F.B.D.



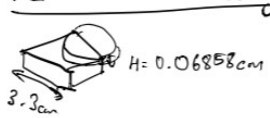
$$\Sigma M = 0 \quad \Rightarrow \quad \sum M_o = 0 = F_{scale} \cdot L_2 - F_{cap} \cdot L_1$$

$$F_{scale} = \frac{F_{cap} \cdot L_1}{L_2}$$

$$F_{scale} = \frac{(69.33\ldots N)(3cm)}{6.0\,cm}$$

$$\boxed{\therefore F_{scale} = 34.66\ldots N}$$

For Stress Analysis:



$$\frac{F_{cap}}{A} < \sigma$$

Thickness of cap:

$H = 0.06858\text{cm}$

$l = 3.3\text{cm}$

Cross-Section Area:

Approximate as rectangle with the thickness of cap (H) & Horizontal length of the opening (l):

$$A = l \cdot H = (3.3\text{cm})(0.06858\text{cm})$$

$$\therefore A = 0.2263\ldots\text{cm}^2$$

$$\text{Stress} = \frac{F_{cap}}{A} = \frac{69.33\ldots\text{N}}{0.2263\ldots\text{cm}^2} = \underline{306.359\ldots\text{N/cm}^2}$$

Ultimate Tensile Strength: $35\text{ MPa} \times \frac{100\text{ N/cm}^2}{1\text{ MPa}} = 3500\text{N/cm}^2$

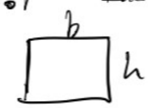
So **Stress on Cap < Ultimate Tensile Strength**

For Buckling:

Critical Buckling Force: $T_B = -\pi^2 \left(\frac{E \cdot I}{L_o^2}\right)$

$E = 3.5\text{ GPa} \times \frac{10^5\text{ N/cm}^2}{1\text{GPa}} = 3.5\times10^5\text{ N/cm}^2$ $\quad L_o = 6.0\text{ cm}$

For Area moment of Inertia:



$$I = \frac{bh^3}{12}$$

Where $h = 0.5\text{cm}$
$b = 4.5\text{ cm}$

$$I = \frac{(4.5\text{cm})(0.5\text{cm})^3}{12}$$

So

$$T_B = -\pi^2 \left(\frac{(3.5\times10^5\text{N/cm}^2)\cdot\left(\frac{(4.5\text{cm})(0.5\text{cm})^3}{12}\right)}{(6.0\text{cm})^2} \right)$$

$$\therefore T_B = -4497.8665 \ldots N$$

$$\boxed{\therefore T_B = -4.5 \times 10^3 \ N}$$

The magnitude of $F_{spring} = \|F_{spring}\| = 11.56 \ N$

The magnitude of $T_B = \|T_B\| = 4.5 \times 10^3 \ N$

So $\boxed{\|F_{spring}\| < \|T_B\|}$

As shown in my math analysis, I am able to say that my design is partly successful as the stress is lower than the ultimate tensile strength and the magnitude of the buckling force is smaller than the critical buckling force, but to determine whether my design is completely successful, I need to further consider whether or not my design fit the needs and wants of my user.

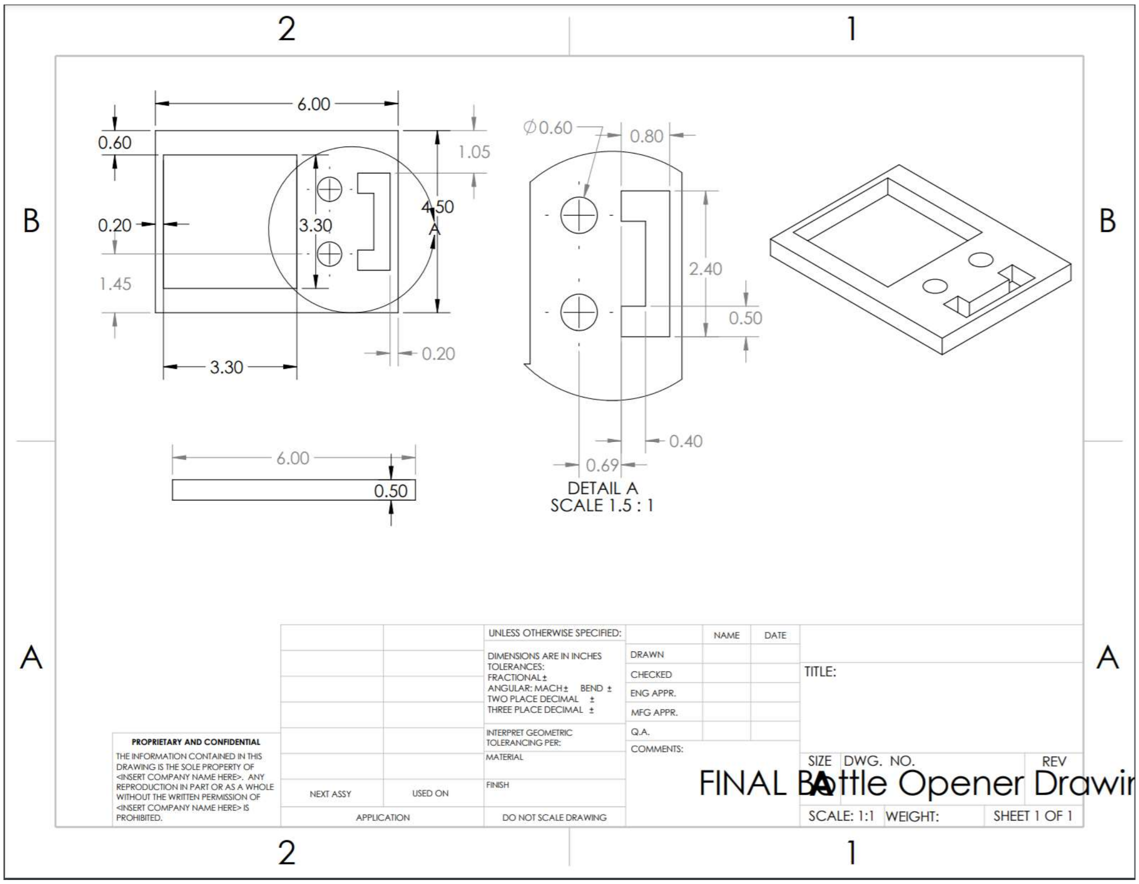
As mentioned before, I used the technique of surveying Paula for my human centered research process and asked her specific questions that would allow me to understand what features of the bottle opener she needed and preferred. For the first question, I asked “Where will you be using the bottle opener” to understand what environment the bottle opener should be tailored towards and got the response of simple “regular bottles, like beer bottle caps.” Moving on, I asked her if she had any specific general designs in mind, such as a classical hole bottle opener or an edge hooked bottle opener, which she responded by saying a “classical hole, flat shape.” Then I asked her if she had any preferences in how big she wants the bottle opener and she replied by saying that she would want a bottle opener that is “not too big but big enough so that it is still works.” Finally, I asked if she would want any custom feature such as an engravement of initials on her bottle opener and she replied by saying that she would want a “smiley face.” This method of surveying Paula then allowed me to come up with five different sketches of bottle openers that all matched her description. My iterative design process started off by drawing several sketches of different possible ideas that match Paula's wants and needs, showing the sketches to my user and seeing if the sketch was what she had in mind or not and which sketches she liked, prototyping the top two sketches using cardboard and techniques such as scoring and layering, re-designing and scaling for CAD and to meet volume requirements, getting final affirmation from user, and finally creating the CAD design on SOLIDWORKS for 3D Printing.

The final design ended up being a rectangular bottle opener with the hole being a square of 3.3cm by 3.3cm and at the other end of the strip, I engraved a smiley face as Paula desired, which ended up more aesthetically pleasing than anticipated as it was reminiscent of a character from the game Minecraft. While the design met all the constraints of the project and met the needs of Paula, it might be too short as the length of the bottle opener ended up becoming only 6.0cm due to material constraint and scaling, which in turn could be a little bit uncomfortable for the user as it might be too short. However, Paula did want a small bottle opener, so I do not see that being a huge issue. When I showed Paula the CAD design for the bottle opener, she said that it was what she had hoped for and that it met her wants as a user.

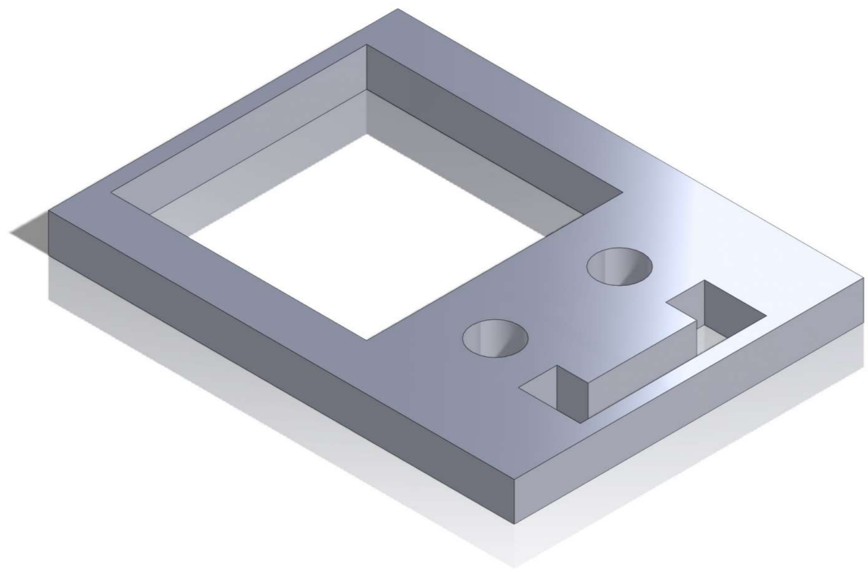
This process of designing a bottle opener with the focus of the user helped me realize the difficulties in making sure that the bottle opener would be functional and not undergo stress or buckling failure, making sure that the bottle opener did not breach any constraints on the project, and most importantly making sure that the bottle opener met the needs of the user. During the sketching and prototype phase of my design process, I did not prioritize keeping my sketch and prototypes within the volume boundaries given, and by the time I got to the CAD process, I had to make significant adjustments to my bottle opener for it to be within the volume boundary. Hence, for iterations, I believe a significant change of approach that will be beneficial is keeping the volume boundaries in mind, all the while not being too worried about it to the point of constraining creativity, so that it is more convenient for later use during the CAD process.

Appendix:

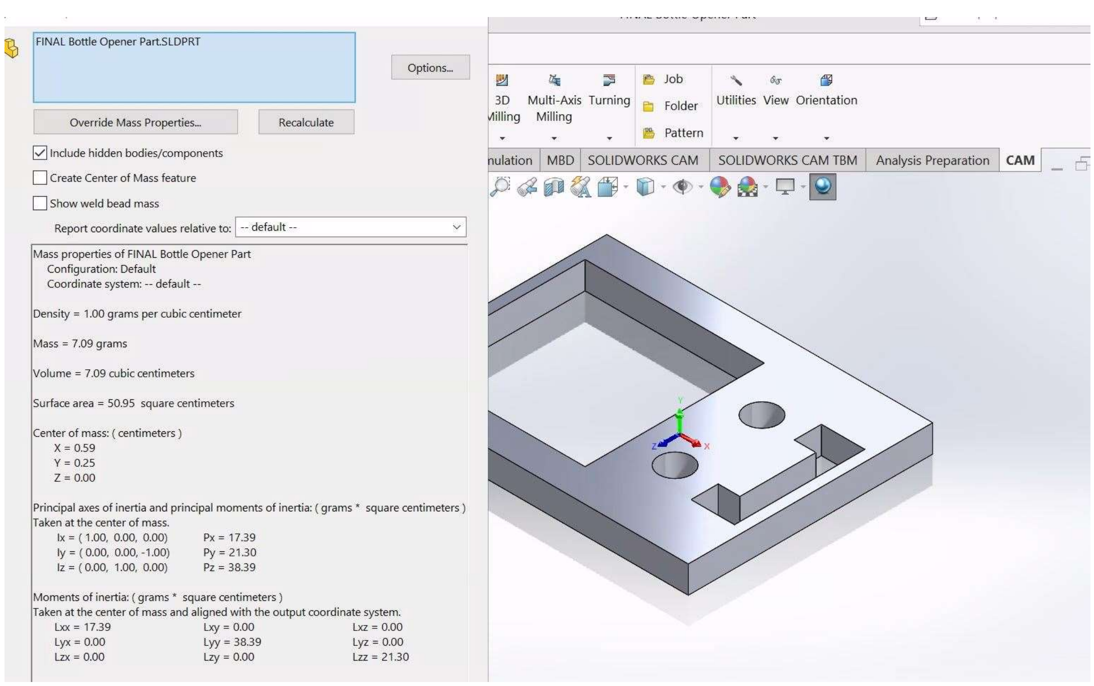
CAD generated Drawing with Dimensions:



Screenshot of CAD Design:

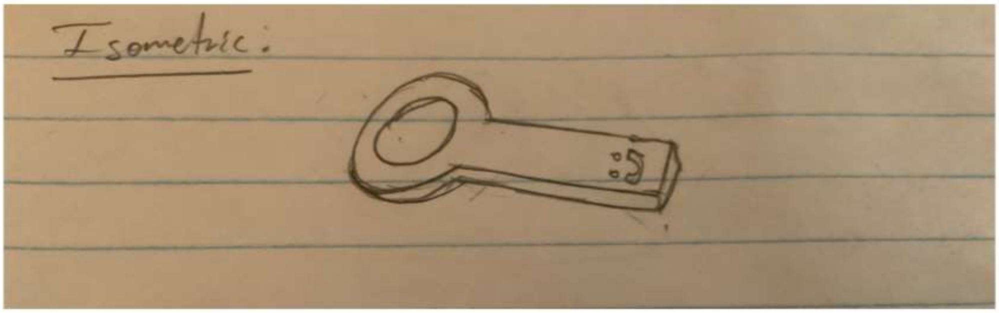


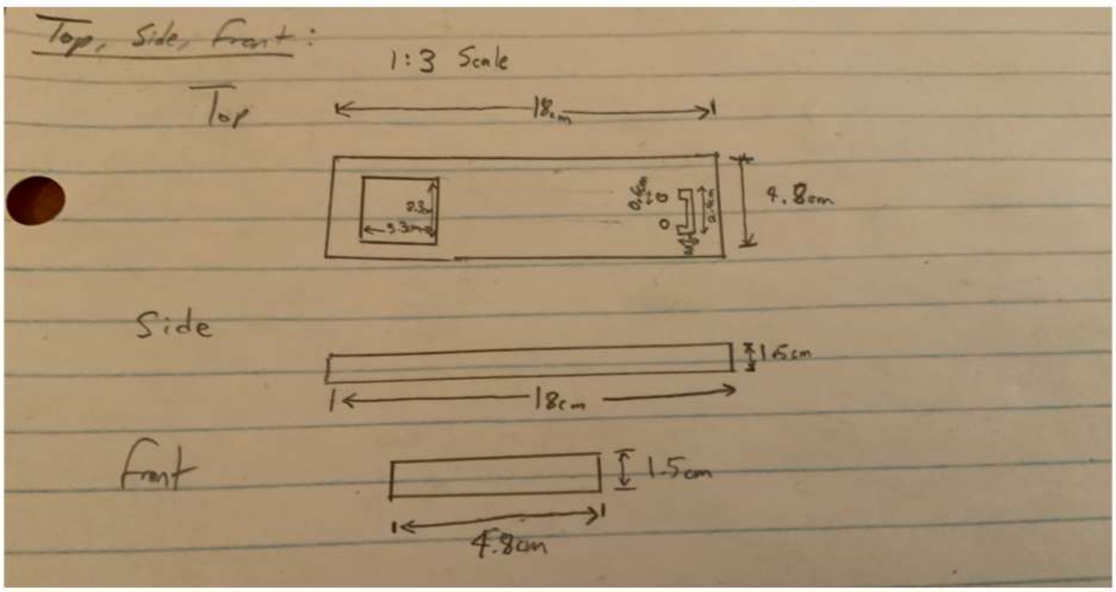
Screenshot of Design Volume:

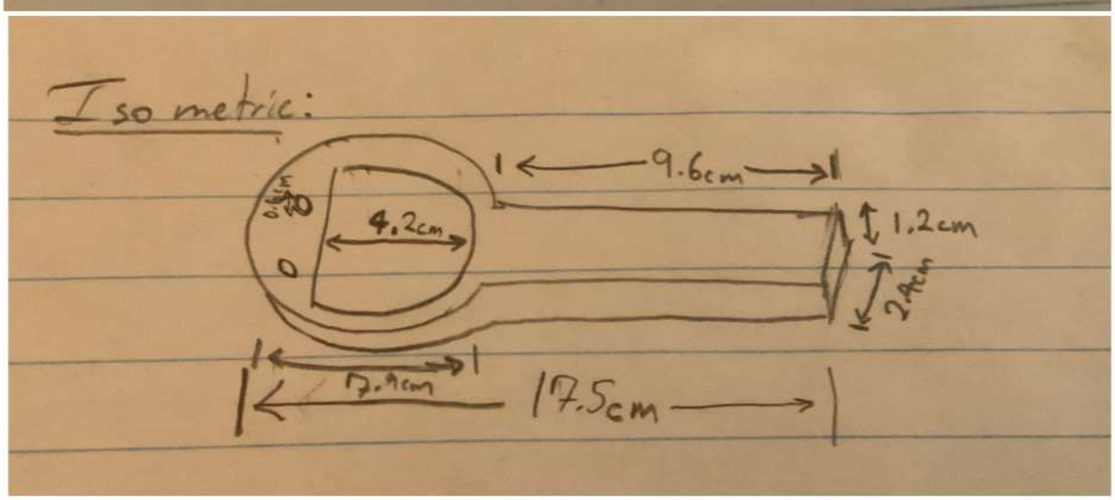


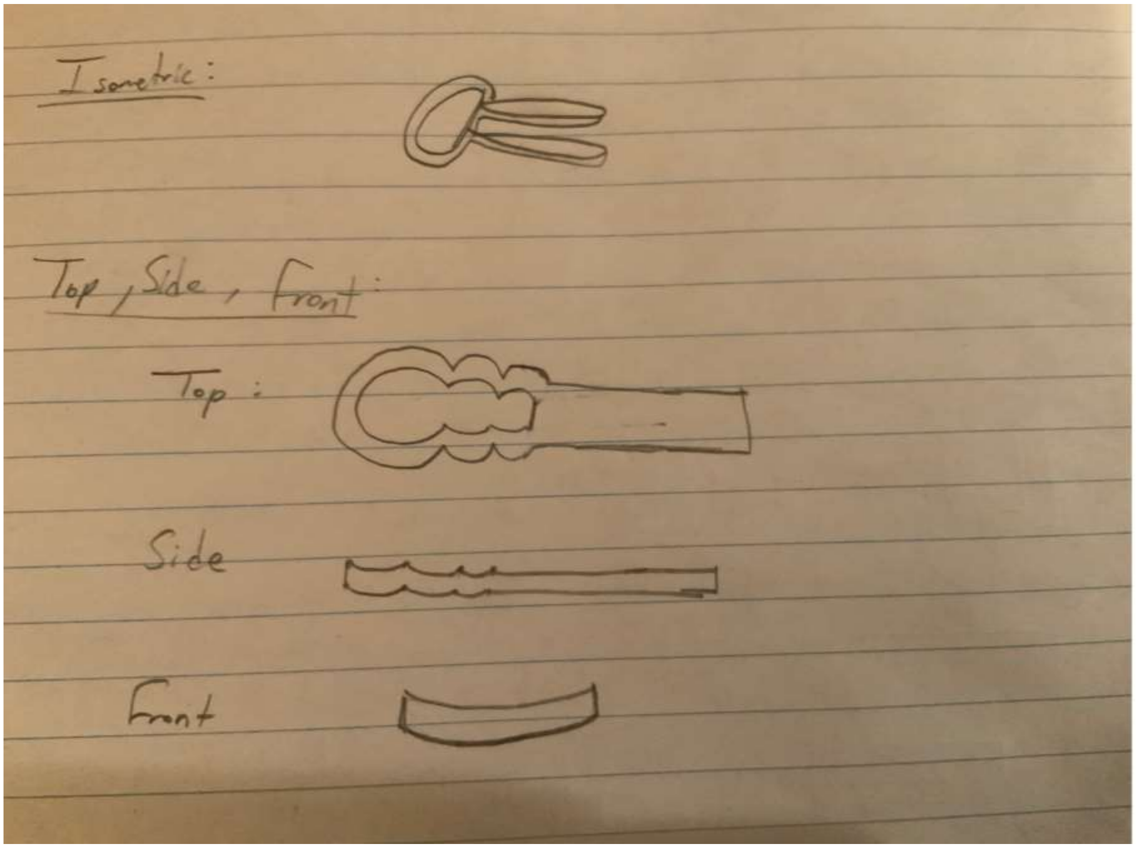
(Volume is 7.09 cubic centimeters which is equivalent to 7090 millimeters cubed which is below 15,000 millimeters cubed)

5 Sketches Image:









2 Images of Physical Prototype: