Final Project Report

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MECH 310: Machine Design

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Problem Statement

The purpose of this project is to design an efficient and user-friendly orange juicer with optimized mechanics and functionality. The juicer mechanism must effectively extract maximum juice with minimal force while accommodating various fruit sizes. Additionally, the integration of a pulp filter requires a manual adjustment system to control pulp content.

The optimal lever height to ensure a snug fit between the fruit and juicer must be determined.

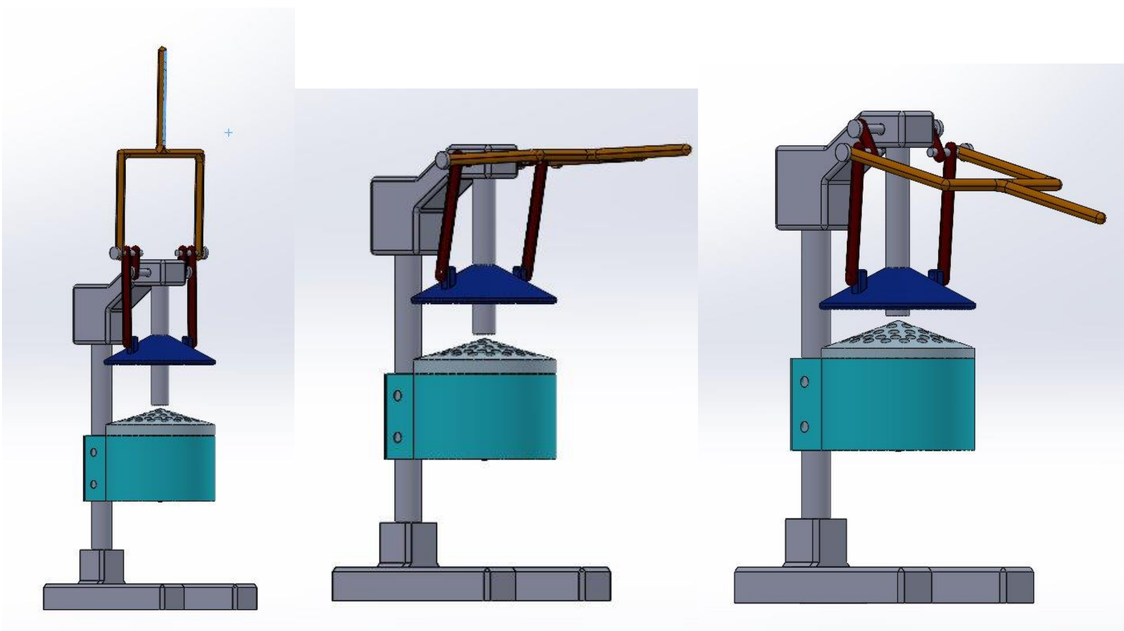
Design Requirements

The following are the design requirements for the project:

- The juicer is for personal or household uses, operated by a single individual.
- The orange must not need to be peeled.
- The pulp contents must be adjustable.
- The juice content must be high yield.
- There must be a high throughput, meaning the output produced must be far higher than the input.
- The mechanism must be easy to clean.
- The pulp must be easy to remove between juicing.
- The machine must accommodate various size oranges.
- The machine must be operated manually, without motors.

Full Design

Figures 1, 2, and 3 depict the final assembly in detail. Starting with Figure 1, the juicer handle is at the upright position and an orange is ready to be placed on top of the juicer cone. The handle can be pressed all the way down and the force applied will squeeze the juice out of the orange.



Figures 1, 2, & 3: Functionality of the juicer assembly

If the user wants to extract the utmost amount of pulp, two hands can be used – one hand pressing down the lever and the other hand rotating the juicer cone. The internal design of the juicer cup was made so that the bearing not only aids in switching the mode of pulp, but also connects to the juicer cone and rotates it.

Base (Jack Michaelis)

Design

The juicer base is based on the design of a chemistry ring stand. The stand's base is 4 inches by 5 inches, which allows it to be extremely balanced and prevents tipping. The material selected for the base was decided to be AISI 1020 Cold Drawn Steel with a yield stress of 3.5e8 N/m^2. Pictured below in Figure 4 is the isometric view of the juicer base with nothing attached.

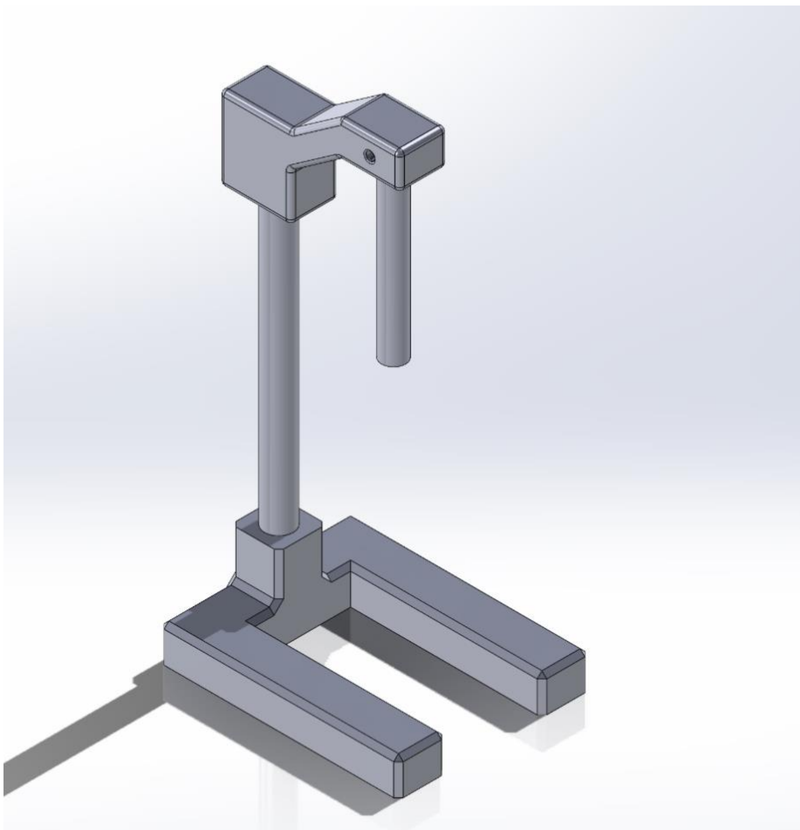


Figure 1: Final Juicer Base Design, Isometric.

Analysis

The juicer stand's safety was ensured through FEA simulation in SolidWorks. Figure 5 below depicts the FEA simulations conducted to ensure the safety of the stand. With a maximum and minimum force respectively 350 Newtons and 200 Newtons. The force was applied to the end of the pin, which was then translated to the center of the pin hole, due to the pin being made rigid. The base of the stand was held fixed and AISI 1020 Cold Drawn Steel was selected as the material.

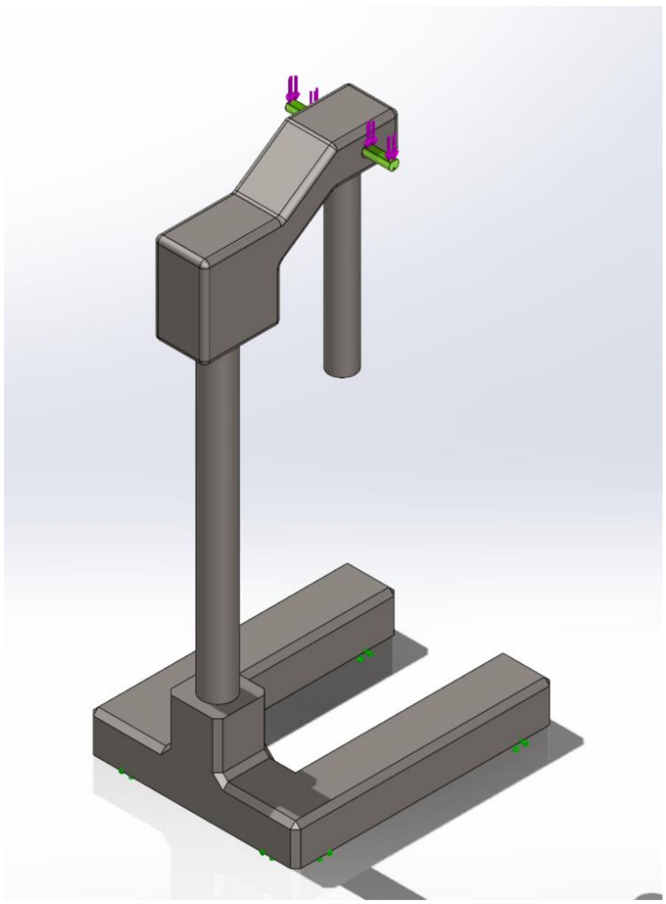


Figure 2: FEA Simulation Forces.

A pin of 2 inches length, with a key insert and two flattened ends, was modeled to focus solely on the stand's strength. The pin was made rigid, which keeps it from moving or bending with the stress, which allows it to transfer the forces to the location we desired. Pictured below in Figure 6, is the drawing of the pin with dimension and a clear view.

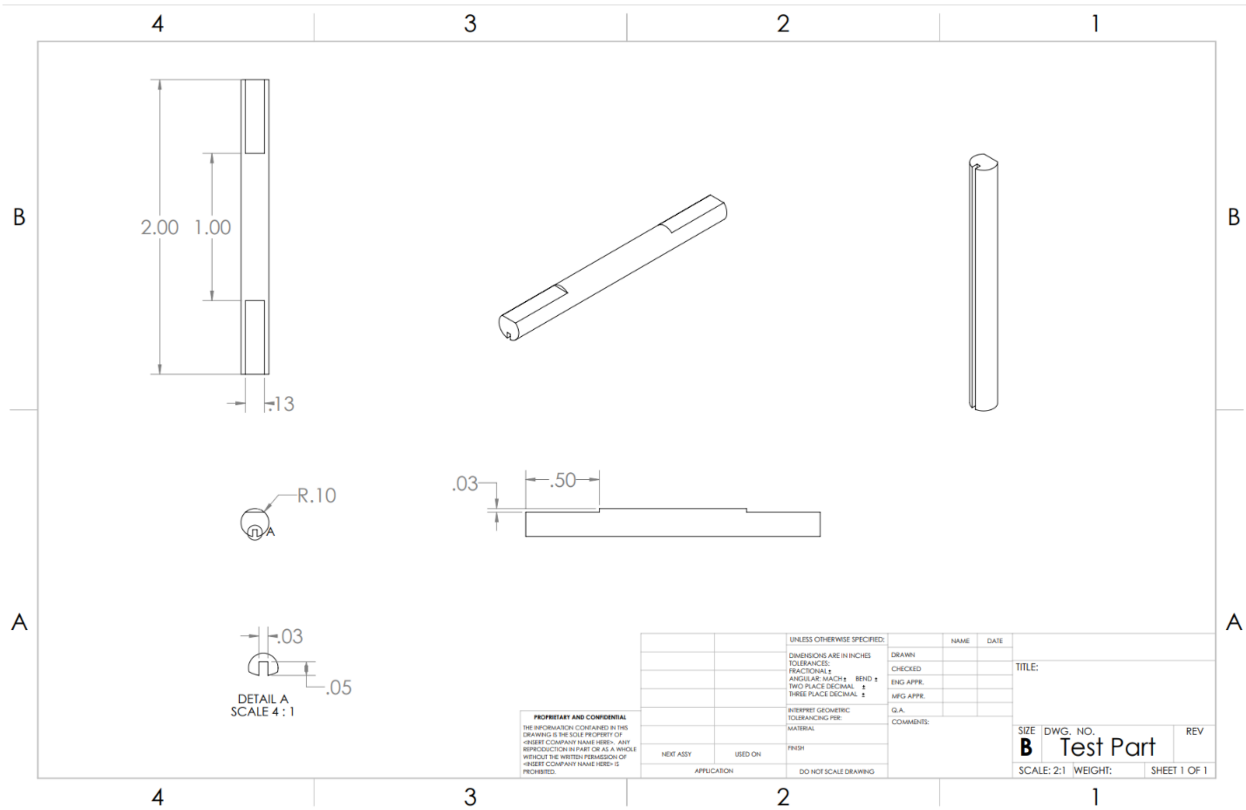


Figure 3: Drawing of Test part.

For the worst case, where the ultimate force is applied to the level. The value of 350N (around 79 lbs.) was chosen as the maximum force a human can exert on a lever. This can be thought of as using your weight to pull or jerk the lever, which is something that is not necessary for squeezing juice. Pictured below in Figure 6, is the Factor of Safety plot for the worst-case scenario with a minimum value of 2.596. This is acceptable as this extremely most likely will never occur. Figure 7 illustrates the displacement of the juicer base, with a max displacement of 2.031 mm (about 0.08 in).

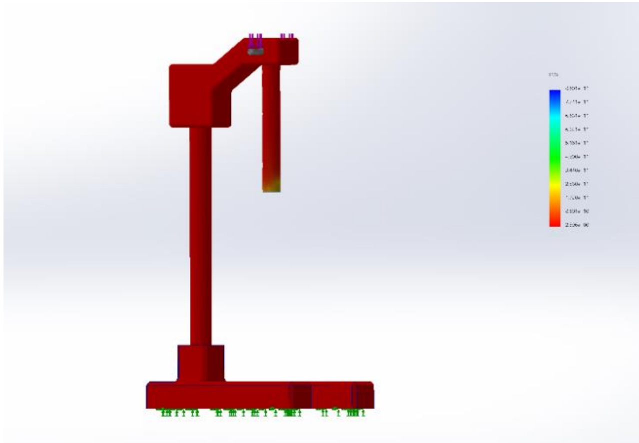


Figure 4: Worst Case (350N) FOS.

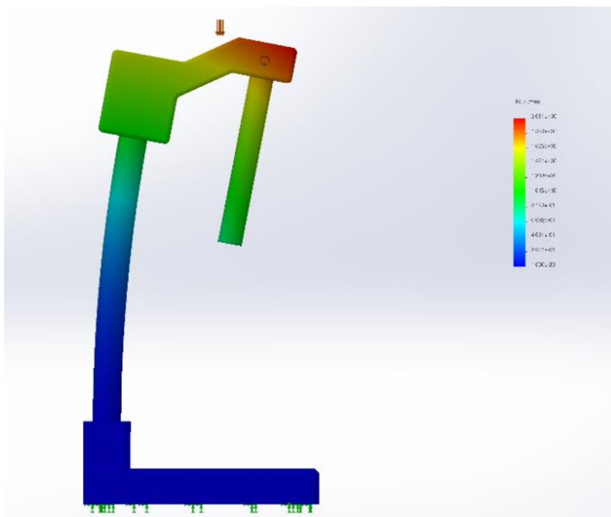


Figure 5: Worst Case (350N) Displacement.

For a more general idea of the forces being exerted on the stand another FEA simulation was conducted under the same condition, however the force was altered to 200N, which is around 45lbs. This is the general force a person with both hands and a little bit of body weight would be able to produce while pulling the lever. This is still a relatively high number for the force applied to the lever, however the results show that the juicer base is stable and safe. Figure 9 shows the Factor of Safety, having a minimum value of 4.546. Figure 10 depicts the displacement of the base when 200 N is applied, with a maximum value of 1.161 mm (about 0.05 in).

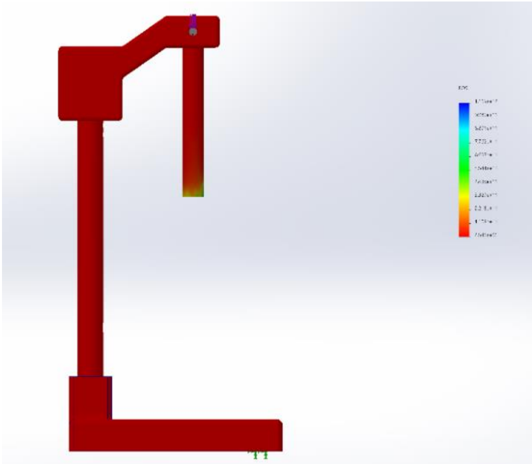


Figure 6: Average (200N) FOS.

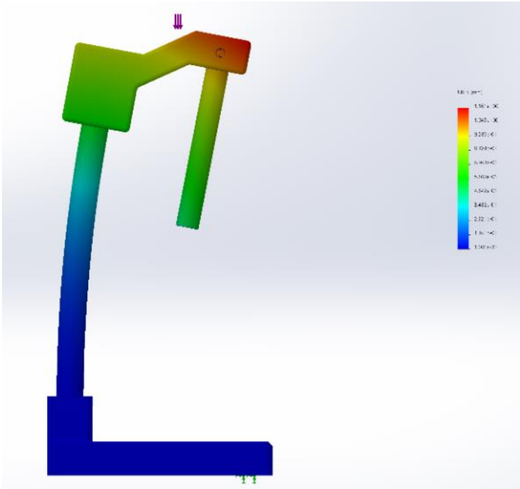


Figure 7:Average (200N) Displacement.

2D Drawings

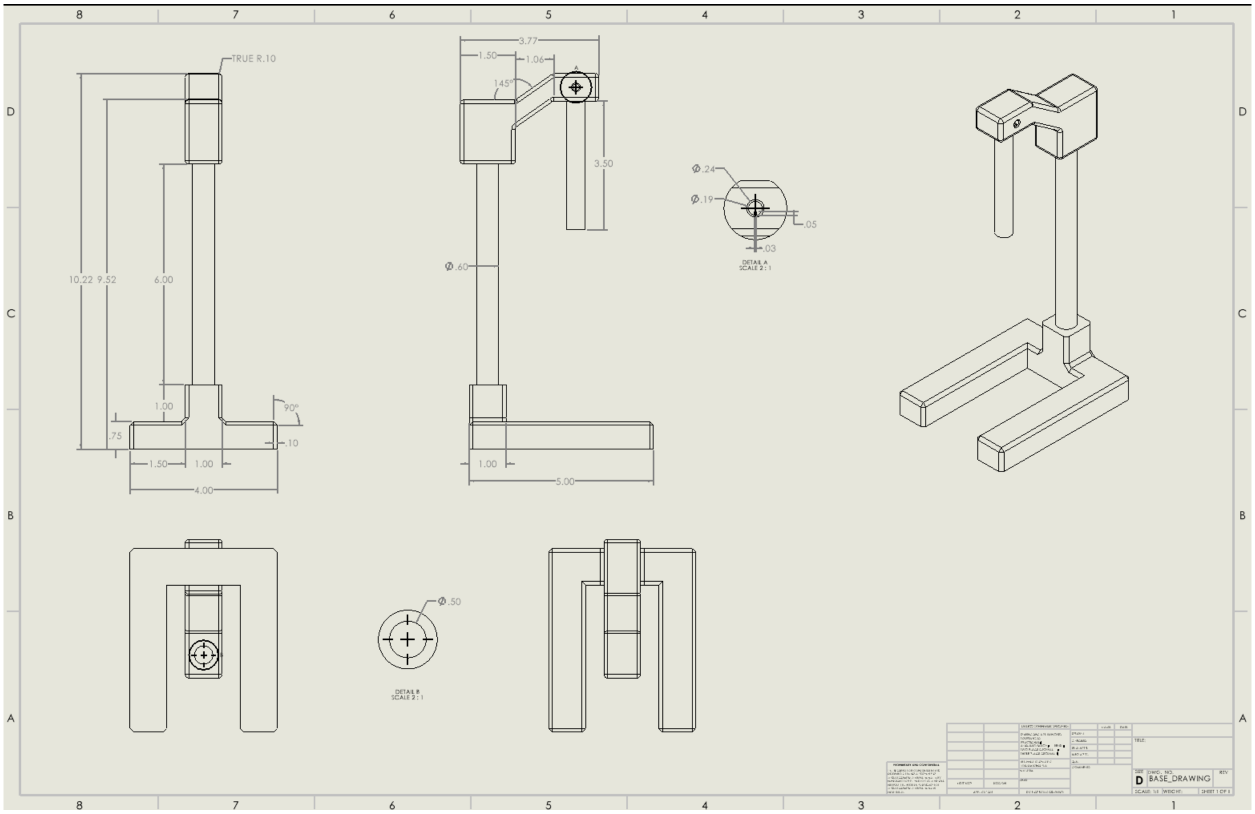


Figure 80: 2D Drawing for the Base.

Arm (Mike Hennessy)

Design

Figure 11 is the full design of the arm, with color coordinated parts.

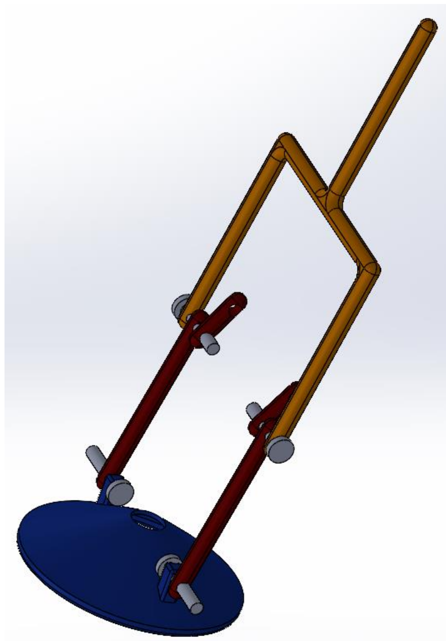


Figure 11: Full assembly of the arm.

Parts

Figures 12, 13, 14, 15, and 16 are separate CAD parts of each part within the arm, coinciding with the same color as the assembly. The top cone and pin are made of stainless steel, and the lever, long connection, and small connection are made of cast iron. These materials were selected based on examples from previous juicers.

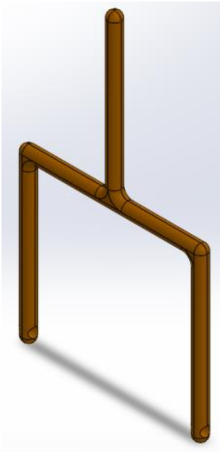


Figure 12: The lever part.

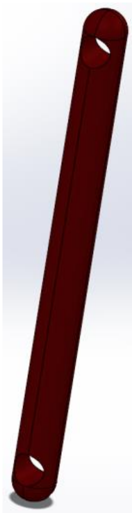


Figure 13: The long connection part.

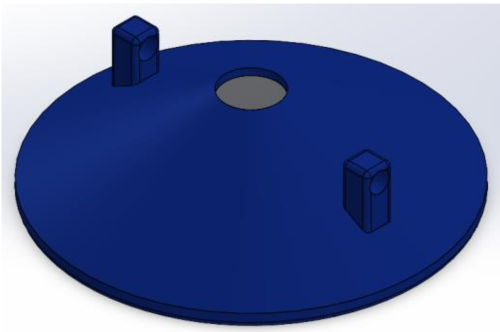


Figure 14: The top cone part.

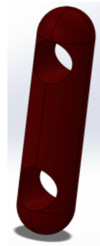


Figure 15: The small connection part.

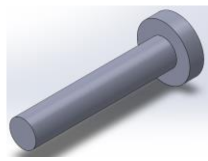


Figure 16: The pin connection part.

2D Drawings

Figures 17, 18, 19, 20, and 21 are 2D drawings of each part, including all dimensions.

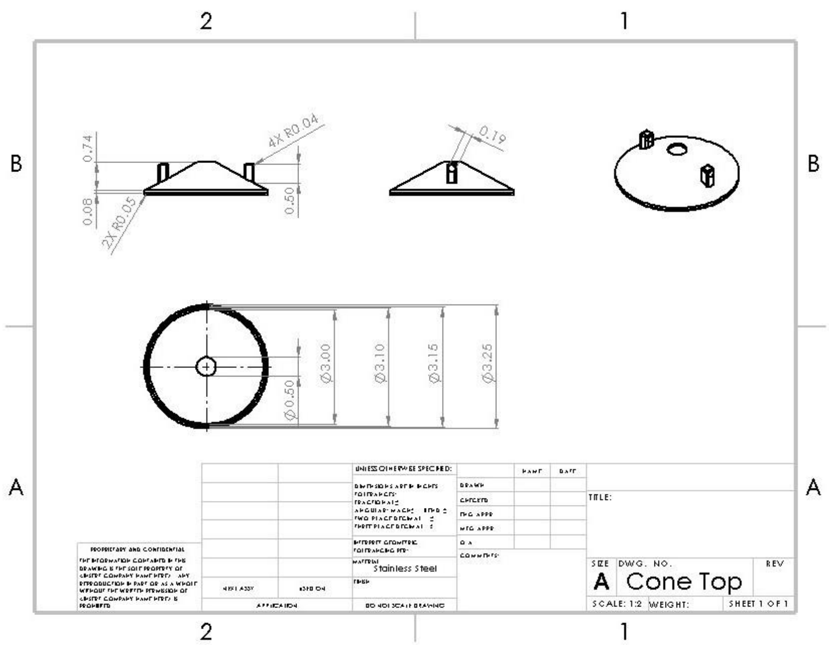


Figure 17: The 2D drawing for the cone top part.

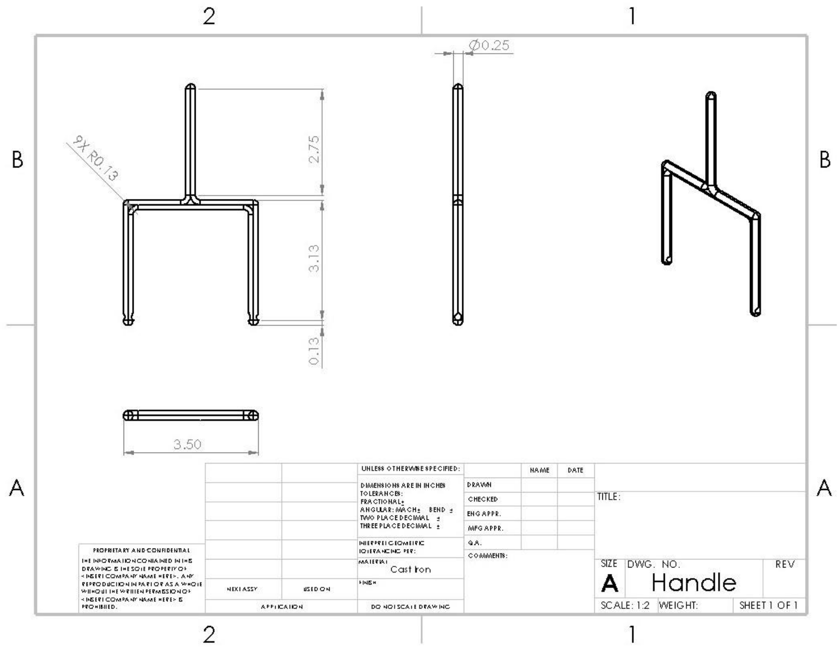


Figure 18: The 2D drawing for the handle part.

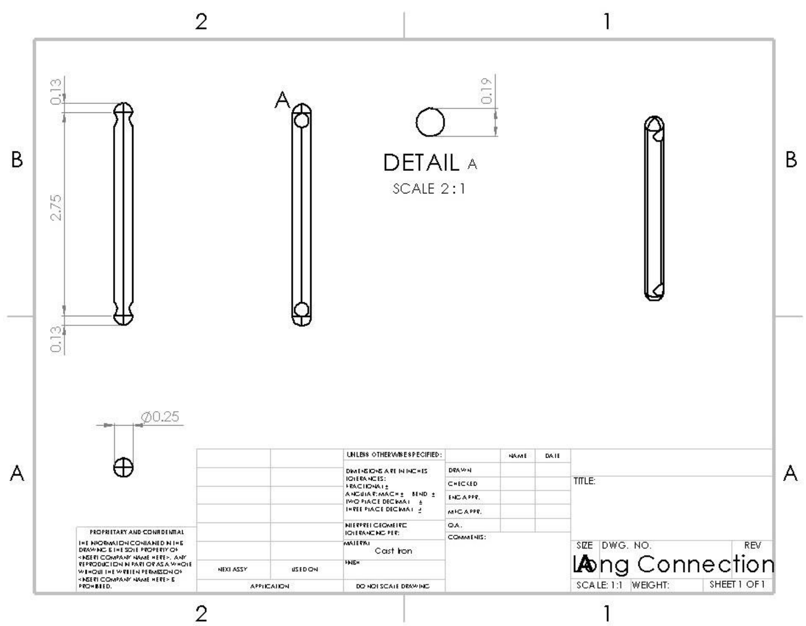


Figure 19: The 2D drawing for the long connection part.

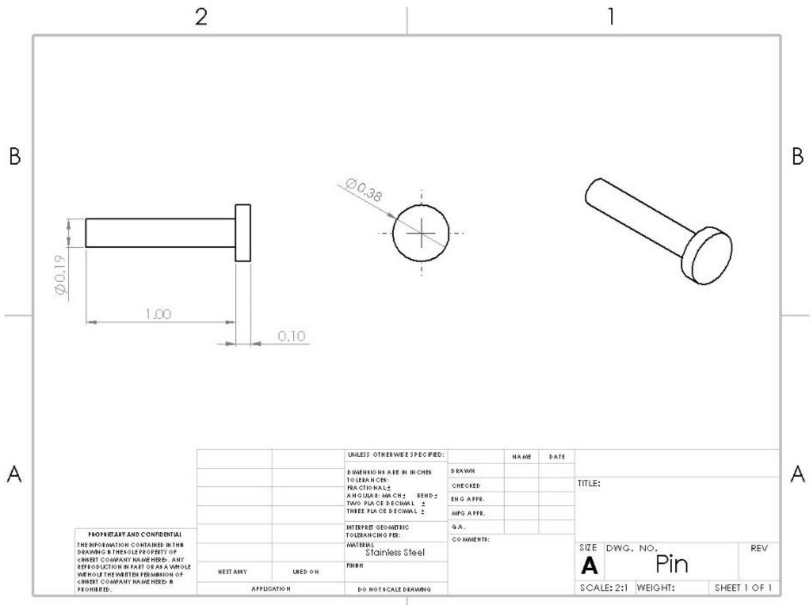


Figure 20: The 2D drawing for the pin part.

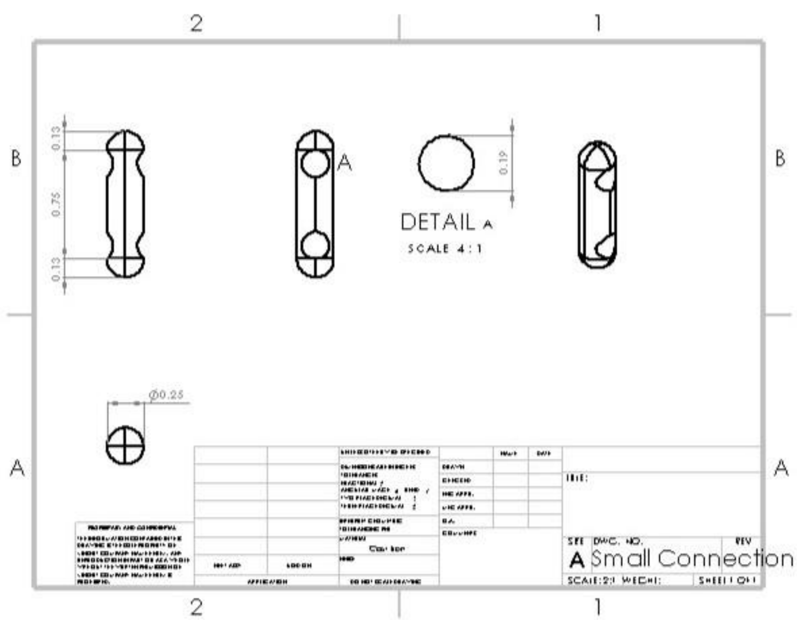


Figure 21: The 2D drawing for the small connection part.

Analysis

A stress test was completed on the entire arm with 9.3 pounds-force placed onto the handle, rotating around the top two pins. The force placed on the entire part is low because the force to squeeze an orange is low and this object mechanism creates a mechanism that uses less force to squeeze the orange than without a machine. The results of the test can be seen in Figure 22. The resulting stresses on each part were low, which can be seen because all the parts are blue. The most stress will be on two of the four pins. These two pins are the ones that are connected to three parts: the lever, long connection, and small connection. Considering the high stress, the pins were made of stainless steels, which are common material for pins in these applications.

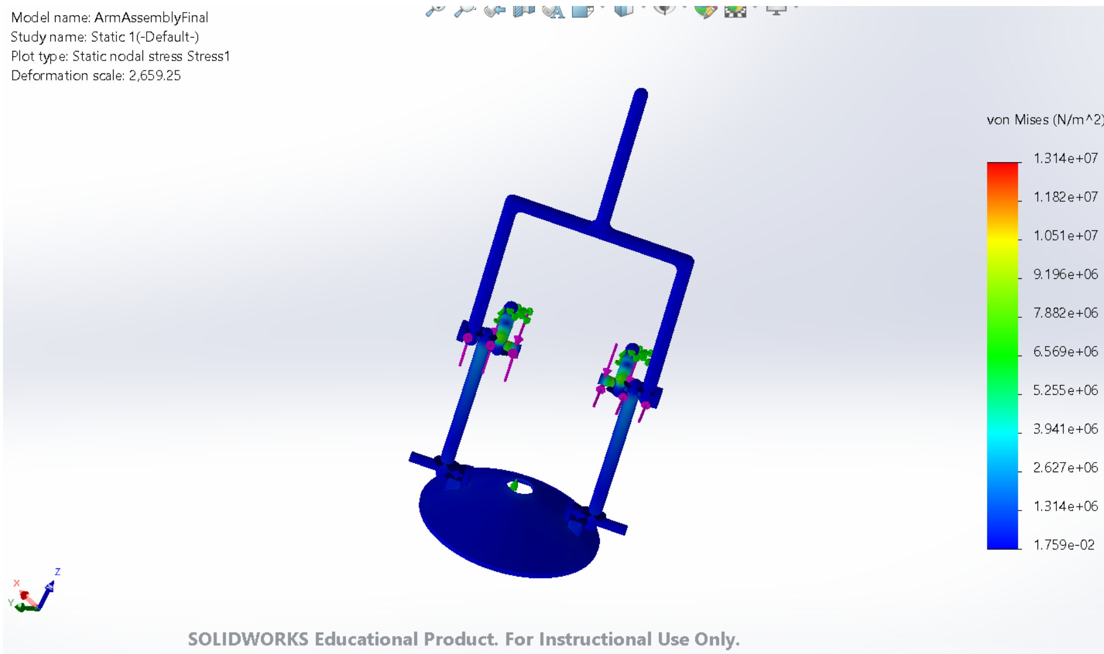


Figure 22: Stress test on the arm assembly with 9.3 lbf torque place on the handle and around the handle's pins.

Cup (Kennedy Necoechea)

Design

The assembly of the juicer cup, the cup that extracts the pulp and juice, is shown in Figure 23.

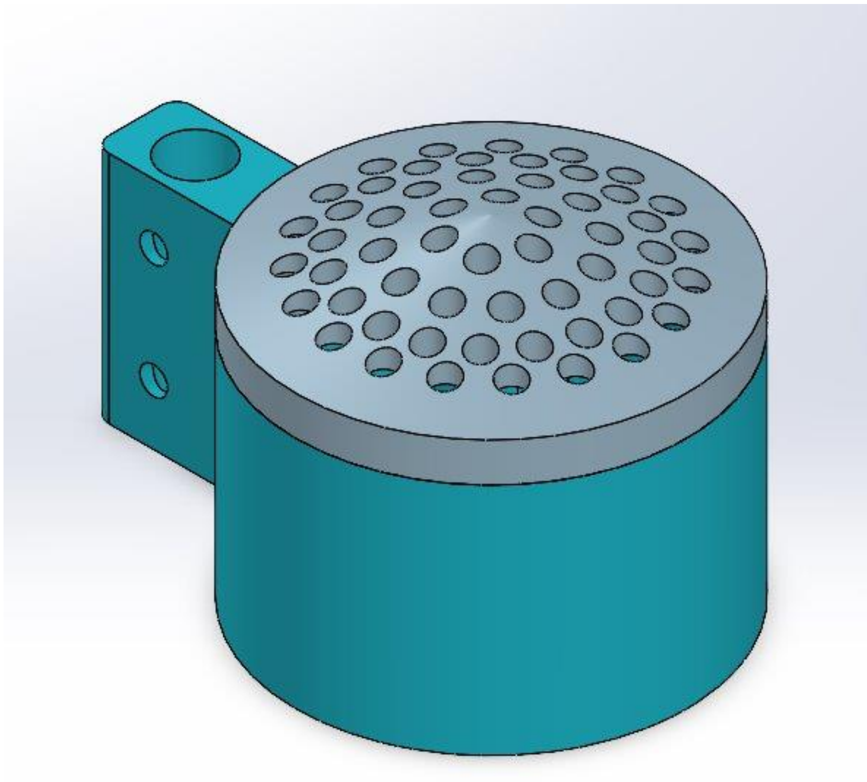


Figure 23: Juicer cup assembly

Parts

The 3 separate parts of the juicer cup are shown in Figures 24, 25, 26. The bottom view of the swivel is shown in Figure 27 for enhanced understanding of how it attaches to the bearing. The juicer cup, cone, and swivel are made of Aluminum 6061 T6. The light duty ball bearing (Figure 28) was found off McMaster Carr, part number 6383K11, and made of stainless steel.

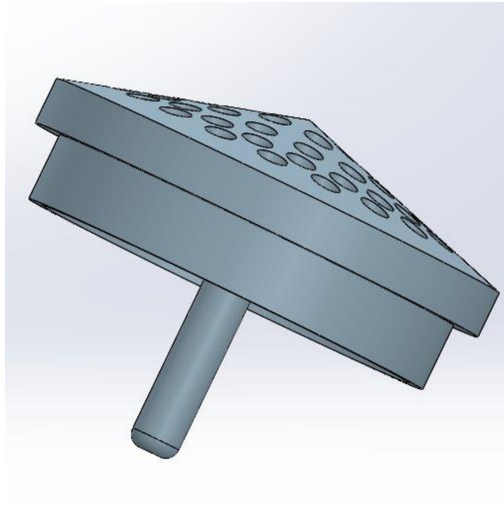


Figure 24: Juicer cone

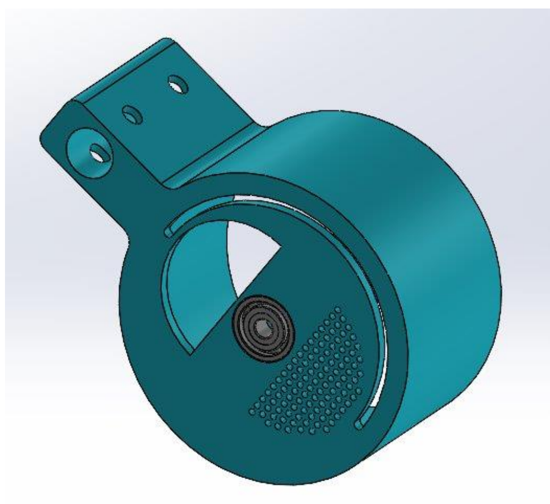
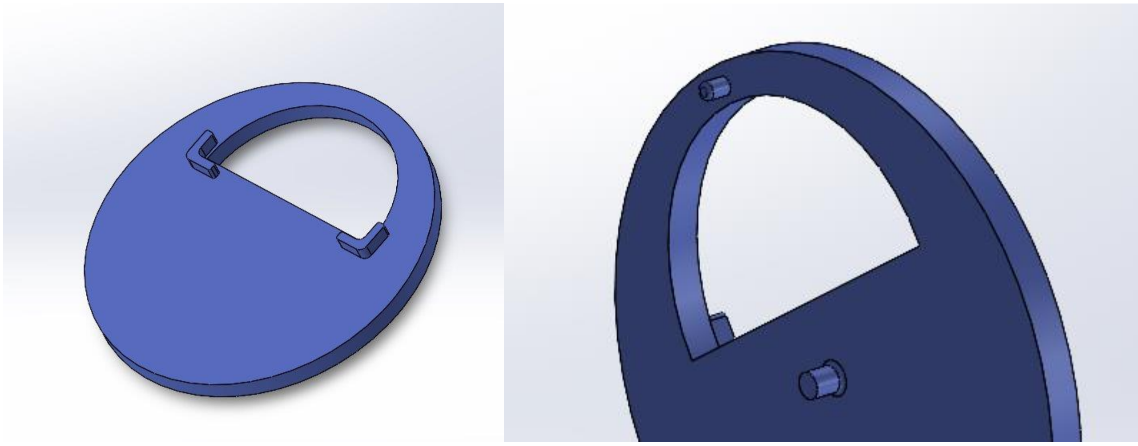


Figure 25: Juicer cup



Figures 26 & 27: Top and bottom views of the swivel

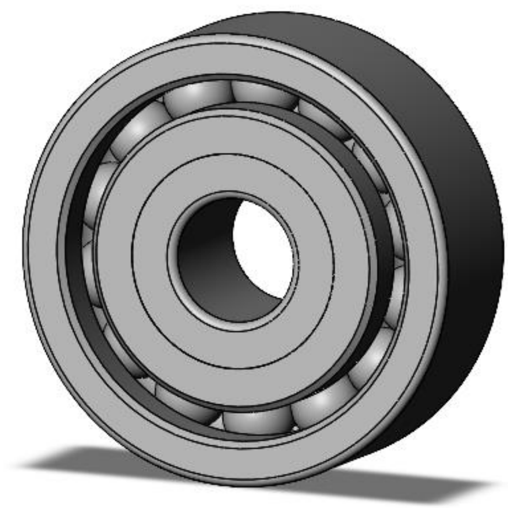


Figure 28: Light duty ball bearing used in juicer cup assembly

A cylindrical registration tab was added to the center of the cup. The cylinder cascading from the top of the juicer cup (Figure 24) registers with the cylinder coming up from the bottom of the juicer cup (Figure 25). The cylindrical fitting has two purposes in the final juicer cup design. Firstly, it will aid as protection around the bearing, so no remnants of juice or pulp can get inside the bearing, defecting its usage. Secondly, it allows the user to spin the top of the juicer cup, to extract more pulp, while pushing down on the lever.

Analysis

Static analysis was completed on the juicer cup to comprehend the stress concentration when a force of 9.3 pounds is applied to the lever. Because the lever transfers force down onto the cup holding the fruit, it is important to focus on the critical points of the cup.

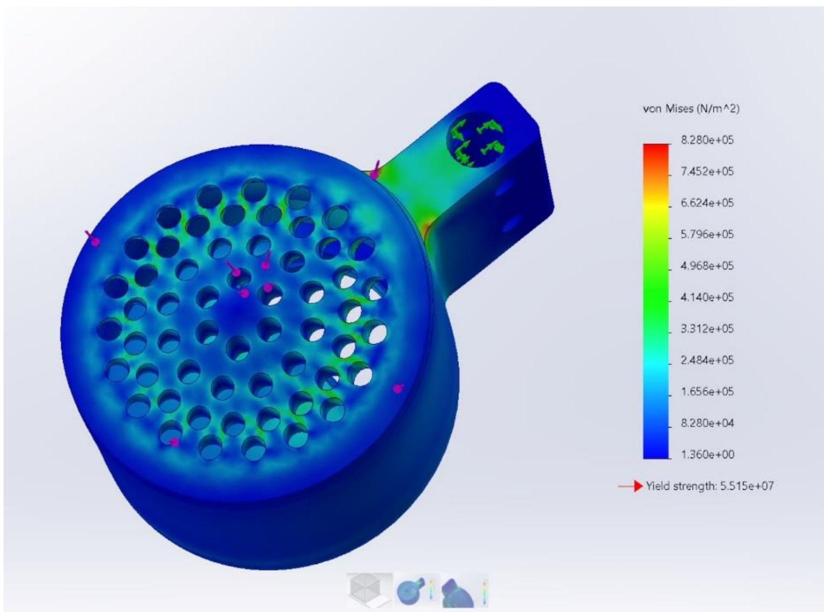


Figure 29: Top view of the static analysis done on the juicer cup

According to Figure 29 and 30, the maximum von Mises stress occurs around the cup's attachment to the handle that slides onto the base of the juicer. The fillets are 0.2 inches and could be largened to 0.25 inches to decrease this maximum stress of 8.28e9 $\frac{N}{m^2}$.

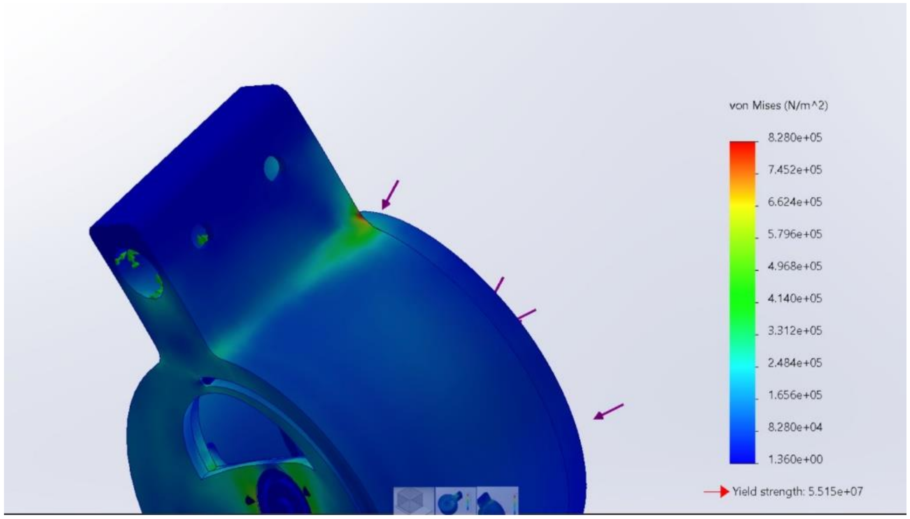


Figure 30: Isometric view of the static analysis done on the juicer cup

2D Drawings

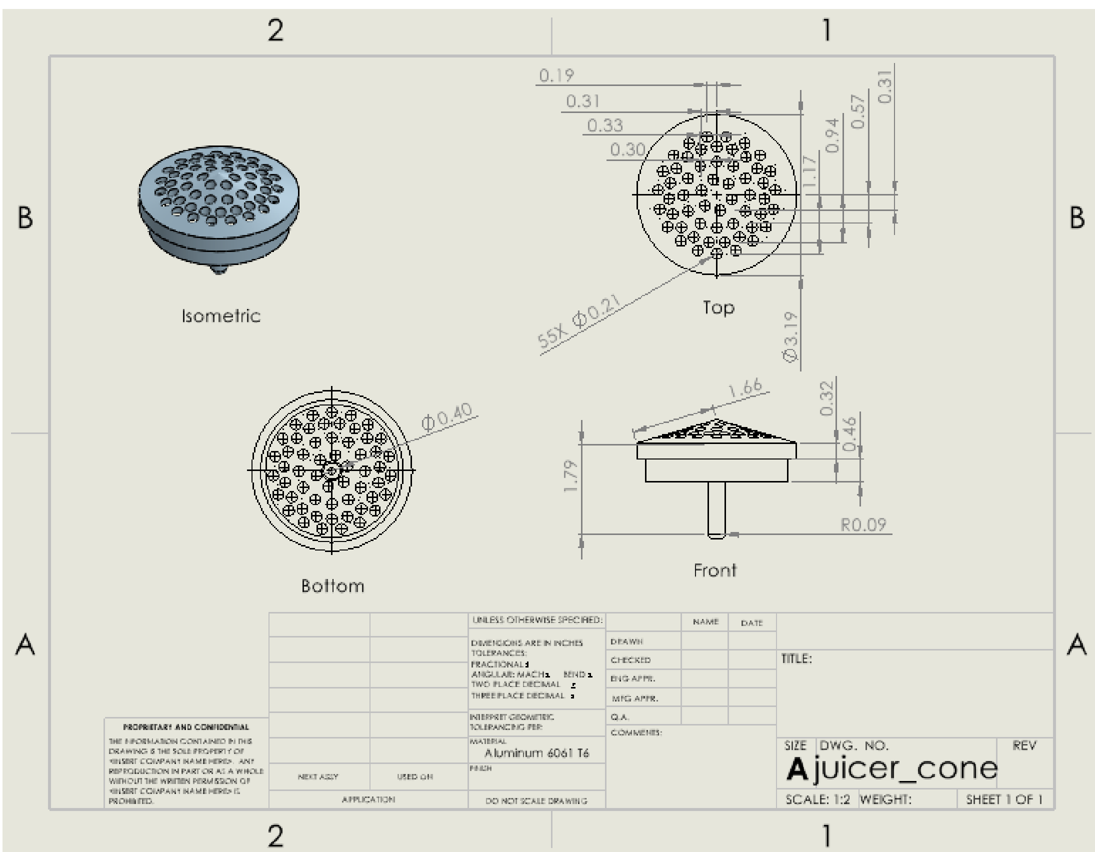


Figure 31: 2D Drawing of the juicer cone

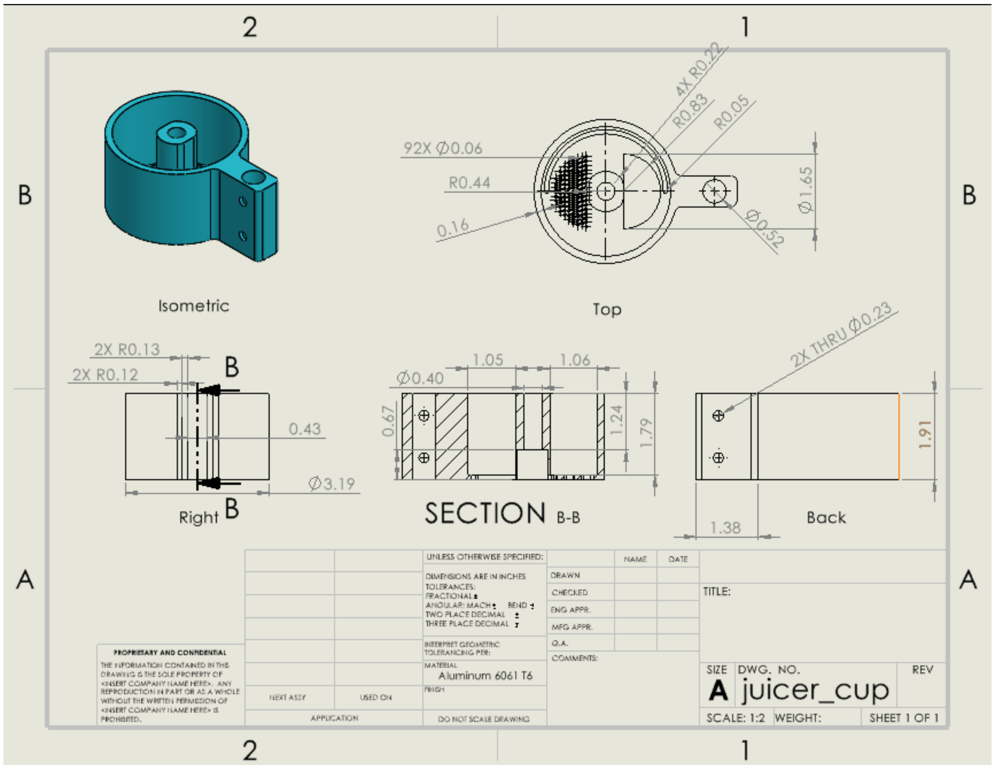


Figure 32: 2D Drawing of the juicer cup

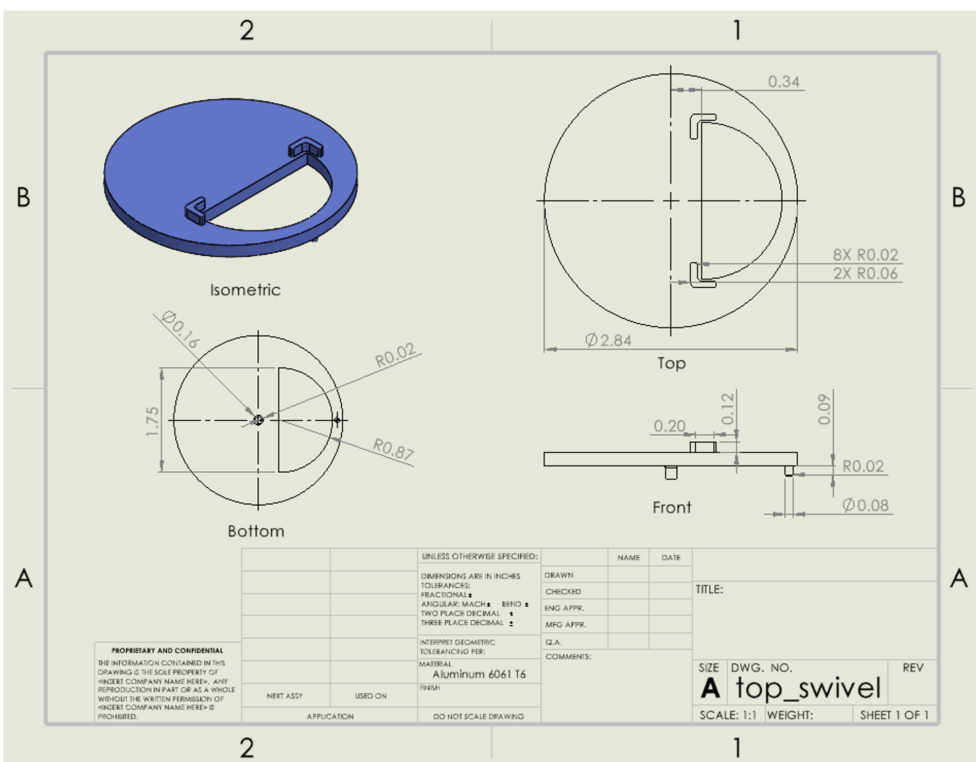


Figure 33: 2D Drawing of the swivel

Potential Design Changes

There are three possible design changes that are feasible and can enhance the juicer. Firstly, an idea that was tested during the second phase of the design was including a helical center axle. The juicer top would spin with this axel when the downward force is applied on the lever. This spin provides more torque on the orange, and therefore can extract more juice with less force while also taking out more pulp. After trying to design this feature, issues were run into with friction, mating, machining, and the possibility of over-engineering. Due to these issues, the feature was scrapped, but with more time for calculations and experiments, adding the feature is feasible.

Secondly, the lever could be modified to provide better torque on the orange. Specifically, increasing the length of the small connection could increase the downward force on the orange, while increasing mobility of the lever. This design change would need a lot of calculations and testing to find what length of each connection is most effective. Increasing the entire length of the lever could also increase torque, but then more stress is on the handle, so it could not be increased enough to where the handle would break.

Lastly, modifying the design so that different sized cones may be switched out could improve the user experience. Currently, the design allows for a variety of orange sizes to be juiced based on the single cone it has and the circular design, but adding different sizes cones could increase this variety of sizes dramatically. Specifically, it could fit fruits as small as grapes and limes, and as large as mangos. Each of these changes have the potential to enhance the design tremendously, decreasing the force needed to juice the fruit and increasing the diversity of juicing items.

Next Steps

The next steps of this project are dependent on the design changes mentioned previously because the implementation of those changes require testing. Firstly, an experiment must be created that tests the effects of rotating the juicer cone to extract more juice. This experiment would prove whether adding the helical center axel makes the product more effective. Based on other designs, the hypothesis is that twisting helps significantly, but it must be tested before finalizing a design change. This experiment would be done manually by placing an orange on a cone and applying a force for five seconds. Then, this activity would be repeated, but for the second trial, the cone must be rotated. After the trials, the volumes of juice and pulp from the experiments would be compared to decide the effectiveness of the twist.

Secondly, to improve the lever mechanism, calculations must be done. Equations must be derived that correlate the dimensions of the lever and its components to the force applied or leverage gained. This could prove which lengths of the parts have the greatest effectiveness and provide the most force on the fruit. The hypothesis is that including a longer “smaller piece” could result in positive effectiveness.

After both the testing of the helical design and the calculations of the lever, these solutions must be implemented. The machining and manufacturing part must follow the calculations and designing.

Conclusions

In conclusion, the comprehensive design journey undertaken for the juicer assembly has yielded a robust and efficient final product. Through meticulous analysis, iterative improvements, and careful consideration of mechanical elements, the juicer has been transformed into a fully functional and advanced machine. The detailed examination of each component, as showcased in Figures 1 to 3 for the assembly, Figures 4 to 7 for the base, Figures 8 to 10 for the arm, and Figures 23 to 33 for the cup, elucidates the thoroughness of our design process. The structural integrity and stability of the juicer stand were ensured through rigorous FEA simulations, as depicted in Figures 5 and 6, providing confidence in its safety and performance. Similarly, stress testing on the arm assembly, as shown in Figure 22, verified its resilience under operational conditions. Additionally, static analysis of the juicer cup highlighted critical stress points, guiding potential design enhancements for optimal performance, as illustrated in Figures 29 and 30.

Exploring potential design changes, such as incorporating a helical center axle, modifying the lever for better torque application, and introducing interchangeable cones, demonstrates our commitment to continuous improvement and innovation. These proposed enhancements aim to further streamline the juicing process, reduce required force, and expand the versatility of the appliance, enhancing user experience.

Moving forward, experimental validation of design modifications and thorough calculations to optimize lever mechanics will be pivotal steps. Implementation of these solutions, guided by rigorous testing and analysis, will culminate in a refined and efficient juicer assembly.

In retrospect, this design endeavor has been a journey of discovery, collaboration, and problem-solving. Each iteration and analysis have contributed to the evolution of the juicer, aligning it more closely with design criteria and user needs. While not every proposed component made its way into the final design, the knowledge gained about mechanical materials and principles has been invaluable. This project underscores the complexity and depth of the design process, showcasing the intricacies involved in engineering a fully functional machine from concept to completion.