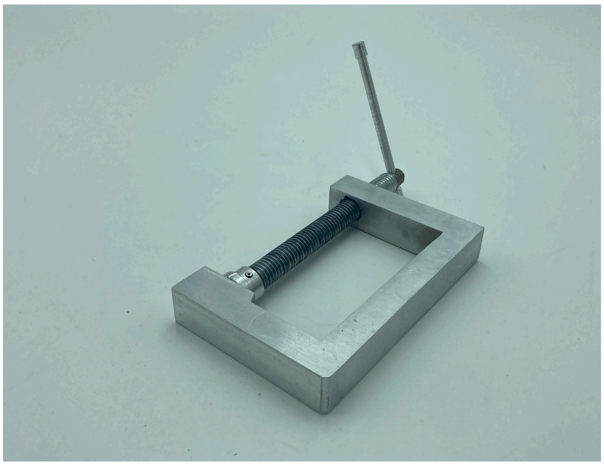
THE UNIVERSITY OF BRITISH COLUMBIA

ENGR 377: MANUFACTURING PROCESSES 2022 Winter Term I

Lab Project Report

Lab Section : L1B
Group Number : B1



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Executive Summary

In the ENGR 377 lab, our objective was to create and build a novel design to experience working in a machine shop and creating documents for work to be done in a shop. Our selected design was a C clamp. The design included six unique parts in total. We encountered problems with the design for attaching our cap to the rod, the waterjet parts, and some errors made while machining. These problems were resolved by keeping our design simple, and creative thinking respectively for each problem. In retrospect, we believe that with more meetings and planning of work to be done, our project could have been more complex and we could have had our design to be more applicable in real life. With proper planning and keeping our design simple, we were able to finish our project within the expected timeline. In future ENGR 377 labs, we believe some introductory videos on how specific machine operations are prepared and carried out could help students to plan their projects more efficiently and with fewer mistakes. Overall, we are proud of the result of our project and have learned about machining operations and communication with machinists.

Introduction

The main objective of this project is to develop a greater understanding of the knowledge of design and model manufacturing process through the manufacture of a product. To collectively design and manufacture a C-clamp successfully under the assigned project specification is the final goal that we have set for ourselves in this project. The design phase of this project necessitates the development of 3D models using Solidworks and accurate engineering drawings. The design of our C-clamp incorporates cylindrical shapes, flats, holes and threads which allows us to engage in a variety of operations, such as turning, milling, drilling, reaming, tapping, and to some extent of preparation of water jet cutting. During the manufacturing process, various machine shop tools and machines must be properly selected and utilized throughout the production of our project. Furthermore, the hands-on lab work in this project also includes the calculation of the machine setting and machine shop safety training.

Methodology/Manufacturing Procedures

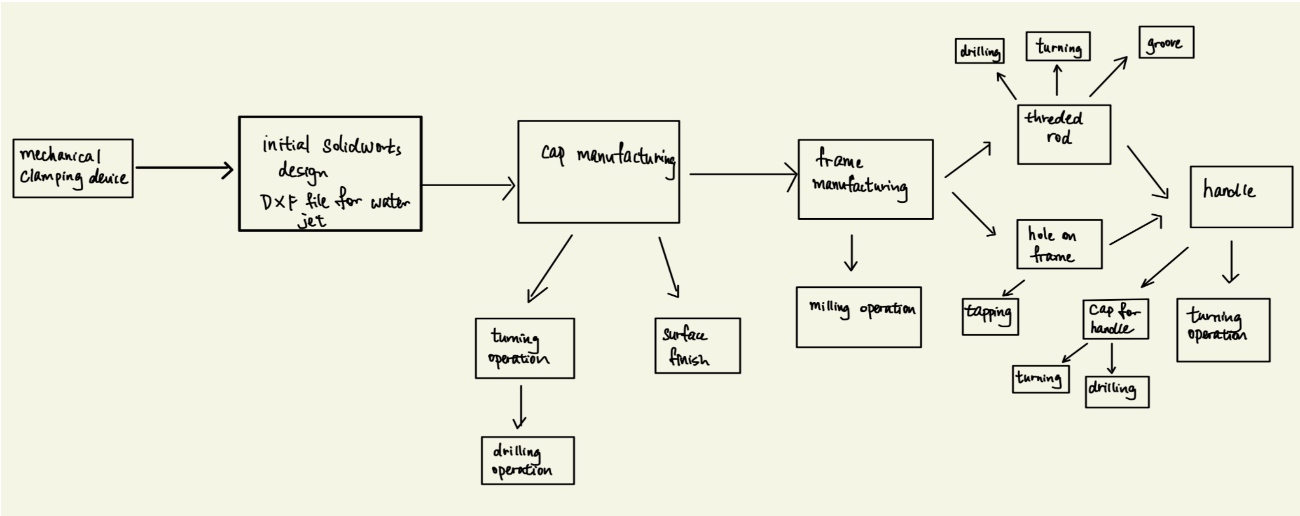

Figure 1.0. Flow chart for manufacturing process

This design is expected to be accomplished within four sessions of labs. The project started with initializing a SolidWorks design, as well as a 2D engineering hand drawing, in the first session. After the SolidWorks design was confirmed with TA and discussed the approximate methodologies as a whole idea, we started with making the swivel for the handle first as it did not require any water jet cutting. The machine we used to finish this section was the lathe machine, and all members were involved in this process. We chose an aluminum rod that has a thickness of around 1.0 in for stock material, which would eventually be turned down to 0.75 in. TA demonstrated to us how to tighten the rod on the chunk and showed us how to use the distance calculator to cut to the desired distance. To turn the diameter of the rod from 1.0 to 0.75 in, the process was done slowly, taking 0.02 in. round by round, to make sure the friction was not interfering too much and the texture was smooth at the end. We also checked if the diameter was turned to the correct number using the calliper several times during turning. After turning the outer diameter to 0.75 in., we then moved on to turn the smaller diameter to 0.6 in. using the same method. To continue manufacturing the swivel, we used the lathe machine to do a drilling operation to drill the hole within the swivel. Before the drilling operation started, we ensured the drilling was at the center by using a center drill bit, which gave a chamfer on the hole and made it easier for afterwards drilling. The drilling operation was also done slowly, taking small inches round by round, to make sure the diameter values were kept on track. The inner diameter of the swivel was drilled to 0.414 in., and the depth was 0.315 in.. The final step for this swivel was to cut the length to 0.5 in. using a saw machine. After the length and all the diameters are finalized and satisfied, we then bring the swivel to the sand grinder machine for aluminum to smooth out the texture.

The frame manufacturing was done during our second session when the water jet was ready. We used a face milling operation to complete the surface finish for the outer surface area of the frame. To accomplish this part, we considered that the drilling machine would be the best choice to use. Before the operation started, we ensured the frame was tightened on the work table by making sure the bars used to level up the frame did not leave any gaps between the work table and the frame. This could also prevent unwanted vibrations during the operation. The speed for this milling operation was slow as we did not intend to cut any specific parts off. All members were involved in this operation.

In our third session, group members were divided into two, Lars and Ellie worked on the threaded rod, and Gurkirat and Owen worked on creating the hole in the frame in order for the threaded rod to go through. In terms of the threaded rod, one end was designed to make a groove on, which a pin with proper size could be used to stabilize the swivel and threaded rod together, and the other end of the threaded rod was designed to turn into a smaller diameter for drilling to easily proceed. Before all the manufacturing went on with the threaded rod, we first made sure the length was cut down to around 6.0 in., which was greater than the critically designed value, to allow extra length in case of any mistakes happened. This was performed using a metal cutting band saw machine. To work on the end for a designated smaller diameter, as often, we used the center drill bit first to ensure the operations were aimed at the center. Then we took off some material on the outer surface of the threaded rod to prevent any uneven surface after being turned. We started to take off the diameter until the diameter of one end reached 0.34 in., and the depth of the turning reached 0.35in. This turning operation was performed on a lathe machine. The hole made on this end of the threaded rod was performed on a drilling machine. The diameter of the hole was calculated based on the diameter of the handle. The value was finalized to be 0.2031 in., which was expected to be slightly smaller than the diameter of the handle so that the handle would not have much movement when in use. This was performed using a 13/64 drill bit, which was the closest and slightly smaller value of the drill bit to the required diameter of the handle. To make the groove on the other end of the threaded rod, the diameter of the groove was first calculated to make sure this value was at least two times greater than the pin size that would eventually go through the groove area, to minimize any stress development on the groove. The diameter was finalized to be 0.3 in. The groove was turned from the back to the front to ensure no extra material was cut accidentally. The groove was finished as the diameter reached 0.3 in. and the distance cut was measured to be 1.0 in. Groove manufacturing was also performed on the lathe machine.

During the third session, Owen and Gurkirat worked on the tapping operation on the frame for the threaded rod to go in. This was performed on a drilling machine. To start with the drilling, the manufacturing side of the frame body was secured and mounted on the work table. The frame was double-checked to be stabilized. We first used the center drill bit to make a chamfer for centring and countersinking. Then a smaller size of drill bit was chosen to continue boring to improve the surface finish and better tolerance on diameter. In the final round, we used a tap for tapping the texture on the frame. All speeds used in operations were according to the tables in Machinery's handbook. Due to friction and unmatch in sizing of the threaded rod and the tapping area on the frame, we added a chamfer on the threaded rod and put on lubricant on the opening of the tapping area on the frame. We were successful in screwing the threaded rod into the frame body. At the end of the third session, with a little amount of time left, we performed a drilling operation on the swivel and on the groove. The diameter of the pin was measured to be 0.1075 in., so the holes on the swivel and the groove were designed to be smaller than this value. With calculated distances, 0.1075 in. from the top side, and 0.315 in. from the left side, the hole's location was decided on the swivel and drilled using the smallest possible drill pit. The same process of operations is performed on the groove.

In the last session, operations on the handle were performed, as well as pinning the threaded rod and the swivel together. The operations on the handle were finished by Lars and Ellie, while Owen and Gurkirat were in charge of looking for the proper material and determining the tool used for making the cap for the handle. The length of the handle was determined to be around 3.5 in. and was cut using the saw machine. The handle was mounted on the chuck and centred. The diameter of the handle was then cut to 0.22 in. as previously designed while leaving a distance of 0.24 in. as a cap for one end of the handle. We have decided to do a press fit between the cap and the other end of the handle, due to the consideration of its small geometry that the stress developed in this interference would not affect much on its structure and function. Owen and Gurkirat have tested out the proper tool for making the cap for the other end of the handle using a test rod. Different sizes of drill bits with diameters smaller than 0.22 in. were used to drill holes on the test rod, with the smallest one used first, then tried out with bigger ones until we discovered the size of the drilled hole the handle could fit into. In the end, we performed the same drilling operation on the 0.26 in. diameter rod for making the cap. We used a file tool to smoothen the surface of the cap. After that, we pushed the handle through the frame and used a hammer to press-fit the handle and the cap together. We performed the same press-fit operation for connecting the swivel and the threaded rod together using the pin. At last, deburring and angle filing using a fine filing were done to remove sharp edges and finishes, to make sure every surface of the design is smooth and fine. The whole design was then completed.

Manufacturing Challenges

Milling the top and bottom surfaces of the C-clamp was a challenge. At first, we assumed the surface could be milled like the other surfaces. But due to the long geometry of the part, it was impossible to clamp the c-clamp in a secure way. We tried milling the top surface by clamping the bottom surface, in this setup, there was a long arm that connected the clamp to the milled surface. This arm causes vibrations to occur, and the surface finish of the part was bad as a consequence. To make the part stiffer, a nut with a bolt screwed on was added in order to increase the stability of the frame's structure which significantly decreases the vibration during the milling process.

To hold the clamp head secure to the threaded rod, we used a pin connection(see *Figure 1,1*). We chose this connection because this is a secure way of holding the parts together, and the clamp head would still be able to rotate around the axis of the spindle. It was challenging to determine the exact location we needed to make the groove in the spindle. We wanted to maximize the spindle depth in the clamp head. Through careful measurements, we were able to determine the optimal depth for the groove. It was important to measure the sidewall depth of the hole since the center of the hole will measure to be deeper. The fit between the clamp head and the spindle has to be a loose fit. Because the head has to spin around the axis of the spindle, a friction fit is not desired. But a loose fit is also not desired as this will have a negative effect on the structural integrity. We made the mistake of turning down the rod first and then searching for a corresponding drill bit. By doing this, we made a mistake in that no drill bit was exactly corresponding with our spindle diameter. We chose the closest drill bit, but this turned out to be too large, thus causing a fit that was too loose. What we should have done was drill the hole first, and then turn down the rod to the corresponding diameter. This way you can try to fit the parts together and turn down the rod until they fit together. This is a way to avoid mistakes in measuring and drilling.

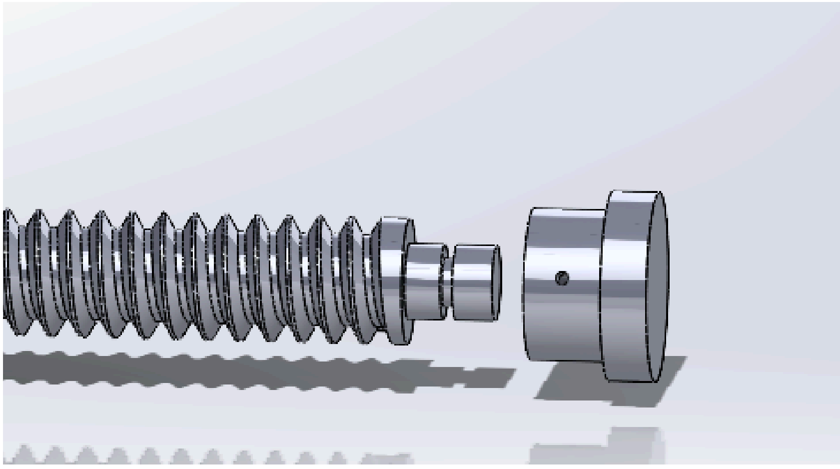

Figure 1.1. Spindle head connection

For the spindle, we used a threaded rod. Both ends of the rod had to be turned down, in doing so the threads on the rod were slightly damaged. This caused a problem when trying to fit the spindle in the hole of the c-clamp. To fix the damage, a die was used to rethread the spindle. A chamfer was also added to make it easier to fit the parts together.

In the handle, a press fit is used to make sure the rod will not slip out of the spindle. One side of the rod has a pommel that was left when turning down the rod. The other side makes use of a press fit. Very small tolerances were used for the press fit to work. Although we knew the theory around press fits, multiple diameters were tried to find the optimal fit. First, the hole was drilled on the female part, then the rod was turned down to several decreasing diameters with each variation. It was hard getting the two parts together. To fix this, a chamfer was made on both parts. Now the parts were easy to put together and to get the desired finish we sanded down the press fit, so the bevels are not shown.

Summary & Conclusion

In this lab, we built a C-clamp and gained experience in machining, effectively planning out our tasks, and adapting to proper communication skills. We took this lab opportunity to create a simple yet useful C-clamp. Although a lot of challenges and issues were encountered, we found various ways to solve these issues: we brainstormed for ideas, fixed some issues, altered a few parts, and achieved a final product we are proud of. Initially started with various designs for vice and trains, narrowed it down to one design; then obtained it from a 2D design to a SolidWorks model and finalized it into a well-developed product at the machine shop. We began with safety rules at the shop and now are confident to be working in the shop. This gave us a hands-on experience with the theoretical knowledge we gained through our lectures. We were able to identify which process we were to use but gained knowledge on the constraints and procedures to be followed when performing it in real life. Fabricating our design, we came across and solved problems like vibrations when milling and drilling, gumming of material when holding it in the chuck, using different speeds, using of centring tool, use of different drill bits, etc which we were in addition to the theory. We also added skills like deburring and angle filing which enhanced the finish of the product, also quoting the lab machinist, "You should be able to run your finger all through and edges and not cut them." We learned that communication and planning before getting a lab is a key aspect of our project, it certainly showed great benefits and reduced confusion. From using machines, simplifying designs, and improving communication to proper planning and time management, from designing to building this project, we learned and polished many technical and soft skills and we're content with the result. We are now equipped with an understanding of machining parts and the timeline for the same, thus polishing us to be better engineers for the future.

APPENDICES

Appendix A: Initial Shop Drawings

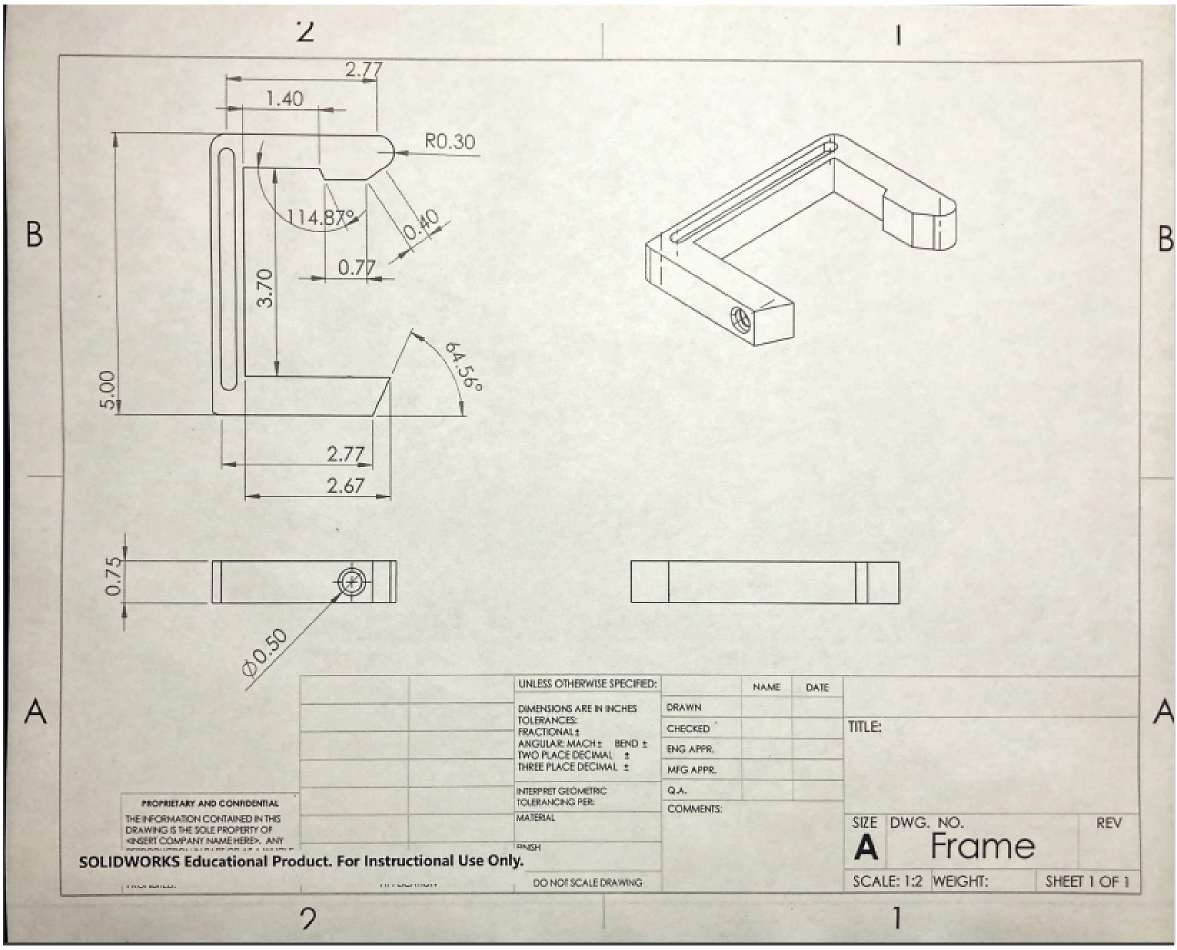

Figure 1.2: Initial Orthographic Drawing for Frame

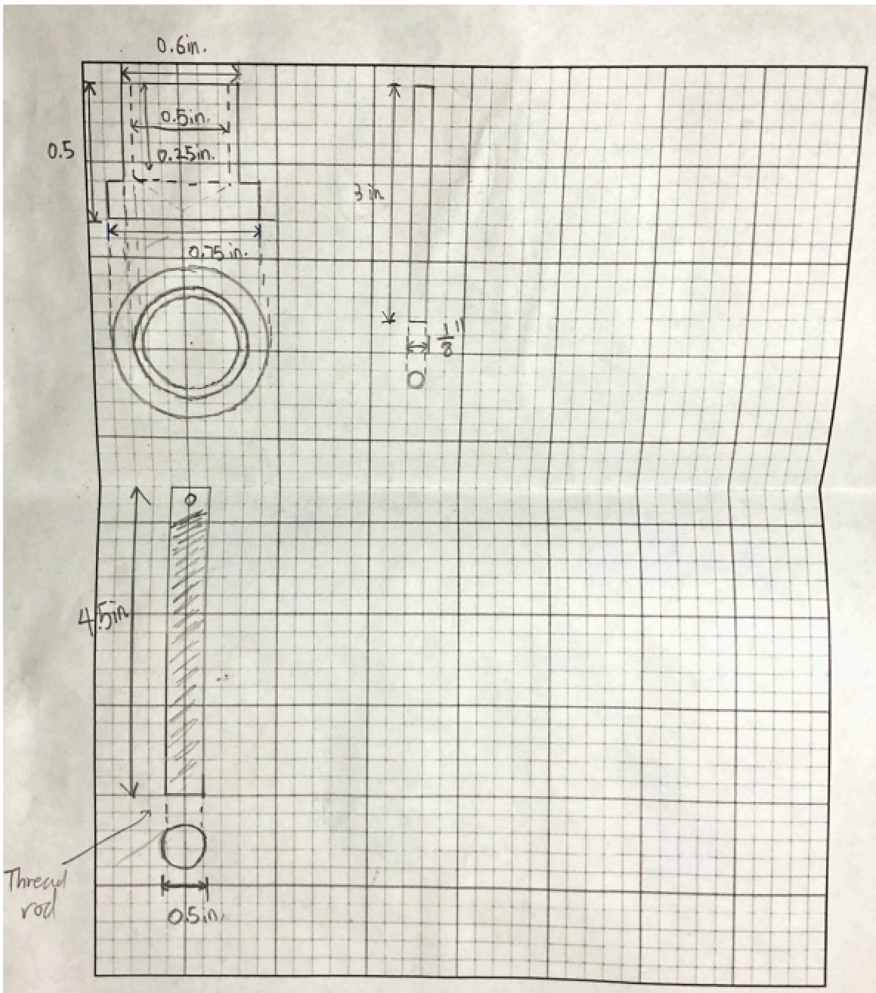

Figure 1.3: Initial Orthographic Drawing for Handle, Threaded Rod and Cap

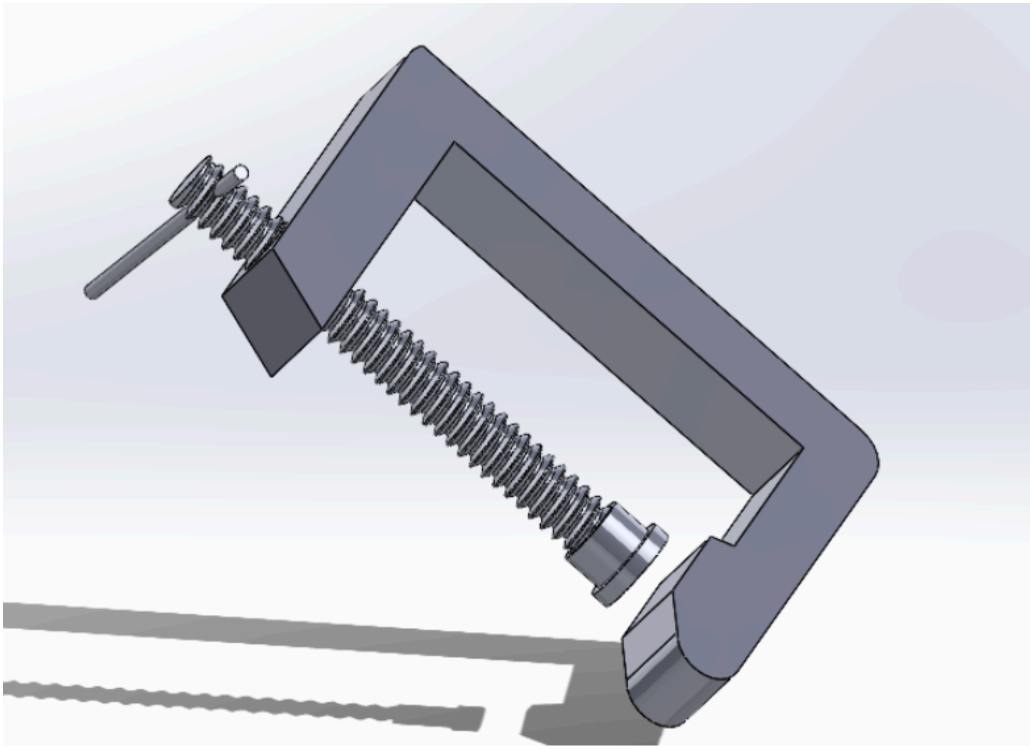

Figure 1.4: Initial Solidworks Assembly File for the C-Clamp

Appendix B: Final Shop Drawings(Changes Along the Manufacturing Process)

Sketches after Initial Shop:

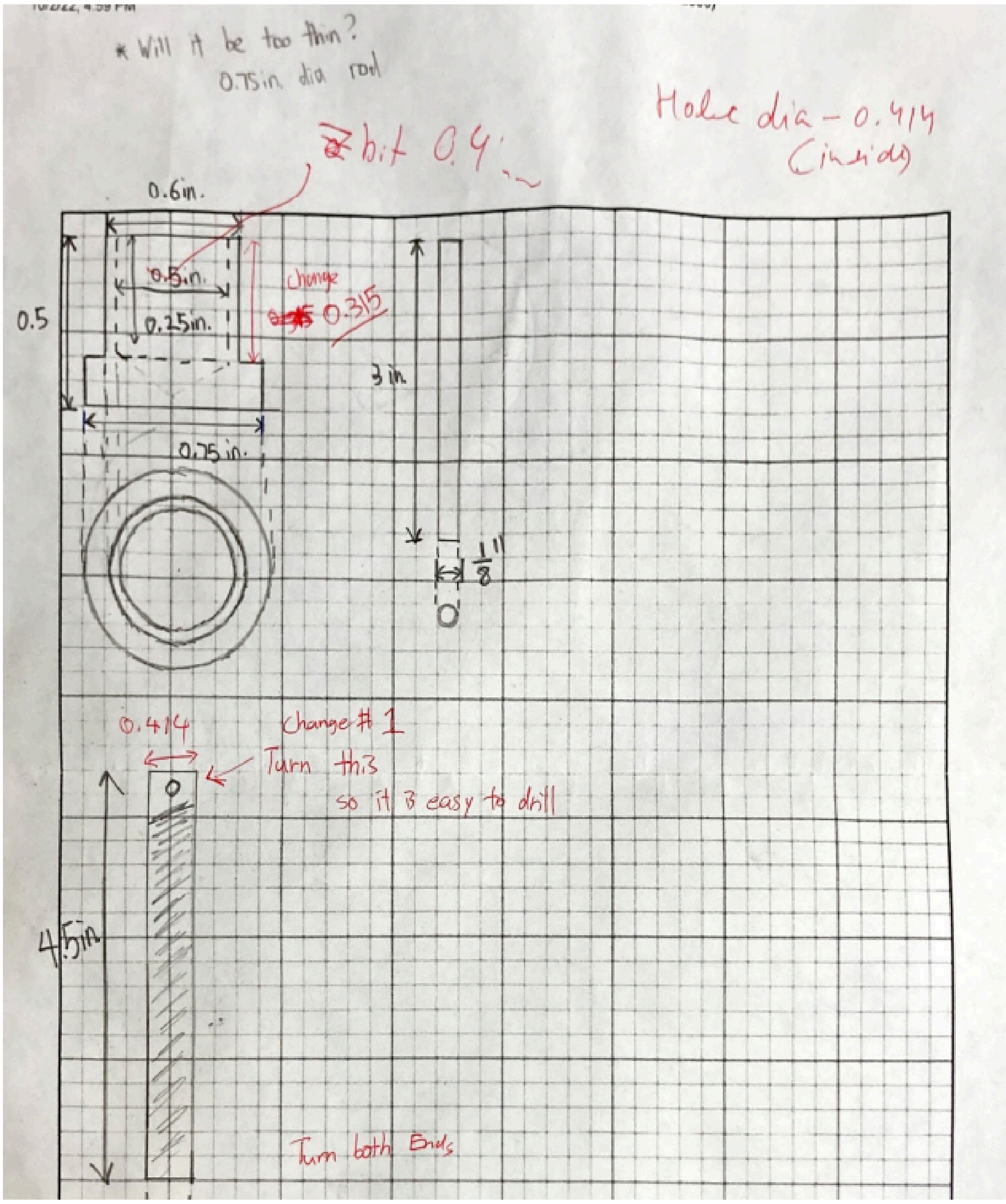

Figure 2.1: Edited Orthographic Drawing for Handle, Threaded rod and Cap

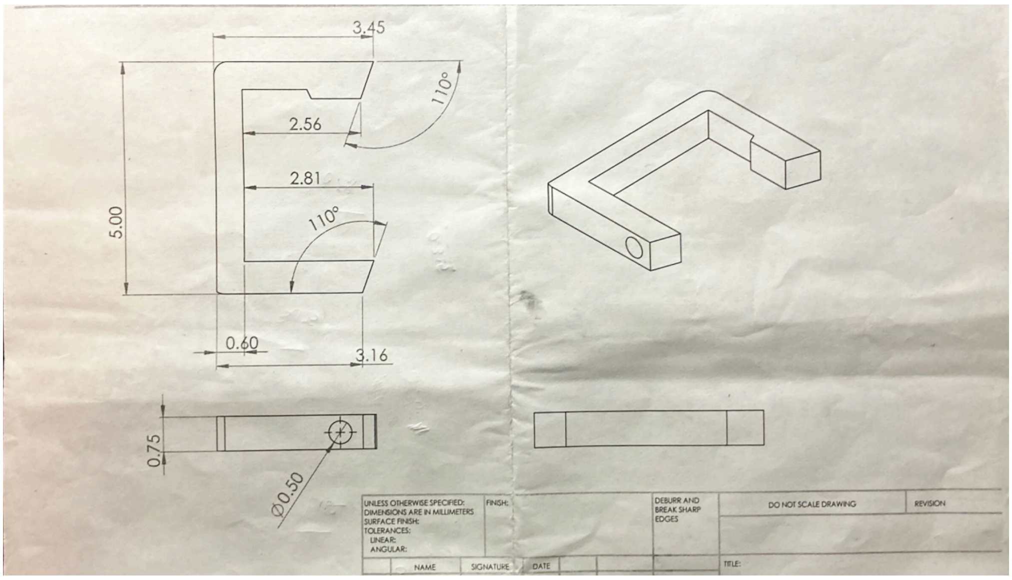

Figure 2.2: Second Orthographic Drawing for Frame

Sketches after 2nd Lab:

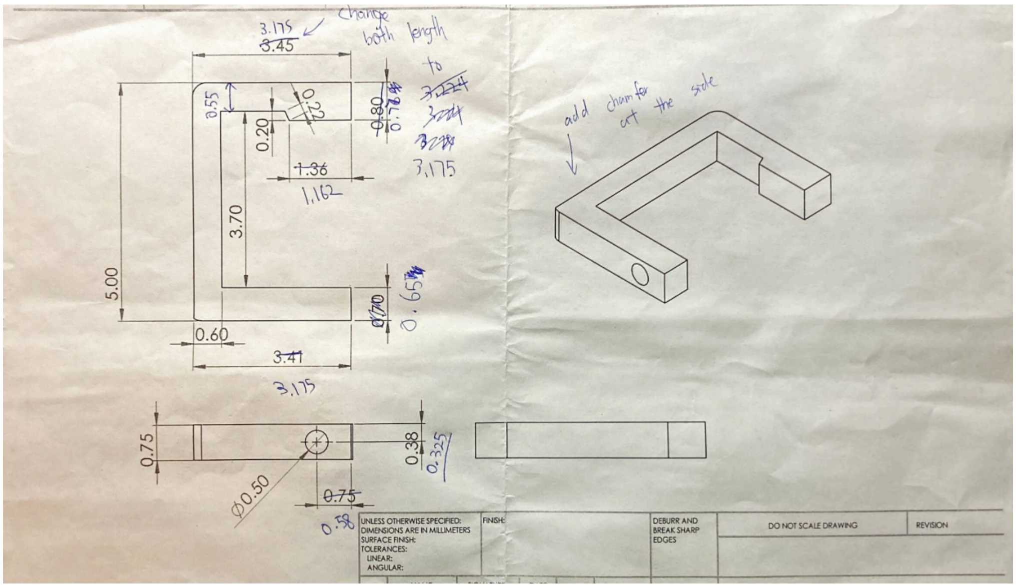

Figure 2.3: Third Orthographic Drawing for Frame with Changed Dimensions

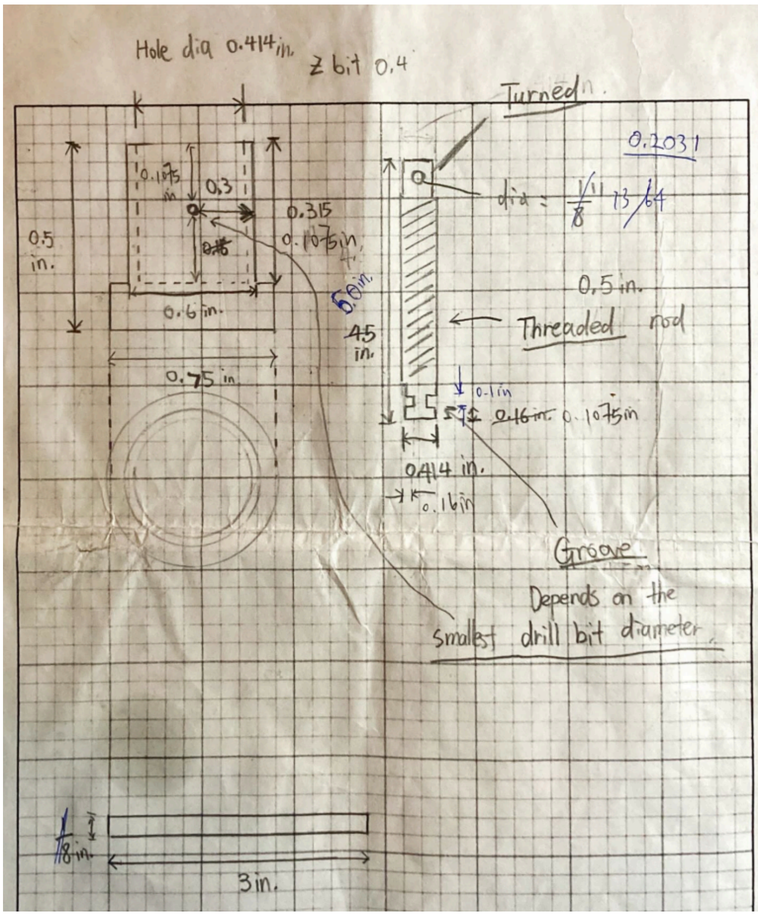

Figure 2.4: Third Orthographic Drawing for Cap, Handle and Threaded Rod with Changed Dimensions

Final Shop Drawings:

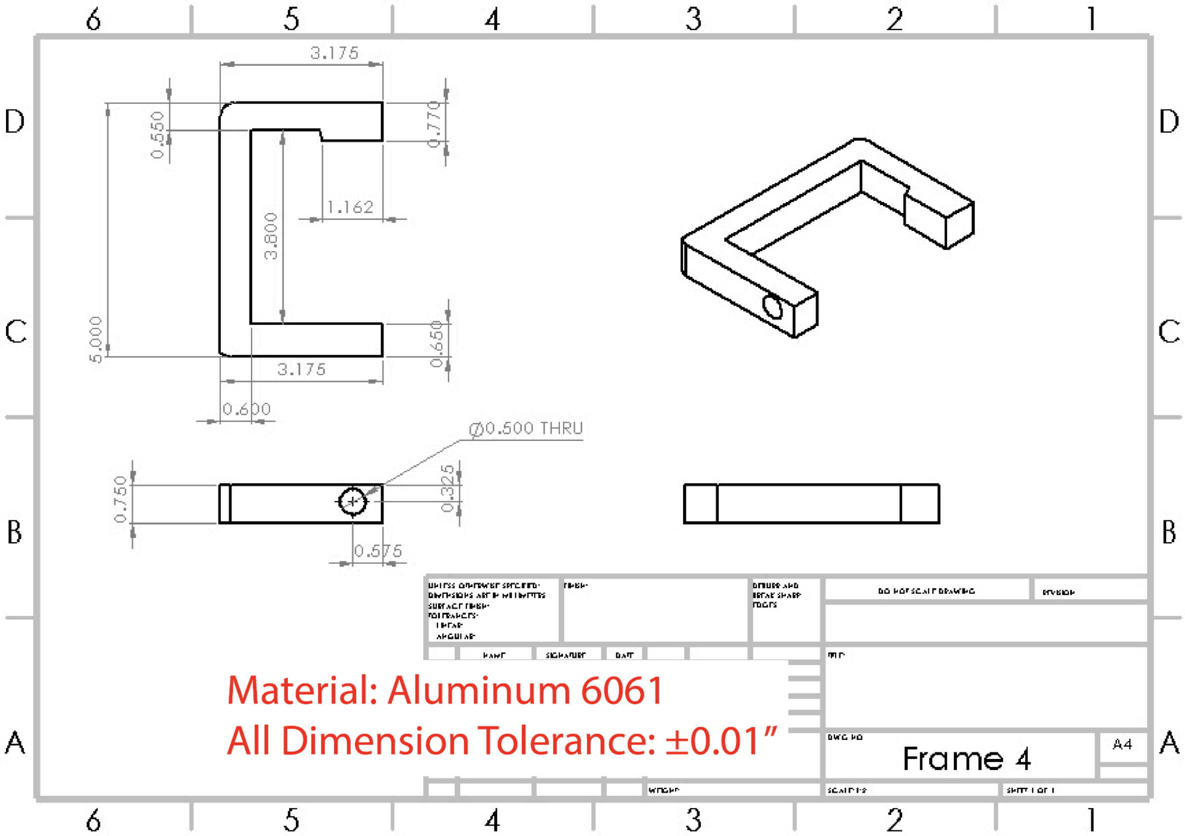

Figure 2.5: Final Orthographic Drawing for Frame with Accurate Dimensions

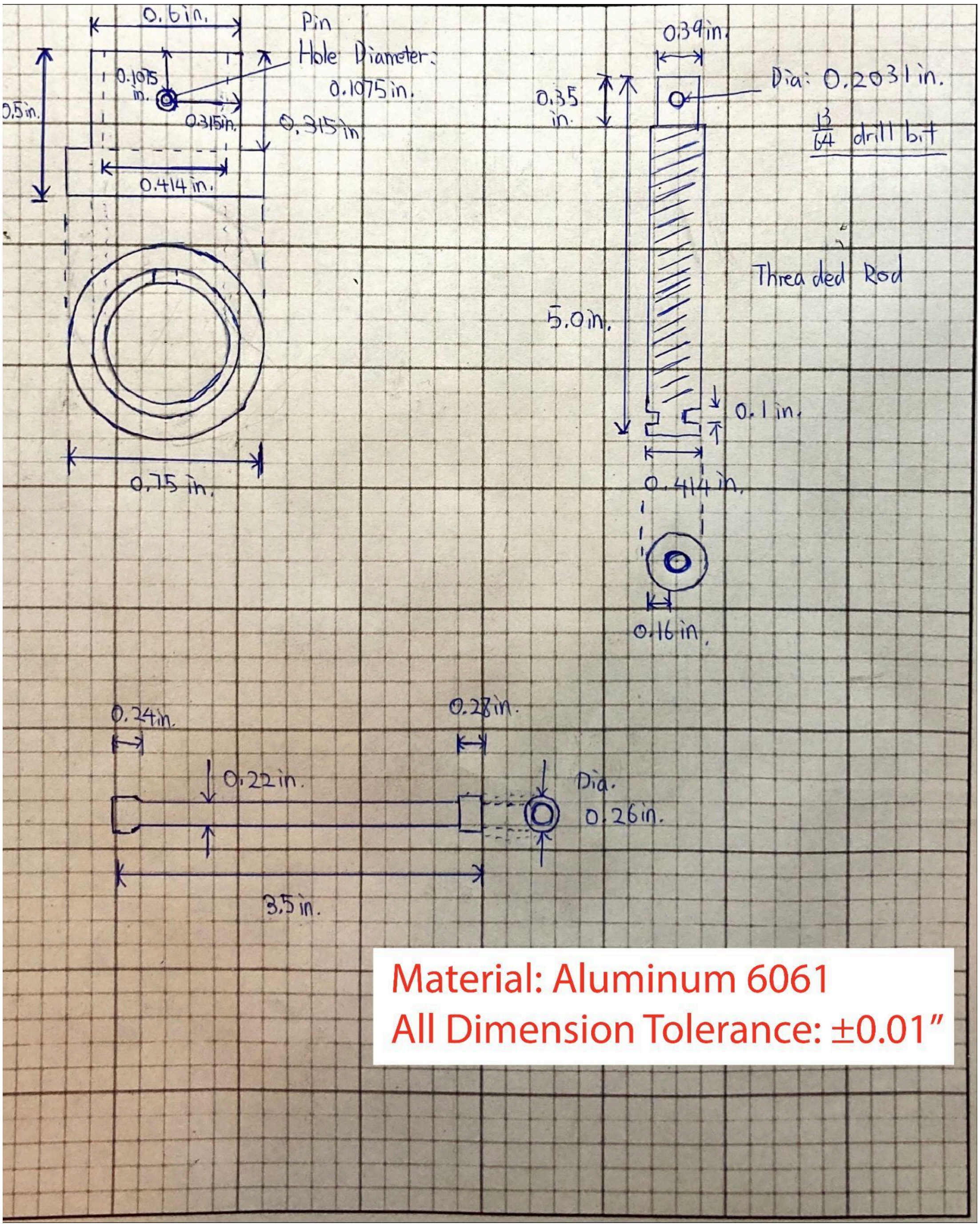

Figure 2.6: Final Orthographic Drawing for Handle, Cap and Threaded Rod with Accurate Dimensions

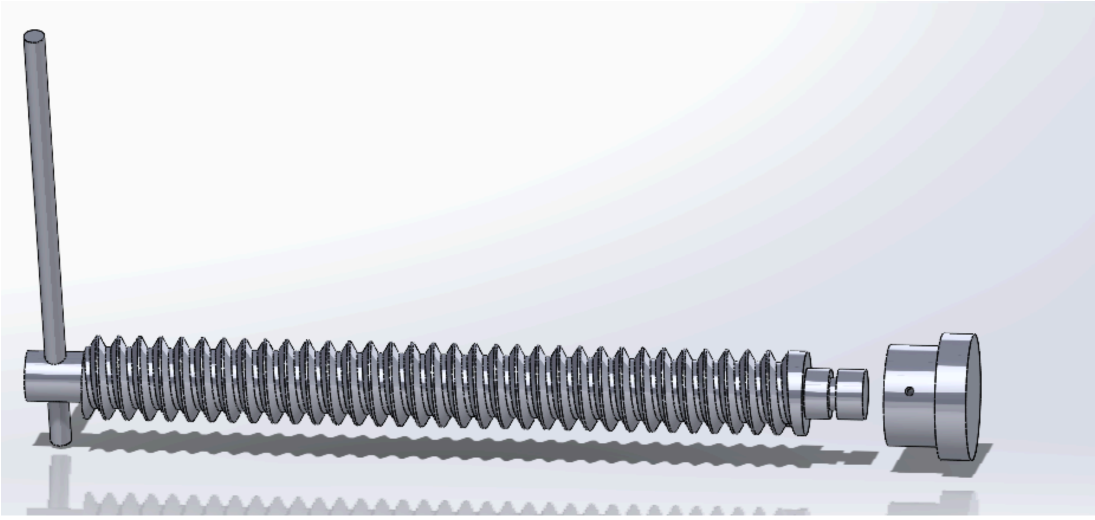

Figure 2.7: Final Solidworks Assembly File for Handle, Cap and Threaded Rod

Appendix C: **Finished Product**

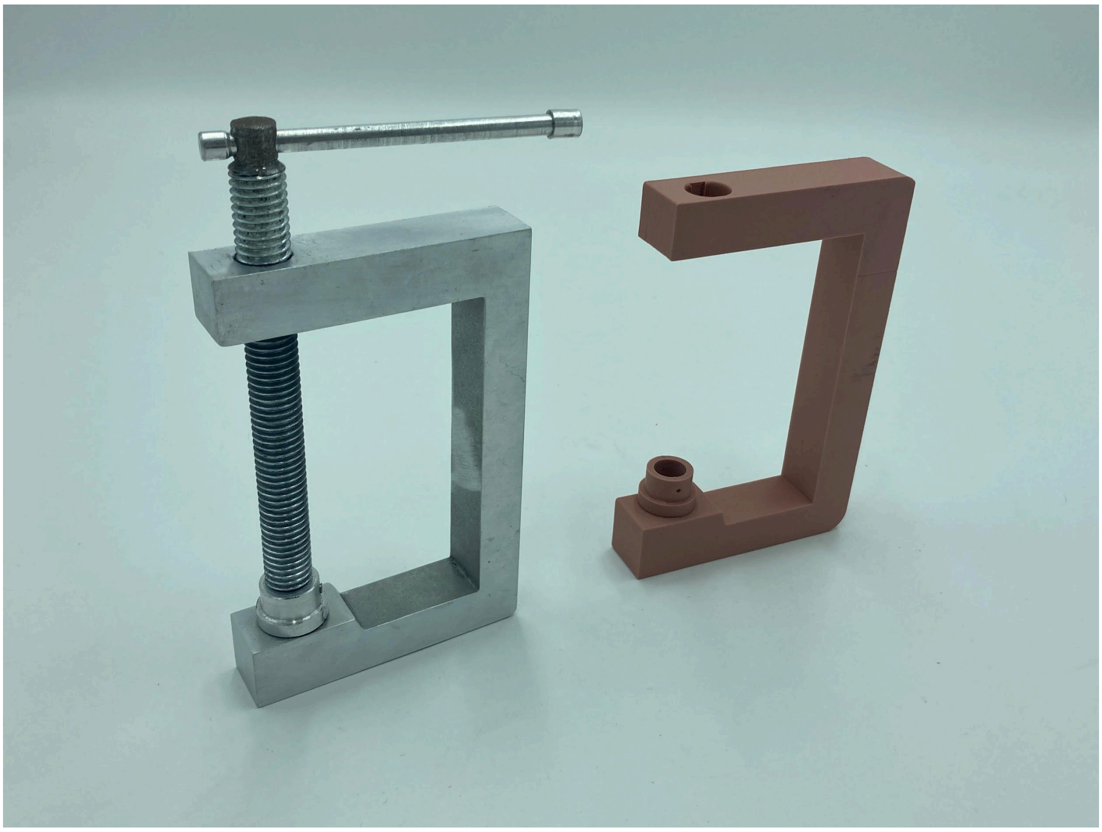

Figure 3.1: Final Product and 3D Printed Prototype

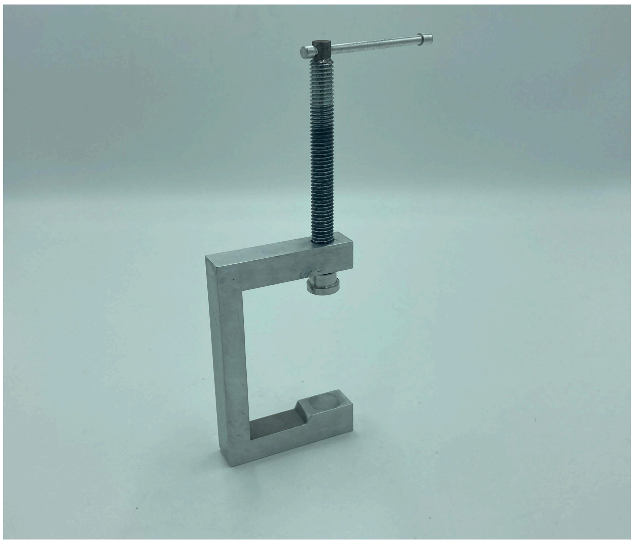

Figure 3.2

Figure 3.3

References

Oberg, E., Jones, F. D., Horton, H. L., Ryffel, H. H., McCauley, C. J., & Brengelman, L. (2020). *Machinery's Handbook* (Vol. 26). Industrial Press, Inc.