Multi-bit Screwdriver Manufacturing Project

MAE 3192 Manufacturing Process & Systems

George Washington University

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Abstract

For this project, the team was assigned to design a manufacturing process plan for a chosen product and then implement the plan in the George Washington (GW) School of Engineering and Applied Sciences (SEAS) machine workshop. The process plan had to include the raw materials, machines to be used and their sequence, fixturing devices needed, cutters needed, deburring and cleaning processes, inspection process, assembly process, and anything else that was anticipated to go into the manufacturing process. The chosen product had to contain several components, which would then require assembly; for the screwdriver, this included the plastic screwdriver handle, the aluminum hex shaft, the brass sleeve, and the two screwdriver heads. Each component from the product had to be small enough to fit inside a regular-sized shoebox. The manufacturing process had to include several different machining processes and tools, as well as be thoroughly documented through video and written descriptions of the separate machining processes. Upon completion and delivery of the product, the team was asked to present the finished product as well as a description of the manufacturing process to the rest of the class.

The importance of the project was primarily to gain familiarity with several different machining processes, and to obtain a valuable skill set in learning to operate some of the machines in the GW SEAS machine workshop. It also provided experience in designing and executing a process plan for the chosen product, as well as the documentation of the manufacturing process. Ultimately, the team was able to successfully and efficiently implement the process plan, manufacture each component of the screwdriver, and deliver the final product within the allowed project timeline.

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I. Introduction

This report presents the Multi-bit screwdriver team's project submission for the Manufacturing Processes and systems course (MAE 3192). The report outlines the preliminary design, final design, and manufacturing of the multibit screwdriver. The team was able to overcome numerous scheduling and health obstacles to design and create a functional multibit screwdriver.

The team's objective was to design and manufacture a comically large multi-bit screwdriver, implementing the machining techniques learned in the Manufacturing Processes and systems course (MAE 3192). To begin the design process, the team set out some design constraints and product requirements in conjunction with requirements outlined by the course instructor who for this project was the customer. The main design constraints were that the multi-bit screwdriver should be able to utilize standard quarter-inch diameter screw bits and to be able to work with a wide variety of screws and nuts increasing its range of applications. The secondary design constraints were that the final product had to fit in a standard shoebox, and consist of four to six components to meet customer specifications.

The team with guidance from the GW SEAS Machine Shop created the multi-bit screwdriver following the standard process of concept design, preliminary design, detailed design, process planning, and manufacturing outlined in the MAE 3192 course. During the conceptual and preliminary design phase, the team prioritized simplicity, practicality, and manufacturability. Once the detailed design stage was reached the team adjusted its parameters to include more specific requirements as the design progressed.

II. Description of the Product/Components

The selected product for this project was a 12 in. long adjustable length multi-bit screwdriver, consisting of four components. The first component was a 7” long, 1.25” diameter plastic shaft, with a 5” long textured grip at the base of the handle consisting of 6 rounded grooves. The second component was a 7” long 0.25” diameter steel hex shaft. The third component was a 0.75” long 0.5” diameter brass sleeve with a 0.25” diameter hex-shaped hole. The final component was a set of 0.25” diameter steel screwdriver heads, consisting of a standard Phillips flathead and a hex head.

Figure 2.1: Rear view of screwdriver.

Figure 2.2: Side view of screwdriver.

Figure 2.3: Front view of the screwdriver.

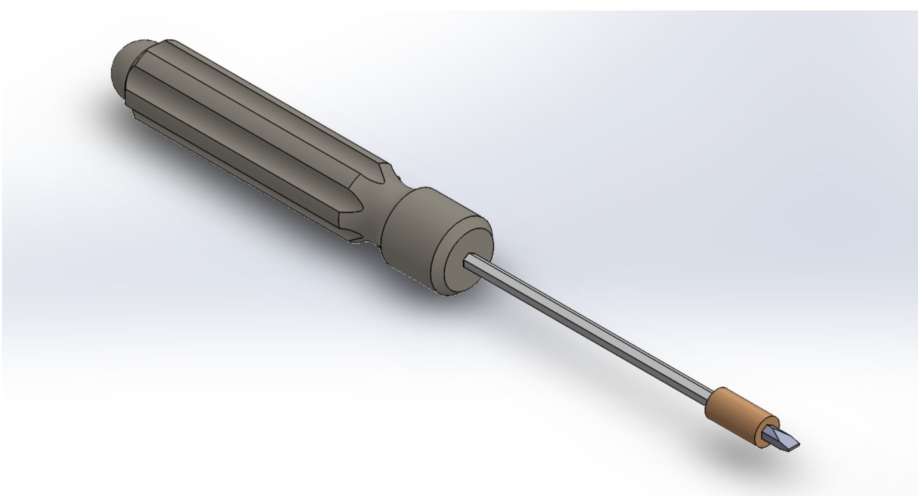


Figure 2.4: 3D CAD model of screwdriver.

(components from "Free CAD Designs, Files & 3D Models |

The GrabCAD Community Library")

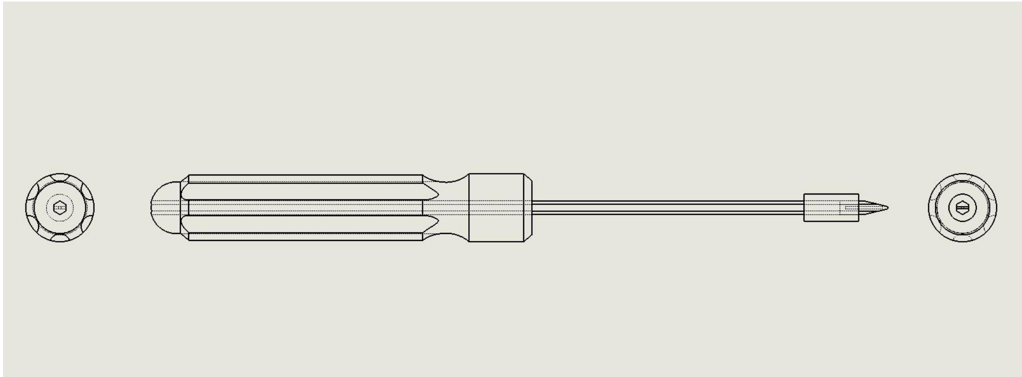


Figure 2.5: 2D Drawing of the model of screwdriver

Component name	Handle	Shaft	Sleeve	Flat-head	Hex-head
Component number	1	2	3	4a	4b
Material	Delrin Acetal Black Plastic	Steel	Brass	Steel	Steel
Description of function	Holds shaft, allows the customer to hold and handle product	Supports brass sleeve to hold the sleeve	Holds the screw bits	Used to drive screws with flat geometry	Used to drive screws with hex geometry
Special requirements	Include ½” hole to shaft and heads when product is not in use	Needs to be hex geometry	Must be brazed onto the shaft to adhere it	Must be able to drive standard flat screws	Must be able to drive standard hex screws

Table 2.1: Component list.

III. Design of Manufacturing Process Plan

Stages	1st set of Processes	2nd set of Processes	3rd set of Processes	4th Processes	Finishing Processes
Handle	• Cut Plastic to 1/8" above required length • Face Off in the lathe @425 RPM spindle speed to required 7" • Sand in Grinder	• Center Drill @ 575 RPM to make pilot hole • Drill 1/4" Diameter hole @ 575 RPM along length of the handle • Drill 1/2" diameter hole down half the length of the handle	• Use J sized drill to make 0.2770" clearance hole for hex broach • Use mill and the hex broach to broach the hole drilled in previous process	• Use Carbide cutter@ 340 RPM to perform stepdown turning. This was done to create a collar to hold on to for milling • Form cut a collar into the handle • Hold collar in millin gmachine to mill 6 grooves into handle with 1/8" ball mill	• Assemble with the other components
Shaft	• Cut steel rod to 1/8" over the required length	• Sand down with grinder to required length	• N/A	• N/A	• Assemble with handle and secure with set screw
Sleeve	• Drill 1/4" hole into brass rod • Broach hex geometry into the drilled hole	• Cut Brass rod with horizontal bandsaw to 1/8" over desired 3/4" length	• Face part off in lathe to desired length • File rod @ 340 RPM to smoothen the surface	• Clean metal with flux to purify metal and promote capillary action • Braze onto shaft with Oxygen and Acetylene at 14-16 psi	• Polish with grinder
Bits	• Cut steel rod to 1/2" using horizontal bandsaw	• Sand w/ grinder	• Hold with collet in the mill and cut with mill to create desired geometry	• Use brush to remove burrs	• Assemble with Brass sleeve and other components

Figure 3.1: Process plan for product components.

Figure 3.1 shows the process plan that was created, outlining the different materials, dimensions, and manufacturing processes that the team planned to use in the manufacturing of the multi-bit screwdriver. The stages section shows the order in which components were manufactured and the processes used to manufacture the components. The plan in Figure 3.1 is actually a modified plan. The original did not include specific spindle speeds for the various processes and did not include a fleshed-out plan to create sleeves for the screwdriver bits. The modifications came as a result of the advice that the team received from the GW SEAS machine shop, and the team's increasing knowledge of manufacturing processes as the MAE 3192 course progressed.

IV. <u>Implementation of Manufacturing Process Plan and Discussions</u>

A. Implementation of Processes:

1. Handle:

For the preparation of the plastic handle for the product, a rod of Delrin acetal black was obtained. The rod was shortened to the desired length with a horizontal band saw.

Figure 4.1: Horizontal band saw.

Followed by the operation, the plastic cylinder was moved to a lathe for edge/face smoothing. The rough surface finish was eliminated by using a face milling operation on the lathe. The part spun at a moderately slow feed rate, to prevent high-temperature increases in the material. The material removed was minimal, as only the edges and the face surface were treated. Therefore rod length or dimensions were not affected.

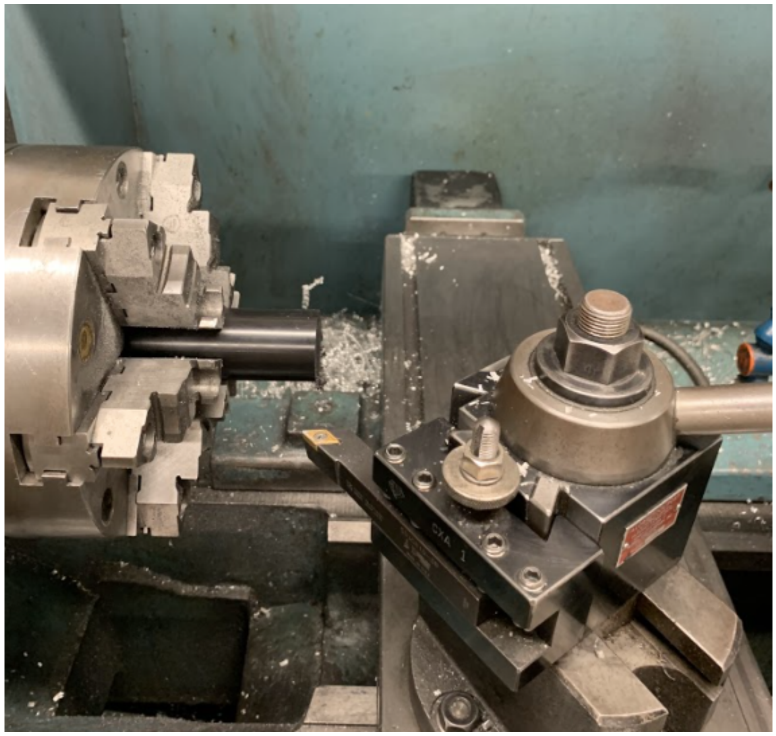


Figure 4.2: Lathe with the carbide tool; face milling operation.

Figure 4.3: Finished rod.

After processing the plastic cylinder, the next step in the process was to begin machining the design features of the handle, starting with the hole for the hexagonal shaft as described in Table 3.1. The piece was placed onto a manual lathe with a horizontal drill. First, a center drill was used to create a pilot hole (Figure 4.4). A ¼” diameter drill was selected to create a through-hole (two-step process). Due to the limitation of the drill bit length, the first step required drilling into the 7-inch plastic rod, from each side, until drill length was reached. The process involved slow in-and-out motions to dispose of excess waste material while drilling (Figure 4.5). Once maximum drill length was reached, the piece was reversed to the other side and the same operation was performed (a pilot hole, followed by drilling). However, due to the length of the plastic rod, center drilling on each side did not create a through-hole. Therefore, the second step involved using an extra-long ¼” drill bit to complete the operation (Figure 4.6). A similar in-and-out technique was used at a relatively slow drilling speed.

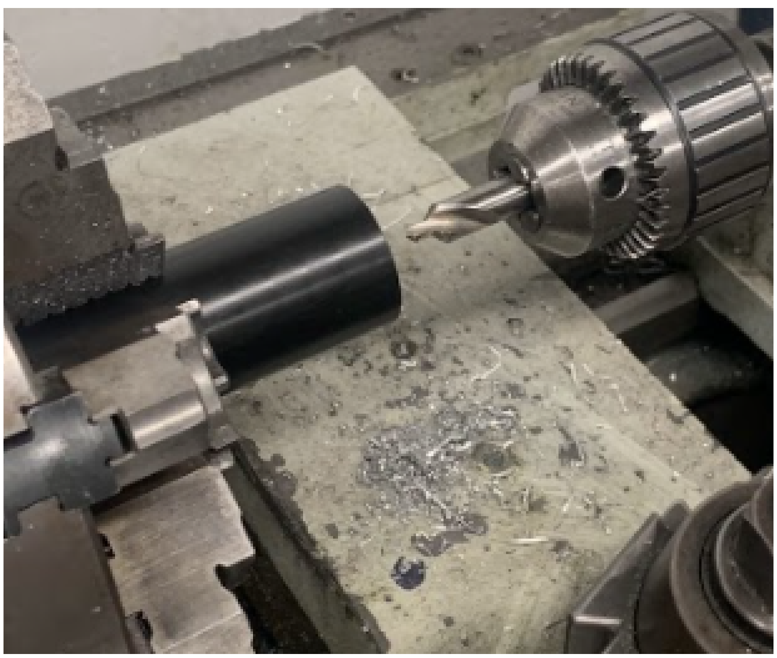


Figure 4.4: Manual lathe; pilot hole operation.

Figure 4.5: Drilling (step one).

Figure 4.6: Drilling (step two).

To store the steel shaft inside the body, the through-hole needed to be of hexagonal geometry. Therefore, broaching through the top face was performed (Figure 4.7). The plastic piece was secured on the table of the vertical mill, and the broaching bit was pressed into the rod via the downward motion and force of the mill.

Figure 4.7: Broaching; vertical mill

Next, the plastic cylinder was placed on the lathe, which was previously used for face milling. Using the carbide tool, turning operations were performed to create handle design features, such as radial curvature. Three turning operations were performed: straight turning, taper turning, and profiling. Starting with straight turning (Figure 4.8), it was done in the following order: bring the carbide tool to face center, set the computer interface at distance zero (y-direction), bring the tool to the outer radius and record the radius (starting point), move the tool desired distance, begin workpiece rotation, slowly move the tool in the x direction by small increments. The straight turning was performed to create a collar in the handle which was later used as a surface to clamp onto in a milling process. Following straight turning, a combination of profiling and taper turning was performed (Figure 4.9). For profiling, the lathe was programmed through in-built profiling radius function, with input variables: desired radius and starting point. After setting up the program, profiling operation was performed via automatic graduate tool movement in combination of x and y directional path to create a half-sphere of the assigned radius. Taper turning operation was used to complete the remaining workpiece radius by similarly using a built-in program with variables: starting position and angle.

Figure 4.8: Straight turning; handle collar.

Figure 4.9: Profiling and tapering; handle rear.

Following turning, form cutting was performed on the lathe. An arch form tool was used to create the handle grip (Figure 4.10). In this process the form was gradually pressed into the workpiece to obtain a desired look.

Figure 4.10: Handle grip design made by the form tool.

And lastly, the handle was moved onto the vertical milling machine, clamped to the collar, as shown in Figure 4.11. Six grooves (every 60°) were milled into the handle. As per other operations, this one was performed at a low material removal rate to prevent high temperature rises and undesired deformations. The handle machining was complete and the part was integrated into the assembly.

Figure 4.11: Milling operation; handle grooves.

2. **Shaft:**

For the preparation of the shaft, a ¼” hexagonal steel rod was obtained and cut to desired length with slight excess length (see Table 3.1). The excess length was removed when the rod was sanded down with a grinder for a smooth edge and surface finish. In addition, the rest of the shaft was sanded for a smooth edge finish. The shaft shape is shown in the figure below (Figure 4.12).

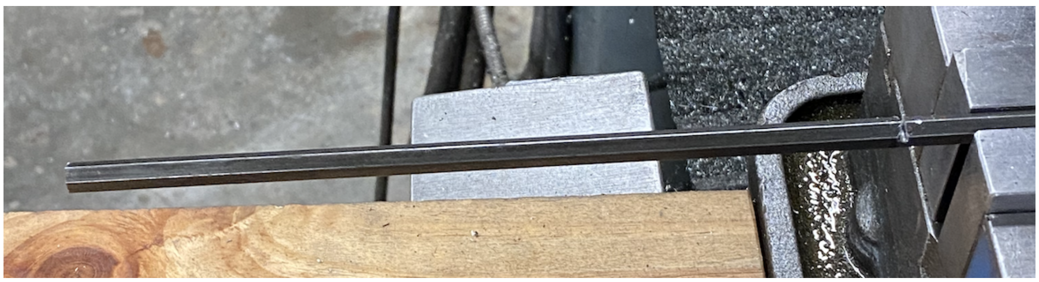


Figure 4.12: Hexagonal steel shaft.

3. **Brass Sleeve:**

For the preparation of the brass sleeve, we used the vertical milling machine to drill a quarter inch diameter hole in a brass rod. A hex geometry was then broached into the drilled hole using the broach tool on the lathe. The brass rod was secured on the table of the vertical mill, and the broaching bit was pressed into the rod via the downward motion and force of the mill. The Brass Sleeve was then cut to approximately 1/8th of an inch longer than the desired 0.75” length with the use of a hacksaw. Because the brass rod we were given was not too long, and due to the relative toughness of the material, the drilling and broaching operations for the brass sleeve were relatively straightforward for us to complete.

Next, the brass sleeve was moved to a lathe for edge/face smoothing. The rough surface finish was eliminated with the use of a face milling operation on the lathe. At this point in the manufacturing process, the team was pretty comfortable with facing operations, and due to the relatively low material removal rate and RPM that the part was spun at, there were again no particular difficulties that the team had to overcome.

The final, and most difficult part of the process for the brass sleeve involved brazing the sleeve onto the shaft with Oxygen and Acetylene. First, we inserted the sleeve about a quarter inch onto the shaft, before solidifying the sleeve in place with the use of the brazing operation. This involved joining the brass sleeve and the steel hex rod shaft by melting a filler metal into the joint, allowing us to attach the two parts without reaching the melting point of either the shaft of the sleeve. Upon completing the brazing process, the sleeve was polished on the grinding wheel in order to purify the metal and promote capillary action. This was by far the most difficult process we had to complete in the entire manufacturing process over the course of the project, and was only made possible by the help of the professionals in the GW SEAS machine workshop. However, it proved to be a great alternative to a welding operation because the relatively low melting point of brass would have meant such a high temperature process could have significantly affected the integrity of the brass sleeve. This would have undoubtedly created a number of issues with tolerancing with the interchangeable drill bits.

Figure 4.14: Brazing the brass sleeve.

4. **Drill Bits:**

The drill bits were machined from the same hex steel rod used to machine the screwdriver shaft. The steel rod was first cut down to about ½" length with the horizontal band saw. Two different steel bits were cut out to make the necessary amount of screw heads required. The different bits were then sanded in the grinder to improve the surface finish and to improve the tolerancing of the bits with the brass sleeve. The bits were then placed in the milling machine and held by the vise as it was too small to be held in the collet. The cut width and depth were then programmed into the digital read-out (DRO) and then the milling process was initiated to machine the flat head screw bit. The hex screw head was machined by simply cutting the steel hex rod down to the required ½" length and then sanded with the grinder to ensure it fit with the brass sleeve.

B. Manufacturing/Machinability Issues:

No major manufacturing issues occurred during the project process, with an exception of one minimal complication. When manufacturing the handle, the broach tool was caught in the plastic rod. As a solution, via gentle hammer strikes the broach bit was pushed out to complete the operation

C. Tolerancing Issues:

Although we did not encounter any significant tolerancing problems, with a very smooth final assembly of parts, there was one small issue of note. Initially, the steel hex rod we planned to use for the two screwdriver heads didn't quite fit tightly enough into the brass sleeve. We therefore decided to choose a different steel shaft of the same dimensions that we found had a *marginally* larger radius, meaning it fit perfectly into the brass sleeve.

D. Division of Labor:

The team members included Moustafa Montaser, Anton Yanovich, Nii Sackar, and Oscar Southwell. Oscar participated in manufacturing of the screwdriver handle, shaft, and sleeve, and was also a secondary report author. Nii participated in product design, creation of the manufacturing process plan, manufacturing of the screwdriver handle, shaft, and screwdriver bits, and the brazing of the sleeve. Anton was involved in product design, machining handle, screwdriver Shaft, CAD assembly/drawing, primary report author. Moustafa, although limited by health related issues, was involved in product design, manufacturing of the screwdriver bits, secondary report author.

E. Lessons Learned:

Over the course of the project, the team quickly discovered the difficulties of coordinating four different schedules in order to find times in which multiple members of our team could meet in the machine workshop at the same time. Although individual work on the manufacturing process was possible, we found it was significantly more efficient to have two team members in the workshop at the same time; one member could work on the manufacturing processes while the other could record the steps taken in the manufacturing process, take pictures/video, and help complete our full account of the process. Eventually, we were able to coordinate our schedules to complete the manufacturing process within the allowable project timeline, by actively planning ahead of our schedules to meet in the machine workshop.

Additionally, we learned to some approximation the wide capability of production of the various manufacturing processes and machines available in the machining workshop. Even though our product was relatively simple, and our process plan did not involve too many complicated processes, we did come to learn that in combination different machining processes can produce parts that might seem impossible simply looking through the lens of individual machining operations. There are also a number of alternatives to more traditional machining operations that allow for production of parts in more specific scenarios with unique difficulties; for example, our use of the brass material for the sleeve of our screwdriver was only made possible by the brazing operation as an alternative to welding.

V. Conclusion

In summary, the project was very successful; the designed process plan eventually met all of the required objectives, and the process plan was successfully carried out in the machine workshop. The final process plan included four separate parts that required assembly, involved a number of different machining processes and operations using a variety of machining tools, and outlined the required steps for manufacturing and assembly of the project. However, it must be noted that the initial proposed process plan was modified to include a greater variety of manufacturing processes, as well as an additional component in the screwdriver (brass sleeve).

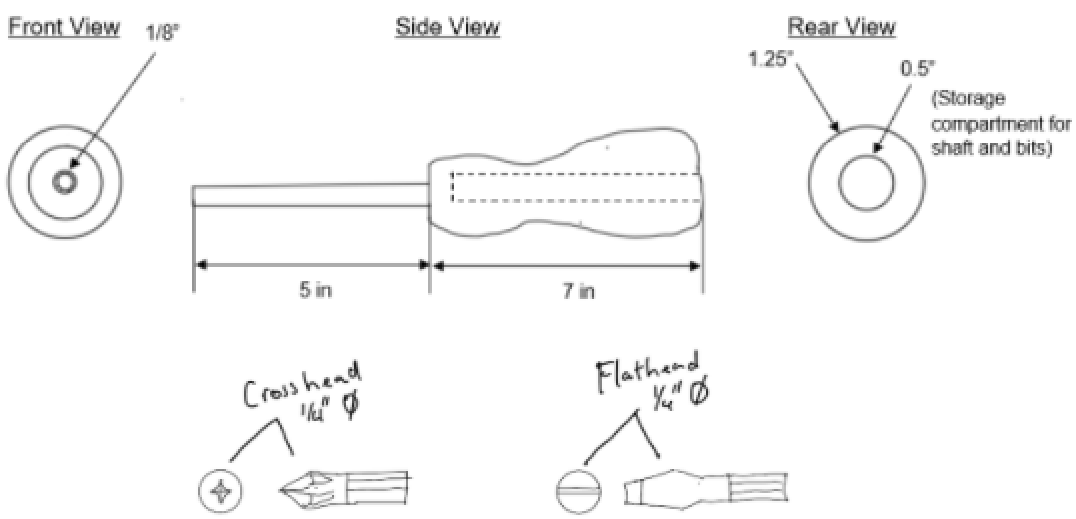
Although the timeframe for this project limited the team from doing so, a potential improvement to the screwdriver to increase the number of different screwdriver heads would be recommended. Since the screwdriver heads are interchangeable within the brass sleeve, increasing the number of different machined screwdriver heads would greatly increase the range of functionality of the screwdriver. Since the team was only able to produce flathead and hex screwdriver heads, the screwdriver was limited to screws of these specific types. Additionally, the screwdriver heads were limited to functionality in a single size of screw; to allow the screwdriver to function for each type of screw of every standard size, a significant number of additional screwdriver heads would have to be included in the manufacturing process.

VI. References

"Free CAD Designs, Files & 3D Models | The GrabCAD Community Library." *GrabCAD*, 2021, grabcad.com/library/tag/download.

VII. Appendices

A. Preliminary Design



Product Component	Material	Dimensions
Screwdriver Shaft	Aluminium	L = 5 in R = ⅛"
Screwdriver handle	Plastic	L= 7in R=1.25" R_{Hole} = 0.5"
Screwdriver bits	Steel	R = ⅛"