Deliverable K – User and Product Manual

GNG 1103[B]

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Table 1: Acronyms

Acronym	Definition
3D	Three-dimensional
CAD	Computer-Aided Design
PLA	Polylactic Acid (Thermoplastic polyester) – 3D printing Material
UPM	User and Product Manual
JJANGC	First Letter of Each Group Members Name/Company Name

1 Introduction

This User Product Manual provides detailed information for our client and costumers to effectively use the JJANGC jig. This UPM provides a detailed and in-depth review on how the jig operates, the BOM, potential warnings, configurations, how to set up the system, user conditions and how to access the system. This document walks you through each important section and subsections to give the user a full and complete understanding of what our JJANGC jig is. There is no security of privacy risks, however, there is a potential safety hazard that can occur if the system isn't set up properly which can be seen in section 2.2 and how to properly set up the system can be seen in section 3.0 of the UPM.

2 Overview

Our client Ambico has a problem with the step where the tapping and drilling of the holes for the screws takes too long to perform. It is important to resolve this problem as it causes bottlenecks in production and reduced efficiency on the production line.

The jig would need to be easily and quickly set up and for a technician to operate. The product will need to be reliable and accurate in its repeated operation in a dusty, loud environment. The product will also need to eliminate the need to measure the holes needed in the tapping and drilling process. The Jig must not damage the door during operation.

Our design is cost effective due to its plastic construction and is durable as well to survive the harsh factory conditions it will be operating in. The design itself is based on the C clamp that is found in most workshops, this makes it familiar to technicians and intuitive on how to operate the product. The product is designed in such a way that if a part breaks, it can be replaced instead of an entirely new unit being purchased. Our CAD files can be easily and quickly modified to fit any new dimensions of future hinge specifications.

Commented [JB1]: What do you mean by files

Commented [GL2R1]: the cad files, blueprints

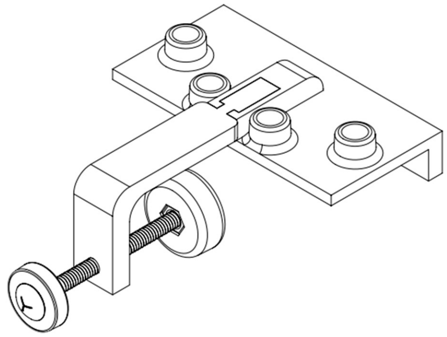

Figure 1: Isometric View of Assembled Jig

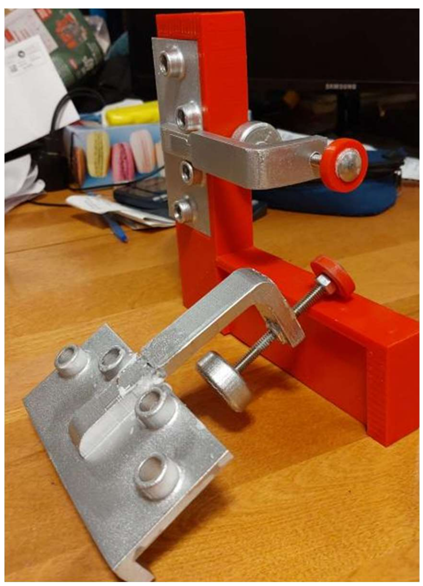

Figure 2: Final Prototypes View I

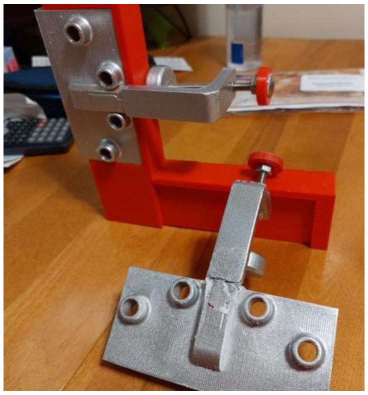

Figure 3: Final Prototypes View II

There is a C-clamp that you can use to tighten the grip of the jig to the door. It has Extrusions to allow drilling and tapping.

It is a flat plate with four elevated bushing holes in the place where the client specified for the drilling. From the flat plate, there is the clamp arm which extends out the rear of the jig and down to the screw assembly. The end of the clamp arm as a hexagonal hole that fits a nut that matches the screw's thread pattern. The screw has the finisher on the end that will contact the door and enable the jig to grip the door. The screw has another hex nut glued to the knob which enables the action of the jig. On the front of the jig is a vertical panel that grips the outside of the door.

2.1 Conventions

When twist is mentioned in the document, it is in reference to the action of turning the screw to tighten the jig against the door's surface.

2.2 Cautions & Warnings

Some warnings about the product before use to ensure proper use by technicians. Before you begin to drill or tap, make sure the clamp is tightened enough to where it won't move. If not properly tightened it could lead to injury or damage to the door and if over tightened can damage both the door and the jig. Make sure the jig is flush with the hinge inlay to ensure perfect alignment and accuracy when drilling. If it's off it could lead to inaccurate drilling/tapping.

3 Getting Started.

Take the jig and place it onto the hinge making sure the clamp is above the backset. As shown below:

Figure 4: Mounting the Jig

Make sure the jig is placed flat and flush on the door. As shown above.

Then twist the knob on top of the jig to the right which will clamp the jig to the door. As shown below:

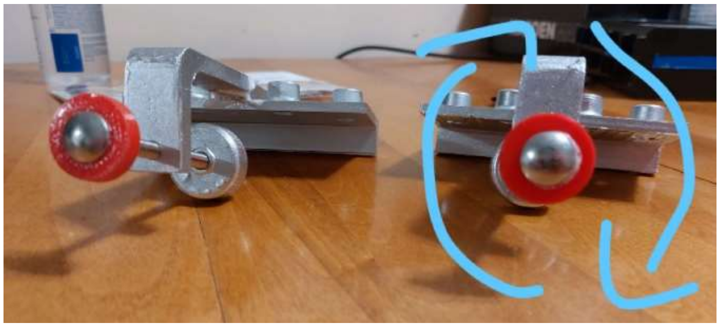

Figure 5: Motion of C-Clamp Screw

Now you can begin to drill and tap through the hole extrusions on the jig.

Figure 6: Pilot Holes for Drilling/Tapping

To remove the jig simply twist the knob of the clamp to the left and it will loosen the system and allow you to remove the jig. As shown in Figure 4.

3.1 Configuration Considerations

The jig will be placed into the routered rectangle on the side of the door. It should be snug then the user would tighten the c-clamp until the jig cannot fall out and will not move when using.

Figure 7: Jig Clamped to Testing Rig

As you can see above the jig sits in the routered rectangle and is ready to be used.

3.2 User Access Considerations

- Operators [Limited access]: They will use the jig for manufacturing or assembly processes. They will be restricted from making significant design changes to prevent errors.
- Inspectors [Limited access]: They will have access to the prototype to understand the design for quality control purposes. Their access would be restricted from making significant design changes to prevent errors.
- Maintenance personal [Limited access]: They will need to access the jig for maintenance purposes. Their access would be restricted to specific maintenance-related features to avoid unintended changes.
- Visitors [Limited access]: They may need to view the prototype for informational purposes. Their action would be limited to prevent any unauthorized actions.
- Manager [Full access]: They will have full access to the prototype to monitor progress, track usage and gather data.

3.3 Accessing/setting up the System.

To set up the jig you will need to use Ultimaker Cura app on MacBook or Windows to access the Ultimaker 2+ 3D printers. You will also need CADing software to create a virtual prototype/part of the prototype to individually print each part. The CAD software used during the project was Solidworks. We use the 3D filament that was available in the makerspace.

Figure 8: Ultimaker Printer and Printing app Ultimaker Cure [1]

Figure 9: Solidworks CAD Software [2]

When you create all the parts necessary you will insert them into the Ultimaker app and adjust the infill and print speed to the desired numbers. After you set it to the desired amounts hit slice and export it onto an SD card which you will then insert into the 3D printer to begin to print. In a perfect world where we had more time, we would use some sort of metal which would incorporate welding and cutting to prepare. However, with the time and cost constraints we couldn’t.

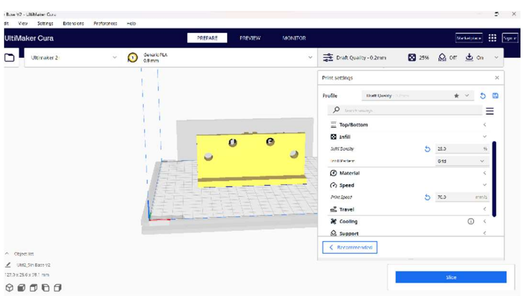

Figure 10: Ultimaker Cure Software

Once you’ve printed all the parts assemble the parts and use gorilla glue for any parts that need to be glued together. You will also need hex nuts and a simple screw from a C-clamp. So that it will thread properly and easier than if it was 3D printed.

Figure 11: Carriage Bolts, Washers, and Hex Nuts [3]

Once it's all assembled you can now place the jig on the desired area where you'd like to drill and tap making sure it is perfectly aligned. Then clamp down the jig making sure it is secure and won't move.

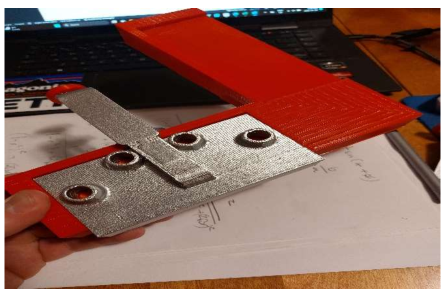

Figure 12: Clamping Jig on Testing Rig

To adjust the jig for different spacings/sizes you simply must change the highlighted property on the CAD design as shown below and everything else will change accordingly. You can make smaller or bigger jigs quickly and easily that are compatible with the desired hinge size. To replace any of the parts you can easily purchase the hex nuts and screws for the C-clamp at your local hardware store. You can reprint any of the parts if they end up breaking. They will simply snap back into place, and you can reinforce them with gorilla glue. If we had more time to make it out of metal the parts would be a lot sturdier and the only pieces that would require replacement over time would be the hex nuts and screws. However, this design ensures a long lifetime with minimal replacements.

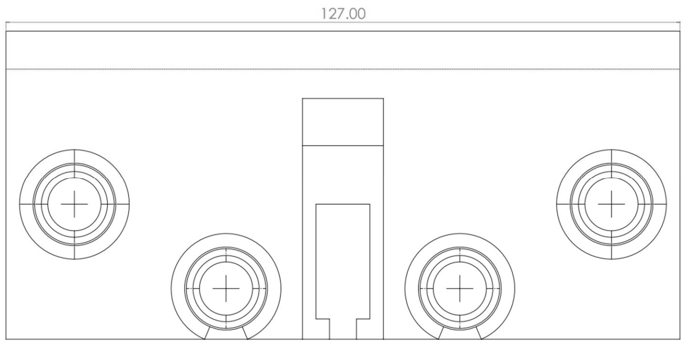

Figure 13: Scaling Dimension for Base

3.4 Exiting the System

To properly put away this jig. Simply twist the knob of the C clamp to the left which will disengage the clamping system allowing the user to remove the jig from the hinge/door with ease. Now you can put it away in a drawer or hang it up in the workshop. Since it’s small and portable it will fit pretty much everywhere.

4 Using the System

Commented [JS3]: should be done now I just added some bs

The different functions of our system can be found in the sections below. This section explains the different features of the jig and their function in the system. The first input is about the screw/clamping mechanism and how it was made and how to operate the part. The next sub sections are about the extrusions on the jig and how they allow the user to drill and tap as well as the stopper/finisher and the features they bring to the system. With each system's input they will have an output which helps the jig perform the job we created it to achieve.

4.1 Screw/Clamping mechanism

The screw/clamping is connected to the shaft of the jig. We threaded it by using a hex nut so it can effortlessly go up and down, without having to thread it ourselves with the 3D printed material. To clamp the system, you just simply twist the knob on top of the screw do tighten and loosen the jig. As shown below:

Figure 14: Rotation of Clamp

4.2 Extrusions/Guiding Holes

The extrusions on the face of the jig allow the user to drill and tap with the utmost accuracy and precision. These guiding holes help guide the user to successfully fulfill the desired task with ease even if they have never used this jig before and eliminated the guessing and measuring of the holes.

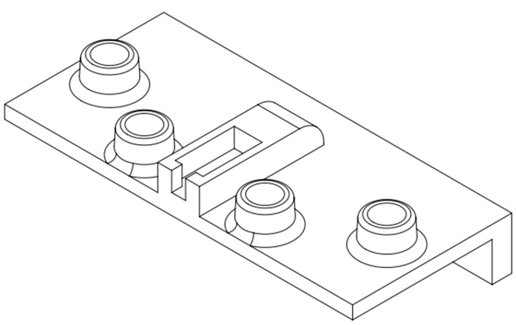

Figure 15: Isometric View of Base

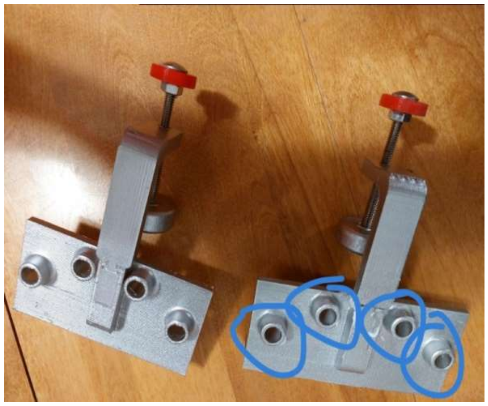

Figure 16: View of Pilot Extrusions II

4.3 Stopper/Finisher

The finisher on the end of the screw allows the clamping mechanism to clamp down with a lot of force keeping the entire system secured on the door, without damaging the wood finish of the door. Our stopper is made from 3D printed material. If we had more time and money, we would have made it a rubber stopper which would add more friction to prevent any slippage as well as not damaging the finish. As shown below:

Figure 17: Isometric View of Finisher

Figure 18: Isometric View of Knob

5 Troubleshooting & Support

If the jig won't tighten anymore, it may be because there's a blockage in the threads. Remove the finisher by twisting it clockwise and then feed the rest of the screw out of the nut. If it becomes impossible with hands a wrench or vice grips to aid with the twisting. Once the screw is removed, use a wire brush to clean anything blocking the threads on the screws. Use a compressed air hose to blow out any dust remaining in the nut before reinserting the screw and capping with a finisher.

The jig bushings have most likely worn out and need to be replaced. You can detach the plate from the clamp arm by pulling them apart as it's held together via friction. You can then take the new baseplate and reattach it to the clamp arm.

5.1 Broken Components

In the final iterations of the jig the extrusion on the c-clamp arm that attaches to the base plate was found easy to break. If the user puts to much downward pressure on the joint it is likely it will snap off.

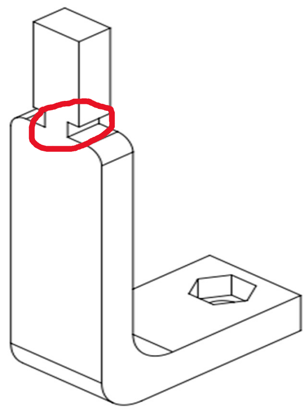

Figure 19: Isometric view of the C-clamp arm with first marked failure point.

The solution for this problem is to print the base plate and c-clamp arm as one piece, that way eliminating the weak point in the design.

Another point of failure that is present in the design is the hex nut that is glued to the insert in the c-clamp arm. It is possible to pop out the hex nut if the user was to tighten the jig too much. However, this is unlikely and never occurred during the testing of any prototypes.

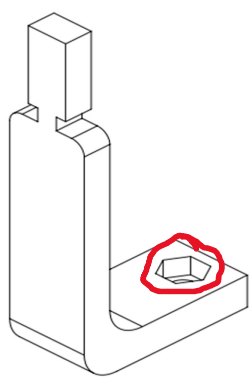

Figure 20 Isometric view of the C-clamp arm with second marked failure point

The solution for this problem is to be cautious when using the jig and not be reckless when tightening the jig. Another solution is to invert the extrusion on the c-clamp so that the hex nut would be placed into the insert from the outside/top of the jig instead of the inside/bottom.

5.2 Special Considerations

Simple: We have made the jig to be a simple design reducing the number of moving parts and points of failure. If there is a failure, we will investigate why the jig failed and attempt to redesign it.

Durable: The jig will be made of a durable material so that it can withstand the hard and rough work that it will be put through. If the jig does not have a high enough durability, we will research better materials to build the jig out of.

Low maintenance: We have made the jig require very little input after initially acquiring the jig. Aside from replacing a rubber buffer on the c-clamp there will be little to no maintenance for the jig. If the jig requires more replacement parts and/or at a more frequent rate, we will investigate either redesigning the jig or changing the material used in the parts.

Easy use: We designed the jig to be easy to use and require little to no prior training to use, this comes from its simple design and the easy-to-change parts. If the jig turns out to be hard to use or the parts become difficult to replace, we will investigate why and adjust the jig accordingly.

Both Jig's prototypes will be made in PLA Plastic for 3D Printing since using plastic in 3D printing is beneficial for prototyping. Indeed, using PLA plastic is more cost-effective than traditional manufacturing methods. In addition, PLA plastic provides design flexibility since it can be tailored to meet different needs. Finally, prototyping in PLA Plastic for 3D Printing will allow our team to make sure the jigs meet performance criteria before investing in expensive tooling and production.

5.3 Maintenance

- Check tighten bolts and screws regularly. Vibration and overall usage can lead to loosening.

- keep the prototype clean and free from dust.

- Regularly inspect all components of the prototype to detect any sign of damage and corrosion.

- Regular maintenance of the product is important for the longevity and proper use of the product.

5.4 Support

If there are issues with the product contact one of the following points of contact.

Design:

Jake Brown: jbrow234@uottawa.ca

Nathan Malench: nmale099@uottawa.ca

Maintenance:

Greyson Lee: glee092@uottawa.ca

Jonathan Swyer: jswye054@uottawa.ca

Marketing:

Connor Harrison: charr127@uottawa.ca

Andrick Grant: agran110@uottawa.ca

6 Product Documentation

The final prototype was designed in Solidworks, and 3D printed using PLA. The parts were designed to be 3D-printed due to budget and time constraints. Using an additive manufacturing technique allowed for iterative prototyping without spending a lot of time, money, and energy. We could print and test parts within hours. The design it's self can be easily modified to manufactured out of steel or other materials. Ideally, the jig has the c-clamp arm and the base made together instead of having to glue or weld components together. Furthermore, a design that combined the two components would be more rigid and be able withstand the torque that the screw will apply when securing the jig.

With the jig being used in a factory, considerations for ease of use, corrosion, durability, and weight need to be considered. If we were to make the jig out of steel, the material would need to be corrosion resistant, lightweight, and have a smooth surface. Choosing a material like stainless steel, the cost of the jig will increase dramatically from our bill of materials. However, after talking with the client on design day, it was mentioned that they would prefer the 3D printed components over the steel counterparts because the risk of scratching the doors was decreased.

One potential solution for manufacturing the c-clamp arm and base together would be beneficial. If we could design supports in such a way to print the components together assembled, the quality of the jig increases. Changing the 3D printing material from PLA to ABS or other filament types would provide better mechanical properties. As for the screw, it was originally designed to be 3D printed, however, the threads always printed poorly. The solution was purchasing steel carriage bolts and hex nuts. The steel components were incorporated into the designing of the 3D printed parts. The hex nuts would have grooves to be pressed into for components like the arm and finisher. By using premanufactured parts for the screw, the jig was able to apply the required torque to secure the jig at any orientation.

The following figures are the dimensions of the components used in the jig.

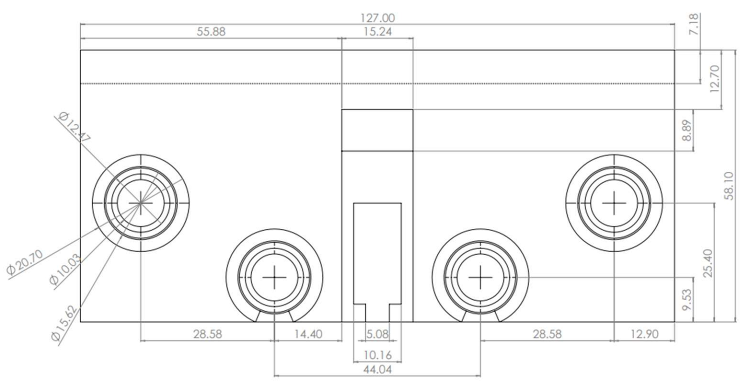

Figure 21: 5" Base Dimensions I

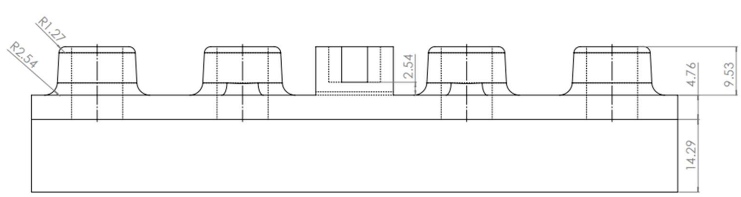

Figure 22: 5" Base Dimensions II

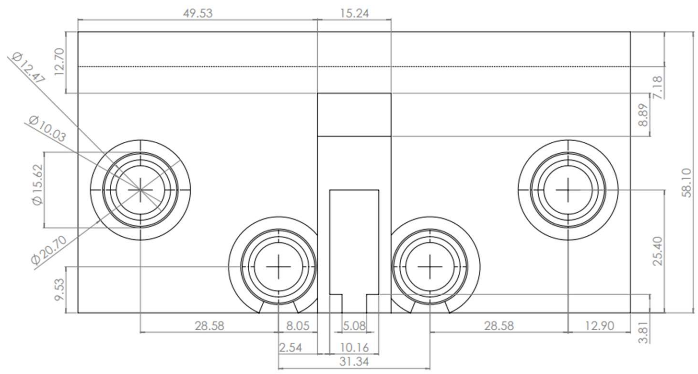

Figure 23: 4.5" Base Dimensions I

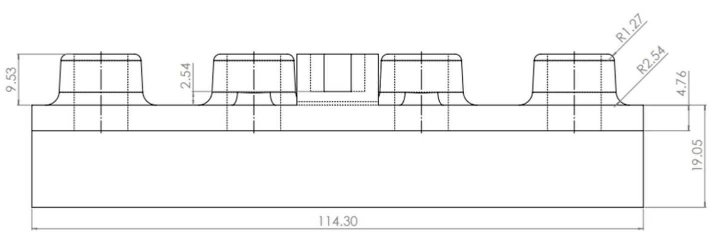

Figure 24: 4.5" Base Dimensions II

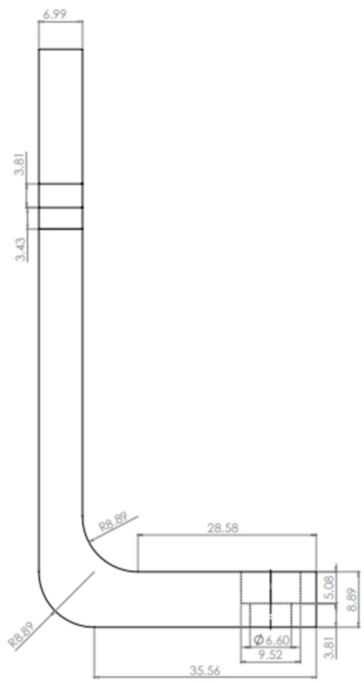

Figure 25: C-Clamp Arm Dimensions I

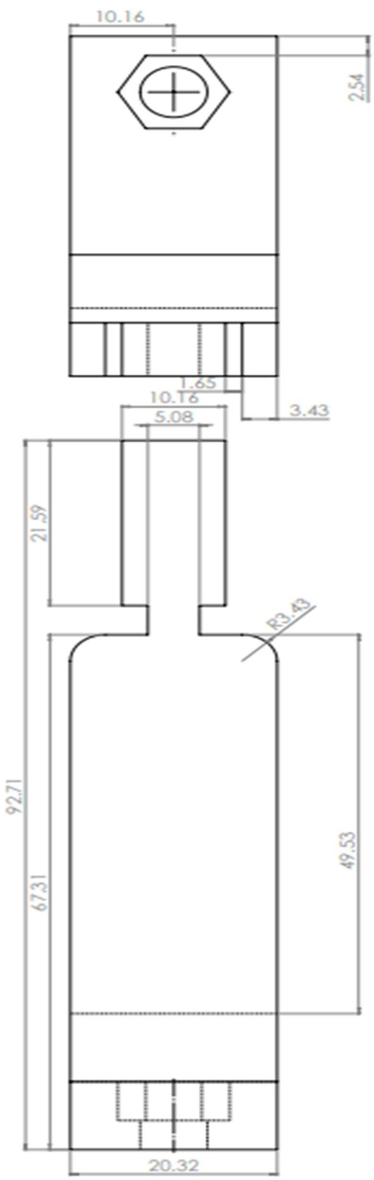

Figure 26: C-Clamp Arm Dimensions II

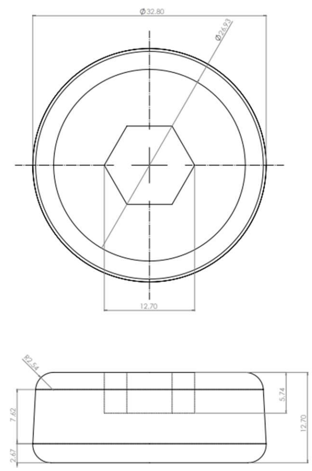

Figure 27: Finisher Dimensions

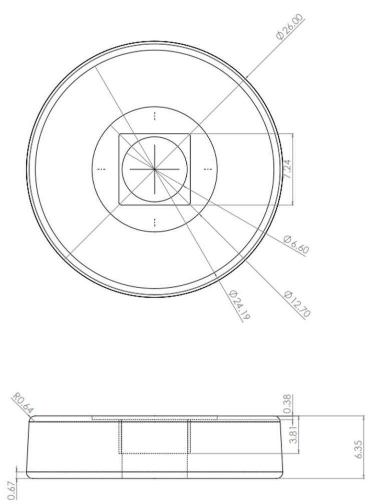

Figure 28: Knob Dimensions

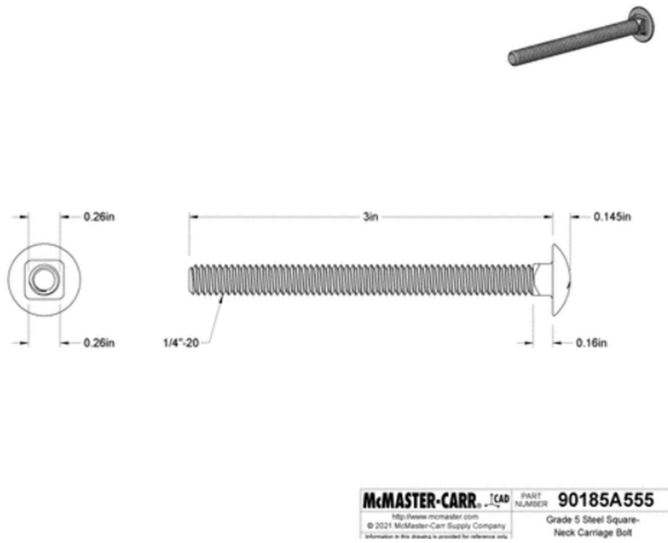

Figure 29: Carriage Bolt [4]

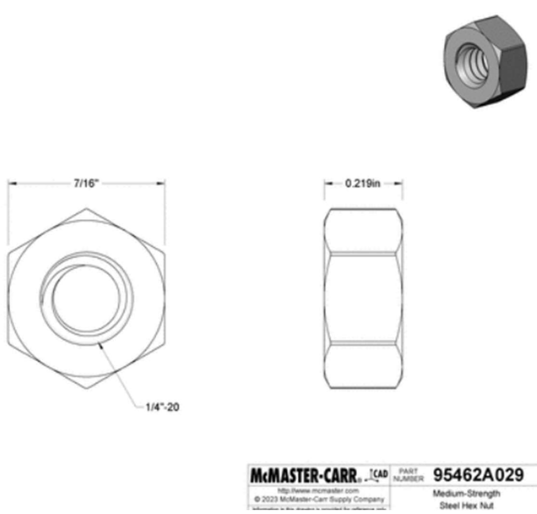

Figure 30: Hex Nut [5]

6.1 Subsystems

6.1.1 BOM (Bill of Materials)

For the Bill of materials, the total was rounded up to the nearest dollar. All totals are in Canadian Dollar CAD. The design of components outside the purchased fasteners, was designed using Solidworks, and printed using the Ultramaker Cure app and Ultrimaker 2^{+} printers in Makerspace.

Table 2: BOM for 4.5" Jig

Component	Workhours	Labour	Material	Material Cost	Total
Base	2.25 hours	N/A	PLA	$2.35in^3$ (38.51 grams) x $0.13/gram	5.00
Base Plate	1.5 hours	N/A	PLA	$0.69in^3$ (11.31 grams) x $0.13/gram	2.00
C-Clamp Base	1 hour	N/A	PLA	$0.18in^3$ (2.95 grams) x $0.13/gram	1.00
Hillman Carriage Bolt, ¼" Thread, 3" length	N/A	N/A	Stainless Steel	1 x $15.99 [6]	16.00
Hillman Hex Nut ¼-20"	N/A	N/A	Stainless Steel	2 x $0.17 [7]	1.00
				Total	$25.00

Table 3: BOM for 5" Hinge Jig

Component	Workhours	Labour	Material	Material Cost	Total
Base	2.25 hours	N/A	PLA	2.35in^3 (38.51 grams) x $0.13/gram	5.00
Base Plate	1.5 hours	N/A	PLA	0.69in^3 (11.31 grams) x $0.13/gram	2.00
C-Clamp Base	1 hour	N/A	PLA	0.18in^3 (2.95 grams) x $0.13/gram	1.00
Hillman Carriage Bolt, ¼" Thread, 3" length	N/A	N/A	Stainless Steel	1 x $15.99 [6]	16.00
Hillman Hex Nut ¼-20"	N/A	N/A	Stainless Steel	2 x $0.17 [7]	1.00
				Total	$25.00

The parts that were 3D printed were not paid for as it is free for students in the Makerspace. All printed parts could be made from steel, aluminum, or other materials, however due to time and budgetary constraints these options were not viable.

6.1.2 Equipment list

List all the equipment that was needed to build this subsystem. This is different than the materials or software listed in the BOM.

Equipment:

- 0.25 nozzle size 3D printer

- 0.4 nozzle size 3D printer

- 0.8 nozzle size 3D printer
- Metal files
- Needle nose pliers
- Standard pliers
- Gorilla Glue
- Flat head screwdriver
- Hammer

6.1.3 Instructions

Step 1: Gather all the necessary equipment and materials specified above.

Step 2: Begin printing the various parts of the jig. Print the Base plates with the extruded holes pointing up. Print the rest of the parts in a manner that reduces the amount of support needed to print. Remember to two C-clamp arms, finishers, and knobs. (Parts are shown in Section 6 Production Documentation). It is recommended to print the base plate and c-clamp arm with larger connections to strengthen the jig.

Step 3: Once a part is done being printed remove the supports from the print. It is recommended to use needle nose pliers.

Step 4: File down all rough surfaces or remaining support residue on all surfaces. Most importantly on the areas that will be used to attach each part together.

Step 5: Organize the parts into two groups (one for each jig). Make sure you have all the required pieces in each group; these include: 1 base plate, 1 c-clamp arm, 1 finisher, and 1 Knob. Then add 1 metal bolt and 2 metal hex nuts.

Step 6: Using gorilla glue, glue the metal hex nuts into the c-clamp arm and knob. While waiting for the glue to dry on the hex nuts glue the top of the bolt to the finisher.

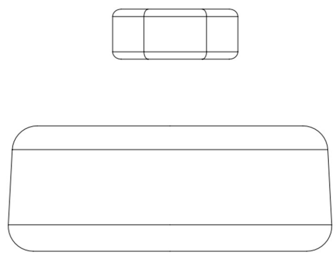

Figure 31: Front Exploded View of Hex Nut and Finisher

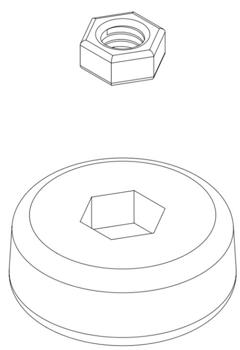

Figure 32: Isometric Exploded View of Hex Nut and Finisher

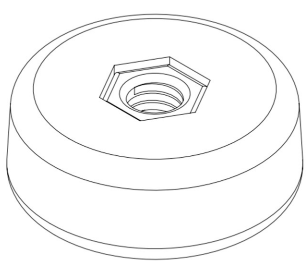

Figure 33: Isometric View of Hex Nut and Finisher Assembled

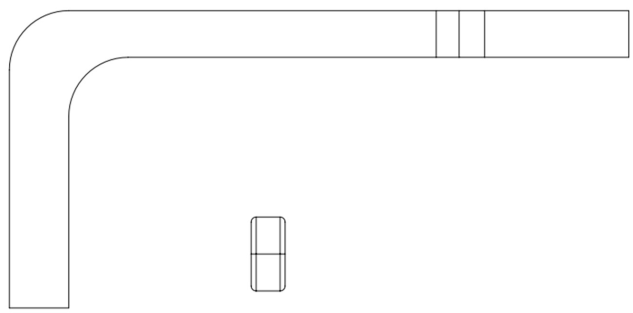

Figure 34: Side Exploded View of Hex Nut and Clamp Arm

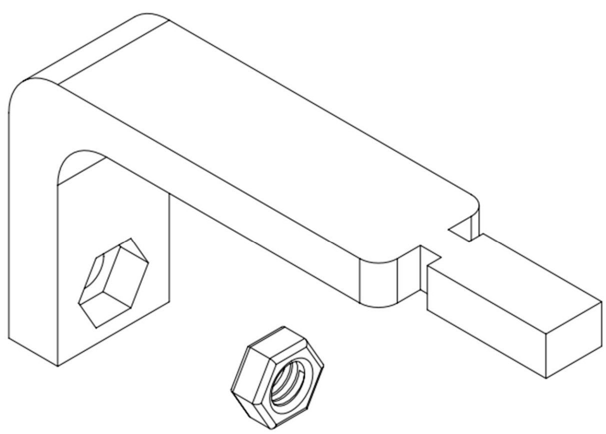

Figure 35: Isometric Exploded View of Hex Nut and Clamp Arm

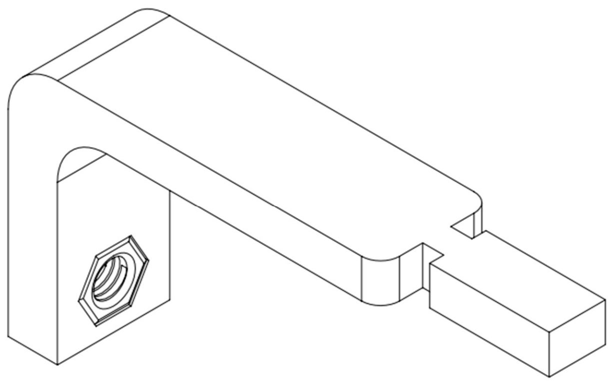

Figure 36: Isometric View of Assembled Hex Nut and Clamp Arm

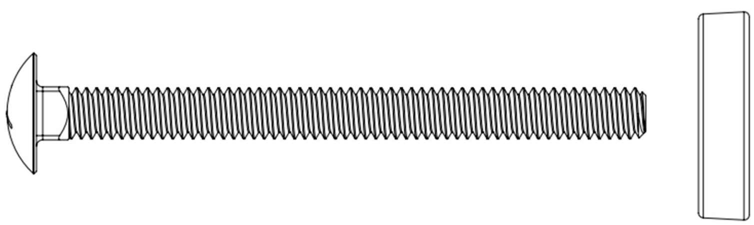

Figure 37: Side Exploded View of Carriage Bolt and Knob

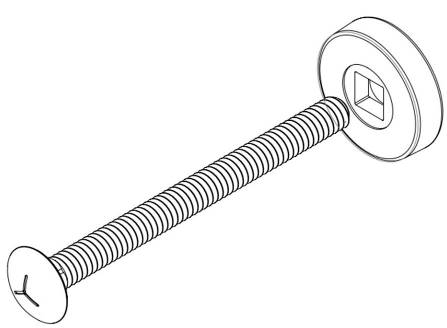

Figure 38: Isometric Exploded View of Carriage Bolt and Knob

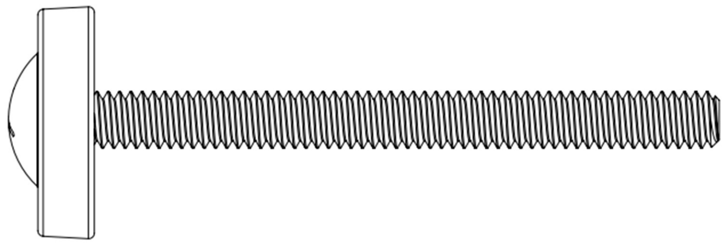

Figure 39: Side View of Assembled Carriage Bolt and Knob

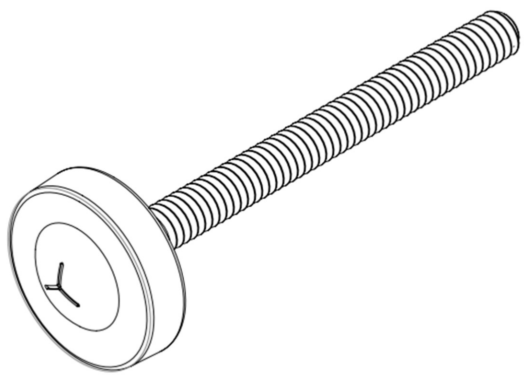

Figure 40: Isometric View of Assembled Carriage Bolt and Knob

Step 7: Attach the c-clamp arm to the base plate by inserting the end of the arm into the top of the base plate. Use moderate pressure to attach. If it is difficult or not possible to attach file down the sides of the c-clamp arm until it fits snuggly in the base plate.

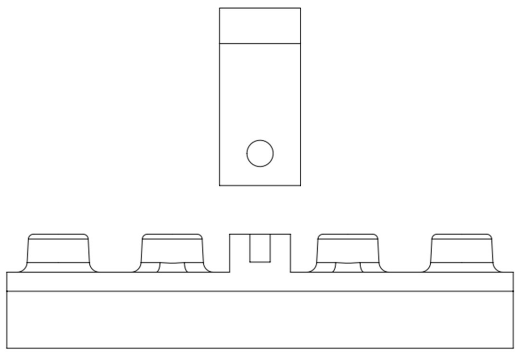

Figure 41: Front Exploded View of Assembling C-Clamp Arm to Base

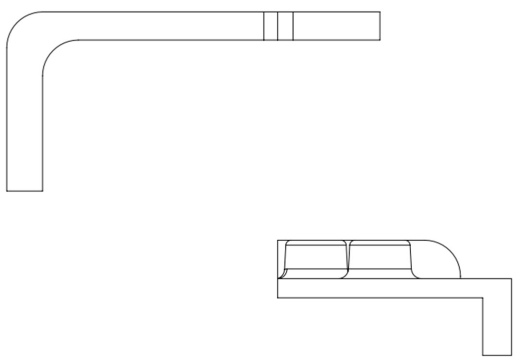

Figure 42: Side Exploded View of Assembling C-Clamp Arm to Base

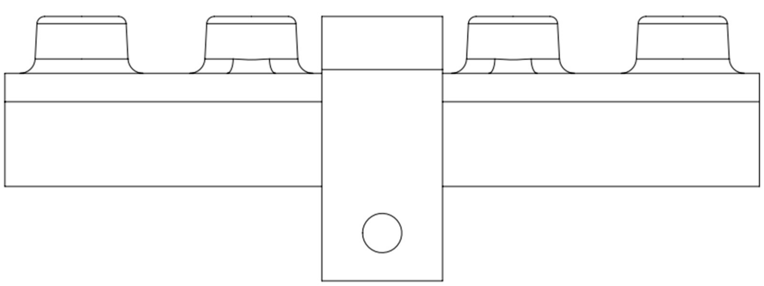

Figure 43: Front View of Assembled C-Clamp Arm to Base

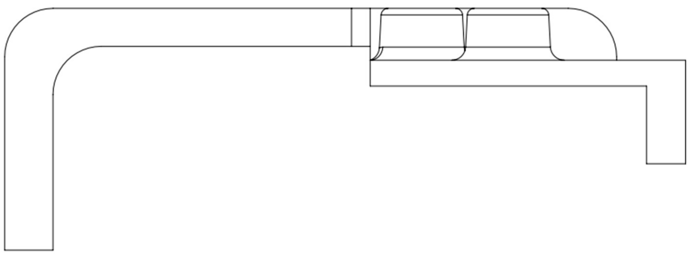

Figure 44: Side View of Assembled C-Clamp Arm to Base

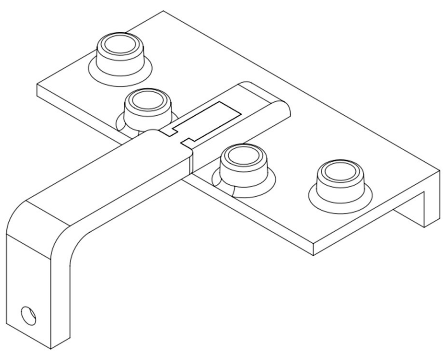

Figure 45: Isometric View of Assembled C-Clamp Arm to Base

Step 8: Thread the bolt (which is now glued to the knob) through the hex nut in the c-clamp arm.

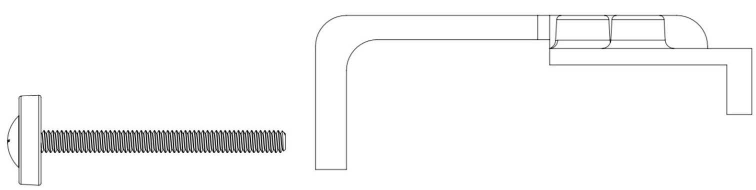

Figure 46: Side View of Exploded C-Clamp Arm and Carriage Bolt

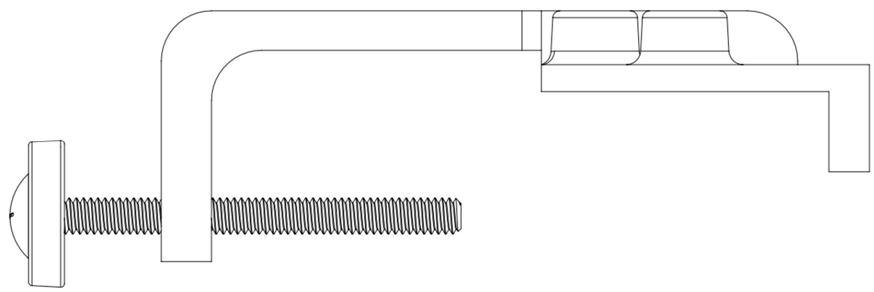

Figure 47: Side View of Assembled C-Clamp Arm and Carriage Bolt

Step 9: Thread the bolt into the hex nut glued into the finisher.

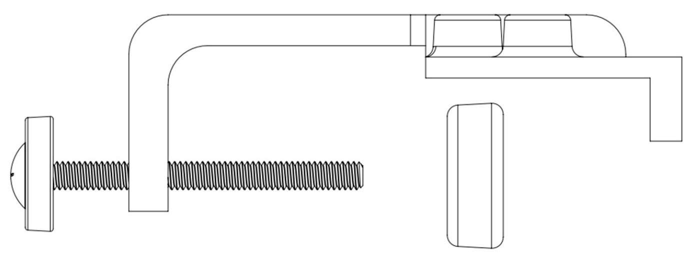

Figure 48: Side View of Exploded C-Clamp Arm and Finisher

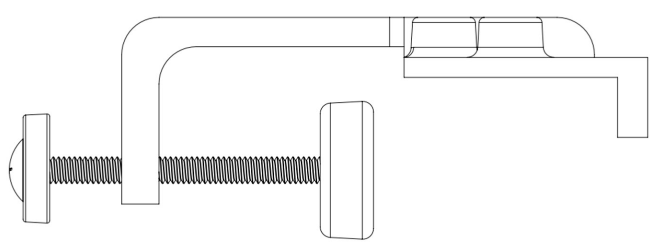

Figure 49: Side View of Assembled C-Clamp Arm and Finisher

Step 10: Repeat steps for another sized jig.

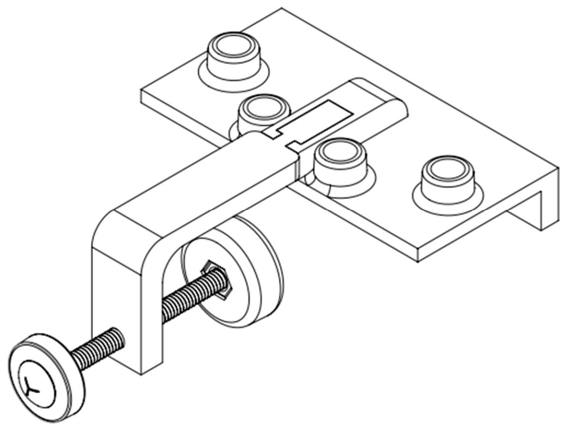

Figure 50: Isometric View of Assembled Jig

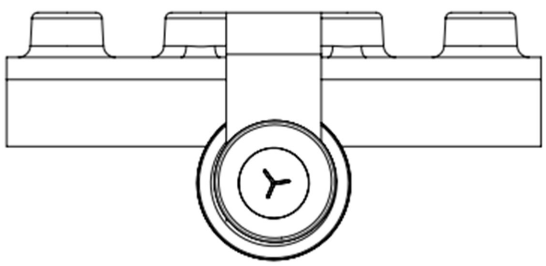

Figure 51: Front View of Assembled Jig

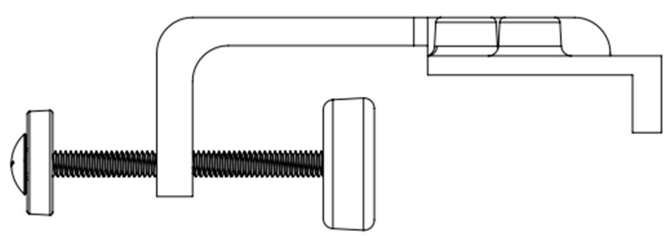

Figure 52: Side View of Assembled Jig

6.2 Testing & Validation

Table 4 Prototype testing plan

Test ID	***Test Objective (Why)***	***Description of Prototype used and of Basic Test Method (What)***	***Description of Results to be Recorded and how these results will be used (How)***	***Estimated Test duration and planned start date. (When)***
1	cost	Use both prototypes, gather materials needed for both.	Make sure the materials for the 4.5" jig do not exceed $10.20, and the cost for the 5" jig does not exceed $10.80	Start: Duration: 1 hour
2	Accuracy	Once again using both prototypes	We will be drilling the holes again, but this time we will be comparing the dimensions of the holes, and making sure they line up with the design criteria.	start: Duration: 1 hour
3	Damage	use both prototypes, no need for any drilling.	We will be fastening the prototypes to a door, and applying varying amounts pressure, to see if the coating really does protect the finish.	start: Duration:1 hour

6.2.1 Stopping Criteria

1. For the first test, the accumulation of materials will continue until the total cost meets $25.00 for either jig.
2. For the second test, we will perform drilling until the exact specifications of the client are met for both jigs.
3. For the third test, we will be applying pressure until we either see damage in the finish of the door, or damage in the clamping mechanism of the jig.

6.2.2 Client feedback

For our next prototype we will be making a few changes, for example, we will be making our tester jig from the 3D printer and no longer wood to ensure accuracy and mimic the door hinges different sizes and backsets. We will also be taking some two-part members and creating them as one-part members to decrease the chance of breaking and eliminating the potential moving parts. Our C clamp arm will be becoming one part. We will add a metallic paint finish to our jig to give it an aesthetic finish. Our C clamp screw is perfectly flush and moves freely within our wanted constraints. We will then test these changes and confirm if they work. Then we will create the final prototype for the 4.5 inch and repeat the same design for the 5-inch jig.

The client feedback was very informative, the c-clamp idea was met with positive reception, but the screw mechanism that we 3D printed was suggested to be replaced with a real, store-bought screw that we could integrate into the 3d printed mechanism. This was because it would prove difficult to 3d print the threads accurately. The store-bought screw will have minimal effect on the overall cost.

They like the C clamp idea however, with the 3d printed screw they suggested to use a real metal/steel screw from the hardware store to be able to thread the screw into the female part because using the 3d printed screw will be hard to successfully print the threading properly without failure and to thread it through without damaging it and making it inconsistent. The metal/steel screw will help us eliminate the uncertainty of getting a screw to print without failure, cut down on time and won't impact our budget very much since it will be minimal cost.

We showed them the prototypes of the other groups to compare ours with theirs. They thought that ours was the best out of all the other prototypes since we don't have any bulky structures and over complicated parts. This ensures the user-friendly approach that the client desires. Multiple groups wanted to use springs, they thought that wasn't the best idea especially if used for clamping the springs will ware and stretch which won't be cost effective if they must always replace them. So, our simple clamping mechanism is perfect since it won't ware as fast and will be more reliable over a long period of time. We also showed them a group who were using sandpaper for grip which they thought wasn't a very good choice since it would damage the finish. They liked our rubber piece on the end of the clamp since it would supply the proper amount of grip and stability to the end of the clamp to prevent any slippage as well as not damaging the wood finish. We also showed them our materials that we have decided to use. They thought it was the best we could do with the 50$ budget that we were given while keeping it durable. They did say that we should add as much metal and steel components as we can to help reinforce the jig but still stay within the desired budget.

6.2.3 Target Specifications

- Rigid (resistant to pressure from the drilling/tapping)

- Functional (fits the design criteria of both the 4.5” jig and the 5”.)
- Fits together, works when the screw is included.

6.2.4 Testing rig

Our first model testing rig was a plank of wood that is routered to the specifications of the 5 in and 4 ½ in hinges. It wasn’t a great way to test the jig as the wood had warped making the routing inaccurate and the depth uneven. When we made the testing rig, we eyeballed the depth with a combination square, this mixed with the warping of the wood’s surface caused the inaccuracies. When the jig was mated with the testing rig, it was established that a new method to test accuracy would be needed. We then devised the plan for a 3D printed test platform that would be more accurate and be able to tell us if our jig would be accurate while the older model would be used to test the drilling capability. The 3D model would be like the wooden model where it’s a plank with a cutout for the jig with markings for the drilling holes of the 5 in and 4 ½ in hinges. Since it’s 3D printed the precision will be much higher.

6.2.5 Testing Results

- Screw test: screw functioned properly, exerted too much torque on the base, further designing of the base is needed.
- Durability: when subjected to repetitive force, the base of the jig snapped.
- Heat test: when subjected to an open flame, parts of the c-clamp arm melted.

6.2.6 Destructive section / Test

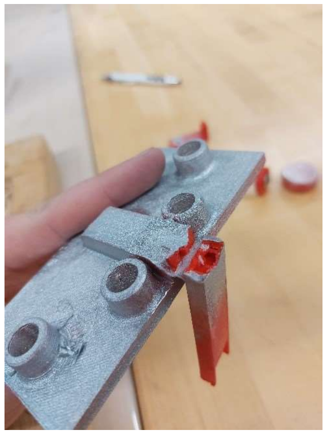

Figure 53: Destructive Testing Part I

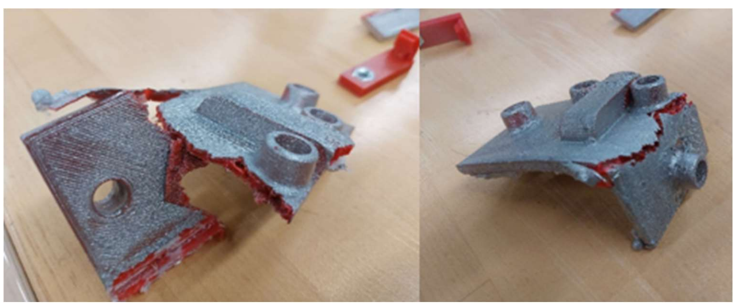

Figure 54: Destructive Testing Part II

The goal of this test is to accurately determine the maximum amount of stress that the jig can handle in the work environment. While also determining sources of failures and weak points in the design.

6.2.7 Acceptable Fidelity

For the accuracy test of the jig, as stated in our test plan we will be doing trials on a wood rig to mimic the door and backset to test the accuracy of our drilling and taping. We will be doing continuous trials of drilling and taping using our jig. We won’t stop until we do multiple successful trials in a row to ensure that the accuracy doesn't change and that it stays consistent. For the durability test we will be measuring how much stress and force it can take, by using various testing methods to test the strength of our jig and the quality of the jig. We will be making changes and modifying it until it reaches the same level of quality or better than the jigs they would use in the workshop. For ease of use will be giving random people the jig to carry out the drilling and tapping and record the performance. We will be doing these field tests until we get a consistent number of successful trials where the user drills and taps the holes to the clients desired measurements without knowing our end goal. This will ensure that the tool is easy to use/ user friendly and won't be confusing in professional hands.

7 Conclusions and Recommendations for Future Work

During the entire project, we learned a few important lessons. The first one is to make sure that arrive early in the 3D printing lab to ensure that we have access to a 3D printer. The 3D printing lab is often busy and there are not enough printers for everybody. Because of this, our final prototype was delayed by a couple of days. These situations can affect the overall result of the project because it can reduce the amount of time that you must test your prototypes or to make a prototype that you can showcase to your client. Also, we learned the importance of starting the project early. By doing this, we made sure that we really understood what we were supposed to do, and we had more time to develop a final product. Starting early gives us an additional buffer time in case the product/prototype isn't satisfying the client's needs. In addition, we recommend that there's a "captain" in each team. Someone with good leadership skills and experience because it will make the project more organized and more enjoyable. It can significantly increase the team's chances of success.

In a scenario where we add a few more months to this project, we would have made an actual steel prototype to test in a more realistic environment. Based on our client's final feedback, we can easily claim that our design meets the criteria but based on the judges from design day, we would have tried to improve our c-clamp mechanism by making it less energy draining.

8 References

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