April 2018

Development of Automotive Handheld Tool

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A Major Qualifying Project Report submitted to the Faculty of Worcester Polytechnic Institute in partial fulfillment of the requirements for the Degree of Bachelor of Science

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Submitted to: Mechanical Engineering Department

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Abstract

In the automotive repair industry doors are being stripped (removing the handle, mirror, side molding) every day to be repainted. Insurance appraisers will pay for up to one hour for removal and installing door moldings. The process includes removing leftover adhesive tape and re-taping for installation. The current industry practice uses a razor blade by hand to remove the adhesive, which is timely and aggravating for technicians. The goal of this project is to develop a motorized handheld tool that removes double-sided adhesive tape from door moldings in a timely fashion. A focus for this objective was modeling a device to fit the tight constraints of the tool's operating path (<0.3in). A second objective was to explore the different angles for our blade to see its effects on adhesive removal. An analysis of the design and its several iterations, along with fabrication details are discussed in this report.

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1.0 Introduction

1.1 Objective of Project

The goal of this product development project is to create a handheld tool which removes double sided adhesives from automotive door moldings. There currently is no long term solution for this process, and as a result technicians are forced to use razor blades by hand for removal. This method of removal is timely, and often aggravating for technicians. After having first-hand experience at an automotive repair shop, our team came up with a solution to expedite this process. After researching and exploring different methods, our team decided on using an oscillating razor blade for quick and effective removal of adhesive tape. The tool is designed to be handheld so the operator can use it with ease and can maintain a steady control over the tool while it is functioning. The system is powered by a 12V DC motor, the motor is powered electrically by a 9V battery and a AAA battery pack inserted on the back end of the tool. The work piece is on the front end of the tool where the head oscillates and the razor blade is held. The head is fitted with a removable feature that allows for the user to change the razor blade out when it becomes dull. The entire tool is encapsulated in a smooth shell that allows the operator to hold it and maintain a grip while under operation.

1.2 Needs Assessment

Body doors are being stripped every day in the automotive repair industry, whether the door itself has damage or the parts on the door need to be removed and installed later (called an R&I in the industry). As an example, let's say a vehicle is hit in the front and the front left fender needs to be replaced. The factory metallic paint on the vehicle means that the repair calls for blending color into the front driver's side door. This blending method helps hide the new paint on replacement fender by transitioning color into the existing body. The parts that are removed when repairing the front door are the: handle, window trim, mirror, molding, and any badges. The rear door only consists of the same list but without the mirror. In each case, the insurance company will typically write (on the estimate) for an R&I on each part for undamaged parts. This can range from 0.1 hours to a maximum of 1.0 hour, and for the case of moldings this includes removing the molding from the door, removing the adhesive from the molding, re-taping the molding, and installing it back on the vehicle. The initial estimate from the insurance company dictates how much money the shop will get for a repair. As a result, it is important that employees not only do quality work but also work in a timely fashion. For the case of moldings this process is more in depth than removing and installing a mirror, which means a shop could potentially lose money on a repair if the employee spends more than the allotted time.

Figure 1: Photo of the automotive painting style/technique called "blending" [1]

Moldings protect the face of doors from hitting other vehicles and objects when at a standstill and they also often play a big role in the aesthetic design of the vehicles body side. For this reason, we see moldings come in all different shapes and sizes, utilizing chrome coating, body color paint, or textured plastic (polyvinyl chloride). In any case, the molding hides the doubled sided tape from someone viewing the car. This makes it especially difficult for technicians when removing the adhesive since the edges of the moldings cannot be damaged. Or else, the damage would be reflected in the overall appearance of the car. This is why traditional oscillators and dremels are not used. The surface needs to be free of adhesive so a liquid promoter can be applied before re-taping the molding for installation. The quality of the surface is left up to the technician and if it is not completely removed, the molding can be at risk of falling off during operation. The forces from the environment on the molding are great, as you can imagine the drag forces on a car driving on the highway at over 70 mph. These forces are the reason it is so important the technicians ensure the surface is completely removed of the old adhesive because even the smallest amount of leftover adhesive can allow enough drag forces to rip the entire molding off.

On the topic of removing the leftover adhesive, moldings have tight workspaces in order to not damage the fragile edge. This is the main reason why other automotive removal tools are not used for this specific process. In terms of lean manufacturing, the current method of removal can be considered an excess processing situation. Our tool aims to effectively remove the double sided adhesive in a time efficient manner, without damaging the molding edges. This is a double edged need since methods are very time consuming, but they are also effective in removing the tape entirely. Our tool needs to be able to remove the tape faster than current methods as well as more, if not as efficiently as current methods.

1.3 Design Goals

As stated in in Section 1.B our tool aims to suit the needs the current industry removal methods lack. The goals for our design are:

1. Removing double sided adhesive down to the surface.
2. Removing adhesive in under two minutes
3. Developing the tool into a handheld application
4. Oscillate in a workspace that is no bigger than small moldings tape (¼” tape)
5. Device can withstand a contact force greater than the adhesive force (30 dynes/cm) [2]
6. Option for exchangeable blades

The initial goal was to figure out a method to remove double sided adhesive from the surface of a door molding. As mentioned before, the common industry practice is to use a razor blade, and we wanted to use that as a base for our research. A second goal was to ensure that the adhesive be removed in a time efficient manner. The current practice takes time, and to make a product which will succeed in the market we had to ensure that it improved this process. The industry standard was set at two minutes to align with the lower boundary of insurance quotes. As mentioned in Section 1.B insurance quotes can be as little as 0.1 hr, which translates to six minutes for the entire R&I process. Another need our tool must satisfy is it must be a handheld tool that can be operated using one hand at a time. During the abstraction and synthesis portion of our design, we wanted to base our tool similar to that of an electric groomer/shaver. The smooth operation of an electric groomer gives the operator full control. This is important because during operation it would be easier for the user to be able to secure the molding with their opposite hand, allowing for a cleaner and more efficient cut. The fourth design parameter is focused on accompanying all sizes and shapes of automotive door moldings. Our tool must appeal to all automotive manufacturers, all makes and models. Our device should be able to operate on even the smallest molding and we used the smallest molding as our baseline (0.55in from 2007 Nissan Rogue). The type of double sided adhesive tape used on car moldings has powerful adhesive forces keeping the two bonded (30 dynes/cm) [2]. These forces make another need for our tool to be able to not only withstand but overcome the adhesive forces of the tape without breaking (for ¼" tape the adhesive force translates to $1.905*10^{-4}$ N). These forces will not only wear down on the structure of our tool but will also wear down on the work piece (the razor blade). Because of this, a need our tool must include is the ability to have interchangeable blades to keep the tool functional even after extended hours of use.

1.4 System Description

The product features a revolving 12V DC motor (Appendix) that through a CAM action causes the razorblade tray to oscillate, the entire mechanism will slide on dual guide shafts which are able to sustain the force of the adhesive to the molding ($1.905*10^{-4}$ N). The tool is powered by a 9V battery and (3) AAA batteries, all wired in series giving the motor 12.5 volts. The base and shell were printed in an Object 260 Connex machine (jets droplets onto build tray and is then cured with UV light) using VeroWhitePlus. The internal components, given their size (features as small as 0.03 in) and robust geometries were printed on a Formlabs Mk. II (uses a liquid resin and is cured with UV light) using a durable polymer resin. The front slide tray encases a set piece, which when locked holds the razor blade in place. The pull tab uses a U-shaped snap fit which when released, pulls out the two shafts that constrain the set piece. Allowing movement of the set piece gives us the option of an interchangeable blade. The slide tray also slides out to allow for the product to be cleaned. The bottom base connects to the top shell by L-shaped snap fit and the overall size of the entire tool is 7.20” x 3.29” x 3.01” in.

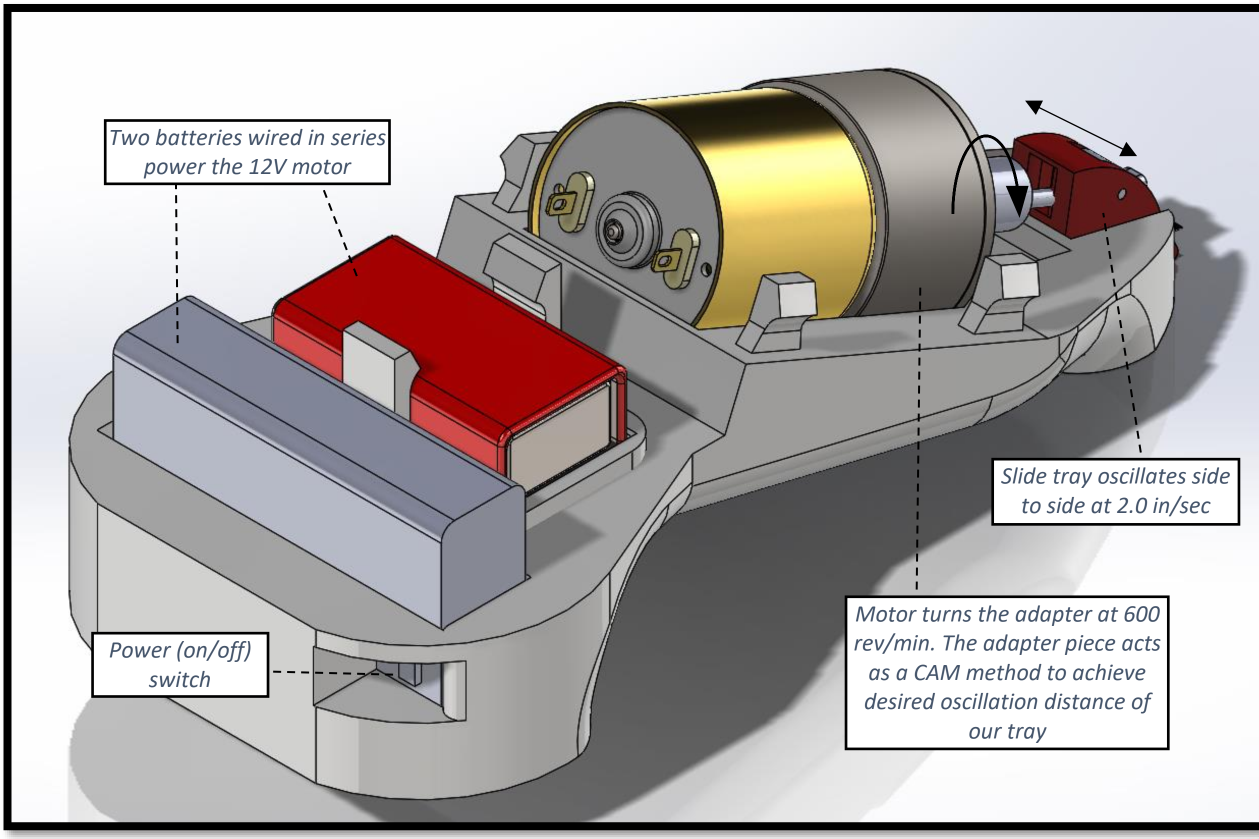
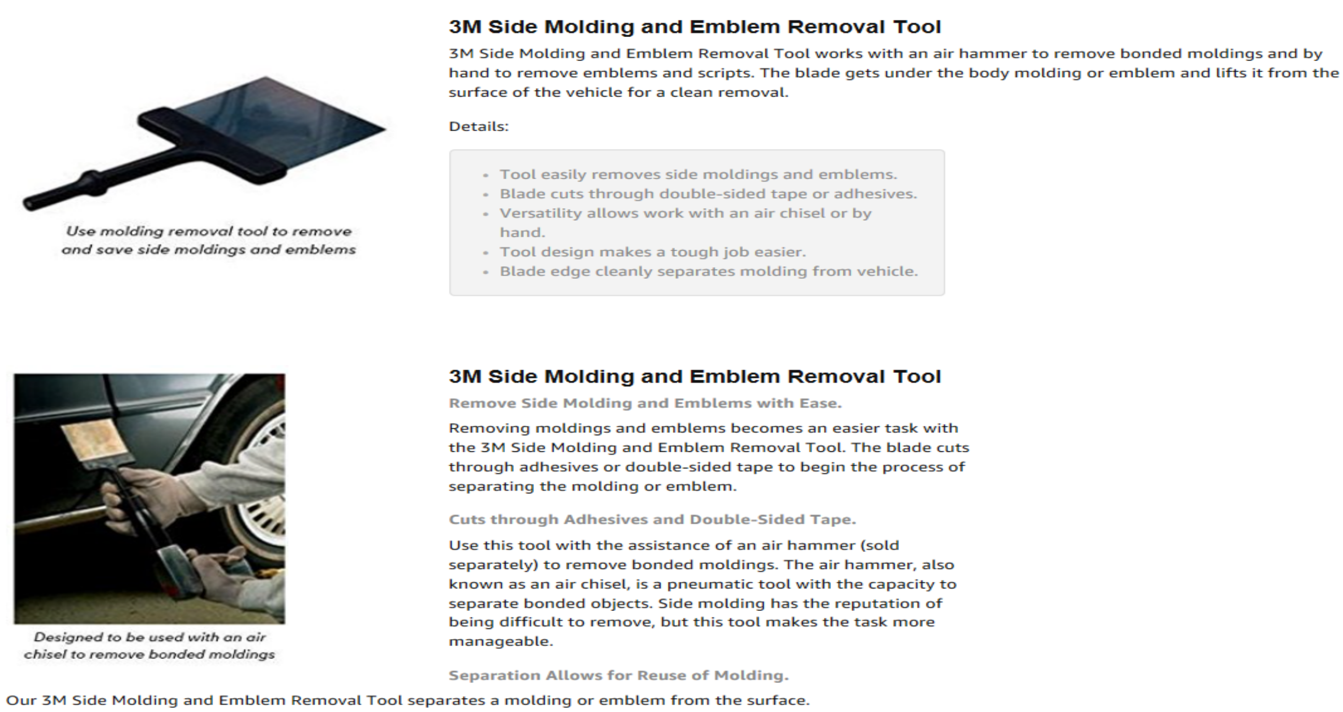


Figure 2: System Description

2.0 Background

2.1 Prior and Current Automotive Tools

The automotive door molding [3] was introduced in the early 80's and the tooling industry has been searching for solutions for removal ever since. The automotive repair industry is one that shares secrets and techniques with one another, but everyone has their own working style. All workers share the same goal, regardless of the means, of doing as little damage to the vehicle as possible to avoid extra repairs. For molding removal this is hard to avoid. One of the first tools to separate the door molding from the body panel was created by 3M. This product (Figure 3) was attached to an air chisel in order to cut through the adhesive and separate the molding from the body. According to amazon this product was first available on November 2006.



3M Side Molding and Emblem Removal Tool

3M Side Molding and Emblem Removal Tool works with an air hammer to remove bonded moldings and by hand to remove emblems and scripts. The blade gets under the body molding or emblem and lifts it from the surface of the vehicle for a clean removal.

Use molding removal tool to remove and save side moldings and emblems

Details:

- Tool easily removes side moldings and emblems.
- Blade cuts through double-sided tape or adhesives.
- Versatility allows work with an air chisel or by hand.
- Tool design makes a tough job easier.
- Blade edge cleanly separates molding from vehicle.

3M Side Molding and Emblem Removal Tool

Remove Side Molding and Emblems with Ease.

Removing moldings and emblems becomes an easier task with the 3M Side Molding and Emblem Removal Tool. The blade cuts through adhesives or double-sided tape to begin the process of separating the molding or emblem.

Designed to be used with an air chisel to remove bonded moldings

Cuts through Adhesives and Double-Sided Tape.

Use this tool with the assistance of an air hammer (sold separately) to remove bonded moldings. The air hammer, also known as an air chisel, is a pneumatic tool with the capacity to separate bonded objects. Side molding has the reputation of being difficult to remove, but this tool makes the task more manageable.

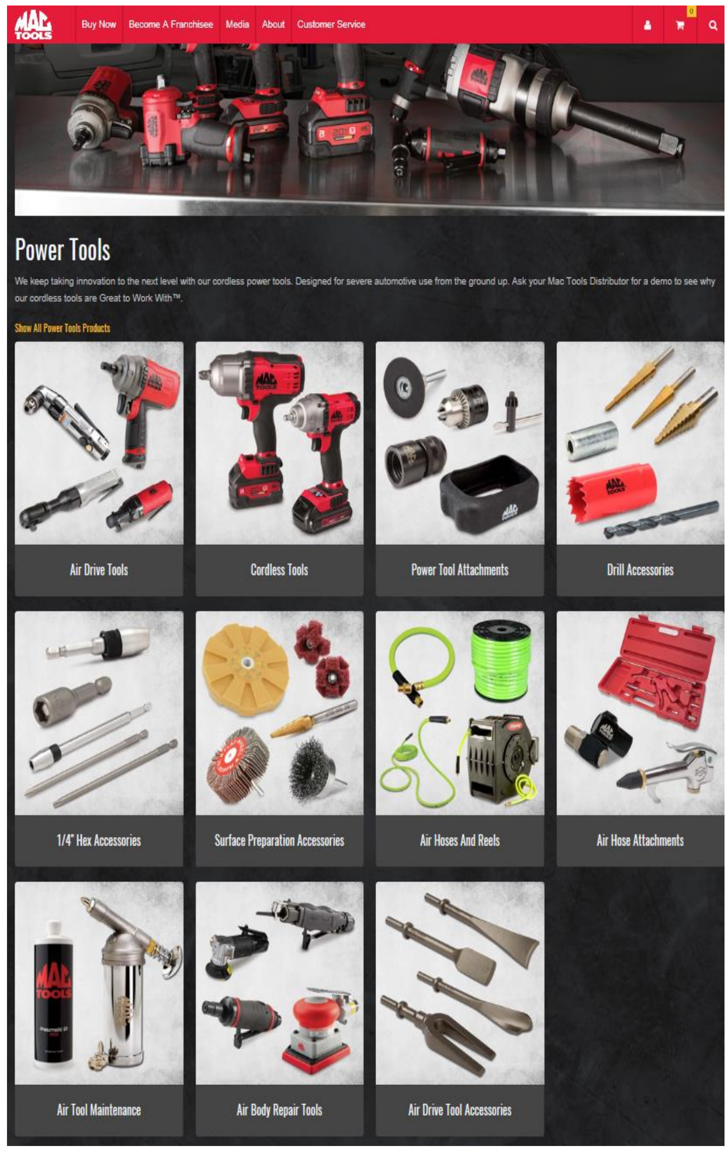
Separation Allows for Reuse of Molding.

Our 3M Side Molding and Emblem Removal Tool separates a molding or emblem from the surface.

Figure 3: A screenshot from Amazon of the product description [4]

A month later, inventor Min-Chi Yu created the plastic trim tool kit [5], which is still widely used today. Prior to this invention, the removal of decorative trims was done by wedging a thin-tipped flathead screwdriver into the gap of the decorative trim and the vehicle surface. The trim kit became very popular and is sold by many automotive tooling companies today. In addition, it is now the main tool for removing moldings from the door itself. The hard plastic allows the user to pry back the molding without damaging the molding or door itself. Both of the tools listed above help provide aid in the process of R&I a door molding. However, neither address the biggest time consumption portion of the process, removing the leftover adhesive from the door

Figure 5: A picture of Min-Chi Yu's plastic tool kit [6]



molding. Industry leader Mac Tools does not offer a device or a solution for this problem, as you can see by the screenshots of their online store.

The competition (Mac Tools, Snap-On, 3M) all dominate the tooling industry for the automotive sector. Their products are sold to perform, be durable, and outlast the competition. Each company (with the exception of 3M) offers 12V ratchets, impact drive wrenches, and drills. We anticipate our product to be in the same category as these power tools. The price points of these tools are high, as they are top of the line products. However, this gives us a good insight to the price ranges for 12V handheld cordless tools.

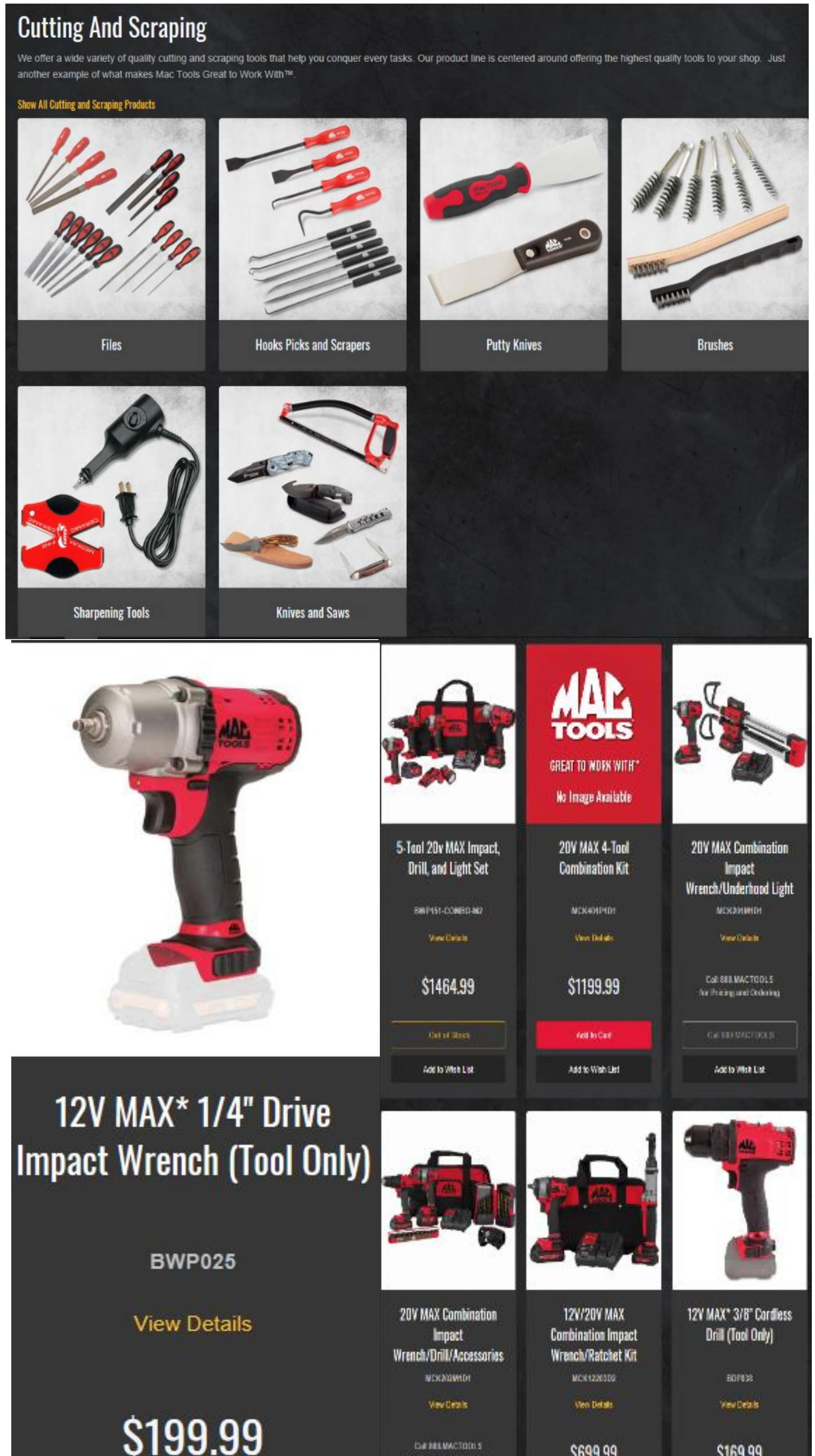


Figure 6: Screenshots from MacTools online power tools catalog [7]

2.2 Description of Customer

The three stakeholders that we were able to identify are the technician, the repair shop management, and the customer of the vehicle. Our primary customer that we are targeting is the technician who physically working on the vehicle. Like many other jobs technicians and mechanics are evaluated on performance, in their case it is quality of work. For the case of adhesive removal, the complete removal before re-taping is left for the discretion of the technician. If the adhesive is not removed completely it will affect the bonding of the new adhesive tape. Which can affect the appearance or worst case, lead to failure while operating (molding falls off car) which is a hazard for everyone on the road. As mentioned before, the standard procedure for removing adhesive from a molding involves using a razor blade by hand. For this, individuals can experience cuts from user error. Even though this is not guaranteed, or occurring for every technician working on a vehicle, it still poses a threat to the mechanics biggest tool, their own hands. For this reason, if we were to create a product to reduce this risk, we can see it appealing to many technicians across the country.

In addition, it is interesting to note the culture of tool sales in the automotive repair industry. The big automotive tool companies (Snap-On, Mac Tools) utilize a franchise method for distribution. Employees are granted a vehicle and drive to local automotive shops where they build relationships with their customers. Franchisee's build these relationships by selling tools directly out of their truck along with passing out handheld catalogs on a weekly basis. The relationships between tooling representatives and workers are very strong since customers are given the option of paying off purchased goods on a minimal or zero interest loan. The method of purchasing tools allows for customers to buy several tools at a time and build up his/her collection (especially helpful for new employees). The environment created by this sales technique makes it very easy for mechanics to spend a lot of money on their tools, and as a result creates an environment where having new tools becomes “the status quo”. Simply put, mechanics love buying new tools.

While mechanics and technicians are our primary focus for sales, it is important to note the other stakeholders that will benefit from our product. The first being shop owners/managers. In a more common than not situation, a customer will return complaining about an improperly installed molding (failing to remove all leftover adhesive and the molding doesn't stick to the door). In this situation, the shop will consider a replacement (OEM or LKQ) or re applying tape to the existing molding if it can be fixed. In either situation, the defect decreases product value of the company, and even worse can enable customers to complain and write bad reviews about the business. From the perspective of the customer, aside from the aesthetic degradation the danger of having a molding failing during operation can lead to an accident which the person is responsible for.

3.0 Experimental Testing

3.1 Design Parameters

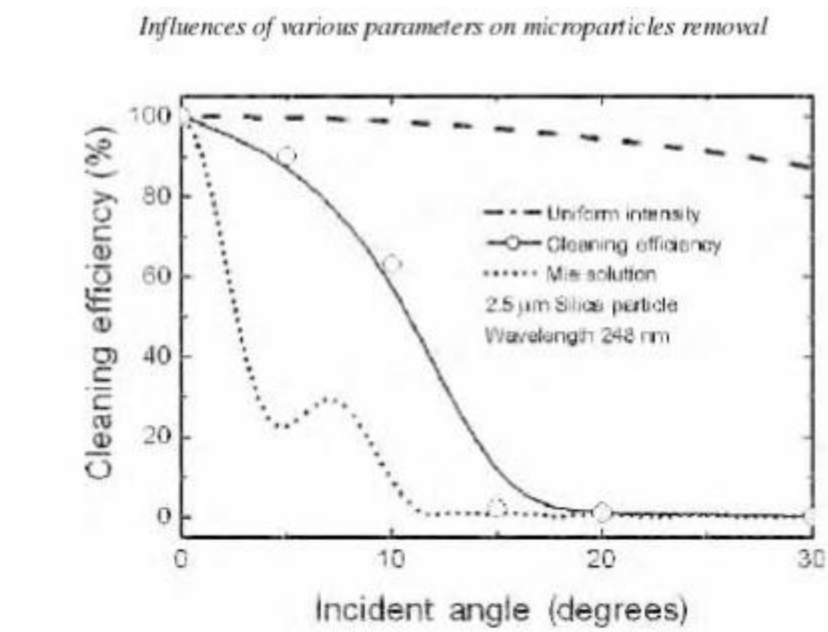
In the abstraction and synthesis portion of our design process, we explored many options to solve the problem of adhesive removal. The three we considered in our brainstorming phase were a razor, laser, and using thermal conduction as means for removal. In product design, it is very important to approach the problem with an open mind and from all angles. After preliminary research into each method, our team found it best to compile our ideas into a Pugh Matrix so we could focus on one method. The Pugh matrix serves as an effective method for comparing and evaluating concepts/designs. For our matrix, we listed important parameters on the left and each member would rank the concept from low (-1), neutral (0), and high (+1).

Method Of Removal	Razor	Laser	Thermal Conduction
Feasibility	+1 +1	-1 -1	-1 0
Assembly will be low cost	+1 +1	0 -1	0 0
Assembly will be safe for users	0 -1	+1 +1	0 0

The device will be robust	0 0	+1 0	+1 0
The device will be compact/portable	+1 +1	0 +1	0 -1
Cordless (battery powered)	+1 +1	0 0	-1 -1
Longevity	-1 -1	0 +1	+1 +1
Totals	**5**	**2**	**-1**

Table 1: A Pugh Matrix featuring our initial design concepts

After deciding that our team was going to pursue the razor idea, we had to develop another set of design parameters for the specific concept. The several vital design parameters we included for the tool to be feasible started with the tool's oscillation distance. Since we designed this tool specifically to remove adhesive from car moldings, knew our device required an oscillation distance of 0.3 inches. This length is equivalent to the width of the smallest standard molding tape. However, we did not know how fast our blade needed to be going to effectively separate the adhesive tape from the door molding. This was our first design parameter we needed to explore further, oscillation speed. A second was the angle of attack the blade would be with the molding. After investigating removal processes from flat plate surfaces, our team came across a study which dealt with the removal of particle adhesives. The study [8] was conducted on the principle of separating adhesives from silicon wafers using advanced methods such as ultrasonic, megasonics, and laser surface cleaning. Now obviously our project is not utilizing these advanced methods but a very important part of the study we found was the variable adjustment of attack angle to optimize removal percentage. As shown in Graph 1, their research concluded that the closer to 0° the angle of attack was, the more effective the removal process was and anything above 20° was found to be ineffective. This helped our decision making later on in our iterative design process when deciding what angle our blade would function at.



Graph 1: Cleaning efficiency vs incident angle from "Particles on Surfaces 8: Detection, Adhesion and Removal" [8]

3.2 Oscillation Experiment

The first phase in this project was the experimental phase where we set out to prove oscillating razor blades are an effective adhesive removal method. To test this, we designed an experiment that utilized something we called the 'Scotch Yoke Mechanism.' The Scotch Yoke Mechanism (Figure 6) translates rotational motion from a 9V motor to linear oscillating motion. Our team decided the most efficient way to build the Scotch Yoke was through a synergetic approach, we decided to use the method of concurrent design. Half of our team designed the components of the Scotch Yoke Mechanism that required 3D rapid prototyping through the use of CAM software, SolidWorks in our specific case. The other half of our team used CAM software to both design and create the parts that we milled using CNC machining.

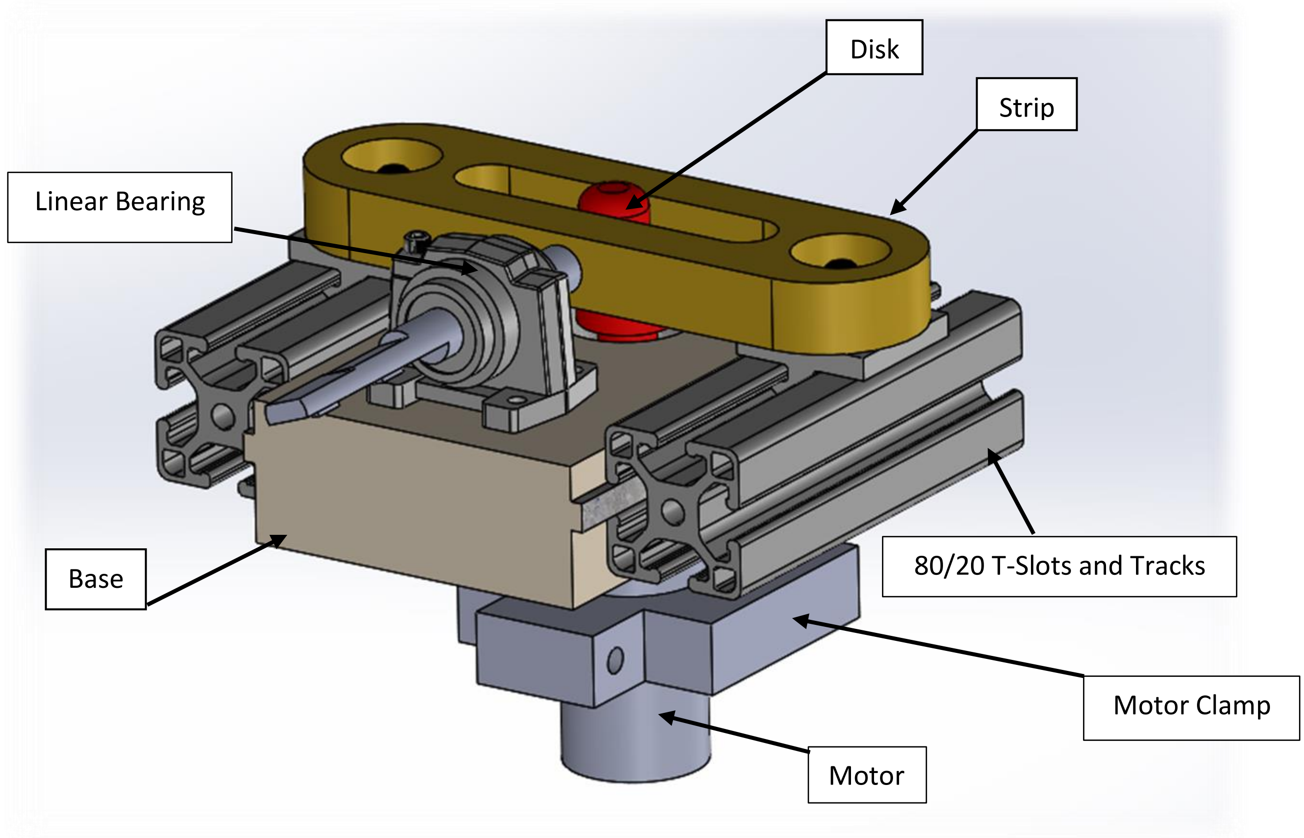


Figure 6: CAD Model of the Scotch Yoke Mechanism

The overall system consisted several main parts, the first being the disk which was a dowel with an offset cylinder on the top. The disk was held on through the base and connected at the top into the strip. The base held the mechanism together and utilizing ball bearings as well as 80/20 T-slots we were able to reduce the frictional losses the system encountered. The clamp held the motor in place, both of which were held steady by the 2x4 blocks we used as stands. By utilizing a set screw to conjoin the two, the motor spun the disk's offset pin which rotated along the strip's center track and caused the strip to oscillate; we placed a modified razor blade onto the end of the strip and used that as our cutting point. We created the parts for the Scotch Yoke Mechanism through CNC machining as well as 3D rapid prototyping. A further elaboration on the dimensions of each individual part can be found in the appendix.

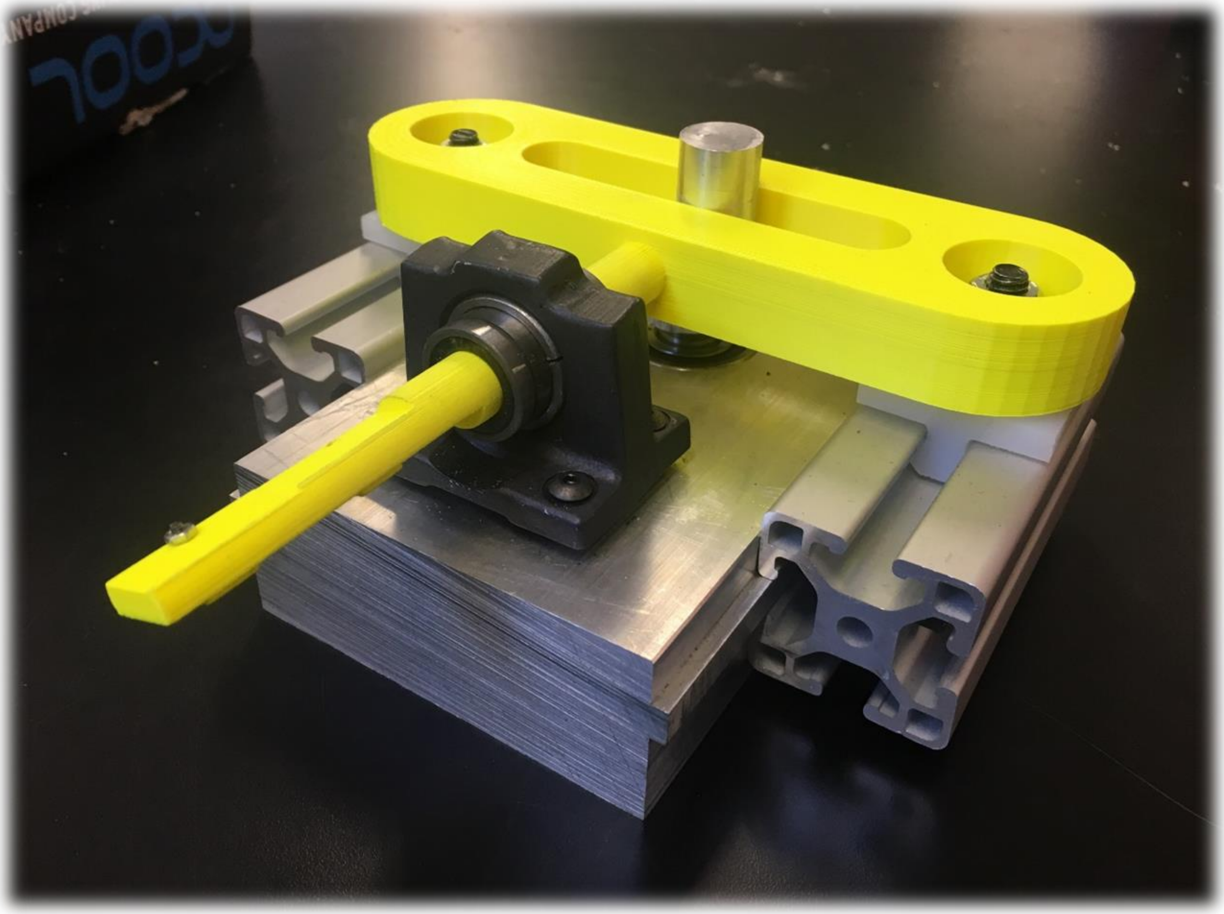


Figure 9: The completed Scotch Yoke Mechanism

Once the parts were finished, we assembled the mechanism and began our experimental testing against a car molding with adhesives attached. Unfortunately when we tested the mechanism it was unsuccessful in efficiently cutting through or separating the tape. After our failure we began an experimental analysis to see exactly where the experiment went wrong. One of the first observations we made was a lack of oscillation speed on the strip. Along with a lack of speed the razor blade also lacked enough torque to physically drive the blade through and cut the adhesive, both of these problems stemming from the motor we used.

If we were to redo this experiment there are a multitude of factors we would have changed. One of the first changes that would have made this experiment more successful would have been redesigning the strip to have four points of stabilization opposed to two (see Appendix 6). Along with the blades lack of cutting speed and the motor's lack of torque, we believe that the two points did not constrain the device in the Z direction enough to keep it perfectly steady during operation. We also believe this, along with the lack of torque from the motor, caused a lack of stability to keep the blade sturdy enough to physically cut the tape. The biggest problem in the experiment was the motor we decided to use and our idea to base the entire experiment around it. In retrospect the smarter course of action would have been to determine our experimental factors (torque, cutting speed, stabilization forces, etc.) and find a motor that suited our needs opposed to suiting our needs to the motor that was most readily available.

The biggest design parameter we learned from our experiment was to alter the oscillation speed of the blade by utilizing a larger motor that had a gearbox, unlike our 9V which lacked one. Also the conjoining relation between the disk and strip (an offset pin on an open ended slot) was the basis for how we designed the internals of our final iteration. The Scotch Yoke Mechanism failed in proving the effectiveness on our theory on separation, but did give us a more wholesome understanding of what exact design factors should be accounted for in our final iteration.

3.3 Validating Proof of Concept

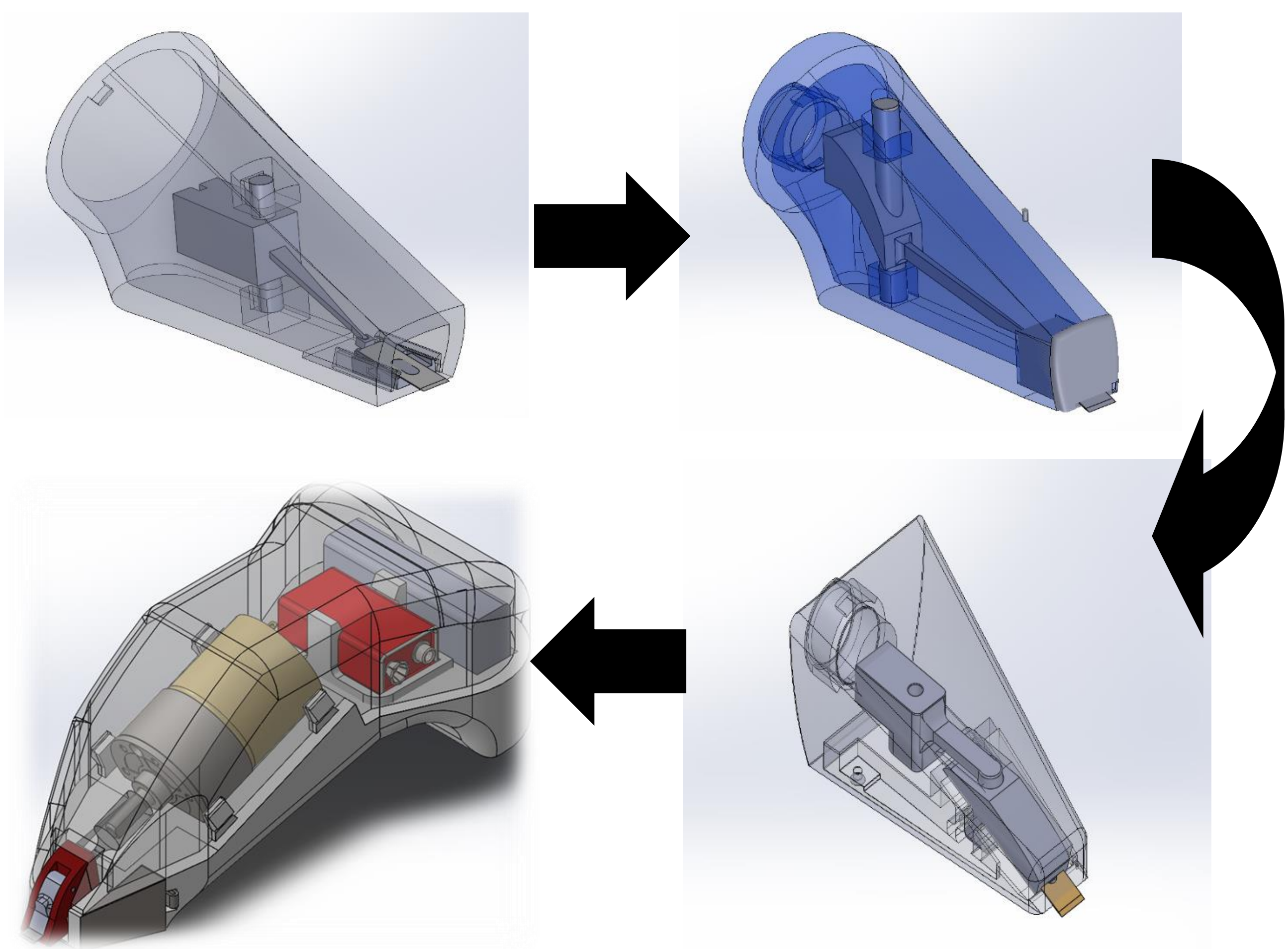
The Scotch Yoke Mechanism failure set our team back months on our project timeline that we mapped out at the beginning of the year. Properly designing and manufacturing another Scotch Yoke Mechanism that accounted for our failures with the original design would have taken us weeks and we only had a handful of days before our deadline. Due to the time we lost, we were forced to resort to coarse means of proving our concept. Our team took an electric groomer that we had at home and cut off the teeth that were meant for cutting hair. We then replaced the teeth with the razor blade used on our Scotch Yoke Mechanism and secured it into place. Then, when the blade was properly secured we turned on the motor and in place of what was once oscillating hair clippers was our razor blade. We then took the handheld blade and tested it against the double sided adhesive connected to a car molding. After doing no calculations or preparation for this experiment other than attaching the blade and hoping it worked, the mechanism luckily provided enough of an oscillation speed and torque to separate the tape from the car molding. Although the prototype was rough it did enough of a job to prove to us that the oscillating razor blade method was an effective means of separating tape, this allowed us to continue the next stage of designing a prototype.

Figure 10: Proof of Concept Prototype

4.0 Technical Sections

4.1 Evolution of Prototypes

The entire design cycle of our tool went through four micro cycles, or iterations. In the beginning our goal was to improve upon our initial prototype used for proof of concept. Improving by optimize a removable head which would attach and use the existing electric shaver as a power source; by the end of our design phase we shifted away from using an existing motor and created a tool that had its own. In each iteration we attempted to explore different design techniques, and the learning outcome was important for each.



4.1.1 Lessons Learned from Iterations 1 + 2

From the first and second iterations, we gained a further understanding on core engineering principles that surround the field of product design. The first being, designing for assembly. In an effort to model a head which could be attached to our electric groomer, we decided to use a loft feature to create our shell shape. Modeling around the razor we attempted to get it as low as possible to the cutting surface and design from there. The adapter was supposed to translate the rotational motion of our offset pin (from the electric shaver motor) and make our tray slide side to side. The blade tray, which held our blade in place through the use of snap fits, was inserted to a block with a cut out for an upside down “T” which would constrain our linear motion. This block was secured by a snap fit hold it down and constrain our oscillating piece in the vertical direction.

There were multiple components we designed that were simply too small for us to feasibly use without breaking due to small tolerances, some as small as three hundredths of an inch; this was also a problem in the first iteration as well but we did not notice it until further examination of the second. It was during these first two iterations that we learned the importance of ANSYS Finite Element Analysis (FEA) in testing the strength of the parts we designed. In iteration 1, we saw this with the snap fits to hold down the blade. Using ANSYS software we confirmed that our parts were too small and they would break under the stress forces applied during use.

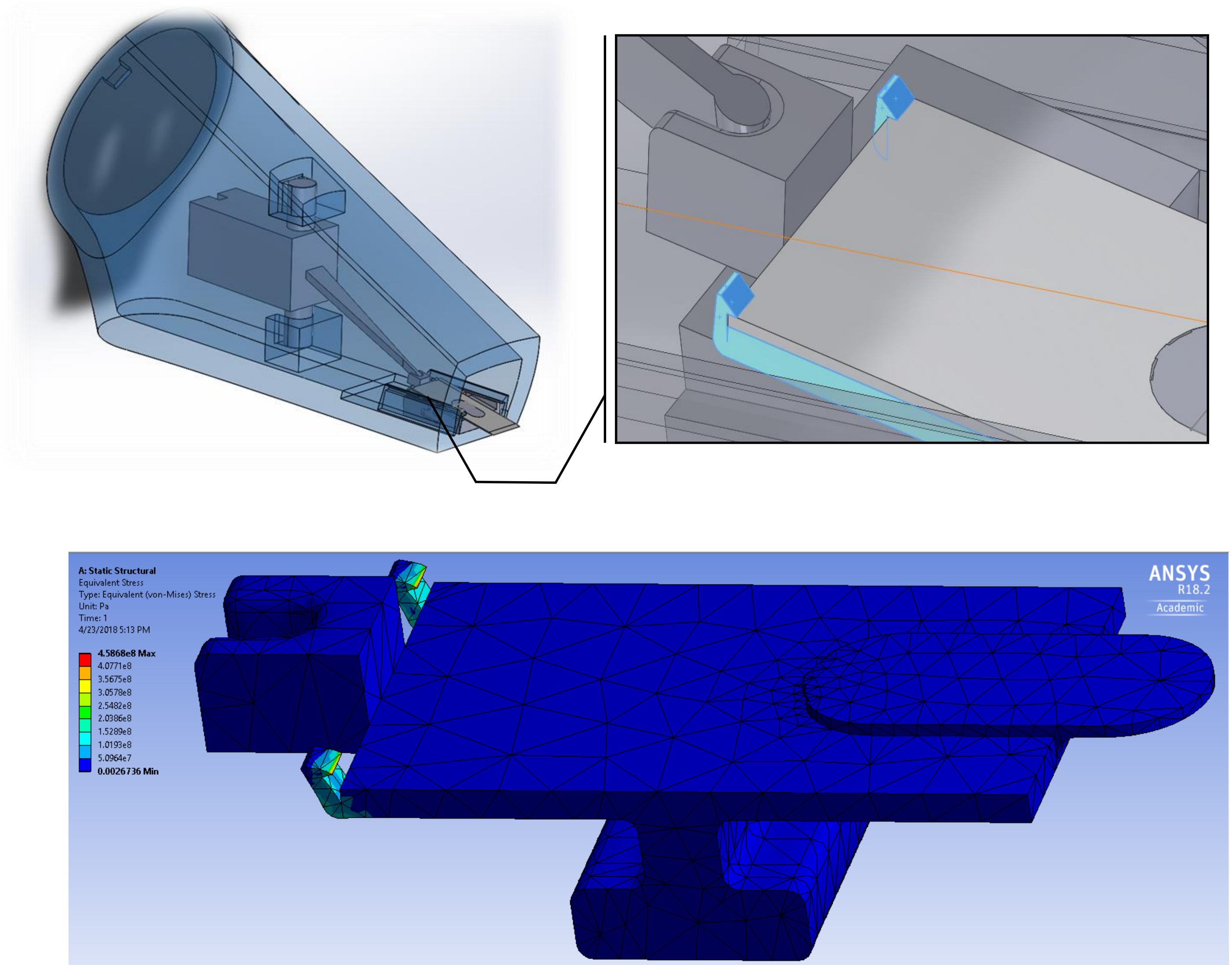


Figure 11: The blade holder from Iteration #1 ANSYS Simulation

In iteration 2, we had problems with the fasteners holding the shell and removable head assembly together. This occurred for two reasons: one that the fasteners do not hold well in ABS for direct screw applications and two, our part was once again designed too thin. This was not the only mistake that was made however. As you can see in Figure 11, the adapter part (1) would not fit through the hole in our shell (2) for when it came time to assemble. This made the device impossible to construct without damaging at least one part. At fault of our own user error and inexperience, we did not account for assembly when designing and this mistake led to a redesign of our first two iterations.

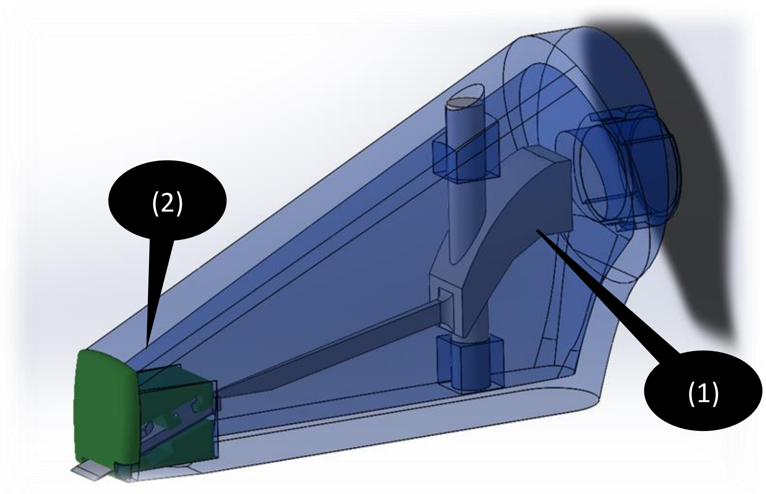


Figure 12: Designing for Assembly Failure, part (1) is too big to go through part (2)

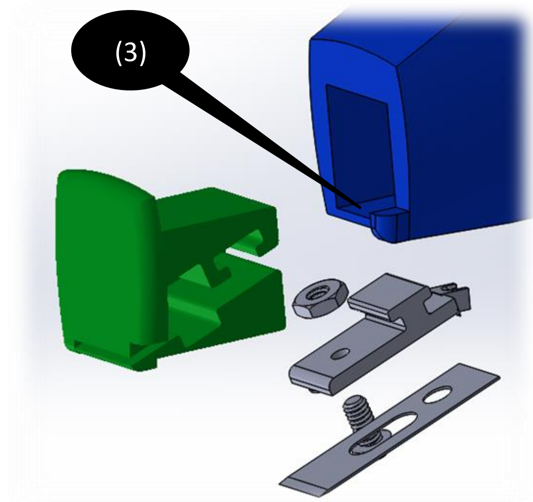


Figure 13: The bottom of the shell (3) was too thin (0.02") for a fastener

4.1.2 Lessons Learned from Iteration 3

The idea of using a single pivot point was another design flaw we realized that also existed in the first iteration. This observation occurred from post processing our part. The "inverted T-track" was not toleranced properly, and as a result our team was forced to use sandpaper to fit the parts. The physical method of sanding was difficult working in the "T-track" as it was <0.03" of clearance. As a result, we found that while sanding we were creating uneven surfaces on all faces of the T-track. This led to a failure in our single pivot point design, because the theoretical constraints did not hold and our slide tray was now twisting due to the irregularities from sanding (creating a bending moment). The was one of our most important failures along the way, since we learned the importance of tolerancing. In addition, we revisited the single pivot point method of constraining our slide tray. Our team concluded that this design would not be a sufficient method, which helped us work more towards the design which was used in our final iteration.

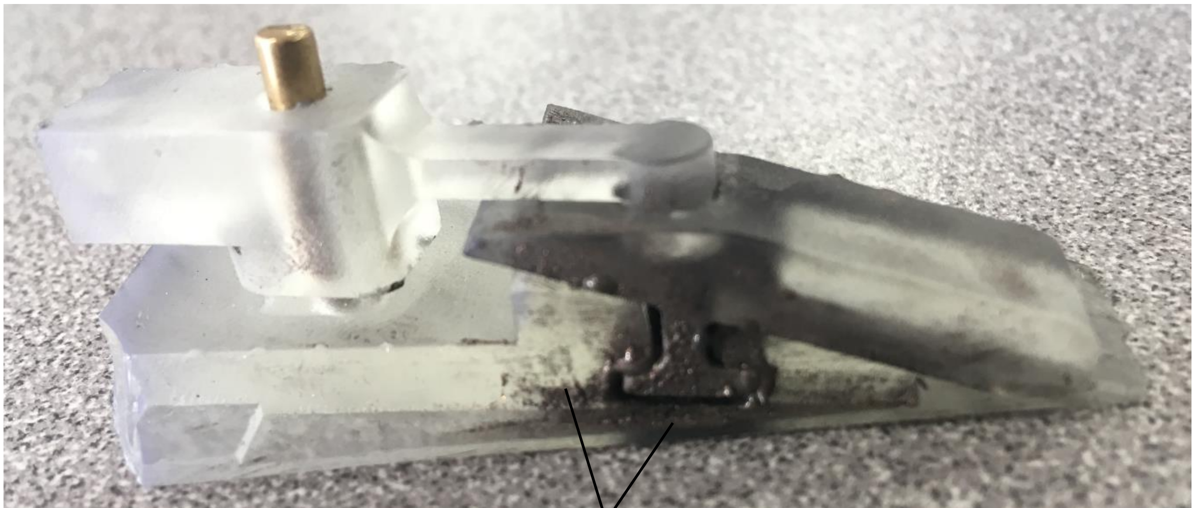


Figure 14: The “inverted T-track” is covered in all purpose grease, which we applied to attempt to fix the bending moment that was occurring as a result of post processing.

Our failures forced us to create a small prototype in an effort to simplify our design and ensure proper constraints. Our idea was that a dual pin constraint would be able to sustain the bending moments more effectively than the single t-track constraint. The simplified prototype consisted of two parts, a base and a slide tray held together by two pins. We applied the learnings from this sub iteration to create fourth which became our final working prototype. The final prototype took the double guide pin approach to the next level and used it as the basis for both locking in the work piece and allowing the design to have an interchangeable blade feature.

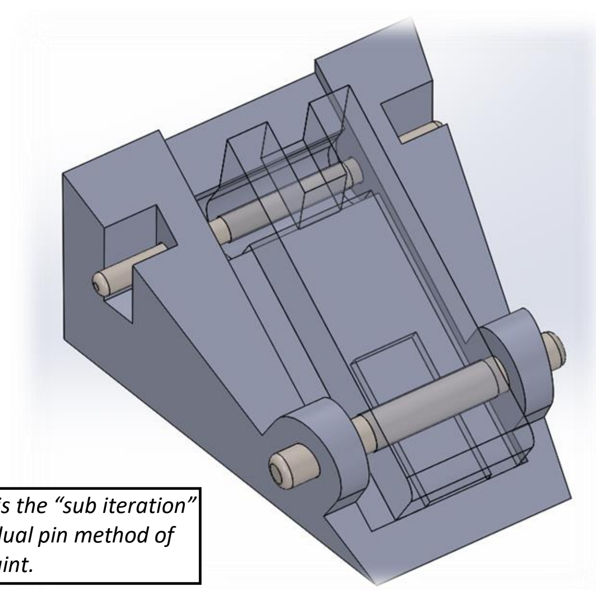


Figure 15: To the right, is the “sub iteration” we made to test the dual pin method of constraint.

4.2 Mechanical Analysis

4.2.1 Designing for Manufacturability

In product design it is important to focus on means of manufacturing when designing a prototype. The way a part is manufactured (especially true with 3D printers) determines much of the physical properties associated: density and surface finish (to name a few). For our project, we used several rapid prototyping machines: Dimension SST 1200, Object 260 Connex, Formlabs Form 2. Prior to designing it is important to first understand how 3D printers work. These rapid prototype machines build parts layer by layer allowing robust geometries and coining the term "3D printing". Each machine builds layers by different methods with different materials:

- **Dimension SST 1200:** Heats a thermoplastic (ABS plastic) using fused deposition modeling. The STL file allows the machine to follow a outline for the tool path for each slice of the part, and then fill each slice.
- **Object 260 Connex:** Drops liquid resin onto a build tray and cures the jetted material with UV light. Secondary support material is used to support the surrounding part.
- **Formlabs Form 2:** Using a fused filament fabrication heats a thermoplastic and prints the outline and then infills the horizontal slices of the part.

4.2.2 Snap-Fits

Our project aimed to learn about snap-fits, which are important in product design as they alleviate the need for fasteners. By removing fasteners we are able to reduce the overall cost of our product. After doing research on the behavior and application of snap fits, we came across a manual (insert citation) that gave us the equations for our application. Using the theoretical calculations we were able to incorporate snap fits into our design. Prior to prototyping we wanted to confirm our calculations by using a finite element analysis software called ANSYS to test the maximum allowable strain (von-Mises) and equivalent (von-Mises) stress to our part. In Figure 16 the snap fit located on the base was tested in ANSYS

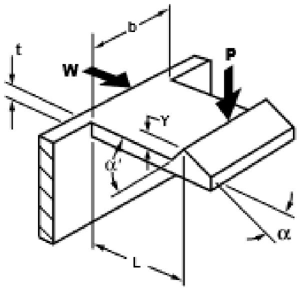


Figure IV-3

MAXIMUM STRAIN (@ BASE)

$$\epsilon = 1.5\frac{tY}{L^2 Q}$$

MATING FORCE

$$W = P\frac{\mu + \tan\alpha}{1-\mu\tan\alpha}$$

Figure 11a: Snap Fits Equations

Allowable Strain Value, e_o

MATERIAL	UNFILLED	30% GLASS
PEI	9.8%[2]	
PC	4%[1] - 9.2%[2]	
Acetal	7%[1]	2.0%
Nylon 6[4]	8%[5]	2.1%[1]
PBT	8.8%[2]	2.0%
PC/PET	5.8%[2]	
ABS	6% - 7%[3]	
PET		1.5%[1]

Figure 15: Allowable strain for Snap Fits on specific materials [9]

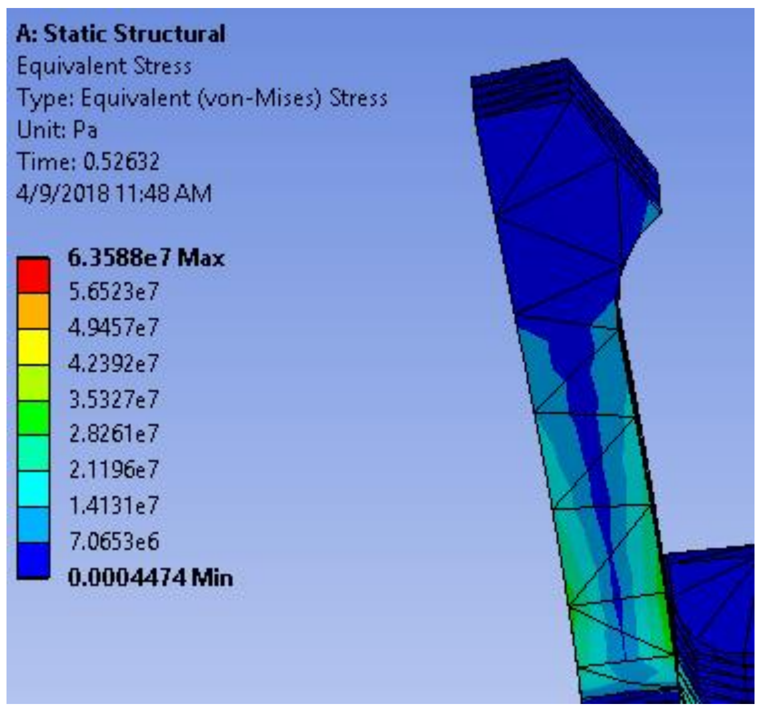


Figure 16: Screenshot of ANSYS Analysis on a Snap Fit Iteration

4.2.3 Blade Path

In order to fit the smaller ¼” adhesive tape, we determined our blade path to be 0.3”. In order to make our slide tray move to the proper horizontal distance, we needed to create an adapter of some sort that could bridge the gap between the slide tray and motor itself. We decided on using a camming method that the pin on our adapter would sit off the center axis, creating the diameter we need.

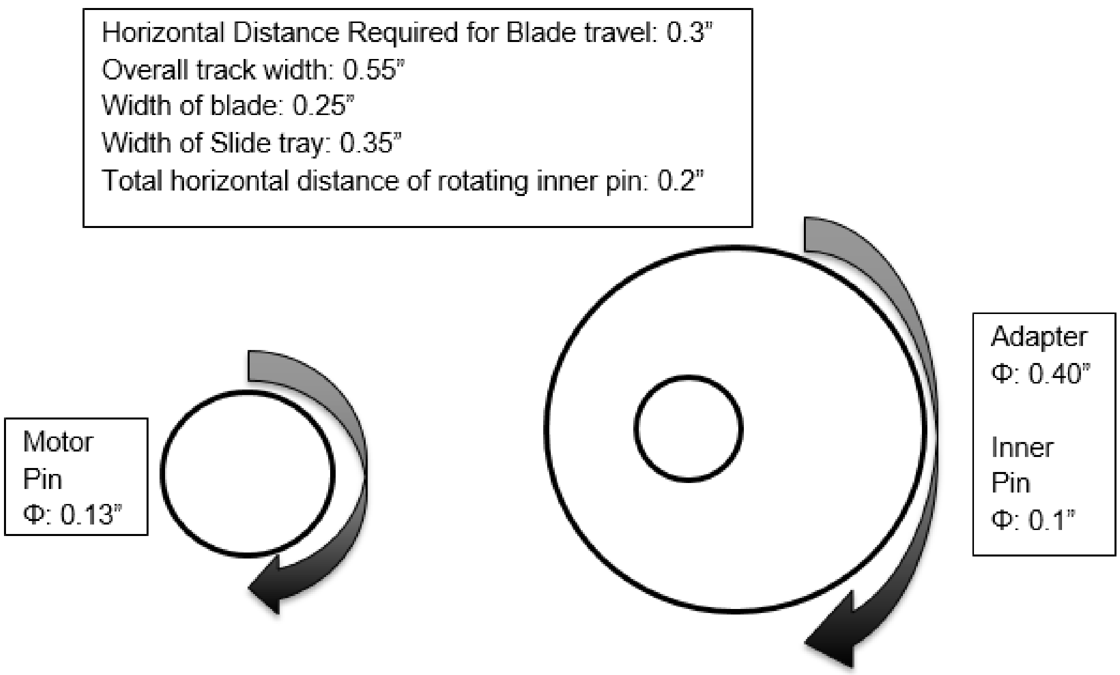


Figure 17: Drawing of the cam motor action

4.3 Electrical

In an attempt to make a handheld automotive tool competitive compared to other handheld electric tools in the industry, we wanted to get the most out of our motor (Appendix). At full load, the torque of our motor is 380 g-cm with a speed of 4,500 RPM. In order to create a compact device and minimize parts we decided to use a AAA battery case which has an integrated switch. While this helped eliminate the need for an extra part we would only be getting 4.5V of power out of our three AAA batteries. This is when we decided to add the 9V and wire it in series with the AAA case to achieve maximum power out of our 12V motor.

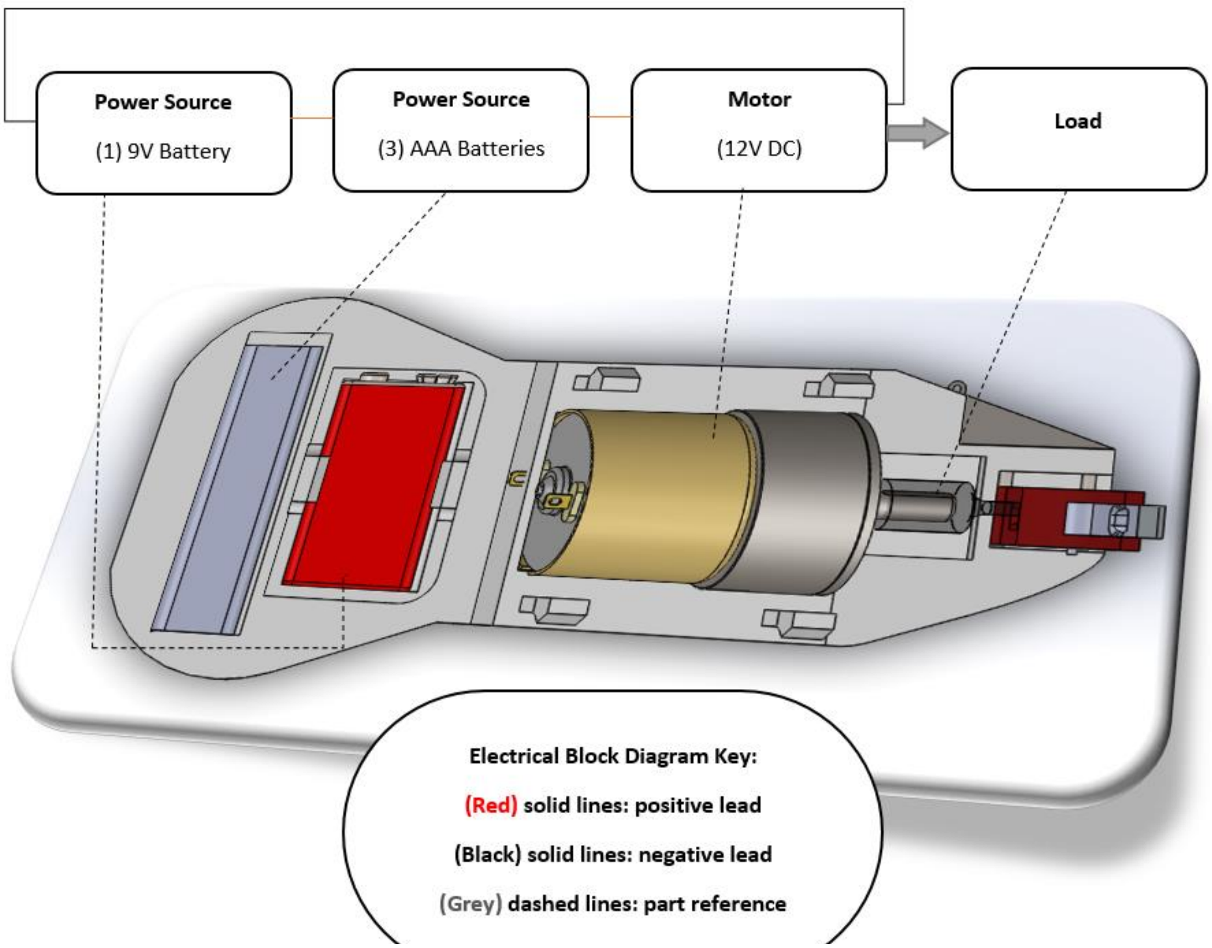


Figure 18: Block diagram of our final iteration

4.4 Final Design

Product Features:

- Overall size:

  7.20” x 3.29” x 3.01”

- Interchangeable blades
- Snap-fit assembly
- Bottleneck Design

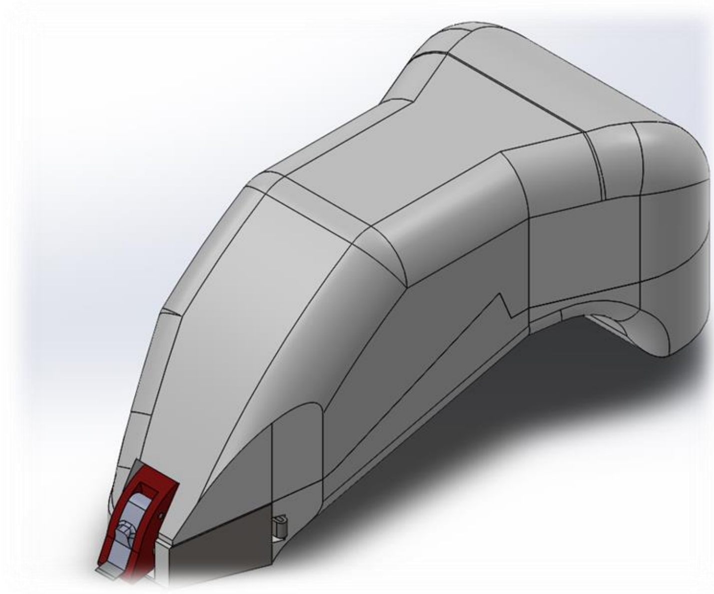


Figure 19a: Overall view of the final design of our tool

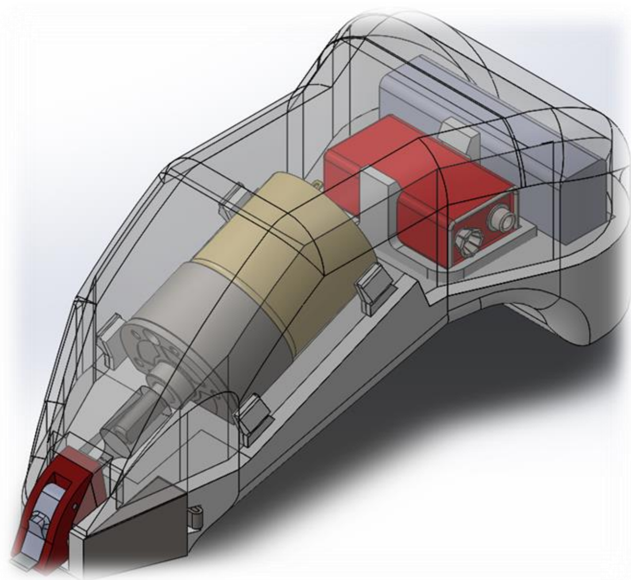


Figure 19b: Internal view of our final design

An oscillating razor blade is an effective tool in removing double sided adhesive tape from plastic moldings. Our team set out to create a tool that utilizes this idea and can potentially be used by workers in the auto body industry, specifically to remove double sided adhesive from car moldings. Throughout the design and production process of the tool our team worked through two main phases; the first phase was to create an experimental setup that proves the oscillating razor blade theory is capable of removing double sided adhesive tape, the second phase was creating a working prototype. Pictured above is the CAD model for our last and final design iteration, pictured below is a transparent view to see the innards of the tool.

The tool's overall size is 7.20" x 3.29" x 3.01" making it just large enough to be operated as a handheld tool. The final design includes snap fit assembly for all parts to allow the piece to be easily taken apart and put back together. The entire tool is powered by a 12V DC motor, which in turn is powered by a 9V battery and 3 AAA's in series to create a full 12.5V of electricity. The tool has a bottle neck design to allow the blade to fit in the tight tolerances of car moldings. Also the most important aspect of our design is an interchangeable blade system. As pictured below, the piece holding down the blade through compressive force (light gray) is constrained through dual pins. The U-shaped snap fit allows for the dark gray tab to be released, thus allowing the compressive tab to be rotated up, the blade to be removed, and a new one to replace it.

For operation:

The pins from the pull tab (1) go through part (2) which constrains the blade from vertical movement.

Blade Exchange:

The pull tab (1) is released through a U-shaped snap fit and the constraining pins are removed from the assembly allowing the part (2) to flip up and allow the user to swap razor blades.

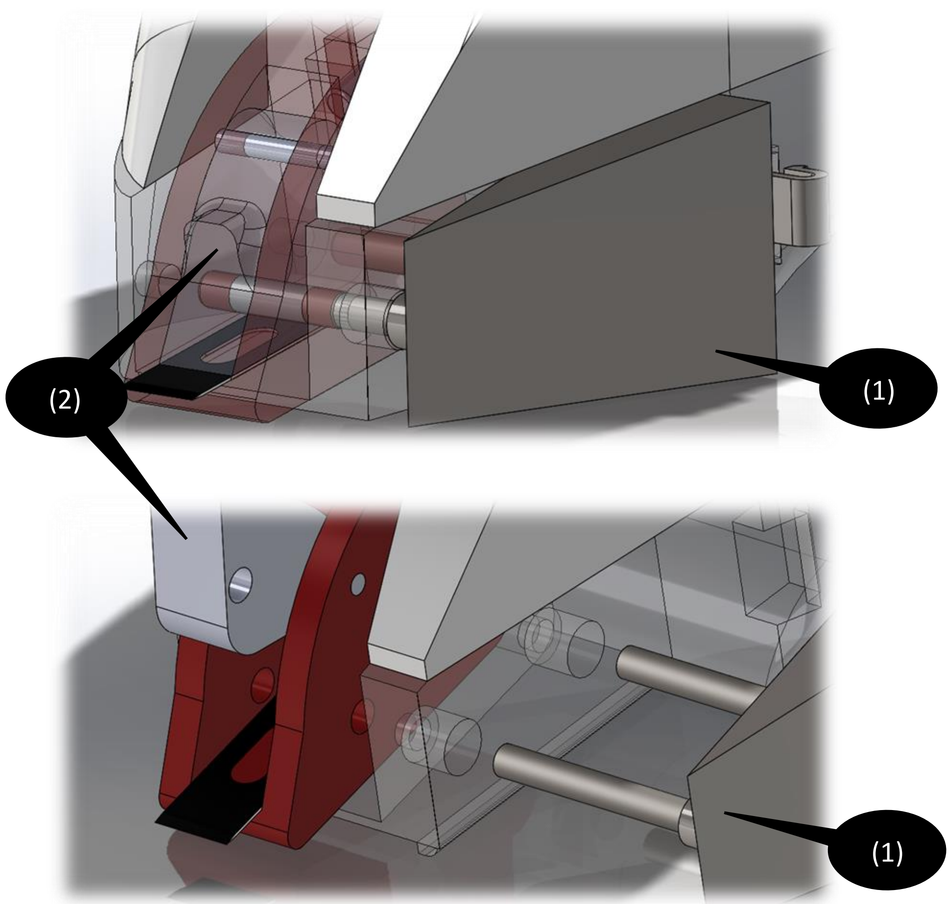


Figure 20: Overall view of the final design of our tool

5.0 Conclusion

Over the course of the Major Qualifying Project, our team gained valuable knowledge and exposure to the many components of product development. We were able to reinforce our skills with CAM (eSpirit), CAD (SolidWorks), FEA (ANSYS), rapid prototyping, and mechanical problem solving. The biggest part of design engineering we learned is that prototyping is an iterative process. Our team has made a lot of progress since our first prototype but believe we still have improvements to make. The tool we developed solved the problem of removing doubled sided adhesive tape from automotive moldings. Reflecting back to our design goals:

1. Removing double sided adhesive down to the surface.
2. Removing adhesive in under two minutes
3. Developing the tool into a handheld application
4. Fit in tight workspace of smaller moldings (¼" tape)
5. Device can withstand a contact force greater than the adhesive force (30 dynes/cm)
6. Option for exchangeable blades

We were able to accomplish everything except (4) fit in tight workspace of smaller moldings. The reason for this being, while we focused around the design of an effective product, we did not account for the overhang that the tool has when being exposed to the molding. For this reason, we do not believe end users will be satisfied and we would recommend a redesign. For this redesign, we are considering changing the orientation of the tool. That is, if the prototype we developed were vertical with the molding we would want it to be perpendicular to the tape.

Future steps for this project are going to include pursuing a redesign. Hopefully then after developing a second handheld iteration we could be one step closer to our final goal of applying for a patent. Upon receiving a patent, we are looking to approach a larger company to bring this tool into production, and hopefully we can see this in a future tool catalog.

Bibliography

[1] [Digital image]. Retrieved April 3, 2018, from https://i.ytimg.com/vi/I99bFomwZ8I/maxresdefault.jpg ; www.imgkid.com/painted.art.car.shtml

[2] Saint-Gobain Abrasives Inc, D. H. (1989). *U.S. Patent No. US4839206A*. Washington, DC: U.S. Patent and Trademark Office.

[3] Nissan Motor Co Ltd, T. M & S. S (1982). *U.S. Patent No. US4421802A*. Washington, DC: U.S. Patent and Trademark Office.

[4] [Digital image] "3M Side Molding and Emblem Removal Tool, 08978, 6 per case: Automotive". Retrieved from https://www.amazon.com/3M-08978-Molding-Emblem-Removal/dp/B000K2S6FO

[5] M. Y. (2006). *U.S. Patent No. US20080127473A1*. Washington, DC: U.S. Patent and Trademark Office.

[6] [Digital image]. Retrieved April 24, 2018, from https://www.dentcrafttools.com/trim-tools.html

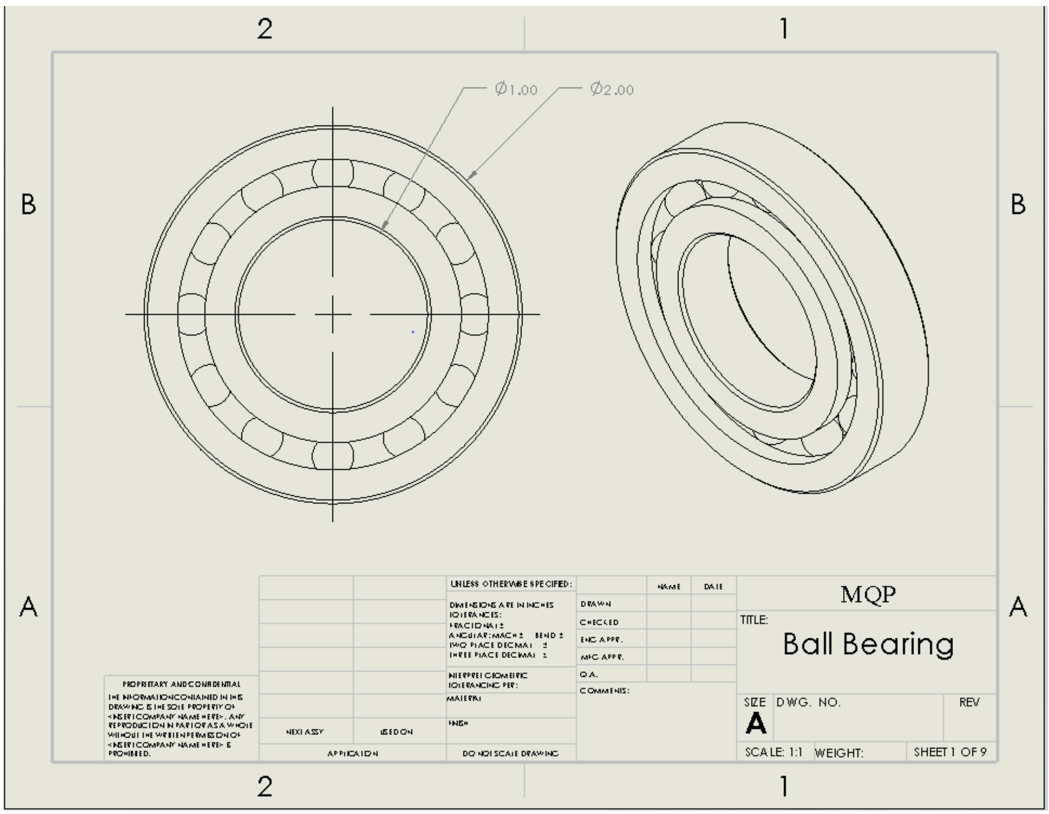
[7] [Digital image] "Power Tools". Retrieved April 2, 2018, from https://www.mactools.com/en-us/products/Power_Tools

[8] Mittal, K., & Mittal, K. L. (Eds.). (2003). *Particles on Surfaces 8: Detection, Adhesion and Removal*. p. 327. Retrieved from https://ebookcentral-proquest-com.ezproxy.wpi.edu/lib/wpi/reader.action?docID=253651&query=#

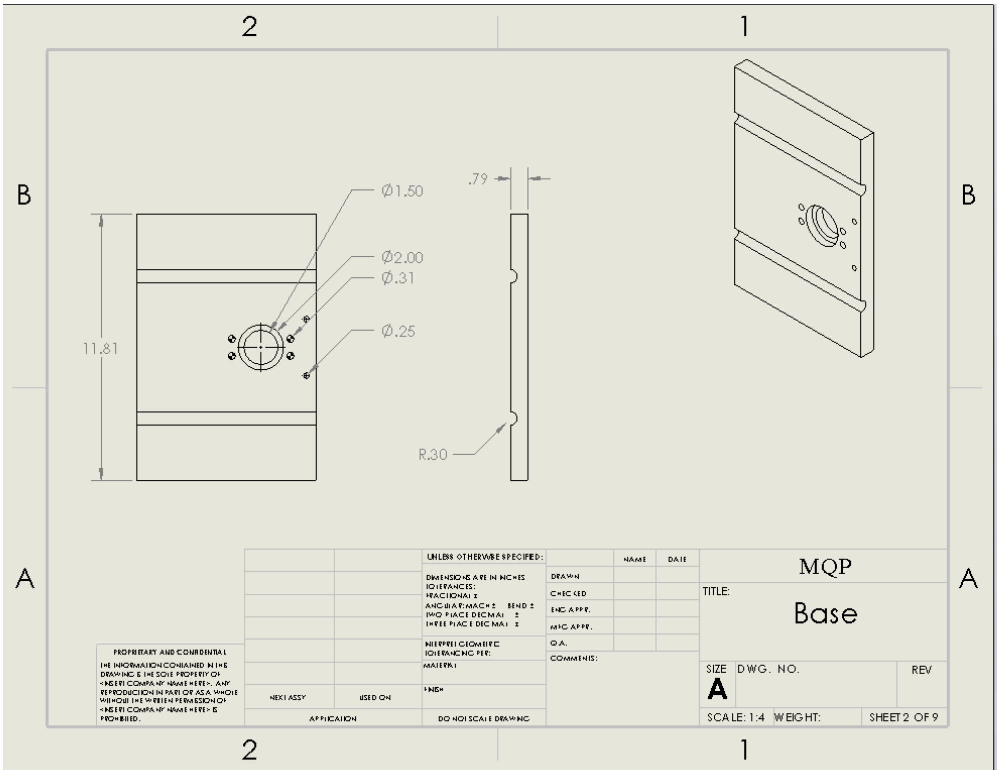
[9] BASF Corporation. (2007). Snap-Fit Design Manual. Technical Expertise, 1-24. Retrieved from http://web.mit.edu/2.75/resources/random/Snap-Fit Design Manual.pdf

Appendix

Appendix 1. Ball Bearing



Appendix 2. Scotch Yoke Base

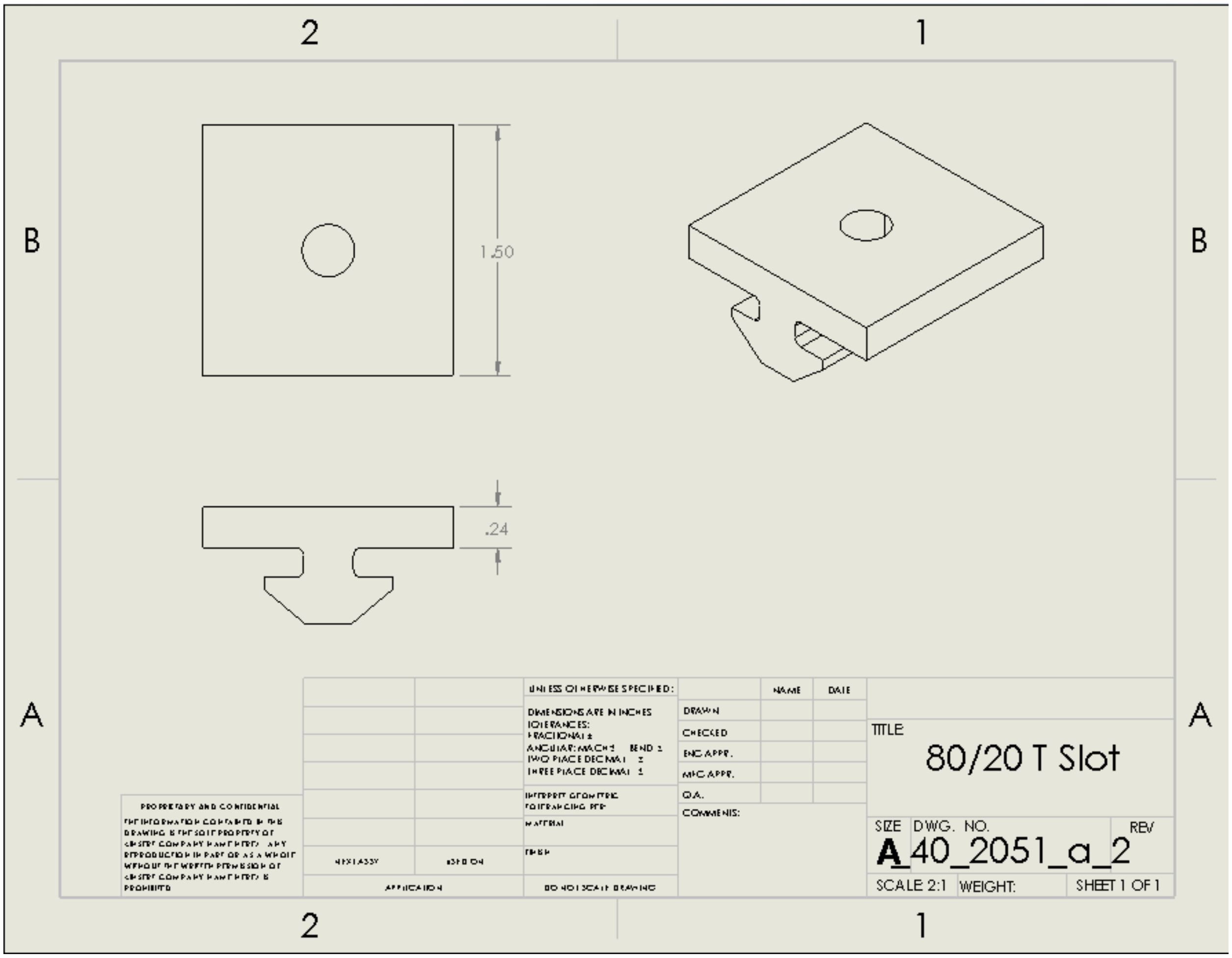


Appendix 3. Motor Specs

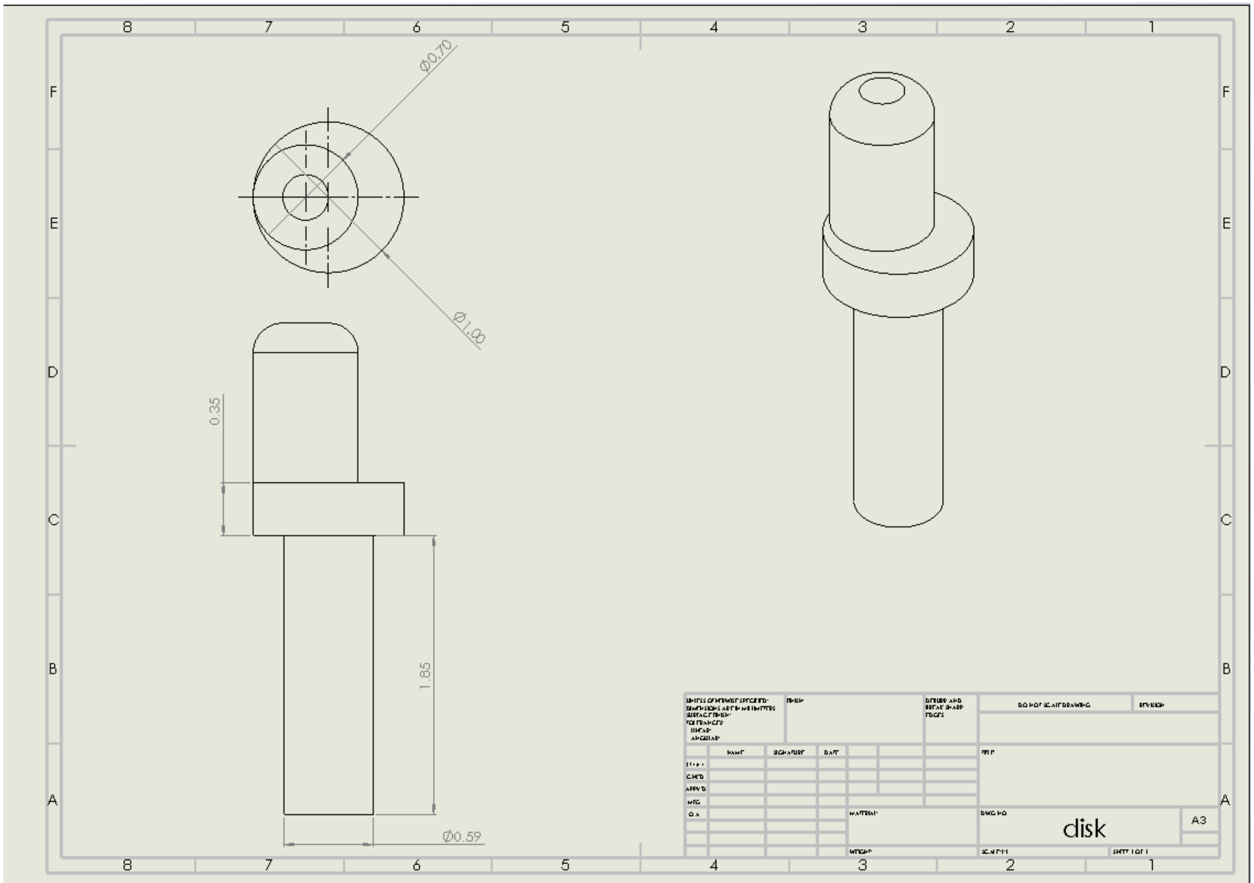
Mabuchi 555 12V DC Motor - Printer / Portable Drill / Robotics Hobby Motor

- Hobby electric motor manufactured by Mabuchi
- Model: RS-555PH-3255
- Relative low speed and high torque make it great for portable drill and robotics use
- Rated current: 2 A
- Operates on 12 VDC nominal
- Motor starts to spin at approximately 1 VDC
- No load speed of 5,500 RPM
- 180 mA no-load current draw @ 12 V
- Full load torque: 380 g-cm (5.3 oz-in)
- Full load speed: 4,500 RPM
- Full load current: 2.4 A
- Stall torque: 1,360 g-cm (18.9 oz-in)
- Stall current: 11.8 A
- 5 Pole armature
- Two threaded (M3-0.5) mounting holes on 25 mm center located on pulley end
- Can be operated in either direction, simply reverse power supply polarity
- D-Type shaft dimensions: 13 mm long x 3.17 mm (1/8") diameter
- Dimensions (not including shaft): 58 mm long x 37 mm diameter
- Weight: 7.7 oz. (218 g)
- Features solder eyelets for easy power connection (can also use 3/16" quick connect terminals)

Appendix 4. 80/20 T Slot



Appendix 5. Disk



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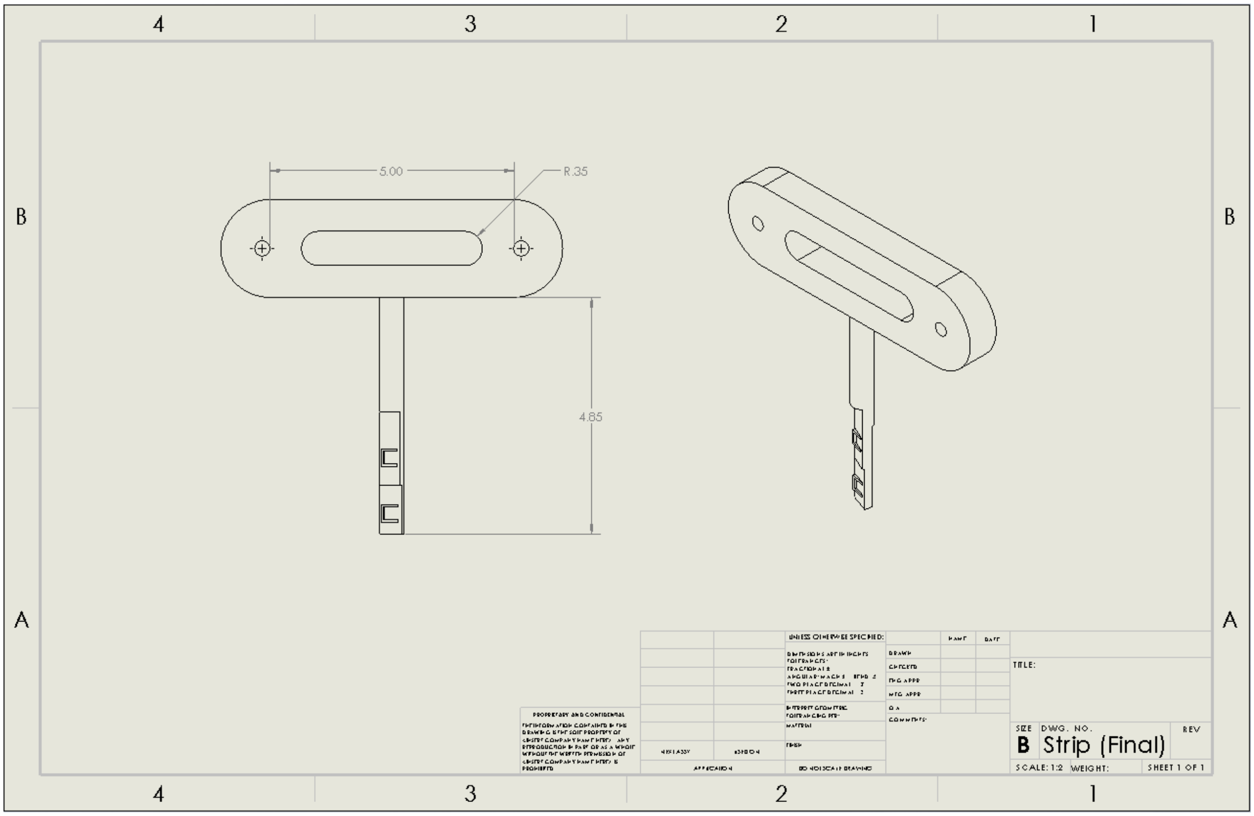
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