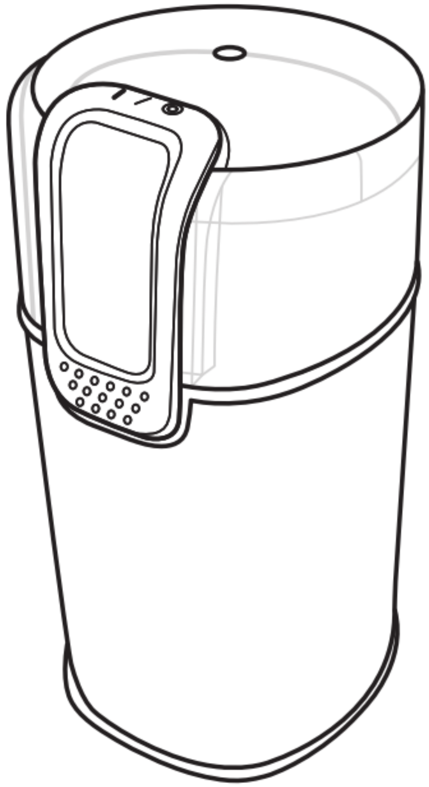

Reverse Engineering of an Electric Coffee Bean Grinder

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MCEN 5045: Design for Manufacturing
Professor Dan Riffell

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Table of Contents

Table of Figures

Table of Tables

Introduction

An electric coffee bean grinder is a common household kitchen appliance. According to the National Coffee Data Trends in 2020, 7 in 10 Americans drink coffee every week–62% of which drink coffee every day [1]. Although this accounts for most Americans, less than 20% of these coffee drinkers grind their own coffee at home [2]. Our team aims to reverse-engineer an affordable, at-home coffee grinder for the everyday drinker. Grinding freshly roasted coffee beans before brewing is a crucial step to coffee perfection. An electric blade coffee grinder breaks coffee beans into smaller pieces via propeller-shaped stainless-steel blades revolving at a very high speed (20,000 to 30,000 RPM). The team chose this item because we are interested in optimizing an electromechanical system and improving a common existing product.

The goal of this project is to offer alternative manufacturing processes and designs that may address design for assembly (DFA) and design for manufacturing (DFM) challenges. These challenges directly address the concerns of the consumer such as ease of use, longevity, and number of parts. This report aims to document the purchased coffee grinder compared to the redesign. The main goals include:

(i) Increase the DFA efficiencies and reduce error-proofing and secondary operations
(ii) Propose improvements in materials and manufacturing processes
(iii) Compare and discuss the economic analysis of the product

Product Description

The coffee grinder in Figure 1 was purchased from Amazon for $15.59 and is currently rated at 4.5 out of 5.0 stars. An image of the original product is shown below. The product can grind up to 30 grams of coffee beans in 10 seconds. The user manual states the coffee grinder can blend coarse, medium, or fine based on your application.

Figure 1: Purchased Electric Coffee Grinder

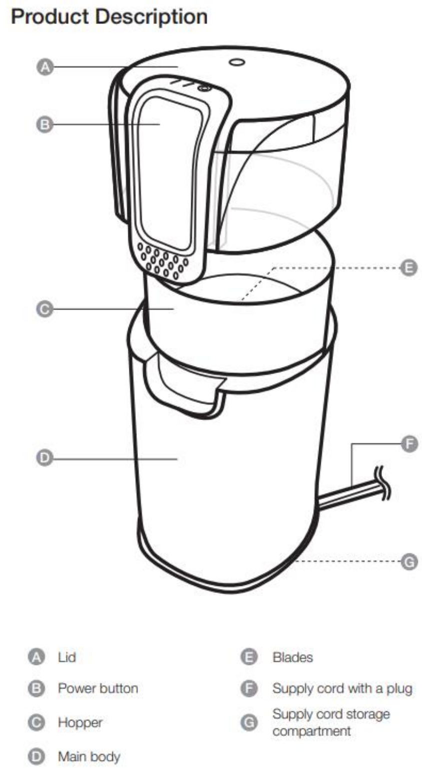


Figure 2: Product Exploded View from Amazon Basics Coffee Grinder

Before creating schematics of the product and the subsystems, the user manual of the product was examined. The manual included an exploded view of the part, technical specifications, and instructions for use. The information gained from this step helped better inform the decision-making process for the redesign of the coffee grinder.

Black Box Diagram

The black box model is a simple illustration of the fundamental signals of energy and material coming into and out of the device of interest, in our case an electric coffee bean grinder. It helps us understand the fundamentals of our device and gain perspective on what the device needs to do. For example, prior to making this diagram, it was not readily apparent that the visual size of the beans mid-way through the grinding process was one of the essential visual outputs of the device.

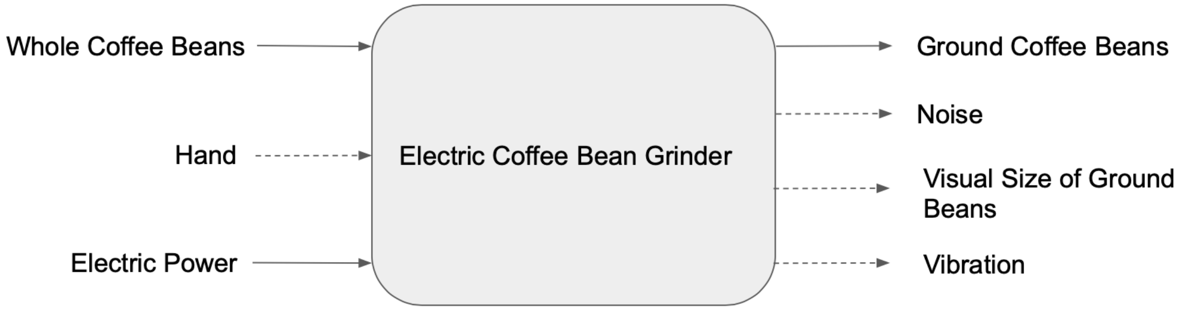


Figure 3: Electric Coffee Bean Grinder Black Box Diagram

Glass Box Diagram

Displayed below is a diagram to show the physical acts of nature that are happening through the sub-assemblies of the coffee grinder assembly. The mechanical motion of the assembly stems from the motor to rotate the blade arm of this machine. Having a power switch allows this system to be controlled to start and stop functions.

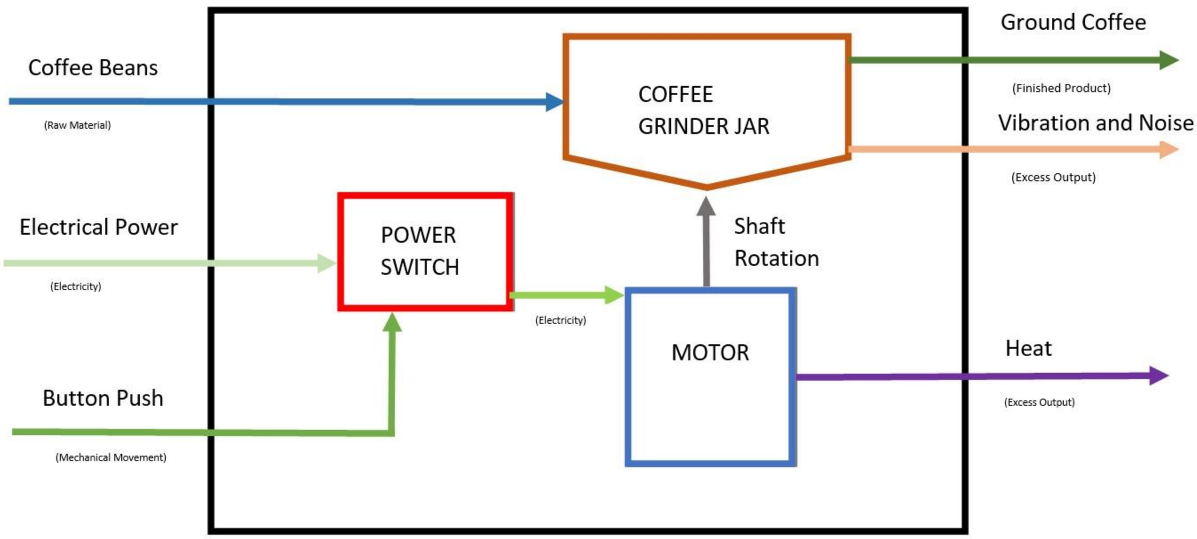
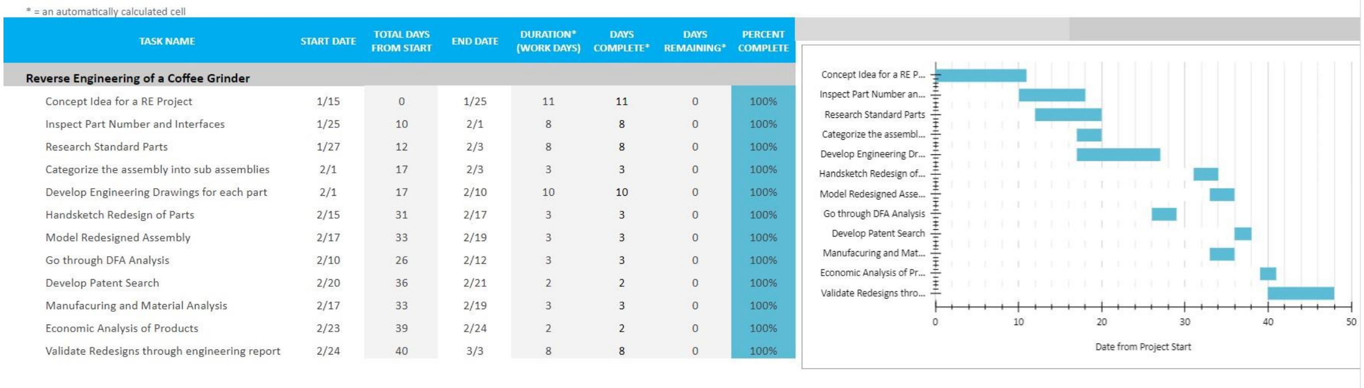


Figure 4: Electric Coffee Bean Grinder Glass Box Diagram

Gantt Chart

In developing a Gantt chart for the schedule of our project, our team had the ability to stay on track with redesigns and the manufacturing analysis throughout the project's lifetime. Through this chart, we have mapped out the schedule from ideation, research of standardized parts, engineering drawings, DFA analysis, patent searches, material analysis, economic analysis, and validation of redesign through this engineering report.



* = an automatically calculated cell

TASK NAME	START DATE	TOTAL DAYS FROM START	END DATE	DURATION* (WORK DAYS)	DAYS COMPLETE*	DAYS REMAINING*	PERCENT COMPLETE
Reverse Engineering of a Coffee Grinder							
Concept Idea for a RE Project	1/15	0	1/25	11	11	0	100%
Inspect Part Number and Interfaces	1/25	10	2/1	8	8	0	100%
Research Standard Parts	1/27	12	2/3	8	8	0	100%
Categorize the assembly into sub assemblies	2/1	17	2/3	3	3	0	100%
Develop Engineering Drawings for each part	2/1	17	2/10	10	10	0	100%
Handsketch Redesign of Parts	2/15	31	2/17	3	3	0	100%
Model Redesigned Assembly	2/17	33	2/19	3	3	0	100%
Go through DFA Analysis	2/10	26	2/12	3	3	0	100%
Develop Patent Search	2/20	36	2/21	2	2	0	100%
Manufacuring and Material Analysis	2/17	33	2/19	3	3	0	100%
Economic Analysis of Products	2/23	39	2/24	2	2	0	100%
Validate Redesigns through engineering report	2/24	40	3/3	8	8	0	100%

Figure 5: Coffee Grinder Team Gantt Chart, Spring 2022

Fishbone Diagram

The fishbone diagram decomposes the coffee grinder into three subassemblies connected to the main body. The coffee grinder itself is shown at the head of the fish with a horizontal line connecting three angled lines. Each of these angled lines represents a subassembly with shorter horizontal lines denoting an individual component.

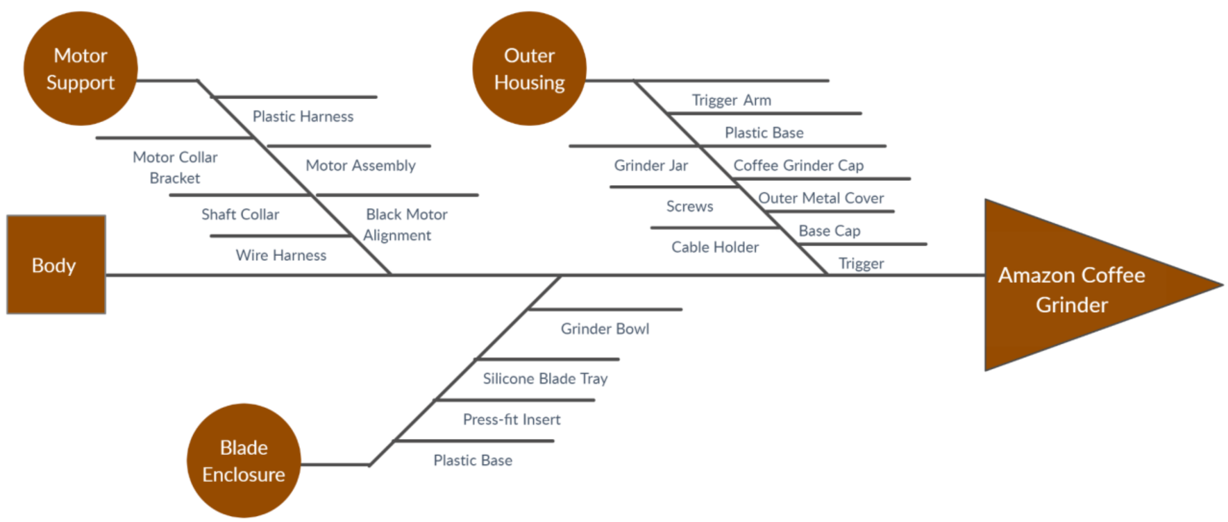


Figure 6: Fishbone Diagram of Original Coffee Grinder

Patent Search

To understand the coffee grinder on hand as well as optimizations to the products that already exist, a patent search was performed. The aim of this research was to determine what changes to the basic coffee grinder could provide a foundation for coming up with design changes for our reverse engineering project.

(1) The first patent was found to be EP3300643A1 (Improved Electric Coffee Grinder); IPC: A47J4/50, published on April 4, 2018.

This model comprises of a hopper, a grinding compartment disposed under said hopper, a grinding assembly, pushing means disposed of in the mouth of the grinding compartment and joined to actuation means of the grinding assembly, in such a way to push the coffee beans from the hopper to the compartment; the pushing means consist in a disk provided with a peripheral notch to let the beans pass through, and tab with obtained along with the profile of said notch and inclined towards the hopper, which is suitable for pushing the coffee beans towards the grinding compartment during rotation of the disk.

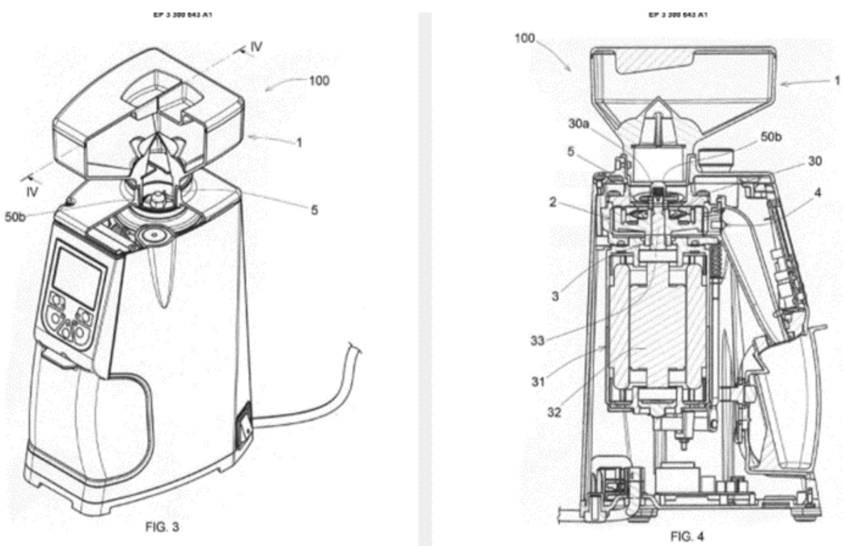


Figure 7: Patent Image, Improved Electric Coffee Grinder (EP3300643A1)

(2) Another patent like our product is RO134019A2 (Coffee Grinder); IPC: A47J42/22; published on April 30, 2020.

This design relates to a coffee grinder for two coffee types, which grinds and doses the coffee, provides granulation settings depending on the profile of the coffee beans, as well as the almost full discharge of the ground coffee from the grinding chamber, close to zero. The grinder consists of two coffee containers which are arranged parallel at the top part, each connected to one channel, each such container being provided with a coffee blocking blade which closes or opens the channel, allowing the supply of volumetric charging devices which are positioned on the sides of each container, while, at the bottom part of the volumetric charging device there is a graduated grid permitting grinding adjustment. There is also a blade describing a rotation from left to right and vice versa as controlled by the PCB, the blade having the role of outputting the ground coffee while discharging the grinding chamber to almost zero level, each use being metered and recorded by means of some metering devices.

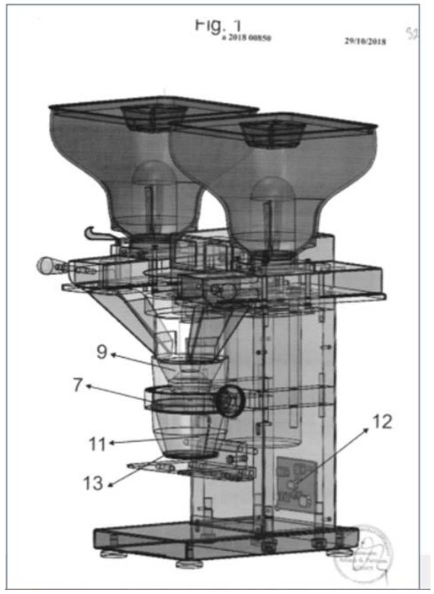
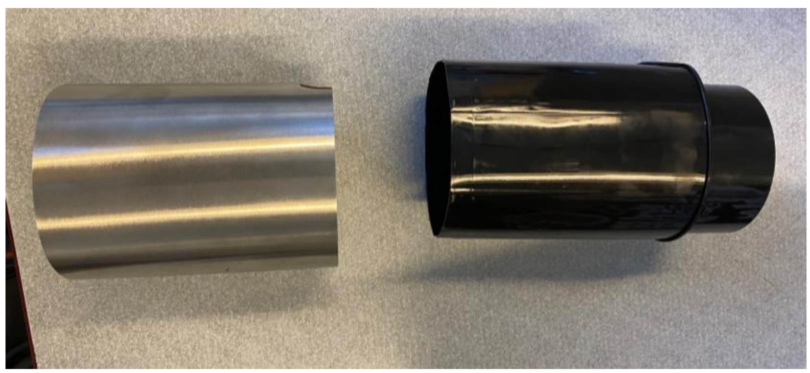


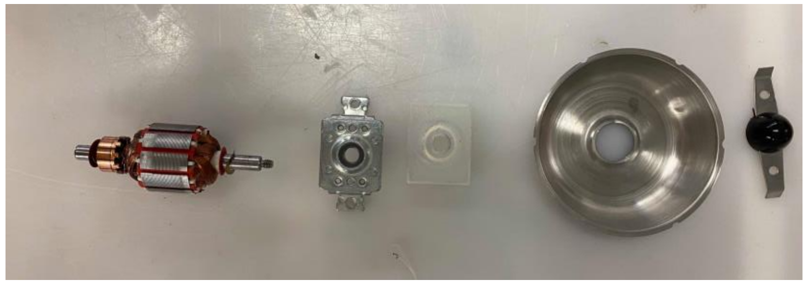
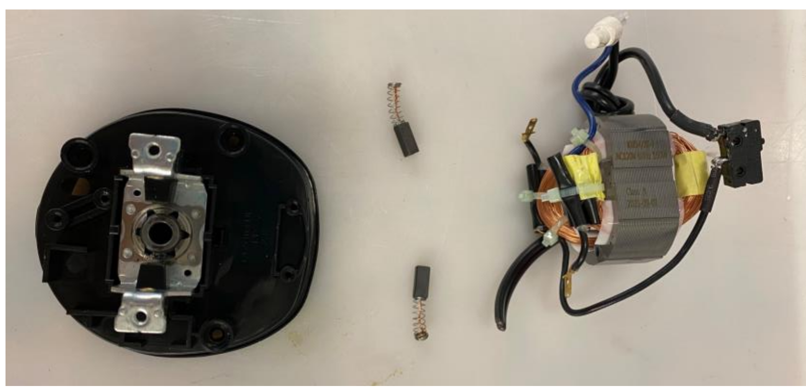
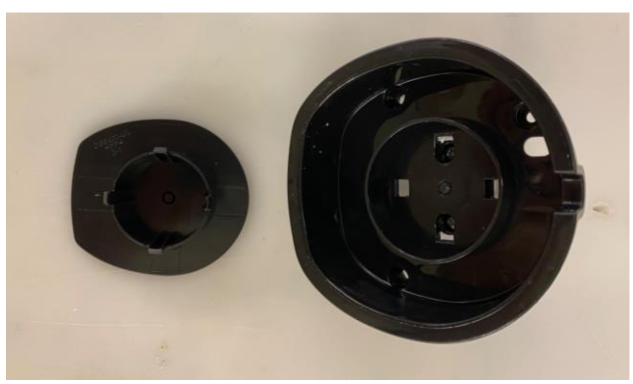
Figure 8: Patent Image, Coffee Grinder (RO134019A2)

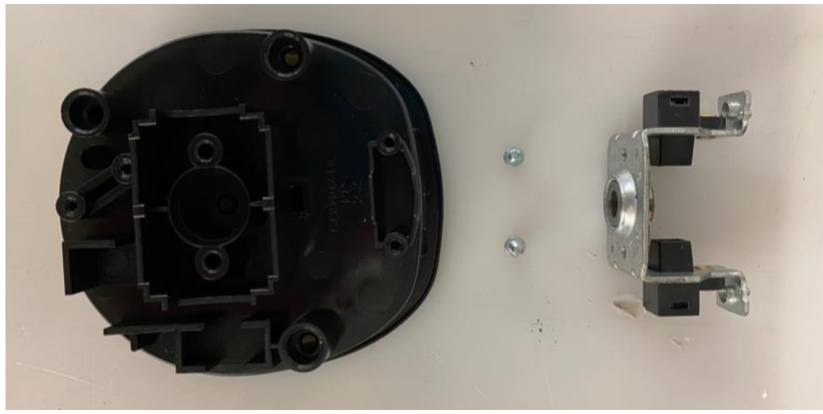
Disassembly Pictures with Labels

The following is a set of steps for disassembly of the electric coffee grinder of interest. It is essential to take it apart to gain access to all its components. But it is also useful to gain insight into the order in which the parts can be put together for our assembly analysis.

Table 1: Disassembly Procedure and Images

Disassembly Step Note	Image
1. Unscrew the plastic base and slide apart	
2. Separate metal housing from plastic housing	
3. Unscrew upper motor collar from outer motor coil	

Disassembly Step Note	Image
4. Unscrew motor shaft from blade arm threaded insert	
5. Unscrew wire clamp and switch clip and cut power chord	
6. Remove motor harness and motor contacts	
7. Unclip bottom cap	

Disassembly Step Note	Image
8. Unscrew bottom motor collar	

Hand Sketches of Original Design and Design Changes

A sketch of the original assembly helped the team begin thinking about the redesigning process and ways to immediate ways to improve the design.

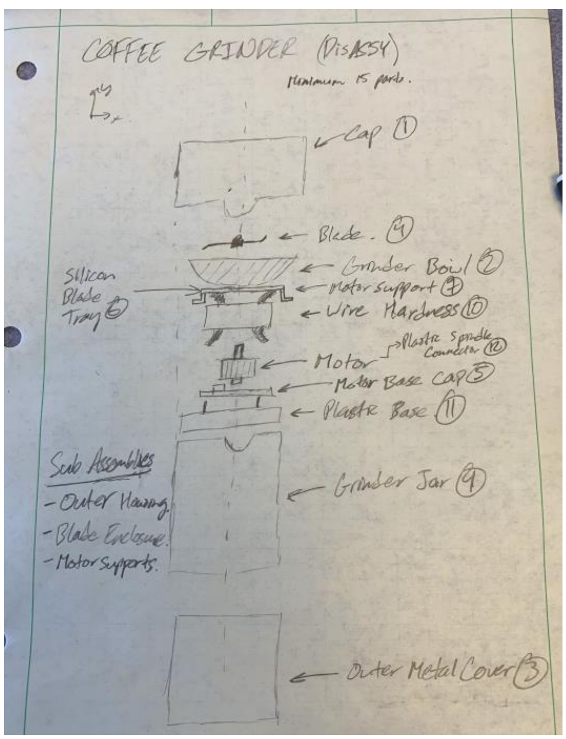


Figure 9: Original Sketch of Exploded View

Redesign 1: Cap and Trigger

Through sketching the two parts of the grinder cap and trigger we found that the two can be combined into having a flexible hinge point at the trigger to be injection molded into one part.

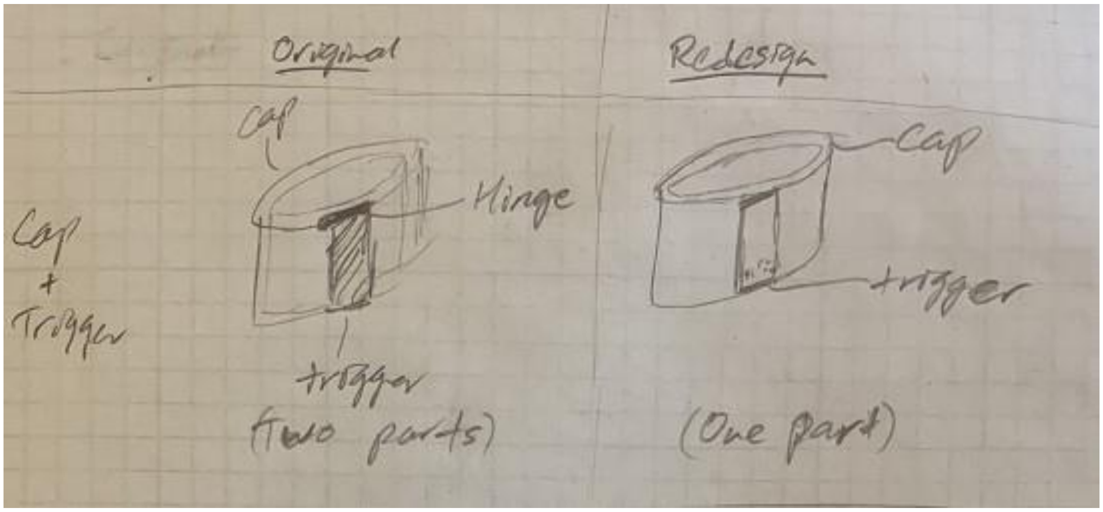


Figure 10: Cap and Trigger Redesign Sketch

Redesign 2: Removal of Outer Housing

This assembly comes with an aluminum cover that is placed over the jar for an aesthetic look. The extra cover serves no technical function as our team decided to redesign the jar to be thicker instead of having this external cover. Where the cover bought handling and orientation issues when assembling.

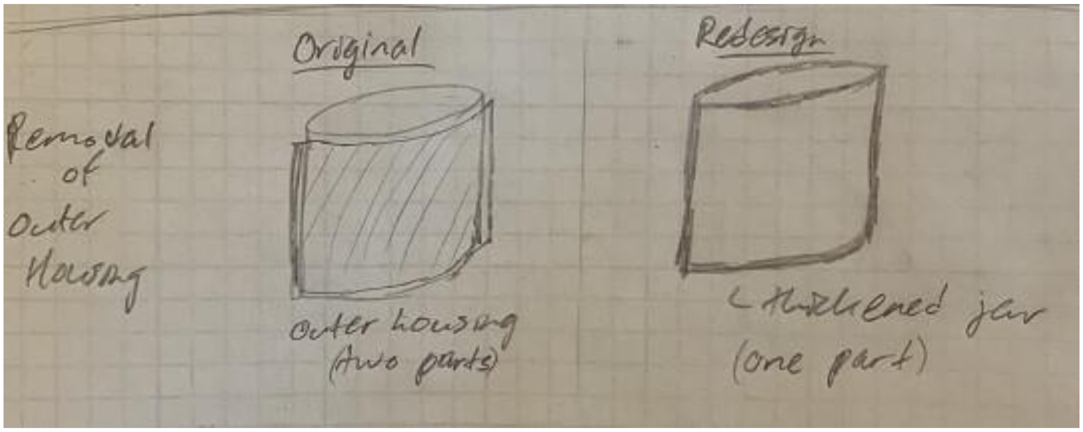


Figure 11: Removal of Outer Housing Sketch

Redesign 3: Removal of Cable Holder from Base

The power cable that connected wires to the motor had been held down into placed internally for the system. The cable holder’s only function had been to direct the cable on the mold of the assembly while in production. Therefore, we had the idea to thicken the cord and remove this feature to simplify our assembling process.

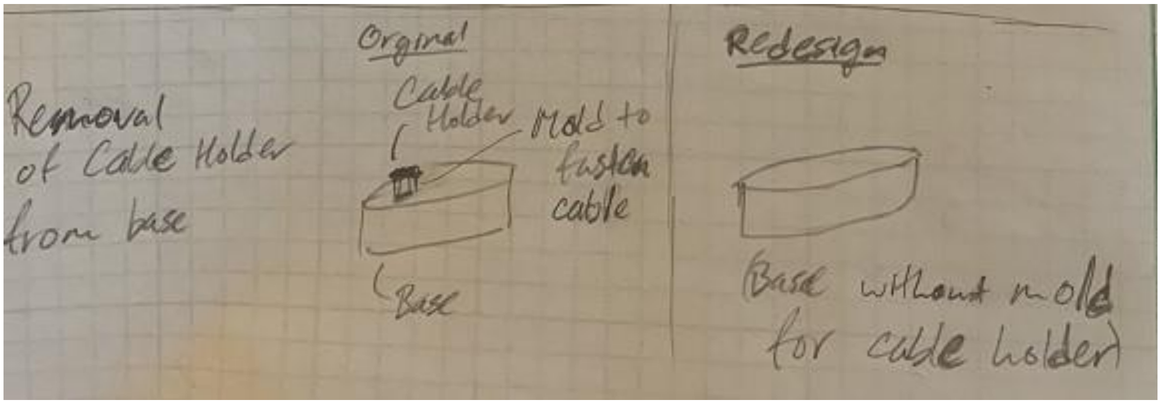


Figure 12: Removal of Cable Holder Sketch

DFA Analysis and Comparison

In the initial DFA analysis, our team aimed to have improved metrics in redesigns and a reduction in part count. Displayed is the DFA from earlier in the semester to the revised DFA chart with new metrics.

Original DFA Matrix

Assembly Name: Coffee Grinder Team: Four Beans Date: 2/15/2022

If the answer is Yes to any of the metrics or questions enter a 1. If the answer is No then enter 0. Each cell must have a number.

Part		DFA Complexity		Functional Analysis / Redesign Opportunity				Error Proofing		Handling			Insertion				Secondary Operations				
Part Number	Part Name	Number of Parts (Np)	Number of Interfaces (Ni)	Theoretical Minimum Part	Part Can Be Standardized (if not already standard)	Cost (Low/Medium/High)	Practical Minimum Part	Assemble Wrong Part/ Omit Part	Assemble Part Wrong Way Around	Tangle, Nest, or Stick Together	Flexible, Fragile, Sharp or Slippery	Pliers, Tweezers, or Magnifying Glass Needed	Difficult to Align/ Locate	Holding Down Required	Resistance to Insertion	Obstructed Access/ Visibility	Re-orient Workpiece	Screw, Drill, Twist, Rivet, Bend, or Crimp	Weld, Solder, or Glue	Paint, Lube, Heat, Apply Liquid or Gas	Test, Measure or Adjust
	Blade Enclosure																				
10.1	Grinder Bowl	1	2	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
10.2	Blade Arm	1	2	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
10.3	Pressfit Insert	1	1	1	0	0	1	0	0	0	0	0	1	0	1	0	0	1	0	0	0
10.4	Silicon Blade Tray	1	2	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
	Motor Support																				
9	Motor Assembly	1	3	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1
9.1	Motor Collar Bracket	1	2	1	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0
9.3	Shaft Collar	1	2	1	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0
9.2	Wire Hardness	1	2	1	0	0	1	0	0	1	0	0	1	0	1	0	1	1	1	1	1
9.5	Brush Caps	2	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
	Outer Housing																				
1	Plastic Base	1	2	1	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
2	Base Cap	1	1	0	0	2	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
3	Cable Holder	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	Button Clip	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	Grinder Jar	1	2	1	0	1	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0
6	Outer Metal Cover	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	Trigger	1	2	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
8	Coffee Grinder Cap	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	Screws	4	8	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0
	Totals	22	34	12	0	5	11	3	0	1	2	0	3	0	2	1	4	10	1	1	3
	Design for Assembly Metrics	27.34958866		54.5%	←Theor. Effy. Pract. Effy.→		50.0%	0.25		0.25			0.50				1.58				
	Targets	25		55.0%			45.0%	0.29		0.21			0.40				1.25				

Figure 13: Original DFA Chart- Amazon Coffee Grinder

Revised DFA Matrix

Assembly Name: Coffee Grinder **Team:** Four Beans **Date:** 3/2/2022

If the answer is Yes to any of the metrics or questions enter a 1. If the answer is No then enter 0. Each cell must have a number.

Part		DFA Complexity		Functional Analysis / Redesign Opportunity				Error Proofing		Handling			Insertion				Secondary Operations				
Part Number	Part Name	Number of Parts (Np)	Number of Interfaces (Ni)	Theoretical Minimum Part	Part Can Be Standardized (if not already standard)	Cost (Low/Medium/High)	Practical Minimum Part	Assemble Wrong Part/ Omit Part	Assemble Part Wrong Way Around	Tangle, Nest, or Stick Together	Flexible, Fragile, Sharp or Slippery	Pliers, Tweezers, or Magnifying Glass Needed	Difficult to Align/ Locate	Holding Down Required	Resistance to Insertion	Obstructed Access/ Visibility	Re-orient Workpiece	Screw, Drill, Twist, Rivet, Bend, or Crimp	Weld, Solder, or Glue	Paint, Lube, Heat, Apply Liquid or Gas	Test, Measure or Adjust
	Blade Enclosure																				
7.1	Grinder Bowl	1	2	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
7.2	Blade Arm	1	2	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
7.3	Pressfit Insert	1	1	1	0	0	1	0	0	0	0	0	1	0	1	0	0	1	0	0	0
7.4	Sicilion Blade	1	2	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0
	Motor Support																				
6	Motor Assembly	1	3	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1
6.1	Motor Collar Bracket	1	2	1	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0
6.2	Shaft Collar	1	2	1	0	0	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0
6.3	Wire Hardness	1	2	1	0	0	1	0	0	1	0	0	1	0	1	0	1	1	1	1	1
6.4	Brush Caps	2	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
	Outer Housing																				
1	Plastic Base	1	2	1	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
2	Base Cap	1	1	0	0	2	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
3	Button Clip	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	Grinder Jar	1	2	1	0	1	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0
5	Coffee Grinder Cap	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	Screws	4	8	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0
	Totals	15	32	11	0	4	10	3	0	1	2	0	3	0	2	1	4	10	1	1	2
	Design for Assembly Metrics	21.9089023		73.3%	←Theor. Effy. Pract. Effy.→		66.7%	0.27		0.27			0.55				1.64				
	Targets	25		55.0%			45.0%	0.29		0.21			0.40				1.25				

Figure 14: Revised DFA Chart

<u>DFA Metrics:</u> In this team's DFA analysis, the assembly has shown that there can be a part reduction from 18 to 15 different components. In completing this part reduction, our DFA metric had been improved to a lower DFA Complexity Number, increasing Theoretical Efficiency and Practical Efficiency. The full DFA evaluation tables can be found in the appendix.

Table 2: DFA Summary Chart

Category	Original DFA Metric	Revised DFA Metric
DFA Complexity	27.350	21.909
Theoretical Efficiency	54.5%	73.3%
Practical Efficiency	50.0%	66.7%
Error Proofing	0.25	0.27
Handling	0.25	0.27
Insertion	0.50	0.55
Secondary Operations	1.58	1.64

DFA Complexity Number

In reducing the overall part count we were able to reduce the interfaces between the parts to the assembly. The trigger that connects to the coffee cap has been modular into one injection modeled part. The outer housing had been removed to thicken the jar. Then finally the cable holder had been removed to decrease unnecessary parts and replace when a thicken cable. Therefore, it will be a smoother assembly time for technicians when processing the coffee grinders.

Theoretical and Practical Efficiency

The practical minimum number of parts results in having 10 parts. This displaced our practical efficiency to be 66.7% which was a 16% increase from the 50.0% metric we had in the initial DFA model. This improved metric gives our team an improved chance to model the assembly with fewer than the initial 23 parts.

Error Proofing

The error proofing in our assembly had decreased due to removal of the cable holder which decreased our overall number of screws to the assembly. Included in reduction of the error proofing metric is the removal of the outer covering to allow for one less assembly process. This reduction in parts allowed this metric to decrease from 0.25 to 0.27.

Handling

Handling has increase from 0.25 to 0.27 due to the reduction of the part count. Therefore, increasing our technician's performance when completing the overall assembly.

Insertion

The major alignment issues come from the screws and press-fit insert. The screws are a common practice for technicians, but the installation of a press-fit insert does have resistance for insertion therefore will need a technician with a steady hand. The change in the amount of screws results in an increased insertion metric from 0.50 to 0.55.

Secondary Operations

In removal of the trigger there is one less testing operation on the hinge of the cap assembly. Since this part is now combined with the coffee grinder cap. Then in removing the cable holder from the assembly, the number of screws has decreased the steps needed for the assemblers to attach parts. These redesigns have a decreased secondary operations metric from 1.50 to 1.64.

Analysis of Initial Design

Fastener Reduction

During disassembly of the coffee grinder, there were several DFA and DFM practices identified that have already been incorporated into this design. Snap-fit features eliminate the use of fasteners in most of the assembly. For example, the base cap, plastic base, trigger and the grinder jar incorporate this function and reduce the time it takes to assemble parts into the grinder. It securely fastens the base of the grinder onto the main body and is difficult to disassemble without damaging the snap features. This is a good protection against consumers attempting to take apart the grinder since there are no parts that need to be replaced in the lifetime of the product. The use of fasteners to mount the motor onto the plastic base and shaft collar was deemed necessary for motor stability within the assembly.

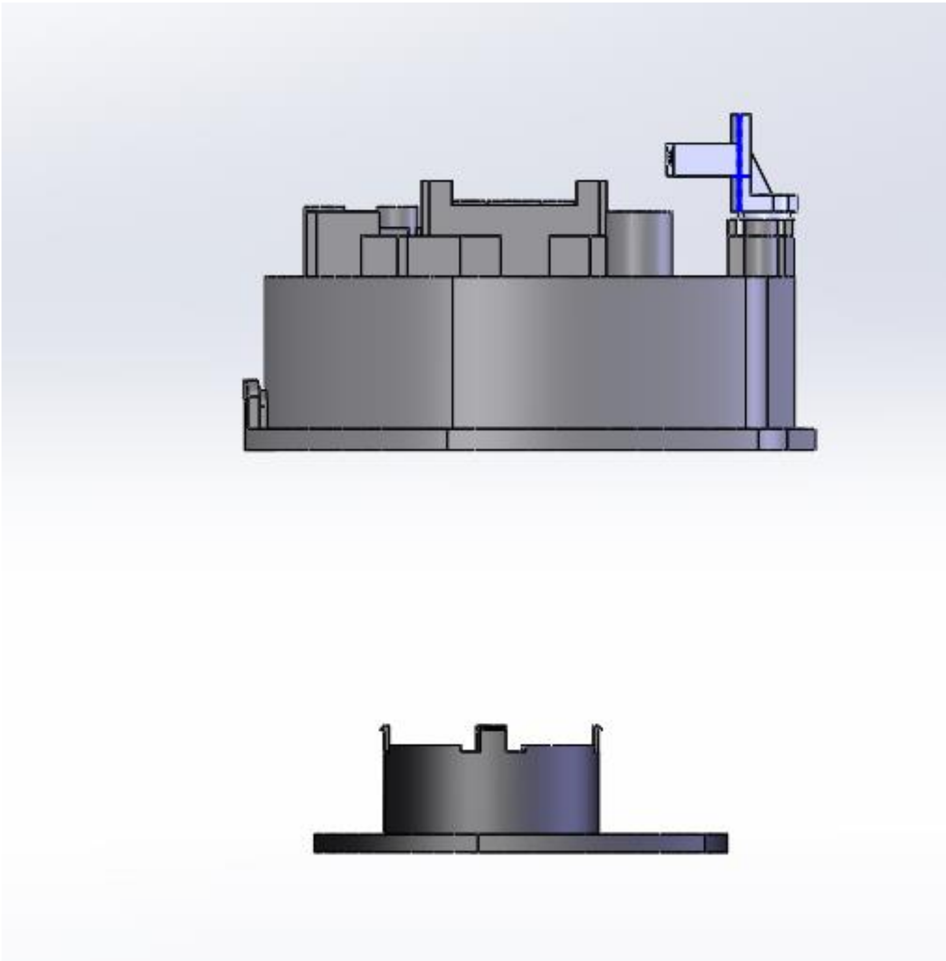


Figure 15: Snap fit feature demonstration for the base cap

Design for Self-Insertion and Self Alignment via Asymmetry

The trigger extends from the cap button down to the momentary button on the plastic base, where it connects the circuit for the motor to spin the steel blade. The connection between the top portion of the assembly and the plastic base has a specially designed profile geometry that decreases the possibility of assembling the part the wrong way. The asymmetry in the profile allows for the insertion to only one possible way of inserting the trigger. The self-alignment feature incorporated into the design helps reduce confusion in assembly by creating asymmetric geometry and alignment walls incorporated into the receiving piece.

Another asymmetrical feature worth noticing is the outer housing itself including the grinder jar, grinder cap, outer metal cover and plastic base. This profile has a partly circular and partly elliptical opening (flat surface on one edge) to call out the orientation of the cap lid on the grinder body.

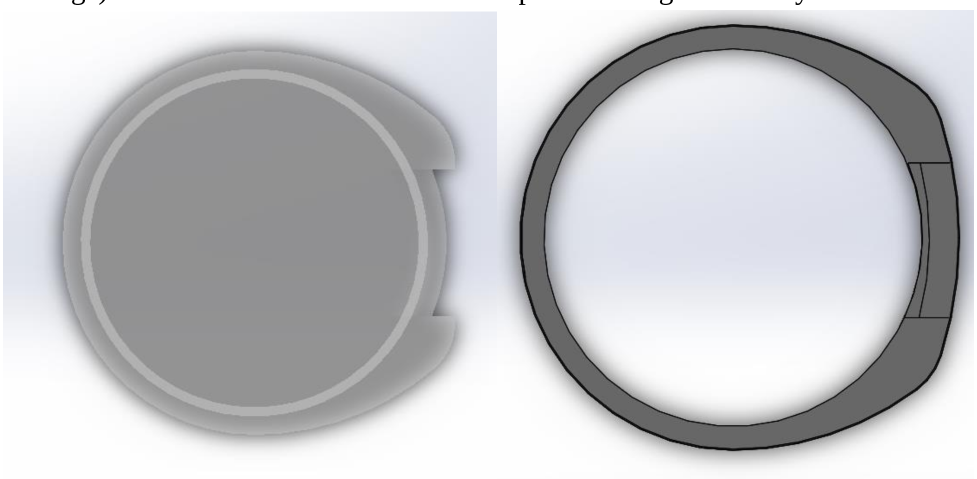


Figure 16: Asymmetrical Profile of Cap (left) and Grinder Jar (right)

In summary, there are many assembly methods that give an overall efficient process due to snapping features and self-alignment during assembly. This proves to be very advantageous since the entire grinder housing is a cavity that parts must be assembled into. It is apparent that there were multiple iterations that occurred before this model was put into production, but the relatively high insertion index reflects this difficulty of installing parts into the grinder body. With this, an effort was made to simplify the design by reducing part count, error proofing and need for any secondary operations.

Summary of Initial Design Ideas Explored

- Reduce Part Count
    - Remove motor Alignment on Collar Bracket
    - Remove silicone tray
    - Remove outer housing
    - Redesign coffee grinder cap
- Reduce error proofing by standardizing motor collar and shaft collar brackets in the motor support assembly
- Reduce the need for any secondary operations

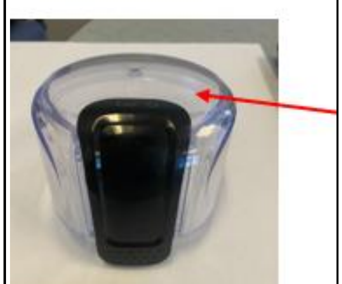
Materials and Manufacturing Analysis

Material Analysis

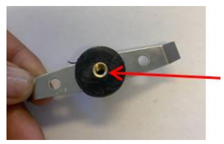
The assembly is divided into three subassemblies: the outer housing, blade enclosure, and motor support. These categories were based on functionality and connection between the parts. Before analyzing the materials used, a part count of the original grinder is listed in the table below including an assigned part number.

Table 3: Bill of Materials for Amazon Coffee Grinder

Part #	Part	Image	Quantity	Material
Outer Housing Subassembly				
1	Plastic Base		1	ABS
2	Base Cap		1	ABS
3	Cable Holder		1	ABS/PE

Part #	Part	Image	Quantity	Material
4	Button Clip		1	ABS
5	Grinder Jar		1	ABS
6	Outer Metal Cover		1	Aluminum Alloy
7	Trigger		1	ABS
8	Coffee Grinder Cap		1	Acrylic

Part #	Part	Image	Quantity	Material
Motor Support Subassembly				
9.1	Motor Collar Bracket		1	Steel Alloy
9.2	Wire Hardness		1	Various
9.3	Shaft Collar		1	Steel Alloy
9.4	Motor		1	Various
9.5	Brush Caps- Black Motor Alignment		2	ABS

Part #	Part	Image	Quantity	Material
Blade Enclosure Subassembly				
10.1	Grinder Bowl		1	Aluminum Alloy
10.2	Blade Arm		1	Steel Alloy
10.3	Press-Fit Insert		1	Brass
10.4	Silicon Blade Tray		1	Silicone
11-15	Flat head Screws		5	Steel

Blade Arm

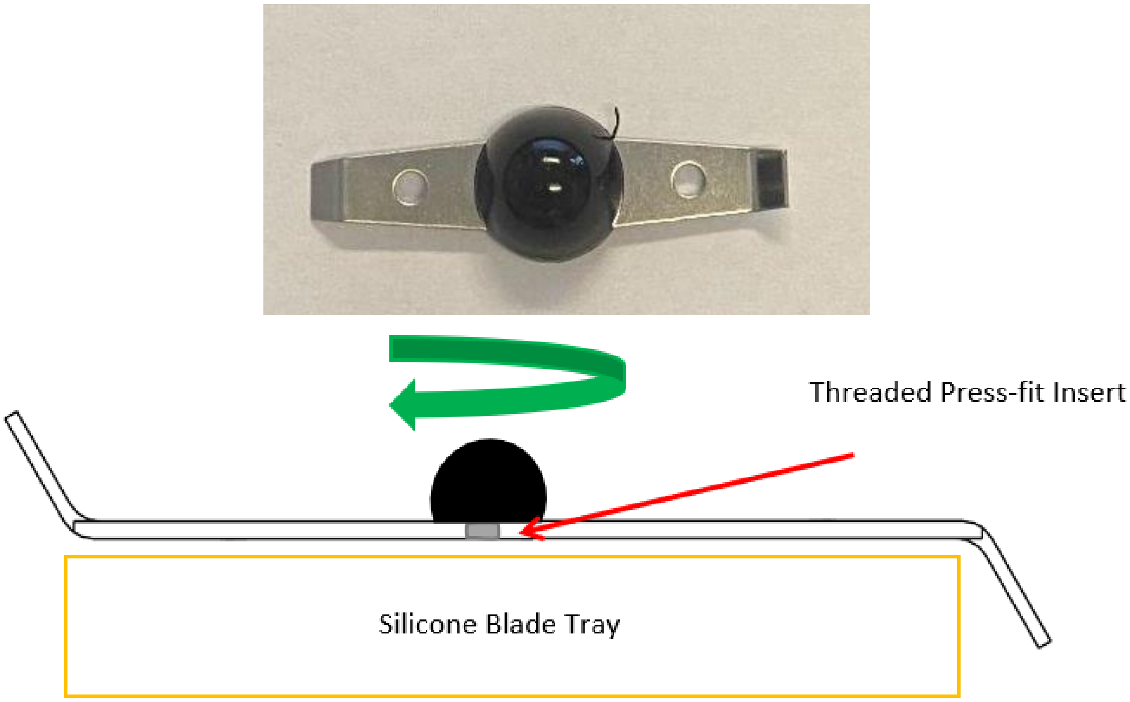


Figure 17: Blade Arm Component and Interfaces

Function:

Rotate about the center of the assembly and grind coffee beans to the user's needs

Constraints/Requirements:

- Sharp enough to be effective
- Must connect properly to the motor
- Must interface with a soft material (like silicone) to reduce noise and vibration
- Easy and safe to handle for assembler
- Sufficient material stiffness
- Low-cost relative to assembly

Objective:

Potentially remove the press-fit insert part or change material to decrease cost without compromising strength

Relevant Equation:

$$Cost = \frac{C_m \rho}{\sigma_w} V$$

The basis of the relationship between the cost of the material and strength is based on several variables where Cm = cost per unit mass, ρ = density of the material, σ_w = safe working stress of other material, and V = volume of the material used [3].

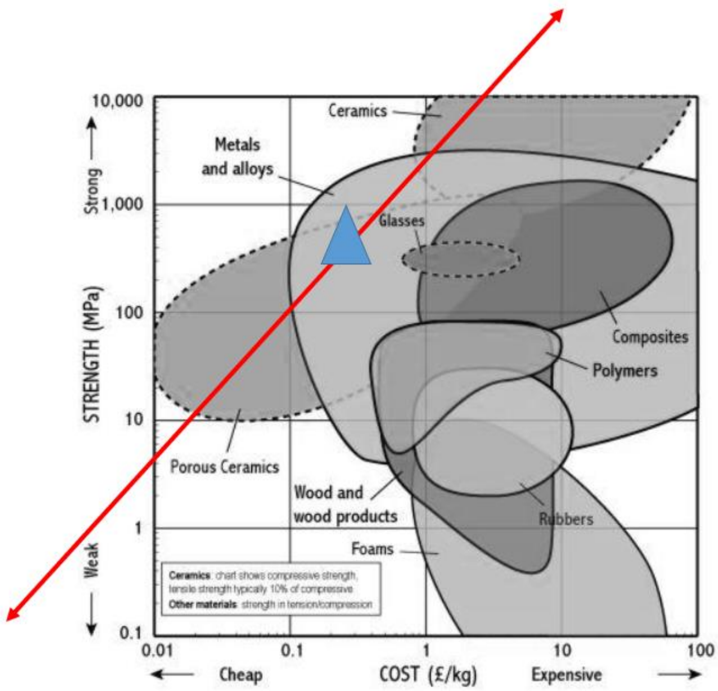


Figure 18: Ashby Chart for Blade Arm (Strength vs. Cost)

Pictured above is the Ashby chart that aims to meet the objective of decreasing cost and maintaining or improving strength. Currently, the material selected for the blade arm is a steel alloy, which has a typical strength of 415 MPa and costs roughly 0.19 English lbs./kg ($0.25/lb. U.S.D). The current selection is denoted by the blue triangle on the red guideline.

Materials that Meet the Strength vs. Cost Objective:

Porous Ceramics
Pros: strong, good thermal resistance and insulation, lightweight, durable
Cons: Cannot withstand high-pressure

Ceramics
Pros: Chemically resistant, lightweight, durable

Cons: Easily cracked or chipped

Explore Other Metal Alloys
Pros: Cheaper cost relative to current selection
Cons: requires expensive manufacturing process

Based on the Ashby chart, ceramics, and other metal alloys are alternative materials to act as the blade arm. Although ceramics possess many advantages, such as lightweight and thermal resistivity, it may easily be cracked or damaged. This alone risks the main function of the coffee grinder not working properly. Another concern with choosing a ceramic blade would be packaging and transportation. Exploring other metal alloys presented the easiest transition for alternative designs.

Supporting Information:

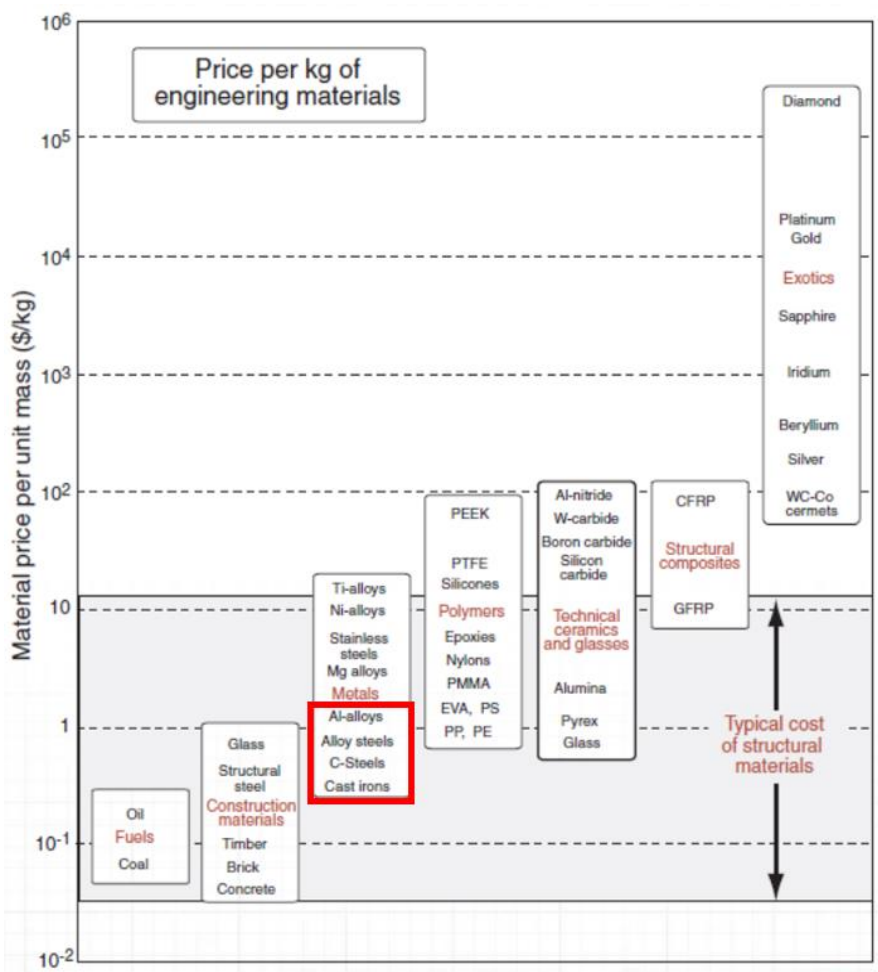


Figure 19: Material Selection Supporting Information- Blade Arm

According to this figure, other metal alloys that are roughly the same price as the current steel blade selection are denoted by the red box.
Alloy Steels- corrosion resistance, high strength, and hardness

C-Steels- high strength but difficult to bend and mold
Cast Irons - long-lasting but heavy, can rust easily, becomes very hot

Final Conclusions:

The material for the blade arm should remain steel alloy.

Outer Metal Cover

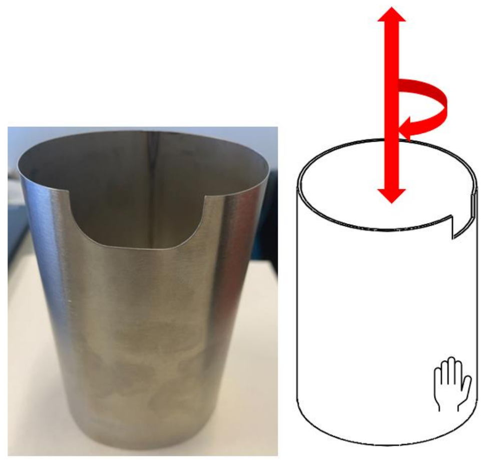


Figure 20: Outer Metal Cover Interaction Diagram (user directly touches this part)

Function:

Aesthetic design and protection of outer housing

Constraints/Requirements:

- Safe to handle for consumer
- Easy to clean
- Low-cost relative to assembly
- Hard enough to protect against physical damage to the product
- Avoid costly manufacturing processes

Objective:

Potentially remove the part and exploring comparable materials that reduce the need for metal manufacturing

Relevant Equation:

$$Cost = \frac{C_m \rho}{\sigma_w}$$

The basis of the relationship between the cost of the material and strength is based on several variables where Cm = cost per unit mass, ρ = density of the material, and σ_w = safe working stress of material [3]

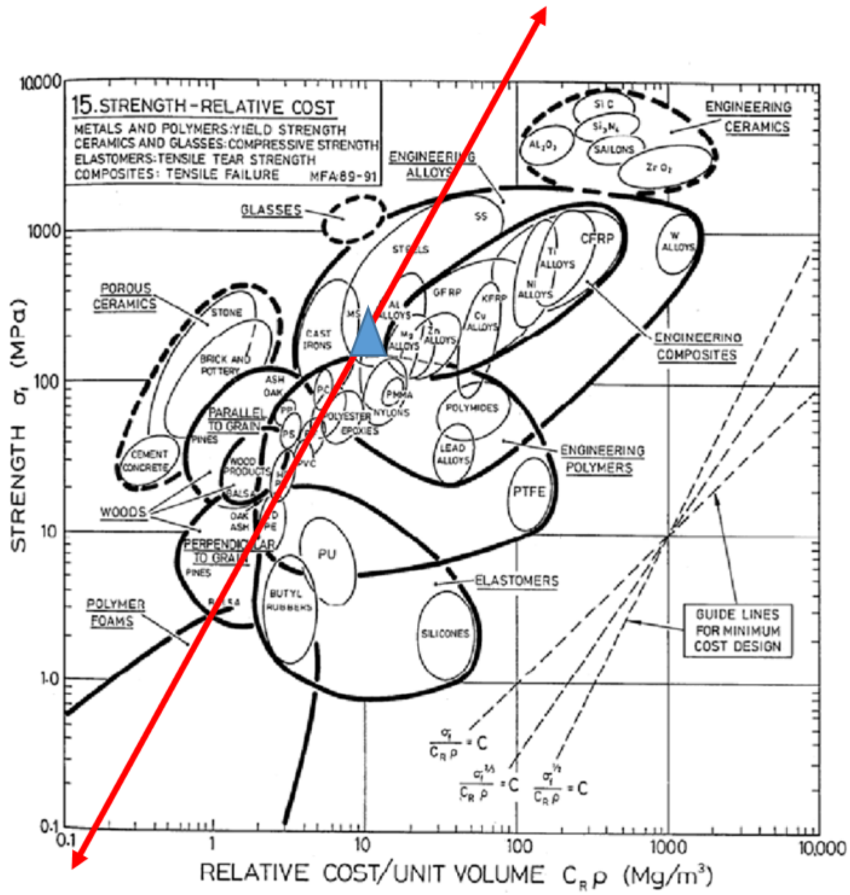


Figure 21: Ashby Chart for Outer Metal Cover (Strength vs. Cost/Unit Volume)

Pictured above is the Ashby chart that aims to meet the objective of exploring cost-effective solutions that may replace the current material and manufacturing process. Currently, the material selected for the outer cover is an aluminum alloy, which has a typical strength of 100-1000 MPa and costs roughly $2.64/lb. The current selection is denoted by the blue triangle on the red guideline.

Materials that Meet the Strength vs. Cost/Volume Objective:

Engineering Polymer

Pros: Easy processing, Resistant to chemicals
Cons: Cannot withstand high temperature, can have low strength and hardness

Elastomer
Pros: Wear resistance, Heat resistance, Easy processing
Cons: Low hardness, permeable to fluid

Polymeric Foam
Pros: Lightweight, good thermal insulation, high strength per unit weight, easy to mold
Cons: Variable density

Based on the Ashby chart, engineering polymers, elastomers, and polymeric foam are alternative materials for the outer metal cover. The main function of this part is to provide a sleek aesthetic look. It does protect the outer body to some extent but is relatively thin and likely will only shield from scratches and dents. Arguably any of these materials could be aesthetically pleasing to users. In addition to the material cost, there are high maintenance costs for machinery, and you need high production energy to manufacture this material repeatedly. Elastomers, like rubber and silicone, would serve great against wear and tear. Practically, however, this material would be hard to clean. Polymeric foam has many materials property advantages; however, it has variable density and high manufacturing costs at a large scale. By process of elimination, an engineering polymer was further selected.

Supporting Information:

Values for Production Energy and Amount of CO_2 Produced

Material	Production Energy (H_p) MJ/kg	CO_2 Burden, [CO_2] kg/kg
Low-carbon steels	22.4–24.8	1.9–2.1
Stainless steels	77.2–80.3	4.8–5.4
Aluminum alloys	184–203	11.6–12.8
Copper alloys	63.0–69.7	3.9–4.4
Titanium alloys	885–945	41.7–59.5
Borosilicate glass	23.8–26.3	1.3–1.4
Porous brick	1.9–2.1	0.14–0.16
CFRP composites	259–286	21–23
PVC	63.5–70.2	1.85–2.04
Polyethylene (PE)	76.9–85	1.95–2.16
Nylons (PA)	102–113	4.0–4.41

Figure 22: Material Selection- Supporting Information, Outer Metal Cover

According to this figure, several engineering polymers produce significantly less production energy and CO_2 burden compared to the aluminum alloy. The specific metrics are highlighted within the red boxes on the figure above. Furthermore, the idea of eliminating this part could also be argued based on this conclusion. The outer metal cover interfaces the grinder jar (part #5), which is made of ABS–an engineering polymer.

Figure 23: Outer Metal Cover and Grinder Jar

Final Conclusions:

Combine outer metal cover and grinder jar parts and create an extra layer of thickness of ABS

Trigger

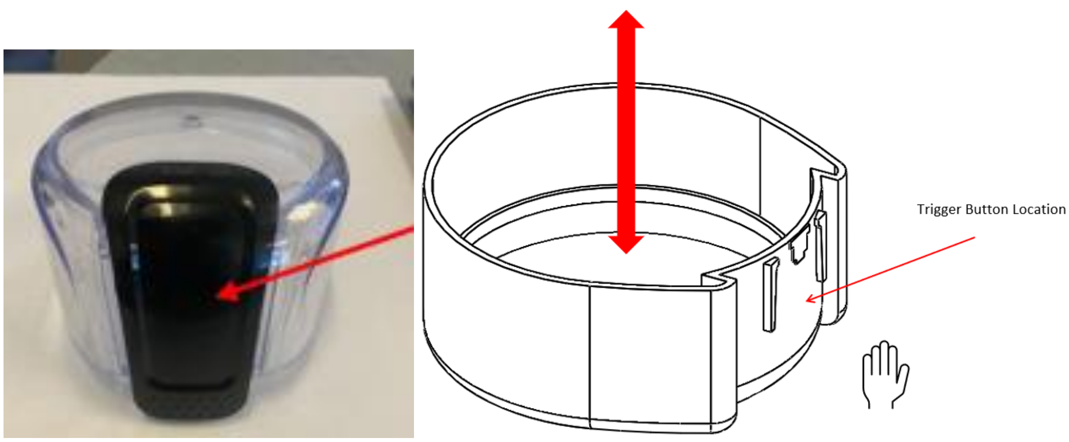


Figure 24: Trigger Component Interaction Diagram

Function:

Activate spring that allows user to open grinder cap

Constraints/Requirements:

- Able to function with spring mechanism
- Able to mate appropriately with coffee grinder cap
- Fairly durable for user interaction
- Cheaper than current material cost

Objective:

Decrease cost by reducing the need of the part, potentially combine with coffee grinder cap

Relevant Equation:

$$Cost = \frac{C_m \rho}{\sigma_w}$$

The basis of the relationship between the cost of the material and strength is based on several variables where Cm = cost per unit mass, ρ = density of the material, and σ_w = safe working stress of material [3]

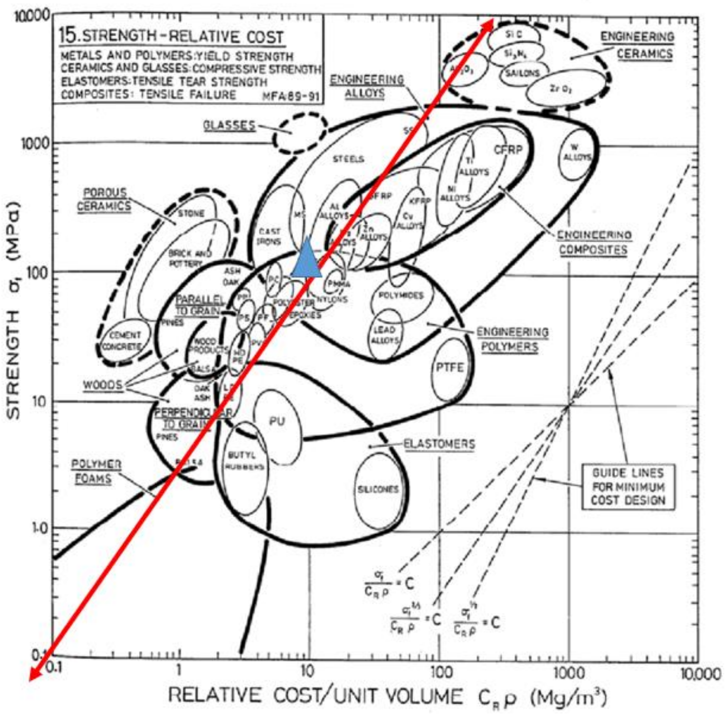


Figure 25: Ashby Chart for Trigger (Strength vs. Cost/Unit Volume)

Pictured above is the Ashby chart that aims to meet the objective of exploring cost-effective solutions that may replace the current material and manufacturing process. Currently, the material selected for the trigger is ABS, which has a typical tensile strength of 70 MPa and costs roughly $1.05/lb. The current selection is denoted by the blue triangle on the red guideline.

Materials that Meet the Strength vs. Cost/Volume Objective:

Porous Ceramics:
Pros: strong, good thermal resistance and insulation, lightweight, durable
Cons: Cannot withstand high-pressure

Engineering Polymer:
Pros: Wear resistance, Heat resistance, Easy processing
Cons: Low hardness, permeable to fluid

Polymer Foam:
Pros: Lightweight, good thermal insulation, high strength per unit weight, easy to mold
Cons: Variable density

Based on the Ashby chart, porous ceramics, engineering polymers, elastomers, and polymeric foam are alternative materials for the trigger. The main function of this part is to mechanically activate the spring-loaded system to open the grinder jar cap. Currently, the material is ABS, an engineering polymer. Replacing this part with a porous ceramic would introduce many additional costs for starting a new manufacturing process given this material is not used anywhere else in the assembly. Porous ceramics would not be an appropriate replacement for this part because it is hard to clean and very brittle. Polymer foams are hard to streamline and manufacture at a large scale. Based on this reasoning, the alternative material should remain within the engineering polymers category.

Supporting Information:

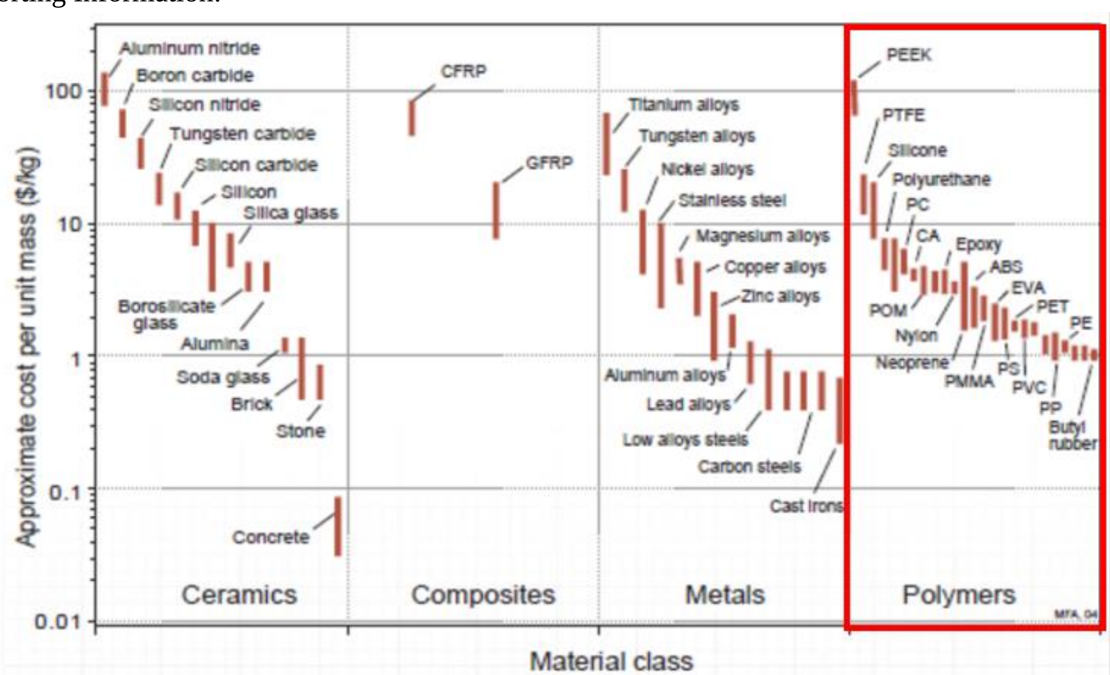


Figure 26: Material Selection- Supporting Information, Trigger

According to this figure, there are many polymers that are cheaper per unit mass ($/kg) than nylon and ABS including PVC. The polymers are highlighted within the red box on the figure above.

Final Conclusions:

Change material to PVC polymer and combine with the grinder jar cap

Cable Holder

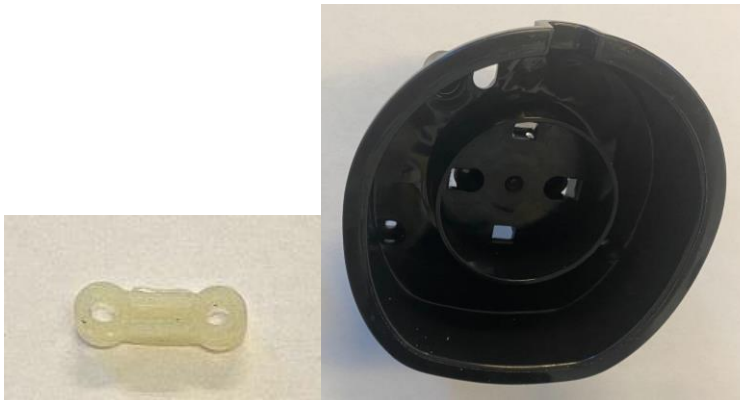


Figure 27: Cable Holder (left); Base Cap and Plastic Base (right)

Function:

Hold cables connected to the plastic base, holes allow for screws to secure

Constraints/Requirements:

- Mate with base cap and hold internal parts in place

Objective:
Reduce cost by eliminating part that does not have functional purpose

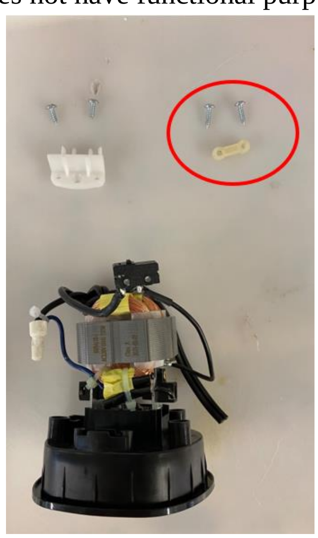


Figure 28: Exploded view of the cable holder with additional screws and support motor assembly

Supporting Information:

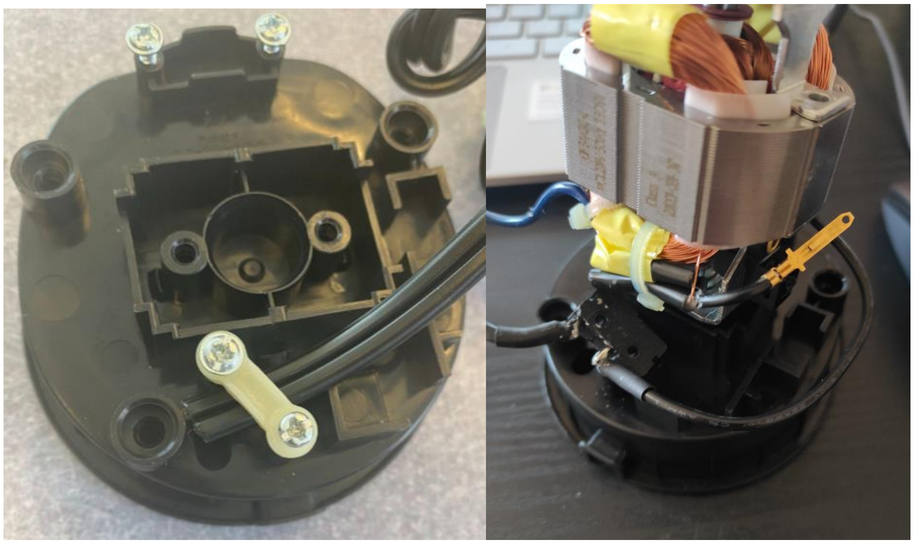


Figure 29: Cable Holder Disassembly Pictures, with holder (left), without (right)

Currently, the cable holder is made of ABS material. This is a common engineering polymer, much like the material of the plastic base. A part of our redesign is to eliminate this part along with the hardware screws necessary for assembly. Instead, we found that you were able to assemble the parts without the cable holder with reinforcements on the wire itself. This will not require any additional material analysis since only the thickness of the wire will be changed.

Manufacturing Analysis

The purpose of this section is to ensure that every manufacturing process is selected so the product will be acceptable to consumers functionally, economically, and aesthetically. The selection of this process is typically based on five major considerations: type of process, degree of vertical integration, the flexibility of resources, a mix between capital and human resources, and degree of customer contact. For the coffee grinder, process selection was explored for the redesign of the grinder cap. This section evaluates the process selection after changing this material.

Process Selection

Trigger

The original design of the trigger is made of an ABS polymer that was likely manufactured through injection molding. This is a well-streamlined process that is able to provide both material and design flexibility. It is also highly efficient and has fairly low scrap rates. Some of the disadvantages to this method are the high tooling and lead times. The manufacturers of the original Amazon coffee grinder most likely will have injection molding machines and protocols in place for a variety of materials. Currently, the trigger mates only with the grinder jar cap to activate the mechanical spring in the assembly. The main function of this assembly is to hold the coffee ground beans in the bowl and allow the user to operate the grinder.

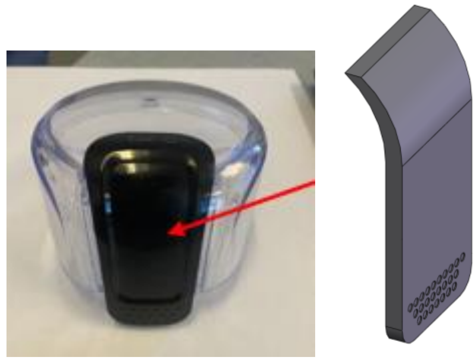


Figure 30: Trigger on Grinder Jar Cap

Currently, the trigger and grinder jar cap are injection molded separately and must be assembled. This is a secondary process that will be eliminated by the combination of these parts. In this section, the idea of PVC (polyvinyl chloride) assembly combining the trigger and the grinder cap is evaluated. To meet this objective, the alternative solution must have comparable functionality and processing capabilities.

The first step for justifying a change in this process selection is to look at the complexity of the part. The trigger resembles shape S4 the most (section open, closed at one end). This value can be used to determine the applicable manufacturing processes.

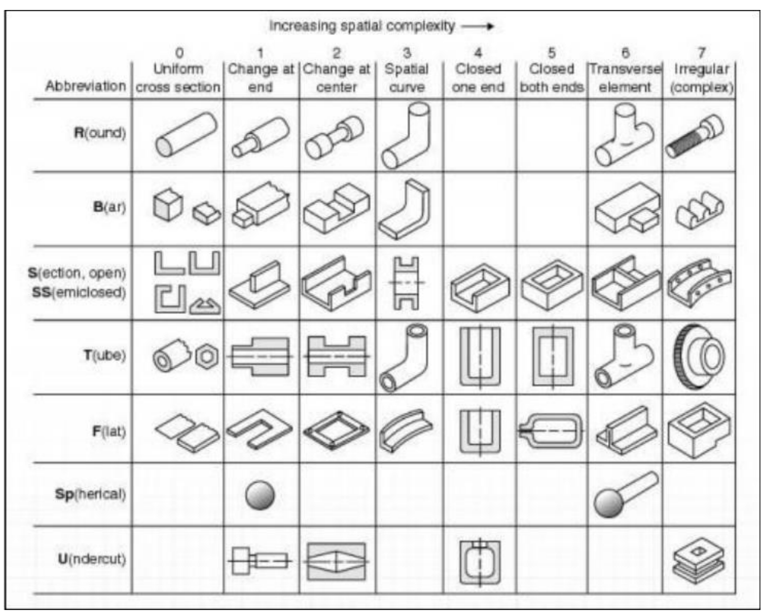


Figure 31: Manufacturing Process Shape Complexity Chart

Ability of Manufacturing Processes to Produce Shapes	
Process	**Capability for Producing Shapes**
Casting processes	
Sand casting	Can make all shapes
Plaster casting	Can make all shapes
Investment casting	Can make all shapes
Permanent mold	Can make all shapes except T3, T5; F5; U2, U4, U7
Die casting	Same as permanent mold casting
Deformation processes	
Open-die forging	Best for R0 to R3; all B shapes; T1; F0; Sp6
Hot impression die forging	Best for all R, B, and S shapes; T1, T2; Sp
Hot extrusion	All 0 shapes
Cold forging/cold extrusion	Same as hot die forging or extrusion
Shape drawing	All 0 shapes
Shape rolling	All 0 shapes
Sheet-metal working processes	
Blanking	F0 to F2; T7
Bending	R3; B3; S0, S3, S7; T3; F3, F6,
Stretching	F4; S7
Deep drawing	T4; F4, F7
Spinning	T1, T2, T4, T6; F4, F5
Polymer processes	
Extrusion	All 0 shapes
Injection molding	Can make all shapes with proper coring
Compression molding	All shapes except T3, T5, T6, F5, U4
Sheet thermoforming	T4, F4, F7, S5
Powder metallurgy processes	
Cold press and sinter	All shapes except S3, T2, T3, T5, T6, F3, F5, all U shapes
Hot isostatic pressing	All shapes except T5 and F5
Powder injection molding	All shapes except T5, F5, U1, U4
PM forging	Same shape restrictions as cold press and sinter
Machining processes	
Lathe turning	R0, R1, R2, R7; T0, T1, T2; Sp1, Sp6; U1, U2
Drilling	T0, T6
Milling	All B, S, SS shapes; F0 to F4; F6, F7, U7
Grinding	Same as turning and milling
Honing, lapping	R0 to R2; B0 to B2; B7; T0 to T2, T4 to T7; F0 to F2; Sp

Figure 32: Ability of Manufacturing Processes to Produce Shapes

Using the characterization chart above, it is evident that injection molding gives the designs the freedom to create any shape with proper coring. All the processes in the table listed above that can produce shape S4 are included in the chart below for further screening and review.

Table 4: Selection Process for Manufacturing of Trigger Cap Assembly

Possible Process	Pass or Fail	Reason for Rejection
Injection Molding- ABS	P	Thermoplastic used in injection molding
Injection Molding- PVC	P	Synthetic plastic- can come in rigid and flexible
Casting	F	Does not work for current material selection
Powder Metallurgy	F	Does not work for current material selection

Based on the material constraint, casting and powder metallurgy were automatically eliminated. The remaining processes were screened further for characteristics for the down-selected manufacturing process as shown below.

Table 5: Screening Process for Down-Selected Manufacturing Processes

Process	Cycle Time	Process Flexibility	Material Utilization	Quality	Tooling Cost	Total
Injection Molding- ABS	4	1	4	3	2	14
Injection Molding-PVC	2	1	4	4	1	12

PVC material is a thermoplastic polymer that comes in two forms: rigid and flexible. The material is best known for its resistance to environmental degradation due to its high density and strength. Some of the advantages of PVC injection molding are that it is fairly inexpensive, and the material is recyclable. Many of the steps for PVC injection molding are very similar to any other plastic. The only concern that may arise with this process is the complexity of the manufacturing. The cycle time will at least double to create the trigger and cap assembly. In addition, the PVC injection molding would require a double-sided mold made from steel, aluminum, or copper and testing to ensure functionality is not compromised.

Cost Estimation Sheet

Cost Element	Symbol	Unit	Trigger 7	Coffee Grinder Cap 8	ReDesigned Trigger & Cap
			Part Name & Number:		
Material Cost	cm	USD/lb	1.5	1.92	0.61
Material Waste Fraction	f	fraction	0.05	0.05	0.05
Mass of part	m	lb	0.1	0.12	0.22
Cm Unit Cost of Material	**Cm**	**USD**	0.16	0.24	0.14
Labor Cost	cw	USD/hr	25	25	25
Production Rate	n dot	unit/hr	120	120	120
CL Unit Cost of Labor	**CL**	**USD**	0.21	0.21	0.21
Tooling cost	ct	USD/set	1000	1000	1000
Tool Production Run	n	units	10000	10000	10000
Tooling Life	nt	units	50000	50000	50000
Number of Machines	nm		1	1	1
Sets of Tooling Required	k	sets	1	1	1
Unit Cost of Tooling	**CT**	**USD**	0.10	0.10	0.10
Capital Equipment Cost (all)	ce	USD	30000	30000	30000
Capital Write Off Time	two	yrs	5	5	5
Hours/ yr Equipment is Operated	Hyr	hr/yr	2000	2000	2000
Load Fraction	L	fraction	1	1	1
Load Sharing Fraction	q	fraction	0.111	0.111	0.111
Unit Cost of Capital Equipment	**Ce**	**USD**	0.00	0.00	0.00
Factory Overhead	cOH	USD/hr	3.33	3.33	3.33
Production Rate	n dot	unit/hr	120	120	120
Unit Cost of Factory Overhead	**COH**	**USD**	0.03	0.03	0.03
Total Unit Cost (USD)			0.50	0.58	0.48
Qb Units Produced to Break Even			2944.86	2016.87	3237.60
1:3:9 Sanity Check	**Material**	**1**	0.16	0.24	0.14
	Mfg.	**3**	0.47	0.73	0.42
	Price	**9**	1.42	2.18	1.27

Figure 33: Cost Analysis of Process Selection for Redesign, Trigger, and Grinder Cap Assembly

The cost-analysis for the redesign of the trigger and grinder cap assembly is shown above. Combining the part and using the cheaper PVC material led to the total unit cost decreasing by about 50%. The coffee grinder cap is currently made of acrylic, one of the more expensive polymers for injection molding. The cost of ABS is also much higher than PVC, as shown in Figure 19 in the materials selection section. Due to the improvement in the total unit cost of this redesign, it is recommended to be a PVC assembly.

Economic Analysis of Product

The following section contains a summary of the Economic analysis table which can be seen in the appendix, along with its corresponding equations. The analysis of the screws, motor and press fit insert are omitted since they are purchased off the shelf components.

Assumptions:

We will assume that all parts are manufactured on 8 hours a day 5 days a week 50 weeks a year schedule and that processes with a slower cycle time will receive additional machines to keep them at the same net production rate as the faster processes. We also assumed a manufacturing run of 10,000 units. Most capital costs were average costs of applicable scaled equipment.

Break-even unit sold equation Q_B:
Break-Even Point for 10000 Unit production run capital investment equation

$$Q_B = \frac{f}{P - v}$$

QB = break-even point
F= fixed costs ($)
P= sales price ($/unit)
V= variable costs ($/unit)

Cost Estimation Sheet

			Part Name & Number:				
Cost Element	Symbol	Unit	Plastic Base 1	Base Cap 2	Cable Holder 3	Button Clip 4	Grinder Jar 5
Total Unit Cost (USD)			0.65	0.65	0.42	2.33	0.65
Qb Units Produced to Break Even			1584.60	1584.60	5159.27	21848.99	2944.86
1:3:9 Sanity Check	**Material**	1	0.32	0.32	0.08	0.09	0.16
	Mfg.	3	0.95	0.95	0.24	0.28	0.47
	Price	9	2.84	2.84	0.71	0.85	1.42

			Part Name & Number:				
Cost Element	Symbol	Unit	Outer Metal Cover 6	Trigger 7	Coffee Grinder Cap 8	Motor Collar Bracket 9.1	Wire Hardness 9.2
Total Unit Cost (USD)			3.49	0.50	0.58	0.69	2.06
Qb Units Produced to Break Even			3884.64	2944.86	2016.87	1955.14	203.56
1:3:9 Sanity Check	**Material**	1	0.66	0.16	0.24	0.13	1.15
	Mfg.	3	1.98	0.47	0.73	0.39	3.45
	Price	9	5.94	1.42	2.18	1.18	10.35

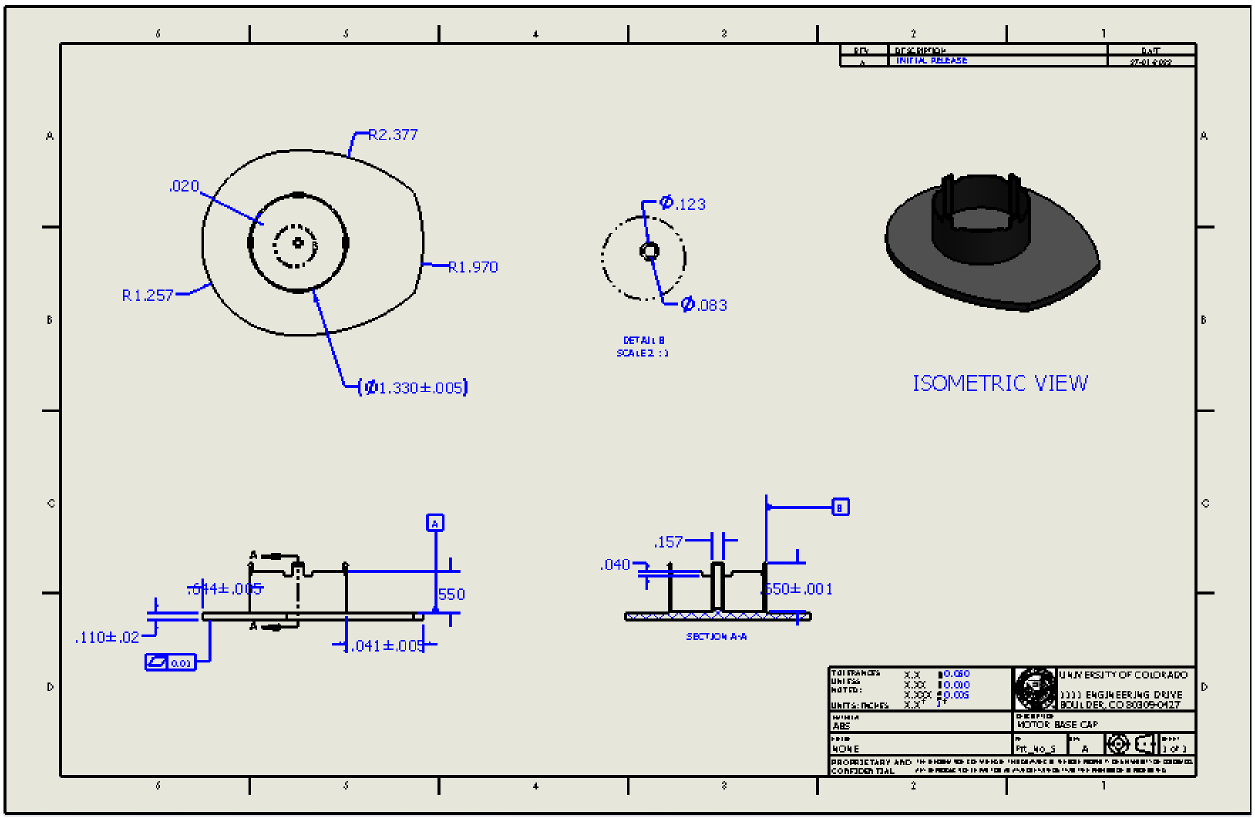
			Part Name & Number:				
Cost Element	Symbol	Unit	Shaft Collar 9.3	Brush Cap 9.5	Grinder Bowl 10.1	Blade Arm 10.2	Silicon Blade Tray 10.4
Total Unit Cost (USD)			4.39	0.50	2.35	0.65	4.03
Qb Units Produced to Break Even			15533.56	2944.86	20061.28	3174.07	22942.72
1:3:9 Sanity Check	**Material**	1	0.13	0.16	0.16	0.28	0.16
	Mfg.	3	0.39	0.47	0.47	0.84	0.49
	Price	9	1.18	1.42	1.42	2.52	1.48

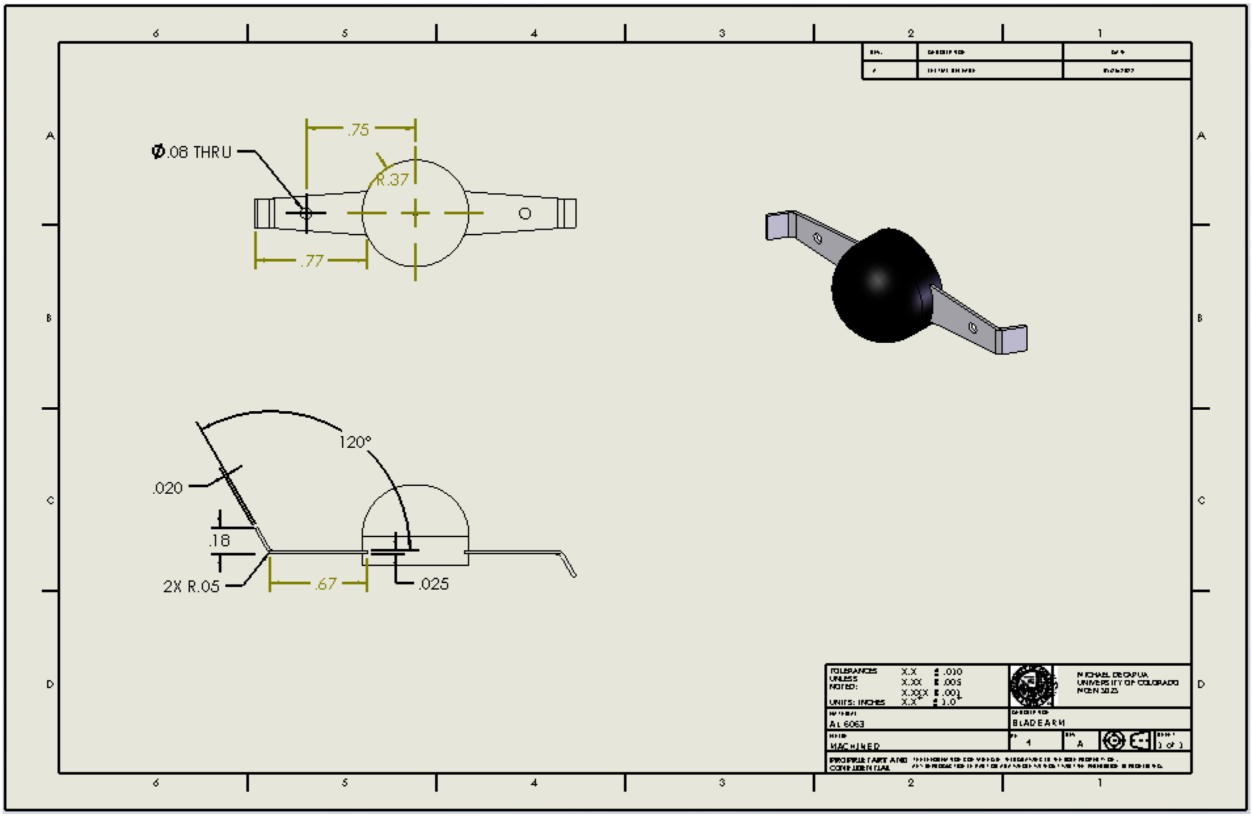
Figure 34: Economical Analysis of Parts with Corresponding Part Number

We can see from the Qb across the board in yellow that almost all of our parts will be profitable at the proposed volume of 10,000 units produced and generally it should only take until about 5000 units produced to make most of the components profitable. We also note that the estimated manufacturing cost per unit roughly agrees with our 1:3:9 rule of thumb which is reassuring. You may note that a shocking number of the cells in the economic analysis table in the appendix are identical. This is the case because many the parts share 2 processes: Sheet bending and Plastic Injection Molding. This means they have a lot in common and will look similar.

Dimensioned Orthographic Drawings

The dimensioned orthographic drawings of the crucial parts of our three sub-assemblies- Outer Housing, Motor Support and Blade Enclosure are shown below. These parts were chosen because they are the main components of our Coffee Grinder and most of these parts have holes into which the fasteners go to assemble the unit. Each drawing has the main orthographic views (along with isometric), fully dimensioned with tolerances, and required notes. Then we have the assembly drawings of the coffee grinder in the next section.

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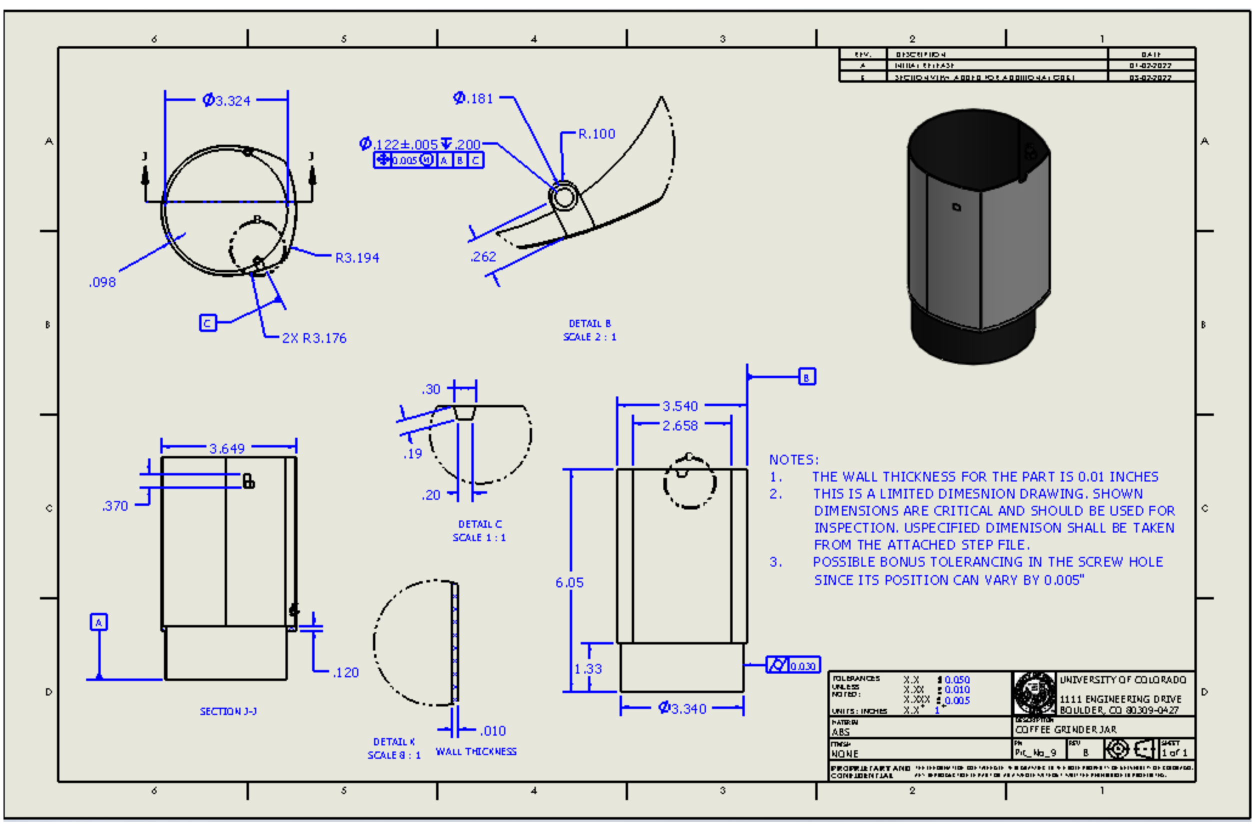
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R.100
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2X R3.176
DETAIL B
SCALE 2 : 1
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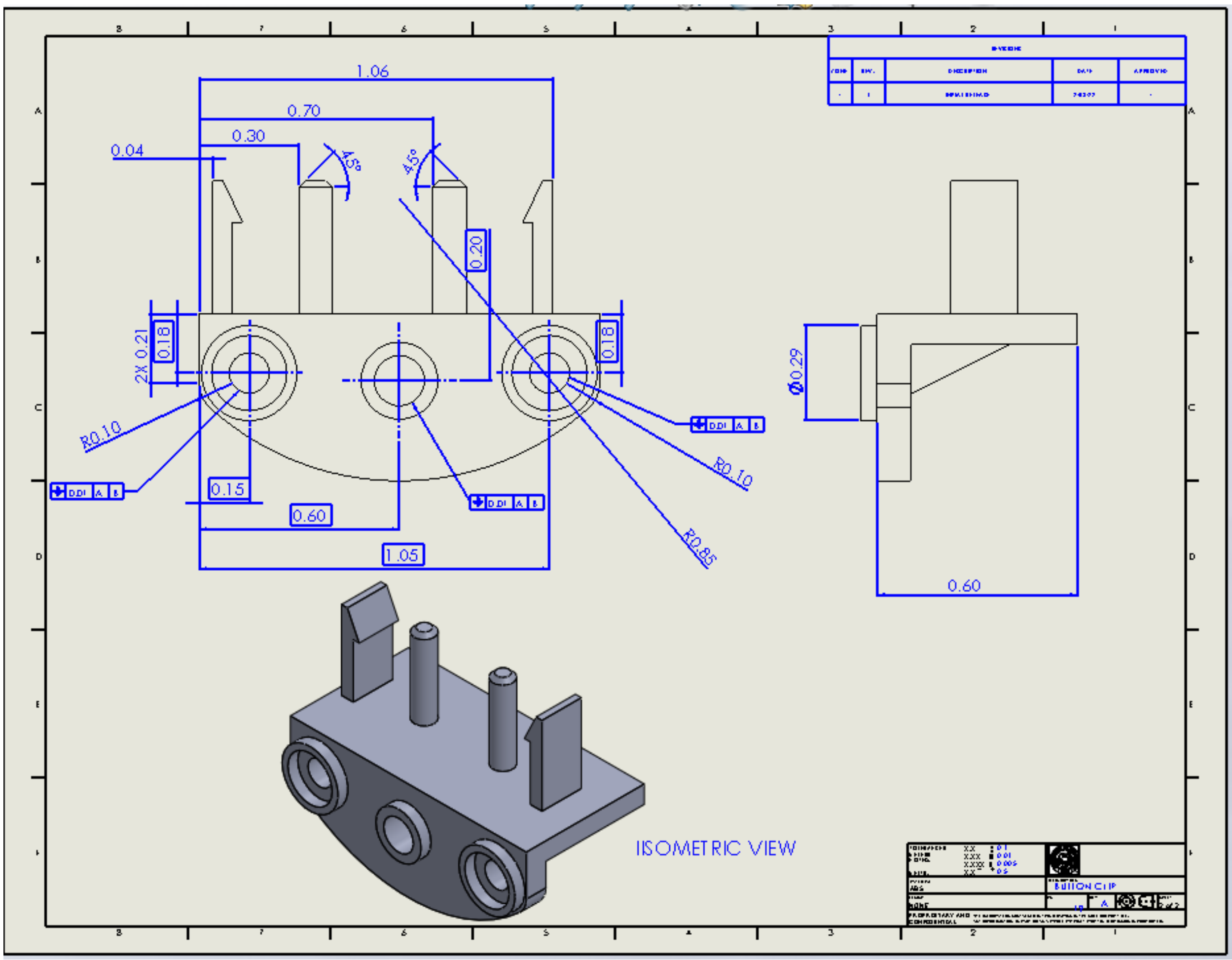
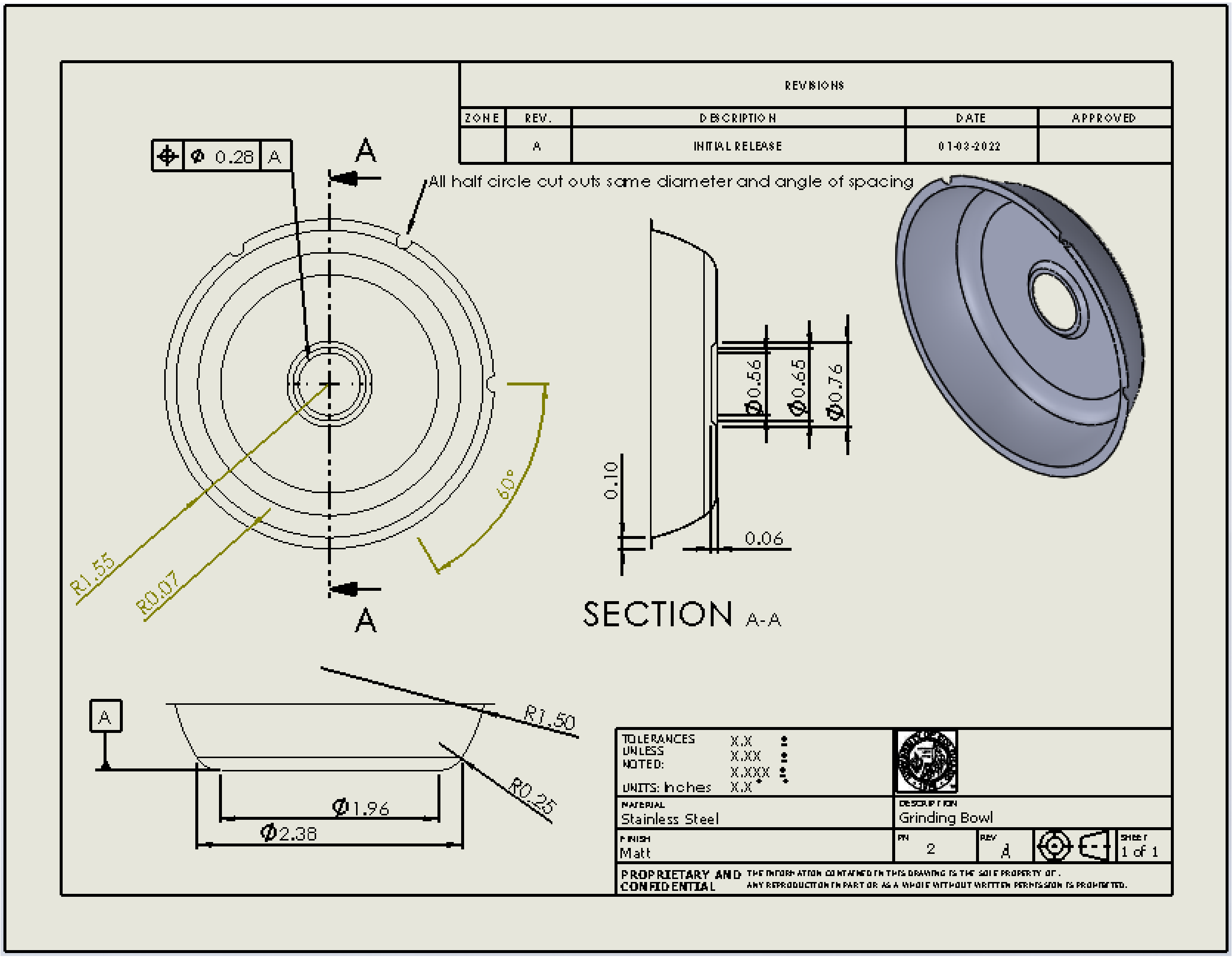
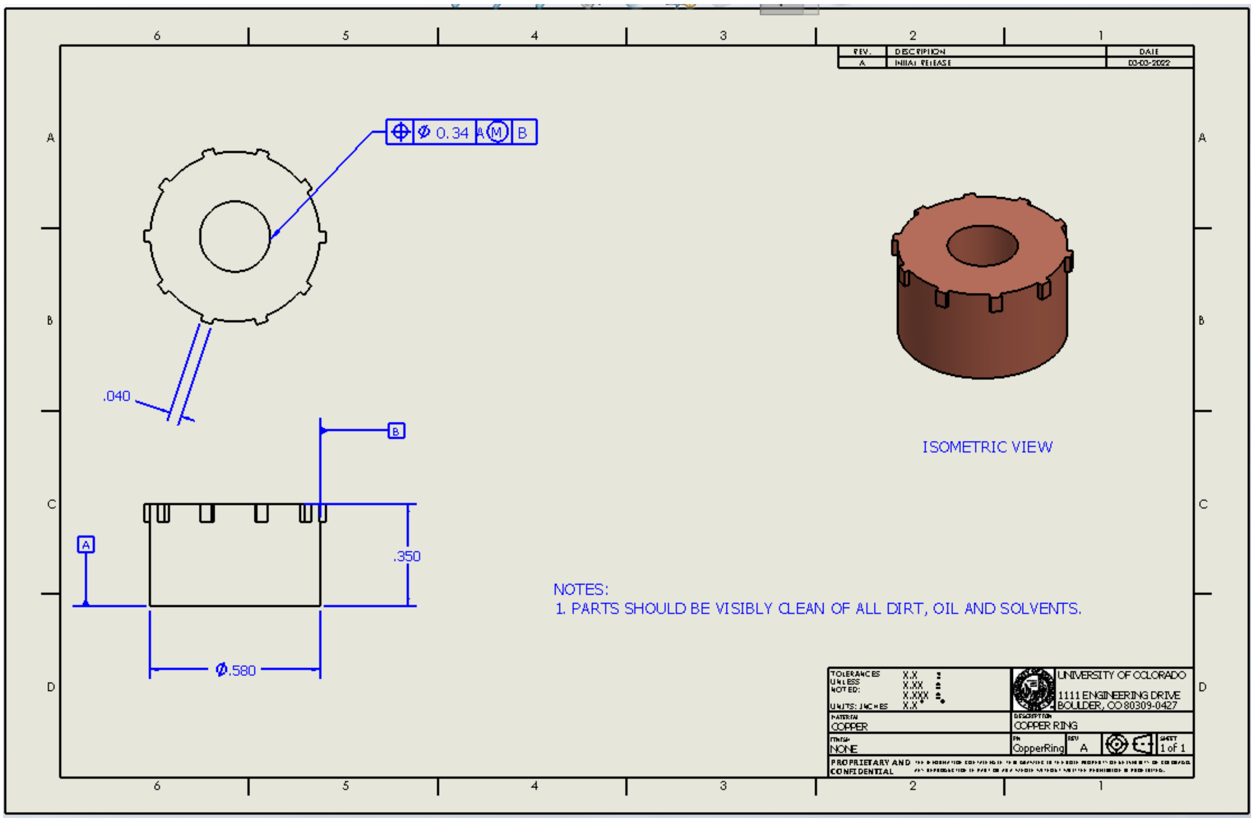
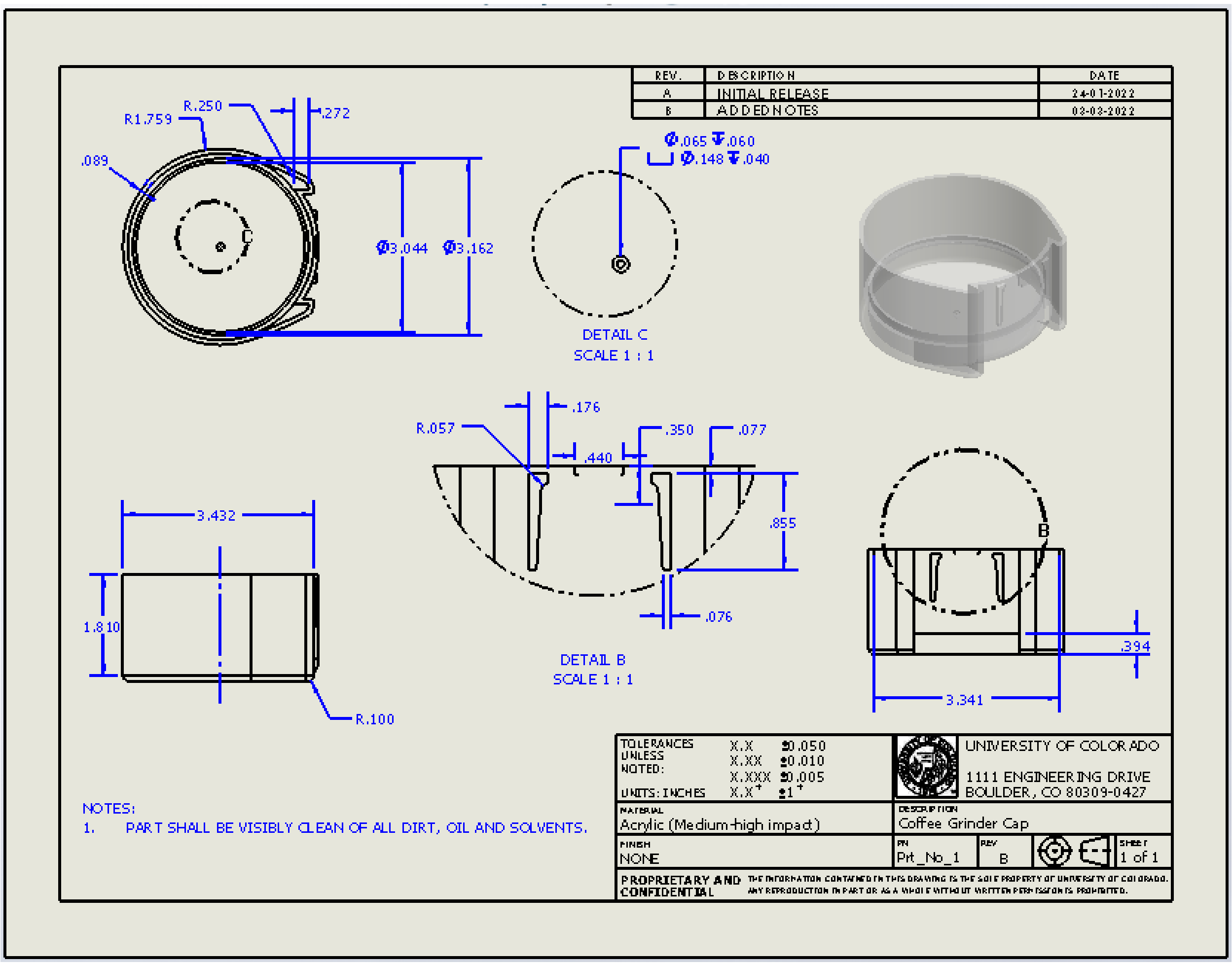
.19
.20
DETAIL C
SCALE 1 : 1
3.540
2.658
3.649
.370
.120
SECTION J-J
DETAIL K
SCALE 8 : 1
.010
WALL THICKNESS
6.05
1.33
Ø3.340
NOTES:
1. THE WALL THICKNESS FOR THE PART IS 0.01 INCHES
2. THIS IS A LIMITED DIMESNION DRAWING. SHOWN DIMENSIONS ARE CRITICAL AND SHOULD BE USED FOR INSPECTION. USPECIFIED DIMENISON SHALL BE TAKEN FROM THE ATTACHED STEP FILE.
3. POSSIBLE BONUS TOLERANCING IN THE SCREW HOLE SINCE ITS POSITION CAN VARY BY 0.005"
UNIVERSITY OF COLORADO
1111 ENGINEERING DRIVE
BOULDER, CO 80309-0427
COFFEE GRINDER JAR
ABS
NONE



1.06
0.70
0.30
0.04
45°
45°
0.20
0.18
2X 0.21
0.18
R0.10
0.15
0.60
1.05
R0.10
R0.85
Ø0.29
0.60
ISOMETRIC VIEW
BUTTON CLIP


REVISIONS
ZONE
REV.
DESCRIPTION
DATE
APPROVED
A
INITIAL RELEASE
01-03-2022
Ø 0.28 A
A
All half circle cut outs same diameter and angle of spacing
R1.55
R0.07
60°
Ø0.56
Ø0.65
Ø0.76
0.10
0.06
SECTION A-A
R1.50
R0.25
Ø1.96
Ø2.38
TOLERANCES UNLESS NOTED:
X.X
X.XX
X.XXX
X.X°
UNITS: Inches
MATERIAL
Stainless Steel
DESCRIPTION
Grinding Bowl
FINISH
Matt
PN
2
REV
A
SHEET
1 of 1
PROPRIETARY AND CONFIDENTIAL


REV. DESCRIPTION DATE
A INITIAL RELEASE 03-03-2022
Ø 0.34 A M B
.040
B
A
.350
Ø.580
ISOMETRIC VIEW
NOTES:
1. PARTS SHOULD BE VISIBLY CLEAN OF ALL DIRT, OIL AND SOLVENTS.
TOLERANCES UNLESS NOTED:
UNITS: INCHES
X.X
X.XX
X.XXX
UNIVERSITY OF COLORADO
1111 ENGINEERING DRIVE
BOULDER, CO 80309-0427
MATERIAL
COPPER
DESCRIPTION
COPPER RING
FINISH
NONE
PN
CopperRing
REV
A
SHEET
1 of 1
PROPRIETARY AND CONFIDENTIAL



REV.
DESCRIPTION
DATE
A
INITIAL RELEASE
24-01-2022
B
ADDED NOTES
03-03-2022
R1.759
R.250
.272
.089
C
⌀3.044
⌀3.162
⌀.065 ↧.060
⌴ ⌀.148 ↧.040
DETAIL C
SCALE 1 : 1
R.057
.176
.350
.077
.440
.855
.076
DETAIL B
SCALE 1 : 1
B
.394
3.341
3.432
1.810
R.100
TOLERANCES UNLESS NOTED:
X.X ±0.050
X.XX ±0.010
X.XXX ±0.005
UNITS: INCHES
X.X° ±1°
UNIVERSITY OF COLORADO
1111 ENGINEERING DRIVE
BOULDER, CO 80309-0427
MATERIAL
Acrylic (Medium-high impact)
DESCRIPTION
Coffee Grinder Cap
FINISH
NONE
PN
Prt_No_1
REV
B
SHEET
1 of 1
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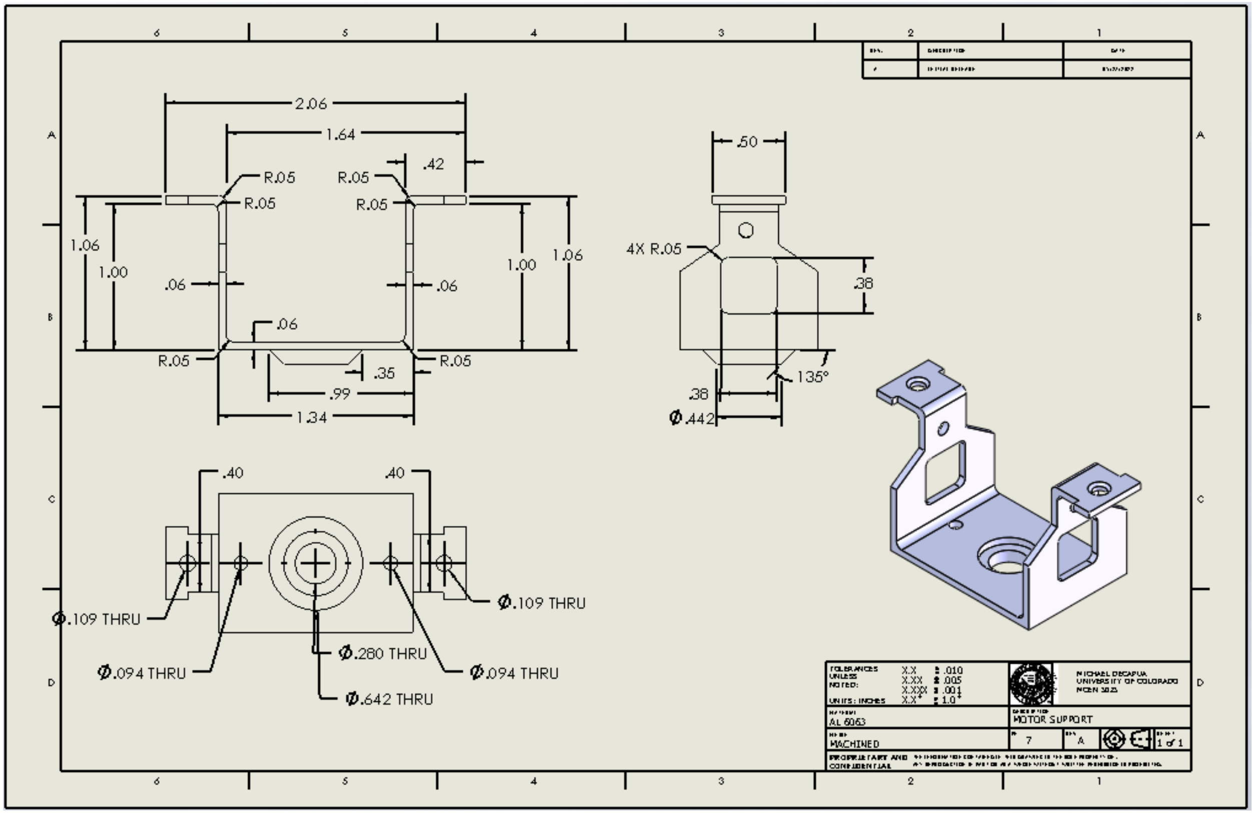
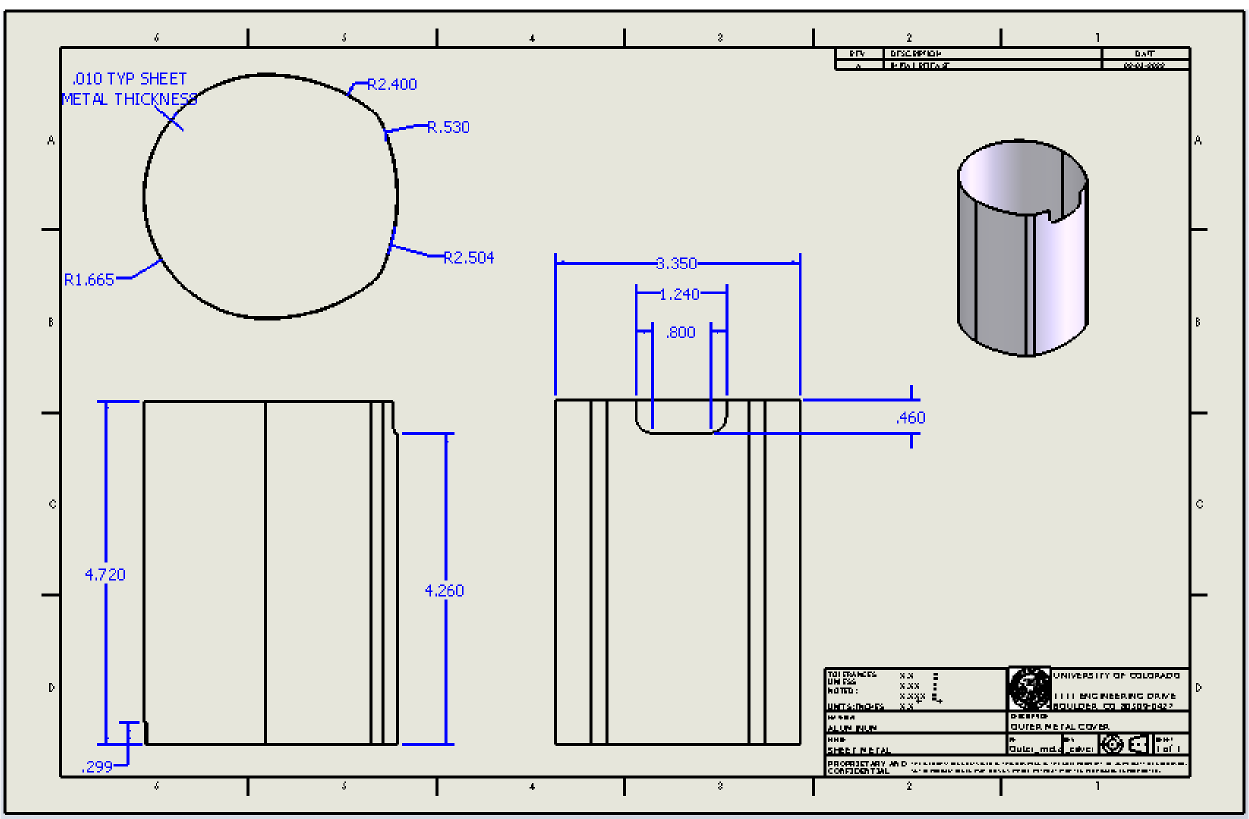
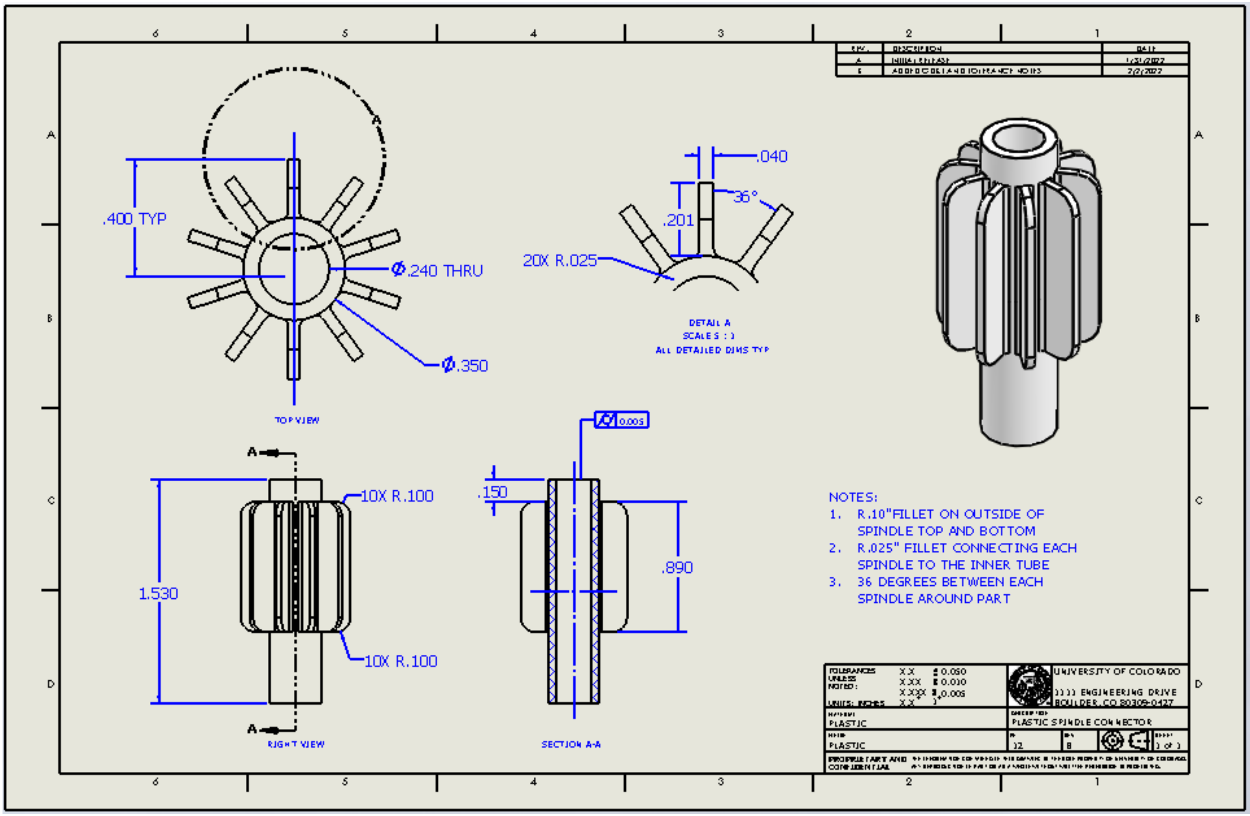
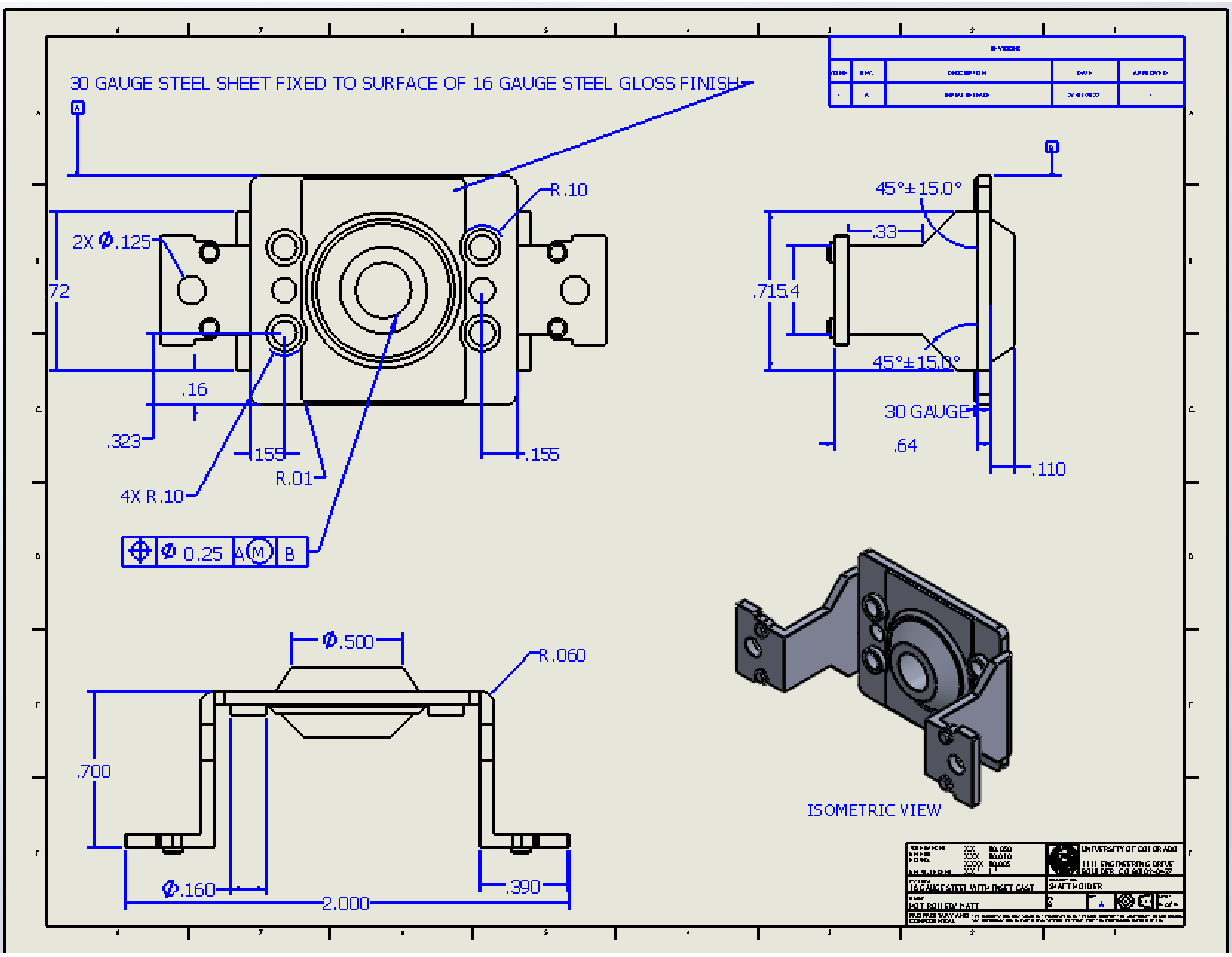
NOTES:
1. PART SHALL BE VISIBLY CLEAN OF ALL DIRT, OIL AND SOLVENTS.

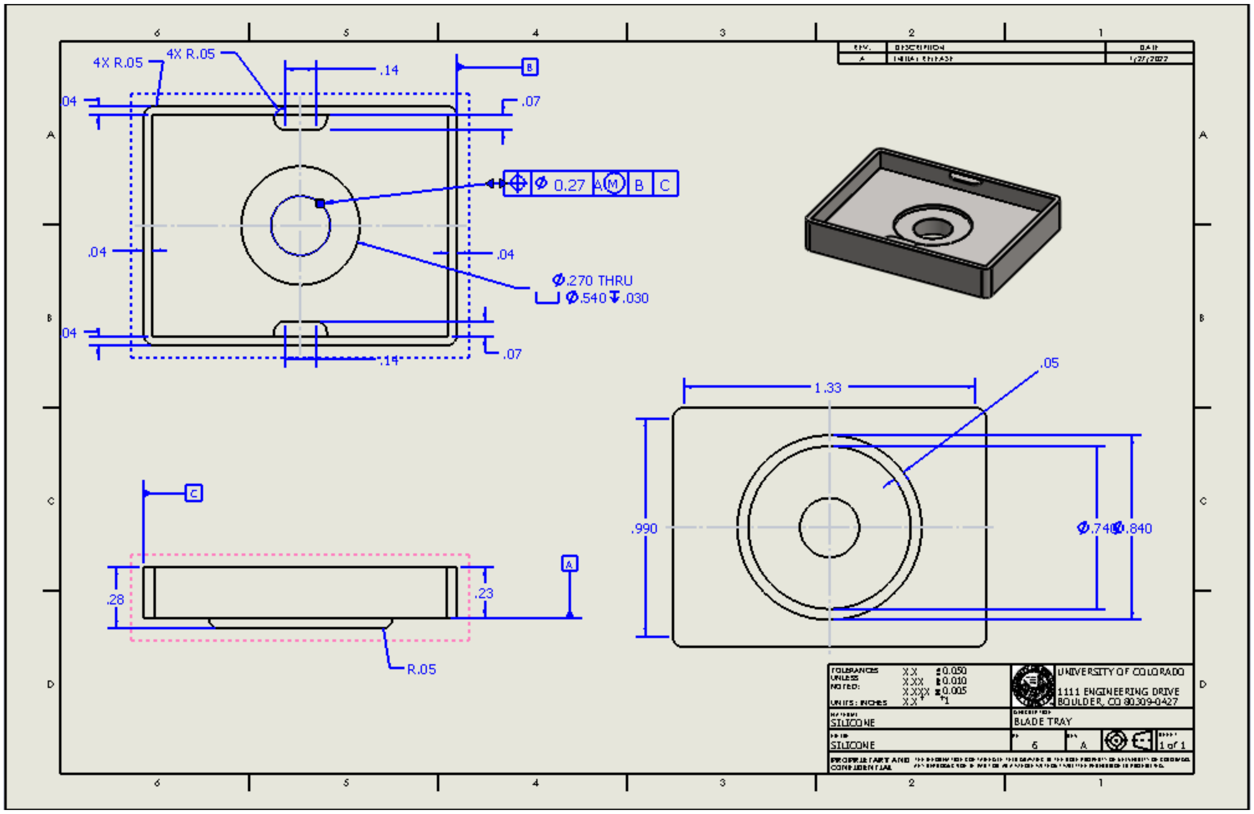

2.06
1.64
R.05
R.05
R.05
R.05
.42
1.06
1.00
.06
.06
.06
1.00
1.06
R.05
R.05
.35
.99
1.34
.50
4X R.05
.38
135°
.38
Ø.442
.40
.40
Ø.109 THRU
Ø.109 THRU
Ø.280 THRU
Ø.094 THRU
Ø.094 THRU
Ø.642 THRU
AL 6063
MACHINED
MOTOR SUPPORT
MICHAEL DECAPUA
UNIVERSITY OF COLORADO
MCEN 3025
PROPRIETARY AND CONFIDENTIAL


.010 TYP SHEET
METAL THICKNESS
R2.400
R.530
R2.504
R1.665
3.350
1.240
.800
.460
4.720
4.260
.299
UNIVERSITY OF COLORADO
OUTER METAL COVER
SHEET METAL
PROPRIETARY AND CONFIDENTIAL

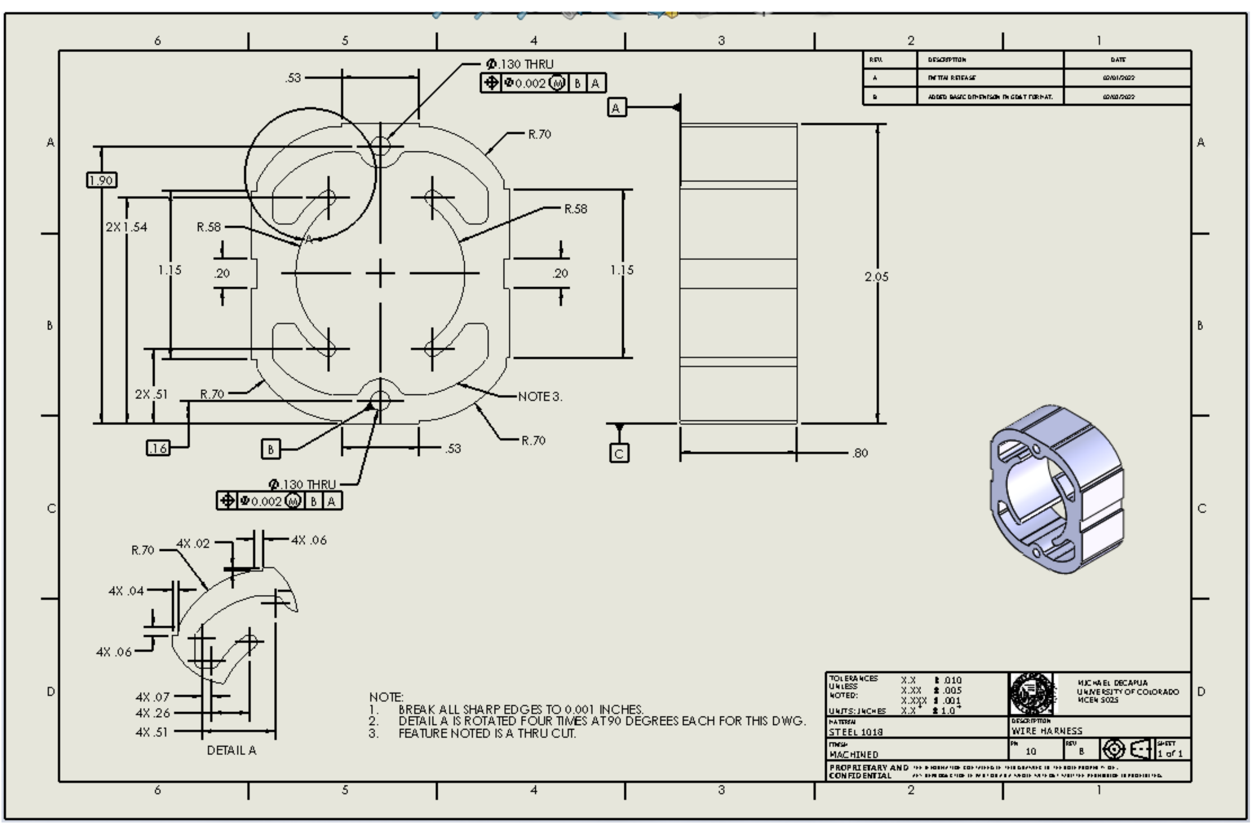


.400 TYP
Ø.240 THRU
Ø.350
TOP VIEW
.040
36°
.201
20X R.025
DETAIL A
SCALE 5 : 1
ALL DETAILED DIMS TYP
10X R.100
1.530
10X R.100
RIGHT VIEW
.150
.890
SECTION A-A
NOTES:
1. R.10"FILLET ON OUTSIDE OF SPINDLE TOP AND BOTTOM
2. R.025" FILLET CONNECTING EACH SPINDLE TO THE INNER TUBE
3. 36 DEGREES BETWEEN EACH SPINDLE AROUND PART
UNIVERSITY OF COLORADO
PLASTIC
PLASTIC SPINDLE CONNECTOR

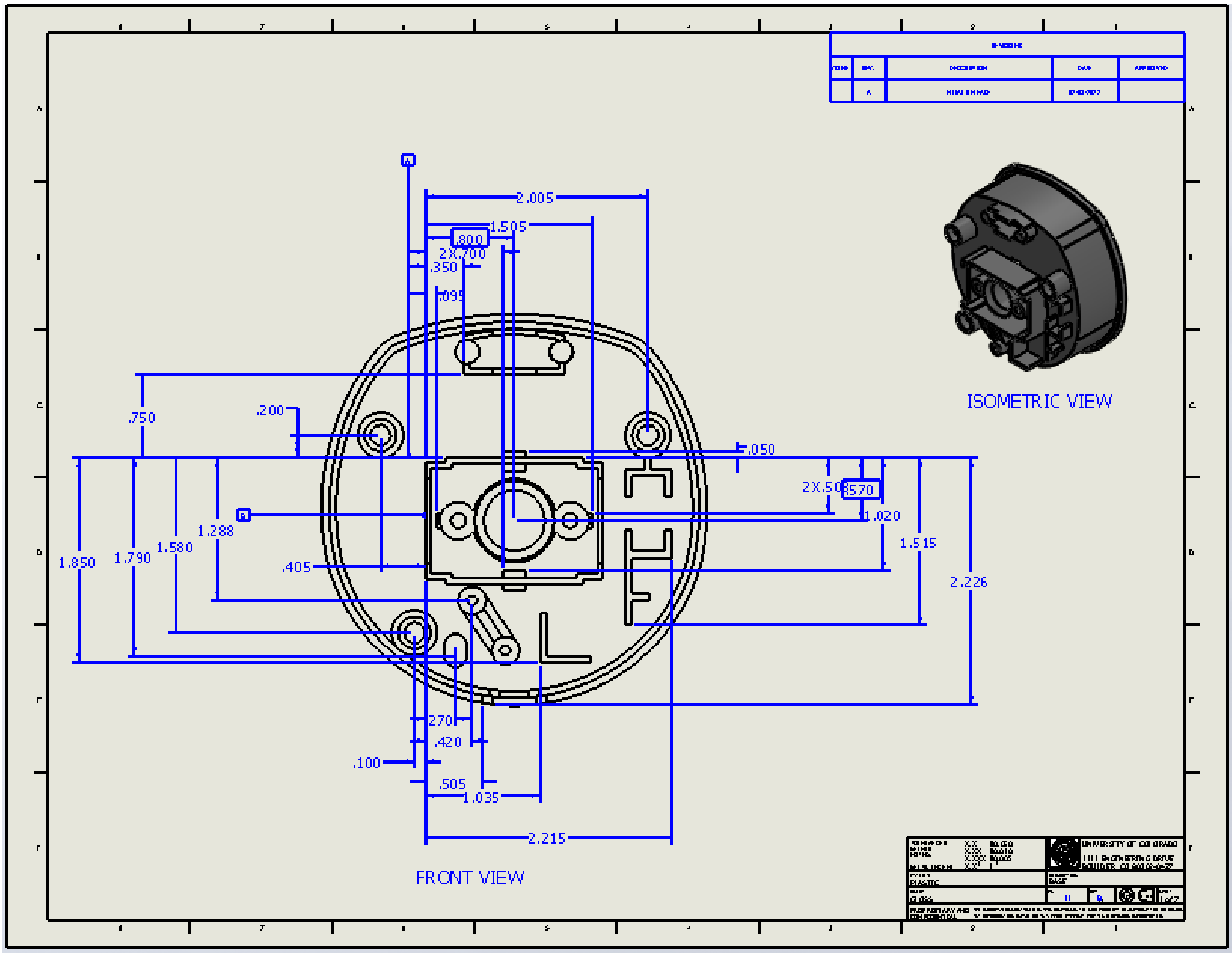

30 GAUGE STEEL SHEET FIXED TO SURFACE OF 16 GAUGE STEEL GLOSS FINISH
R.10
2X Ø.125
.72
.16
.323
.155
R.01
.155
4X R.10
Ø 0.25 A M B
45°±15.0°
.33
.715
.4
45°±15.0°
30 GAUGE
.64
.110
Ø.500
R.060
.700
Ø.160
2.000
.390
ISOMETRIC VIEW



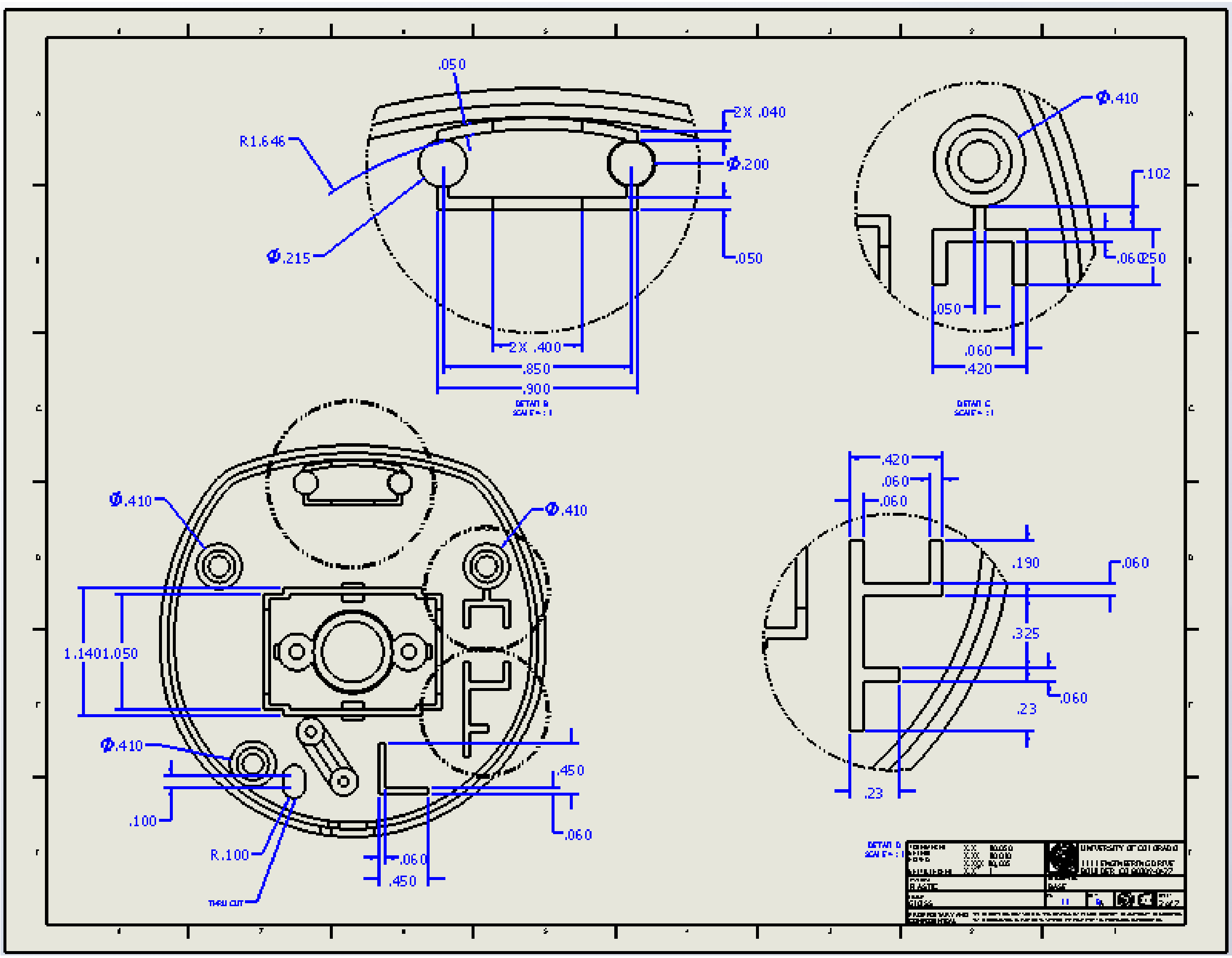
4X R.05
.14
.07
Ø 0.27 M B C
.04
Ø.270 THRU
Ø.540 ↧.030
.07
.05
1.33
.990
Ø.740
Ø.840
C
A
.28
.23
R.05
UNIVERSITY OF COLORADO
1111 ENGINEERING DRIVE
BOULDER, CO 80309-0427
BLADE TRAY
SILICONE
1 of 1

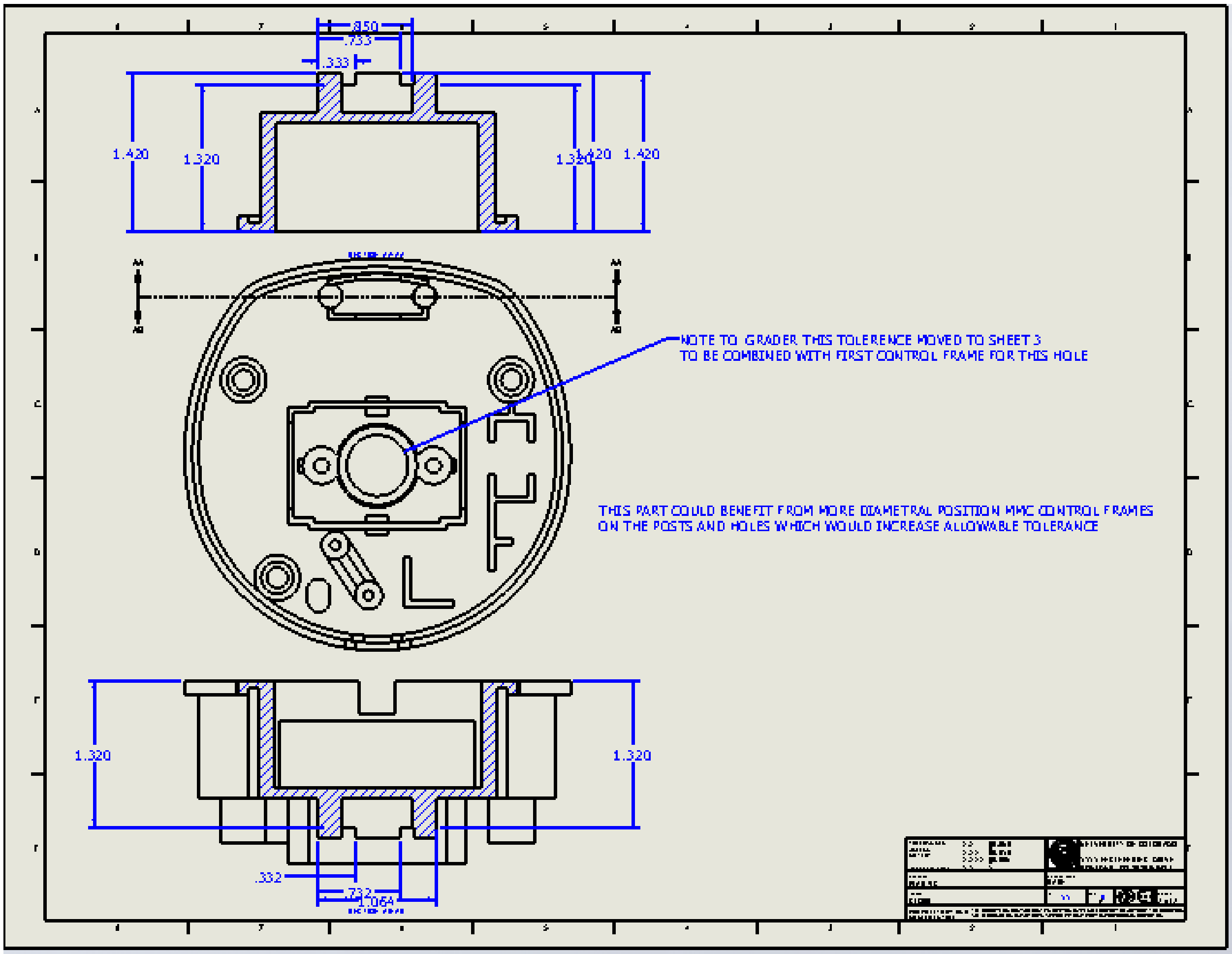


.53
Ø.130 THRU
Ø0.002 M B A
R.70
1.90
2X 1.54
R.58
1.15
.20
2.05
2X .51
.16
NOTE 3.
.80
R.70
4X .02
4X .06
4X .04
4X .07
4X .26
4X .51
DETAIL A
NOTE:
1. BREAK ALL SHARP EDGES TO 0.001 INCHES.
2. DETAIL A IS ROTATED FOUR TIMES AT 90 DEGREES EACH FOR THIS DWG.
3. FEATURE NOTED IS A THRU CUT.
UNIVERSITY OF COLORADO
WIRE HARNESS
STEEL 1018
MACHINED
1 of 1



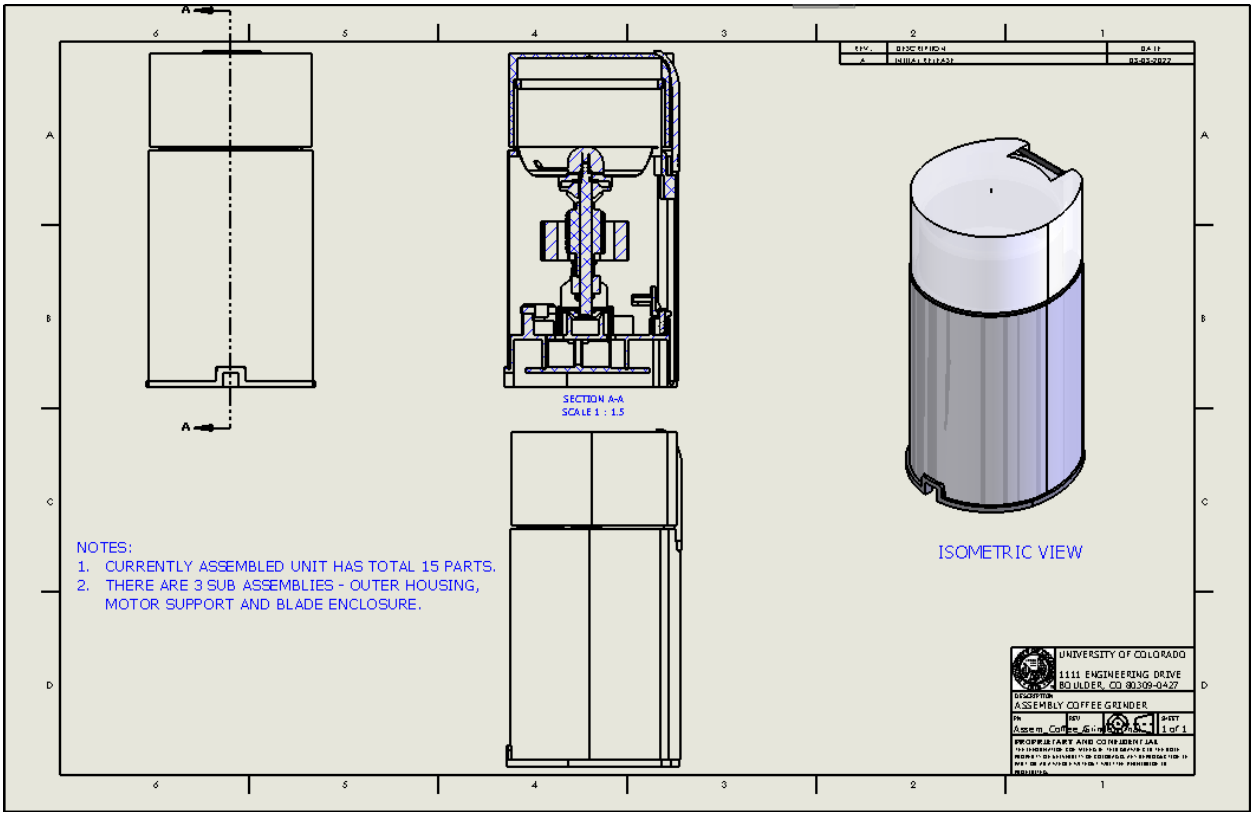
2.005
1.505
.800
2X.700
.350
.095
.750
.200
.050
2X.500
.570
.020
1.515
2.226
1.850
1.790
1.580
1.288
.405
.270
.420
.100
.505
1.035
2.215
ISOMETRIC VIEW
FRONT VIEW
UNIVERSITY OF COLORADO


.050
2X .040
R1.646
Ø.200
Ø.215
.050
2X .400
.850
.900
Ø.410
.102
.060
.250
.050
.060
.420
.420
.060
.060
Ø.410
Ø.410
.190
.060
1.140
1.050
.325
.060
.23
Ø.410
.450
.100
.23
.060
R.100
.060
.450
UNIVERSITY OF COLORADO



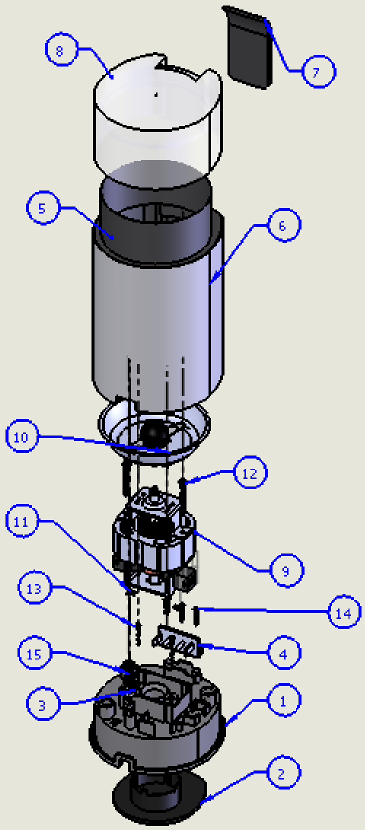
Assembly Drawings of Product

The assembly drawings of the original product as shown below include the outer housing, motor support, motor assembly, and exploded view of all the parts.



SECTION A-A
SCALE 1 : 1.5
NOTES:
1. CURRENTLY ASSEMBLED UNIT HAS TOTAL 15 PARTS.
2. THERE ARE 3 SUB ASSEMBLIES - OUTER HOUSING, MOTOR SUPPORT AND BLADE ENCLOSURE.
ISOMETRIC VIEW
UNIVERSITY OF COLORADO
1111 ENGINEERING DRIVE
BOULDER, CO 80309-0427
ASSEMBLY COFFEE GRINDER
1 of 1
PROPRIETARY AND CONFIDENTIAL

REV.	DESCRIPTION	DATE
A	INITIAL RELEASE	02-03-2022



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	5045CG1	ABS PLASTIC BASE	1
2	5045CG2	ABS MOTOR BASE CAP	1
3	5045CG3	ABS CABLE HOLDER	1
4	5045CG4	AL BUTTON CLIP	1
5	5045CG5	ABS COFFEE GRINDER JAR	1
6	5045CG6	AL OUTER METAL COVER	1
7	5045CG7	ABS TRIGGER CAP	1
8	5045CG8	ACRYLIC GRINDER CAP	1
9	5045CG9	MOTOR SUPPORT ASSEMBLY	1
10	5045CG10	BLADE ENCLOSURE ASSMEBLY	1
11	91099A152	Passivated 18-8 Stainless Steel Phillips Flat Head Screw	2
12	91771A098	Passivated 18-8 Stainless Steel Phillips Flat Head Screw	2
13	91771A108	Passivated 18-8 Stainless Steel Phillips Flat Head Screw	2
14	91771A133	Passivated 18-8 Stainless Steel Phillips Flat Head Screw	2
15	91771A891	Passivated 18-8 Stainless Steel Phillips Flat Head Screw	3

NOTES:
1. PLACE ITEM 9 (MOTOR SUPPORT ASSEMBLY ONTO ITEM 1 BOTTOMING ON THE CENTRAL LIP.
2. WHILE RESTRICTING SHAFT ROTATION OF ITEM 9 (MOTOR ASSEMBLY) THROUGH BOTTOM ACCESS HOLE ON ITEM 1 (BASE), SCREW ITEM 10 (BLADE ENCLOSURE) TO THE SHAFT OF ITEM 9.

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1111 ENGINEERING DRIVE
BOULDER, CO 80309-0427

DESCRIPTION
ELECTRIC COFFEE GRINDER

P/N: Assem_exploded_view | REV | SHEET 1 of 1

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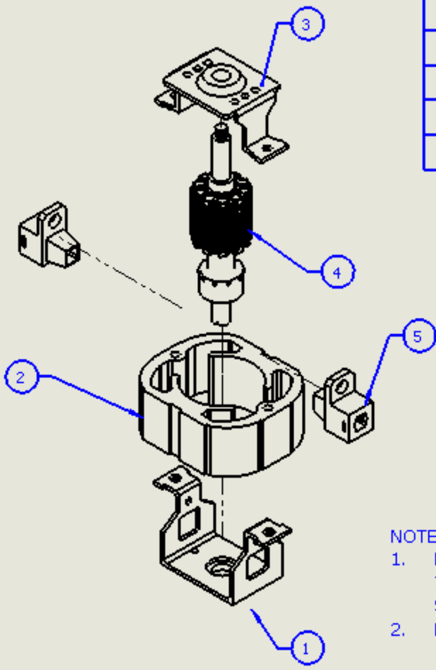
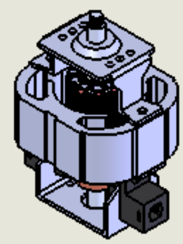
REV.	DESCRIPTION	DATE
A	INITIAL RELEASE	03-03-2022

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	5045MS 1	MOTOR COLLAR BRACKET	1
2	5045MS 2	WIRE HARNESS	1
3	5045MS 3	SHAFT COLLAR HOLDER	1
4	5045MS 4	MOTOR	1
5	5045MS 5	BRUSH CAPS	2





ISOMETRIC VIEW

NOTES:

1. PLACE ITEM 3 (SHAFT COLLAR)ONTO THE SHAFT OF ITEM 4 (MOTOR).
2. PLACE ITEM 2 (HARNESS) ONTO ITEM 1 (SUPPORT) CONCENTRIC WITH THE SHAFT OF ITEM 1.

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1111 ENGINEERING DRIVE
BOULDER, CO 80309-0427

DESCRIPTION
MOTOR SUPPORT ASSEMBLY

PN	REV	SHEET
Motor Support Assembly		1 of 1

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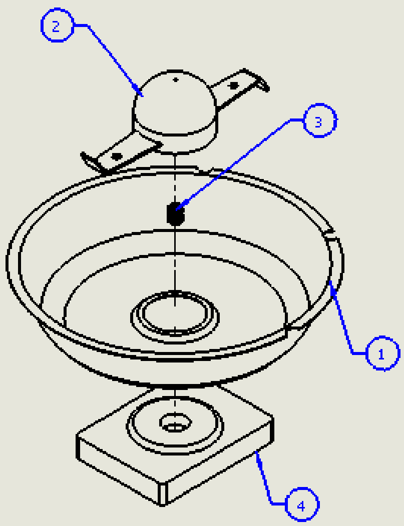
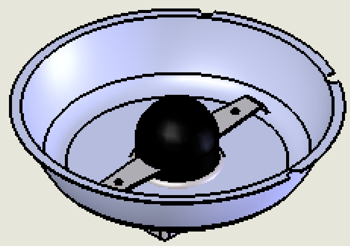
REV.	DESCRIPTION	DATE
A	INITIAL RELEASE	03-03-2022



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	5045BE 1	GRINDING BOWL	1
2	5045BE 2	BLADE	1
3	92394A111	18-8 Stainless Steel Screw-to-Expand Insert for Plastic	1
4	5045BE 3	SILICON BLADE TRAY	1



ISOMETRIC VIEW

NOTES:
1. PLACE ITEM 1 (BOWL) ONTO ITEM 4 (SILICON TRAY).
2. PLACE THE ITEM 3 (SCREW) INTO THE HOLE OF ITEM 2 (BLADE) TO MAKE THE PRESS FIT.

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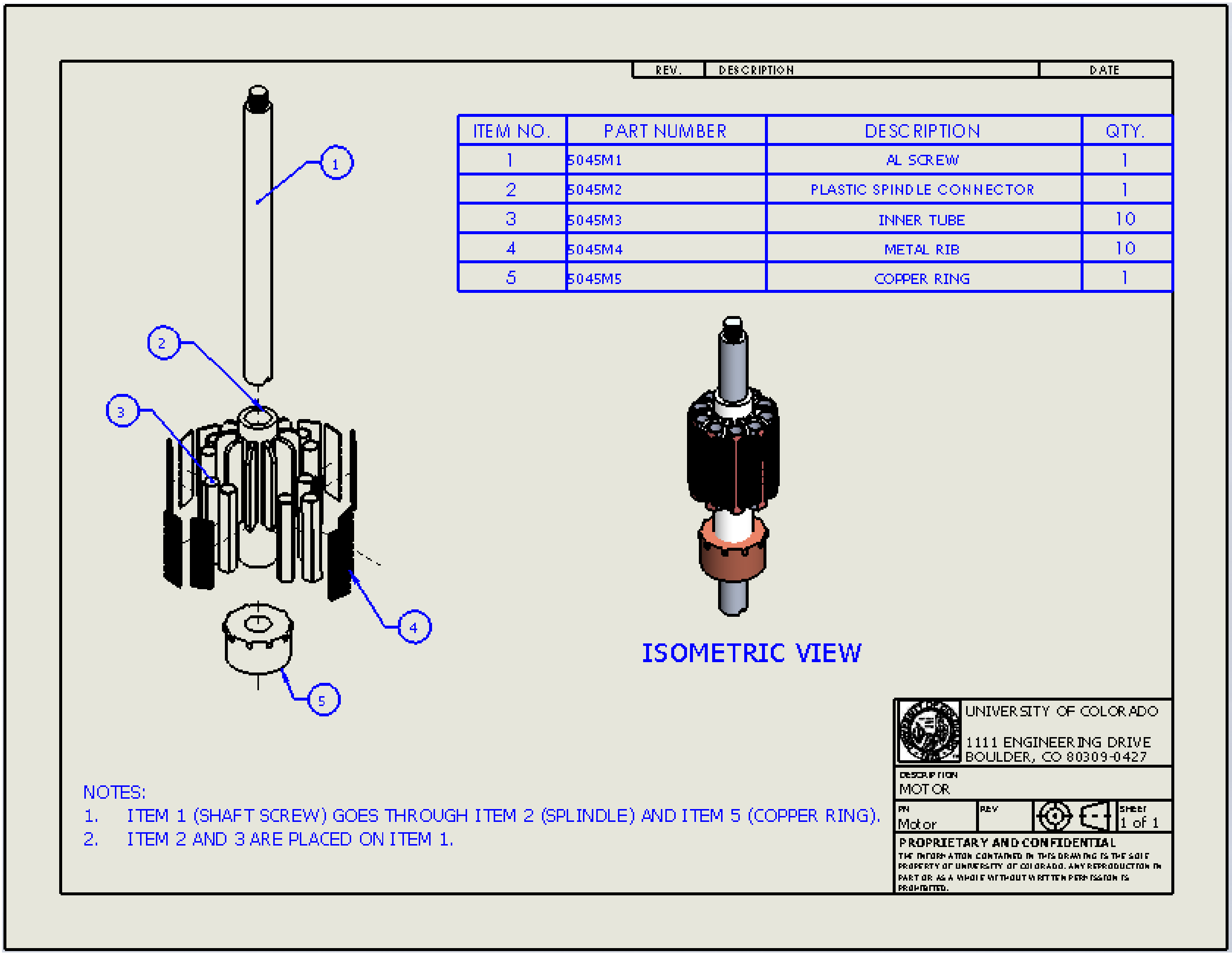
BOULDER, CO 80309-0427

DESCRIPTION
BLADE ENCLOSURE ASSEMBLY

PN	REV	SHEET
Blade EnclosureAAssembly		1 of 1



Discussion of Professional, Ethical, and Safety Issues

There are a couple safety issues with regards to assembly. The blade is relatively sharp and could pose a hazard to assembly workers. Sufficient safety equipment for handling will have to be supplied to limit minor injury. There are some safety concerns for the end user as well, the trigger for the blade is somewhat recessed but it still could be triggered from a FMEA perspective while it is unlikely the potential consequences of injury are great enough to consider redesigning the trigger assembly to reduce the likelihood of this.

Finally, there is an ecological concern regarding the unnecessary use of energy intensive materials like steel. Particularly the outer housing steel cover did not need to be made of steel to achieve a positive aesthetic effect. There are multiple other low impact and renewable materials that could have served a similar purpose with similar or better effects and limited un-necessary global warming.

Discussion of the Redesign

<u>Part Reduction:</u> A total of three parts have been reduced from this overall model.

1. We combined the cap and cap trigger
2. We eliminated the other metal housing and thickened the grinder jar wall to maintain structural integrity
3. We removed a plastic part that held the power cable in place that was redundant to the soldering and wire harness

- Combining cap and the trigger into one part made of PVC polymer
  - The trigger to the cap is an identical material to the cap of the coffee grinder. This is one singular component that is injection molded reducing this process to one manufacturing process.

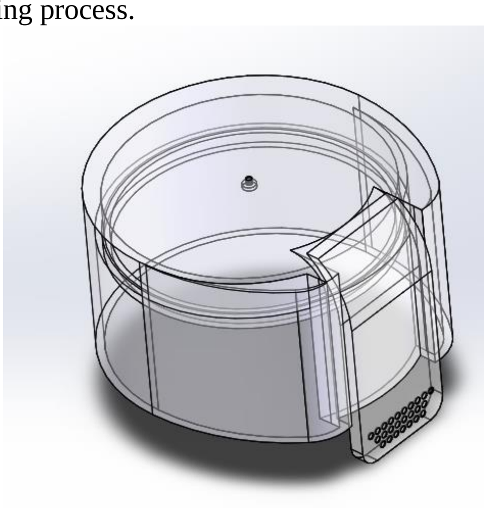


Figure 35: Redesign of Trigger and Grinder Jar Cap

- Remove outer metal housing/combine to reduce parts by thickening wall of grinder jar
  - The outer metal housing has been removed from the jar to eliminate the assembly process of having two components for the external geometry. As a result, the jar is thickened for use by the grinder.

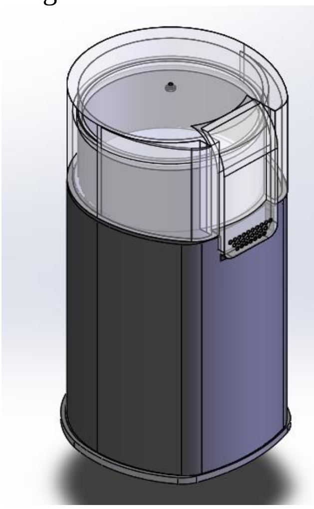


Figure 36: Redesign Removal of Outer Metal Cover

- Remove cable holder to eliminate unnecessary parts
  - The power cable had been removed since the function had only been to hold the main power line in place for assembly. This feature has been decided to be removed with the decision to thicken the power cable for this assembly. The position on this cable holder has been shown by the arrow in the diagram below.

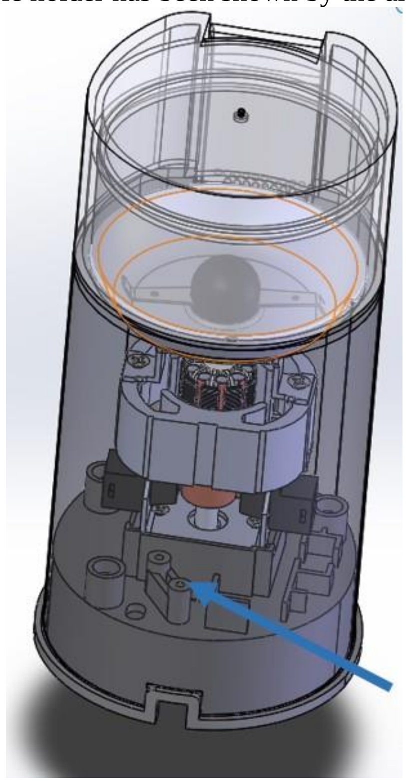


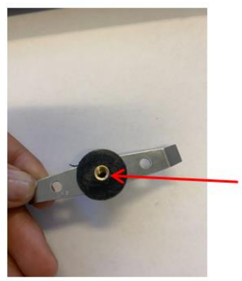
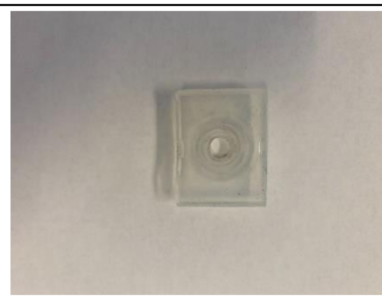
Figure 37: Redesign Removing Cable Holder

Table 6: Bill of Materials for Amazon Coffee Grinder

Part #	Part	Image	Quantity	Material
Outer Housing Subassembly				
1	Plastic Base		1	ABS

Part #	Part	Image	Quantity	Material
2	Base Cap		1	ABS
3	Button Clip		1	ABS
4	Grinder Jar		1	ABS
5	Coffee Grinder Cap/Trigger Assembly		1	PVC

Part #	Part	Image	Quantity	Material
Motor Support Subassembly				
6.1	Motor Collar Bracket		1	Steel Alloy
6.2	Wire Hardness		1	Various
6.3	Shaft Collar		1	Steel Alloy
6.4	Motor		1	Various
6.5	Brush Caps- Black Motor Alignment		2	ABS

Part #	Part	Image	Quantity	Material
Blade Enclosure Subassembly				
7.1	Grinder Bowl		1	Steel
7.2	Blade Arm		1	Steel Alloy
7.3	Press-Fit Insert		1	Brass
7.4	Silicon Blade Tray		1	Silicone
8-12	Flat head Screws		5	Steel

Conclusion

The Amazon Basics electric coffee grinder is a simple kitchen appliance for home use. The grinder allows the user to select their preferred grain size based on their application. The team was interested in exploring if there could be improvements made to this everyday product. The purpose of this report was to demonstrate practical analysis techniques, such as DFA and DFM, to justify implementing design and or process changes. The three main goals of this project were to demonstrate an improvement on the DFA matrix, be able to propose improvements to materials and manufacturing processes, and better understand the economic analysis of the product.

The disassembly process started with unscrewing the plastic base from the bottom. This released the connection to the inner grinder jar and exposed the inner components. Several more pieces of hardware were unscrewed to remove the brackets and cable holder around the motor. Disassembling was quite difficult and required multiple part orientations and a screwdriver. This gave the team an idea of how many secondary steps might be necessary for the forward assembly.

Once the product was disassembled, the team was able to start brainstorming redesigns starting with sketching the original assembly. The sketching process also helped analyze how intricate the design was and if there were obvious parts to eliminate first. Many of the parts within the motor support assembly like the motor assembly, cables, and coils, were likely purchased off-shelf so they were not considered for redesign. However, there appeared to be a lot of attention directed to the outer housing. This is likely due to the emphasis on the aesthetic and industrial design of the product. Examples of the additional effort in the housing can be observed by the original material of the grinder cap and aluminum outer metal cover.

Material analysis was performed on the redesigned parts: blade arm, outer metal cover, trigger, and cable holder. The idea to target these parts first was largely contributed to the DFA matrix conclusions. There were secondary operations associated with the wire-harness, however, the team chose not to focus on the redesign consequences of an electrical PCB. Eliminating the part count was proven to be the most effective way to reach our goals and achieve maximum redesign success. After performing the material analysis, it was determined that the material on the blade arm is optimal for the cost and function. The outer metal cover, cable holder, and trigger were eliminated from the assembly to increase the cost per unit of coffee grinders. This was an ambitious goal but the challenge allowed for exploring various manufacturing processes for sheet metal, polymers, and assembly.

The original design contained a total of 18 parts and three subassemblies. Each of these parts were analyzed using the DFA matrix to determine if there were any obvious areas of improvement to improve the experience for manufacturing operators. The redesign will include implementing the grinder cap and trigger assembly by PVC injection molding, thickening the ABS grinder jar, and removing the cable holder. The economic analysis and the DFA matrix supported the decision to move forward with this redesign.

References

(1)NCA releases 2020 National Coffee Data Trends, the "Atlas of American Coffee" (ncausa.org)
(2) • Coffee grinding method coffee drinkers United States by type 2020 | Statista
(3) Comparison of Specific Properties of Engineering Materials (gvsu.edu)

Appendix

Economic Analysis Table:

Cost Estimation Sheet

			Part Name & Number:				
Cost Element	Symbol	Unit	Plastic Base 1	Base Cap 2	Cable Holder 3	Button Clip 4	Grinder Jar 5
Material Cost	cm	USD/lb	1.5	1.5	1.5	1.5	1.5
Material Waste Fraction	f	fraction	0.05	0.05	0.05	0.05	0.05
Mass of part	m	lb	0.2	0.2	0.05	0.06	0.1
Cm Unit Cost of Material	**Cm**	USD	0.32	0.32	0.08	0.09	0.16
Labor Cost	cw	USD/hr	25	25	25	25	25
Production Rate	n dot	unit/hr	120	120	120	120	120
CL Unit Cost of Labor	**CL**	USD	0.21	0.21	0.21	0.21	0.21
Tooling cost	ct	USD/set	1000	1000	1000	20000	1000
Tool Production Run	n	units	10000	10000	10000	10000	10000
Tooling Life	nt	units	50000	50000	50000	50000	50000
Number of Machines	nm		1	1	1	1	1
Sets of Tooling Required	k	sets	1	1	1	1	1
Unit Cost of Tooling	**CT**	USD	0.10	0.10	0.10	2.00	0.10
Capital Equipment Cost (all)	ce	USD	30000	30000	30000	10000	30000
Capital Write Off Time	two	yrs	5	5	5	5	5
Hours/ yr Equipment is Operated	Hyr	hr/yr	2000	2000	2000	2000	2000
Load Fraction	L	fraction	1	1	1	1	1
Load Sharing Fraction	q	fraction	0.111	0.111	0.111	0.111	0.111
Unit Cost of Capital Equipment	**Ce**	USD	0.00	0.00	0.00	0.00	0.00
Factory Overhead	cOH	USD/hr	3.33	3.33	3.33	3.33	3.33
Production Rate	n dot	unit/hr	120	120	120	120	120
Unit Cost of Factory Overhead	**COH**	USD	0.03	0.03	0.03	0.03	0.03
Total Unit Cost (USD)			0.65	0.65	0.42	2.33	0.65
Qb Units Produced to Break Even			1584.60	1584.60	5159.27	21848.99	2944.86
1:3:9 Sanity Check	**Material**	**1**	0.32	0.32	0.08	0.09	0.16
	Mfg.	**3**	0.95	0.95	0.24	0.28	0.47
	Price	**9**	2.84	2.84	0.71	0.85	1.42

Cost Element	Symbol	Unit	Outer Metal Cover 6	Trigger 7	Coffee Grinder Cap 8	Motor Collar Bracket 9.1	Wire Hardness 9.2
			Part Name & Number:				
Material Cost	cm	USD/lb	2.64	1.5	1.92	0.92	0.92
Material Waste Fraction	f	fraction	0.6	0.05	0.05	0.3	0.2
Mass of part	m	lb	0.1	0.1	0.12	0.1	1
Cm Unit Cost of Material	**Cm**	USD	0.66	0.16	0.24	0.13	1.15
Labor Cost	cw	USD/hr	23	25	25	25	25
Production Rate	n dot	unit/hr	60	120	120	80	40
CL Unit Cost of Labor	**CL**	USD	0.38	0.21	0.21	0.31	0.63
Tooling cost	ct	USD/set	12000	1000	1000	1000	1000
Tool Production Run	n	units	10000	10000	10000	10000	10000
Tooling Life	nt	units	100000	50000	50000	50000	5000
Number of Machines	nm		2	1	1	2	1
Sets of Tooling Required	k	sets	1	1	1	1	2
Unit Cost of Tooling	**CT**	USD	2.40	0.10	0.10	0.20	0.20
Capital Equipment Cost (all)	ce	USD	10000	30000	30000	5000	1000
Capital Write Off Time	two	yrs	5	5	5	5	5
Hours/ yr Equipment is Operated	Hyr	hr/yr	2000	2000	2000	2000	2000
Load Fraction	L	fraction	1	1	1	1	1
Load Sharing Fraction	q	fraction	1.000	0.111	0.111	0.333	1.000
Unit Cost of Capital Equipment	**Ce**	USD	0.02	0.00	0.00	0.00	0.00
Factory Overhead	cOH	USD/hr	2	3.33	3.33	3.33	3.33
Production Rate	n dot	unit/hr	60	120	120	80	40
Unit Cost of Factory Overhead	**COH**	USD	0.03	0.03	0.03	0.04	0.08
Total Unit Cost (USD)			3.49	0.50	0.58	0.69	2.06
Qb Units Produced to Break Even			3884.64	2944.86	2016.87	1955.14	203.56
1:3:9 Sanity Check	**Material**	1	0.66	0.16	0.24	0.13	1.15
	Mfg.	3	1.98	0.47	0.73	0.39	3.45
	Price	9	5.94	1.42	2.18	1.18	10.35

Cost Element	Symbol	Unit	Shaft Collar 9.3	Brush Cap 9.5	Grinder Bowl 10.1	Blade Arm 10.2	Silicon Blade Tray 10.4
			Part Name & Number:				
Material Cost	cm	USD/lb	0.92	1.5	1.5	1.4	0.96
Material Waste Fraction	f	fraction	0.3	0.05	0.05	0.5	0.3
Mass of part	m	lb	0.1	0.1	0.1	0.1	0.12
Cm Unit Cost of Material	**Cm**	USD	0.13	0.16	0.16	0.28	0.16
Labor Cost	cw	USD/hr	25	25	25	10	20
Production Rate	n dot	unit/hr	80	120	120	80	200
CL Unit Cost of Labor	**CL**	USD	0.31	0.21	0.21	0.13	0.10
Tooling cost	ct	USD/set	19520	1000	19520	1000	12500
Tool Production Run	n	units	10000	10000	10000	10000	10000
Tooling Life	nt	units	50000	50000	50000	50000	100000
Number of Machines	nm		2	1	1	2	3
Sets of Tooling Required	k	sets	1	1	1	1	1
Unit Cost of Tooling	**CT**	USD	3.90	0.10	1.95	0.20	3.75
Capital Equipment Cost (all)	ce	USD	5000	30000	10000	19520	20000
Capital Write Off Time	two	yrs	5	5	5	5	5
Hours/ yr Equipment is Operated	Hyr	hr/yr	2000	2000	2000	2000	2000
Load Fraction	L	fraction	1	1	1	1	1
Load Sharing Fraction	q	fraction	0.333	0.111	1.000	0.333	1.000
Unit Cost of Capital Equipment	**Ce**	USD	0.00	0.00	0.01	0.01	0.01
Factory Overhead	cOH	USD/hr	3.33	3.33	3.33	3.33	2
Production Rate	n dot	unit/hr	80	120	120	80	200
Unit Cost of Factory Overhead	**COH**	USD	0.04	0.03	0.03	0.04	0.01
Total Unit Cost (USD)			4.39	0.50	2.35	0.65	4.03
Qb Units Produced to Break Even			15533.56	2944.86	20061.28	3174.07	22942.72
1:3:9 Sanity Check	**Material**	1	0.13	0.16	0.16	0.28	0.16
	Mfg.	3	0.39	0.47	0.47	0.84	0.49
	Price	9	1.18	1.42	1.42	2.52	1.48

Economic Analysis Equations:

Determination of Unit Cost for Three Processes

	Cost Element	Low-Pressure Permanent Mold	Injection Molding	Squeeze Casting
	Material cost, c_m ($/lb)	0.60	1.80	0.60
$C_M = \frac{mc_m}{1-f}$	Fraction of process that is scrap, f	0.1	0.05	0.1
	Mass of part, m (lb)	8.6	4.1	8.6
	C_M unit cost of material	**$5.73**	**$7.77**	**$5.73**
$C_L = \frac{c_w}{n'}$	Labor cost, c_w ($/h)	25.00	25.00	25.00
	Production rate, $\dot{n}$, (units/h)	38	45	30
	C_L unit cost of labor	**$0.66**	**$0.55**	**$0.83**
	Tooling cost, c_t ($/set)	80,000	70,000	80,000
$C_T = \frac{c_t k}{n}$	Total production run, n (units)	500,000	500,000	500,000
	Tooling life, n_t (units)	100,000	200,000	100,000
	Sets of tooling required, k	5×2	3×2	5×2
	C_T unit cost of tooling	**$1.60**	**$0.84**	**$1.60**
	Capital cost, c_e ($)	$100{,}000 \times 2$	$500{,}000 \times 2$	200,000
$C_E = \left(\frac{1}{n'}\right)\left(\frac{c_e}{Lt_{wo}}\right)q$	Capital write-off time, t_{wo} (yrs)	5	5	5
	Load fraction, L (fraction)	1	1	1
	Load sharing fraction, q	1	1	1
	C_E unit cost of capital equipment	**$0.17**	**$0.74**	**$0.44**
	Factory overhead, c_{OH} ($/h)	60	60	60
$C_{OH} = c_{OH}/n'$	Production rate, $\dot{n}$ (units/h)	38	45	30
	C_{OH} unit cost of factory overhead	**$1.58**	**$1.33**	**$2.00**
	Total unit cost = $C_M + C_L + C_T + C_E + C_{OH}$	**$9.74**	**$11.23**	**$10.60**