PAPER SHREDDER:
Gate 5
MAE 364: Manufacturing Processes

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Due: 5/9/2016
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Introduction

The final gate submission in the manufacturing processes project for the paper shredder compiles all information and analysis contained in the previous gates to deliver a succinct and in-depth report. The paper shredder is a unique product manufactured using several different processes, which is a promising source in examining and understanding the many different facets of manufacturing. This report goes in depth on the design influences of the pump, specifically the global, societal, environmental, and economic (GSEE) and technical factors. These factors are also considered for the two suggested revisions for the pump. The report then provides a thorough analysis of the manufacturing processes of the individual components and assembly of the product. The discussion for the suggested revisions is then provided to show the tradeoffs and impacts that the revisions would have on the product.

Design Influences

Background

The history of the paper shredder goes back to the beginning of the 20th century. In 1909 the very first paper shredder can be accredited to the inventor Abbot Augustus Low who resided in Piercefield New York. Low’s product offered an improved method of disposing paper and was patented on August 3, 1909. Unfortunately, Low’s invention was never manufactured. However, in the year 1935 in Germany a man by the name of Adolf Ehinger created a paper shredder that was styled after a hand-crank pasta machine and was manufactured in the same year. As the story goes, Ehinger needed to shred his anti-Nazi propaganda to avoid problems with the government at the time. Ehinger later had his shredders marketed to the government and other institutions while converting the hand crank model to an electric model. The company Ehinger started was called EBA Maschinenfabrik and continues to operate to this day as EBA Krug & Priester GmbH & Co. Paper shredders have also played other vital roles in history. For example, before the U.S. embassy in Iran was taken over in 1979, important documents and papers where shredded before they were stolen to be used for malevolent purposes. Until the mid-1980’s most citizens did not have paper shredders and only government entities used them. This changed when the privacy of citizens and identity theft became an issue. [3]
Manufacturing

The paper shredder was first created in the early 1900’s but never saw mass production at this time. In the year 1935, paper shredders were put to use again, so manufacturing began implementation in Germany. For the manufacturing, several different processes were used and are still used today but with substantial upgrades. One of these processes is casting. This process is used to create the blades which cut the paper. Since the blades are made out of metal, they can withstand varying loads of paper. Most shredders nowadays are primarily composed of plastic. Injection molding is used to create the bucket, upper and lower portions of the shredder’s body along with the power knob, motor mounts, and plastic gears. The PCB was etched in with a chemical process, while the metallic gears appear to be either machined or stamped from a thicker sheet of metal after disassembling and analyzing. The shredding blade holders appear to be bed milled from a metal rod. Lastly, the shredder’s mounting plate was most likely drilled in from a piece of a stamped metal sheet. There are other standard components, like the screws, that are created from standard manufacturing processes that several companies are known to do. They also could have been purchased for the products and are not unique compared to the other components of the paper shredder. [4][5]

Global

With the rise of the information networks, it has made our lives more convenient to use our own information and identity to do many things, such as send emails, purchase things online, buy using credit, etc. However, it has also made us more vulnerable to be targeted for that very same information. Someone else could use your own information to their own gain. Paper shredders are made to essentially add a layer of security to our lives which allows us to dispose of sensitive information in a safe manner. This usage is seen worldwide due to the extent in which these information networks or the internet has spread, and have made it necessary to dispose of information safely. Depending on the complexity of the shredder itself (if may use more slicers, and different orientations) the price may be higher or lower. It is worth noting that its global influence is beyond individual use, and it transcends into large companies or businesses that need complete security once they need a document removed. Large corporations that truly have extremely sensitive information require complete disposal of documents, because failure to do so could be catastrophic to the companies and its employers. In which case the shredders needed for these scenarios may be very expensive and advanced to reach that level of security. This also goes into the realm of complete hard drive and media deletion off of computers.
Societal

Security is a concern that many people have, and one that everyone should have. Identity theft can be accomplished by gaining information that may be confidential to an individual. However, much of the information that can be easily deemed confidential is thrown out on a regular basis by people around the world. In the United States there are over 8 million instances per year that pertain to stolen identity. Many of these cases could have been prevented with cautionary action, such as destroying sensitive information using a paper shredder. They serve as a protective stance that allows someone to discard this information in a safe manner by ripping up the document which holds sensitive information. Worth noting is that paper shredding is also a good way to practice recycling. With the ever growing concern of the environment, paper shredding can serve as a great incentive to protect the environment, and keep an individual’s identity safe.

Economic

Most consumer-sold and office-use paper shredders have many plastic components. These plastic components are likely manufactured using molding methods due to high production rates. The production rates are driven by a high and stable demand for paper shredders. Future sales of paper shredders are not in jeopardy. In fact, demand should only increase based on the increased threat of identity theft and forgery. Although, as many financial and personal documents become electronic, paper shredder sales will take a slight hit. Regardless, paper shredders will likely always be needed in business environments, at least in the foreseeable future.

Due to the generally low-cost of most paper shredders, many people and businesses generally replace the entire paper shredder when it ceases to function. This, in a way, minimizes life cycle costs. Assuming the shredders have a decent lifespan, there is usually no need to purchase a specific part to replace it. People and businesses will more than likely purchase a newer, better shredder, since the design generally increases in reliability over time. However, if a part did need to be replaced, the part should be generally easy to obtain from the manufacturer. The person or business would most likely have to worry about shipping costs unless the shredder is still under warranty.

Some of the components in the paper shredder can be purchased from other manufacturers to help lower the cost of production. These components could include hardware such as screws and washers as well as electrical components. Paper shredder manufacturers more than likely stick with the components that are specific to paper shredders. In contrast, as paper shredders become more complex, more components may have to be designed and manufactured by the paper shredder companies themselves.
Environmental

As paper shredders become more sophisticated, so does the manufacturing process. Many shredders now have silent operation capabilities to help reduce noise produced during operation. Some have built in power saving features such as sleep mode that reduce energy consumption when the shredder is not in use.

As for the manufacturing processes themselves, there are a variety of environmental impacts that go along with a multitude of manufacturing techniques. Casting seems to be used for many of the metal components. The environmental effects of casting can sometimes be traumatic, including emission of harmful particles and poisonous gases. Injection molding can result in effects associated with plastic pollution. This can include non-biodegradable plastics being disposed of incorrectly, or contributing to poor conditions of landfills. Chemical processes could be used in the manufacturing process, and pollution caused by some of these chemicals can create issues for the environment.

From an external point of view, paper shredders indirectly create some environmental benefits. Sometimes the clippings are used as animal bedding or as kindling for fire. Otherwise the paper is usually recycled. [1][2]
Design Revision Motivation

Revision 1: Collection Bin Snap Tabs

The paper shredder (Figure 1), when fully assembled, has two main components. These components are the shredder case and the collection bin. The shredder case houses the shredder assembly, the motor, and all the major components of the paper shredder. All of the metal and electrical components are contained within. The collection bin is simply a container that collects the shredded paper. Currently, the two components are not joined together. The shredder case sits on top of the collection bin. The proposed design revision would be to replace the two hand slots used to remove the shredder case with snap tabs that are part of the mold. This would ensure that if the paper shredder is knocked over or falls during transportation that it would remain intact. Two major areas of concern to address in a redesign is the design for manufacturability as well as the GSEE and technical influences.

Figure 1
DFM Analysis

The most important aspect to consider from a profit standpoint when proposing a redesign for a product is cost. There are three major areas that can be broken down by cost: component cost, assembly cost, and support cost. In terms of component When combined together, upper management can begin to see where these design improvements can really benefit the company while still ensuring integrity of the paper shredder.

As for the component cost, the two components concerned in this design improvement are the shredder case and the collection bin. The proposed changes to the paper shredder are two snap tabs at each of the hand slots on the sides of the paper shredder shown in Figure 2. Each component would likely experience a very slight increase in cost. This is due to a very slight increase in the amount of material needed for the mold. The molds would include the shape needed for the snap tab for each of the two components. This would also make the mold more complex and make the mold slightly more expensive. The design would need to ensure that the mold can still be easily removed from the mold. These two increases in price would be the only cost changes associated with the component.

The assembly cost would not be affected at all because the paper shredder comes fully assembled in the box packaging. The shredder case already sits on top of the collection bin, and it would be the same for the proposed design. It is proposed that the snap tabs will have “buttons” that will release the tabs so that the shredder case can be detached whenever it needs to be emptied. Therefore, the assembly cost is not affected by the new design proposed.

The support cost would also not change much. The only aspect that could possibly be considered as an increased support cost would be an increase in the plastic material needed to be shipped to the manufacturing facility. This is nearly negligible, however, because the
company is already purchasing large amounts of plastic from the supplier. This cost is also factored into the increase in component cost, and should not be considered twice.

The tradeoffs for the new component design are also important to consider when proposing the design to upper management. The main tradeoff that the management team will be concerned with will be the increased complexity of the molds. This will lead to a slight increase in price and the engineering team will need to ensure that the component can still be easily ejected from the mold. The tradeoff, though, is that the product is now more structurally sound and easier to transport for the end user. The whole paper shredder can now be moved without the user having to worry about the two major components detaching from one another and either causing a mess, injury, or damage of the shredder and/or other property. The collection bin can be easily detached, however, by pressing the snap tabs to release the shredder case. No other tradeoffs are very important to consider for this redesign.

GSEE and Technical Influences

The global influences for this redesign are that it becomes a much safer, easier to use, and reliable product that generates a positive impact. The societal impacts are that the design is easier to transport without causing injury. The economic effects are that the shredder are that the additional manufacturing time could cost slightly more in the long run, but the reality is a safer and more efficient product for the end user. The paper shredder may also receive less dropping damage and result in a longer lifespan. The environmental effects are that that the manufacturing process may use slightly more plastic in the long run but this could be considered negligible. The technical influences are that the paper shredder casing and the collection bin are not attached in any way which present many different potential issues. The design was focused around finding a solution to this problem using a temporary joint type. The overall connection between everything is that the positive impacts of the technical influences outweigh any negative impacts found in the GSEE factors.
Revision 2: Shredder Blade Assembly

To revise the shredder blade assembly, for reduced cost, improved performance, and easier manufacturability, the shredder blade assembly is changed from an assembly of plastic spacers and metal teeth, rods and c-clips to a purely sand cast part. This would remove the need for powder metallurgy, and plastic products in the assembly, removing the need for a human worker to perform an assembly. The assembly below would be turned into one net part, capable of much higher loads, due to its denser metal structure [Figure 3 Shredder Blade Assembly]

![Figure 3 Shredder Blade Assembly](image)

DFM Analysis

For cost Impact, two things have to be considered. The first that the net amount of metal would remain unchanged, with the exception of the 3 percent density gained on the transition from powder metallurgy to sand casting causing a slight increase in cost for the Metal Teeth, and the metal Tooth rod. The second being that the plastic spacers will not be required after the casting, dropping their price to zero. The energy required to melt down plastic for the plastic spacers would be in turn altered into energy to melt down the steel for the blade and rod assembly.
Transitioning to sandcasting for the entire assembly would introduce new material that would have to be ground away near the blades, increasing the price of the assembly, but the blades would have to be ground already, and the process to remove excess material and grind the blades can be combined in a single process. Thus this price increase would be fairly insignificant.

Support cost would be slightly increased, with the teams hired to prepare the green compact for powder metallurgy instead prepping sand for mold production, so the molds for each part can be prepared. Stock to melt down into molten steel would also have to be obtained and prepared, the heat for melting would also require operators and maintenance workers to have altered uniforms and safety requirements. In addition, energy costs to keep steel for casting molten would be high, and need to be accounted for in the final cost of the product.

The revision would have tradeoffs, in design and production speeds, especially. When producing the new component, any flaws that hinder the performance of the part could be difficult to fix, and require the part to be melted back down and remade. Since molds would be moderately difficult to produce, the time required to produce the component would increase, but would be made up for in the fact that the production of four components and assembly time of them as well would be compared to this production time. Tradeoffs when shipping would be minimal, since the product is most likely assembled in the same facility it is produced in, and might additionally decrease the time required to assemble the shredder, since no assembly time is required for the component itself. Tradeoffs in component strength would be positive due to the greater metal density, and heat treatment applied through the cooling of the part.

GSEE and Technical Influences

The global factors for this redesign are that less separate parts are going to need to be shipped and sold for repairs. The societal impacts of this revision are that the repairs for the device will be much less frequent and easier to accomplish. The economic factors are related in that there is less cost associated with replacement parts and that the shredder itself will last longer. The manufacturing could end up rising the cost of creation, however. The environmental factors are negligible in that the component still requires roughly the same amount of material. The energy required to manufacture it could be decreased. The technical influences behind the redesign stemmed from a desire to simplify and shorten the manufacturing process while also requiring a smaller quantity of components for the shredder. This also cuts down on assembly time. The overall connection between the factors and influences are that the GSEE factors and technical influences create much more of a positive impact for the manufacturer as well as the end user.
Component Analysis

Top Plate

Material: plastic (Black thermoplastic, PC ABS)
Surface finish: Varying, from soft to very fine.
Size: (moderately large)
Feature detail: very fine

For the top plate of the shredder, with its fine curves and edges and good surface finishes, it can be easily assumed that the part is injection molded. Supporting evidence found on the part includes the over thirty ejector pin marks on the inner portion of the part, and the very large injector gate on the outer body of the part, nearly a half a centimeter in diameter. Very light flashing is also visible on the parts outer edges near the base, and each surface has a taper on it, to help ease the process of removing the part from the mold. Hollow portions are visible on the part, such as the main paper feed and holes for the screws that affix components to the part, and were produced in post processing, made visible by the residual burrs and change in surface finish in areas of the operation. This is most easily seen on the hole made for the shredders power switch, where burrs from the cut are still abundant on the part in Figure 2.

The material type of the part is plastic, more specifically PC ABS, a thermoplastic. This is indicated through a stamp inserted into the die itself, labeling the plastics that are usable, as well as indicating the time of production and possible setting time (Figure 3). Since this is a thermoplastic, it can be assumed that all operations done after the initial mold were done with some sort of temperature control, and that most all defective parts were recycled back into the production line, as scrap plastic for the injector.
Bottom Plate

Material: plastic (Black thermoplastic, PC ABS)
Surface finish: Varying, from soft to very fine.
Size: (moderately large)
Feature detail: fine

The Bottom Plate of the shredder, like the top plate, is most likely made through injection molding. This like the top plate is supported by the high number of ejector marks, and light flashing on the sides of the part, in addition to a very large gate where plastic entered the mold. The outer surface of the mold has a softer finish to it, to appeal to the user, while the inner surface of the part has a very fine surface finish, to assist in proper cooling, and keep the part from holding onto the mold. This part contains additional defects contributed to injection molding, such as deformities in the parts ribbing, and flashes on the screw mounts, where extra material rode up the tall section of material.

PC ABS plastic was also used for the bottom plate to keep uniformity for the entire design, and to reduce plastic types being brought into the production process. This allows the factory to reuse both parts in the same plastic collection, and melt them down again when defects occur. In addition, the use of a thermoplastic allows the factory to save any waste made during drilling for the screw posts after the initial mold.
Tooth Holder

Figure 12

The Teeth Holder is most definitely made through injection molding, followed by minor finish operations such as holes and edge cleanup. The part has 46 ejector pins across its two long channels of combs, and is moderately thin walled, with enough thickness to prevent the teeth of the shredder from failing through the plastic. There is ribbing on the bottom surface of the part, angled to allow easy removal of the part from its die, and 4 injection gates are located on the outer corners of the part, to ensure that material was evenly distributed to each crevice in the part. After being injection molded, the part was then drilled across four tabs on the outer edge of the part, through injector pin marks, and then four holes were drilled into the side faces of the holder as well. Defects across the part include heavy flashing on the center gap of the combs, and reduction in plastic for the component molds added on after the initial mold was completed. Burrs still remain on the drilled holes as well, visible in Figure 9.

Since the part has compound molds added to its base, we can assume it is a thermoplastic, since the part would have to be melted to add an additional plastic structure, and still retain its molecular form when it cools again. The part benefits from this since without its melting capabilities, the initial mold would have to be much more complex to incorporate the added components. In addition, the compound components have high complexity, with hollows inside of their added components, increasing the mold complexity, as seen in Figure 10.
Motor Mounting Brackets

Material: Plastic (indistinguishable between thermoplastic and thermoset)
Surface Finish: Fine
Size: Small-Medium
Detail Quality: Good

The motor mounting brackets are most likely made through injection molding, with many of the same part cast at once on a product tree. This is visible through the snapped tabs on the edges of each part, and is beneficial for the factory, increasing production rates dramatically. Injection is picked over investment for the two parts due to their flat and even surfaces, and their thin walls. This also lets the factory take advantage of the extreme production capabilities of injection molding, and make a large volume of parts cheaply. Defects in the parts include ejector pin marks on the bottom faces of each part, and flashing on the end of each part's connecting rods.

The material used was likely a Thermoplastic, to reduce waste when taking the sprue off of each part, allowing the factory to melt down and reuse the material for another molding cycle. However, using a thermoplastic can also be an issue, regarding the temperature of the shredders motor during normal operation. The plastic needs to be able to withstand the temperatures of the motor without deforming or failing, in the worst case even melting. Which would lead to the benefit of using a thermoset instead, as they often have better temperature resistance.
Metal Teeth

Material: Metal (steel or iron)
Surface Finish: poor
Size: small
Fine Detailing: Poor

The metal teeth appear to be produced through powder metallurgy, with multiple grinding and finishing processes added in to give the smooth faces and fine points of the blades. The powder metallurgy would give the initial shape of the tooth, and then it would be ground on its faces and points quickly to give the edges it desires. Defects through the processes are easy to spot, in surfaces where the powder did not fully compress and form into the net shape, one can quickly see the amount of metal that did not settle correctly in the mold, and the rough edges given by this defect. For many of the teeth in the shredder, the lack of material is almost enough to reduce the shredders effectiveness, however the hardness is still substantial, and capable of preforming the forces needed for the shredding.

The teeth are made out of metal to increase the shredders long term durability, and to keep a better shredding edge. The teeth must be able to cut through several sheets of paper at any given time, and also break and cut through staples that have been left in the pages. The increased hardness can be given cheaply through the powder metallurgy, and the energy saved in the production process. The addition of the holes on half of the blades allows for better separation of the papers it passes into the shredder (Figure 14)
The guard is most likely made through injection molding, with compound molds added to increase the features of the part in the injection molding process. This is supported by the array of ejector pins on the back of the guard, and the identical hinges on the back of the guard, which have left marked defects on the back of the guard, as pictured below. The use of a thermoplastic such as PC ABS allows the manufacturer to reduce waste, and better treat the plastic, for the guard, there will be repeated stresses on the part, from human interaction and paper loading, and having a proper grain structure and good surface for paint to bond onto is extremely beneficial. The paint on the surface of the part will last a lot longer, if heat treated onto the part, and the added molds for the hinges will hold better after a heat treatment as well. With a thermoplastic this is only achievable once, during the setting stage.
The shredder and gear mount is most likely produced through injection molding, with ejector gates present over the entire surface of the device, and what appear to be four injector gates, whose still molten plastic was deposited on the surface of the part, this evidence of the parts plastic still being too hot is shown again through the depth of the ejector pin marks, which nearly punch all the way through the main surface of the part. Like many injection molded parts, the mount has ribs stretching across the surface to reduce the possibility of bending, and support the thin walls. This would also be injection molded due to the fact that the walls are as thin as they are.

Since the part supports the two sets of shredder blades, the surface of the part has to have low friction, to help aid the motor. ABS plastic can have a really good surface finish, which would enable this low friction. The plastic also reduces the risk of injury during assembly of the shredder. Due to its soft edges. The part will also cause a point of failure for the shredder, so the shredder will stop when too much is loaded into the shredder, and the motor keeps going.
White Plastic Washer for Shredder Teeth

- Material: ABS Plastic
- Surface Finish: good
- Size: Small
- Feature Detail: good

The shredder teeth washer is easiest made through extrusion, due to its symmetry on its axis, and the manufacturers need for high volumes of the part. With extrusion, the plastic can be loaded into a specially shaped high pressure tube, and then cooled as it is passed through the shape at high pressure. It is then cut into specific lengths, and if present burrs can be removed in post processing. To cut costs post processing is most likely not done for the production of the part, but is justified, as the parts look raw on the cutting edge, but contain no visibly large burrs. Some of the parts can be slightly off balance, with some uneven loading of material, but this is also of little consequence.

Thermoplastics are very easy to extrude, and in the case of a poor extrusion, can be reused without loss. This reduces the prices of the part greatly, and to benefit, extrusions like this can be very easily automated. The parts are to be expected to see little to no heat buildup, so the risk of failure to heat transfer are very little.
Shredder and Gear Mount

Material: Metal (light color, possibly steel)

Surface finish: smooth, with indents and slight long extrusions, and holes

Size: L: 5 3/16, W: 2 9/16 inches

Feature detail: cylindrical guide rods/shafts

For the shredder and gear mount, this component has a good surface finish with no indication of grit or ejector marks, which can be a result of post machining. The holes of the component appear to be very smooth on the inside but rough on the top edge, and with the precise locations of the holes gives evidence of stamping. The round curved edges on the side and very precise indentions on the surface of the component gives more evidence for stamping. Thus, this component can be assumed that is was created with a stamping process. The supporting evidence for this claim first is the holes on the part. Some of the holes are round while others are small and square with precise locations and with the rough top edges and smooth inside these types of holes are hard to achieve with milling and a stamping process can achieve this in one step. Another evidence is the sides of the component, though the front face is smooth, the edges themselves are rough and sharp as a result of a cut which comes from stamping. Lastly, the two horizontal edges are rounded downward which comes from the stamping mold. This is explained when the stamp is happening, the mold on that position is created to allow the material to shape around that portion to allow that bending. The rods are made out of steel most likely from extrusion which would provide the hollow center. After, a post process of machining was used to create the threading inside.

The material type for this component is metal and more specifically a type of steel (most likely). This is indicated from the weight of the product. The product is heavy for being a relatively small component which indicates being made of steel. Plus, if this component was cast iron, the color of the component would be a darker color while this color is bright and a light grey. If defective pieces are found on the product, they would be re-smelted for use in another batch or another product.
Mounting Bracket

Material: metal (light color most likely steel)
Surface finish: smooth, round edges, holes
Feature details: three’s holes each at the corners a specific equal difference away.
Size: Height: 1 9/16 in, Base: 1.5 in

For the mounting bracket the component has a good surface finish with no indication of grit or ejector marks, which can be a result of post machining and not sand casting. The holes of the component appear to be very smooth on the inside and on the top portion of the component but rough on the edge on the bottom side, and with the precise locations of the holes gives evidence of stamping. The round curved edges on the side and with a square cut on the surface of the component gives more evidence for stamping. Thus the component can be assumed that is was created with a stamping process. Supporting evidence is first the rough edges on the bottom face of the component. This comes from the cut of the machine leaving a slightly sharp rough edge. Other evidence comes from its shape. Since this is a triangle, multiple pieces can be next to each other and cut at once each is a benefit of stamping. Also with no signs of grit sand casting is out of the option. Plus, since the material is steel, to use permanent mold casting would be very difficult because of steels high melting temperature. But, this piece can be heated up to allow cutting from the stamping which can also explain surface marks from the stamp.

The material type for this part is metal or more specifically steel. This is indicated first from its color. Since the part is light grey, a lot of steels made are of this color. Also the weight of the part indicates it being steel. If the part was aluminum, it would be lighter and also shinny. While steel is on the heavier side, and is not shinny. It can be assumed that all operations done after the initial process is with a temperature control environment, because a higher temperature could distort the component and deform it while also changing its properties. Rejects are most likely sent back to a foundry to be melted down and reused for more products.
C-Clip

Material: metal (most likely steel)
Surface finish: top and bottom smooth, but bottom edges rough
Size: very small
Feature detail: cuts for snapping into place to a groove (good tolerances)

For the C clip, it can be easily assumed that this part was created from stamping. One reason is because of its size. To machine this part would create stress on the thinner section of the component which could cause tension and result in breaking. Stamping would also provide the needed cut for the component. What this is meant by the shape of the cut and how small the cut is to the outside of the part, machining would be too risky to because of the risk of breaking. Whereas stamping can achieve this cut and shape in one step making the process more efficient. Also, because of the size of the component, multiple parts can be stamped out at once for fasting productivity.

The material type for this part is metal or more specifically steel. This is indicted for the role of this part. This part is needed to hold the metal gears of the shaft which requires great strength and that comes from the properties that steel has. Also cast iron wouldn’t be sturdy enough to withstand the tension, where steel would be easily able to withstand the required force and more if needed. If pieces are defective, most will be just re-smelted to use in another batch or for another product.
Large Metal Gear

Material: metal (most likely steel)
Surface finish: top and bottom smooth, the teeth are relatively smooth but the edges are slightly sharp
Size: the diameter is 2 3/16 in
Feature detail: has 44 teeth, and irregular shape cut

For the large metal gear, this part is most likely constructed by the use of Powder Metallurgy. Supporting evidence is since this material is steel which is very hard to shape, powder metallurgy allows difficult materials to be used. Since steel has such a high melting point, expendable mold process is very unlikely since the mold would be made out of steel as well. Also, most gears are made from powder metallurgy, because this process provides great tolerance which is required for a gear. Milling would also take way too long and slow production. Also, gears are a very common part in many components, and this system provides production methods for positive economic effect. To get the smooth surface finish, a process to extra pieces off could have been sand blasting in which this process provides a smooth surface but also leave marks of scraping which could have been the results of pellets hitting it, through shot peening(Figure 26).

The material type for this part is metal but more specifically steel. This is proven because of the materials color which is a light grey. Most steels are of this color while other colors like dark grey are held by iron. Another reason is that since this piece is going to be rubbing up against other gears and parts, it requires great strength and that comes from steels. It can be assumed that post processes are just surface finishes because of the type of process done, most of the part is completed and only needs surface finish to be completed. It is also inferred that defective pieces which may include snapped gears, the part would be re-smelted to be used for other parts or for another batch.
11 Tooth Gear

Material: metal (most likely steel)
Surface finish: top and bottom smooth, the teeth are relatively smooth but the edges are slightly sharp
Size: the diameter is 1 ¼ in
Feature detail: has 11 teeth, and irregular shape cut

For the 11 tooth metal gear, this part is most likely constructed by the use of Powder Metallurgy. Supporting evidence is since this material is steel, it is very hard to shape but powder metallurgy allows difficult materials to be used. Since steel has such a high melting point, expendable mold process is very unlikely since the mold would be made out of steel and you cannot have two materials of the same in a mold. Also, most gears are made from powder metallurgy, because this process provides great geometric details required for a gear compared to a process like machining. Which would also take way to long and slow production. Also, gears are a very common part in many components, and this system provides production methods for positive economic effect. To get the smooth surface finish, a process that could have been used is machining which might explain the scrap marks on the part. Also, the slight divot in the cut could be the result of a defect in the process or needed to move the gear into place(Figure 27).

The materials type is metal but more accurately steel. This is indicted for the need of the strength of the component. Tis because these gears will be rubbing up against other parts and because of that great strength is required for failure not to happen. Also from the color being a light grey this indicates steel because a darker color like black or dark grey would indicate iron present. Most of the defective pieces will be melted back down for reuse for other parts or into another batch.
Large and Small Plastic Gears

Material: plastic (Colorless thermoplastic, possibly nylon)
Surface finish: very fine
Size: small (D = 1.5 in [tooth to tooth]), large (D = 2 in [tooth to tooth])
Feature detail: very fine

For the large and small plastic gear, it is relatively easy to distinguish what manufacturing process has been used, that being injection molding. Since this is a fairly common part, they could likely be used for both the shredder, and a variety of other products in the same facility that it was produced in. This requires it to have a very large production volume, and require a quick production rate. Since the parts require accurate detail on its teeth, it needs to be easily temperature controlled and have a fine surface finish, and endure very few fatigue stresses, like those found in machining. These traits then lead to the likeliness of the part being injection molded. Supporting evidence found on the part includes injector gates and ejector pin marks, and slight deformation on the surface of where the pins were present. Also visible is what seems to be a very slight draft on the gears thinner edge, implying that there was a minor draft in the mold as well, used to ease the ejection process of the gear.

The material type can only be assumed as a thermoplastic, since no proper melting tests have been done to preserve the integrity, but this would be of benefit to the manufacturer, to save on waste from incomplete or poor injections. The finish is also oily in texture, which leads to the high possibility of the plastic being nylon or some derivative of nylon. This however has no effect on the process of injection molding, other than the temperature of the process. Since the material is plastic, and finishing process after casting would be visible through burrs or notches made on the part, from drilling or cutting, and only removable through more expensive finishing processes. Since these are not present as well, we can assume that the part came out of the die in its finished state. Also, the only main difference between the small gear and the large gear is that the larger gear has a metal component with it. This can indicate that this specific gear will undergo high stresses in which the initial connector part cannot be made of plastic for it might not be strong enough. So, for safety sake metal needs to be used. If defective pieces are found, since they are thermoplastics and not thermosets. They can be re-melted and reused for another batch.
Circuit Board

![Circuit Board Image](image33.png)

**Material:** Copper  
**Surface finish:** Laminated finish  
**Size:** Medium  
**Feature detail:** Moderate tolerances with the etching, and

The circuit board used in the paper shredder is actually a printed circuit board. The method to get the geometry is often stamping since the boards themselves are very thin in nature, and the tolerances needed are not exceptionally high. It is commonly made out of copper sheets layered over a silicate substrate, in variations of layers of each material. These copper sheets are laminated into the substrate and is etched to reveal the copper and allow conductivity along that etched section of copper that still remains, as visible in Figure 30.

The material used to create the circuit board is harder to assume given the geometry and the colors that it has. However, the best option would be copper. Copper has very good conductive properties which would make it a very good material to use in just about any electrical application. Other metals may be used but it would no longer be cost effective, and may limit the ability to use a pre-purchased standard, and further save on production costs.

Since the circuit is fairly simple, and simple etchings like this can be done on a relatively high scale and speed, the circuit board is most likely produced in house or ordered from a nearby facility. The assembly of the circuit being done both manually and autonomously. The smaller ICs and transistors on the board being done on an autonomous jig, as shown by the incredibly consistent and identical soldering marks on the board for these components. The additional wiring connections for the power into the board, and the motor connections are very thick in excess soldering material, and inconsistent in size, displaying that these connections were most performed through cheap labor, as visible in Figure 30.
Infrared Emitter and Receiver

Material: Silicon (inside) Polycarbonate (outside)
Surface finish: Smooth
Size: Small
Feature detail: Fine indents and holes.

The manufacturing of LED’s such as infrared emitters or receivers have two main processes. One is to make the housing for a semiconductor, and second is to essentially insert a semiconductor inside a plastic housing. The process in making the housing for the semiconductor, or the bulb is quite easy to see. Injection molding of a thermoplastic can give consistent and quick results and opposed to having it thermoset. It also allows recyclability which may be advantageous for the company. The material is most likely polycarbonate due to its ability to be a clear plastic, as well as its ability to be released from the mold that it is in easily.

The diode inside the bulb or housing is most likely silicon. Silicon is part of the semiconducting family, and it is most likely the material that was used inside the infrared LED’s. The reasoning behind this is that germanium competes with silicon in regards to semiconducting material, but its acts more as an insulator when it heats up, as opposed to silicon which acts more as a conductor. For this reason, it is a more logical choice to have silicon as the material inside. The process that makes the silicon into a semiconductor is lengthy, but the main method is by doping a very thin layer of silicon called a wafer. Doing this alters the electrical capabilities of the element and primes it to be used.
Electric Motor

Material: Metal housing and bronze wires
Surface finish: Smooth/fine finish
Size: Medium
Feature detail: Fine and Coarse

The motor works on the principle of having AC current go through an inductor incased in a magnetic housing. For this reason, multiple parts can be looked at simultaneously. The metal housing seems to be made by using die cast molding. This can be seen due to the fine detail that it has. When making motors such as these you need consistency, and for this reason it is more logical to use that casting method. Such materials can be made out of aluminum, given its color. The problem with this is achieving the magnetic properties required. This can be done by polarizing the metal in post-production. Another possible metal could be cobalt or nickel which exhibit magnetic properties.

The material can be easily seen as being copper due to its color. Copper is also one of the best materials to choose due to its ability to conduct electricity quite easily, thus, using other materials may be counterproductive and costlier at the end. The manufacturing process to make the copper seen is most likely a combination of hot rolling and drawing. Hot rolling allows a square billet that may have molded to be turned into bars. From these bars drawing would continually stretch them until they reach their desired width.
Switch

Material: Black thermoplastic most likely PC ABS
Thermoplastic, with copper and aluminum components inside the case.
Surface finish: Smooth/fine finish
Size: Small
Feature detail: Fine, stampings of the production company and product type must be legible.

The housing of the switch is most likely made out of thermoplastic. Plastic is a very good insulator, and naturally an easy choice to make when creating a housing for a built in circuit. The piece itself has two halves, which can easily be made through injection molding. The part is very simple with no complex geometries, other than flat indenting for the labeling which would be very simple to produce with an injection process, through an added fitting inside the mold, for when any labeling information must be changed, as seen in Figure 33. Additional electrical components can be added into the inside of the component, and allow for quick snap together production.
Assembly Analysis

C-clip to Rotating Rod

Joint Method: Temporary
Joint Type: Mechanical
Component Material: Rod (Aluminum), C-clip (Steel)

Component Bulk Geometry: The overall geometry features of this joint is a long cylindrical rod that is used to apply rotational force to the shredders. The C-clip is a flat, circular piece of metal with material removed to fit correctly to the rotating rod.

Component Local Geometry: The rod has material cut out, decreasing the local diameter, in order to fit the C-clip. The C-clip has enough material cut out to fit around the rod in a way that allows it to be a temporary joint.

Load/Flows Experienced: The primary load experienced by this joint is mechanical rotation.

Discussion: The purpose of this joint is to join the rotating rod to the C-clip. The design concerns surrounding this joint stem from the necessity to hold the rotating rod and shredders in place. The two components joined together are shown in Figure 3. Here it is shown that the C-clip fits nicely around the cut-out portion of the rotating rod. The joint separates the two different sections of the bar. The rod, Figure 2Figure 3Figure 1, is most likely cut from a long cylindrical aluminum rod and then machined down from there. The C-clip, Figure 1, is also most likely cut from a cylindrical piece of steel and then material is removed from there. This joint is purely mechanical and does not involve adhesives, welds, clips or screws.
11 Tooth Gear to Rotating Rod

Joint Method: Temporary  
Joint Type: Mechanical  
Component Material: Rod and Gear (Aluminum)

ComponentBulk Geometry: The overall geometry features of this joint is a long cylindrical rod that is used to apply rotational force to the shredders. The 11 tooth gear is generally circular with 11 teeth protruding as well as a center hole.

Component Local Geometry: The metal rod is machined at the very end so that it has flat parts to fit the metal gear. The eleven tooth gear has uniquely shaped gear teeth that mesh geometrically to the motor gears.

Load/Flows Experienced: The primary load experienced by this joint is mechanical rotation.

Discussion: The purpose of this joint is to join the 11 tooth gear to the rotating rod. The design concerns applicable to this joint are that the gear needs to be able to properly transmit rotational energy from the motor gears to the rod that spins the shredders. The two components are joined together as shown in Figure 6. Here it is shown that the flat part of the gear fits snugly around the flat geometries of the rod and stops at the end of the flat part. A C-clip is then secured in the slot behind the gear. The rod, Figure 4Figure 2Figure 3Figure 1, is most likely cut from a long cylindrical aluminum rod and then machined down from there. The gear, Figure 5, is most likely created using powdered metallurgy, as are most gears and components of similar shape. This joint is purely mechanical and does not involve adhesives, welds, clips or screws. However, the gear is covered in a light layer of lubricating oil.
Wires and Circuit Board

Joint Method: Permanent
Joint Type: Adhesive (Solder)
Component Material: The wirers are made of copper, the circuit board is made out of plastic, and the adhesive is solder.

Component Bulk Geometry: The bulk geometry for the above jointing method is the rectangle circuit board overall. As well as the wirers that connect to the circuit board.
Component Local Geometry: The local geometry for the jointing method is the holes that wirers go through, where solder can connect the too.
Load/Flows Experienced: The load/flow that the jointing experiences is experiencing is electrical load. This is because the connection allows electric to flow from the wires to circuit board to allow the sheered to communicate.
Discussion: In Figure 77 if show how the two components are joint together. The two components are a permanent jointing method because the two components can’t come apart unless the joint is broken. We know that the component is joint together through an adhesive because the solder is a material that is conductive and melted on the wirer/circuit board. One of the concerns when using this process is that if the permanent joint does break, the solder will have to be cleaned off of the wires and circuit board and then reattached. During this process the user could potentially damage the circuit board. But since this is load seeing a load of electrons running through the joint, the joint should break at any point.
Teeth Holder and Bottom Plate

**Joint Method:** Temporary  
**Joint Type:** Mechanical screws  
**Component Material:** The two components being jointed together are the Teeth holder and Bottom Plate which are both made out of plastic. As for the screws they are made out of aluminum, we know this because they are not magnetic.

![Figure 44](image)

**Component Bulk Geometry:** The two piece over all are joint through a flat surface. Both components lay on top of one another. Over this is was protects any unwanted pieces to touch the sheered itself.  
**Component Local Geometry:** Both components have total of four holes, two on each side. This is where the mechanical screw is fastened to both components to connect one another.  
**Load/Flows Experienced:** The load that the joint experience is the vibration from the motor and the sheering of the paper. As well as the weight from both plates and all the components inside the teeth holder and bottom plate.  
**Discussion:** In Figure 88 it shows the right side where the two holes are so the Teeth holder and Bottom plate my both be fastened. This is a Temporary joining process because the screws may be moved and place back on whenever the user or manufacture wants. One concern when using this type of joining is over time the screws can come lose and slowly unthread them self from the component this would cause the shredder to slowly fall apart. Does to the vibration of the motor over time this is a very possible scenario.
Switch to Top Plate

Joint Method: Temporary
Joint Type: Clip.
Component Material: Plastic

**Component Bulk Geometry:** Oval shape, (1.5 inches long and .5 inches wide)
**Component Local Geometry:** Protrusion from the bottom, and indentation on the fillet
**Load/Flows Experienced:** Shear forces on the protruded component

**Discussion:** This component is made with the process of injection molding and this is valid because this component is plastic and you can see the ejector marks on the bottom face. The purpose of the piece is to turn the machine on and off by moving the piece to either side (left or right). The design concerns for this component is to make sure that the clip is to be properly aligned and sturdy. The protrusion needs to be small enough for the clips to fit into the square but also large enough so that the whole component doesn’t shake around causing malfunctions. From this moving, the protrusion also needs to be able to handle shear forces from sliding back and forth constantly according to Figure 99 and Figure 1010. As a result, this component is an important piece since this is the section that will turn the machine on and will have dealings with other moveable parts, so this section needs to be strong.
Metal Gear to Plastic Gear

**Joint Method:** Permeant  
**Joint Type:** Press Fit.  
**Component Material:** Plastic and metal

![Figure 48](image1.png)

**Component Bulk Geometry:** Circle with 32 teeth, (D = 2 inches) [Plastic Portion] 
**Component Local Geometry:** Small diameter entrance for the press fit  
**Load/Flows Experienced:** Axial forces from being connected to a metal rod  
**Discussion:** Press fit is when you have the main component diameter and the piece you wish to combine with has a slightly larger diameter than the main component diameter shown in Figure 12. Thus, when you press the object into the main component, the larger diameter will shape into the component and become a permeant joint show in Figure 12. Design concerns for this joint is making sure that the metal gear component is placed far enough in the plastic gear. This is a concern because if the force being applied is large, the joint could fall apart and cause the component to fail (Figure 111). Also, the component that is being press fit in must be a strong material so that it can be able to handle the forces applied. Which is why the material for this part is a metal. Another concern is making sure that during the joining process, either piece don’t break under the pressure of press fitting. To prevent this, the metal component can be heated up so that it can go into the plastic gear smoothly and seamlessly.
Motor Mounts

Joint Method: Temporary
Joint Type: Mechanical
Component Material: The mounts are made of plastic and contain holes for mounting directly to the motor.

Component Bulk Geometry: Both mounting plates have holes intended for screws and are designed specifically for each side of the mounting plate shown above.
Component Local Geometry: On the smaller of the two plastic mounts, there contains four molded plastic protrusions (Figure 14). Along with its small profile, it allows for clearance between the plate and the gear train. The larger mount contains a countersink hole in the center to allow for a direct fit to the motor. The four larger holes around the mounts' fascia are meant for proper alignment of the smaller mount, plus the reinforcement of screws so the motor can be secured through both the plate and mounts.
Load/Flows Experienced: The mounts experience loads from the gears, screws, and motor. The mounts also experience the vibrational energy from the motor.
Discussion: Both mounting plates are uniquely designed to fit the tolerances and criterion that they were designed for. The protrusions on the smaller gear allow for it to easily “snap fit” and align with the bigger holes on the larger mount. This alignment allows for quick fastening using a screw to secure the motor to the metal plate. The countersink hole in the larger mount will only allow the motor to fit one way and when it does fit, the motor becomes flush with the larger mount allowing for the output shaft to reach a drive gear on opposite side of the motor guard (Figure 13).
Snap Fit Window

**Joint Method:** Temporary  
**Joint Type:** Mechanical  
**Component Material:** Both pieces are plastic, one is clear plastic for a viewing window, the other is opaque black plastic.

**Component Bulk Geometry:** Thin walls with plastic tabs that allow for quick and easy assembly and disassembly.  
**Component Local Geometry:** The container has thin walls and light ribbing along the edges to allow for proper alignment with the top cover and secure it.  
**Load/Flows Experienced:** The container experiences the load of the top plate that exerts the entire weight of the shredder on to it. The container also experiences the vibrational energy from the motor.  
**Discussion:** The snap joints are physically molded into the plastic of the viewing window (clear plastic). The snap is fitted into a similar shape in the container. Along the edges of the hole is a small ribbing along the inside allows for the snaps to “catch” and hold together (Figure 16). Some of the concerns involved with this joint include proper fitting and durability for when the height of the paper exceeds the height of the viewing window (Figure 15).
Plastic Gear Mount to Plastic Tooth Holder

Joint Method: Temporary  
Joint Type: Mechanical (Two Screws)  
Component Material: Plastic to plastic bonds

Component Bulk Geometry: Flat plate with holes and raised geometry  
Component Local Geometry: Parts are fastened along flat plates between both parts, and holes are predrilled between each part. Self-threading plastic screws finish the fastening.  
Load/Flows Experienced: The two parts experience torque and axial forces from the screw, and its compression on the two parts. This is a relatively minor force, and unless it is overloaded during production, will not be damaged during normal usage.  
Discussion: There are some concerns over longevity of the joint, when repairs are done over the life of the product, that the threads of the plastic will experience wear, and begin to fail, especially when vibrations from standard use build up over time. The plastic joint (Figure 18) can also become brittle with age, due to heat from the shredder and environment. As shown the screws attaching the plastic are the only form of fastening on the part, so if they lose grip, the joint will detach and the system may fail (Figure 17). This failure would have to occur after many life cycles of the part.
Motor Mounting Plate to Plastic Tooth Guard

Joint Method: Temporary
Joint Type: Mechanical (two screws)
Component Material: Metal and Plastic

Component Bulk Geometry: Motor mounting bracket (Figure 19) consists of thin flat plate geometry with minor bends and mounting perforations, and the plastic tooth guard consists of thin walled geometry, with curves and ribbing specific to injection molding.

Component Local Geometry: Local fastening geometry consists of two flat surfaces, with holes inserted into the motor mounting plate to guide the screws, and holes inserted into the plastic tooth guard, to allow for creation of threads by the plastic self-tapping screws.

Load/Flows Experienced: Both joined components experience torque and axial forces from the stresses resulted from the screw after its insertion.

Discussion: The mechanical joining of using a screw to fasten two or more parts together has its advantages and disadvantages. For this application the fastening allows the shredder to be more accessible to the user, to make repairs, or replace parts when broken after extended life. For the two parts, there is little risk of the screws becoming loose, due to the elastic nature of the plastic, and the lack of forces required to damage the fastening on the plastic (Figure 20). Concerns of the fastening are that when produced in the factory, over tightening of the screw will ruin the joint, and require that the first part to fail will have to be replaced. The fastening will also require that screws be sourced for the joint, which will bring up material cost and the cost for manufacturing. Since the operating environment is fairly sterile for a paper shredder, oxidization of the screw and plate due to the large crack space between the two can be ignored.
Revision Criteria

Revision 1: Collection Bin Snap Tabs

The paper shredder (Figure 1), when fully assembled, has two main components. These components are the shredder case and the collection bin. The shredder case houses the shredder assembly, the motor, and all the major components of the paper shredder. All of the metal and electrical components are contained within. The collection bin is simply a container that collects the shredded paper. Currently, the two components are not joined together. The shredder case sits on top of the collection bin. The proposed design revision would be to replace the two hand slots used to remove the shredder case with snap tabs that are part of the mold. This would ensure that if the paper shredder is knocked over or falls during transportation that it would remain intact. Two major areas of concern to address in a redesign is the design for manufacturability and the impact on the design.

Figure 57
Design for Manufacturability

The most important aspect to consider from a profit standpoint when proposing a redesign for a product is cost. There are three major areas that can be broken down by cost: component cost, assembly cost, and support cost. In terms of component cost, when combined together, upper management can begin to see where these design improvements can really benefit the company while still ensuring integrity of the paper shredder.

As for the component cost, the two components concerned in this design improvement are the shredder case and the collection bin. The proposed changes to the paper shredder are two snap tabs at each of the hand slots on the sides of the paper shredder shown in Figure 2. Each component would likely experience a very slight increase in cost. This is due to a very slight increase in the amount of material needed for the mold. The molds would include the shape needed for the snap tab for each of the two components. This would also make the mold more complex and make the mold slightly more expensive. The design would need to ensure that the mold can still be easily removed from the mold. These two increases in price would be the only cost changes associated with the component.

The assembly cost would not be affected at all because the paper shredder comes fully assembled in the box packaging. The shredder case already sits on top of the collection bin, and it would be the same for the proposed design. It is proposed that the snap tabs will have “buttons” that will release the tabs so that the shredder case can be detached whenever it needs to be emptied. Therefore, the assembly cost is not affected by the new design proposed.

The support cost would also not change much. The only aspect that could possibly be considered as an increased support cost would be an increase in the plastic material needed to be shipped to the manufacturing facility. This is nearly negligible, however, because the
company is already purchasing large amounts of plastic from the supplier. This cost is also factored into the increase in component cost, and should not be considered twice.

The tradeoffs for the new component design are also important to consider when proposing the design to upper management. The main tradeoff that the management team will be concerned with will be the increased complexity of the molds. This will lead to a slight increase in price and the engineering team will need to ensure that the component can still be easily ejected from the mold. The tradeoff, though, is that the product is now more structurally sound and easier to transport for the end user. The whole paper shredder can now be moved without the user having to worry about the two major components detaching from one another and either causing a mess, injury, or damage of the shredder and/or other property. The collection bin can be easily detached, however, by pressing the snap tabs to release the shredder case. No other tradeoffs are very important to consider for this redesign.

Impact on Design

The summary of the redesign will be changes to the collection bin, and this will include, the sides of the bin being completely flushed on all sides and no dip on the sides. From this change will lead to another change in which the shredder case will have snap taps in which they will snap into the bin (Error! Reference source not found.). This will be needed for if the product falls over, the contents won’t fall out. These changes will not have any major impacts on the function of the product because these changes are made to be more user friendly. As a result, these changes will keep the same functionality as the previous model.

![Figure 59: Full Product](image_url)
Tradeoffs

| More Material | More material needs to be added to the component because of the addition of the snap tabs. Also, the bin will have more material for making the sides of the collection bin flushed with the top portion. With the addition of material, more weight will be added but will be negligible compared to the overall product. |
| Mold becomes complex | With the addition of parts added to the shredder. The mold needs to change as well. Since shredder case was made with injection molding which requires mold. The mold will now have to include the snap tap which will make the mold complex. Since the snap tap won’t be large so the mold won’t be a very difficult change to make. |
| Secure-ability | The collection bin will have greater secure-ability because the snap tabs will keep the collection bin connected to the shredder case. In case of the product falling over, the contents will stay in the collection bin and will not spill all over the place. |

In the transportation of this product in the factory, nothing will change because there are no changes to the bulk geometry of the product. When looking at shipping, this newly designed product’s shipping cost could increase in price. This price increase could result from the weight increase of the additional components and material. Though this price won’t be very much because the weight increase isn’t dramatic. The life cycle of the part can be seen as increasing with the new design because of the secure-ability factor. This factor will help because if the product does fall over, first the contents of the bin will not fall out and the shredder case will stay attached which will save the internal components from falling around.
Revision 2: Shredder Blade Assembly

To revise the shredder blade assembly, for reduced cost, improved performance, and easier manufacturability, the shredder blade assembly is changed from an assembly of plastic spacers and metal teeth, rods and c-clips to a purely sand cast part. This would remove the need for powder metallurgy, and plastic products in the assembly, removing the need for a human worker to perform an assembly. The assembly below would be turned into one net part, capable of much higher loads, due to its denser metal structure [Figure 3 Shredder Blade Assembly]

![Shredder Blade Assembly](image)

*Figure 60 Shredder Blade Assembly*

Design for Manufacturability

For cost Impact, two things have to be considered. The first that the net amount of metal would remain unchanged, with the exception of the 3 percent density gained on the transition from powder metallurgy to sand casting causing a slight increase in cost for the Metal Teeth, and the metal Tooth rod. The second being that the plastic spacers will not be required after the casting, dropping their price to zero. The energy required to melt down plastic for the plastic spacers would be in turn altered into energy to melt down the steel for the blade and rod assembly.
Transitioning to sandcasting for the entire assembly would introduce new material that would have to be ground away near the blades, increasing the price of the assembly, but the blades would have to be ground already, and the process to remove excess material and grind the blades can be combined in a single process. Thus this price increase would be fairly insignificant.

Support cost would be slightly increased, with the teams hired to prepare the green compact for powder metallurgy instead prepping sand for mold production, so the molds for each part can be prepared. Stock to melt down into molten steel would also have to be obtained and prepared, the heat for melting would also require operators and maintenance workers to have altered uniforms and safety requirements. In addition, energy costs to keep steel for casting molten would be high, and need to be accounted for in the final cost of the product.

The revision would have tradeoffs, in design and production speeds, especially. When producing the new component, any flaws that hinder the performance of the part could be difficult to fix, and require the part to be melted back down and remade. Since molds would be moderately difficult to produce, the time required to produce the component would increase, but would be made up for in the fact that the production of four components and assembly time of them as well would be compared to this production time. Tradeoffs when shipping would be minimal, since the product is most likely assembled in the same facility it is produced in, and might additionally decrease the time required to assemble the shredder, since no assembly time is required for the component itself. Tradeoffs in component strength would be positive due to the greater metal density, and heat treatment applied through the cooling of the part.

Impact on Design

**Error! Reference source not found.** shows how the full redesign would look. As you can see the Shedder Blade Assembly would be one solid piece instead of including multiple components. The function of the overall Assembly which is now a single component would not change. The reasons being is the function of the component is to spin and shred paper. By making it a single component the overall function is still the same. Now certain steps of creating the assembly and materials used in the assembly are no longer used.
Transportation of the overall design is now cut down due to this redesign. Instead of transporting four different components (C-clips, Metal Teeth, Spacer, and Tooth Rod) is now cut down to one component. This decreases the cost of moving different component around the manufacture warehouse. As well this decrease labor and time putting the full assembly together. When shipping the overall shredder due to the possibility of this resign having an increase weight due to the fact that is one solid piece, shipping cost would increase. When looking at this on a larger scale, the shipping of multiple shredder could add up quickly.

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Conclusion

The processes used in the production of the paper shredder provide a great variety of techniques that supplement knowledge on manufacturing. From the individual components to the different joining methods used in the assembly of the final product, it can be inferred that the production behind the paper shredder is fine-tuned to the point of unique specialization. The individual components are made up of both plastic and metal materials, with varying geometries, sizes, functions, etc. The metal components are usually directly involved in the purpose of the product: to shred the paper. The rotating rod, teeth, some of the gears, clips, and some of the other components are metal and manufactured using different processes. The remaining components that serve different functional roles such as the collecting bin, shredder body, etc. are plastic to reduce cost and reduce weight. Permanent and non-permanent joining methods are used to assemble the components. Many of the individual components are designed in a way that permits them to be properly joined together. Overall, the final gate submission for the group project provides a great source of supplemental material in developing a more versatile understanding of the manufacturing processes involved in a specific product, the paper shredder.
Project Bonus

Optimization

The outer shell of the paper shredder was made using thermoplastics and consequently it was most likely paired by using thermoforming. The price of the material and process can both be cut down by using thermoset plastics and injection molding techniques. The implementation of this would be very straightforward. Thermoforming machines and materials get replaced by the thermosetting counterparts. There are very little constraints when thermosetting and injection molding for this application. In fact, most of them can be neglected and the only notable constraints would be the quality of the final products surface finish, and the inability for most thermoset plastics to be eco-friendly. The final product will usually be inherently of lesser quality due to the superior surface finish that is accomplishable when using thermoplastics. Worth noting is that due to the great flexibility that thermoset plastics have, they can be implemented in just about any way, including the shell form that the paper shredder uses. When weighing the downfalls of the thermoset and thermoplastic materials, and taking into account that the paper shredder is meant to be a practical tool; not a novelty, thermosetting and injection molding will yield better results due to the save in cost. Special consideration may be needed when injection molding the plastic.

There are several considerations that need to be taken into account when thermosetting a plastic, and forming it using injection molding. Namely one of the biggest constraints that it may have may be the initial cost of the tooling. Inherently injection molding is more expensive than the thermoforming counterpart when the pieces become larger. For example: thermoforming a large 50 by 50-inch plastic plate may be three times cheaper than
injection molding it for obvious reasons (you would need more precision and more injectors).

However, due to the given size that the piece has, which is relatively small and slim, the price of this may be negligible, especially if parts are made in mass production since injection molding can produce more parts than thermoforming, which can offset the initial tooling cost.

Implementation of the new tooling can also be very quick. Due to the similarities of both thermoforming and injection molding using thermoset plastics, replacing certain machinery could be easily done. Worth noting is that the mechanical properties of thermosets are often better than those of thermoplastics. This may actually be of advantage if the shredder were to ever fall on a critical side. Overall, reducing costs of the material and very possibly the tooling can actually yield better economical and structural results.
Physical Prototyping of Design Revision

The prior design had no form of fastening the top lid to the base and simply sat on top of the bin. This was not the best design and actually posed a potential safety hazard to pets and humans. If the shredder was tipped over at any point with the waste bin half full or completely full, it would create a mess that the user would need to clean up.
To fix this problem, mechanical fasteners were added to the final design of the paper shredder to accommodate for these safety concerns. The major revision to the paper shredder that was done was the addition of Velcro straps that allow the shredder to keep the lid on during operation and transport. The straps allow the lid to stay in place on the bin and allow the lid to stay connected to the base at all times. This is important because the guards on the machine were not very effective.

Figure 2: Shows a guard that the device uses. Ineffective protection against fingers and other objects.
Upon disassembling the shredder, there was no clear evidence of a sensor that measured the position or orientation of the paper shredder. This means that if the paper shredder was in operation and was bumped or pushed over, the entire unit would fall over and inevitably; the top lid that contained all shredding parts would come off with the blades still spinning; as well as spilling the contents of the collection bin. Incorrect use of this hardware can lead to very serious injuries.

Figure 3: Shows the redesign done to the paper shredder as well as testing the new design

To keep the cost of the shredder as close to the original cost as possible, Velcro strips were used because they are relatively cheap, strong, and easily applied to the completed assembly. Velcro is a mechanical fastener which allows for removal. The Velcro strips use adhesives to attach to the part. These adhesives create a strong non-molecular bond with the plastic on the bin and the top lid. If for some reason the strips needed to be removed from the
assembly, they can be peeled off with some effort. The only evidence that there was ever anything on the part itself would be the residual glue that stays behind when peeled, but this can be removed with common household chemicals or Goo Gone.

Once the Velcro strips are applied to the side of the bin and the top lid sitting on top of the collection bin, verify that the soft Velcro strips are aligned. Once aligned, apply the long strip that contains the rough textured Velcro (this is the side that contains the small hooks) to the already mounted strips on the part. Run two fingers across the entire length of the strip, ensuring a tight fit with the soft strips all the way to the edges. Repeat three times in a triangular pattern on the front and back.

Another reason Velcro is used is because it is easy and quick to unfasten. Simply pull on an edge of the outer strip and pull down or up depending on whether the top or bottom is grabbed. Applying a pulling force in this manner makes the Velcro come apart and removes the restraint from the top lid. This ease of access allows the Velcro to be a valuable part of security without inhibiting the use of the paper shredder.

The Velcro is positioned on the shredder in a way that does not inhibit the shredder’s main function: shredding paper. This means that the user is still able to shred 7-8 sheets of papers at a time as well as credit cards and other important documents. To empty the shredder once it gets full, the user will need to follow the instructions above in quick release and removal. The extra time (seconds) needed to remove and reapply the Velcro once the paper shredder is empty is nearly seamless.

When deciding what type of fasteners to use on the shredder, many ideas were thought of, including snap tabs and snaps. The problem with these arises from the need to use extra
tools for application and removal (if required.) Velcro strips were chosen because they are able to be installed by unskilled workers and are easy to remove from the assembly without leaving permanent damage. Screws and bolts are strong, but can be stripped. They also leave a permanent hole in the figure that usually be rebuilt easily. They also require tools to remove from the unit and not every office or home will have a screwdriver.

The addition of the Velcro strips on the paper shredder will make a shredder that is safer for the world. The shredding unit is protected from harm if the top lid was dropped on the ground. Humans, pets, and animals are protected from any accidents that occur if the paper shredder is tipped over, both while in operation and while the unit is in the off position. No more will the dog or cat be able to make a mess in the house if the shredded paper is housed in a bin with a top lid that does not come off with undoing the Velcro straps. Perhaps one of the best qualities of the addition of Velcro onto the part is that it can be recycled or thrown out with everything else. There is no need to take it elsewhere to be disposed of. The other quality that the Velcro poses is the inexpensive installation onto the shredder as explained above. No tools or equipment is required, only human hands.
References


