

PRECIOUS PLASTICS – REDESIGNING MACHINERY

Manufacturing Design & Technology

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Task 1

“Precious Plastic is a project trying to boost plastic recycling worldwide. We try to do that by providing tools and knowledge to people around the world. For free, of course. Trying to give people solutions to fight plastic pollution.” (Plastics, 2018)

Precious Plastic is a company that are trying to contribute to tackling the ever-increasing problem involving plastic waste and the negative effect it has on the environment.

Precious Plastic is a company that specialise in designing small scale machines that are based on much larger industrial counterparts. They have then utilised these smaller scale machine designs to create a basic recycling process which involves breaking recyclable plastic down with a shredder and then turning it into something else via extrusion, injection or compression moulding machines. These scaled down machines are designed to be built at a low cost as most of the materials required to build them can be picked up in scrapyards. Precious Plastic aim to globalise their view of easily accessible miniature recycling plants so that they are a common thing in today's world. They aim to achieve this by providing people with open source designs that are available from their website. Downloadable kits provide the necessary drawings, CAD files, instructions and information for people to download and use to build the different types of machinery that are promoted by Precious Plastic.

The Shredder

“The shredder is the backbone of Precious Plastic. Thanks to this machine we can shred bigger plastic objects into small flakes. Smaller flakes are easier to store and wash. The shredded plastic can be used as raw material for the other machines or be sold back to the industry. You can select the output size of these flakes by changing the sieve inside the machine.” (Plastics, 2018)

This report aims to analyse and improve the Shredder machine that has been designed by Precious Plastics. The machine is basic, using blades attached to a rotating shaft to shred plastic into small flakes which can then be used for a different process made available by the Precious Plastic machines. This report aims to analyse this existing machine and with the help of appropriate changes, possibly improve several aspects of the machine, including efficiency, costs and cycle times.

Flaws



Figure 1.0 (Plastics, 2018)

When reviewing the design for this version of the Shredder machine, it comes across as a well-built small structure, ideal for small projects. It is fully capable of doing its job of shredding recyclable plastic into small flakes, allowing them to be used in a different processed offered by Precious plastics themselves. However, when comparing this machine to that of its industrial counterpart, there are several big flaws that separate the two.

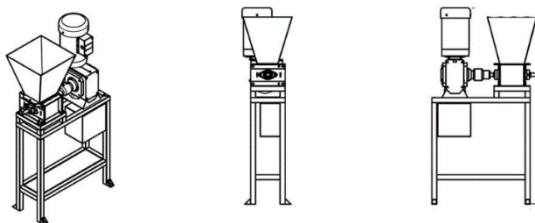


Figure 1.1 (Plastics, 2018)

One of the main flaws of this machine is the time taken for it to shred an item. Due to the size of the hopper and location of the shredder blades, plastic inserted into the machine is free to bounce around the hopper as it deflects off the shredder blades. This will prolong the time taken for an item to be completely shredded, overall increasing the cycle time and therefor overall time taken for the shredding process to

be completed. Cycle times are a massive factor in industry and companies always attempt to minimise them as best they can.

Another flaw with this machine could arguably be the location of the shredder blades and how they are not completely contained. Due to the size and shape of the hopper located above the shredder blades, they could be seen as somewhat exposed to outside interference. The only thing separating the user from encountering the blades is the 300x300mm hopper. The square opening does not provide much closure for the razor-sharp blades and the 300mm depth means that in the event of an unfortunate accident, a limb could easily enter through the hopper and come into direct contact with the shredder blades.

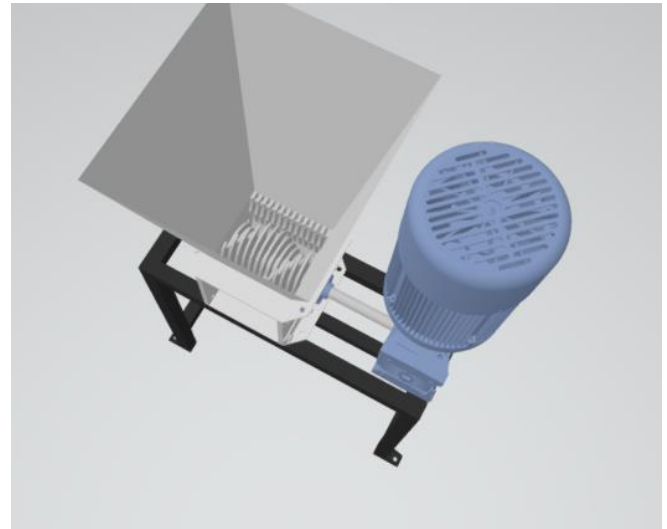


Figure 1.3 (Plastics, 2018)

Costs

Build Cost

Bill of materials shredder

Description	Material	Details	Quantity	Where to get it	Remarks	Price
Machine parts						
3mm sheet	steel	cutted	1x	Scrapyard/Hardware store	optional stainless steel	30
5mm sheet	steel	cutted	1x	Scrapyard/Hardware store	optional stainless steel	40
6 mm sheet	steel	cutted	1x	Scrapyard/Hardware store	optional stainless steel	40
● Hexagon bar	Steel	27M	32cm	Metal shop		15
L Angle profile	Steel	30x30x3mm	100cm	Scrapyard		10
Mesh	metal	150x180x1.5mm		Scrapyard	perforated sheet or drill holes yourself	2
Sheet metal	Steel	1mm		Scrapyard		7
Electronics						
Motor	-	+/- 2kw	1x	Scrapyard	preferable +/- 70 RPM	30
Power switch	-		1x	Scrapyard/Hardware store		3
Led indicator	-	220V	1x	Hardware store		3
Powercord	-		5 M	Scrapyard/Hardware store		
				Total		€180
						Price varies depending on where you live

Figure 1.4 (Plastics, 2018)

Figure 1.4 shows the breakdown of the approximate cost of the materials required to build the Shredder machine that was designed by Precious Plastics. The physical cost of the raw materials required to build the machine is reasonable, totalling €180

(approx. £160). Almost half of the materials required for the build can be located in a scrapyard, which brings the overall cost down massively. Some of the materials can also be recycled, potentially bringing the total cost down even more. However, despite these relatively low building costs, the running costs are what may cause problems in the long run.

Energy Costs

The estimated energy costs for running the 2KW motor on average of six hours in a working day could be worked out using an online energy cost calculator (Sust-It, 2017). The motor could cost £1.85 to run per day, which does not seem like much. However, when the frequency of use is considered, and this figure is multiplied by five to represent the working days of the week (Mon-Fri) that figure rises to £9.25. If this figure is then applied to ballpark 50 working weeks in the calendar year, a total yearly energy cost of £462.50 is given. This annual cost will also continue to grow as the number of machines increases as the full recycling process consists of at least 3 machines, bringing the total annual cost to over £1200. These figures are not entirely accurate due to the various factors that would be variable in the real world e.g. resistance on the motor, run time duration.

Safety

Due to the fact that the Shredder machine consists of multiple sharp rotating blades, it is vital that the appropriate working practices are followed when operating it. Failure to do so could result in a nasty injury to anyone trying to use the machine.

One of the main concerns when it comes to safety with this machine is in relation to the shredder blades. These blades are designed so that they are strong and sharp enough to shred plastic into small flakes, meaning that the blades will cause a serious injury if encountered by the user.

The Precious Plastics safety briefing that comes with each machine download pack states

“The machines are made using basic tooling. Although the tools are simple, they can still hurt you. Make sure to use the right safety equipment when you start building, safety glasses, welding gloves, hearing protection etc.” (Plastics, 2018)

One of the safety practices that has been put in place for this machine is that the shredder machine consists of a large hopper fitted on top of the blades to isolate them from any outside interference. This hopper is large enough to contain the plastic put into the machine, allowing it to shred. It is also large enough to ensure that the blades cannot be accidentally encountered by the person operating the machine. Although this hopper is acting as a safety guard, hazards can still occur. To minimise the risk of these hazards occurring, the Provision and Use of Work Equipment Regulations 1998 (PUWER) should be followed. These regulations state the different procedures that should be followed to ensure the safety of those working with equipment. Two examples of PUWER that should be applied to the shredder machine are:

“Preventing access to dangerous parts

- Where guards cannot give full protection, use jigs, holders, push sticks etc if it is practicable to do so.
- Control any remaining risk by providing the operator with the necessary information, instruction, training, supervision and appropriate safety equipment.” (HSE, 2013)

Failure to comply with the above legislation could lead to serious injury as in the event of plastic being jammed in the blades, trying to move the plastic that is in the process of being shredded can be very dangerous if a person does not know what procedures to follow. Push sticks can be used to ensure that the plastic is being fed into the shredder, however in the event of the shredder jamming, the machine should be isolated from its power source. This information would be provided to the operator on the appropriate training briefing for using the machine.

Current Products

The current products that are being produced by the machines built via the Precious Plastic downloadable kits are mainly small-scale day to day objects that can be bought as small gifts. There is not really a market for this type of field yet as the priority is mainly just recycling plastic instead of throwing it away and adding to the plastic pollution problem. However, although the current products are not life changing ideas, the future may hold something different.

Plastic recycling is on the rise due to the severity of how waste plastic has affected the environment in today's world. A collection of plastic waste has gathered in the Pacific Ocean over the decades, especially since plastic packaging was first introduced. This 'island' consists of over 80,000 tonnes of plastic waste and is roughly twice the size of France (iNews, 2017). Now that these Ocean clean-up programmes are in full swing, these plastic recycling ideas could potentially take off and fill a gap in the market if an idea surfaces which will utilise waste plastic.

One of these ideas is to use recycled plastic to repair roads by filling potholes with a newly designed compound consisting of recycled plastic. The company MacRebur claims that they are able to replace the bitumen that is used in asphalt with waste plastic that has been shredded down into microbeads. These plastic pellets are melted completely into the bitumen leaving no remaining microbeads left in the asphalt mix. This idea was introduced to improve sustainability as fossil fuels are running out and this idea aims to reduce the amount of fossil fuel usage. (MacRebur, 2018). There are environmental and practicality concerns with this idea but if it was to take off, the demand for plastic shredding would increase massively. The shredder designs provided by Precious Plastic would likely contribute to this movement, however the machine itself may not be compatible for use. The shredder machine would not be able to cope with industrial levels of work and would have to be enlarged and modified to cope. The designs however could provide inspiration for the building of industrial sized shredders that would be able to cope with the workload.

Task 2 – Specification

Design Specification

1. Low Costs
2. Good Performance
3. Low Energy Usage
4. Safety
5. Environmental
6. Parts are accessible
7. Some parts are versatile
8. Simple to operate
9. Easy to maintain
10. Not hard to manufacture
11. Quality

After analysing the different characteristics of the shredder machine design that was made available by Precious Plastic, it was apparent that improvements could be made. When designing the new product, it is important that the points raised in this design specification are followed to a certain extent. The specification points have been ranked in order of priority to ensure that the new design does not stray too far away from the original, as only certain aspects need to be tweaked. The main aspects of the specification that will likely make the biggest difference to the overall process are the safety and efficiency aspects. The flaws mentioned in the previous section of the report were related to these areas so if they can be amended, the new design is likely to be a success.

Product Design Specification

1. Performance
 - a) The shredder must be able to cut through plastic bottles
 - b) The shredder must be able to run off a motor and by manually turning a flywheel if needed.
2. Efficiency
 - a) Use something to ensure the plastic does not bounce around
 - b) Use two blade shafts instead of one
3. Costs
 - a) Keep the build costs low
 - b) Keep the run costs low
4. Safety
 - a) The shredder blades must be covered by safety guarding/hopper
 - b) Operator guide provided to ensure the safe operation of the machine
 - c) Perspex window by shredder blades to allow operator to spectate the process without removing any safety guards, keeping
 - d) Accessible emergency stop button
5. Environmental
 - a) Use as much recycled material as possible to build
 - b) Include alternative power source
6. Simplicity
 - a) The machine must not be too complicated and put people off wanting to build
7. Competition
 - a) Recycling and waste disposal plants
8. Maintenance
 - a) Shredder must be compatible for regular maintenance checks
 - b) Blades can be easily removed for repair
 - c) Annual motor service
 - d) Blades regularly checked for damage
9. Manufacturing
 - a) Keep simple
10. Quality
 - a) Will have to be tested to ensure parts move freely
 - b) Will have to be tested to ensure it can carry out its primary function correctly

11. Customer
 - a) Council
 - b) Schools/Universities
 - c) People interested in contributing to the Precious Plastic movement
12. Life span
 - a) Machine should be able to last several years if maintained correctly

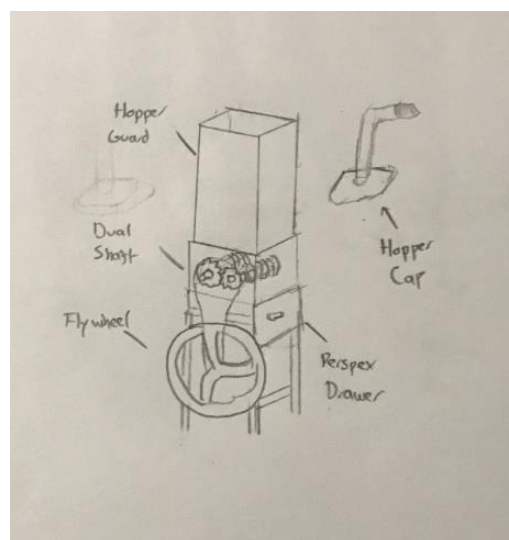
Task 3 – Pugh Matrix & QFD

Analysing Three Product Designs

This section of the report aims to analyse and assign three different designs that were drawn up as possible designs for the improved shredder machine. Each of the designs aims to improve the overall characteristics of the shredder by taking the flaws mentioned in Task 1 of the project into account. The designs will focus on these flaws and attempt to provide an alternative approach and avoid or at least reduce the severity of the shredder machine flaws.

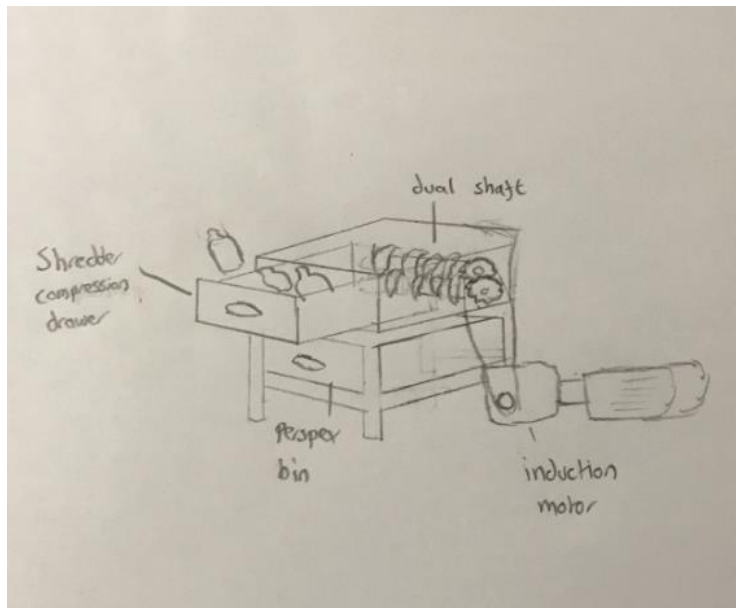
Design 1

The first design aims to tackle and reduce the energy costs and cycle times of the already existing shredder by modifying several aspects. The first modification is the introduction of a flywheel to turn the cogs of the blades instead of an electric motor. The electric motor can still be attached in the case of a higher demand however. This part-time flywheel will save money on run costs with the value depending on the ratio of which it is used instead of the motor. An additional shaft has been added to this design meaning twice the number of blades, potentially compensating for the slower turn rate of the flywheel. The blades will remain double pointed to ensure the manufacturing process does not become too complicated as there are now double the amount of them with the additional shaft being introduced. This design also includes a different shaped hopper to act as more of a guard to the shredder blades. The opening remains the same width throughout, allowing the idea of a hopper cap to be utilised. This hopper cap can be used to ensure that the plastic does not bounce around inside the hopper, speeding up the shred time. A Perspex drawer or waste bin can be placed underneath the sieve to give a visual of the quantity of shredded plastic.



Design 2

This design is completely different to that of the original shredder. The plastic is inserted into the machine via a drawer horizontal to the blades. This draw can then be manually pushed shut or closed with the use of a cylinder. This ensures that the plastic is fed into the shredder blades and does not spend any time bouncing around. However, due to the fact that it is horizontal to the blades, the gravitational effect is lost, likely adding some seconds back onto the total cycle time. This design consists of four-point blades along a single shaft making it simple for the user to construct and maintain.



Design Analysis

To help aid with selecting a final design that would then be implemented to the manufacturing stage of the process, a Pugh Matrix can be used to evaluate the different areas of the Product Design Specification against one another. The score for each of these areas can then be tallied up and added to a total figure, giving the result of which design idea scored the highest.

Specification	Priority	Design 1	Design 2
Costs	5	4	5
Performance	5	4	2
Efficiency	5	4	5
Safety	4	4	2
Environmental	4	3	4
Simplicity	3	3	3
Maintenance	3	2	2
Manufacturing	3	2	3
Product Quality	2	3	1
Total	151	112	110

Materials Used

Part	Quantity	Material
Blade	14	Stainless Steel
Spacer	14	Stainless Steel
Hex Shaft	2	Stainless Steel
Gear	2	Steel
Sieve	1	Perforated Steel
Hopper	1	5mm Sheet Steel
Housing	1	Box Cut Steel
Shaft Key	2	Steel
Perspex Drawer	1	Perspex

Quality Function Development

When it comes to designing any sort of product, good quality should be considered as one of the main priorities. The quality of a product can either be in relation to the needs and requirements of the customer or to the characteristics of the finished product. Ideally both of these fields need to be taken into account to ensure that a product is of good quality before being manufactured and produced. To ensure that a product is of a good quality before undergoing further development in the manufacturing process, a technique called Quality Function Deployment (QFD) can be applied to a product to ensure that the relationship between the customers' requirements and the product characteristics is strong enough to warrant that the product will receive positive feedback, hence safeguarding that it will be successful on the market (Solutions, 2016). As well as being used to compare the relationship between customer requirements and product characteristics, a QFD matrix can also be used to compare the correlation between each product characteristic that has been prioritised.

These Matrix diagrams are often used by management within industry to try and maintain production and manufacture rates as management can step in if they notice any dips in either. If there is a sudden dip in productivity, then there is likely a problem somewhere in the chain. Management would then be able to use the correlation pyramid that is located at the top of the matrix to try and pin point the issue. If there is a high correlation between two characteristics, then they almost rely on each other in the process chain. For example, in Ford Bridgend Engine Plant, Sigma engines are produced at around 600 engines per shift (1800 a day). As each engine makes its way through the assembly line, it undergoes different stages of the manufacturing process. This means that if there was a problem at a station on the assembly line (e.g. the wrong sized gasket was being used), when the engine undergoes and fails helium testing, if it is not immediately apparent why the failure occurred then the correlation pyramid can be used to check which areas of the line correlate with the helium testing facility. Process of elimination will then narrow the fault down to a number of stations to undertake further analysis.

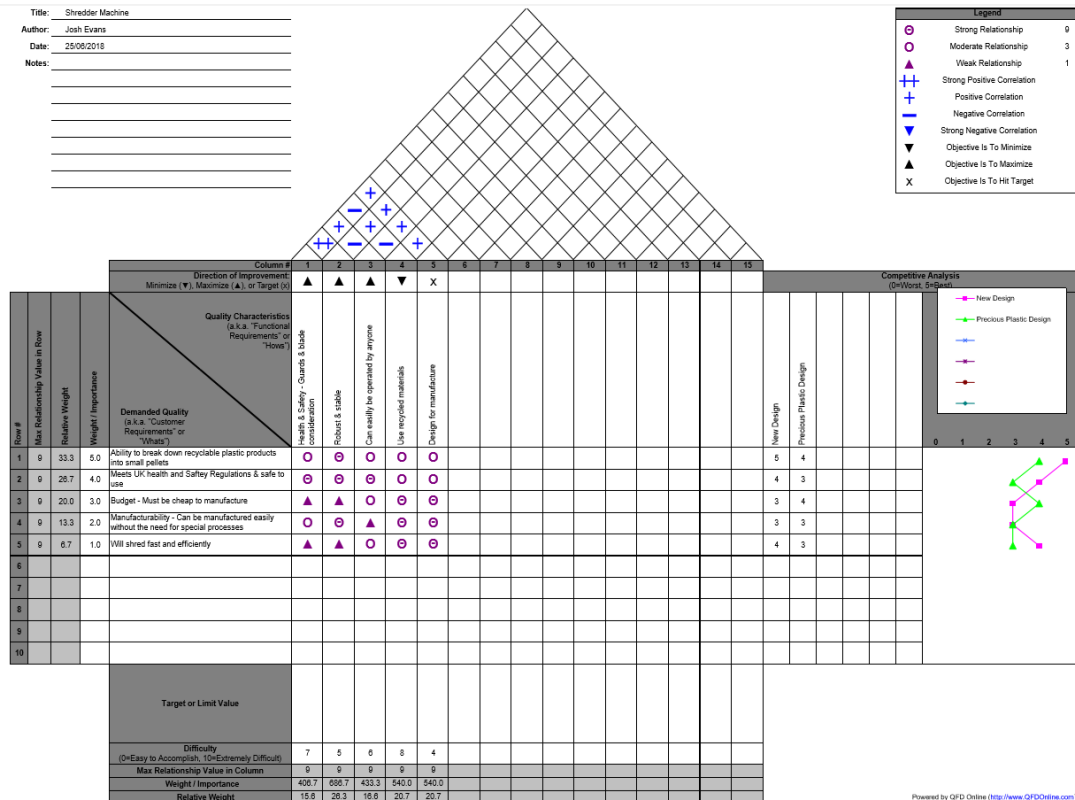


Figure 3.0

Figure 3 shows the QFD Matrix for the new and improved shredder machine. To the right side of the image, there is a brief comparison between the new design and the design provided by precious plastic. Although the precious plastic design is slightly cheaper to manufacture, the safety aspect of the new design is greater. The new design is also rated more efficient than the precious plastic design. When comparing the factors of efficiency, safety and build cost, the two most important for this design are efficiency and safety, as the cost difference is not huge. The initial hit of a higher build cost will be worth it in the long run as the product is safer and will run more efficiently.

Task 4 – Final Design

The design that was selected after undergoing several stages of critical analysis was Design 1. To ensure that this design meets the points listed in the Product Design Specification, it had to be significantly different to the original design that was provided by the Precious Plastic download pack. Although low cost was listed in the product specification, it was not the highest on the priority list as quality would have to come into play as well. Trying to save too much on build costs could affect the product quality so it was important that these two requirements met in the middle to ensure that the product is a success.

Significant Characteristics

The new design consists of several different features that aim to improve the points raised by the PDS earlier in the report. The significant characteristics of the new design are:

Efficiency Related

- Two Hex-Shafts

The use of two shafts instead of one aims to increase the efficiency and overall performance of the shredder. The use of a hex shaft instead of a key shaft was implemented due to how the same blade would be compatible for different orientations on both shafts. This saves time and money during the manufacturing process of the machine.

- Removable Flywheel

This alternative mean of powering the system was introduced to attempt to reduce energy costs. This feature will mean that the plastic will shred at a much slower rate but will not be using up any electricity. It can be removed from the machine and replaced with the motor if need be.

- Perspex Draw

Located beneath the shredder sieve, this draw/container will catch any plastic shavings produced by the shredder. When visibly full, the operator can then empty into a shavings bin and continue shredding.

Safety Related

- Hopper Cap

This device can be inserted into the hopper to prevent plastic bottles from moving around and bouncing off the shredder blades. This feature was implemented to reduce the time taken for the machine to shred as it makes up for the lost time taken for the plastic to settle down within the hopper. This feature can be developed further to become a permanent fixing as oppose to an external optional extra.

- Emergency Stop

An emergency stop is to be included within the motor circuit to ensure that the blades can be isolated immediately if required. This stop will have to be in an accessible position that will be within reaching distance for the machine operator at all times.

Design for Manufacture

When designing a product for manufacture, the goal is to design a product that is not too complex to manufacture, making the overall process slightly easier. Doing so will likely keep material, design and manufacturing costs at a reasonable level. A guideline provided by (UNM, 2017) states 10 factors that should be considered when designing a new product.

1. Reduce the total number of parts.
2. Develop a modular design
3. Use of standard components.
4. Design parts to be multi-functional
5. Design parts for multi-use.
6. Design for ease of fabrication
7. Avoid separate fasteners
8. Minimize assembly directions
9. Maximize compliance
10. Minimize handling

The shredder design reviewed in this report displayed elements of some of these factors. This was mainly due to hexagonal shaft design as it meant that all the blades and spacers used on the machine could use a more simplistic design. It allowed the blades to be offset in various positions without the use of an additional blade shape, therefore saving money on that field. Despite the design using an additional axel for the second batch of blades, the parts count was still reasonably low. Parts such as the blades and spacers are much more simplistic in terms of manufacturing as they are identical in design meaning that the additional blades should not influence the manufacturing process as the continuity of them should outweigh the fact that the design requires a higher quantity.

Failure Mode Effect Analysis

Function	Potential Failure Mode	Potential Effects of Failure	S	Potential Cause(s) of Failure	O	Current Process Controls	D	R P N	Recommended Action(s)
Shredder	Plastic could jam the shredder blades.	The machine would experience unwanted downtime.	6	Too much or wrong type of plastic inserted into machine.	4	Check plastic for any foreign objects before shredding.	5	120	Isolate machine before trying to dislodge any chewed-up plastic from in between blades. Changing the orientation of blades may help shred larger plastic at a slower rate.
	Shredder blades become blunt.	Shredding process will take much longer	7	Excessive Use.	2	N/A	4	56	Isolate machine and replace blades. This can be achieved by removing the gears allowing the shaft to come free.
Hopper	Hopper cap gets stuck inside hopper.	No more plastic would be able to be inserted into hopper causing downtime.	6	Hopper cap being forced in at an angle or too far into the hopper.	3	Take care when attempting to compress plastic.	6	108	Isolate machine and lubricate hopper walls.

Key:

S – Severity

O – Occurrence

D – Detection

RPN - Risk Priority Number (S x O x D)

Standard Operating Procedure

Purpose: Safe Operation of Shredder Machine (Powered by Flywheel)

	Instruction
Step 1	Turn flywheel to check blades are running correctly.
Step 2	Check plastic to ensure there are foreign objects included e.g. stones, coins.
Step 3	Feed plastic into hopper. Turn wheel until plastic starts to shred.
Step 4	Repeat Step 3 until the Perspex draw beneath the blades looks full
Step 5	Remove draw and dispose of shavings into a shavings bin.
Step 6	When finished, ensure blades have stopped turning and place hopper cap in hopper to protect blades.

Purpose: Safe Operation of Shredder Machine (Powered by Motor)

	Instruction
Step 1	Run motor so blades start to rotate. Ensure all blades are moving correctly.
Step 2	Check plastic to ensure there are foreign objects included e.g. stones, coins.
Step 3	Feed plastic into hopper. Use hopper cap to steady the plastic if it starts to jump around inside the hopper.
Step 4	Repeat Step 3 until the Perspex draw beneath the blades looks full
Step 5	Remove draw and dispose of shavings into a shavings bin.
Step 6	When finished, isolate power from motor and place hopper cap in hopper to protect blades.

Corrective Actions: If any of the steps cannot be met because something goes wrong, the blades need to be stopped immediately. This can be achieved by stopping the flywheel or hitting the emergency stop button to isolate the motor. The user should then seek the advice of the machine attendant and they will decide on the appropriate actions to take.

Conclusion

Overall, the modified design of the precious plastic shredder machine met the requirements set. It still does the job of a plastic shredder, but it now functions safer and whilst using less energy. These factors would have brought the running costs down massively, with the material costs remaining fairly similar as the majority can be bought cheaply in a scrapyard.

The added flywheel option ties in nicely with Precious Plastics ethics as the lack of energy used to power equates to a lack of fossil fuels being burned. Only time will tell whether that option is a success but on paper it will boost the efficiency of the machine. The problem with the flywheel is the effort that has to be put into operating it. Some people may not want to manually turn a flywheel. There are other options available that could be used to utilise the flywheel idea like connecting a bike chain to the gears instead of a motor. This method would certainly suit Precious Plastics way of thinking and could be a future design option.

Focussing on the design itself, the dual shaft may not have been the best option as twice the components means twice the build cost. Although this was not completely the case, a different approach could have been taken to decrease the build cost slightly. The extra shaft also increases the complexity of regular maintenance as there are more components that have to be taken out for checks. The use of the two shafts however, meant that the housing for the blades did not require any knife blades to assist the rotating axel. This closes the gap slightly in terms of build price.

In conclusion, the vision that Precious Plastic are trying to get across is brilliant, however there just does not seem to be a market for it at this moment in time. In years to come there might be a rise in the demand for recycling plastic but until then this type of machinery will not be a very profitable market choice. Despite this, Precious Plastic can still take the educational route and promote their vision through schools, universities and local councils. The shredder is still able to function as it should but it now obeys the UK health and safety legislation far better than the Precious Plastic model had previously. This is due to the change in hopper shape which means that the blades are much more enclosed than they were in the original design. This makes the machine much more user friendly, potentially ideal for young people in schools to operate on school trips to recycling plants to promote recycling waste plastic

Precious Plastics goal is to raise awareness about the harm that waste plastic is causing the planet today so if they can spread the word as best they can now, it could lead to some market success in the foreseeable future.

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