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The Design and Fabrication of Mini PET Bottle Shredder Model

Abdullah Khabir Saharudin[1], Wan Mohd Wardi Abdul Rahman[1]*

[1]Department of Mechanical Engineering Technology, Faculty of Engineering Technology,
Universiti Tun Hussein Onn Malaysia, 84600 Panchor, Johor, MALAYSIA.

*Corresponding Author Designation

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Abstract: This thesis presents a project on the design and fabrication of a mini PET bottle shredder machine model to save the cost of purchasing external materials by producing plastic chips for use in a Workshop Practice Course at a university in Malaysia. The goal of the project is to substitute aluminum and mild steel with solid round plastic bars as work pieces, leading to advancements in workshop practice course lessons and learning sessions. The project includes studying the design and fabrication of the plastic shredder and shredding PET bottle plastic into tiny pieces, with a focus on safety factors, power requirements and efficiency. The literature review includes an introduction to plastics and their properties, and the methodology includes problem identification, a Gantt chart, and selection of appropriate manufacturing techniques. The project encountered some problems such as safety issues, cost concerns and problem with the distance between the shredder and spacer.

Keywords: Bottle Shredder, Blade Analysis, Fabrication Bottle Shredder Model

1. Introduction

The purpose of the project is to save the cost of purchasing external materials by producing plastic chips or small fragments as raw material for preparing solid round bars for use in the Workshop Practice Course at the Machine Workshop, Faculty of Engineering Technology, Pagoh Campus, Universiti Tun Hussein Onn Malaysia. The project focuses on designing and fabricating a bottle shredder machine for lathe workshops, which is expected to bring about innovations in learning sessions and workshop practice course lessons as well as indirect cost savings from reduced external material purchases.

The project's problem statement includes issues such as PET bottle cannot be shred and the high cost of fabrication of the shredder machine. The objectives of the project are to study plastic

**Corresponding author: wardi@uthm.edu.my*

shredders' design, theory, functionality, and fabrication and analyze and fabricate process to the design of the machine. The scope of the project includes studying the design and fabrication of the plastic shredder and shredding PET bottle plastic into tiny pieces.

2. Literature Review

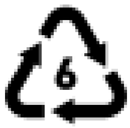
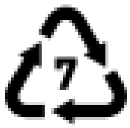
The author conducts research on the machine, its capabilities, and the materials it can break down using a variety of sources such as the internet, journals, books and guidance from supervisors. The review also includes an introduction to plastics and their properties, as well as an explanation of the different types of plastics and their uses. It is noted that not all plastics are suitable for all uses and that there is a standard type coding system in place to identify the suitability of a particular plastic for a specific use.

2.1 Plastic Code

Plastics Industry Association (2018) There are several types of plastic codes that are used to identify and classify different types of plastic. These codes, known as the "Resin Identification Codes," are found on the bottom or side of most plastic products and consist of a triangle made up of three chasing arrows and a number within the triangle. The number corresponds to the type of plastic that the product is made from. Table 3.2 shows plastic resin Identification code and examples.

Table 2.1: Resin Identification Code

Code	Plastic	Scientific Name	Examples	Recyclable/Non-Recyclable
1	PETE	Polyethylene Terephtalate	Soft drink and water bottles, food packaging, fruit, juice containers and cooking oil, shampoo bottles	Recyclable
2	HDPE	High Density Polyethylene	Milk, water, juice jugs, yogurt pots, soap dispenser, cleaning products, grocery bags	Recyclable
3	PVC	Polyvinyl Chloride	Pipe and window fitting, thermal insulation, car parts, trays for sweets, bubble foil, food foil	Non-recyclable
4	LDPE	Low Density Polyethylene	Frozen food bags, bread bags, food bags, shopping bags, magazine wrapping	Non-recyclable

	PP	Polypropylene	Ketchup bottles, microwave meal trays, wall covering, syrup bottle, yogurt container	Recyclable
	PS	Polystyrene	Cosmetic bag, plates and cups, CD cases, egg cartons, protective packaging	Non-recyclable
	OTHER	Other	5-Gallon water bottles, other plastic including acrylicnylon, fiberglass, baby bottle	Non-recyclable

3. Methodology

The production method of the project in terms of materials and installation. The goal is to control excessive production and equipment costs. The steps involved in the production of the project include finding appropriate materials and equipment, sketching the outline of the project, and drawing the design of the project. The design process includes problem identification, a Gantt chart to organize work procedures, a project flowchart to show the process of the project, and selection of appropriate manufacturing techniques. The project design and selection stage involve rough sketch work and taking into account factors such as durability, time allocation, costs, and availability of materials.

3.1 PUGH Method

The Pugh Method is a systematic and structured approach for evaluating and comparing different design options for a particular problem or challenge in this case, it is used to evaluate and compare the different concepts of a plastic shredder machine. The Pugh Method begins by defining the problem or challenge, which in this case is the need for a plastic shredder machine. Next, the different design options, or concepts, are identified. Once the concepts have been identified, a set of criteria are established that will be used to evaluate and compare the options, such as cost, performance, ease of use, portability, safety, and environmentally friendly. All the concepts are shown in Appendix A. Each design option is evaluated against the criteria and given a score.

Table 3.1: Three Different Concept

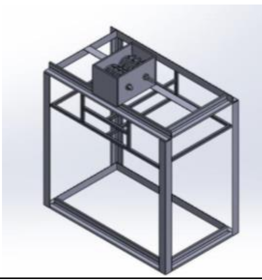
1st Concept	2nd Concept	3rd Concept
		

Table 3.2 PUGH Method Between Concepts Design

Criteria	1st Concept	2nd Concept	3rd Concept
Ergonomic	+	+	+
Cost	-	+	-
Number of Components	-	+	-
Mobility	-	+	+
Sum of +	1	4	2
Sum of -	3	0	2
Total Score	-2	4	0

The scores are then used to rank the options, with the highest scoring option being the preferred choice. Based on the Table 3.2 the value of + and - weight was set up to representing the better than or worse than of each criterion of Ergonomic, Cost, Number of components, and Mobility for each concept and the value then will be sum in order to get the total value for each concept. So, the conclusion is that the 2nd Concept is better than 1st and 3rd Concept.

2.3 Motor Equations

In the design and fabrication of a bottle shredder machine, the choice of motor is critical for achieving the desired shredding performance. The motor's torque, which is the rotational force it can produce, plays a crucial role in determining the shredding capacity of the machine. The relationship between the motor's torque, speed, and power can be described using the equation: -

$$\text{Power (Watts)} = \text{Torque (Nm)} \times \text{Speed (rpm)} / 5252 \quad Eq. 1$$

For example, if the torque of the power window motor in a bottle shredder is 20 Nm and the speed is 2000 rpm, the power generated by the motor would be:

$$\text{Power (Watts)} = 20 \text{ Nm} \times 2000 \text{ rpm} / 5252$$

$$= 754.48 \text{ Watts}$$

The accuracy of this calculation is dependent on the consistency of the motor's performance and the validity of the assumptions used in the equation.

4. Results and Discussion

The analysis includes calculating the amount of power required to drive the machine tool placed in the feeding section, as well as considering factors the motor power and the material chosen to build the machine. The structural material used in the production of the machine is plate and iron bars. Angle bars were chosen due to their high resistance, high melting temperature and because they are cheaper compared to other types of bars. Safety factors are highlighted as an important element in producing any project to prevent failure and accident. Several safety improvements were made to the machine, including covering the moving mechanisms with iron plates to reduce the risk of accidents.

4.1 Results

The result of the Mini PET Bottle shredder is shown in Figure 3.1 The components is consisting of shredder blade, feeder part, motor, shaft, bearing, shaft coupler, machine frame, and drawer. The electronic components that is used in the machine are power supply, emergency push button, buck converter, and switch on/off button. This project function cannot shred bottle plastic as this project is the first project implementation. The recommendations for the next implementation are stated on chapter 5, in recommendation.

An analysis of mild steel as a material used in the construction of shredder blades for bottle shredders. Mild steel is a low carbon steel that is relatively soft and ductile, which makes it easy to work with and shape using standard metalworking techniques. However, it can also be heat-treated to increase its strength and hardness, which makes it more suitable for use in applications that require high levels of wear resistance. Mild steel is relatively inexpensive compared to other types of steel, which makes it an attractive option for use in cost-sensitive applications. However, mild steel is prone to corrosion in certain environments, especially in the presence of moisture or acidic substances. Also, it may not be as wear-resistant as other types of steel, such as high carbon or tool steel. Overall, mild steel is a good choice for shredder blades in many applications due to its strength, hardness, and cost, but it's important to carefully consider the specific requirements and constraints of the application to ensure that mild steel is the most suitable material.

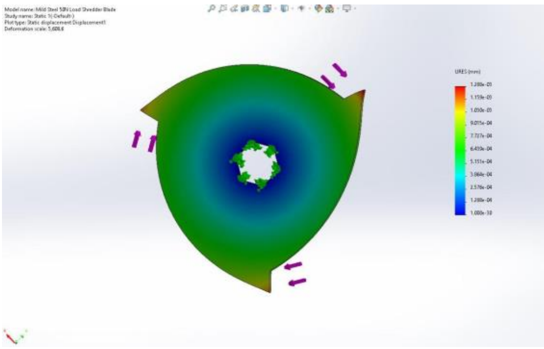


Figure 1: Stress Analysis on Mild Steel Blade

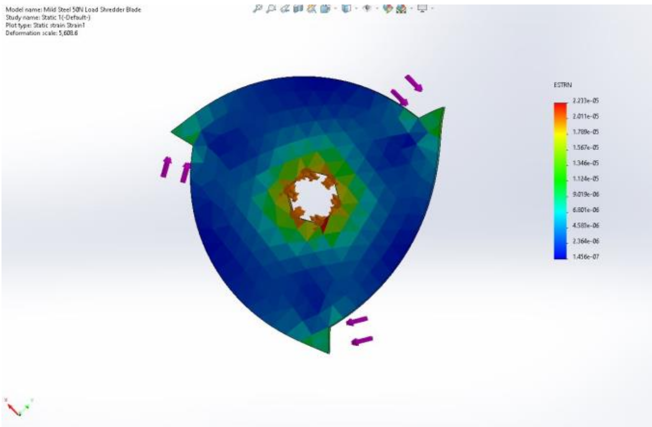


Figure 2: Strain Analysis on Mild Steel Blade

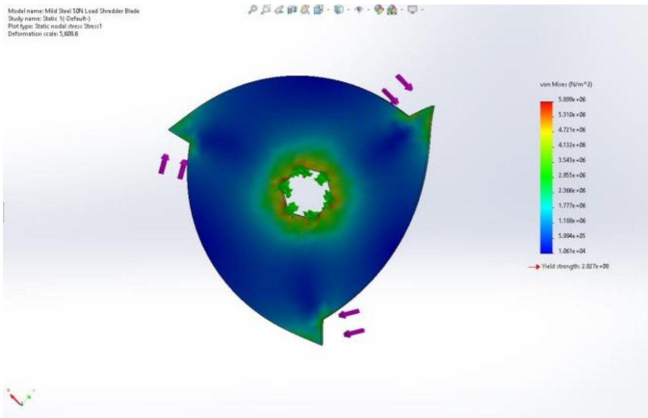


Figure 3: Displacement Analysis on Mild Steel Blade

Table 4.1: FEA Analysis on Alloy Steel, Mild Steel & Stainless Steel

Types of Analysis	Alloy Steel	Mild Steel	Stainless Steel
Stress	6.274×10^6 = 6274000	5.899×10^6 = 5899000	5.691×10^6 = 5691000
Strain	2.341×10^-5 = 0.00002341	2.233×10^-5 = 0.00002233	2.356×10^-5 = 0.00002356
Displacement	6.274×10^6 = 6274000	1.288×10^-3 = 0.001288	1.354×10^-3 = 0.001354

The table 4.1 presents the results of a Finite Element Analysis (FEA) on three types of materials, namely Alloy Steel, Mild Steel, and Stainless Steel. The FEA study includes the calculation of stress, strain, and displacement values for each of the materials. The results show that Alloy Steel has the highest stress value at 6.274 × 10^6 N/m^2, while Stainless Steel has the highest strain value at 2.356 × 10^-5.

The displacement values for the three materials vary, with Alloy Steel having the highest value at 6.274 × 10^6 m, followed by Mild Steel at 1.288 × 10^-3 m and Stainless Steel at 1.354 × 10^-3 m. These results provide valuable insights into the mechanical properties of the materials and can be used to inform the design and fabrication of the bottle shredder machine.

3.4 Figures

Figures should be numbered based on the section number and formatted based on the style as presented in the following:

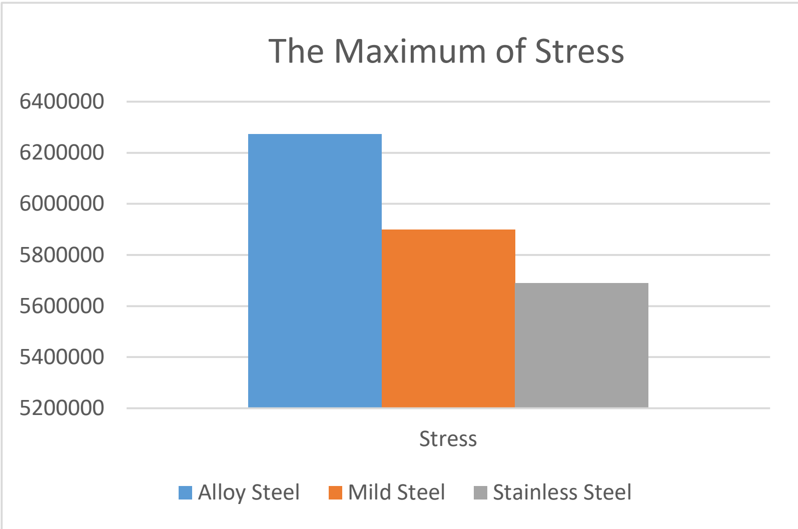


Figure 4: The Maximum of Stress Bar Graph

A graph analysis of maximum stress for alloy steel, mild steel, and stainless steel shredder blades under a load of 50N shows that the alloy steel blade experiences the highest maximum stress level, with a value of 6,274,000. The mild steel blade has a maximum stress of 5,899,000 and the stainless steel blade has a maximum stress of 5,691,000. This indicates that under a load of 50N, the alloy steel blade is subjected to higher levels of stress compared to the mild steel and stainless steel blades. However, it's important to note that this analysis is based on a single load of 50N and further testing and analysis would be required to draw any definitive conclusions about the relative performance of the three types of blades under different loads.

5. Conclusion

The thesis discusses the results of a mini PET bottle shredder project. It explains the effectiveness of the design and method of the machine, as well as the problems and objectives outlined in Chapter 1. The machine is able to shred plastic bottles up to the size of a drink PET bottle. The chapter also discusses the issues encountered during the design and construction of the machine, such as safety concerns and high cost of materials. The use of angle bars or steel angles is used to strengthen the structure of the machine and prevent damage or erosion, and the design of the machine and equipment used is effective. However, the project did not fully achieve its stated objectives and some problems were encountered during implementation such as safety issues, cost concerns and problem with the distance between the shredder and spacer.

5.1 Recommendation

To improve the design and functionality of the machine, it is recommended to take several steps. Firstly, incorporating the use of higher torque motors such as stepper motor NEMA bipolar stepper motor with a holding torque of 40 N.cm, ensuring that the motor can provide the necessary rotational force to shred the bottles effectively. It will allow for better shredding capabilities and increased efficiency in the machine. Secondly, ensuring that the distance of the shredder is close between 0.1 to 0.5mm with the use of spacers can help to improve the overall performance and safety of the machine. Thirdly, conducting market research to survey components cost and size can help to identify the most cost-effective and suitable components for the machine. Fourthly, consulting with experienced professionals in building similar machine models can provide valuable insights and guidance in the design and construction process. Finally, researching the availability of mechanical components before finalizing the design can help to avoid delays and ensure that all necessary components are readily available. By taking these steps, the overall design and functionality of the machine can be greatly improved.

Acknowledgement

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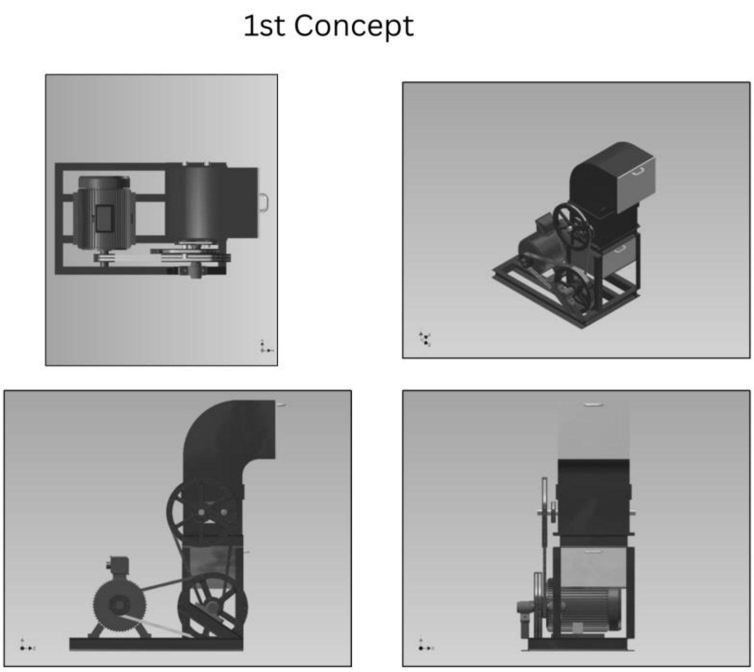
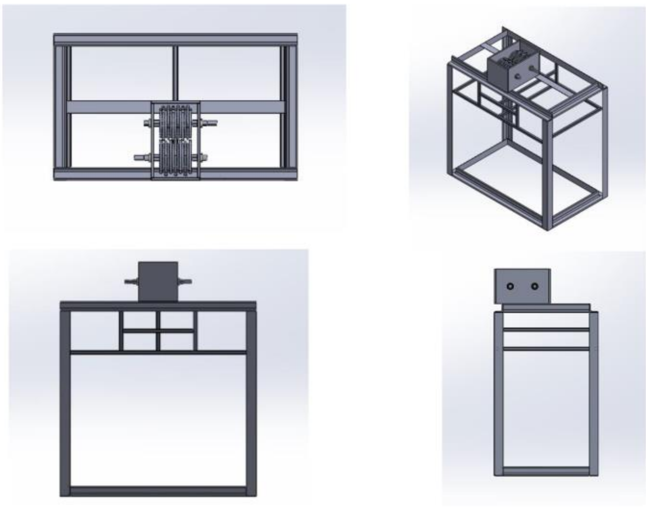
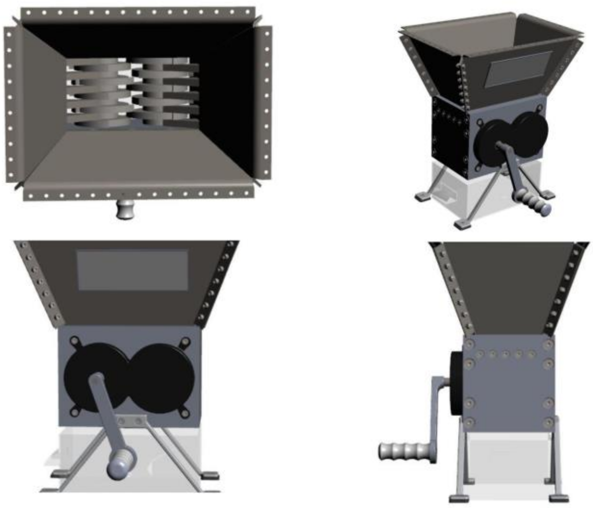
Appendix A



2nd Concept



3rd Concept



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