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Design of Shredding System in Recycle Vending Machine

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Abstract: The design of the shredding system in recycle vending machine is used to shred paper, plastic bottles, and cans. By integrating this shredding system, the materials can be crushed into smaller pieces, thereby optimizing storage space for each form of material and it has proven to be an effective solution for reducing the size of paper, plastic bottles, and cans. This innovation aims to assist university students in minimizing plastic waste generation, specifically by enabling them to conveniently dispose of cans, bottles, and paper waste in recycle vending machines. To develop a comprehensive shredding system, a unified shredding machine design was created for paper, plastic bottles, and cans, incorporating a wall separation mechanism to segregate the materials during the shredding process. The design process involved employing SolidWorks for 3D modeling and conducting calculations and simulation analyses to validate the design's efficacy. The design and simulation results confirm the feasibility and efficiency of the shredding process. This study presents a concise summary of the proposed shredding system, highlighting its potential impact on waste reduction in university settings. Implementation of this system in recycling vending machines can contribute significantly to the overall reduction of plastic waste, benefiting both the environment and the university community.

Keywords: Shredding System in Recycle Vending Machine, Paper, Can, Plastic Bottle, SolidWorks, 3D modelling

1. Introduction

The recycle vending machine (RVM) was built to have a shredding process to shred all the items, but it will have a separating part in the shredding system based on the type of the item. The difference between this machine and others is that it can recycle multiple items, including cans, plastic bottles, paper, and glass bottles, and is designed to generate a return when any recyclable item is placed in an e-wallet or money.

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Figure 1 illustrates an example of an RVM. In 1920, the United States produced the first RVM, also referred to as a "Bottle return and Handling machine." More than 100,000 RVMs have been installed as of late in various locations throughout the world [1]

Figure 1: Recycle vending machine

The New York City Housing Authority (NYCHA) conducted a research study, and the results show that participants believed RVMs would be the most flexible alternative and that could be positioned closer to their buildings than garbage collection stations, making it more convenient [2]. The recycle vending machine (RVM) is a device that accepts used and empty bottles and cans and then sends credit or other incentives to the recycler, based on the amount of containers recycled. In the late 1950s, the Swedish business Wicanders created this device. The recycle vending machine's objective is to assist in the reduction and recycling of this wastage. Most unrecycled beverage bottles are dispersed throughout the environment, including in landfills, rivers, oceans, and lakes. The RVM provides incentives for recycling to reduce this waste. [3]

The first RVM was established in India, 2016. Known as the "Swachh Bharat Recycle Machine," it was first set up in Indian train stations on World Environment Day. Only bottles with an authentic bar code were accepted by the machine, which had a daily capacity of 500 bottles. Users might choose from three reward options: donation, mobile recharge, or discounts at businesses connected to the machine provider. After that, the plastic was given to businesses that produce fibres for use in clothing or grocery bags. [4]

A lot of marine life was harmed by this improper trasher because they mistook it for food. Aside from that, the trash that humans threw into the sea destroyed their shelter. This put marine life in danger because their lives were threatened by the trash. [5] Figure 2 shows a hawaiian monk seal chews on a single-use plastic bottle.

Figure 2: A hawaiian monk seal chews on a single-use plastic bottle

Over 1.4 trillion beverage containers are thrown away globally each year because of waste being produced at an increasing rate. This instance demonstrates that the beverage's user was higher [2]. The first RVM was established in India, 2016. Known as the "Swachh Bharat Recycle Machine," it was first set up in Indian train stations on World Environment Day. Only bottles with an authentic bar code were accepted by the machine, which had a daily capacity of 500 bottles. Users might choose from three reward options: donation, mobile recharge, or discounts at businesses connected to the machine provider. After that, the plastic was given to businesses that produce fibres for use in clothing or grocery bags. [4].

The objective of this project is to design a comprehensive shredding system to reduce the space of the storage part. With this machine, students at the university can reduce the plastic waste such as cans, bottles, and paper waste that they produce themselves.

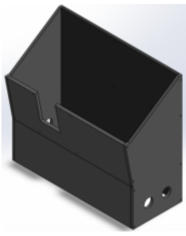
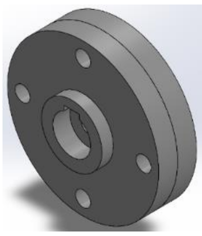
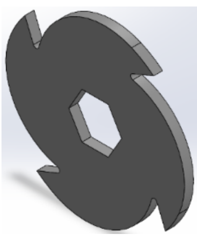
2. Materials and Methods

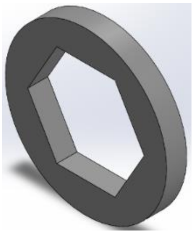
The components or parts listed below have been chosen for the SolidWorks design. Ultimately, the entire product design is created by integrating all the designs.

2.1 Materials

Stainless steel is the primary material utilized in the development of this project. Stainless steel is often intended to withstand the high loads and stresses experienced during shredding and to operate smoothly and last a long time, so proper lubrication and maintenance are essential. Table 1 shows the material selection and manufacturing process was selected

Table 1: Material selection and manufacturing process

Parts	Material Selection	Manufacturing Process
 Frame	**Material** - Magnesium alloy **Description** - Strength and toughness - Corrosion resistance	**Process involved** - Cutting - Drilling
 Coupling	**Material** - AISI 1045 **Description** - Ease of machining and availability - Adequate strength and toughness	**Process involved** - Drilling - Slotting
 Blade	**Material** - Titanium alloy **Description** - Good balance of hardness - wear resistance, and toughness	**Process involved** - Grinding - Turning

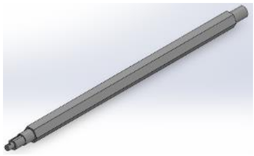


Hex Washer

Material
- Brass

Description
- Good strength
- Wear resistance
- Corrosion resistance

Process involved
- Turning
- Cutting



Shaft

Material
- AISI 1045

Description
- Good strength
- Toughness
- Durability

Process involved
- Cutting
- lathe

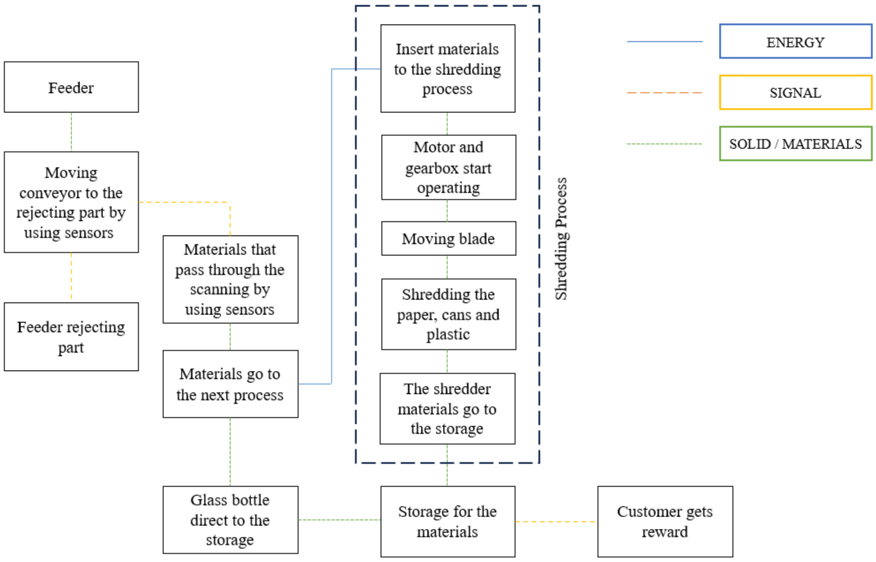


Figure 3: Clustered diagram for design process

2.2 Equipment

The motor used for this case study were DC Motor Model MGFRK 100-22, Motor speed 1400rpm, motor power 1.2kW and voltage 420V. Figure 4 shows a worm-gear reduction gearbox is attached to a motor and lowers the motor's rotational speed while boosting the production of torque.

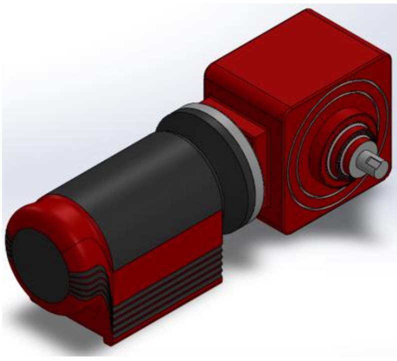


Figure 4: Worm-gear reduction gearbox is attached to a motor by using solidwork simulation.

2.3 Conceptual Design

In this part, it's choosing the best idea based on a morphology chart for incorporation into a product design. Therefore, it is crucial to develop a concept evaluation that minimizes the vagueness of the design's content while simultaneously enhancing its efficiency and objectivity.

Table 2: Concept selection

No.	Function	Specification
1.	Gear Drive	Stainless steel
2.	Shredder Blades	Titanium alloy
3.	Hopper	Magnesium alloy
4.	Hexagonal Shaft	Stainless steel
5.	Hex Washer	Brass

2.4 Design Selection

After completing all the necessary steps, several factors were considered when selecting the final design. Functionality, safety, material choices, and dimensions are all factors to consider when developing a design. Figure 5 below shows the final drawing shredding system using solidwork.

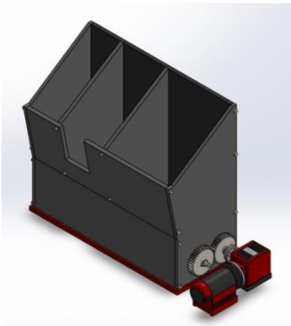


Figure 5: Final drawing shredding system

2.4.1 Shredding Process Flow

The shredding mechanism consists of blades and a washer on a rotating shaft. As the motor and gearbox rotate the shaft, the blades also operate, creating a cutting or shearing action. The cans, plastic bottles, or paper meet the rotating blades as they pass through the shredding mechanism. The blades effectively cut, slice, or shred the materials into smaller pieces. Finally, the shredded materials are discharged from the machine through an output. ready for further processing. Figure 6 shows the process of shredding system was operate.

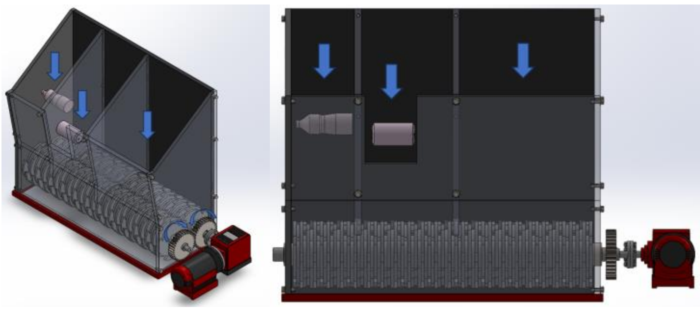


Figure 6: Process of shredding system

Once the materials are fed into the shredding system, the blade will start operating to shred the paper, plastic bottles, and cans based on their feeders, which were already separated from the beginning. Figure 7 shows the power transmission starting to rotate to shred the can, paper, and plastic bottle.

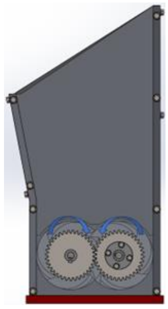


Figure 7: Power transmission starts to rotate.

2.5 Equation

This equation and formula are used to determine the torque, speed, and force needed to shred the paper, plastic bottle, and can. Furthermore, to minimize the cost of making the shredder system, we need to take serious consideration into account so that we can calculate and make comparisons on the benefits and advantages of the shredder system for us and our community.

$$\tau = \frac{F}{A} \quad \text{Eq. } 1$$

$$F = \frac{T \times d}{r^2} \quad Eq. 2$$

$$\tau = \frac{T \times d}{(r^2 \times h \times t)} > \tau_g \quad Eq. 3$$

$$\frac{\omega_1}{\omega_2} = \frac{n_1}{n_2} = \frac{d_2}{d_1} = \frac{T_2}{T_1} \quad Eq. 4$$

$$F_{cutting} = 0.27 \times C \quad Eq. 5$$

$$Output\ Speed(gearbox) = \frac{Input\ speed\ (motor)}{Gear\ ratio} \quad Eq. 6$$

Total costs and profits will be calculated below:

$$Material\ cost = 1.2 \times Total\ Price\ of\ component \quad Eq. 7$$

$$Manufacturing\ cost = 3 \times Material\ cost \quad Eq. 8$$

From the total manufacturing cost, it will be multiplied by 2 and plus the material cost to get the total selling price for the shredding process.

$$Sell\ Price = (2 \times Manufacturing\ cost) + Total\ cost\ of\ standard\ part \quad Eq. 9$$

3. Result and Discussion

Product specifications are a comprehensive list of criteria and standards that specify the ideal qualities, functions, and performance parameters of a product. The details of the specification of shredding process are shown in Table 3.

Table 3: Specification of shredding process

Product Specification	Description
Weight	235.388kg
Dimension	468mm x 1202mm x 850mm
Speed	70rpm
Specification of motor and gearbox:	
• Type of motor	Model MGFRK 100-22
• Power	1.2kW
• Voltage	420V
• Speed	1400rpm
• Type of gearbox	NMRV90 worm-gear reduction
• Gear ratio	1:20

3.1 Blade Structure Analysis

In this section it consists of three test part simulation analysis for blade. Figure 8 shows the result of the pressure analysis that has been made. From the result the highest value of the pressure lies on the blade is 3.542×10^5 (N/m^2). Meanwhile, the lowest pressure lies on the blade part is 5.698×10^2 (N/m2) and the yield strength for the blade is 3.77×10^8. This result shows the material of the blade can withstand the pressure on the blade

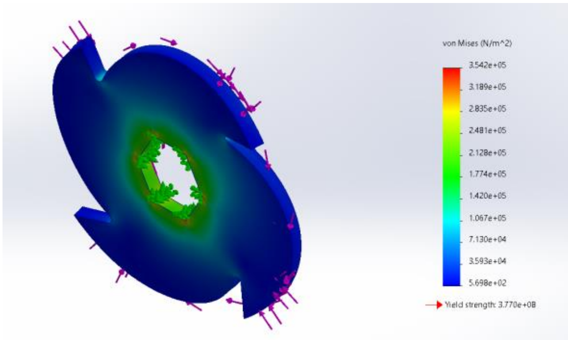


Figure 8: The result of the pressure analysis for blade

The next test of the simulation analysis is the displacement test. Figure 9 shows the displacement test was defined as URES in the SolidWork simulation test. The outcome of the result shows the highest value is 2.431×10^{-4}mm and the lowest value for this displacement simulation test is 1.00×10^{-3}mm. These results indicate that the response of the blade to external forces is variable.

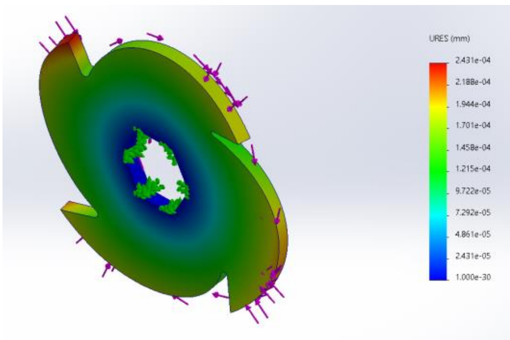


Figure 9: The result of the displacement for blade

The last test of the simulation analysis for the blade is the strain test. Figure 10 shows the strain test was defined as ESTRN in the SolidWork simulation test. The outcome of the result shows the highest value is $2.78x10^{-6}$ and the lowest value for the strain test is $5.79x10^{-9}$. Analyzing these strain patterns will aid in optimizing the performance and durability of the blade for the shredding materials.

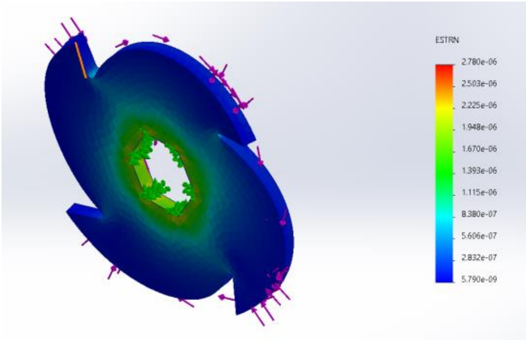


Figure 10: The result of the strain test for blade

3.2 Shaft Structure Analysis

Figure 11 shows the von misses stress for the shaft analysis has been made. From the result it can be seen that the highest value of the pressure lies on the shaft is $1.906x10^6$ (N/m2). Meanwhile, the lowest pressure lies on the shaft is $7.525x10^{-1}$ (N/m2) and the yield strength for the blade is $5.3x10^{24}$. This result demonstrates the durability and dependability of the shaft structure, it can withstand the applied loads and potential stress concentrations.

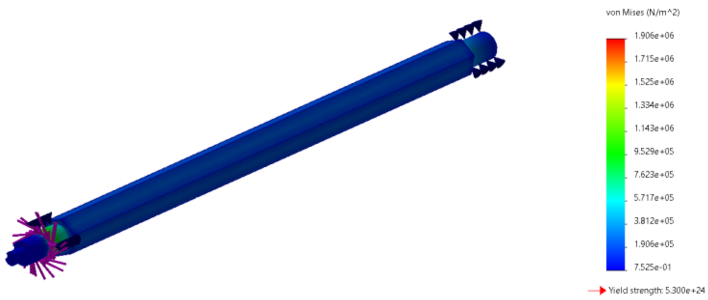


Figure 11: The result von misses stress for shaft

The next test of the simulation analysis is the displacement test. Figure 12 shows the displacement at the highest value is $3.032x10^{-7}$mm and the lowest value for this displacement simulation test is $4.759x10^{-10}$mm. The result shows the shaft These results demonstrate the variability in the blade's response to external forces and show potential structural integrity issues.

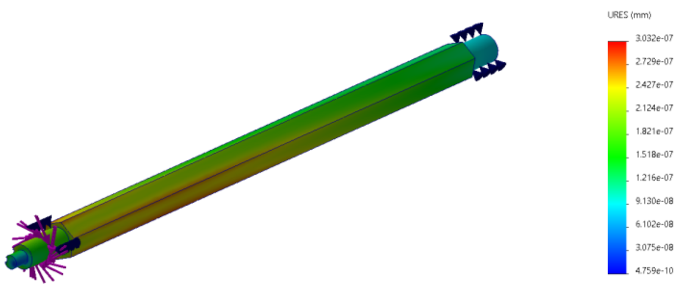


Figure 12: The result of the displacement for shaft

The last test of the simulation analysis for the blade is the strain test. Figure 13 shows the result of strain test that was made in SolidWork simulation test. The outcome of the result shows the highest value is 6.218x10 and the lowest value for the strain test is 7.621×10^{-16}. thus, the structure of the shaft is safe.

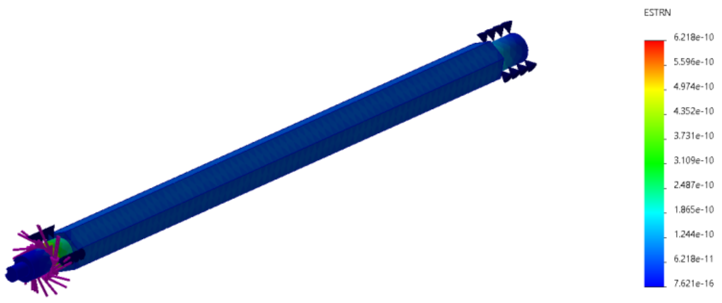


Figure 13: The result of strain test for shaft

3.3 Body Structure Analysis

The frame is an essential component in the design and operation of a shredding machine since due to the supports the functioning and durability of the device. Figure 14 shows the von misses stress for the frame analysis has been made. From the result it can be seen that the highest value of the pressure lies on the shaft is 7.955×10^{5} (N/m2). Meanwhile, the lowest pressure lies on the shaft is 8.857×10^{-7}(N/m2). From the result it can be seen there is no fracture that happen on the frame, it shows the material of frame in supporting the component was successfully.

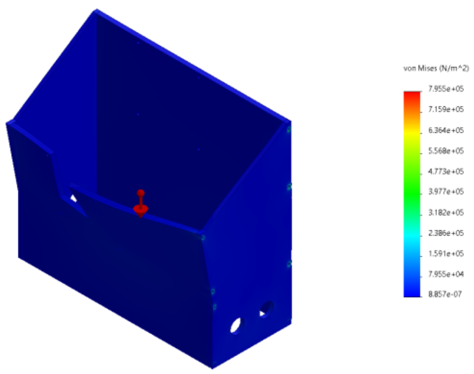


Figure 14: The result von misses stress for frame

Figure 15 shows, the displacement at the highest value is 2.892×10^{-3}mm and the lowest value for this displacement simulation test is 1.00×10^{-30}mm. This small value of displacement will not lead to any danger.

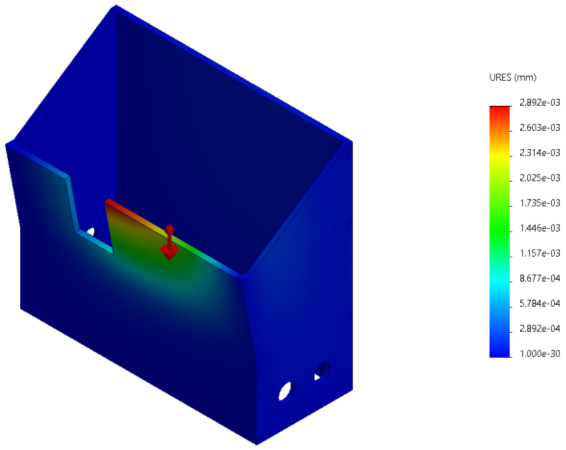


Figure 15: The result for the displacement for frame

The last analysis of the simulation was the strain test analysis. Figure 16 shows the strain test result. The outcome of the result shows that the highest value is $8.417x10^{-6}$ and the lowest value for the strain test is $1.303x10^{-9}$. From the result, it shows that the test on the frame was successful, the material selection for the frame was able to support the shaft, bearing, and other component that related to the frame.

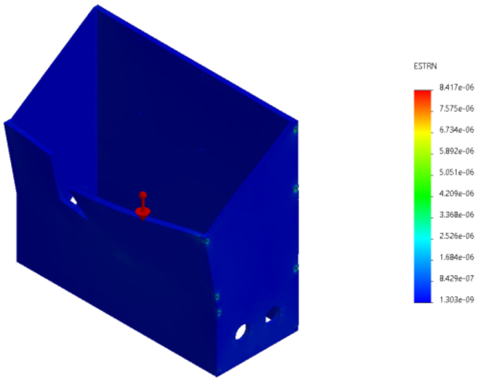


Figure 16: The result strain test for frame

4. Conclusion

The design of the shredding process in the recycle vending machine presented in this study showcases innovative features that enhance efficiency and promote effective material separation. The inclusion of a wall within the shredder with dimensions based on the specific materials being processed, such as paper, plastic bottles, and cans, ensures that the shredder does not mix different materials during the shredding process. The overall weight of the machine, which stands at 235kg, demonstrates a robust construction that can handle the shredding requirements efficiently. The machine's speed of 70 rpm contributes to a consistent and reliable shredding process, ensuring a high level of performance and throughput. Furthermore, the comprehensive analysis conducted using SolidWorks simulation analysis provides valuable insights into the structural integrity and performance of the shredding system.

Overall, the design of the shredding process in the recycle vending machine exemplifies innovation and careful consideration of key factors such as material separation, machine weight, speed, and structural integrity. By incorporating these elements, this design offers a promising solution for efficient and effective recycling within vending machines, contributing to sustainable waste management practices.

Acknowledgement

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