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Design and Fabrication of a Locally Made Plastic Shredder

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Abstract: *Plastic waste management is a growing environmental concern due to the increasing production and disposal of plastic materials, which contribute to pollution and ecological degradation. Conventional plastic shredders are often expensive and inaccessible to small-scale recyclers, necessitating the development of cost-effective and locally fabricated alternatives. The project focuses on designing and fabricating a locally made plastic shredder that addresses plastic waste management challenges. The methodology involved a series of steps including needs assessment, literature review, conceptual and detailed design, material selection, fabrication, assembly, testing, and optimization. The shredder was designed to be cost-effective and efficient, utilizing locally available materials and expertise. Materials used included Aluminium and steel alloys for the frame, copper wire for the motor, high-quality bearings, rubber seals, and various electrical components. Tools employed in the fabrication process ranged from hand tools and power tools to welding equipment and testing instruments. Safety gear was also emphasized to protect workers during the fabrication and operation processes. The testing phase covered functional testing, load testing, efficiency testing, safety assessments, durability testing, environmental testing, and quality control inspections. Design calculations focused on parameters such as shredding capacity, torque, shear force, blade design, hopper volume, material feed rate, structural integrity, energy consumption, and shredder efficiency. Results indicated that the locally made plastic shredder effectively shredded various types of plastic waste, with a satisfactory shredding capacity of 0.21 kg/hr and a shredder efficiency of 83.12%. The torque transmitted by the shaft was 62.50 Nm, and the shear force required to cut through plastic was 2843.5 N. The blade speed was calculated at 41.89 rads/sec, with a cutting speed of 4189 m/sec. The energy consumption of the shredder was 4.48 Kwh. The project concluded that locally made plastic shredders could significantly contribute to sustainable plastic waste management, resource conservation, and environmental protection.*

Keywords *Design and Fabrication, Energy Efficiency, Plastic Pollution, Plastic Shredder, Recycling, Waste Management*

1. INTRODUCTION

Plastic waste has become one of the most pressing environmental issues globally, posing significant challenges to sustainable waste management. The global production of plastics has resulted in large quantities of plastic debris that pollute land and marine ecosystems, with over 5 trillion plastic pieces, weighing over 250,000 tons, floating in the oceans [1]. This pollution not only threatens wildlife but also impacts human health through the contamination of food and water supplies [2]. As plastic waste continues to accumulate, particularly in developing nations, effective recycling and waste management strategies are urgently needed. One promising solution is the development of locally made plastic shredders, which can support small-scale recycling initiatives and contribute to the circular economy [3].

The recycling of plastics is essential for reducing the environmental impact of plastic waste. Plastic shredders play a critical role in this process by breaking down plastic materials into smaller, more manageable pieces that can be further processed or repurposed [4]. By implementing locally fabricated shredders, communities can reduce their reliance on external technology and materials, thus lowering costs and increasing access to recycling solutions [5]. The creation of a locally made plastic shredder is not only an environmentally beneficial solution but also a way to promote local economies by utilizing locally available materials [6].

The design of plastic shredders varies, with many models using rotary knives or shredding mechanisms that differ in complexity depending on the type of plastic waste being processed [7]. Innovations such as multilayered shredders designed for handling diverse plastic types, including multilayered plastics, can further enhance the versatility and efficiency of these machines [8]. By designing shredders suited to local needs, it becomes possible to handle various waste plastics and ensure the effective recycling of materials such as PET bottles and polypropylene plastics [9, 10].

In addition to their ecological benefits, locally made shredders can provide socio-economic advantages. They create job opportunities, improve waste management infrastructure, and contribute to reducing the environmental footprint of plastic production [9]. As noted by Callister & Rethwisch [3], advances in material science have made it possible to fabricate these machines using locally sourced materials, which enhance the sustainability and practicality of such innovations.

Furthermore, this approach aligns with the growing emphasis on circular economy models, where waste is viewed not just as refuse, but as a resource for new production cycles [11, 12, 13]. The design and fabrication of locally made plastic shredders is the key step in addressing the mounting issue of plastic waste. By promoting recycling, reducing plastic waste, and providing accessible solutions for local communities, these machines are an essential part of the move towards a more sustainable future [14, 15, 16].

The aim of this study is to design and fabricate a locally made plastic shredder that enhances plastic waste management by providing an affordable, efficient, and durable solution for recycling plastic materials. This project seeks to optimize material selection, blade design, and operational efficiency to ensure the effective shredding of different types of plastic waste while promoting sustainability and environmental conservation.

2. RELATED WORKS

The design and fabrication of a locally made plastic shredder have become critical areas of focus due to the growing need to manage plastic waste sustainably. This section reviews relevant studies on the environmental, technological, and material considerations for plastic shredders. Plastic waste management is a pressing issue globally. Jambeck et al. [8] identified that over 8 million metric tons of plastic enter the ocean annually, necessitating interventions like shredding to mitigate environmental damage. Similarly, Schmidt et al. [18] revealed that rivers significantly contribute to marine plastic pollution, underscoring the importance of local waste management technologies. Barnes et al. [2] demonstrated how plastic fragments accumulate and persist in ecosystems, creating long-term challenges for environmental health. The ecological impacts of plastic waste are further explored by Rochman et al. [17], who highlighted the degradation of ecosystems due to plastic debris. Thompson et al. [22] emphasized the potential human health risks posed by microplastics, adding urgency to developing technologies for efficient plastic waste processing. Eriksen et al. [5] quantified the sheer scale of global plastic pollution, estimating over 250,000 tons of plastic floating in oceans, reinforcing the need for effective shredding solutions. The technical aspects of shredder design have also been widely studied. Achmad et al. [1] proposed a multilayer plastic shredder with optimized blade configurations to enhance cutting efficiency. Gareth and Parkinson [4] focused on the cost-effective fabrication of shredders, emphasizing modularity for ease of repair and scalability. Vaishnavi [23] similarly presented designs that prioritize operational efficiency and durability. Sudhakara and Raju [19] highlighted mini shredders tailored for small-scale operations, addressing challenges in decentralized waste management. Advancements in design are essential for promoting circular economies. José-M. et al. [9] proposed an innovative shredder that facilitates recycling by improving the mechanical properties of shredded plastic, enhancing its usability in new products. McKurai et al. [11] designed a user-friendly PET bottle shredder aimed at household recycling, supporting grassroots waste management efforts. Material selection is another critical component in shredder development. Callister and Rethwisch [3] explored material science principles relevant to shredder blade design, emphasizing wear resistance and mechanical strength. Reddy and Raju [16] stressed the importance of selecting durable materials to ensure long-term performance in plastic shredders. Surgude et al. [20] addressed blade wear and motor efficiency in their design, presenting solutions to enhance the lifespan of shredding machines. The economic implications of plastic shredders are also significant. Geyer et al. [7] analyzed the lifecycle of plastic materials, advocating for technologies that transform waste into reusable resources, such as shredders. Kumar et al. [10] examined India's recycling systems and emphasized shredding as a cost-effective method to recover resources from plastic waste. Environmental science research has further contextualized the importance of shredding in reducing waste. Clark et al. [4] reviewed global plastic waste reduction strategies, identifying shredders as vital tools for achieving sustainable waste management. Parkinson [14] discussed integrating shredders into local recycling systems to minimize the environmental footprint of plastic waste. From an operational perspective, Olodu and Akokhia [13] demonstrated how combining manual and automated functions in machinery could optimize efficiency, an approach that could benefit shredder design. Sudhakara and Raju [19] explored similar hybrid approaches, offering insights into balancing affordability and effectiveness. Minig et al. [12] designed a user-friendly household PET plastic bottle shredder aimed at promoting a green economy. The study highlights the need for compact, energy-efficient designs that encourage household participation in recycling. The incorporation of safety features and ease of operation were key considerations in making shredding more accessible to the general public. Similarly, Patil [15] developed a plastic shredding machine focused on affordability and fabrication feasibility. The study outlined various mechanical components such as blades, motors, and frames, optimizing their configurations to achieve high shredding efficiency while maintaining cost-effectiveness. The work demonstrated that locally fabricated shredders could significantly reduce dependence on expensive imported models, making plastic recycling more accessible to small-scale industries and local communities. Tejero-Olalla et al. [21] proposed a novel approach to recycling plastic waste through the development of an advanced shredder optimized for circular economy practices. Their study focused on improving material recovery, reducing energy consumption, and designing modular components for easy maintenance and adaptability to different types of plastics. The findings suggest that integrating automation and sensor-based monitoring systems can enhance shredding precision and operational efficiency.

In conclusion, the reviewed literature demonstrates that designing and fabricating a locally made plastic shredder is a multidisciplinary challenge involving environmental, technological, and economic considerations. Advances in material science, innovative design approaches, and the growing need for sustainable waste management reinforce the importance of developing effective shredding technologies.

3. METHODOLOGY

3.1 Conceptual Design and Specifications

After the research phase, the team organized brainstorming sessions and design workshops to develop creative solutions for the shredder. Several design concepts were proposed and evaluated based on technical feasibility, cost, and user preferences. The team established performance criteria such as shredding capacity, energy efficiency, durability, and safety. These specifications formed the foundation for the conceptual design, which outlined the basic structure and function of the shredder, including key components like the motor, shredding mechanism, and frame.

3.2 Detailed Design and Engineering

In the detailed design phase, the team created engineering drawings and CAD models of the shredder. Using CAD software allowed for precise modeling of the shredder's components, optimizing their geometry and ensuring manufacturability. This also facilitated stress analysis to identify potential weak points in the design, particularly around the shredding blades and motor mounts. The design ensured that the machine would be able to handle various plastic materials with sufficient force and efficiency. Special attention was paid to ease of assembly and maintenance, ensuring that the machine could be built and repaired with locally available materials and skills.

3.3 Material Selection and Procurement

Material selection was based on several factors, including strength, durability, cost, and availability. The main materials used included steel for the blades and structural frame, aluminium for some lightweight components, and copper wire for the motor. The shredder's blades were designed with a safety margin to ensure they could handle the shearing forces involved in cutting plastic. Calculations were made for shear stress and safety margins, ensuring that the chosen materials could withstand operational loads. Steel, with yield strength of 250 MPa, was chosen for the blades, with a factor of safety between 2.0 and 4.0. Procurement protocols were established to ensure the consistency and quality of materials. Collaborating with suppliers helped in sourcing high-quality components, and samples were tested before fabrication to ensure their suitability for the application.

3.4 Fabrication and Assembly

The fabrication process took place in a workshop equipped with essential machinery, including welding equipment, lathes, and power tools. Hand tools like screwdrivers, wrenches, and pliers were used for assembly, while power tools like drills and grinders helped in shaping and assembling the components. Welding was an integral part of the assembly process, especially for joining the steel frame and shredding chamber components. The assembly process followed a structured approach, starting with the frame, and then mounting the motor, followed by installing the shredding mechanism. Measuring instruments ensured the precise alignment of the parts, preventing errors that could affect the machine's performance. Electrical components were installed and tested, including the motor and safety features such as emergency stop switches. Rubber seals were added to protect sensitive components from dust and moisture.

3.5. Testing and Optimization

Once assembled, the shredder underwent rigorous testing. Functional tests ensured that all mechanical components, such as the motor and shredding blades, operated correctly. Load testing was performed to evaluate the shredder's capacity under different conditions, including varying plastic feed rates and material types. These tests helped to identify areas for optimization, such as blade clearance and motor speed, which were fine-tuned to improve shredding efficiency and performance. Safety testing was also conducted to ensure the shredder was safe to operate. Emergency stop buttons and safety guards were tested for effectiveness, and electrical systems were checked for insulation and grounding to prevent accidents.

3.6. Testing and Quality Control

The shredder underwent additional quality control measures to ensure durability and reliability. Durability testing simulated long-term use to identify potential wear and fatigue in the mechanical components. Noise and vibration tests ensured that the machine operated within acceptable limits. The final quality control inspections verified the alignment, assembly, and finish of the shredder, ensuring that it met the required standards for performance and safety.

3.7 Conceptual Designs

The conceptual design of the plastic shredding machine consists of detailed orthographic and isometric views that illustrate key components. Figures 1 to 3 present the base of the machine from top, side, and perspective views, highlighting the structural foundation. Figures 4 to 7 illustrate the hopper and shredding chamber from various angles, including back, side, top, and 3D views, showcasing the material input mechanism and cutting unit. These views provide clarity on how plastic waste will be guided into the shredding chamber. Figures 8 to 10 display the entire plastic shredding machine in composite, side, and 3D views. These final illustrations integrate all subsystems; base, hopper, and shredding chamber into one functional unit. The 3D representations offer a realistic visualization of the assembled machine, aiding fabrication and future modifications. The designs ensure structural stability, ease of maintenance, and efficiency in plastic shredding operations.

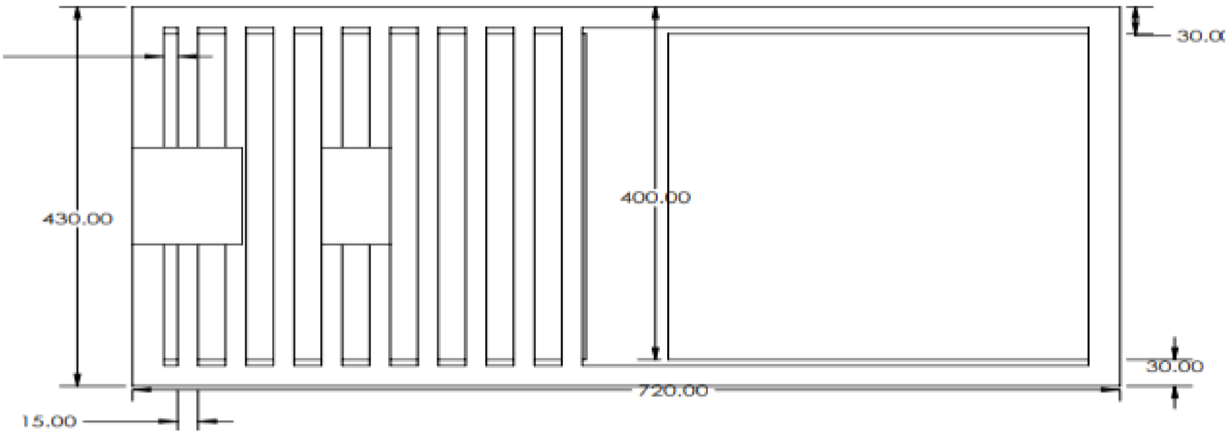

Figure 1: Top view of base

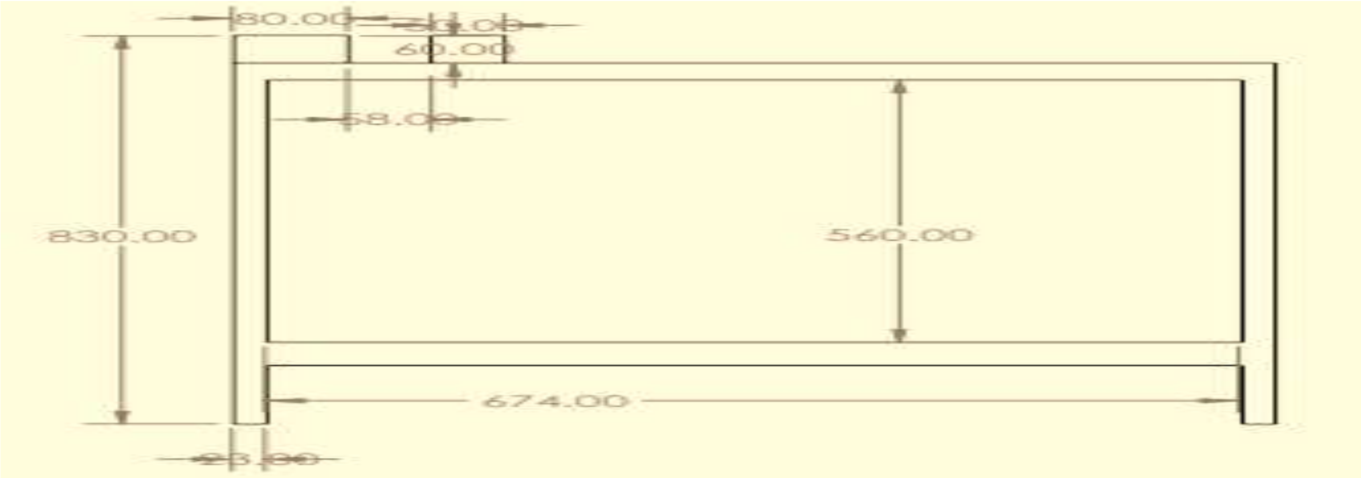

Figure 2: Side view of base

Figure 3: The base

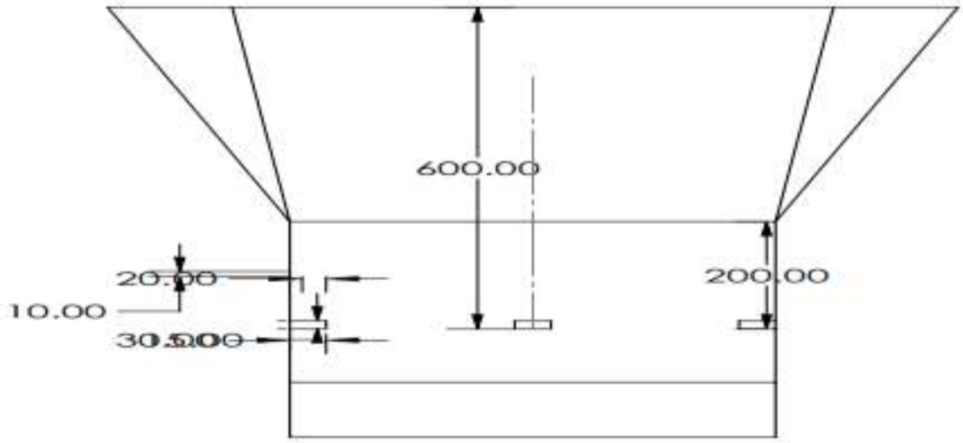

Figure 4: Back view of hopper and shedding chamber

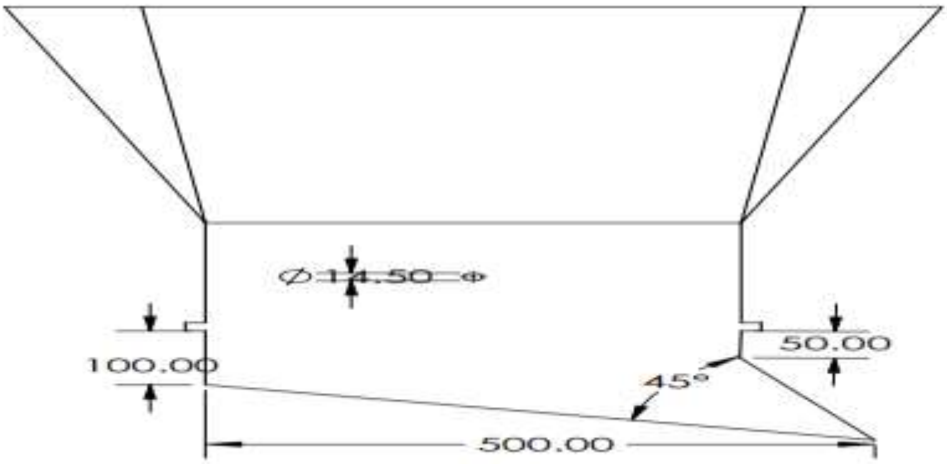

Figure 5: Side view of hopper and shredding chamber

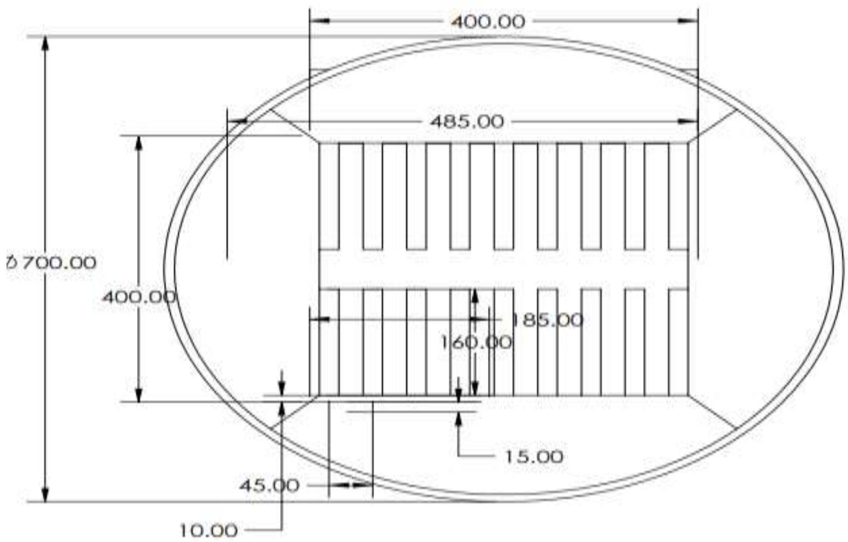

Figure 6: Top view of shredding chamber

Figure 7: 3D view of shredding chamber and hopper

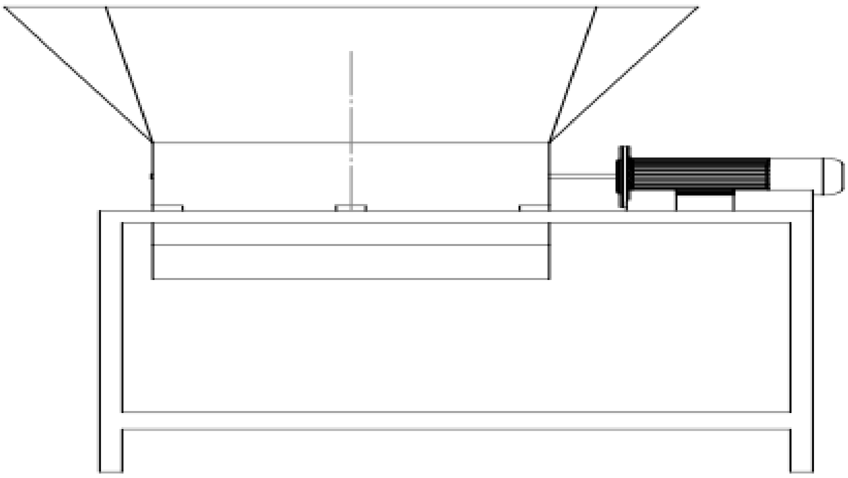

Figure 8: Composite view of the plastic shredding machine

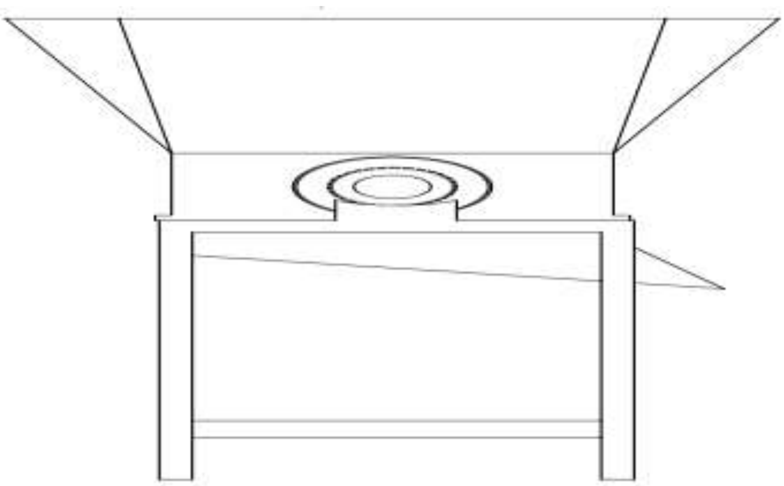

Figure 9: Side view of the plastic shredding machine

Figure 10: 3D view of the plastic shredding machine

4. DESIGN CALCULATIONS, RESULTS AND DISCUSSION

4.1 Design Calculation Formulars

Design calculations for the locally made plastic shredder typically involve several key parameters and considerations.

1. Shredding Capacity: The desired shredding capacity was determined by measuring the amount of plastic waste shredded per unit of time, such as kilograms per hour or pounds per minute.

$$Shredding\ capacity = Throughput = \frac{\text{Mass of shredded plastic (kg)}}{operating\ time}$$

$$Q = \frac{m}{t} \quad (1)$$

Where: Q = Throughput (kg/hr.), m = Mass of shredded plastic (kg), and t = operating time (hr.)

2. Torque Transmitted by Shaft: The torque transmitted by the shaft is the twisting force required to rotate the blades to shred the plastic.

$$Torque = Motor\ Power \times Rotational\ speed$$

$$T = P \times \frac{2\pi N}{60} \quad (2)$$

Where: T = Torque Transmitted by Shaft in Nm, P = Motor Power (KW), and N = Rotational Speed (rpm)

3. Shear Force: The shear force is the force required to cut through the plastic material.

$$Shear\ Force = Shear\ Strength \times Cutting\ Area$$

$$F = \tau \times A \quad (3)$$

$$A = t \times L \quad (4)$$

Where: F = shear force (N), τ = Shear Strength of the plastic material (N/mm^2), A = Cutting Area (mm^2), t = Thickness of the PET Plastic (mm), L = Length of the PET Plastic (mm)

4. Blade Design Calculations: This involves calculating the blade's thickness and the shredder blades' rotational speed.

$$Blade\ Thickness = \frac{shear\ force}{yeild\ strength\ of\ blade\ material}$$

$$t = \frac{F}{\sigma} \quad (5)$$

Where: t = Thickness (mm), F = Shear Force (N), σ = Yield Strength of blade material (MPa)

$$Blade\ Speed\ (\omega) = \frac{2\pi N}{60} \quad (6)$$

Where: ω = Angular Velocity of the Blade (rads/sec), N = Blade RPM

$$Cutting\ Speed\ (s) = Blade\ Circumference\ \times Blade\ rpm$$

$$s = \pi \times d \times \frac{N}{60} = w \times r \quad (7)$$

Where: s = Cutting Speed (m/sec), d = Blade Diameter (mm), and N = Blade RPM

The Rotational Speed (N) Calculation was obtained using Equation 8

$$N = \frac{V}{2\pi r} = \frac{w \times r}{2\pi r} \quad (8)$$

5. Hopper Volume: The volume of the hopper determines how much plastic can be loaded into the shredder.

$$Volume\ of\ hopper\ (V) = \frac{1}{3}\left(A_1 + A_2\sqrt{A_1 + A_2}\right)h \quad (9)$$

Where: V = Volume of Hopper (mm^3), A_1 = Area of Top Base (mm^2), A_2 = Area of Bottom Base (mm^2), h = Height of Hopper (mm)

6. Material Feed Rate: The material feed rate is estimated based on the shredding capacity, particle size distribution, and material density.

$$Material\ Feed\ Rate = \frac{mass\ of\ plastic\ to\ be\ shredded}{operating\ time}$$

$$f = \frac{m}{t} \quad (10)$$

Where: f = Material Feed Rate (kg/hr), m_1 = mass of plastic to be shredded (kg), t = operating time (hr)

7. Structural Integrity: Performed structural calculations to ensure the integrity and stability of the shredder's frame, rotor assembly, and other structural components.

$$Shear\ Stress\ on\ blades = \frac{shear\ force}{area}$$

$$\tau_{blade} = \frac{F}{A} \quad (11)$$

Where: τ = Shear Stress on blades (N/mm^2), F = Shear Force (N), and A = Area of blade (mm^2)

$$Bending\ Moment\ (\sigma) = \frac{M.y}{I} \quad (12)$$

Where: σ = Bending Stress (MPa), M = Bending Moment (N.mm), y = Distance from the neutral axis to the outer fiber (mm), and I = Second Moment of Inertia (mm^4)

$$Torsional\ Stress\ (\tau_{shaft}) = \frac{T \times r}{J} \quad (13)$$

Where: τ_{shaft} = Torsional Stress (MPa), T = Torque Transmitted by the Shaft (N-m), r = Radius of the Shaft (mm) J = Polar Moment of Inertia (mm^4)

8. Energy Consumption: The energy consumption of the shredder is estimated from the motor power rating and the duration of operation.

$$Energy\ Consumed = motor\ power \times operating\ time$$

$$E = P_{motor} \times t \quad (14)$$

Where; E = Energy Consumed (KWh), P_{motor} = Motor Power (KW), and t = Operating Time (hr)

9. Shredder Efficiency: The shredder efficiency is evaluated by determining how effectively the shredder was able to convert electrical energy into mechanical energy required to shred the plastic.

$$Shredder\ Efficiency = \frac{power\ output}{power\ input}$$

$$\eta_{shredder} = \frac{P_{output}}{P_{input}} \quad (15)$$

$$P_{input} = V \times I \quad (16)$$

Where: P_{input} = Power Input (KW), V = Voltage (volts), I = Current (Amperes)

$$P_{output} = T \times \omega \tag{17}$$

Where: P_{output} = Power Output (KW), T = Torque (N.mm), ω = Angular Velocity (rads/sec)

10. Energy Efficiency: The energy efficiency of the shredder design is evaluated by calculating the power consumption per unit of shredded material.

$$Energy\ Efficiency = \frac{useful\ work\ output}{total\ energy\ input}$$

$$\eta_{energy} = \frac{E_{output}}{E_{input}} \tag{18}$$

$$E_{output} = E_{input} \times \eta_{shredder} \tag{19}$$

Where: E_{input} = Energy Input = Motor Power (KW), E_{output} = Energy Output (KW), $\eta_{shredder}$ = Shredder Efficiency

4.2 Design Calculations

Shredding Capacity: From Equation 1

$$Q = \frac{m_2}{t}$$

Where: m_2 = 0.62kg, t = 3hours

$$Q = \frac{0.62}{3} = 0.21 kg/hr$$

Torque Transmitted by the Shaft: From Equation 2

$$T = P \times \frac{2\pi N}{60}$$

Where: P_{motor} = 2HP ≅ 2X0.746KW=1.492KW, N = 400 RPM

$$T = 1.492 \times \frac{2\pi \times 400}{60} = 62.50\ N.m$$

Shear Force: From Equation 4

$$A = t \times L$$

Where: t = 0.25mm, L = 235mm

$$A = 0.25 \times 235 = 58.75\ mm^2$$

From Equation 3

$$F = \tau \times A$$

Where: τ = 48.4 MPa, A = 58.75 mm^2

$$F = 48.4 \times 58.75 = 2843.5\ N$$

Blade Design: Blade Thickness: From Equation 5

$$t = \frac{F}{\sigma}$$

Where: F = 2843.5 N, σ = 250MPa (for Mild Steel) ≅ 250 N/mm^2

$$t = \frac{2843.5}{250} = 11.374\ mm$$

Blade Speed: from Equation 6

$$\omega = \frac{2\pi N}{60}$$

Where: N = 400rpm

$$\omega = \frac{2 \times \pi \times 400}{60} = 41.89\ rads/\text{sec}$$

Cutting Speed: From Equation 7

$$S = \pi \times D \times \frac{N}{60}$$

Where: D = 20mm, N = 400rpm

$$S = \pi \times 20 \times \frac{400}{60} = 418.88\, m/s$$

The cutting speed (V) of the shredder blade was calculated using the formula:

V= ω × r

Where: V = Cutting speed (mm/s), ω = Angular speed (rad/s), r = Blade radius (mm), the angular speed (w) of the blade was obtained as 41.89 rad/s

Shear force F_s = 2843.5 N
Blade material yield strength τ_y =250 N/mm²
Cutting speed V= 4189 mm/sec
Blade radius r=100 mm
cutting speed (V) = 41.89 × 100 = 4189 mm/s

Rotational Speed (N) Calculation: $N = \frac{V}{2\pi r} = \frac{w \times r}{2\pi r}$; From Equation 8

$$N = \frac{4189}{2 \times 3.142 \times 100} = 4189 mm/s$$

Hopper Volume: From Equation 9

$$V = \frac{1}{3}\left(A_1 + A_2\sqrt{A_1 + A_2}\right)h$$

Where: d_1 = 300mm, d_2 = 240mm, h = 300mm

$$A_1 = \pi \times \frac{d^2}{4} = \pi \times \frac{300^2}{4} = 70685.83\, mm^2$$

$$A_2 = \pi \times \frac{d^2}{4} = \pi \times \frac{240^2}{4} = 45238.93\, mm^2$$

$$V = \frac{1}{3}\left(70685.83 + 45238.93\sqrt{70685.83 + 45238.93}\right)300 = 1547351246\, mm^3 \cong 1.555$$

Material Feed Rate: From Equation 10

$$f = \frac{m_1}{t}$$

Where: m_1 = 0.72kg, t = 3hours

$$f = \frac{0.72}{3} = 0.2\, kg/\,hr$$

Structural Integrity:

Shear Stress on the blade: From Eqn.11

$$\tau_{blade} = \frac{F}{A}$$

Where: F = 2843.5 N, A = L × W = 45 × 20 = 900mm

$$\tau_{blade} = \frac{2843.5}{900} = 3.16\, N/mm^2$$

Bending Moment:

$$M = F \times \frac{D}{2} = 2843.5 \times \frac{20}{2} = 28435\, Nm$$

$$y = \frac{D}{2} = \frac{20}{2} = 10mm$$

$$I = \frac{\pi \times D^4}{64} = 7853.98\ mm^4$$

From Equation 12

$$\sigma = \frac{M \times y}{I}$$

Where: M = 28435 Nm, y = 10mm, I = 7852.98 mm^4

$$\sigma_{shaft} = \frac{28435 \times 10}{7852.98} = 36.21\ MPa$$

Torsional Stress:

$$J = \frac{\pi}{32} \times D^4 = \frac{\pi}{32} \times 20^4 = 15707.96\ mm^4$$

$$r = \frac{D}{2} = \frac{20}{2} = 10mm$$

T = 62.50 N.m ≅ 62500 N.mm

From Equation 13

$$\tau_{shaft} = \frac{T \times r}{J}$$

$$\tau_{shaft} = \frac{62500 \times 10}{15707.96} = 39.79\ N/mm^2$$

Energy Consumption:

From Equation 14

$$E = P_{motor} \times t$$

Where: P_{motor} = 1.492KW, t = 3 hours

$$Energy\ produced\ by\ Electric\ Motor(Input),\ E = 1.492 \times 3 = 4.48\ KWh$$

Shredder Efficiency:

From Equation 16

$$P_{input} = V \times I$$

Where: V = 210 volts, I = 15 Amps

$$P_{input} = 210 \times 15 = 3150\ Watts$$

From Equation 17

$$P_{output} = T \times \omega$$

Where: T = 62.50 N.m, ω = 41.89 rads/sec

$$P_{output} = 62.50 \times 41.89 = 2618.13\ Watts$$

From Equation 18

$$\eta_{shredder} = \frac{P_{output}}{P_{input}} X100\% = \frac{2618.13}{3150} X100\% = 0.8312 = 83.12\ \%$$

Output Energy, E_{output}:

From Equation 19

$$E_{output} = E_{input} \times \eta_{shredder}$$

Where: E_{input} = 4.48Kwh , $\eta_{shredder}$ = 0.8312

$$Energy\ output, E_{output} = 4.48 \times 0.8312 = 3.720kwh$$

Table 1: Detailed design results

S/N	Formula	Symbols	Values	S.I. Unit
1	Shredding capacity	Q	0.21	Kg/hr
2	Torque transmitted by the shaft	T	62.50	N.m
3	Shear force	F	2843.5	N
4	Blade thickness	T	3.37	Mm
5	Blade speed	ω	41.89	Rads/sec
6	Cutting speed	S	2408.55	m/sec
7	Hopper volume	V	1.55	m^3
8	Material feed rate	F	0.24	Kg/hr
9	Shear stress on blade	τ_{blade}	3.16	N/mm^2
10	Bending Stress on Shaft	σ_{shaft}	36.21	N/mm^2
11	Torsional stress on shaft	τ_{shaft}	39.79	N/mm^2
13	Power Input	P_{input}	3150	Watts
14	Power Output	P_{output}	2618.13	Watts
15	Energy Input (Energy Consumption)	E_{input}	4.48	KWh
16	Energy Output	E_{output}	3.72	KWh
17	Energy Efficiency (Shredder Efficiency)	$\eta_{shredder}$	83.12	%

4.3. Discussion

The results of this study reveal that the locally fabricated plastic shredder demonstrates high potential for improving plastic waste management, particularly at the grassroots level. With a shredding capacity of 0.21 kg/hr, a blade speed of 41.89 rad/sec, and an energy efficiency of 83.12%, the shredder offers a practical and energy-efficient solution for processing plastic waste. This efficiency is a notable achievement, considering the challenges associated with plastic recycling technologies in developing nations, as highlighted by Eriksen et al. [5], who pointed out that inadequate collection systems and inefficient processing methods hinder recycling efforts globally. The shredder's ability to process plastic waste at a rate of 0.21 kg/hr, though modest, is sufficient for small-scale, community-level operations. Compared to industrial shredders, which typically handle much larger volumes, this design specifically addresses the limitations in local settings where resources, infrastructure, and waste management facilities are often scarce [16]. This aligns with the findings of Kumar et al. [10], who emphasized the importance of appropriate, small-scale technologies in developing economies to stimulate local recycling initiatives and job creation. In terms of energy consumption, the shredder requires 4.48 KWh to operate, with an output of 3.72 KWh. This efficiency rate of 83.12% compares favorably with the energy efficiency of larger industrial shredders, which typically range between 60% and 90% depending on design and load capacity [19]. The results also support the argument made by Barnes et al. [2], who noted that optimizing energy consumption in waste processing technologies is essential for minimizing the environmental footprint of recycling operations. The shredder's design takes into account local manufacturing capabilities, enabling communities to build and maintain these machines using locally available materials and expertise. This not only promotes recycling but also fosters economic development, aligning with the principles outlined by Geyer et al. [7], who advocated for localized solutions in addressing plastic waste management challenges. The integration of indigenous knowledge into the design and fabrication process further supports the claim by Thompson et al. [19] that community involvement is critical in developing sustainable waste management practices. When comparing this study's results to previous literature, it is evident that the locally made plastic shredder fills a crucial gap in plastic recycling at the community level. While industrialized nations benefit from large-scale shredding and recycling operations, developing countries, as noted by Jambeck et al. [8], often lack the infrastructure to support such systems. This study contributes a viable alternative by providing communities with the tools needed to manage their own plastic waste, thereby reducing the environmental impact of plastic pollution while also fostering local economic growth.

Figure 11: The Base of the plastic shredding machine

Figure 12: The base and blade of the plastic shredding machine

Figure 13: The plastic shredding machine

5. CONCLUSION

This study highlights the potential of locally fabricated plastic shredders as a practical solution for managing plastic waste, particularly in developing communities. By promoting local manufacturing and encouraging grassroots involvement, these shredders can address the growing issue of plastic pollution while fostering economic development. The integration of indigenous knowledge and accessible technology makes this approach both sustainable and scalable. This initiative not only supports environmental stewardship but also strengthens recycling efforts, contributing to broader goals of sustainable waste management. The findings emphasize the importance of localized solutions in combating global plastic waste challenges.

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