Design and Fabrication of Plastic Shredder & Extruder Machine

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***Abstract* - This paper details the engineering of a dual-stage recycling system consisting of a high-torque rotary shredder and a thermostatic single-screw extruder. The primary challenge in decentralized recycling is the non-uniformity of input waste. This research demonstrates how a synchronized hopper system and PID-controlled heating zones can convert post-consumer High-Density Polyethylene (HDPE) into high-quality recycled filament. The study concludes with a performance evaluation based on throughput (kg/hr) and tensile strength of the extruded product.**

Plastics are inexpensive, lightweight and durable materials, which can readily be moulded into a variety of products that find use in a wide range of applications. However, current levels of their usage and disposal generate several environmental problems. Recycling is one of the most important actions currently available to reduce these problems and represents one of the most dynamic areas in the plastics industry today. The recycling process in this project involves the Design, Analysis and Simulation of Plastic Shredder and Extrusion Machine.

Plastic Shredder and Extrusion Machine has been successfully conceptualized and designed. The material selection and solution principle are worked out using weighted evaluation technique. Specific Materials and Machine elements are selected based on basis design criteria. Detail design is calculated for each component using total design approach.

The control system is prepared for the temperature regulation on the extrusion machines and direction control of the AC motor.

The system is designed to be cost-effective, energy-efficient, and suitable for small- to medium-scale recycling operations. It utilizes readily available materials and components, making it accessible for local industries and communities. By converting plastic waste into reusable forms, the machine helps reduce environmental pollution and supports sustainable waste management practices. The proposed solution contributes to the circular economy by promoting the reuse of plastic materials and minimizing dependence on virgin resources.

I. INTRODUCTION

Plastic pollution remains one of the most pressing environmental challenges of the 21st century. While industrial recycling exists, the carbon footprint of transporting low-density plastic waste to centralized plants is high. This paper proposes a localized "Closed-Loop" system.

Production of plastics has been increasing globally due to its burgeoning applications, including food and beverage packaging, textile, automotive, and manufacturing, along with medical devices such as surgical equipment, drips, and blister packs for pills.

Hence; there is the need to promote the recycling of plastic materials. Plastic recycling is bound to realize a lot of savings in production costs, conserve limited resources, and alleviate environmental pollution. Several intricate processes are involved in plastic recycling prior to the further processing step into a new product, such as sorting, crushing, shredding, and washing. Commonly, the plastic recycling process is carried out through centralised networks, which leads to a low recycling rate due to the challenge in the collection, separation, and sorting processes together with the transportation of the plastic waste that requires significant capital and extensive operating investment. Therefore, a shredder machine was proposed at the recycling centre as the primary machine for the recycling process.

The shredder machine was utilised to shred the waste plastic into tiny sizes for a further recycling process. A plastic shredding machine is a mechanical device used to cut plastic materials into smaller pieces. The machine is designed to reduce the size of plastic waste and make it easier to transport and process for recycling or disposal. The plastic-shredding machine works by using a series of blades or knives to shred the plastic into small pieces, which can be further processed into pellets or melted down to create new plastic product.

Plastics extrusion is a high-volume manufacturing process in which raw plastic is melted and formed into a continuous profile. Extrusion produces items such as pipe/tubing, weather stripping, fencing, deck railings, window frames, plastic films and sheeting, thermoplastic 1 coatings, and wire insulation. Plastic extruder is a machine to recycle the plastic garbage to be something that is more valuable. The process of this machine is to extrude the plastic by heating process. The purpose of this machine is to reduce plastic garbage in the world and recycle plastic waste. The most widely used extrusion machines are the single and the twin screw extruders. These machines have the following main components: electric motors, drivetrain, bearing, feeding system, screw, heating and cooling system, barrel, die and temperature and pressure sensors.

This project focuses on designing and implementing a plastic shredder and extruder machine that is efficient, economical, and easy to operate. The aim is to provide an accessible solution for recycling plastic waste and encouraging environmentally responsible practices.

II. OBJECTIVES

- To design a shredder capable of processing 5-10 kg of plastics per hour.
- To engineer an extruder that maintains a consistent melt flow index (MFI).
- To analyse the mechanical properties of the recycled output.
- Select a material with desired properties for the design of Plastic Shredder and Extrusion machine.
- To design a Plastic Shredder Machine that is safe and reliable.
- To design a plastic extrusion machine.
- To reduce the size and design the machine in compact form.
- To develop a model for the plastic shredding machine.

III. LITERATURE REVIEW

- The "Precious Plastic" Movement: Analysis of open-source recycling hardware.
- Degradation of Polymers: How repeated heating cycles affect the molecular weight of polymers like PET and PP.
- Mechanical Size Reduction: The physics of shear force vs. impact force in plastic shredding.

IV. DESIGN METHODOLOGY

- The Shredder Unit:

  The shredder uses a "hexagonal shaft" design to prevent blade slippage.
  - Blades: Constructed from AISI D2 Tool Steel, hardened to 58 HRC to resist wear from contaminants.
  - Motor Torque Calculation:

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

Where, T = Torque
P = Power in Watts
n = RPM

A high-reduction gearbox (30:1) is utilized to ensure the blades can shear through thick-walled HDPE containers.

- The Extruder Unit:

  The extruder is a single-screw type with a 20:1 Length-to-Diameter (L/D) ratio.
  - Heating Zones: Three distinct 500W band heaters are used to create a temperature gradient.
  - Screw Geometry: Includes a constant-pitch screw with varying flight depths to increase compression in the transition zone.

HARDWARE SPECIFICATIONS

Component	Specification	Material/Type
• Shredder Motor	2.2 kW (3 HP)	Three-phase AC
• Extruder Motor	0.75 kW (1 HP)	DC Gear Motor (High Torque)
• Heating Elements	220V / 500W	Mica Band Heaters

• Control System	PID Controller	Rex-C100
• Sensors	K-Type Thermocouples	Stainless Steel Probe

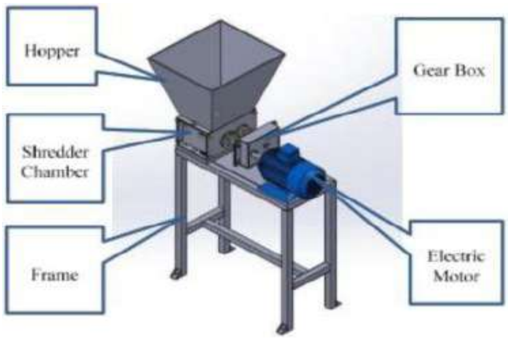
I. Shredder Motor:

A shredder motor is a high-torque electric motor—typically a universal or induction type—designed to drive cutting blades through gears, converting electrical energy into mechanical force to shear paper, plastics or heavy materials. These motors prioritize high torque over speed to prevent jamming, often using reduction gears to increase cutting power.

II. Extruder Motor:

An extruder motor is a precision-controlled actuator—typically a stepper motor—that drives the feeding mechanism in extrusion systems, pushing materials like thermoplastic filament (in 3D printing) or plastic pellets (in industrial manufacturing) into a heated chamber at a controlled rate. It converts electrical energy into mechanical torque to ensure consistent material flow, proper mixing, and precise extrusion.

III. Control System:



- Hopper:
  A shredding machine hopper is the large, funnel-shaped entry point or "mouth" where materials are loaded, acting as the initial feeding mechanism. It guides materials down to the cutting chamber, ensuring a steady, efficient flow and reducing the risk of clogging. Hoppers also act as a safety barrier and can include systems to push material into the blades.
- Shredder Chamber:
  A shredder chamber is the central, enclosed housing of a shredding machine where material reduction takes place. It contains high-torque rotating shafts, specialized cutting blades, and often stationary knives that shear, tear, or crush materials like metal, plastic, or paper. Key components include the hopper for feeding, rotor shafts, and a screen for sizing.
- Gear Box:
  A gearbox in a shredding machine is a critical power transmission component that converts high-speed, low-torque power from the electric motor into low-speed, high-torque output necessary for shredding materials. It acts as the "heart" of the machine, enabling it to break down tough items like metals, plastics, and rubber by multiplying the twisting force (torque).
- Electric Motor:
  An electric motor in a shredding machine provides the rotational power to drive cutters, breaking down materials like paper, plastic, or metal into smaller pieces. These motors, often AC induction motors (industrial) or DC motors (small office), power a gear system to create high torque for shredding, making them more energy-efficient and simpler to maintain than hydraulic alternatives.

V. WORKING PRINCIPLE

The principle of operation for a shredder and an extruder machine are different, but they are often used together in recycling and manufacturing processes (especially plastics).

1. Shredder Machine – Working Principle

A shredder is used to reduce the size of materials (plastic, metal, paper, rubber, etc.).

⚙️ Basic Principle:

It works on the principle of cutting, shearing, and tearing forces.

- Material is fed into the machine.
- Rotating blades or cutters grab the material.
- The material is:
  - Cut by sharp edges
  - Sheared between rotating and fixed blades
  - Torn into smaller pieces
- Output is smaller, uniform-sized particles

Key Mechanism:

- Low speed, high torque rotation
- Multiple shafts (single, double, or quad shaft designs)

Example Uses:

- Plastic recycling
- Metal scrap processing
- Paper shredding

2. Extruder Machine – Working Principle

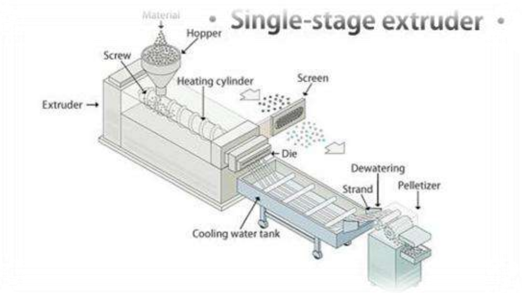
An extruder is used to melt and shape material (commonly plastics).

⚙️ Basic Principle:

It works on the principle of heat + pressure + shear flow to convert solid material into a continuous shaped product.

1. Feeding: Raw material (pellets or flakes) enters through a hopper.
2. Melting: A rotating screw pushes material forward inside a heated barrel.
   Heat comes from:
   a) External heaters
   b) Friction (shear heat)
3. Mixing & Compression:
   Material is compressed and uniformly melted.
4. Shaping (Die):
   - Melt is forced through a die.
   - The die gives the final shape (pipe, sheet, filament, etc.).
5. Cooling: The shaped material is cooled and solidified.

BLOCK DIAGRAM



VI. EVALUATION OF THE PRODUCED FILAMENT

In this work, PET is picked as the main object of interest. PET is understood to melt at a temperature of around 170 to 180℃. Therefore, the temperature is varied to investigate the quality of the produced PET filaments. The temperature applied was varied from 180℃ to 260℃ with an increment of 20℃. For each temperature variation, the produced filament was visually inspected, and the results are tabulated in Table 3.

No	Temperature in degree Celcius	Filament Quality
1	260	Too Liquid
2	240	Too Liquid, Black Color
3	220	Black Color
4	200	Good Transparency, optimum result
5	180	Extruder clogged, plastic melts and coagulates inside the barrel

VII. APPLICATIONS OF SHREDDER AND EXTRUDER MACHINE

Shredder and extruder machines are widely used across various industries due to their ability to process and recycle materials efficiently. Their key applications include:

1. Plastic Recycling Industry:
   Used to shred plastic waste (bottles, containers, packaging) and convert it into reusable raw material through extrusion, helping reduce environmental pollution.
2. Waste Management Systems
   Municipal and industrial waste facilities use these machines to reduce waste volume and process recyclable materials effectively.
3. Manufacturing Industry
   Extruders are used to produce plastic products such as pipes, sheets, films, and profiles, while shredders help recycle production scrap.
4. E-Waste Recycling
   Shredders break down electronic waste into smaller components, which can then be separated and processed further.
5. Agricultural Applications

Used to recycle agricultural plastic waste like mulch films, drip pipes, and containers into reusable products.

6. 3D Printing Industry
   Extruded recycled plastic can be used to create filament for 3D printers, supporting low-cost and sustainable prototyping.
7. Packaging Industry
   Helps in recycling packaging materials and producing new packaging products, reducing raw material consumption.
8. Construction Industry
   Recycled plastic from extrusion can be used in making tiles, panels, pipes, and other construction materials.
9. Small-Scale and Cottage Industries
   Enables local entrepreneurs to recycle plastic waste and produce useful items, creating employment opportunities.

VIII. FUTURE SCOPE

The future scope of shredding and extruding machines is highly promising, especially with the growing global focus on recycling, sustainability, and efficient material processing.

1. Advanced Automation and Smart Control:
   Future machines can be integrated with sensors, IoT, and AI-based monitoring systems to enable automatic operation, fault detection, and real-time performance optimization, reducing human intervention and improving productivity.
2. Enhanced Recycling Capabilities:
   Development of machines capable of handling mixed and contaminated plastics more efficiently will expand their use in large-scale recycling plants and municipal waste management systems.
3. Energy Efficiency Improvements:
   Innovations in motor design, heating systems, and insulation can reduce power consumption, making the machines more eco-friendly and cost-effective.
4. Compact & Portable Designs:
   There is strong potential for small, portable units suitable for households, small industries, and rural areas, promoting decentralized recycling and waste management.
5. Multi-Material-Processing:
   Future systems may be designed to process a wider range of materials such as e-waste, biomass, rubber, and composites, increasing versatility.
6. Integration with 3D-Printing:
   Extruded recycled plastic can be directly used as filament for 3D printing, enabling circular manufacturing and supporting innovation in prototyping and small-scale production.
7. Improved Safety Features:
   Advanced safety mechanisms like automatic shut-off, overload protection, and enclosed systems will enhance operator safety.
8. Cost Reduction and Accessibility:
   With technological advancements and mass production, these machines are expected to become more affordable, encouraging adoption in developing regions.

IX. CONCLUSION

The fabrication of a shredding and extruding machine demonstrates an effective approach to converting waste materials, especially plastics, into reusable products. By integrating shredding and extrusion processes into a single system, the machine enhances efficiency by reducing manual handling, processing time, and material loss.

The shredding unit successfully reduces large plastic waste into smaller, uniform pieces, making it suitable for further processing. The extruding unit then melts and reshapes the shredded material into continuous forms, ensuring consistent quality and usability of the output. This combined system supports recycling efforts, promotes sustainable manufacturing, and helps minimize environmental pollution.

Overall, the project highlights the importance of innovative design, proper material selection, and precise fabrication techniques. It proves that such machines can be cost-effective, efficient, and valuable for small-scale industries, recycling units, and educational purposes, contributing to a circular economy and better waste management practices.

Plastic shredder and extruder machines play a crucial role in mechanical plastic recycling by converting waste plastics into reusable raw materials such as flakes, pellets, and finished products. Together, they help reduce plastic pollution, conserve natural resources, and support a circular economy. With increasing global focus on sustainability, strict environmental regulations, and rising demand for recycled plastics in packaging, construction, automotive, and consumer goods, the importance of these machines is steadily growing. Although challenges like contamination and quality degradation exist, technological advancements in sorting, washing, and extrusion are improving recyclate quality. Overall, plastic shredders and extruders have strong future scope worldwide and represent a sustainable, economically viable solution for plastic waste management.

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