Design of a Shredder-Type Plastic Cutting Machine with a Capacity of 100 kg/h

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**Abstract.** This study aims to design an efficient plastic shredding machine to support recycling processes. Key technical considerations included cutting force, torque analysis, and the selection of a V-belt transmission system, supported by literature reviews and empirical observations. Mathematical engineering approaches were employed to determine machine capacity, blade configuration, and motor power requirements. The finalized design incorporates eight stationary blades and nine dynamic blades, optimized for effective plastic fragmentation. Results demonstrate that the machine achieves a shredding capacity of 160 kg/h, surpassing the initial target of 100 kg/h. The design process adhered to French’s systematic methodology, encompassing problem analysis, conceptual design, embodiment, and detailing. This research contributes to sustainable waste management by enhancing the efficiency of preliminary plastic recycling stages.

# INTRODUCTION

Plastic waste has become one of the biggest threats to ecosystems today, taking approximately 50 to 100 years to decompose naturally [1]. According to the World Economic Forum in 2016, around 160 million tons of plastic waste are currently present in oceans worldwide, and this amount continues to grow each year [2]. If this trend persists, by 2050 the volume of plastic waste in the oceans will exceed that of fish [3].

Recycling plastic waste is an efficient method of managing this environmental problem. The first step in the recycling process involves shredding or cutting plastic into smaller pieces [4]. Smaller plastic fragments are easier to process in subsequent stages such as washing, drying, and melting to produce new products. At this stage, the plastic shredder machine plays a vital role [5][6]. Before shredding plastic into smaller pieces, plastic waste must first be sorted by type and quality.

This initial size reduction simplifies the washing process by removing dirt and debris, followed by drying to reduce moisture content before melting the plastic into granules or pellets. These recycled plastic pellets can be reused as raw materials for a variety of products, including consumer goods, automotive components, and packaging materials [7]. Moreover, plastic waste can be transformed into fuel or high-value chemicals using mechanical methods as well as pyrolysis and catalytic pyrolysis technologies, offering more creative and sustainable waste management solutions [8].

Because smaller plastics are easier to process in later steps, the shredder machine plays a critical role in the overall recycling process [9]. The purpose of a plastic shredder is to break down various types of plastic, including PET bottles, plastic bags, and other plastic containers [10]. This machine is capable of producing uniform plastic flakes using a cutting mechanism involving rotary and stationary blades. The productivity of the recycling process is highly dependent on the efficiency of the shredder machine. Therefore, the capacity and design of the shredder must be optimized to meet current waste-processing demands [10].

A plastic shredder machine consists of several components that are assembled into a working system [11]. Among these components are the blades—specifically two types used in shredders and crushers [12]. In this design, shredder blades are selected due to their suitability for small-sized output and desired capacity [13]. The shredding system may use a transmission mechanism such as a V-belt or gear drive [14]. Some machine configurations use two dynamic blades and one or more static blades, or a combination thereof [15][16]. Supporting components such as shafts, pulleys, and pillow blocks are also integrated to effectively transmit power to the blades and ensure optimal cutting performance [17]. To address safety and aesthetics, the machine is also equipped with a protective cover or chamber where the shredding process takes place [18], along with designated inlet and outlet sections for plastic material flow [19].

This design study addresses the problem of determining an appropriate transmission system for a plastic shredder machine. Specifically, it seeks to answer: what type of transmission system is most suitable for the machine, and how much power must be transmitted to shred plastic at a capacity of 100 kg/hour? Therefore, the objectives of this study are to determine the type of transmission system used in the machine and to calculate the motor power required for transmission.

The scope of this research focuses on designing a shredding mechanism capable of processing 100 kg of plastic per hour. The design considerations include determining the cutting speed, cutting force on the blades, blade torque, and motor power requirements, along with the transmission system design.

# Methodology

The design method applied in this study follows a structured engineering design process consisting of the following stages:

1. Problem Analysis

This initial stage involves identifying the design objectives by analyzing and defining the core problems related to the development of the plastic shredding machine.

1. Conceptual Design

At this stage, general solution concepts are generated in schematic form, allowing flexibility for further refinement and evaluation.

1. Embodiment Design

In this phase, the proposed concepts are developed in more detail. Several concept variants are considered, each with specific technical approaches and configurations.

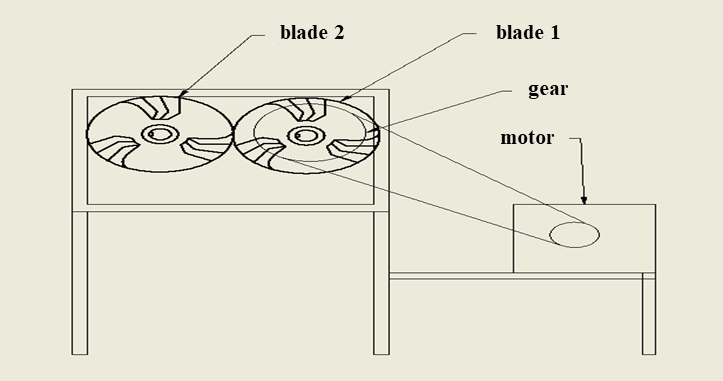
1. Detail Design

The final phase focuses on creating detailed working drawings and specifications using computer-aided design (CAD) tools to ensure accuracy and minimize design errors.

Two design concepts were proposed and compared in this study:

1. Design Concept 1

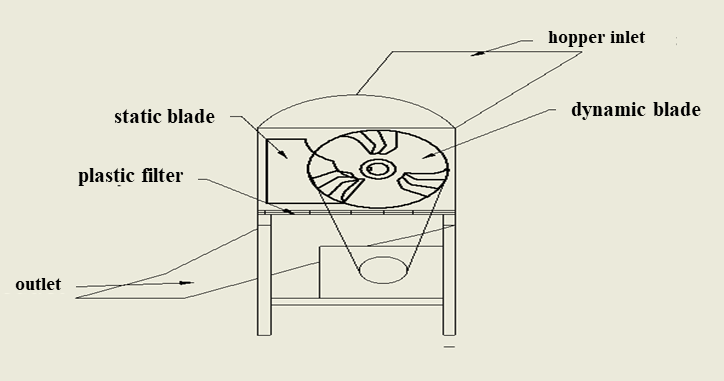
Utilizes an internal combustion engine connected to a gear-based transmission system, as shown in Fig. 1. The cutting mechanism consists of two counter-rotating blades that shred plastic material into smaller fragments.

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**Figure 1.** Design Concept 1

1. Design Concept 2

Employs an electric motor connected to a pulley system for transmission, as shown in Fig. 2. The cutting system uses two blades, with one rotating and the other stationary, to perform the shredding process.

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**Figure 2.** Design Concept 2

A weighted evaluation matrix (Table 1) assessed both concepts against criteria like durability, component count, operability, and cost. Concept 2 scored higher (94/100) due to its lower maintenance needs, cost-effectiveness, and portability.

|  |  |  |  |
| --- | --- | --- | --- |
| **TABLE 1.** Design concept evaluation. | | | |
| **Criteria** | **Max Weight** | **Concept 1** | **Concept 2** |
| Strength and Durability | 10 | 10 | 10 |
| Number of Components | 10 | 8 | 9 |
| Ease of Operation and Maintenance | 10 | 8 | 10 |
| Size | 10 | 8 | 10 |
| Cost | 10 | 6 | 10 |
| Portability | 10 | 6 | 10 |
| Speed Variation | 10 | 9 | 9 |
| Marketability | 10 | 10 | 10 |
| Aesthetics | 10 | 10 | 10 |
| Accuracy and Precision | 10 | 9 | 10 |
| Total | 100 | 84 | 94 |

Based on the evaluation results, Design Concept 2 was selected for further development. The selected design concept was refined using Autodesk Inventor 2025 for 3D modeling and simulation. Specifications of the workstation included an Intel i7-9750H processor and 8 GB RAM to handle computational demands. Key calculations:

* Blade configuration: 8 stationary + 9 dynamic blades for balanced load distribution.
* Transmission: V-belt selected for its flexibility and shock absorption [15].
* Motor power: Calculated based on torque and cutting force requirements.

The final design prioritized safety with an enclosed shredding chamber and dedicated inlet/outlet systems [19,20].

# Results and Discussion

## Component Calculations

### Machine Capacity

The machine capacity is calculated using the following equation:

 (1)

Where:

Q = machine capacity (kg/h)

M = assumed mass of plastic per revolution (0.5 g)

n = target rotational speed (RPM)

Calculation:



The planned machine capacity of 160 kg/h exceeds the target of 100 kg/h to ensure better operational efficiency.

### Shaft Torque

To calculate the shaft torque, the following formula is used:

 (2)

Where:

T = Torque (Nm)

P = Motor power (kW)

n = Shaft speed (rpm)

Given:





### Cutting Force

Cutting force is calculated as:

 (3)

Where:

F = Cutting force (N)

T = Torque (Nm)

R = Blade radius (m)

Given:





### Shaft Design

The shaft diameter is calculated using the shear stress formula:

 (4)

Where:

τ = Allowable shear stress

Assuming the material is S35C with an allowable shear stress of 86.6 MPa



The minimum required shaft diameter is 16.7 mm; a practical shaft size of 20–30 mm is recommended for real-world applications.

### Key Design

Key length is calculated using the following formula:

 (5)

Where:

T = Torque (Nmm)

τ = Shear stress (MPa), assumed 60 MPa for mild steel (Shigley)

b = Key width (mm)

h = Key height (mm)

Given:





A standard key length of 50 mm is selected based on the result.

### Pulley Ratio

The pulley ratio is calculated using:

 (6)

With D1 =100 mm, motor speed 1400 rpm, and shaft speed 600 rpm, we get:



A pulley of 250 mm is chosen based on market availability.

### V-Belt Length

The V-belt length is estimated using:

 (7)

Assuming center distance C = 50 cm, large pulley D = 25 cm, and small pulley d = 10 cm:



### Mechanical Power

Mechanical power required is calculated by:

 (8)

where:

F = 795.8 N

v = 6.28 m/s (blade linear speed),

𝜂 = 0.85 (transmission efficiency)



### Outlet Area

Outlet area is calculated using:

 (9)

Given:

Mass flow rate Q = 0.0277 kg/s

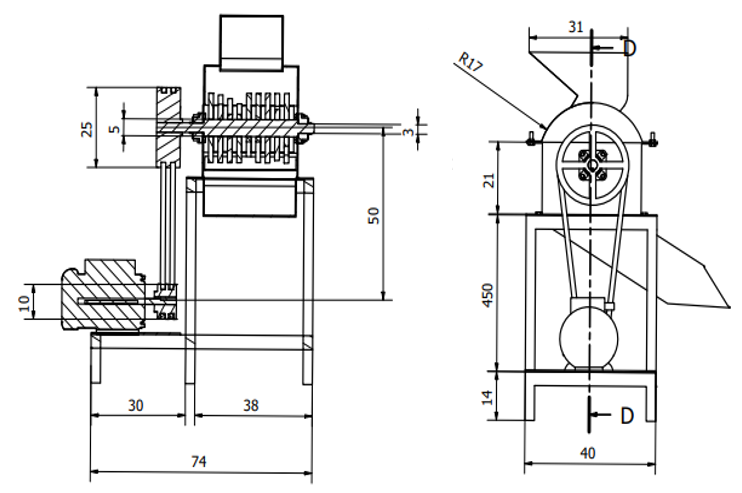
Bulk density of PET = 500 kg/m3

Flow velocity v = 0.3 m/s



An outlet area of 28 cm² is used in the design to ensure sufficient material flow.

The final design of the shredder-type plastic cutting machine is illustrated in Fig. 3.



**Figure 3.** Final design of the shredder-type plastic cutting machine.

# CONCLUSION

The primary objective of this study—to develop a plastic shredding machine with a target capacity of 100 kg/h—has been successfully achieved through design and technical analysis. The machine, equipped with nine dynamic blades and eight static blades, demonstrated an actual shredding capacity of up to 160 kg/h, exceeding the design requirement and offering an operational efficiency margin. Technically, the shredding process requires a cutting force of 795.8 N, and the calculated motor power needed is approximately 5.88 kW (7.88 HP), based on a transmitted torque of 79.58 Nm. These specifications consider real-world conditions, including potential clogging and feed inconsistencies. Overall, the design effectively addresses the need for a reliable and efficient shredding solution for small to medium-scale plastic processing, as stated in the introduction.

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