# Ergonomic Approach to Building Design Paper Shredding Machine

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**Abstract.** Paper waste poses a significant environmental challenge due to its slow decomposition rate. While paper waste can have adverse environmental effects, recycling offers a viable solution by repurposing paper into new products. To address the issue of paper waste effectively, it is essential to focus on both its collection and destruction. One promising approach is the development of a simple, efficient paper shredder designed to enhance operational efficiency. This research involved designing and manufacturing a paper-cutting machine using ergonomic principles, which is capable of achieving a higher capacity compared to existing market alternatives. The resulting shredded paper can be utilized as a base material for glassware production and can also be recycled into paper pulp, providing an alternative raw material for new paper products.

**Keywords:** Chopper, Machine Capacity, Paper-Cutting Machine

## 1 Introduction

As of recent reports, paper waste in Indonesia has reached 12.02% (Saputra & Fauzi, 2022). Despite the environmental challenges associated with paper waste, including its slow decomposition, recycling provides a viable solution by enabling the repurposing of paper into various products. To mitigate the environmental impact of paper waste, it is crucial to implement effective collection and disposal strategies. One promising approach is the development of a simple, efficient paper shredder designed to enhance operational efficiency. Once processed into flakes or chips, the shredded paper can be used as a material for producing briquettes, which have demonstrated potential in the market (Saputra & Fauzi, 2022). Utilizing paper waste through recycling or reuse is essential not only to reduce waste but also to conserve natural resources used in paper production (Wahyono, 2001). Recycled paper can be transformed into a range of new products, including notebooks, clothing labels, business cards, calligraphy materials, and arts and crafts supplies (Azzahra, 2023).

In response to this issue, we have designed and manufactured a paper-cutting machine based on ergonomic principles. Previous studies have explored the application of ergonomics in various contexts. For instance, Kristina et al. (2020) examined how the ergonomics concept of participation could enhance circular economic systems and promote independent waste management, specifically for recycling Tetra Pak


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packaging. Addressing ergonomic risks involves recognizing the central role of human factors in work design (Rothmore et al., 2017). Inefficient tools can expose workers to physical ergonomic hazards, leading to increased fatigue, discomfort, and injury (M Hafizul, 2020).

Ergonomics-based design focuses on optimizing the interactions between humans and system components to improve overall well-being and performance (M Noor, 2020). According to Manuaba (2006), effective ergonomic design considers factors such as nutritional needs, muscle power and biomechanics, body posture, social conditions, work environment, work and rest times, human-machine interaction, and information processing. Implementing ergonomic principles can enhance the comfort and efficiency of work tools, contributing to a healthier work environment. Previous research has shown that participatory ergonomics approaches, which involve workers in the design process, can effectively reduce work-related accidents and musculoskeletal disorders (Ugbebor & Adaramola, 2012).

The research problem explored in this study focuses on designing a paper shredding machine based on ergonomic principles. The objective is to develop a paper shredding machine model that integrates ergonomic considerations to improve both functionality and user comfort.

## 2 Methodology

This research focuses on the design and development of a paper-shredding machine. The product design methodology employed is based on the framework developed by Sugiyono, which outlines a systematic approach to research and development. The methodology consists of ten key steps: (1) Potential Analysis: Identifying and analyzing the potential needs and requirements for the paper shredding machine; (2) Data Collection: Gathering relevant data and information to inform the design process; (3) Product Design: Developing initial design concepts and specifications based on the collected data; (4) Design Validation: Evaluating the proposed design through validation processes to ensure it meets the required standards and specifications; (5) Design Revision: Making necessary adjustments and improvements to the design based on validation feedback; (6) Product Trial: Conducting trials of the product to assess its performance and functionality in real-world conditions; (7) Product Revision: Revising the product design based on trial results and user feedback; (8) Usage Trial: Implementing the revised product in practical settings to evaluate its usability and effectiveness; (9) Final Revision: Making final adjustments to the design based on usage trial outcomes; (10) Production: Preparing for and initiating the production of the finalized paper shredding machine design.

This structured approach ensures a comprehensive and iterative process, allowing for continuous improvement and refinement of the product design to meet both user needs and functional requirements.

# 3 Result and Discussion

## 3.1 Result

The design of the paper shredding machine is based on the operational principle of a paper cutting machine, utilizing a dual-roller cutting mechanism. The cutting process is achieved through the counter-rotating motion of two rollers, each equipped with cutting knives. Paper is fed between these rollers, which feature a circular groove pattern that facilitates the shredding process.

The machine's design incorporates an electric motor as the primary source of power. This motor drives the system through a belt mechanism connected to a pulley. The rotational motion from the motor is transferred via the belt to the machine shaft, which supports the knife holder where the rotating knives are mounted. This configuration ensures efficient operation and precise cutting of the paper.

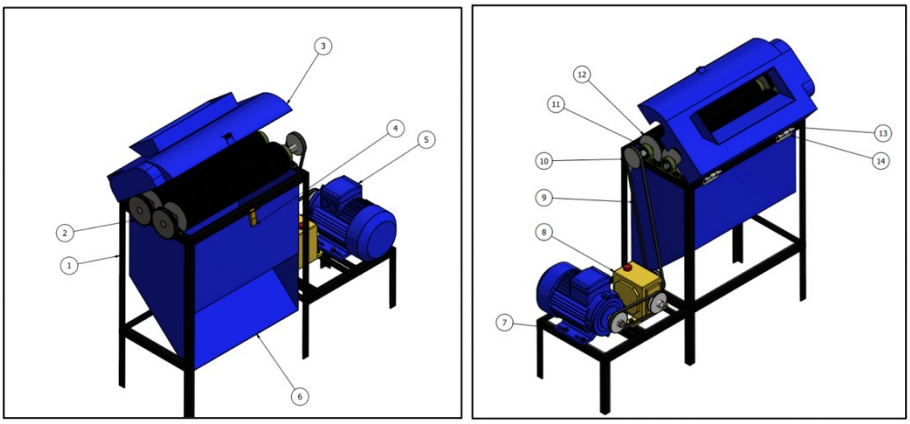


**Figure 1.** Paper shredding tool design model

Information:

| | | | |
|---|---|---|---|
| 1. | Frame | 8. | *Gearboxes* |
| 2. | *Gears.* | 9. | *V- Belt* |
| 3. | Close top | 10. | *Pulleys* |
| 4. | Top lid lock | 11. | Bearing |
| 5. | Motorcycle. | 12. | Shredding Knife |
| 6. | *Output* Hole | 13. | Hinge bolt |
| 7. | Bolt | 14. | Hinge |

## 3.2 Discussion

**Design.** The design of the paper waste shredding machine aims to address the limitations of existing models. Key considerations for the design include:

1. Power Source: The machine utilizes an electric motor as the primary power source, eliminating the need for manual operation.
2. Ergonomic Specifications: The machine's dimensions are designed to ensure operator comfort and to facilitate easy integration into various workspace environments.
3. Ease of Operation and Maintenance: The machine is designed for straightforward operation and maintenance, with accessible components for routine care.

**Machine Operation Procedures.** The operational procedures for the paper waste shredding machine are outlined as follows:

1. Preparation: Place the paper intended for shredding at the machine's input area. Activate the machine by connecting the electric motor plug to the power socket and switching the machine to the ON position.
2. Feeding: Insert the paper into the inlet chute of the machine. If the paper is too thick, feed it in smaller portions to ensure proper shredding.
3. Shredding Process: The paper will be processed by the cutting knives, which will shred it into smaller pieces.

**Testing.** The results of the product specification design in designing the paper waste chopping machine are:

**Table 1.** Product specifications

| No. | Component parts | Size |
|---|---|---|
| 1 | Capacity | 1 kilo per 6 minutes |
| 2 | Movers | Phase Electric Motor |
| 3 | Motor Rotation | 2800 rpm |
| 4 | Pully Knife | 10 Inches |
| 5 | Connecting Pulley | 3 Inch |
| 6 | Shafts | 19mm |
| 7 | V- Belt | Type A 51 |
| 8 | Pillows Block | Type 209 |
| 9 | Iron elbow | 30mm |

The evaluation of the paper waste shredding machine design will be conducted through several stages of testing, including:

1. Physical Inspection: This involves verifying that the machine’s physical dimensions and materials conform to the design specifications. The inspection will assess compliance with standard material requirements and the use of supporting equipment according to established design standards.
2. Operational Testing: The machine will be tested to ensure it operates as intended. This includes evaluating the functionality of the cutting mechanism, which consists

of two counter-rotating shafts equipped with circular knives. Each knife is designed with claws on both sides to grip and shred the paper waste effectively.

3. Safety Assessment: Safety features and protocols will be examined to ensure that the machine adheres to safety standards and operates without posing risks to users.
4. Cutting Performance Evaluation: The machine's efficiency in shredding paper waste will be assessed. This involves measuring the quality of the shredded output and determining the machine's effectiveness in processing different types and sizes of paper.

The paper waste shredding machine, once tested and verified, will be ready for operational use, meeting the specified design and performance criteria.

**Figure 2.** Machine enumerator paper

**Enumeration Result Data.** The results of the paper waste chopper test as a test sample showed the following results:

**Table 2.** Data from chopping results with a spiral knife

| No. | Test | Time |
|---|---|---|
| 1 | Enumeration of the First 1 Kg | 6 minutes 39 seconds |
| 2 | Enumeration of the First 2 Kg | 11 minutes 21 seconds |
| 3 | Enumeration of the First 3 Kg | 18 minutes 40 seconds |
| 4 | Enumeration of the First 4 Kg | 25 minutes 34 seconds |
| 5 | Enumeration of the First 5 Kg | 31 minutes 21 seconds |
| 6 | Second 1 Kg Enumeration | 6 minutes 12 seconds |
| 7 | Second 2 Kg Enumeration | 12 minutes 21 seconds |
| 8 | Second 3 Kg Enumeration | 18 minutes 55 seconds |

| No. | Test | Time |
|---|---|---|
| 9 | Second 4 Kg Enumeration | 25 minutes 12 seconds |
| 10 | Second 5 Kg Enumeration | 31 minutes 10 seconds |

The performance test of the paper shredding machine demonstrated satisfactory results. The machine successfully shredded 1 kg of paper with a thickness of 0.3 mm in 6 minutes and 25 seconds. This performance is consistent with findings from related research. For instance, Burlian (2018) investigated the design of a plastic waste shredder with a capacity of approximately 33 kg/hour. The study concluded that the design parameters employed provided effective shredding capabilities, with the first blade arrangement exhibiting the highest capacity compared to the second and third arrangements, which were 33.26 kg/hour and had varying cut sizes (4-8.5 cm), respectively (Burlian et al., 2018).

Additionally, the results align with those of Subhidin et al. (2020), who explored the design of a paper shredding machine with a capacity of 75 kg/hour. This study supports the findings of the current research, indicating that the developed paper shredding machine meets expected performance standards and is competitive with existing models in terms of efficiency and capacity (Subhidin et al., 2020).

## 4 Conclusion

Based on the analysis and discussion, the paper shredding machine operates effectively, achieving a shredding speed 3 to 4 times faster than manual methods. The machine is powered by a 0.75 kW electric motor, equipped with a 34 mm diameter drive shaft, a 3-inch drive pulley, and a 10-inch driven pulley. It utilizes a No. A 51 V-belt with a length of 1194 mm. These specifications ensure efficient performance in shredding paper waste, successfully meeting the design objectives and operational requirements.

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