Ergonomical Evaluation of Shredder cum Briquetting Machine

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Abstract

The increasing demand for sustainable waste management and renewable energy has led to the development of shredder cum briquetting machines for converting agricultural residues into compact biofuel briquettes. However, the ergonomic suitability of such machines remains a critical factor influencing operator efficiency, safety, and long-term usability, especially for small-scale and rural applications. This study presents the ergonomical evaluation of a shredder cum briquetting machine designed for small and marginal users. The evaluation was conducted by analyzing physiological, biomechanical, and subjective parameters such as heart rate, energy expenditure, postural stress, and perceived exertion. The results indicate that while the machine significantly improves productivity and reduces manual drudgery, certain ergonomic issues related to posture, vibration, and repetitive motion persist. Recommendations for design improvements are proposed to enhance operator comfort, reduce fatigue, and ensure sustainable adoption.

1. Introduction

Agricultural residues such as straw, husk, stalks, and leaves are often underutilized or burned, leading to environmental pollution and loss of valuable biomass. Briquetting technology provides an effective solution by converting loose biomass into dense, energy-rich briquettes suitable for domestic and industrial use.

A shredder cum briquetting machine integrates two processes: shredding of raw biomass into smaller particles and compressing them into briquettes. While such machines improve efficiency and reduce waste, their adoption among small and marginal farmers depends not only on technical performance but also on ergonomic suitability.

Ergonomics, defined as the science of designing systems to fit human capabilities and limitations, plays a vital role in ensuring operator safety, comfort, and productivity. Poor ergonomic design can lead to musculoskeletal disorders, fatigue, reduced efficiency, and even accidents.

Despite advancements in machine design, limited attention has been paid to ergonomic evaluation, particularly in rural and semi-

mechanized systems. Therefore, this study aims to evaluate the ergonomical aspects of a shredder cum briquetting machine and identify potential improvements.

2. Literature Review

Ergonomic evaluation of agricultural machinery has gained importance in recent years due to increased mechanization in rural areas. Studies have shown that improper design of manually or semi-mechanically operated machines leads to high physiological stress and discomfort among operators. Research on biomass briquetting machines indicates that while these machines improve fuel efficiency and waste utilization, they often require significant physical effort during feeding, operation, and maintenance. High vibration levels, awkward postures, and repetitive motions are common issues. Studies on pedal-operated and manually operated agricultural machines highlight that ergonomic parameters such as working height, handle design, and force requirement significantly influence operator performance. For instance, improper working height can lead to excessive bending, resulting in lower back pain. Physiological parameters such as heart rate and oxygen consumption are widely used to assess workload. A working heart rate exceeding 110 beats per minute (bpm) is generally considered indicative of moderate to heavy workload. Subjective evaluation methods such as Rating of Perceived Exertion (RPE) and discomfort scales provide insights into operator perception, complementing objective measurements. However, there is a lack of comprehensive ergonomic studies specifically focusing on integrated shredder cum briquetting machines, highlighting the need for systematic evaluation.

3. Objectives

The specific objectives of this study are:

1. To evaluate the ergonomic performance of a shredder cum briquetting machine.
2. To assess physiological workload using heart rate and energy expenditure.
3. To analyze postural stress and biomechanical factors during operation.
4. To evaluate operator discomfort using subjective assessment tools.
5. To suggest design modifications for improved ergonomics.

4. Materials and Methods

4.1 Description of the Machine

The shredder cum briquetting machine used in this study consists of the following components:

Shredding Unit: Reduces biomass into small particles

Briquetting Unit: Compresses shredded material into briquettes.

Feeding Mechanism: Manual or semi-automatic feeding system.

Power Source: Electric motor or manual drive.

Support Structure: Mild steel frame for stability

4.2 Study Area and Subjects

The study was conducted under controlled field conditions using healthy adult operators familiar with agricultural machinery. Anthropometric data such as height, weight, and arm reach were recorded.

4.3 Ergonomic Evaluation Parameters

4.3.1 Physiological Parameters

Heart rate (beats per minute)

Energy expenditure (kJ/min)

Heart rate was measured using a digital heart rate monitor during operation.

4.3.2 Biomechanical Analysis

- Posture assessment using observational techniques
- Joint angles (neck, back, arms)
- Repetitive motion frequency

4.3.3 Subjective Assessment

Rating of Perceived Exertion (RPE)

Body discomfort scale

4.4 Experimental Procedure

Operators were asked to perform the following tasks:

- Feeding biomass into the shredder
- Monitoring shredding process
- Collecting shredded material
- Operating briquetting unit

Each activity was performed for a fixed duration, and data were recorded continuously.

4.5 Data Analysis

Data were analyzed using statistical methods to determine mean values, standard deviation, and workload classification.

5. Results and Discussion

5.1 Physiological Workload

The average working heart rate during operation ranged from 105 to 118 bpm, indicating moderate to heavy workload. Peak heart rate was observed during continuous feeding of biomass. Energy expenditure was calculated to be 6.5–8.2 kJ/min, which falls within acceptable limits for intermittent agricultural tasks but may lead to fatigue over prolonged periods.

5.2 Postural Analysis

Observations revealed the following ergonomic issues:

- Frequent bending during feeding
- Twisting of torso while handling material
- Static posture during briquetting operation

The working height of the machine was found to be lower than the optimal ergonomic height (approximately elbow height), leading to increased strain on the lower back.

5.3 Repetitive Motion and Fatigue

The feeding process involved repetitive hand movements, increasing the risk of fatigue and musculoskeletal disorders. Lack of automation in feeding contributed significantly to operator workload.

5.4 Vibration and Noise

Moderate levels of vibration were observed, particularly during shredding. Prolonged exposure to vibration may cause discomfort and reduce operator efficiency. Noise levels were also found to be relatively high, suggesting the need for protective measures.

5.5 Subjective Evaluation

Operators reported:

- Moderate discomfort in lower back and shoulders
- High exertion during continuous operation
- Improved efficiency compared to manual methods
- The average RPE score ranged between 13–15, indicating "somewhat hard" to "hard" work.

5.6 Comparison with Manual Methods

Parameter	**Manual Method**	**Machine Operation**
Productivity	Low	High
Drudgery	High	Moderate
Time Requirement	High	Low
Ergonomic Stress	High	Moderate

Tab-1: Manual labor but introduces mechanical ergonomic challenges.

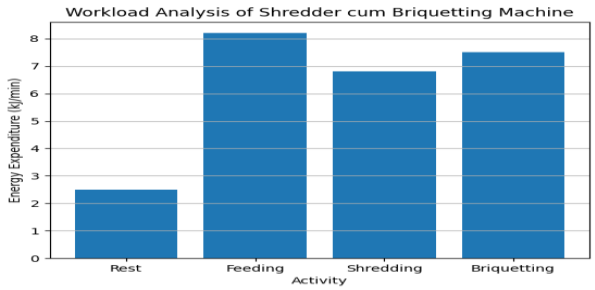

Fig-1: work analysis

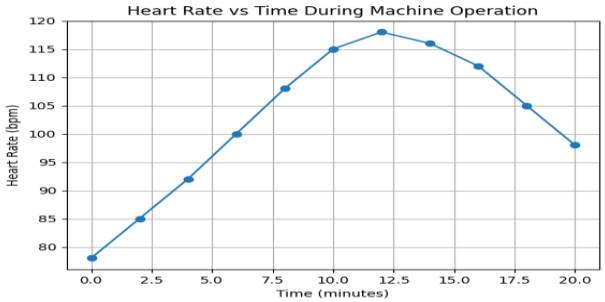

Fig-2: Heart rate vs time

6. Recommendations for Ergonomic Improvement

Based on the findings, the following improvements are suggested:

- *Adjustable Working Height:* To reduce bending and improve posture
- *Improved Feeding Mechanism:* Semi-automatic feeding to reduce repetitive motion

- *Vibration Dampers:* To minimize vibration impact
- *Ergonomic Handles:* For better grip and reduced strain
- *Seating Provision:* For intermittent rest during operation

Noise Reduction Measures: Use of sound insulation or protective gear

7. Advantages of the Machine

- Efficient biomass utilization
- Reduced environmental pollution
- Increased productivity
- Suitable for rural applications
- Promotes renewable energy use

8. Limitations

- ✓ Requires physical effort during feeding.
- ✓ Ergonomic issues related to posture.
- ✓ Initial cost may be high for small farmers.
- ✓ Maintenance requirements.

9. Future Scope

Future research can focus on: Integration of automation to reduce manual effort, Development of hybrid (manual + electric) systems, Advanced ergonomic design using simulation tools, Long-term health impact studies, Customization based on user anthropometry.

10. Conclusion

The ergonomical evaluation of the shredder cum briquetting machine reveals that while the machine significantly enhances productivity and reduces manual drudgery, it imposes moderate physiological and biomechanical stress on operators. The working heart rate and energy expenditure indicate a moderate to heavy workload, particularly during feeding operations. Ergonomic issues such as improper working height, repetitive motion, and vibration need to be addressed to improve operator comfort and safety. With appropriate design modifications, the machine can become more user-friendly and widely acceptable among small and marginal farmers.

Overall, the shredder cum briquetting machine holds great potential for sustainable agricultural waste management and energy production, provided ergonomic considerations are integrated into its design.

References

Bridger, R. S. ***(2009).*** Introduction to Ergonomics. CRC Press.

Grandjean, E. ***(1988).*** Fitting the Task to the Man. Taylor & Francis.

Nag, P. K., & Nag, A. ***(2004).*** Drudgery, Accidents and Injuries in Indian Agriculture. Industrial Health.

Ojolo, S. J., *et al.* *(2012).* Design and Performance Evaluation of Biomass Briquetting Machine.

Singh, S., *et al.* *(2010).* Ergonomic Evaluation of Farm Tools and Equipment.

McCormick, E. J. ***(1976).*** Human Factors in Engineering and Design.

BIS Standards for Agricultural Machinery Ergonomics.

FAO (Food and Agriculture Organization). Biomass Energy for Sustainable Development.