STM JOURNALS

Journal of
Polymer & Composites

ISSN: 2321-2810 (Online)
ISSN: 2321-8525 (Print)
Volume 13, Special Issue 1, 2025
DOI (Journal): 10.37591/JoPC

https://journals.stmjournals.com/jopc

Review JoPC

# Designing of Shredder Machine for Recycling Post Consumer Denim Waste for Making Composite Denim Boards

Vivek R. Sharma[1,*], P. V. Washimkar[2], P. N. Belkhode[3]

**_Abstract_**

*India has a population of about 1.35 billion in 2020 and as fabrics account for 4% of India's GDP, customers spend roughly 68 billion dollars on apparel and footwear each year. Currently, the short lifecycles of apparel products due to rapid fashion cycles and increased buying power of Indian consumers in urban as well as in rural areas are resulting in significant amounts of postconsumer textile waste in the form of used clothing. Denim is one of these prominent textile wastes, and while being formed of cotton fibres, it takes a long time for it to decompose in landfills. One of the crucial activities in the processing of post-consumer denim waste is cutting it to the necessary size. The motor-driven shredder machine can be used for cutting. Thus, this paper offers calculations of the designing of dual rotor electrical driven shredder machine. The major component of the shredder machine is shaft and blade of the machine. The geometry of blade, blade orientation, space between the blade is considered as the major variables in design the shredder blade. As orientation of blade affects the shredding performance, a spline shaft is designed to orient the blades in specific angles. The static analysis of shredder blade and shaft is performed using SolidWorks to ensure the safe design of the components of the shredder machine. This designed shredder machine is going to be utilized to shred the post consumer denim to make the composite denim board.*

**Keywords:** Shredder machine, design, solid works, post-consumer denim waste, composite boards

## INTRODUCTION

In 2020, India boasted a population of approximately 1.35 billion. With textiles constituting 4% of the country's Gross Domestic Product (GDP), the annual expenditure on clothing and footwear by consumers amounted to around 68 billion dollars [1] [2]. The prevalent trend of rapid fashion cycles, coupled with increased purchasing power among Indian consumers in both urban and rural areas, has led to shortened lifecycles of apparel products. Consequently, this has resulted in a substantial volume of post-consumer textile waste, encompassing used and second-hand clothing. Notably, denim, despite being crafted from cotton fibers, exhibits a slow degradation process, contributing to environmental harm [3]. This, in turn, has adverse implications for society at large.

Furthermore, denim stands as one of the predominant fabrics globally, making the environmental impact associated with denim jean production particularly hazardous due to the vast quantity of jeans manufactured and utilized by consumers today. To assess the environmental footprint of denim products throughout their life

***Author for Correspondence**
Vivek R. Sharma

[1]Research Scholar, Department of Mechanical Engineering, Government College of Engineering, Chandrapur, Maharashtra, India
[2]Associate Professor, Department of Mechanical Engineering, Government College of Engineering, Chandrapur, Maharashtra, India
[3]Assistant Professor, Department of General Engineering, Laxminarayan Institute of Technology, Nagpur, Maharashtra, India

Received Date: June 19, 2024
Accepted Date: September 11, 2024
Published Date: December 09, 2024

**Citation:** Vivek R. Sharma, P. V. Washimkar, P. N. Belkhode. Designing of Shredder Machine for Recycling Post Consumer Denim Waste for Making Composite Denim Boards. Journal of Polymer & Composites. 2025; 13(Special Issue 1): S934–S945p.

cycle, it is crucial to examine their impact during production, usage, and disposal, and take targeted measures to mitigate this impact effectively [4]. Textile waste is categorized based on its origin, encompassing pre-consumer, post-consumer, and industrial textile waste. Pre-consumer waste comprises the remnants of production processes, ranging from raw materials to finished products ready for the market. This category includes offcuts, shearing, selvedges, second grade garments, export surplus, etc., all of which are homogenous and clean, presenting significant potential for reuse and recycling. On the other hand, post-consumer textile waste involves products that have completed their life cycle and are no longer functional or aesthetically appealing to the consumer. Meanwhile, industrial textile waste results from manufacturing processes and is referred to as "dirty waste" [3].

The textile and apparel industry, with its extensive environmental impact spanning cultivation, fabric and garment manufacturing, and the disposal of post-consumer items in landfills, grapples with significant environmental and resource-related challenges [5]. To address some of these challenges, numerous fashion companies now offer customers options for handling their worn-out clothes, including denim jeans. Despite these efforts, studies indicate that less than 1% of the collected clothes are recycled, with nearly 80% primarily sold on the second-hand market in impoverished nations or repurposed as blankets or insulation material globally. The remaining 20% is either domestically sold on the second-hand market, sent to landfills, or subjected to incineration [6]. resulting in adverse environmental consequences and consequently impacting society. This increasing trends in the generation of post-consumer cloth waste expresses that there is increasing demands in the waste treatment technologies. Shredder machines have emerged as crucial equipment in various industries, especially in waste management and recycling. These machines are designed to efficiently break down and reduce the size of a wide range of materials, including paper, cardboard, plastics, metals, and more.

## REVIEW OF LITERATURE

Dr. Fauzia Siddiqui et. al. conducted a study focused on the design and enhancement of a paper shredder machine utilized in both government and private organizations for the secure destruction of confidential and crucial documents. The design is segmented into three primary divisions: the bladed sign featuring various profiles and dimensions, the second division involving transmission and cutting forces, and the third part encompassing the model of the frame and blade. This modeling process was executed using SolidWorks, a 3D modeling software, for motion study and analysis purposes [5].

Sudhakara Reddy and Thunga Raju conducted a study on the structure and modification of a paper shredder machine employed in government and private organizations for the purpose of destroying confidential and important documents. The design is segmented into three main divisions: the blade structure featuring various profiles and dimensions, the second division involving transmission and cutting forces, and the third part encompassing the model of the frame and blade. This modeling process was accomplished using SolidWorks, a 3D modeling software employed for motion study and analysis. [6] S. Vijay Ananth et al. developed a plastic shredder machine for cutting domestic and industrial plastic waste for recycling. The design involves mechanical components like the shredder blade and frame, incorporating design calculations to enhance cutting efficiency. The generations of plastic shredder machines exhibit advancements in transmission mechanisms, ranging from low-noise belts to metal gears.

I. M. Sanjay Kumar et al. focused on designing and developing a shredder machine specifically for cutting coconut leaves and areca leaves. The resulting shredded powder is utilized in the preparation of vermicompost. This waste shredder machine is engineered to reduce agricultural waste and transform it into a valuable and nutritious fertilizer [7]. Varun Bhaskar et al. created a system to break down plastic into small, irregularly shaped particles that can be stored for subsequent processing. This process aids in the production of new plastic products. The recycled plastic particles undergo treatment in an extrusion machine, transforming them into wires resembling plastic fibers. These fibers can then be utilized in a 3D printer for various applications [8].

 

Cristian Pedraza et al. examined the intricate force conditions of a crusher, conducting a detailed analysis of the stress characteristics and fatigue life of the blades using the transient finite element method. The study identified the maximum stress distribution pattern in the shredder blades, revealing the mechanism of deformation-induced fracture. Experimental validation ensured the reliability of simulation results. Notably, at a rotation speed of 268 RPM, the blades exhibited higher maximum tension. The comparison of two working geometries and three construction materials established criteria for selecting the optimal blade, emphasizing optimal functionality [9].

M. Sakthivel et al., in their research, focused on the design and analysis of the sharp edges of twin shaft shredders. The twin shaft shredder machine was developed using PRO and CREO software, and a comprehensive analysis of the proposed model was conducted by comparing it with a twin shaft shredder model selected from diverse hardware designs of manufacturing firms. The model incorporates 16 sharp edges, with the cutting edges traditionally made from 20MnCr5 steel, heat-treated under specific conditions. Currently, there is a transition to materials such as EN36, EN19, EN31, and EN8. The study investigated displacement, maximum stress, and shear concerns for the materials under the same load conditions [10].

Sekar Ravi studied the plastic shredders in expediting and enhancing their functionality. This study was focused on optimizing the shredder blade to improve the grinding of plastic waste into fine-grained particles. This optimization results in reduced labor requirements, eliminating the need for skilled workers in the industry. The recycling process for plastic waste demands less energy due to the compact form of the waste, subsequently reducing processing time in the industry. Moreover, the machine employed in this project is cost-effective, making the overall project economically efficient [11].

The existing literature highlights a predominant focus on research related to plastic shredder machines, while recycling technology for used clothing remains relatively underexplored. This research paper addresses this gap by concentrating on the design of a shredder machine specifically tailored for post-consumer denim waste. By emphasizing the importance of tackling textile waste, particularly from discarded denim, the study aims to contribute to the advancement of recycling technologies in the fashion industry. The unique focus on post-consumer denim waste aligns with the growing concern for sustainable practices, emphasizing the need for innovative solutions in textile recycling beyond traditional plastic-centric approaches. This research endeavors to bridge the knowledge gap and pave the way for more sustainable practices in textile recycling, especially to process the post-consumer denim cloths into shredded fibers. These shredded denim fibers can be utilized in making denim composite boards.

## DESIGN PROCEDURE OF SHREDDER

The design procedure of shredder machines follows a consistent structure. Each design typically incorporates: (i) designing a shaft and geometry of blades, (ii) a motor, gearing, bearings, and transmission, (iii) a hopper, and (iv) a framework. However, design aspect (i), encompassing the shaft-blade combination, stands out as the most intricate element due to its significant impact on machine efficiency. Additionally, this component necessitates frequent maintenance to address wear and tear incurred during the shredding operation. The complexity of this design aspect underscores its critical role in the overall functionality of the shredder machine, emphasizing the need for careful attention and maintenance protocols to ensure optimal performance. Consequently, this research paper directs its attention towards a more detailed examination of the design and assembly process pertaining to the shaft.

### Designing of Shredder Blade

The blades employed in the shredder machine exhibit diverse geometric variations. The design considerations for these blades encompass factors such as the number of cutting edges (teeth/hooks), cutting angle, grabbing surface, and the thickness of the cutter blades. Inadequate blade design may result in the shredder machine being incapable of effectively shredding more resilient objects or could lead to clogging, necessitating a reversal of the spin direction [12]. Therefore, the precision and appropriateness of blade design are crucial elements influencing the overall performance and operational efficiency of the shredder machine. Based on the research carried out by Yepes C P *et. al*., suggested that the double edges blade with the curved grabbing surface experience the lesser stress compared to the flat grabbing surface [13], hence in this research article a double edge curved blade geometry is considered for the shredder as shown in Figure 1.

The tensile strength of denim fabric typically ranges between 57 to 75 megapascals (MPa) for the warp and weft directions, respectively [14]. Additionally the rivets or chains have maximum strength of about 172 MPa. Considering this the maximum tensile strength is considers as 172 MPa and cutting area of 12 $mm^2$ for designing. The maximum cutting force generated on the blade is about 1032 N considering the 50% shearing strength.  Given the repetitive loading and impulse actions involved, the blade material selected as AISI 4340 steel, characterized by a yield strength of approximately 710 MPa. The details of the geometry of the blade is shown in Figure 2.

**Figure 1.** Double edge blade with curved grabbing surface.

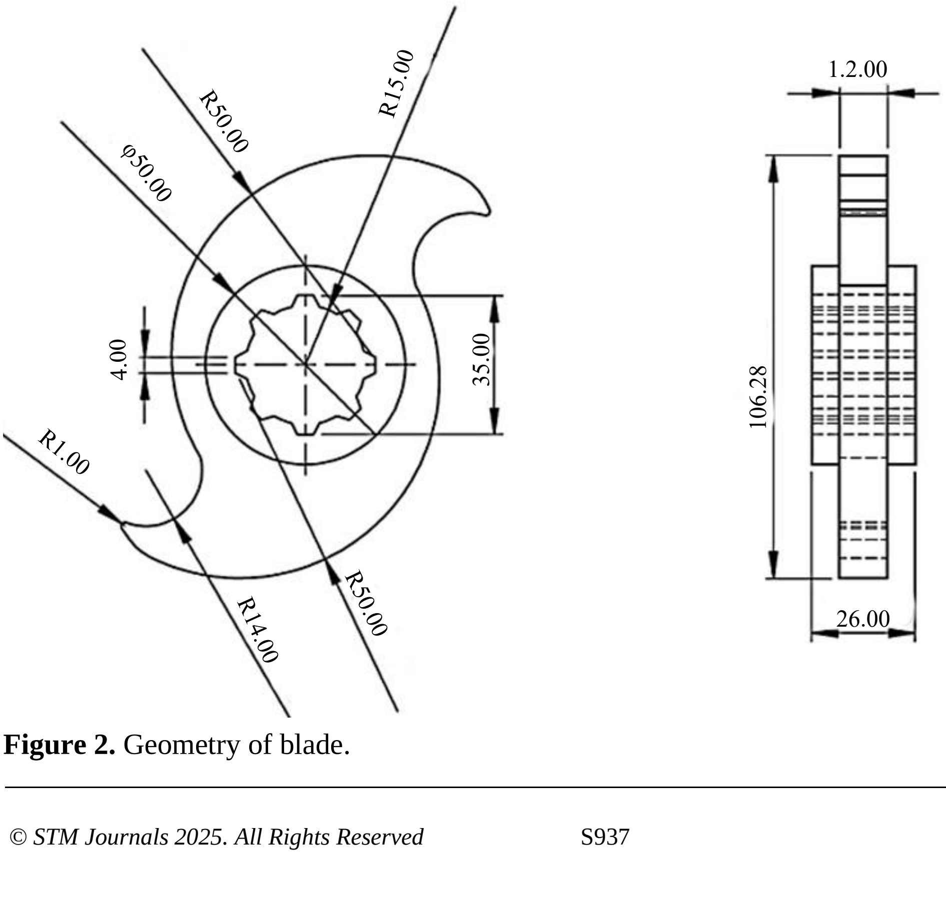


**Figure 2.** Geometry of blade.

 

The blade analysis was conducted using SolidWorks, considering a force of approximately 1032 N, which is equivalent to the cutting force exerted by blade. The fixture is applied at the center of the bladed as shown in Figure 3(a) and considering six blade engagement at a time a force of 1032 N is applied at the tip of the blade illustraded in Figure 3(b). For the analysis, a four-point standard tetrahedral mesh was utilized, with an element size of approximately 4.2 mm. The analysis revealed that the maximum stress generated on the blade reached 6.72 MPa at the blade tip, with a maximum strain of approximately $1.166 \times 10^{-3}$, as illustrated in Figure 4(a). Additionally, the maximum displacement observed in the blade was approximately $9.037 \times 10^{-3}$ mm at the blade end, as depicted in Figure 4. (b).

**Designing of Shaft**

The design of the shaft is a critical aspect in shredder machine development, influencing efficiency and durability. It involves meticulous considerations such as material selection, dimensions, and structural integrity. The shaft's design complexity stems from its central role in transmitting power and supporting the blades. In a shredder machine, blades are affixed onto dual rotating shafts, with interspersed gaps. During operation, the material to be shredded is guided between two sets of blades aligned along parallel axles. These blades intertwine with overlapping radii from opposing axes, facilitating cutting at the interface of the opposing blade sets [15]. To prevent material skipping, the blade must be arranged in a specific orientation. Consequently, a spline shaft design is chosen for the shredder machine's shaft in this research, enabling precise alignment of the blades to one another. This configuration ensures optimal performance and effective material processing during shredding.

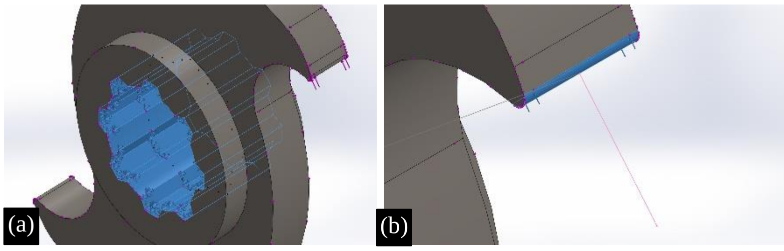

**Figure 3.** (a) Fixture applied for analysis (b) Force application area.

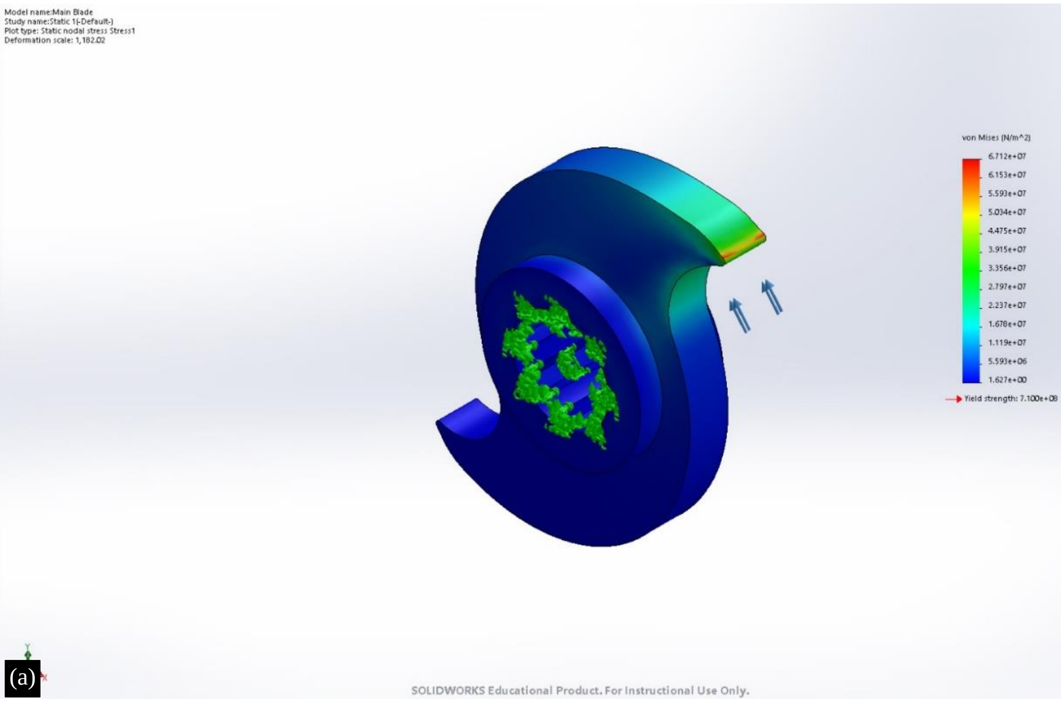

**Figure 4.** (a) Stress generated on blade.

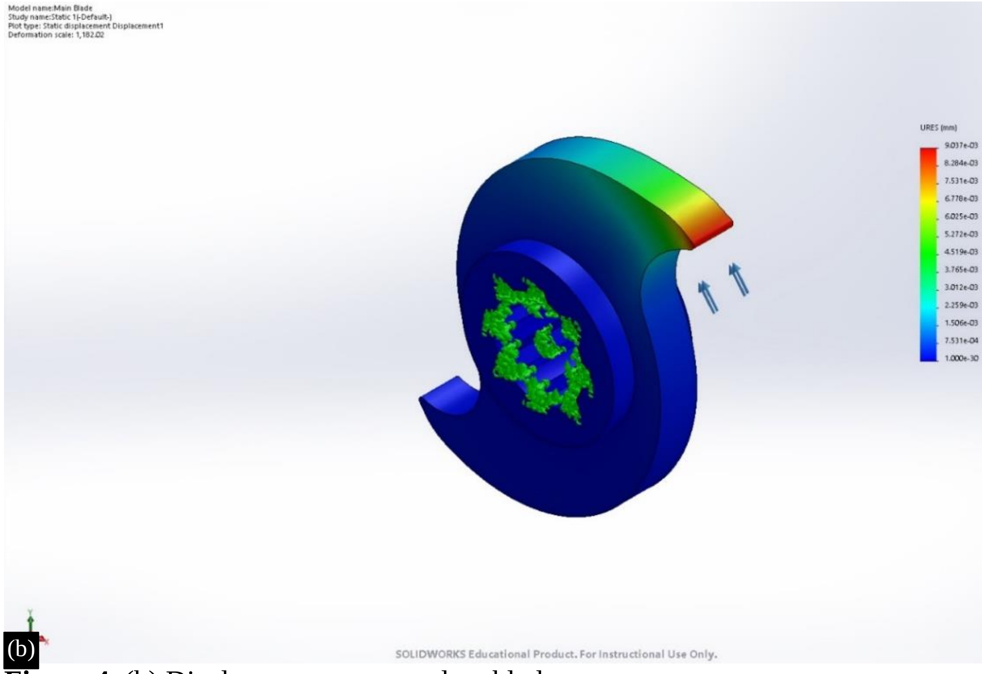


**Figure 4.** (b) Displacement generated on blade.

The shaft length is determined to be approximately 570 mm, accounting for an effective cutting length of 270 mm for the blades along the shaft as shown in Figure 5.

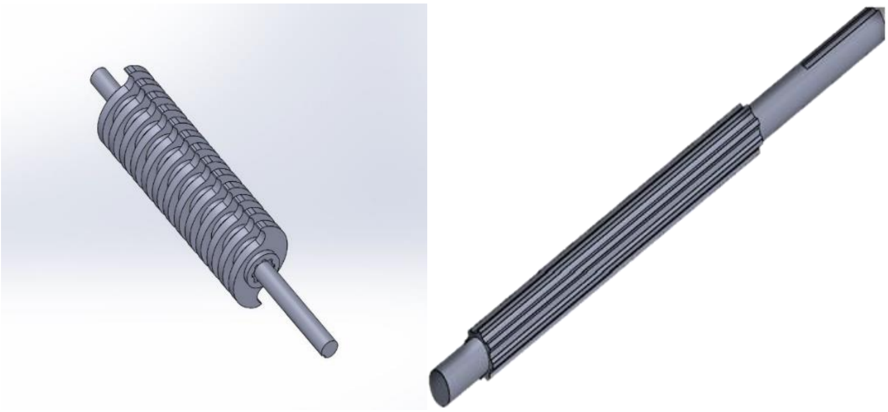

**Figure 5.** Shaft effective length.

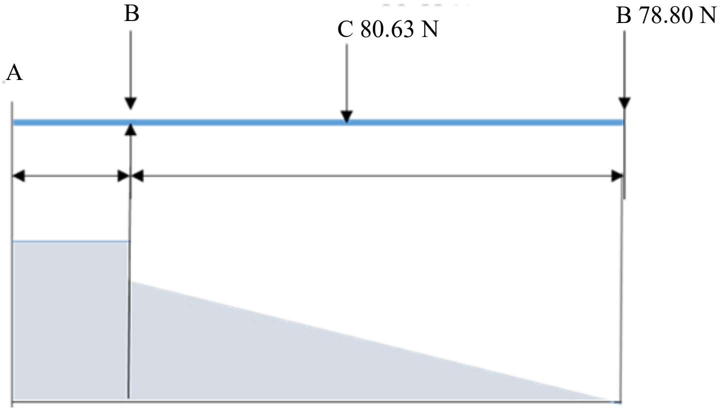


**Figure 6.** Loading condition of shaft.

 

In this study, the assumption is made of unit area application of the cutting force, and for a single blade, the torque is calculated as 21328 N-mm based on a blade size of 172 mm by 62 mm. Given the blade orientation, three blades engage simultaneously. Therefore, the total torque exerted by the three blades (T) is computed as 63984 N-mm, equivalent to approximately 64 N-m.

Given the circumstance, it is anticipated that the feeding of the denims will result in suddenly applied loads with minor shocks, depicted in Figure 6. In this investigation, key factors influencing the mechanical behaviour of the system are identified, including the combined shock and fatigue factors for bending ($K_m$) set at 2.0 and the corresponding factor for torsion ($K_t$) also established at 2.0. Further parameters considered include the weight of denims (10 N), the weight of the shredder blade (70.63 N), and the weight of the pulley assembly (78.80 N). Significantly, the maximum bending moment (Mb) is calculated to be 12706 N-mm. The shear force on the shaft is illustrated in the Figure 7.

In accordance with the ASME Code, the equation 1 governing shafts under torsion, bending, and fatigue is denoted as equation 1. Employing an allowable shearing stress of 160 MPa and considering AISI 1045 steel as the shaft material, the calculated diameter of the shaft is determined to be 16.24 mm. However, factoring in considerations such as keyway, spline, and the desired factor of safety, the standard diameter of the shaft is revised to 35 mm. This determination ensures compliance with industry standards and safety margins, thereby optimizing the design for robust performance in the intended application.

$$d^3 = \frac{16}{\pi\tau}[(K_b M_b)^2 + (K_t T)^2]^{0.5} \quad \text{(Equation 1)}$$

Utilizing the aforementioned calculations, the shaft design is executed within SolidWorks, with the specifics of the shaft geometry meticulously outlined and depicted in Figure 8.

The shaft analysis is performed using SolidWorks, where a total of 12 blades are mounted on the shaft, with a torque of 310 Nm applied for the analysis. A four-point standard tetrahedral mesh with an element size of approximately 7.8 mm is employed. Results indicate that the maximum stress on the blade reaches 5.34 MPa at the shaft's end, with a maximum strain of approximately 1.833 x $10^{-4}$, as depicted in Figure 9(a). Additionally, a maximum displacement of approximately 9.241 x $10^{-2}$ mm is observed at the blade end of the shaft, as shown in Figure 9(b).

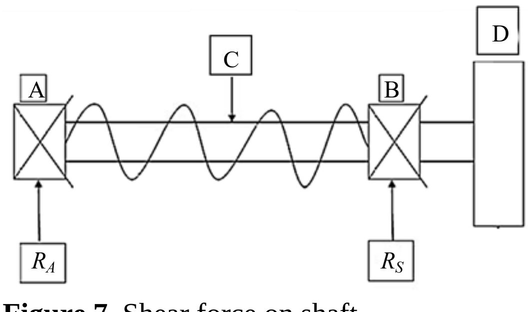


**Figure 7.** Shear force on shaft.

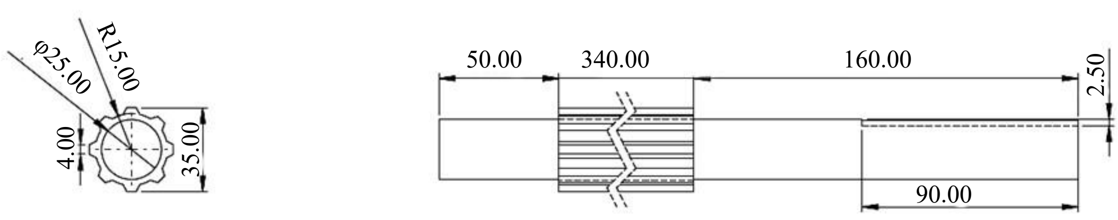


**Figure 8.** Geometry of shaft.

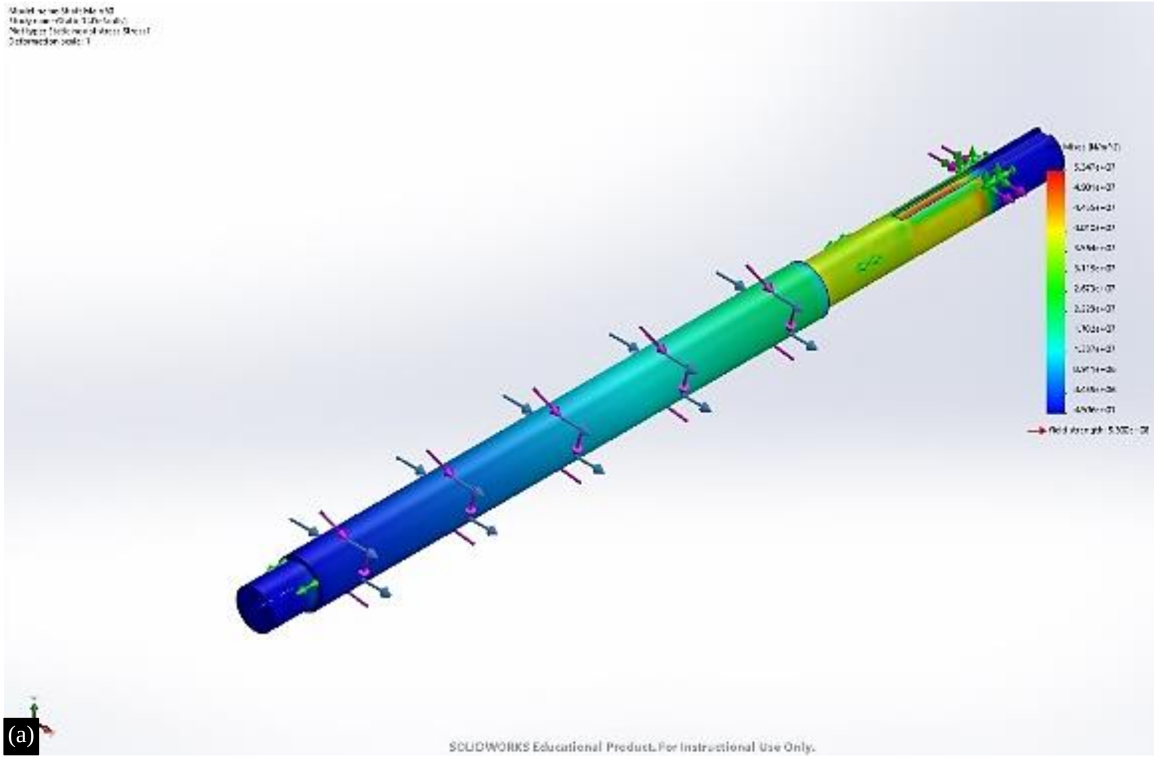

**Figure 9.** (a) Stress Generated on Shaft.

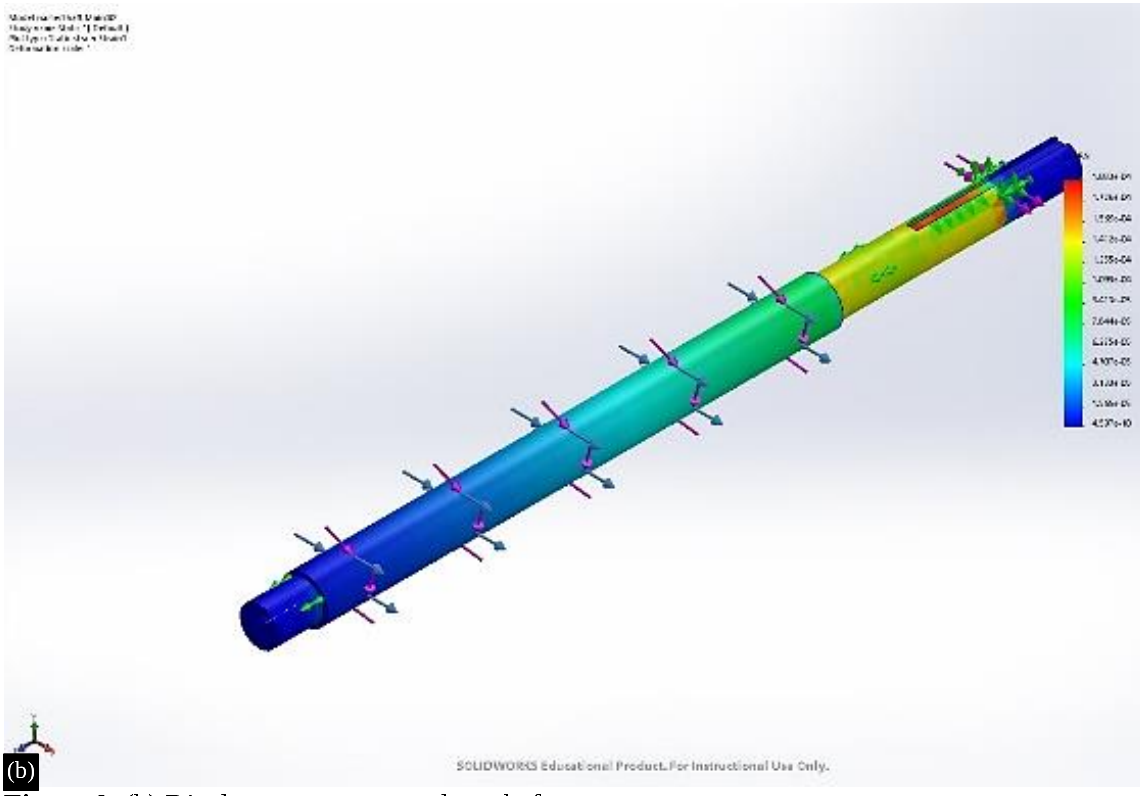

**Figure 9.** (b) Displacement generated on shaft.

**Designing of Motor, Gearing and Transmission**

The motor in the shredder machine serves as the power source, driving the rotational motion of the blades to facilitate efficient shredding of materials with controlled speed and torque. Incorporating the motor specifications, the total torque requirement for the 12 blades is determined to be approximately 310 Nm. Kumaran P. et al. proposed that the ideal operating speed for shredders falls within the range of 60 to 100 rpm designed for processing plastic waste and electronic waste [16]. Considering a power requirement at 60 rpm, and factoring in a mechanical efficiency of 80%, the rated power of the motor is calculated to be 2.15 kW, equivalent to approximately 2.87 hp. However, for practical purposes, the rated power of the motor is rounded up to 3 hp, ensuring sufficient power output to meet operational demands and account for any variations or contingencies in performance.

Efficient power transmission is crucial in shredder machines, and for cost-effective solutions, belt drives prove optimal. The use of belt drives provides an economical means of speed reduction and power transmission in shredder machines. This method ensures reliable performance while catering to budget constraints, making it a practical choice for achieving the necessary torque and speed required for effective material shredding in various applications. In this study, a standard electric motor with specifications including a power rating of 3 hp, a speed of 1440 rpm and a torque of 13.3 N-m is utilized. To effectively transmit power and achieve the desired speed reduction, a pulley system is employed. The pulley system consists of two steps: Step 1 involves a 75 mm single groove pulley connected to a 360 mm single groove pulley, while Step 2 utilizes a 75 mm double groove pulley coupled with a 360 mm double groove pulley. These configurations are illustrated in Figure 10.

In the realm of gear and bearing selection for the shredder machine, specific parameters have been meticulously considered. The gear specifications entail a module of 4 mm, 20 teeth, a face width of 64 mm, a factor of safety (FOS) of 1.5, and a hardness rating of 240 Brinell Hardness Number (BHN). Complementing the gear, a deep groove ball bearing is chosen with an inner diameter of 35 mm, an outer diameter of 80 mm, a race width of 21 mm, and impressive load-bearing capacities—19 kN for static loads and 22 kN for dynamic loads. These selections are critical for ensuring optimal performance and durability in the shredder's mechanical components [17].

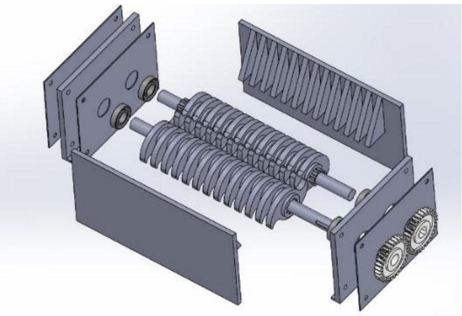

**Figure 10.** Pully system configuration.

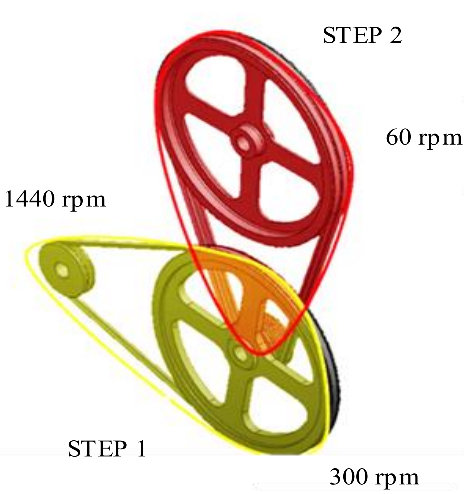


**Figure 11.** Exploded view of shredder assembly.

 

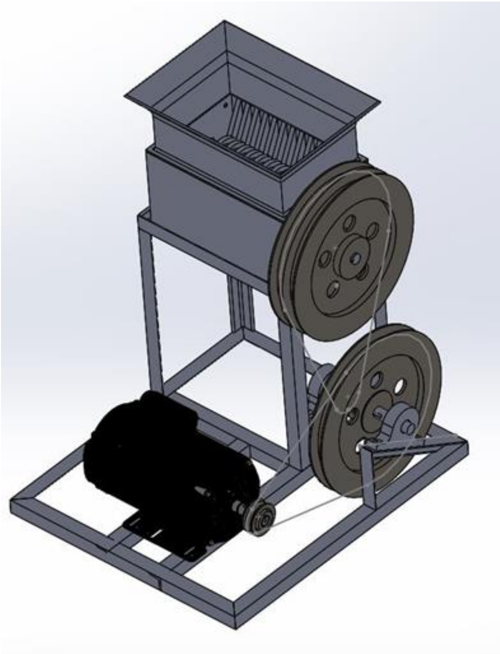

**Figure 12.** Overall schematic view of shredder machine.

The detailed configuration of the shaft and blade assembly, coupled with the gear and bearing arrangement, is visually presented in Figure 11 through an exploded view. This comprehensive illustration provides a clear depiction of the interrelation and spatial arrangement of these crucial components within the shredder machine. Additionally, the overall volume of the shredding compartment is specified as 400 mm x 270 mm x 200 mm, underscoring the dimensions of the operational space dedicated to the shredding process.

The frame of the shredder machine is constructed from AISI 1015, cold-drawn steel, adhering to material specifications of 35mm x 35mm x 5mm. This robust framework provides structural integrity and support to the entire assembly, ensuring stability during operation. With an overall volume measuring 750 mm x 650 mm x 845 mm, the machine's dimensions are substantial, accommodating its various components and allowing for effective shredding operations. Figure 12 offers a comprehensive pictorial representation of the machine, illustrating its overall structure and design layout for visual reference and analysis [18].

## RESULTS AND DISCUSSION

The results from the static analysis of the shredder blade, as illustrated in Figures 4(a) and 4(b), indicate a maximum stress of 6.72 MPa at the blade tip. This stress level is significantly lower than the yield strength of the material, ensuring structural integrity under operational conditions. The analysis also revealed a maximum strain of approximately 1.166 x $10^{-3}$, which is within acceptable limits. Furthermore, the maximum displacement observed in the blade was approximately 9.037 x $10^{-3}$ mm, confirming that the deformation remains within the permissible range. The results from the static analysis of the shaft indicate that the maximum stress on the blade reaches 5.34 MPa at the shaft's end, as depicted in Figure 9(a). The maximum strain observed is approximately 1.833 x $10^{-4}$. Additionally, a maximum displacement of approximately 9.241 x $10^{-2}$ mm is observed at the blade end of the shaft, as shown in Figure 9(b). These values suggest that the shaft performs within the acceptable stress, strain, and displacement limits under operational conditions. Additionally, M. F. Nasr et al. [19] indicated that the maximum Von Mises stress in their analysis was 201 MPa. This value is considered safe compared to the yield stress of the blade material, which is made of low carbon steel for a paper cutter. The maximum total mechanical strain reported was 1.4 x $10^{-3}$, and the maximum deformation was 0.97 x $10^{-5}$ m[20].

 

## CONCLUSION

In this study, a groundbreaking method is presented for the design and calculation of a shredder machine meticulously crafted to meet the unique requirements of post-consumer denim shredding. The comprehensive analysis conducted on the shredding machine not only underscores its potential but also highlights its efficiency in handling moderate volumes of denim clothing with remarkable effectiveness. Employing SolidWorks software for this analysis adds an extra layer of assurance, ensuring the model's safety and reliability in practical applications. These noteworthy findings not only contribute valuable insights to the current understanding of denim recycling technology but also establish a solid foundation for the development of an optimized shredder model, poised for future large-scale production. The implications of this research extend towards the prospect of advancing denim recycling practices on a broader scale, promising significant strides in sustainable and efficient textile waste management.

## REFERENCES

1. "Office of the Registrar General & Census Commissioner, India," [Online]. Available: https://censusindia.gov.in/.
2. "Fashion united Fashion industry statistics India.," Indian brand equity foundation Textile Industry & Market Growth in India, 2017. [Online].
3. P. AP and M. J. Denim, "Sustainability in Denim 1st ed. United Kingdom," Woodhead Publishing, Elsevier Ltd, 2017, pp. 257-282.
4. R. S., "Roadmap to Sustainable Textiles and Clothing: Regulatory Aspects and Sustainability Standards of Textiles and the Clothing Supply Chain," Springer Science+Business Media, pp. 23-57, 2015.
5. F. Siddiqui, "Design and fabrication of paper shredder machine," International Journal of scientific and engineering research, vol. 8, no. 3, pp. 18-23, 2017.
6. S. Reddy and T. Raju, "Design and Development of mini plastic shredder machine," IOP Conf. Series: Materials Science and Engineering, 2017.
7. I. S. Kumar and T. H. Kumar, "Design and Development Of Agricultural Waste Shredder Machine," International Journal of Innovative Science, Engineering & Technology, vol. 2, no. 10, 2015.
8. V. Bhaskar, M. Prabhahar, L. Prabhu and S. Krishnamoorthi, International Journal of Chenical Science, vol. 14, pp. 560-568, 2016.
9. C. Pedraza, P. -. R. M. Angel and P. -. M. G. José, "Analysis by Means of the Finite Element Method of the Blades of a PET Shredder Machine with Variation of Material and Geometry," Contemporary Engineering Sciences, vol. 11, pp. 4113 - 4120 , 2018.
10. M. Sakthivel, G. Rajeshkannan, M. Naveenkumar and M. Muralimanokar, "DESIGN AND ANALYSIS OF TWIN SHAFT SHREADER USING PRO-E AND HYPERWORKS SOFTWARE," International Journal of Advanced Research in Basic Engineering Sciences and Technology, vol. III, no. 24, pp. 836-858, 2017.
11. S. Ravi, "Utilization of Upgraded Shredder Blade and Recycling the Waste Plastic and Rubber Tyre,," in Proceedings of the International Conference on Industrial Engineering and Operations Management , Paris, France, 26-27, 3208-3216, 2018.
12. R. A.V. and B. U. H., "Optimal design and analysis of twin shaft shredder," IJRI, vol. 4, no. 13, pp. 805-811, 2017.
13. C. P. Yepes, R. M. Pelegrina and G. J. P. M, "Analysis by means of the finite element method of the blades of a PET shredder machine with variation of material and geometry," Contemporary Engineering Sciences, vol. 3, no. 11, 2018.
14. J. T. Lee, M. W. Ki, Y. S. Song, T. J. Kang and J. R. Youn, "Mechanical properties of denim fabric reinforced poly (lactic acid)," Fibers and Polymers, vol. 11, p. 60–66, 2010.
15. P. D. Raut and S. M. Bhalgat, "Cutter blade design for shredder machine," International Journal of Scientific and Research Publications, vol. 10, no. 6, pp. 1022-1027, 2020.
16. P. Kumaran, N. Lakshminarayanan, V. M. A, R. George and J. JoJo, "Design and analysis of shredder machine for e-waste recycling using CATIA," in IOP Conference Series: Materials Science and Engineering, Kancheepuram, Tamilnadu, India, 2020.

 

17. T. Asmamaw, T. Abebe, E. A. and R. Mebrhatu, "Development of Dual Shaft Multi Blade Waste Plastic Shredder for Recycling Purpose," International Journal of Research and Scientific Innovation, vol. VI, no. I, 2019.
18. "Shredding Machines," IQS Directory, 05 May 2023. [Online]. Available: https://www.iqsdirectory.com. [Accessed 05 May 2023].
19. Yehia, Nasr, Mohamed and Khaled, "Stress Analysis of a Shredder Blade for Cutting Waste Plastics," Journal of International Society for Science and Engineering, vol. 1, no. 1, pp. 9-12, 2019.
20. S. VijayAnanth, T. Sureshkumar, C. Dhanasekaran and A. Kumar, "Design and fabrication of plastic shredder machine for clean environment," International Journal of Management, Technology and Engineering, 2018.

 