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Design and Construction of a Coconut Coir Chopping Machine Based on a Three-Phase Induction Motor with Frequency Variation for Cocofiber Quality Optimization

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Abstract

Coconut coir is an abundant by-product of coconut processing that remains underutilized, particularly in Bahodopi District, Morowali Regency. Coir chopping is still carried out manually, which is time- and labor-intensive and produces uneven results. This study aims to design and build a robust, easy-to-operate coconut coir chopping machine capable of efficiently converting coir into cocofiber. The engineering method was applied, comprising literature study, design using SolidWorks, frame strength simulation, material selection, assembly, and testing. The machine is driven by a three-phase induction motor (1400 rpm, 50 Hz) equipped with an inverter, allowing the blade rotation speed to be varied at 15, 30, and 50 Hz. Testing used approximately 3 kg of dry coir for each variation. The results show that the machine can chop coir at a capacity of 180 kg/hour, with the best result—fine and even—obtained at 30 Hz. Static simulation of the frame under an 800 kgf load produced a maximum stress of 374.421 MPa and a minimum safety factor of 0.939, indicating the need to reinforce the critical points of the frame. This machine is expected to help the Bahodopi community process coir more easily and to create new economic opportunities.

Keywords Chopping Machine; Coconut Coir; Cocofiber; Frequency Variation; Design And Construction

INTRODUCTION (Palatino Linotype 11, Space 1.15, Justify)

Coconut husk is one of the largest components of the coconut fruit, accounting for approximately 35% of its total weight. It consists of two main components: coconut fiber (cocofiber) and coconut pith (cocopeat) (Ningtyas et al., 2022). Coconut fiber is the fibrous layer located between the hard shell and the coconut flesh. Due to its high strength, durability, and elasticity, it has been widely utilized in various industries, including carpet manufacturing, organic fertilizer production, and handicraft materials. Therefore, shredding coconut husk is an essential preliminary step that facilitates subsequent processing stages. This process requires equipment capable of operating quickly, efficiently, and consistently to produce high-quality fiber.

However, in many regions, particularly in Bahodopi District, Morowali Regency, most local communities still lack access to coconut husk shredding machines. As a result, the shredding process is commonly performed manually using simple methods, such as beating or tearing the husks apart, which require considerable physical effort and processing time. Moreover, these conventional methods often produce uneven fiber sizes and lower-quality outputs. The design of a coconut husk shredding machine should therefore consider several important technical aspects, including machine strength, the size and uniformity of the shredded fiber, ease of operation, and occupational safety, as the shredding process poses a significant risk of injury if not properly managed.

Several previous studies have developed coconut husk shredding machines; however, not all of these designs are suitable for practical implementation under local conditions. Nugraha et al. (2025) developed a coconut fiber shredding machine intended for planting media and liquid organic fertilizer production from potato seedlings. Although the machine successfully separated cocopeat from cocofiber, it paid limited attention to operator safety. Fajrul and Suhardiman (2022) designed a coconut husk decomposing machine for producing cocopeat and cocofiber, but the machine exhibited limitations in terms of efficiency and operational effectiveness. Meanwhile, Yusnita and Arifin (2021) modified the blade geometry by adopting a curved blade design, resulting in more uniform and finer fiber while reducing motor load by approximately 10%. Saputra and Mulyadi (2022) implemented an inverter-based speed control system that reduced power consumption by approximately 12%, improved shredding consistency, and enhanced machine stability. A summary of these relevant studies is presented in Table 1.

Table 1. Summary of Relevant Studies

Researcher (Year)	Research Focus	Main Findings / Limitations
Nugraha et al. (2025)	Coconut husk shredding machine for planting media and liquid organic fertilizer	Successfully separated cocopeat and cocofiber with a capacity of 7 kg/h; limited consideration of operator safety
Fajrul & Suhardiman (2022)	Coconut husk decomposing machine for producing 50 kg of cocopeat and cocofiber	Functional machine; however, efficiency and operational effectiveness were not fully optimized

Yusnita & Arifin (2021)	Modification of curved blade design	Produced finer and more uniform fiber while reducing motor load by approximately 10%
Saputra & Mulyadi (2022)	Application of an inverter for motor speed control	Reduced power consumption by approximately 12%, improved shredding consistency, and enhanced machine stability

Based on the literature review, it can be observed that regulating rotational speed through frequency variation has significant potential to improve the quality of shredded coconut fiber. Nevertheless, this approach has not been extensively investigated for simple and affordable machines intended for use by rural communities. Therefore, this study aims to design and develop a robust, user-friendly coconut husk shredding machine that meets the practical needs of local communities. In addition, the machine performance will be evaluated under several frequency variations using a three-phase induction motor equipped with an inverter. The proposed machine is expected to enable coconut husks to be processed into cocofiber more practically, rapidly, and efficiently while simultaneously creating new economic opportunities for the residents of Bahodopi District.

METHODS (Palatino Linotype 11, Space 1.15, Justify)

2.1. Research Methods and Stages

This research employs an engineering method focusing on the processes of designing, fabricating, and testing the device. The stages begin with a needs assessment and literature review to establish a design basis, followed by the design process using SolidWorks software, material and component selection, machine assembly, and functional testing. Experimental methods are used to evaluate the device's performance, covering shredding capacity, operational efficiency, and analysis of the shredded output. In summary, the research workflow proceeds from the literature review, mechanism design planning (tools and materials), mechanism design, and fabrication, to device testing. If test results are unsatisfactory, the process reverts to the design planning stage; if satisfactory, it proceeds to data collection and report compilation.

2.2. Location and Schedule

The research is conducted at the Machine Maintenance Engineering Study Program Workshop, Morowali Metal Industry Polytechnic (PILM)—located in Padabaho Village, Bahodopi District, Morowali Regency, Central Sulawesi Province—from January to July 2025.

2.3. Tools and Materials

The tools utilized include SolidWorks software for 3D design conceptualization and simulation; welding equipment for joining the frame and metal components; a grinding machine for cutting iron and finishing welds; and a drilling machine for creating bolt and nut mounting holes. Key materials include 5×5 mm steel bars for the cutting blades; an ST 60 steel shaft (30 mm diameter, 1000 mm length, $\sigma = \pm 61.2$ kg/mm²) serving as the main drive shaft; ST 37 steel plate for bearing mounts and panels; UCF 204 (Ø20 mm) pillow block bearings to support the shaft; and 4×4 mm angle iron for frame leg reinforcement.

2.4. Machine Element Calculation Procedures

The design of machine components is based on several fundamental machine element equations, namely: motor power $P = V \times I \times \cos \varphi$; Pulley rotation ratio $N1/N2 = D2/D1$; motor torque $T = (P \times 9550)/n$; shaft diameter based on torsional load $D = (16T/\pi\tau)^{(1/3)}$; initial blade shaft speed (RPM) = frequency × 28 (based on motor characteristics); sudden torque due to load $T = F \times r$; machine capacity $Q = M/t$; and linear blade speed $v = (2\pi n/60) \times r$. The notations are: V for voltage, I for current, cos φ for power factor, n for rotational speed, D for diameter, τ for the material's allowable shear stress, F for force, r for blade radius, M for the mass of shredded material, and t for shredding time..

RESULTS AND DISCUSSION (Palatino Linotype 11, Space 1.15, Justify)

3.1. Machine Design

The coconut husk shredding machine was designed using **SolidWorks** software. In general, the machine consists of several main components, including a three-phase electric motor as the prime mover, pillow block bearings to support the rotating shaft, a belt and pulley transmission system, a control panel, a steel frame, a cutting blade cover, vibration dampers, and an output chute for the shredded material. During operation, coconut husks are fed into the machine through a hopper and are subsequently shredded by high-speed rotating blades. The rotational motion of the blades generates cutting and tearing forces that separate the husks into smaller fibers. The shredded material is then discharged through the output channel for drying or further processing.

3.2. Frame Strength Simulation

A static structural simulation was conducted to evaluate the mechanical strength of the machine frame under an applied load of **800 kgf** distributed over several loading surfaces. The frame was fabricated entirely from **AISI 1020 low-carbon steel**, which has a yield strength of **351.571 MPa**. The simulation generated four primary parameters: equivalent strain, resultant displacement, von Mises stress, and the factor of safety (FOS). The simulation results are summarized in **Table 2**.

Table 2. Static Structural Simulation Results of the Machine Frame (800 kgf Load)

Parameter	Type	Minimum	Maximum
Strain	ESTRN: Equivalent Strain	0.000	0.001
Displacement	URES: Resultant Displacement	0.000 mm	1.211 mm
Stress	VON: von Mises Stress	0.001 MPa	374.421 MPa
Factor of Safety	Automatic	0.939	312,026.063

The simulation results indicate that the maximum equivalent strain reached **0.001**, corresponding to approximately **0.1%** of the original length, which is relatively small and suggests that the frame material remains within the elastic deformation region (**Figure 2**). Likewise, the maximum resultant displacement of **1.211 mm** is sufficiently small and remains within the acceptable design tolerance

Conversely, the maximum von Mises stress reached **374.421 MPa**, exceeding the material's yield strength of **351.571 MPa**, indicating the possibility of localized plastic deformation (**Figure 4**). This observation is consistent with the minimum factor of safety of **0.939**, which is below the recommended safe value of 1.0, suggesting the presence of a critical region susceptible to structural failure under the full design load. The exceptionally high maximum FOS value results from regions of the frame subjected to negligible stresses

Overall, the simulation demonstrates that the majority of the frame structure operates safely under the applied loading conditions. However, localized stress concentrations require structural reinforcement. This improvement can be achieved by increasing the dimensions of the structural members or installing reinforcing plates at critical locations to achieve a recommended factor of safety of at least **1.5**, which is commonly adopted for general mechanical design.

3.4. Machine Specifications

The specifications of the developed coconut husk shredding machine are presented in **Table 3**.

Table 3. Specifications of the Coconut Husk Shredding Machine

Component	Parameter	Value
Machine dimensions	Length	130 cm
	Width	80 cm
	Height	100 cm

Cutting blade	Length	16 cm
	Width	3.5 cm
	Thickness	1 cm
	Blade spacing	5 cm
Three-phase motor	Type	Y2-8024
	Voltage	220/380 V
	Frequency	50 Hz
	Current	2.01 A
	Speed	1400 rpm

3.5. Experimental Testing

The machine was experimentally evaluated using approximately **3 kg** of dried coconut husks under three operating frequencies: **15 Hz**, **30 Hz**, and **50 Hz**. The testing procedure began with an inspection of bolt tightness and motor connections, followed by a no-load test to ensure smooth shaft and cutting drum rotation. Subsequently, loaded tests were conducted while observing machine vibration and the quality of the shredded fiber. The testing process is illustrated in **Figure 6**, whereas the resulting cocofiber is shown in **Figure 7**. The experimental results are summarized in **Table 4**.

Table 4. Experimental Results under Different Frequency Variations

No.	Frequency (Hz)	Speed (rpm)	Mass (kg)	Time (min)	Capacity (kg/h)	Shredding Quality	Remarks
1	15	420	3	1	180	Coarse and uneven	Blade speed too low
2	30	840	3	1	180	Fine and uniform	Best overall performance
3	50	1400	3	1	180	Faster but slightly coarse	Additional vibration damping required

The experimental results demonstrate that at **15 Hz**, the blade rotational speed was relatively low, producing coarse and non-uniform shredded fibers. Increasing the operating frequency to **30 Hz** significantly improved the quality of the shredded material, resulting in finer and more homogeneous cocofiber. At **50 Hz**, the shredding process became considerably faster; however, the resulting fibers were relatively coarser, and machine vibration increased noticeably, indicating the need for additional vibration damping. Consequently, an operating frequency of **30 Hz** represents the optimum condition, providing the best balance between shredding quality and machine stability. Although the theoretical processing capacity remained constant at **180 kg/h** for all frequency settings because the same sample mass and processing time were used, the quality of the shredded fibers was strongly influenced by blade rotational speed.

3.6. Evaluation and Improvements

Based on the experimental findings, several improvements are recommended. First, the cutting blades should be sharpened periodically, particularly when operating at high rotational speeds, to maintain consistent shredding quality and produce finer cocofiber. Second, machine vibration experienced during operation can be reduced by installing rubber vibration isolators beneath each of the four machine legs, thereby improving operational stability. Finally, to enhance operator safety, protective guards should be installed around the exposed belt and pulley transmission system to minimize the risk of accidental contact during machine operation.

CONCLUSION (Palatino Linotype 11, Space 1.15, Justify)

The designed and constructed coconut coir shredding machine performs effectively in line with the research objectives. It is capable of shredding coconut coir into fiber at a rate of up to 180 kg/hour. Testing across three frequency variations revealed that the machine operates most optimally at 30 Hz, producing a fine and uniform output. Static simulation of the frame indicates a maximum stress of 374.421 MPa and a minimum factor of safety of 0.939, suggesting a need for reinforcement at critical points of the frame. Overall, the machine proves to accelerate and simplify the coconut coir processing workflow and holds the potential to create new business opportunities for the community in Bahodopi District

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