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Design and Fabrication of an Innovative Rattan Splitting Machine for Efficient and Sustainable Production of High-Quality Rattan Material

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Abstract

This research was conducted to address the limitations of the traditional rattan splitting process, which had been time-consuming, labour-intensive, and heavily reliant on manual labour to produce thin strips for furniture and handicrafts. To improve productivity and alleviate physical strain on workers, a fully mechanical rattan splitting machine was developed and tested, purposely designed without modern technology that could be unfamiliar to the labour force. The machine was built with a durable blade system that precisely split rattan into thin, uniform strips, ensuring consistent, and high-quality results. Its compact and adaptable design included adjustable settings to accommodate different rattan sizes and thicknesses, powered by electricity for straightforward operation and maintenance. Research involved meticulous engineering design, material selection, prototype construction, and performance testing to measure efficiency, precision, and consistency in output quality. Key findings revealed significant reductions in manual labour requirements, increased production speed, and uniform quality in processed rattan strips. These results indicated that the machine had greatly enhanced productivity within the rattan industry, enabling larger-scale production with consistent quality. In conclusion, the mechanical rattan splitting machine provided a practical and efficient solution for the industry, transforming a labour-intensive process into a streamlined operation that increased productivity, lowered labour costs, and maintained product standards. This development represents a significant advancement for the rattan industry, offering a sustainable solution that meets the current capabilities of the workforce while supporting industry growth and modernization.

1. Introduction

The rattan industry has been an integral part of Sri Lanka's cultural and economic heritage. For centuries, artisans have crafted a variety of rattan products, from furniture and jewelry to baskets and stairs. The historical importance of rattan production is particularly prominent in rural communities like Weveldenia, Wevelduwa, and Wevelpanawa, where local livelihoods have long depended on this trade. However, in recent years, the industry has encountered numerous challenges. Declining support, resource limitations, and a shift of skilled workers to

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other sectors have constrained growth, leading to a decline in the production of quality rattan goods. This downturn not only threatens the livelihoods of families dependent on rattan but also affects Sri Lanka's competitiveness in the global market. [1]

Revitalizing the rattan industry is essential for the economic stability of many Sri Lankan communities, requiring a blend of marketing, government backing, and technological innovation. Modernizing production through machinery can enhance efficiency, elevate product quality, and reduce dependence on outdated manual techniques. Additionally, promoting rattan as an eco-friendly substitute for plastic could increase demand. These modernization efforts are critical: revitalizing the rattan industry would improve profitability and create sustainable employment in rural regions [2].

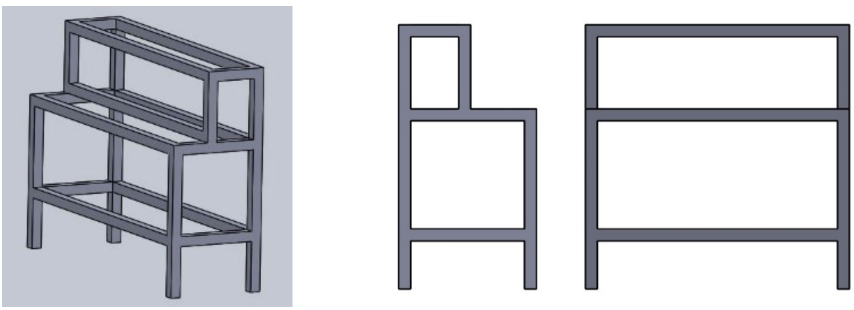
Our research focuses on a key challenge in rattan production—rattan splitting. Traditionally, this labor-intensive, manual task has been inefficient, wasteful, and posed safety risks. In collaboration with CINEC Engineering and initiated by the Ministry of Small and Medium Enterprises, our research seeks to design a mechanical solution for automated rattan splitting. By tackling this bottleneck, the study aims to improve production efficiency, enhance worker safety, and support the industry's revival.

The development of a mechanical rattan splitting machine aims to address the industry's pressing needs. This research proposes a practical, cost-effective solution to enhance the splitting process, boost worker safety, and contribute to the rattan industry's long-term sustainability. Through the application of engineering principles and technology, this study aspires to lay the groundwork for a more sustainable and prosperous future for Sri Lanka's rattan sector.

2. Research Methodology

The methodology for the design and development of the rattan splitting machine followed a structured approach to ensure that the project objectives were met effectively. The research process was divided into several phases:

2.1 Frame Design



(a) (b)

Fig. 1 *(a) Frame Design; (b) Side and front view design*

The frame structure, designed as an A-frame, was engineered for stability and strength to support the machine under operational loads. Comprising beams, columns, and slabs, it provided the necessary structural integrity to hold the machine's components, including the pulling area, cutting system, pushing area, and motor. This moment-resisting frame was chosen for its strength and cost-effectiveness, with each component carefully calculated for shear stresses, bending moments, and center of gravity. Support bars were added to the floor stand to prevent tipping, and a larger base was implemented for further stability shown in Fig,1. Structural analysis ensured the frame's safety and durability, meeting all required specifications. [3] [4].

2.2 Pushing, Pulling Systems, Stick Inner and Cutter System

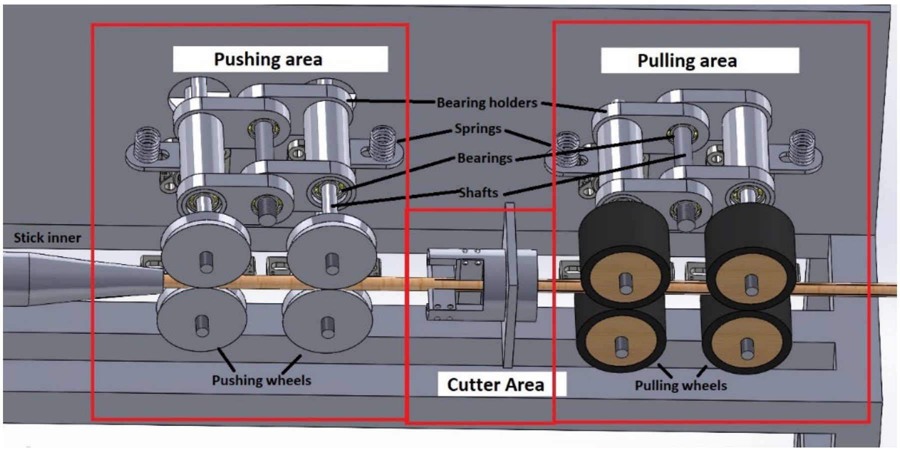


Fig. 2 *Pushing, pulling systems, stick inner and cutter system*

The rattan splitting machine integrates pushing, pulling, stick inner, and cutter systems to ensure efficient and precise material processing. The pushing system uses V-cut wheels, roller bearings, and adjustable springs to feed rattan sticks toward the cutter with steady pressure, adapting to various stick diameters via an adjustable bearing shaft. The pulling system, positioned after the cutter, consists of motor-driven, rubber-coated wheels and a vibration-reduction catching mechanism. It maintains consistent extraction speed and minimizes material damage through controlled spring force. The stick inner mechanism involves manually inserting the rattan between upper and lower wheels, where the adaptable upper wheel ensures firm engagement regardless of stick size. The cutter system features a wedge-shaped stainless-steel blade secured by a guide plate and holder, splitting sticks into four or six parts depending on the cutter configuration. Structural designs prioritize strength, replace ability, and safety, supported by optimized shaft types, bearing brackets, and flange-mounted assemblies. SolidWorks simulation tools were used to analyze the overall structural stability and performance under load conditions. However, detailed stress and durability analysis specifically for critical components, such as the push and pull rollers, was not conducted and will be considered for future design improvements to further enhance machine reliability.

2.3 Power transmission and Motor System

2.3.1 Power Transmission Selection and System

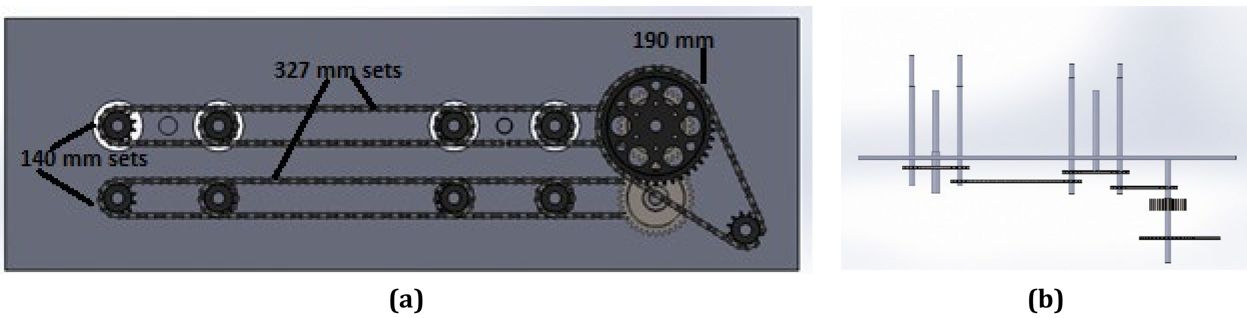


Fig. 3 *Cahin spocket & gearing system (a) Front view; (b) Top view*

To enhance efficiency and affordability, the rattan splitting machine utilizes a single motor driving a sprocket and chain transmission system. Sprockets, sourced locally, enabled low-cost, long-distance power transfer compared to gears, which would have increased complexity and cost. The system powers eight primary shafts through small and large sprockets connected by a #35 chain Fig.3. Specific sprocket assemblies (140mm, 327mm, and 190mm) ensure smooth operation and torque optimization. For motor-to-sprocket transmission, bevel gears were selected for 90-degree torque transfer with high load capacity. Additionally, spur gears connected the motor to pushing shafts, supporting efficient, low-noise, and reliable performance.

2.3.2 Motor Selection and Connection

To minimize vibration in the rattan splitter, the motor was connected to the machine in a way that avoided coupling the motor's rotation directly to the wheel. This method helped to reduce overall machine vibration during operation. Instead, the motor was attached directly to the wheel's rotation, minimizing negative effects on performance while ensuring efficiency. High-quality machine parts were selected for durability and reliability, ultimately enhancing the longevity and cost-effectiveness of the rattan splitter. This approach contributed to a more efficient and affordable design with minimal adverse effects on machine performance.

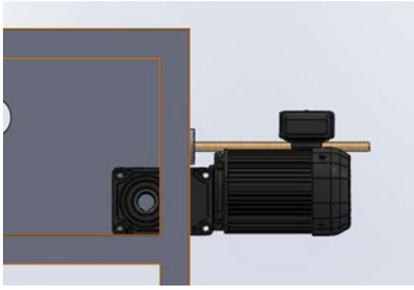


Fig. 4 *Motor connected to the machine*

Table 1 *Motor comparison*

Feature	AC Motors	DC Motors
Power Source	Alternating current (AC)	Direct current (DC)
Power Transfer	Slip rings and brushes to transfer power to rotor	Commutator to transfer power to rotor
Cost	Less expensive	More expensive
Size and Weight	Typically larger and heavier	Smaller and lighter
Speed Regulation	Requires external control circuit	Provides constant torque regardless of speed
Torque Characteristics	High torque at high speeds	Higher torque at low speeds but reduced at high speeds
Typical Applications	High-power applications (e.g., industrial machines)	Small to medium power applications (e.g., power tools)

AC motors were chosen for the rattan splitting machine due to their efficiency, longer lifespan, and lower maintenance needs compared to DC motors. AC motors provide continuous power and are more cost-effective for high-power applications. They also require less maintenance over time, which contributes to overall reliability and durability [5].

Table 2 *AC motor type comparison*

Feature	Synchronous Motor	AC Cumulative Motor	Induction Motor
Operation Principle	Magnetic field synchronized with the rotating magnet	The current flowing through the rotor is cumulative	The current flowing through the rotor is induced
Speed Stability	High	Low to medium	Medium to high
Starting Torque	Medium to high	High	Medium
Power Factor	High	Medium to high	Medium to high
Efficiency	High	Medium to high	Medium to high
Complexity	Complex	Simple	Simple
Cost	High	Medium	Low to medium

After comparing the three motor types, the decision was made to use an Induction Motor for the rattan splitting machine. While synchronous motors offer higher efficiency and power factor, they are more complex and expensive due to the additional equipment required for their operation. Cumulative motors, while simple, have a limited speed range and are not ideal for variable speed applications. In contrast, induction motors are reliable, cost-effective, and capable of handling variable speeds without requiring external excitation, making them the most suitable choice for this application [6].

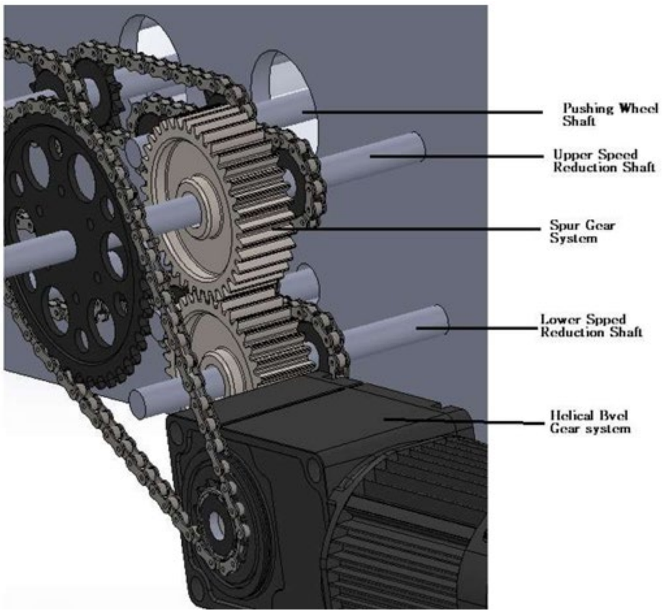


Fig. 5 *Motor connected with sprockets*

2.3.3 Electrical System Design

The electrical system of the rattan splitting machine was designed for efficiency, reliability, and safety in industrial environments. Power requirements for the motor and auxiliary devices were calculated to match operational loads, with voltage and current ratings optimized accordingly [7]. Safety features included proper grounding, overload protection, and the integration of fuses and circuit breakers, ensuring compliance with electrical codes. A modular control system was implemented to simplify maintenance. Copper wiring with high-grade insulation was used, and all connections were securely fastened and clearly labeled. Cable ties maintained wiring alignment, minimizing wear and facilitating easy inspection and troubleshooting.

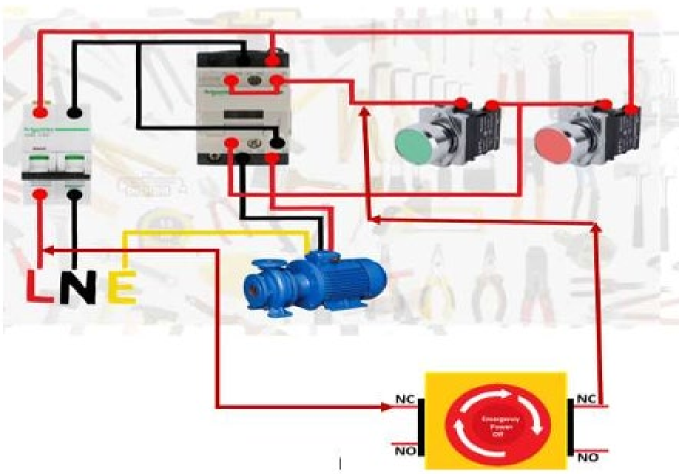


Fig. 6 *Electrical system design*

This design ensures that the electrical system is efficient, reliable, and safe for both operators and the machine itself Fig. 6.

2.4 Calculations for Machine Design

Using the data from the research, detailed calculations were performed to determine the key parameters necessary for the machine's design. These calculations included RPMs, Gear ratios and also forces involved in rattan splitting, stress distribution, and material strength, which informed the selection of suitable components and design features.

2.4.1 RPM and Torque Calculations

Rattan sticks are strong but flexible sticks. Then we cannot use rattan machine high speed. Then machine cannot work high RPM. First measured using ruler and measured assumption speed to the process. Using two distances marked specific length and measured the suitable time using clock.
Then calculated velocity V,

$$V = \frac{moved\ Length}{Time\ duration} \tag{1}$$

Then calculated RPM of pushing and Pulling Wheels,

$$RPM\ (Wheels) = \frac{V * 60}{(2 * \pi * r)} \tag{2}$$

V- Velocity measured
π - Constant
r - The radius of the pushing and pulling wheels.
60 - Used to convert the result from revolutions per second to revolutions per minute.

Then calculated,
The formula for the force of friction (Ff) between two surfaces in contact is:

$$Ff = \mu * N \tag{3}$$

μ - The coefficient of friction, the properties of the two surfaces in contact
N - The normal force, the force exerted perpendicular to the surface of contact

But,

$$N = mg \tag{4}$$

Then calculated m using vertical Force,

$$m = \frac{F}{g} \tag{5}$$

F - Vertical force want machine to work

Then calculated Torque of wheels want,

$$\tau = r \times Ff \times sin(\theta) \tag{6}$$

r - r is the radius of the object in meters

The force of friction is acting at a perpendicular distance from the center of rotation,

$$\tau = r \times Ff \tag{7}$$

Then added 20% safety factor.

Gear Train Speed reduction Calculations
This machine want to reduce speed of induction motor with high Torque,
The used to calculate RPM reduction,

$$N1T1 = N2T2 \tag{8}$$

N_1 – Driven Gear RPM
N_2 – Drive Gear RPM
T_1 – Number of teeth driven gear
T_2 – Number of Teeth of Drive Gear

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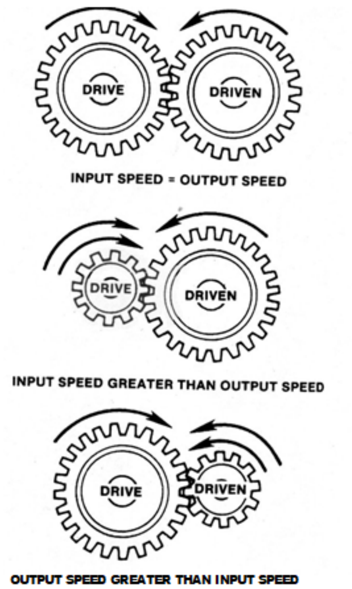


Fig. 7 *Speed variation of gears*

Used that to calculate bevel gear calculations.
The efficiency (η) of a gear system calculate,

$$\eta = \frac{Pout}{Pin} x\ 100\% \tag{9}$$

Then,

$$Pout = \tau out * \omega out \quad and\ Pin = \tau in * \omega in \tag{10}$$

Used,

$$\eta = (\tau out * \omega out)\ /\ (\tau in * \omega in) * 100\% \tag{11}$$

But actual data can difference with friction losses and vibrations. And can consider best ratios of gear wheels with type.

2.4.2 Chain Sprocket Calculations

Calculations for chain sprockets depend on the number of teeth on the sprocket, the pitch of the chain, and the center-to-center distance between the sprockets.
Pitch diameter (Dp) of the sprocket:

$$Dp = \frac{N\ x\ P}{\pi} \tag{12}$$

N - Number of teeth on the sprocket
P - The pitch of the chain

Center to center distance (C) between two sprockets: Used to system design,

$$C = (N1 + N2)\ x\ P\ /\ 2(SF) \tag{13}$$

SF is the sprocket factor (a table of sprocket factors is available from chain manufacturers)
Speed ratio (SR) of the sprocket system: calculated to reduce speed,

$$SR = N2\ /\ N1 \tag{14}$$

Chain length (CL) required for the sprocket system: Used that to measure chain lengths of system.

$$CL = (C\ /\ P) + ((N1 + N2)\ /\ 2) + (2\ x\ K) \tag{15}$$

C - center-to-center distance between the two sprockets in millimeters
P - The pitch of the chain in millimeters
K - Constant (a table of chain constants is available from chain manufacturers)

2.5 Research on Existing Technology and Simulation Software

The development approach for the rattan splitting machine included a detailed study of existing technologies used in similar machines. The team researched mechanical components like gear wheels, roller bearings, springs, electric motors, and shafts. They also considered important physical principles, such as center of gravity and stress distribution, which are critical for machine stability and performance. Academic papers, technical reports, and manufacturer data were reviewed to choose the best technologies for the design. SolidWorks software was used to model and simulate the machine's structure and operation. This helped test the design virtually under different working conditions, allowing the team to find and fix potential problems like stress points or weak areas before making a physical prototype. Simulations of parts like pipes and gears ensured that the design could handle the expected forces. By analyzing simulation results and making improvements, the team created a final design that was efficient, safe, and ready for cost-effective production.

2.5.1 Design Considerations

The design phase involved a detailed investigation into the rattan splitting machine's internal components, focusing on the pushing area and gear wheel system Fig. 8. CAD software was used to create initial designs, explore configurations, and refine the layout, ensuring efficiency, cost-effectiveness, and user-friendly features for workers with varying skill levels.

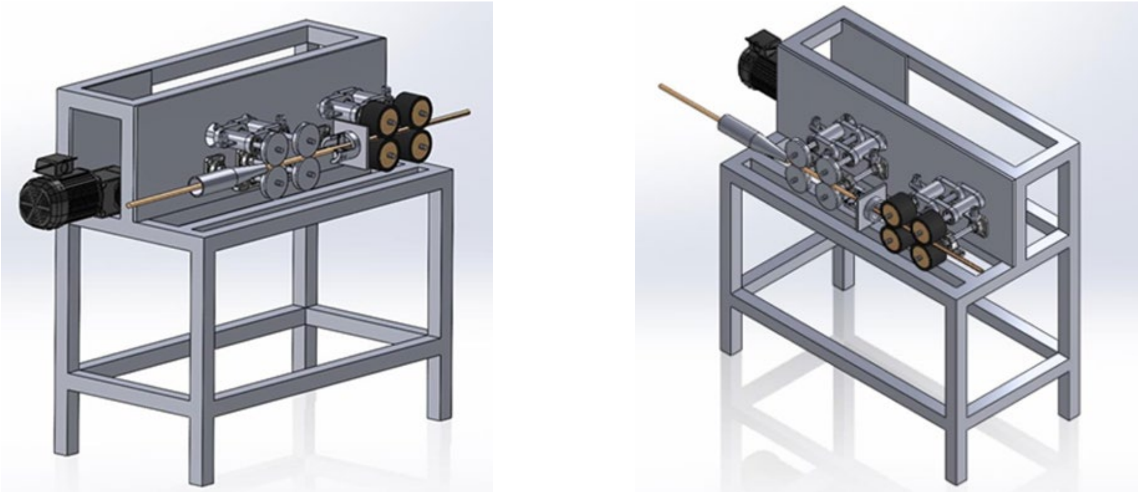


Fig. 8 *CAD design of rattan machine*

The first design sketches aimed at creating a durable structure to withstand the mechanical stresses of rattan splitting. These initial designs were iteratively refined through team discussions and simulation feedback, culminating in a final design that met all project requirements. This systematic approach ensured the final product addressed technical and operational challenges, improving productivity and safety in the rattan industry.

2.5.2 Simulation Summary

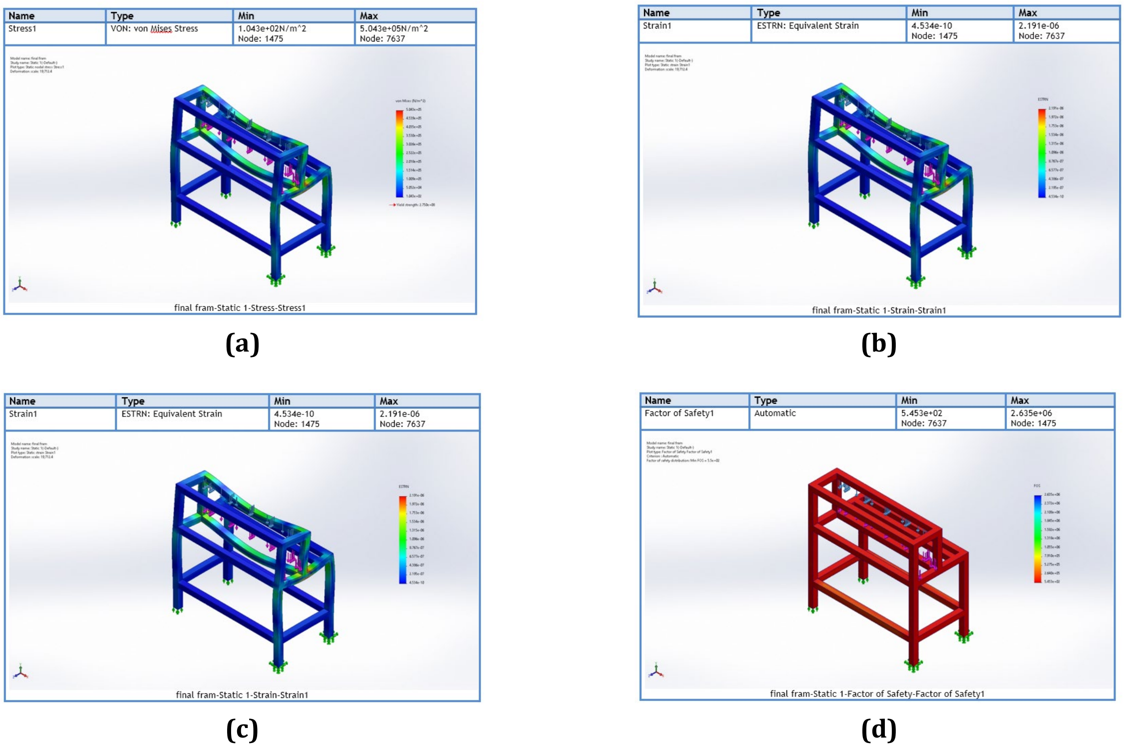


Fig. 9 *(a) Stress simulation; (b) Strain simulation; (c) Displacement simulation; (d) Safety factor simulation*

The simulation of the rattan splitting machine confirmed excellent mechanical performance and safety. The dominant force recorded was 300.008 N in the Y direction, ensuring stable operation. Reaction moments were negligible, indicating well-balanced structural dynamics. Stress analysis showed von Mises stress ranging from 104.3 N/m² to 504,300 N/m², with critical points at nodes 1475 and 7637 Fig.9(a). Strain analysis revealed minimal deformation, with strains from 4.534e-10 to 2.191e-06 Fig.9(b). Displacement was very low, with a maximum shift of 5.831e-03 mm Fig.9(c). The factor of safety ranged between 545.3 and 2,635,000, confirming the machine's high reliability and safe operational performance Fig.9(d).

2.6 Material Selections

The materials required for the construction of the machine were carefully chosen based on their mechanical properties, availability, and cost-effectiveness. Materials such as high-strength steel for the frame and durable polymers for specific components were selected to ensure the machine's longevity and reliability.

Blade Material: High-carbon steel or tungsten carbide for durability and edge retention, ensuring effective and long-lasting cutting with minimal maintenance.
Frame Material: Mild steel or aluminium box bars for a balance of strength, lightweight properties, and ease of maneuverability, providing structural stability while maintaining portability.
Box Bars: Chosen for their availability, low cost, and strength, ideal for small-scale industries.

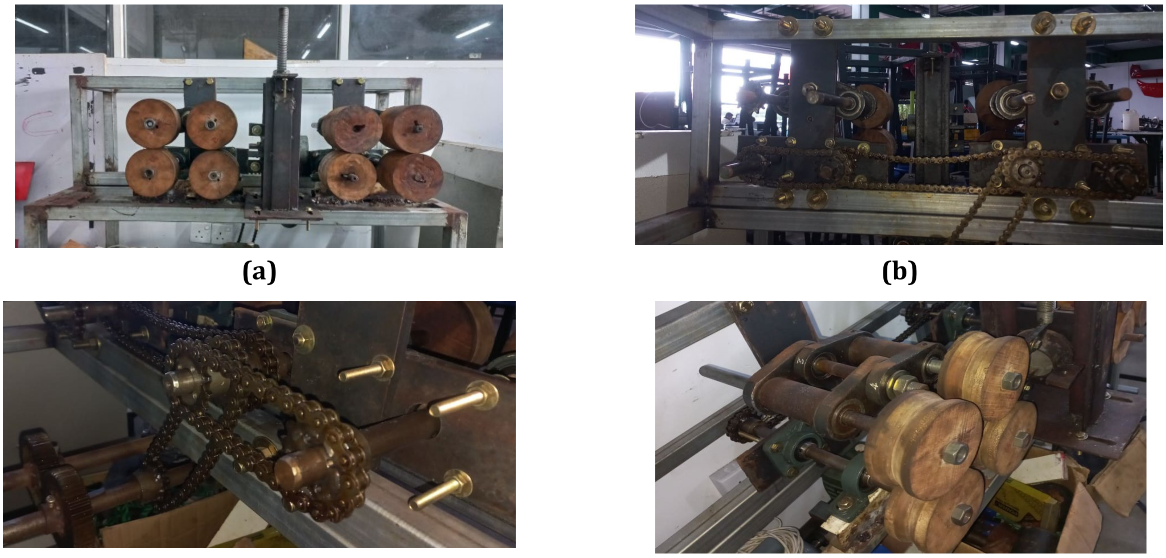
Table 3 *Bar types comparison*

	Box Bar	L Bar	T Bar
Strenght	Average	High	High
Cost	Low	High	High
Weight	Low	High	High
Availability	High	Average	Low
Material	Galvanized Iron	Mild Steel	Mild Steel

Box Bars: Chosen for their availability, low cost, and strength, ideal for small-scale industries.
Compression Springs: Alloy steel for superior fatigue resistance, ensuring durability under repeated loading.
Shaft Material: Medium carbon steel (AISI 1045) for its strength, toughness, and wear resistance in power transmission components.
Motor Housing: Cast iron or aluminium for durability and vibration resistance, with aluminium reducing weight for better handling.
Protective Coatings: Powder coating or galvanization to prevent rust and corrosion, ensuring long-term machine performance in humid environments.

2.7 Fabrication

Once the design and materials were finalized, the fabrication phase began. This involved sourcing materials, manufacturing components, and assembling the machine. Each part was tested during the fabrication process to ensure that it met the required specifications.



(a) **(b)** **(c)** **(d)**

Fig. 10 *(a) Front view of fabrication; (b) Sprocket and gear system; (c) Closed image in sprocket system; (d) Fabricated pushing system*

3. Results and Discussion

A 1 HP motor with an initial speed of 1500 RPM was used, with an estimated reduction to 1300 RPM when accounting for the machine load. Calculations were conducted with an assumed velocity of 0.25 m/s, targeting an optimal wheel speed of 60 RPM for the pushing wheels. The speed was effectively reduced by a 4:1 ratio using a helical bevel gear system, followed by an additional 4:1 reduction via a chain system. This configuration was later adjusted to a final speed of 65 RPM due to the replacement of the sprocket wheel, allowing for improved efficiency. Bajaj Platina gear wheels were incorporated to ensure compatibility and enhance the overall durability of the system.

3.1 Manual Testing

A preliminary time study was conducted to evaluate the duration required for manual rattan splitting. In this assessment, each operator was assigned to split ten 3-meter-long rattan sticks, resulting in a total of twenty sticks processed by two operators. Only the active splitting times were recorded, excluding any idle or setup periods. The choice to use two operators was made based on project scope, available resources, and to establish a basic benchmark for comparison with the proposed automated system. However, it is acknowledged that this limited sample size restricts the generalizability of the findings. Future studies are recommended to incorporate a statistically determined number of participants to improve the reliability and validity of the time efficiency analysis. (Only calculated the times of splitting. Not consider free times.)

Table 4 *Manual 3m stick splitting times*

Stick Number	Time (seconds) Person 01	Time (seconds) Person 02
1	109.4	102.3
2	99.5	106.2
3	108.3	103.7
4	99.7	102.6
5	103.1	103.7
6	102.9	98.6
7	108.6	106.8
8	99.9	102.8
9	106	107.3
10	103.6	101.1

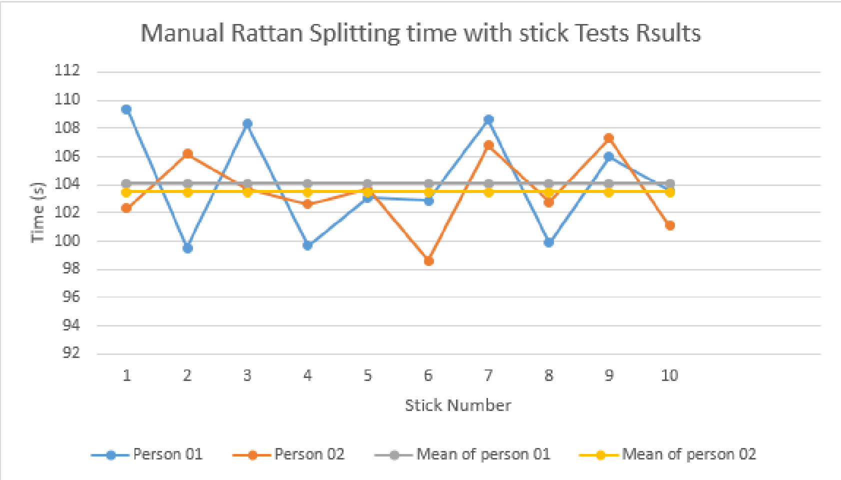


Fig. 11 *Manual rattan splitting time with stick tests results*

3.2 Machine Testing

Several specific factors were considered in the calculations: rattan sticks of nearly equal diameter were selected, all sticks were cut to a uniform length of 3 meters, and a sharp, identical blade type was used with the machine. Two skilled workers operated the machine, and the same timer was employed consistently across tests. Following these preparations, three tests were conducted with the machine, each using ten 3-meter sticks, and the results were recorded.

3.2.1 Machine Tests

Table 5 *Test number 01, 02, 03 results with machine*

Stick Number	Test number 1	Test number 2	Test number 3
	Time (Seconds)	Time (Seconds)	Time (Seconds)
1	12.3	12.8	13.3
2	12.6	14.3	12.5
3	13.1	15.1	15.1
4	12.7	12.9	14.9
5	14.6	14.1	13.6
6	14.3	12.7	13.9
7	13.2	15.3	12.7
8	14.3	12.5	12.2
9	13.5	13.9	14.1
10	12.8	12.6	13.1

For these three tests, specific factors were considered to align with the manual tests: rattan sticks with nearly equal diameters to those in the manual test were selected, all sticks were cut to a consistent length of 3 meters, and the same type of sharp blade used in the manual process was applied. Additionally, the same timer was used for accurate time measurement across all tests.

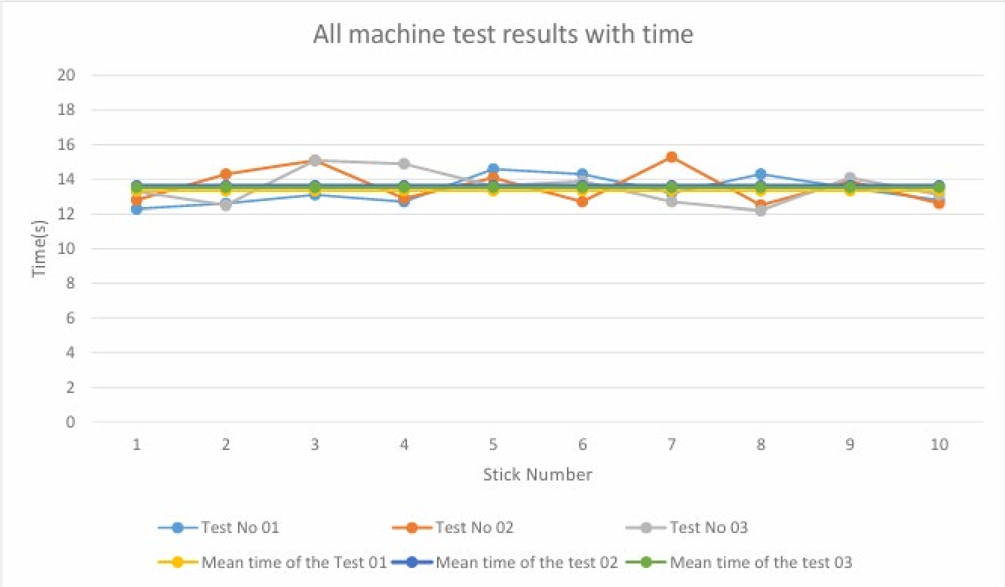


Fig. 12 *All machine test results with time*

3.3 Comparison Tables or Manual and Machine Results

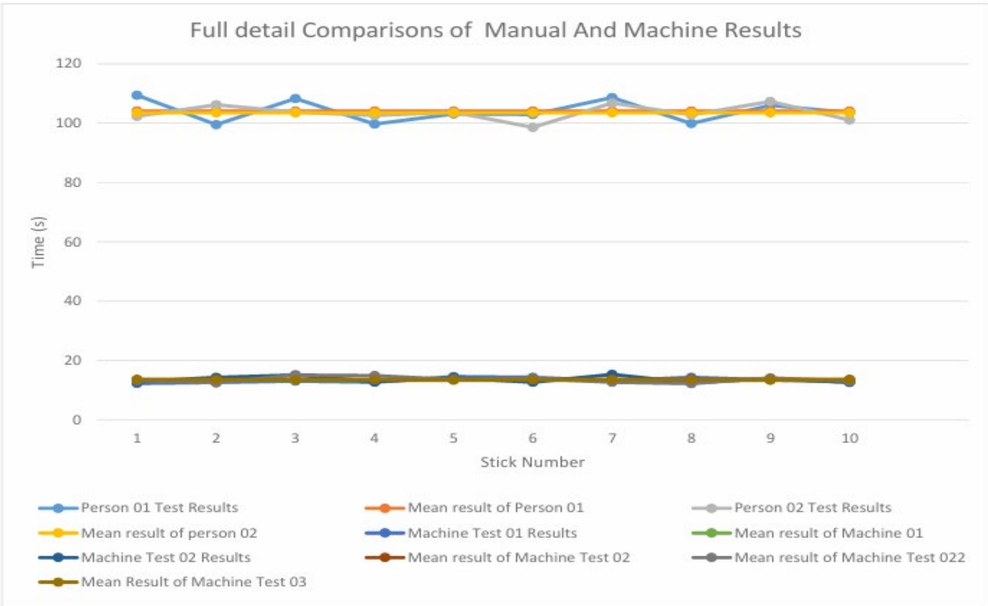


Fig. 13 *Full details comparisons of manual and machine results*

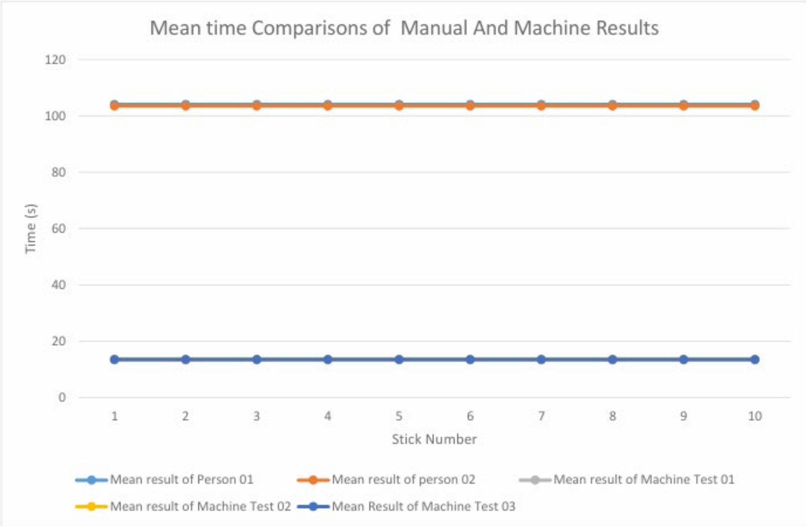


Fig. 14 *Mean time comparisons of manual and machine results*

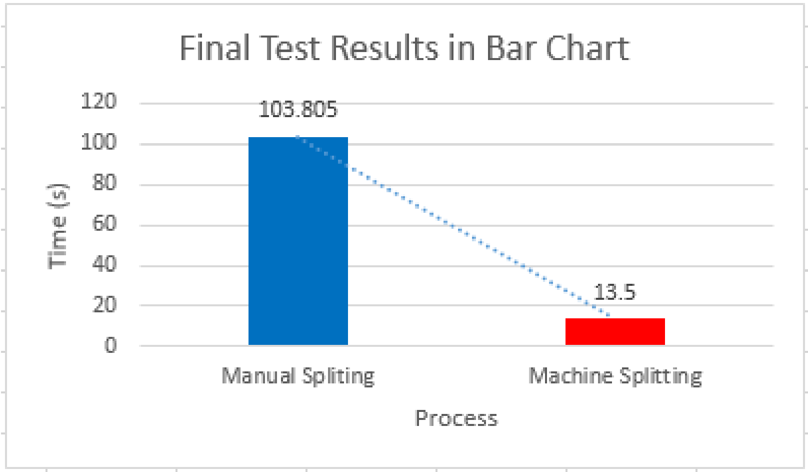


Fig. 15 *Final mean results in bar chart*

4. Discussion

After careful analysis, it is clear that there are significant differences between manual and machine rattan splitting. We employed two skilled individuals using the same equipment and rattan sticks for manual splitting. The mean times obtained were 104.1 seconds and 103.51, indicating that manual rattan splitting of a 3-meter stick takes nearly 2 minutes.

On the other hand, the mean times obtained using the machine were 13.34, 13.62, and 13.54, which is approximately 15 seconds. This means that the ratio of the manual to machine process is nearly 104:14, indicating a reduction in time by more than 7 times when using the machine.

Fig. 10 and fig. 12 show high variation from the mean times when using human power, as individuals can become tired and change their positions frequently, causing many variations from the mean times. However, when considering Fig. 11 and 12 the variation from the mean line is much lower than the manual process, indicating that the splitting process can be more efficient than manual splitting.

Upon analysis of the process, some small variations were observed in the machine splitting process, which could be due to machine vibration, stick hardness, outer surface of the rattan stick, or machine friction. Although stick variations cannot be changed, specific steps can be taken to reduce machine reasons, such as adding lubricants to gear and sprockets, using rubber bush to the frame down, etc.

Fig.12 and 13 clearly shows the differences between time and variation of times. By using this machine, we can speed up our production by more than 7 times and reduce the use of human power in the process. Moreover, machine-splited sticks are smoother than manually split sticks, as they work with the same RPM and low speed, ensuring that the sticks are safely split into pieces. In contrast, manually split sticks do not use the same speed, resulting in a harder surface than machine-splitted sticks.

Another advantage of using the machine is the safety of the user. Many individuals who split sticks by hand and blade have cut sketches on their palms. However, the machine does not touch the blade at any time during use and has a safety switch.

5. Conclusion

The rattan splitting machine is a complex and efficient system that utilizes several key components to achieve the desired output. The moment resisting frame design was selected due to its ability to simplify the design, maintain high strength, and meet budget constraints. The design fulfills all requirements for the machine, including shear stresses, bending moments, center of gravities, and displacements, and structural analyzing calculations were carried out to ensure the design can withstand expected loads and stresses, providing a safe and reliable structure for the machine. Stick welding was utilized to connect the frame components due to its strength and durability.

The cutting, pulling, and pushing areas facilitate the process of safely extracting the split rattan from the cutter and ensuring consistent splitting. The pulling area is equipped with two wooden wheels with rubber coating to ensure proper grip and smooth movement of the rattan stick. The rotational force required for the wheel system is provided by an electric motor connected to a gear system. The gear wheel and chain sprocket system allow for the rotational speed to be adjusted to control the velocity of the rattan stick through the pulling and pushing areas.

The electrical motor provides efficient and reliable power to the system, minimizing energy usage and reducing costs. The electrical system includes on-off switches, safety switches, a wiring system, and contactor, ensuring the safety of the user and the machine. The use of modular components and the implementation of a maintenance schedule and procedures will keep the electrical system in good working order.

The design of the machine ensures low cost and good electric efficiency, making it an economically and environmentally sustainable option for rattan splitting. The machine is a valuable addition to any rattan processing facility, providing a safe, reliable, and sustainable rattan splitting process.

6. Declarations

6.1 Study Limitations

The sudy encountered several limitations that could influence the research outcomes:

- *Budgetary Constraints*: The machine design was repeatedly adjusted to remain affordable for rattan manufacturers, who may have limited budgets, potentially impacting the choice of materials and features.
- *Technological Constraints*: Since many Sri Lankan producers are unfamiliar with advanced technologies (e.g., mechatronics, Arduino, PLC), the machine was designed with simpler mechanisms to ensure accessibility and ease of use.
- *Size and Weight Constraints*: Indoor production environments in Sri Lankan rattan factories necessitated a compact, scaled-down machine design, potentially limiting production capacity and efficiency.
- *Parts, Materials, and Maintenance*: To make the machine durable and affordable, materials and components were selected with low-cost maintenance in mind, and design adjustments were made to simplify upkeep.

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Author Contribution

The study conception and design were performed by A.L.S.S. Wijewickrama and Ishan Virantha. ***Data collection was carried out by A.L.S.S.****: Wijewickrama, Lakshitha Kalhara, Deshan M. Silva, and Shanilka Abewardhana.* ***Analysis and interpretation of the results were conducted by A.L.S.S.:*** *Wijewickrama, Ishan Virantha, and Lakshitha Kalhara.* ***The draft manuscript was prepared by A.L.S.S.****: Wijewickrama. All authors reviewed the results and approved the final version of the manuscript.*

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