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SOLIDWORKS™ Design, fabrication and performance analysis of a banana fiber extraction machine and its components

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K E Y W O R D S

Fiber Extraction

Banana Fiber

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Design Analysis

Sustainability

A B S T R A C T

Banana cultivation is a prominent agricultural activity in Pakistan, particularly in the lower Sindh districts such as Tando Muhammad Khan, Hyderabad, Sanghar, and Mirpur Khas. Each banana plant bears fruit only once in its lifetime, resulting in a significant amount of waste biomass from the pseudo stems after harvest. Utilizing these waste stems can enhance environmental sustainability and increase economic benefits for farmers. Traditional methods of extracting banana Fiber are plagued by inefficiencies, including lengthy processing times and subpar Fiber quality. This study possesses the design and development of a mechanized solution to extract high quality banana Fiber efficiently. The process encompasses the selection of suitable material, detailed design, mathematical analysis, and the assembly of machine components, aiming to address the shortcomings of conventional extraction methods. The performance analysis was conducted for the machine successfully handled banana stems up to 155mm in width and 22mm in thickness, demonstrating its robust capacity and versatility in processing various sizes. The positive simulation results provide a theoretical validation of the design before physical testing, suggesting the machine components are well designed and capable of enduring typical operational stresses. This study addressed Sustainable development goal 8 Decent work and economic growth, 9 industry innovation and infrastructure, 12 Responsible consumption and production and 13 climate action.

1. Nomenclature

b	Width
d1	Diameter of driver pulley
d2	Diameter of follower pulley
E	Modulus of elasticity
F	Force
F	Stripping force.
I	Moment of Inertia.
N1	Speed of driver in rpm
N2	Speed of follower in rpm
P	Wanted Power
r	Radius
r2	Radius of small pulley
r1	Radius of larger pulley.
t	Thickness
T	Maximum tension
Tc	Centrifugal tension.
T1	Tension in stiff side
T2	Tension in slacken side
V	Velocity

X	Distance to separate two pulleys.
y	Deflection in mm.
Θ	Contact angle
σ	Maximum safe stress

2. Introduction

Recently, banana fibres have gained significant attention for use as reinforcement in thermoplastic compounds [1]. This is due to their light weight, low density, recyclability, biodegradability, and excellent mechanical properties, making them suitable for structural applications [2]. The traditional method of extracting fibres from plantain involves storing pseudo-stems in a controlled environment where anaerobic conditions and biological organisms, including bacteria and fungi, break down linen, pectin, and other substances in a conventional process [3]. Traditional methods for extracting plantain fibres typically take about 2 to 6 weeks to decompose the non-fibrous components of the pseudo-stem before the fibres can be harvested [4]. The traditional method of extracting fiber is cumbersome, prompting us to adopt a mechanical approach [5]. We have developed an electric plantain fiber extraction machine discussed in this paper that enhances the extraction rate of plantain fiber and reduces the manual labour involved [5]. This device, designed to be low cost and portable, addresses the needs of farmers and women engaged in this task[6]. The price of the machine varies with the cost of materials such as alloy steel and iron, but it offers guaranteed worker safety [7]. We recommend government subsidies for this equipment to boost exports and improve the national economy [8][4]. It could also expand the paper industry in Pakistan, particularly in the southern region of Sindh, where banana fiber paper, known for its durability of up to 700 years and use in some countries currency, could significantly benefit from this technology. The machine is equipped with 2-HP motor. It can also operate with engines in areas lacking electricity. Due to its excellent mechanical properties, the fiber is deal for enhancing composite materials and producing eco-friendly products such as mats, chemical-free handmade paper, tissues, filters, craft paper, and paper bags[9]. This paper deals with a solution of the problems discussed above in the paragraph like mechanical extraction is time consuming and laborious, so for the purpose we proposed and designed along with fabricating this machine.

2.1 Problem Statement

A banana plant produces fruit only once in its lifetime, leaving behind a substantial amount of biomass in the form of pseudo stems and branches after harvesting. Utilizing this waste material can be environmentally and economically beneficial. Currently, traditional methods for extracting fiber from these stems are inefficient, produce low-quality fiber, and contribute to environmental pollution. Currently, there is no economically feasible fiber extraction machinery available that can effectively separate high-quality fibers from banana pseudo stems.

We developed a new fiber extraction machine aimed at addressing these issues. This machine will be economically accessible, designed with operator safety in mind, and capable of producing higher quality fibers more efficiently and with greater length. The performance of this machine will be validated through comprehensive testing to ensure it meets these goals, thus empowering local communities and improving the utilizing of agricultural waste.

Fig. 1. Banana Fibers

2.2 Brief Introduction of Banana Fiber

The use of banana pseudo-stem fiber in the textile industry dates to ancient times [10]. Historical evidence suggests that the earliest documented production of cloth from banana pseudo-stem fibers occurred in Japan during the 13th century [11]. Notably, Japans currency, the yen, is made from banana fiber. Historically, these fibers were processed to achieve varying degrees of the softness and beauty, resulting in yarns and textiles tailored for specific applications [8], [12]. The fibres extracted from banana pseudo-stems were also used to make product such as carpets, ropes, floral ties [13], [14]. Today, countries like the Philippines and Japan continue to use banana pseudo-stem fibres extensively for industrial purposes [15]. As Asia’s population expands and energy consuming increases, the demand for clothing in the region is also growing [16]. Research points out that a massive amount of banana pseudostems is waste away globally each day [6], [7], [17]. A Philippines articles highlights that the Philippines has the potential to produce over 400,000 tons of these fibres annually [18], [19]. Similarly, it is estimated that the Sindh province alone could generate 250,000 tons of fibres.

2.3 Origin of Banana Fiber

A thorough examination of historical records shows that banana fiber extraction began in Japan in the 13th century [13]. The term “bahofu” in Japanese refers to a garment made from banana fiber, which embodies the true essence of Okinawa [13]. The strategic importance of Okinawa was first recognized by Japanese authorities in the 1930s. post-world war 2, during a period of economic devastation in Japan, banana fibers were instrumental in contributing to the nation’s economic resurgence [20], [21].

2.4 Banana Fibers and Its Types

The banana plant serves two main purposes: it provides delicious fruit and fibers that can be utilized in the textile industry [22]. Banana fiber is a natural, renewable resource known for its strength and disposability. Extensive global research has been concluded on the diverse applications of these fibers, which are harvested from the pseudo-stem of the banana plant [23]. These fibers posses’ mechanical properties that make them suitable for a variety of uses [24]. The height of the stem can vary between 10 and 14 feet. Banana plants are widely found across Asia, Thailand, and other tropical regions.

2.4.1 Classification of banana fiber

The fiber quality within the stem varies and is suited for different applications:

- Internal fibers (fine, smooth, and naturally lustrous): used in delicate textiles such as kimonos and sarees [25]
- Outer strands (coarse): utilized in crafting basketball nets and handbags [15]

2.5 Properties of Banana Fibre

Banana fibre, originated from pseudo trunk of the banana tree, offers a range in beneficial characteristics and diverse applications:

- Physical properties: banana fibre is appreciated for its biodegradability, moisture absorption, UV protection due to its lignin content, and light weight. Its physical and mechanical properties, such as durability, make it suitable for industrial use [22], [26]
- Chemical Properties: it is highly lignocellulosic, containing significant amount of cellulose and hemicellulose, which contribute to its strength and flexibility [2]. The fiber undergoes various treatment to enhance its chemical resistance and bonding capabilities, making it suitable for composite materials[16], [25]

Table 1

Some properties of banana fibers and their applications in several sectors of sustainability

Property	Details
Tensile Strength	Banana fibers exhibit a higher tensile strength (458MPa) and tensile modulus (17.14 GPa) compared to others natural fibers like jute and coir, making them suitable for high-strength application[27].
Biodegradability and Eco-friendliness	Banana fibers are biodegradable and eco-friendly, providing a sustainable alternative to synthetic fibers which are toxic and non-biodegradable[14], [27].
Industrial Applications	Due to their robust mechanical properties, banana fibers are using in making textiles, pulp and paper, reinforced composite materials for automobiles, construction material, and aerospace[14].
Enhancement through treatments	Alkali and enzymatic treatments improve the mechanical properties of banana fibers, enhancing their compatibility and strength in composite material[28].
Sustainability in construction	Banana fibers are used to improve the physical and mechanical properties of concrete, making it an eco-efficient construction material[29].
Potential for local industries	Banana fibers serve as low-cost alternatives for metal removal in industry effluents, suitable for the regions with limited resources[16]

Applications:

- Textile Industry: Banana fiber is used to make high-quality textiles, ropes, and other fabrics due to its strength and texture. It is also being explored for use in nonwomen textiles like sanitary pads and tea bags[2], [30].
- Environmental Applications: Due to its eco-friendly properties, banana fiber is utilized in biodegradable composites and eco-friendly packaging solutions. Its also used in automotive and construction material, reflecting its versatility and sustainability[14], [27].

Table 2

Fibers incorporation in different material type

Material Type	Tensile Strength	Application
Textile Fabric	350-700 MPa	Used in Blends for durable clothing and accessories.
Automotive Components	300-600 MPa	Incorporated in interior panels for light weighting and sustainability.
Paper Products	100-300 MPa	Enhances tear resistance in speciality papers and ecofriendly packaging
Biodegradable Composites	200-500 MPa	Strengthening bioplastics and sustainable building materials

2.6 Manual Ways to Extract Banana Fiber

Banana pseudo-stem fibers are extracted from the plant, which grows above ground and is enveloped by leaf sheaths[31]. Each sheath encases a basal leaf that contributes to forming the pseudo-stem[32]. These fibers can be manually extracted using a method known as stripping, commonly practiced in the Philippines. Alternatively, fibers can be removed using mechanical devices by retting, and chemical extraction involves boiling in a sodium hydroxide solution[23], [25], [33]. In the planting process, the stems are peeled layer by layer; the innermost layer is referred to as luxury, and the separation technique is called tuxing[18]. Fibers are individually detached through tuxing, and then cleaned with a knife and a piece of wood to remove any remaining sheath material[34].

2.6.1 Method of Japan

Since the 13th century bananas have been employed in Japan for the fabrication of textiles and assorted domestic artifacts. In Japan's method of extraction, careful attention is given to the cultivation of the plant. To fabricate yarn, the leaves and stems are subjected to boiling process in a solution known as lai to isolate the fibres. These fibres vary in softness, influencing the properties of the textiles produced. Fibers from the outer layer of the stems are thicker, making them ideal for clothing and home furnishings. Conversely, the innermost fibers are the softest and are used to craft traditional Japanese garments. The entire process is meticulously performed by hand[15], [19], [20], [23], [25], [26], [32], [35].

2.6.2 Nepali methods

In Nepal, the process of the fiber extraction involves using the plant's stems instead of its leaves. The fibers produced through this method have a silky appearance, earning them the name "banana silk fibers. "Nepali women play a significant role in refining these fibers. During the process, only the senescent outer section of the plant are harvested and subjected to aqueous immersion. Once pulp dissolves, the remaining Fibers are then hand dyed, resulting in high quality materials primarily used to craft fine carpets. These carpets are meticulously handwoven, predominantly by Nepalese women[5], [7], [8], [9], [10], [11], [12], [21], [24], [29].

2.7 Yarn Weaving and Spinning Process

In India, an institute for interdisciplinary science and technology has pioneered an advanced technique for extracting banana fibre[8], [28]. This process uses an anaerobic (oxygen-free) environment to separate the enzymes from the fiber in a reactor. After separation, the fibers are cleansed and sun-dried, resulting in a pure white fiber[1], [30], [33]. This method is touted as being cost-effective and environmentally friendly, as it avoids pollution and does damage the fibers. The traditional method of extracting moisture from banana stems involves cutting the stems into small pieces and gently rotating them to eliminate excess moisture[4], [15], [16]. This process is partly mechanical and manual but is time-consuming and can damage the fibers, making it less ideal for mechanical applications. Research has indicated that the conventional processes used for binding fiber to banana stems are too lengthy for practical application today. Instead, innovative approaches are being explored. Notably, banana fiber is considered a cost-effective alternative to cotton, suitable for a wide range of applications. Fabrics made from these fibers are lightweight, breathable due to their excellent moisture absorption, and have the potential to serve as an eco-friendly substitute for many traditional fabrics, adaptable to various climatic condition[17].

2.8 Bleaching Process

Bleaching processes are used to enhance the whiteness of fabric, utilizing a technique known as bleaching. This involves dissolving the natural pigment in banana Fibers, turning them into a colourless material. This step is crucial for removing any colour imperfections and achieving a brighter whiteness in banana fabric[32].

2.8.1 Purpose of bleach

- Remove dyeing material from white fabric while minimizing Fiber degrading
- Enhance the color brightness following dyeing or printing

- Enhance the whiteness of fibers marked as white by utilization of optical brightening agents

2.9 Dimensioning and Starch Application

The application of a protective film to the surface of yarn is referred to as sizing. The process essential for achieving optimal efficiency and is crucial in mechanical procedures[5], [12].

2.9.1 Purpose of sizing:

Sizing is a process applied when the beam is prepared, offering several benefits:

- Enhances the weave-ability of the yarn, improving aspects such as absorption [24]
- Improves fabric quality by reducing the incidence of flaws related to fiber fraying, through enhanced yarn absorption capacity[22], [33]
- Increases the strength of the yarn

2.10 Banana Fibre Decay

- Once the fibre is obtained and their primary colors removed, they are ready for dyeing. The dyes from natural sources such as pomegranates and henna plants are added to the boiling water[34]
- The fibers are then immersed in this boiling dye solution for 15 minutes to an hour, depending on the desired depth of color, after which they are washed and dried[25]
- To prepare the fibers for further processing, they are gathered and either attached to a stick or secured with clips to assist parting[2]

2.11 Natural Fibre Composites and its Mechanical Features

Natural fibers exhibit ensued utilized as reinforcing materials aimed at over three millennia. In modern application, they are increasingly being incorporated into plastics to enhance stability. Common fibers like those derived from banana peels are often used in these plastics. A significant benefit of using these natural fibers is their durability, making them ideal for creating robust polymer composites for practical application. The incorporation of these fibers into polymer matrices necessitates enhanced testing to refine design processes. Research primarily focuses on developing polymer composites, frequently employing fibres like those from banana stems, and assessing their mechanical properties such as modulus of elasticity, hardness, and tensile strength. Elasticity tests are conducted to measure the force needed to buckle the material below a three-point loading scenario. finding helps in selecting materials that can withstand specific loads without bending. Since the physical properties of these materials that can withstand specific loads without bending. Since the physical properties of these materials can vary significantly with temperature changes, it is advisable to conduct tests under conditions that mimic the actual working environment. The Rockwell hardness test measures material hardness by initially applying a small load followed by a larger one, recording the depth of indentation to Guage material resistance. Materials showing less indentation indicate higher hardness, and those with more indentation suggest lower hardness. For example, if a material shows a hardness of C58 at one point and C55 at another, this suggests a softer area with a potential indentation depth increase of 0.00024 inches. Polymer composites containing various natural fibers exhibits a range of mechanical properties. Studies have shown that polymers reinforced with natural fibers often provide superior performance compared to other composites. These materials are versatile and can be used in numerous applications, including the production of automotive chair casings and other components[1], [2], [3], [4], [14], [15], [16], [18], [21], [22], [24], [28], [29], [30], [35].

2.12 Evaluation of Mechanical Property Alterations in Banana Fibres Subjected to Treatment with Sodium Carbonate And Barium Hydroxide

The effectiveness with chemical treatment of banana fibres with sodium carbonate and barium hydroxide have been explored through various experimental iterations. Fibers of varying lengths were treated and incorporated into composites for further chemical treatment. The treated composites underwent tensile, elasticity, impact, and moisture absorption testing, revealing varied results depending on the fiber length and blend used. This allows for the optimization of fiber dimensions and chemical treatments for specific applications. Pseudo's of the banana plant is notably high in fibrous content. Several method chemicals, manual, and mechanical-are available for extracting these fibers. Among these, the mechanical method proves to be the most viable and efficient. This method not only yields fibers of high quality and quantity but is also environmentally friendly and rapid. In this mechanical extraction process, the banana plant's pseudo stem is fed into a specially designed machine that separates the fibers. After extraction, these fibers are dried in the shade for 24 hours and then stored in high-density polyethylene bags to protect them from wind and light, ensuring their longevity. Fibers derived from botanical sources offer benefits such as lower density, reduced cost, and minimal environmental impact. However, their main limitation lies in the weak interfacing among fibre and matrix network. Additionally, the massive cellulose content makes these fibers moisture sensitive. Chemical treatments can modify the surface properties of the fibers to enhance their compatibility with the polymer matrix and strengthen them, reducing moisture absorption. Banana fiber are significantly cheaper than glass fiber, costing about 75% less. Utilizing banana fibers instead of glass fibers in automobile manufacturing could reduce material cost by 61.66%. Given their high elastic strength and low moisture absorption, banana fiber-reinforced composites, particularly those enhanced with OH-2 fiber, are deemed suitable for automotive components and body shells[3], [4], [6], [7], [20], [24], [25], [26], [34], [35].

3. Methodology and Modelling of Parts

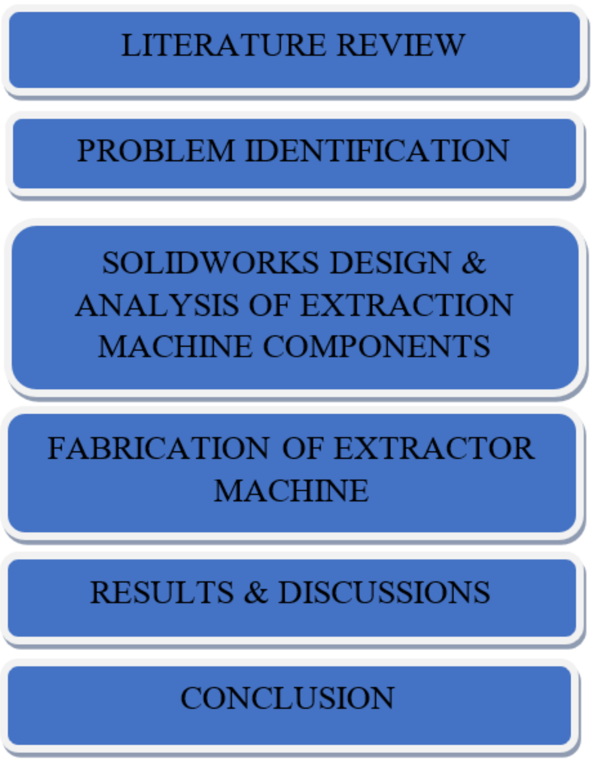


Fig. 2. Methodological Framework

3.1 Overview

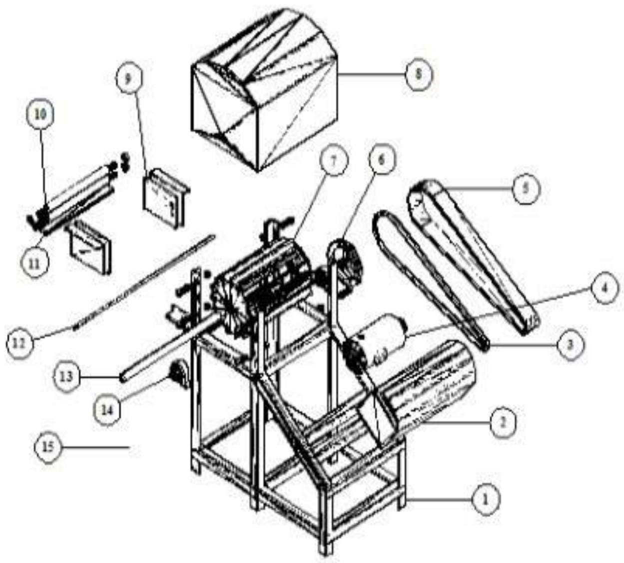
The banana fiber extraction machine optimizes the use of damaged potions of the banana plant, specifically targeting stress concentration from various sections of the banana plant and its stem. Traditional manual or semi-manual techniques for extracting fiber are inefficient and labour-intensive, often degrading the quality of the fiber[4], [12], [29], [30]. This machine is tailored for the specific needs of the banana plant growers, offering them an opportunity to enhance their income by creating additional value from their crop. Constructed mainly from iron and steel, or alloy steel, the cost of the machine may vary by location.

Features of the machine includes:

- Ensures operators safety with minimal maintenance cost during operation
- Produces fibers without synthetic additives, maintaining consistent color and quality
- Machine components are simple to manufacture and widely available in various markets
- The machine is portable, allowing easy relocation
- The lightweight fibers produced are visually appealing. These fibers are used to make banana paper, which is valued for its durability and contributes to profitable returns

3.2 Explanation of System

The motor activates the power system, which exerts force in the roller drum section. This force rotates the roller, processing the cut trunk (pseudo) in fibre strands. machines shearing force effectively breaks down the plant's ribs fed into the device, exerting greater force than that on the plantain vein tissues. Regular pulsing actions press against the rib expulsion bar, equipped with sharp edges to strip away clustered soft tissue. The drum is mounted between the bearings at the ends to minimize friction-related loss in power.



(1) Frame, (2) Motor cover, (3) Belt, (4) Motor, (5) Belt cover, (6) Pulley, (7) Roller drum, (8) Drum compartment, (9) Guide, (10) Inlet, (11) Tissue scrubbing bar, (12) Outlet, (13) Shaft, (14) Bearing, (15) Switch

Fig. 3. Description of Machine[36]

3.3 Modelling Equations

These equations are used to model the components of the machine[36].

Length of Belt for power transmission from motor to rotor drum:

$$L = \pi(r_1 - r_2) + 2x + \frac{(r_2 - r_1)^2}{x} \quad (1)$$

Velocity ratio of belt:

$$\frac{N_2}{N_1} = \frac{d_1}{d_2} \quad (2)$$

Force required to strip the belt:

$$E = \frac{fl^3}{48yI} \quad (3)$$

Torque required to strip the stem:

$$T = f \times r \quad (4)$$

Where T is substituted in Eq. (7)

Arc Length: Arc length expressed in formula is

$$L = \frac{\theta}{360} \times (2\pi r) \quad (5)$$

$$N = \frac{\theta}{360} \quad (6)$$

Where N is substituted in Eq (7)

Required power to rotate the pulping drum:

$$P = \frac{2\pi NT}{60} \quad (7)$$

Transferred power by the belt

$$P = \frac{T_1}{T_2} v \quad (8)$$

$$2.3 \log \frac{T_1}{T_2} = \mu\theta \quad (9)$$

Contact angle: Contact angle in radian is:

$$\theta = (180 - 2a) \frac{\pi}{180} \quad (10)$$

Centrifugal tension is:

$$T_c = m.v^2 \quad (11)$$

Maximum tension present in belt:

Maximum tension is $T = \sigma.b.t$ (12)

$T_1 = T - T_c$ (13)

Bearing Selection: For bearing selection

Force on first bearing:

$$B_1 = [R_{1V}^2 - R_{1H}^2]^2 \quad (14)$$

Resultant forcing on 2nd bearing:

$$B_2 = [R_{2V}^2 - R_{2H}^2]^2 \quad (15)$$

Carrying load of the shaft:

$$Bearing\ life = \frac{60 \times N \times Operating\ time}{10^0} \quad (16)$$

Where N (6) is substituted in Eq (16)

Load carrying on bearing 01:

$$B_1 = (Bearing\ life)^{\frac{1}{k}} \times Load\ factor \quad (17)$$

Load carrying on bearing 02

$$B_2 = (Bearing\ life)^{\frac{1}{k}} \times Load\ factor \quad (18)$$

Table 3

Design consideration of banana trunk

Banana stem length	650 mm
Width of Banana stem	155 mm
Thickness of the Banana stem	10 mm
Maximum deflection of stem after feeding	5 GPa
Modulus of Elasticity of banana stem	3.5 mm
Area Moment of Inertia of stem	$12500 mm^4$

3.4 CAD Design of Extraction Machine

This Machine is equipped with 2HP electric motor as driver for the extraction process. Some of the crucial components of the machine are presented in CAD images.

3.4.1 Frame

Frame a crucial component that encloses machine. For our project, have selected structural steel for the frame due to its sufficient strength to support all components and its cost-effectiveness.

Fig. 4. CAD Model 3D of Extracting Machine

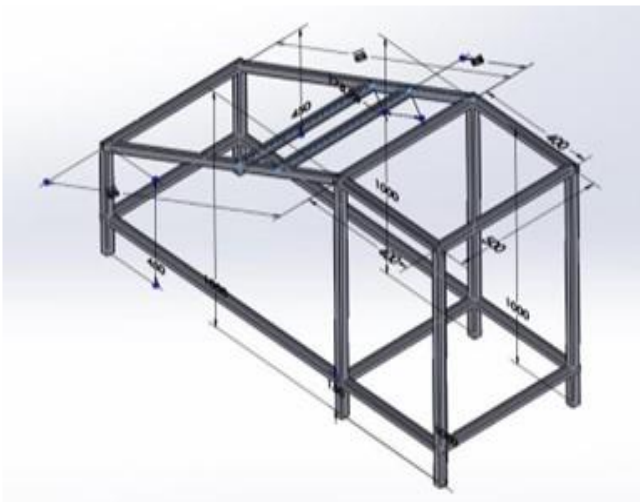


Fig. 5. Supporting Frame with Dimensions

3.4.2 Rotating drum

The roller drum is equipped with a beating blade and, in this design, contains 10 blades. Typically, a roller drum features 17 to 27 blades. Each blade in this drum measures 395 mm in length, 24mm in width, and 4mm in thickness, spaced 38mm a part.

Fig. 6. Rotating Drum

3.4.3 Shaft

This model incorporates a round shaft that is 601.55 mm in length and 30 mm in dia. Positioned along the bearing axis, the shaft rotates, channeling power from the motor to the shredding mechanism via a belt drive system. Subjected to torque, shear forces, and bending moments, the shaft, made from 30mm diameter alloy steel, has been mathematically calculated to ensure durability and efficiency. It is stabilized by deep groove ball bearing at each end. Power is transferred to the shaft through a 200mm diameter pulley attached to one end, achieving speed of 568RPM.

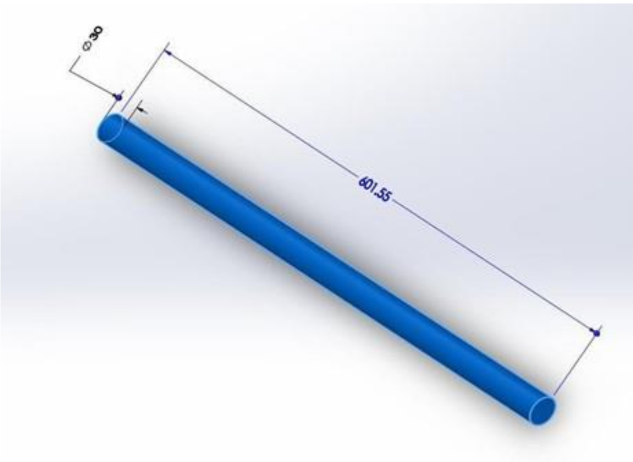


Fig. 7. Shaft

3.4.4 Scrubbing bar

The scrubbing bar, situated near the pupling roller, functions to dissipate heat and separate the fibers. Its surface ensures the effective removal of long and dry residues. Constructed from alloy steel, the bar measures 520mm in length with a diameter of 30mm. During the operation, the tissue scrubbing bar remains stationary.

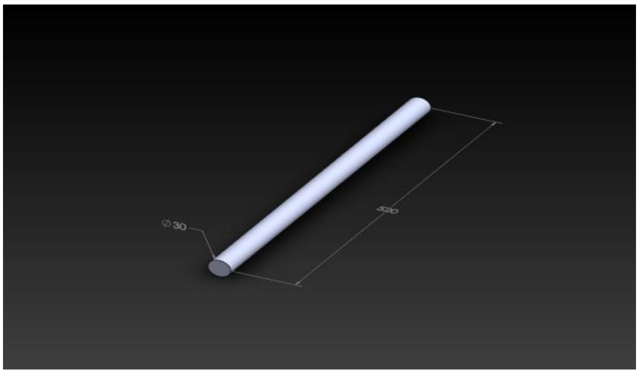


Fig. 8. Tissue-Scrubbing Bar

3.4.5 Feeding rollers

The machine is equipped with two rollers, each 520mm in length and 26mm wide, specifically designed to process cut banana stems. These rollers also act as a safety barrier between the operator's hand and the edges of the machinery. primary functions of these rollers are to handle the pseudo stems delicately and to assist in extracting fibers effectively.

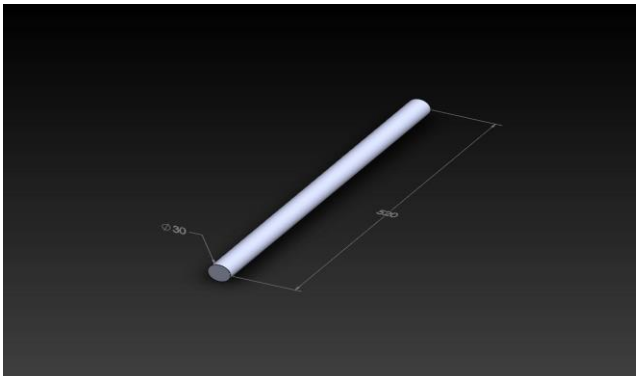


Fig. 9. Feeding Rollers

4. Simulation and Results

4.1 Simulation Results

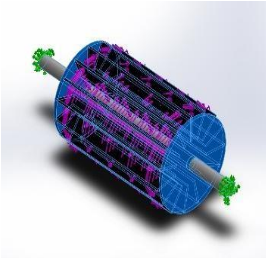
CAD simulations are done only for Roller Drum and Shaft because these components are sustaining the loads.

4.1.1 Simulation of roller drum

The calculation includes fixed value for force, radial force, and the reaction force exerted by the fiber, which are used to assess the drum's pressure tolerance. The selected material, an alloy steel, conforms to production standards with a yield strength of 620.422 MPa and a Tensile Strength of 723.826 MPa. It also features a modulus of elasticity of 210,000MPa and a shear modulus of 79000MPa. The material's density is 7700 kg/m3, and it has a Poisson's ratio of 0.28. These properties ensure the steel's ability to withstand operational stresses and strains effectively.

Table 4

Simulation results for the rotating drum were obtained using SOLIDWORKS

Model Reference	Properties		Components
	Name:	Alloy Steel	Solid Body 1(Cut-Extrude1)(003), SolidBody 2(Boss-Extrude5)(003), SolidBody 3(Boss-Extrude4)(003)
	Model type:	Linear Elastic Isotropic	
	Default failure criterion:	Max von Mises Stress	
	Yield strength:	6.20422e+008 N/m^2	
	Tensile strength:	7.23826e+008 N/m^2	
	Elastic modulus:	2.1e+011 N/m^2	
	Poisson's ratio:	0.28	
	Mass density:	7700 kg/m^3	
	Shear modulus:	7.9e+010 N/m^2	
	Thermal expansion coefficient:	1.3e-005 /Kelvin	
	Curve Data:N/A		

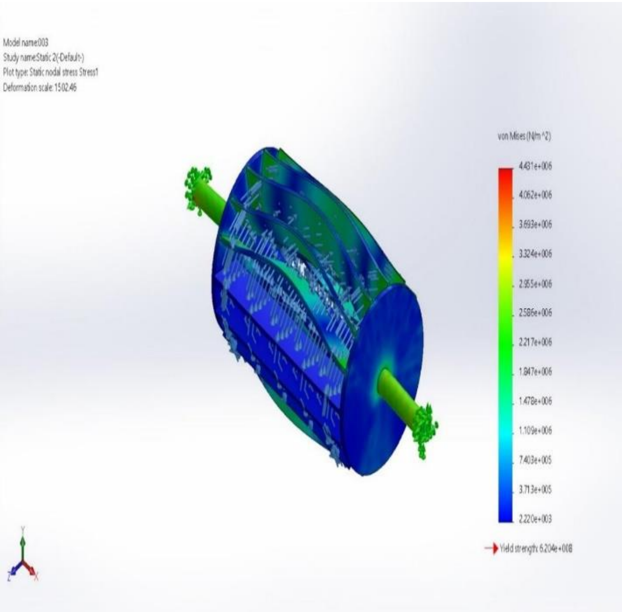


Fig. 10 (a). Von Misses Stress Analysis of Roller Drum

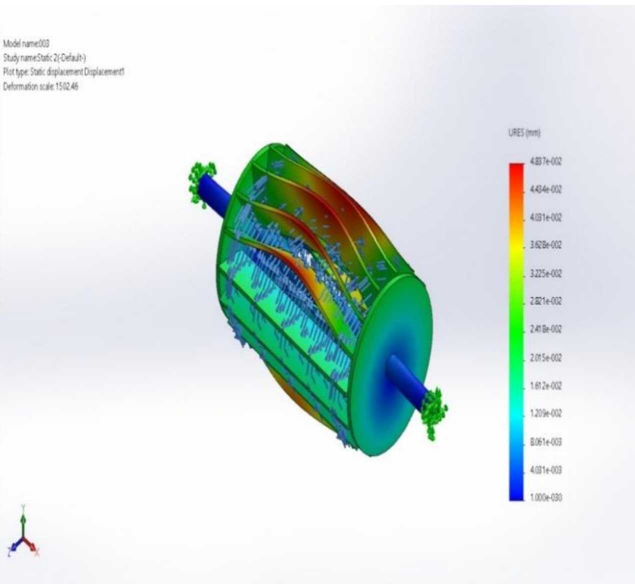


Fig. 10 (b). Total Deformation Analysis of Roller Drum

4.1.2 Simulation results of shaft

The shafts drive belt transfers motor power to cutting tool system via rotation around its impact axis, exposing it to torque and significant mechanical loads. Shaft is made from alloy steel characterized by a yield strength of 620MPa, and tensile strength of 723.826MPa, an elastic modulus of 2.1e+011 N/m^2, and shear modulus of 7.9e+010 N/m^2. The mass density is 7700 kg/m^3, with a Poisson ratio of 0.28.

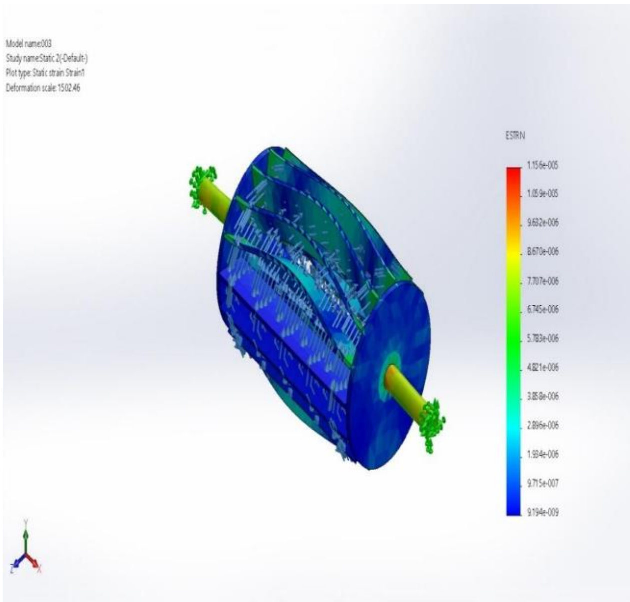
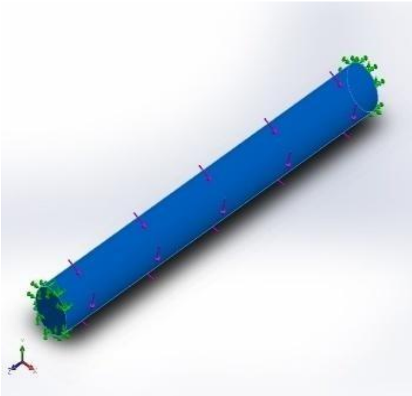


Fig. 10 (c). Von Misses Strain Analysis of Roller Drum

Table 5

Simulation results for the shaft were obtained using SOLIDWORKS

Model Reference	Properties		Components
	Name:	Alloy Steel	Solid Body 1
	Model type:	Linear Elastic Isotropic	(Boss-Extrude1)(Part1)
	Default failure criterion:	Max von Mises Stress	
	Yield strength:	6.20422e+008 N/m^2	
	Tensile strength:	7.23826e+008 N/m^2	
	Elastic modulus:	2.1e+011 N/m^2	
	Poisson's ratio:	0.28	
	Mass density:	7700 kg/m^3	
	Shear modulus:	7.9e+010 N/m^2	
	Thermal expansion coefficient:	1.3e-005 /Kelvin	
Curve Data:N/A			

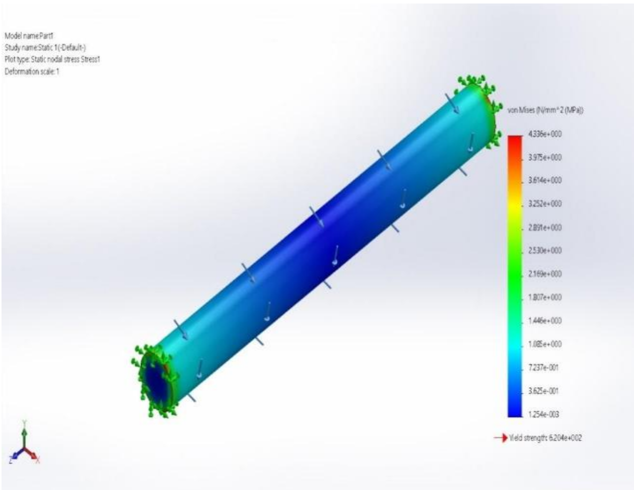


Fig. 11 (a). Von Misses Stress Analysis of Shaft

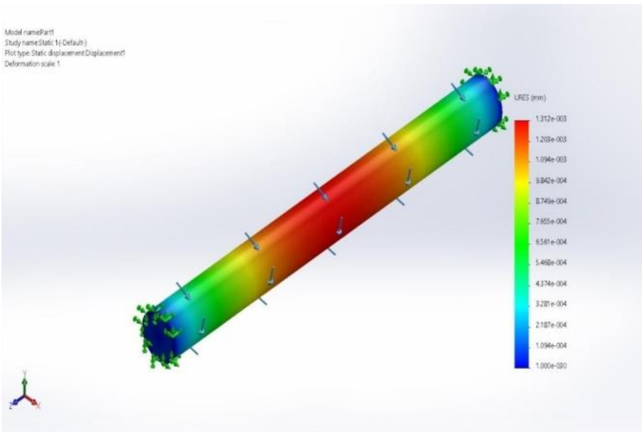


Fig. 11 (b). Total Deformation Analysis of Shaft

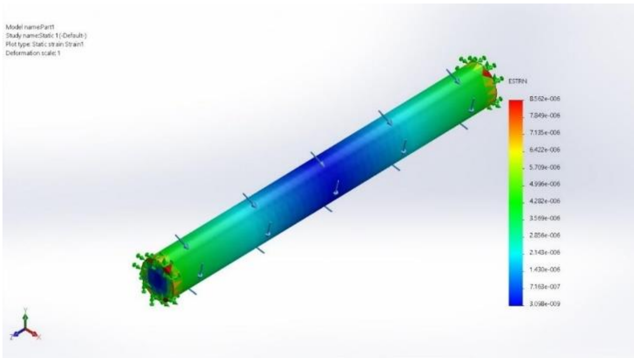


Fig. 11 (c). Von Misses Strain Analysis of Shaft

4.2 Fabrication

The machine is primarily designed for use in the rural regions of the lower belt of Sindh Province in Pakistan. Necessitating components that are straightforward to obtain, maintain, and repair. To ensure the availability and local protection of these parts, we conducted market surveys and visited local manufacturers. This research affirmed our choice of materials used in the design calculations. Subsequently, we sought a workshop close to our university (MUET) to customize the machine according to our specifications. This proximity allows frequent visits to closely monitor and direct the fabrication process. The machine's critical components include the frame and the pulping drum. The drum requires precise manufacturing due to its complex design, which is crucial for machine's efficient operation, stability, and minimization of vibrations. Below is the image of Fabricated drum.

Fig. 12 (a). Front view of Fabricated Roller Drum

Fig. 12 (b). Side view of Fabricated Roller Drum

Fig. 12 (c). Lateral view of Fabricated Machine Along with All Components

Fig. 12 (d). Front Input Section of Fabricated Machine

4.3 Structural Analysis of Roller Drum

Table 6

Structural Analysis of Roller Drum with Alloy Steel Material

RPM	Deformation (mm)	Stress (MPa)	Strain
500	0.05112	8.4532	0.002541
1000	0.12453	31.5421	0.001546
1500	0.29881	78.6574	0.001088
2000	0.47116	128.12	0.000619
2500	0.59243	161.8743	0.000772
3000	0.70456	188.0975	0.000913

4.3.1 Analysis

1. Deformation increases with RPM, which is expected because of higher speeds typically leads to greater forces and, thus, more deformation.
2. Stress also increases with RPM, following a similar rationale that higher revolutions result in higher forces exerted on the roller drum, causing more stress.
3. Strain behaves somewhat differently; the values decrease from 500 to 2000 RPM but increase from 2000 to 3000 RPM. This could be due to materials response to stress at different RPMs.

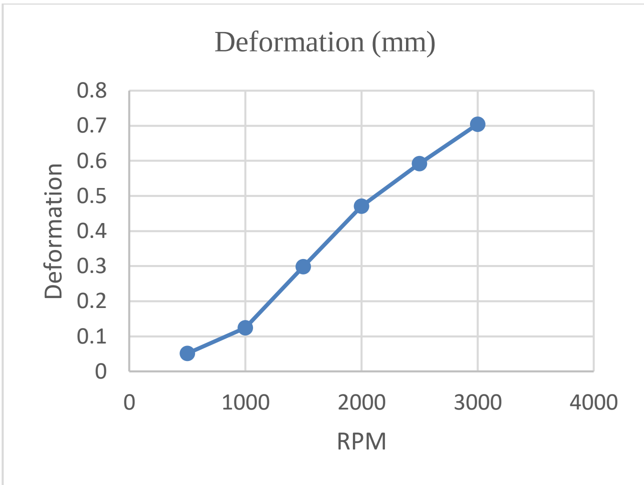


Fig. 13. Deformation vs Speed

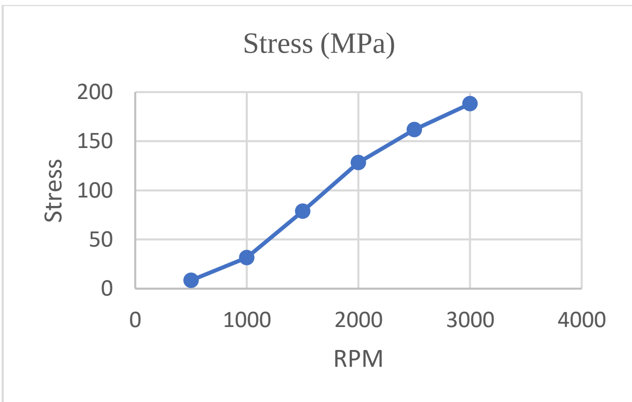


Fig. 14. Stress vs Speed

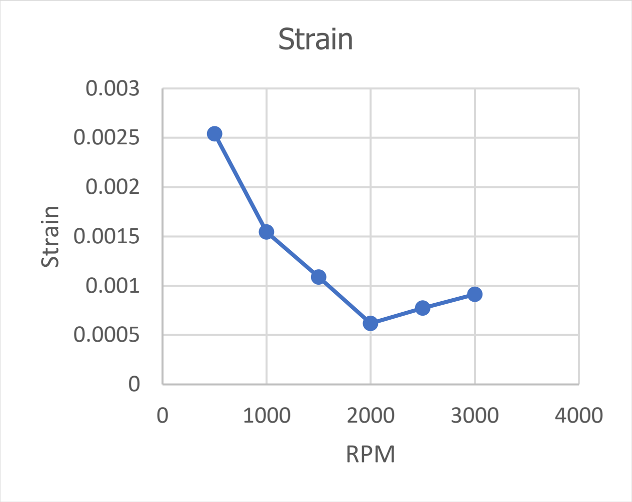


Fig. 15. Strain vs Speed

4.4 Performance Analysis of Extracting Machine

During the project phase, a banana fiber extractor was built and tested. The tests, which used banana trunks with thickness ranging from 4 to 22 mm, demonstrated that the machine could effectively extract fibers from trunks up to 155mm in length using a 220V single-phase motor and a stopwatch to time the extraction process.

Table 7

Experimental results

Sr #	Banana Sliced Trunk Length (mm)	Width (mm)	Thickness(mm)	Operating Voltage (V)	Fiber Extracting Time (sec)
01	220	40	4		6
02	270	80	5		8
03	320	100	8		13
04	370	110	10		17
05	420	115	12	220	23
06	470	120	14		25
07	520	125	16		33
08	570	130	18		38
09	620	140	20		45
10	650	155	22		50

Average Extraction Time Taken: 26 seconds.

The fibers produced are long, strong, and of high quality. They are suitable for all previously mentioned applications. The accompanying image displays fibers that were recently extracted from the machine.

Fig. 16. Fibers Obtained

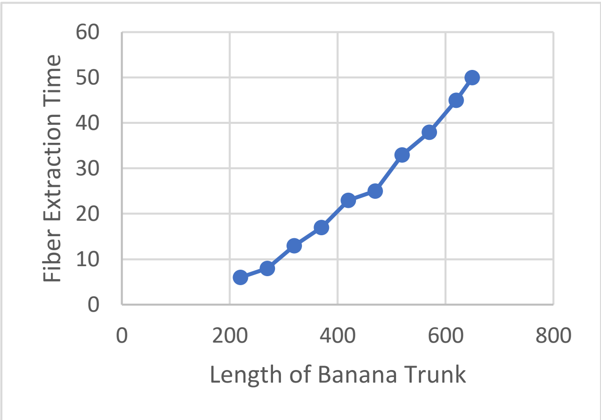


Fig. 17. Fiber Extraction time vs Length of Banan Trunk

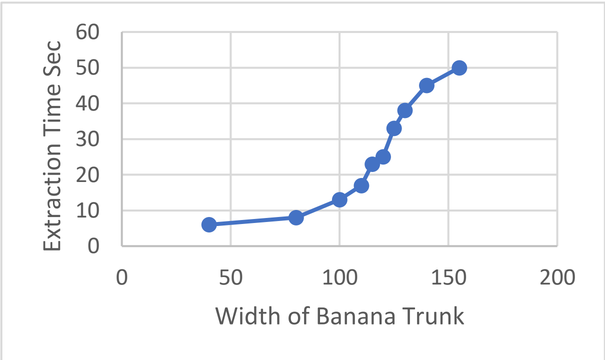


Fig. 18. Fiber Extraction time vs width of Banana Trunk

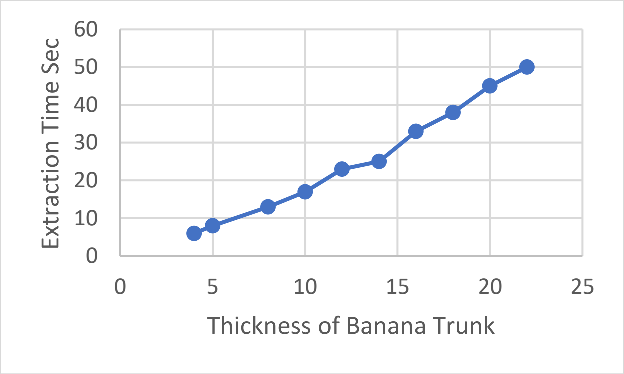


Fig. 19. Fiber Extraction Time vs Thickness of Banana Trunk

5. Conclusion

This project involved the design and construction of a banana fiber extractor machine. Design analysis indicates that a 2HP motor is sufficient to operate the machine, which requires a force of 40N to strip the pseudo trunk. It can accommodate trunks up to 155mm in width and 22mm in thickness. The average time for fibre extraction is recorded at 26 seconds, with the highest quality fibres being sourced from the outer part of the banana stem. The machine features straightforward components that are easy to assemble and disassemble, facilitating simple maintenance for operators. The project also accomplishes the SDGs by study of Banana fibers and its use in various sectors of life because of their sustainability and mechanical properties.

1. The Performance test showed that Stress in the critical components of the machine tends to increase as the RPMs seen in fig 10, 11 12.
2. The test also showed that the deformation in the critical Components like roller drum and shaft is also tends to increase as RPMs.
3. Increase in thickness, width and length of banana fibre plantain increase the extraction time seen in fig 14, 15 and 16.

6. Recommendations

The fibers produced by the machine are comparable to unused cotton fibres and suitable for various applications. Several enhancements can be made to improve the machine:

1. Aesthetic and structural improvements:
   - Refine the machines surface for better aesthetics.
   - Redesign the blades and adjust the feed angle for improved performance.
2. Mechanical and structural enhancements:
   - The current motor can support additional mechanisms.
   - Integrate a method for joining the produced fibres.
   - Assess the structural integrity of the frame to accommodate new mechanisms.
   - Reevaluate the machines vibration performance after modifications.
3. Safety improvements:
   - Enclose the machine and drum to prevent accidental contact.
   - Replace the current sheet metal covering with nonconductive materials like glass fiber or suitable polymers/plastics to mitigate electric shock risks.
4. Automation and efficiency upgrades:
   - Install a sensor on the rotating drum shaft to automate system shutdown during idle periods, reducing electricity costs and enhancing safety.
   - Upgrade the motor to a servo system to increase efficiency and sustainability.

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