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Design of Coconut Milk Pressing Machine with Two Screw Shafts to Improve Extraction Efficiency and Quality

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Abstract

Coconut milk pressing machines play an important role in coconut processing; however, conventional single-screw designs still face limitations related to pressure distribution and extraction stability. This study aims to design and analyze a coconut milk pressing machine, employing a counter-rotating two screw shafts configuration as an alternative to commonly used single-screw systems. The research methodology includes a reverse-engineering approach, analytical calculations to determine pressing capacity, power, torque, and pressure, and finite element analysis (FEA) simulations to evaluate the structural strength of main components. The analytical results indicate that the proposed design achieves a theoretical pressing capacity of 53 kg/h, with a shaft power requirement of 1.11 kW and a pressing pressure of 1.67×10^5 *N/m²*. *FEA results show that the Von Mises stress and deformation remain below the allowable limits of the selected material, indicating a conservative, structurally safe design. All results presented in this study are theoretical and numerical in nature and have not yet been validated through experimental testing. The novelty of this work lies in the application of a counter-rotating two screw shafts configuration, which theoretically provides a more uniform pressure distribution than conventional single-screw systems without a significant increase in power consumption. Future work will focus on prototype fabrication and experimental testing to validate extraction performance, energy efficiency, and hygienic aspects.*

Keywords: two screw shafts; pressing capacity; torque; pressure; machine design.

1. Introduction

Indonesia is one of the world's largest coconut producers, with over 3 million hectares of coconut plantations spread across the archipelago [1]. Coconuts have many benefits and uses, not only in the food and beverage industry but also in the beauty, pharmaceutical, and energy sectors [2]. One of the main products derived from coconuts is coconut milk, which is processed from grated and pressed mature coconut meat [3]. Coconut milk plays a crucial role in Indonesian cuisine, used in various dishes such as rendang, curry, and numerous rice-based preparations. Additionally, coconut milk is also widely used in the making of cakes and other food products. The demand for coconut milk is quite significant, but the traditional process of making coconut milk is still practiced by most of the population in Indonesia [4].

The process of coconut milk production at the household and small-scale enterprise levels is still predominantly carried out using traditional methods, namely manual pressing with cloth or simple tools [5]. This method requires considerable time and physical effort and often yields coconut milk of inconsistent quality [6]. In addition to its low efficiency, direct contact with human hands during the pressing process may reduce hygiene levels and increase the risk of microbial contamination, thereby affecting food quality and safety [7]-[9].

The quality of coconut milk is not solely determined by the amount of extract obtained but also by its cleanliness, viscosity, and sensory characteristics [10], [11]. In the food industry, inconsistencies in coconut milk

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quality can influence the taste, texture, and shelf life of the final product [6], [12]. Contaminated coconut milk poses a risk of product spoilage and potential health hazards to consumers; therefore, pressing technologies that are capable of ensuring both quantity and consistent quality in a sustainable manner are required [12]-[14].

Coconut milk extractors face another issue: the low consistency in the quality of coconut milk produced by existing machines, which often results in varying thickness and protein content due to uneven pressing pressure, Thus, the extracting process affects the taste and shelf life of processed food products. Microbial contamination from the manual procedure also increases the risk of product spoilage, particularly in small and medium-sized enterprises (SMEs) production scales. The development of a dual-counter-rotating screw system is expected to provide consistent extraction in a single stage, meeting food industry standards [15], [16].

Coconut milk pressing machines have been developed as an alternative to traditional extraction methods by utilizing screw press systems [17] or hydraulic systems [9] to extract coconut milk from grated coconut. However, most conventional single-shaft screw press machines still cannot achieve optimal extraction in a single processing stage, requiring multiple pressing stages to achieve maximum yield [15]-[17]. This condition leads to low efficiency in terms of time and energy consumption, as well as inconsistent quality of the resulting coconut milk [21], [22]. In addition, many existing machine designs are relatively large and heavy, making them less suitable for household use, or micro, small, and medium enterprises (MSMEs) [23].

The use of non-corrosion-resistant materials in conventional coconut milk pressing machines also represents a major limitation, as it leads to rapid degradation in the humid, acidic environment of coconut milk, thereby reducing service life and product hygiene [24]. This issue commonly occurs in screw and barrel components that come into direct contact with grated coconut, requiring intensive maintenance and frequent replacement and placing an additional burden on household users and MSMEs [25]. Therefore, selecting corrosion-resistant materials, such as stainless steel [26], is critical to maintaining long-term performance and ensuring compliance with food safety standards [27]-[29]. In addition to material considerations, ergonomic aspects must also be addressed. The operation of coconut milk pressing machines often involves repetitive tasks and uncomfortable working postures, which can lead to operator fatigue and an increased risk of musculoskeletal injuries [30]-[34].

Although various designs for coconut milk pressing machines have been proposed, most previous studies have focused primarily on prototype development or performance testing, without integrating comprehensive mechanical design analysis with structural strength evaluation. Studies on the application of two screw shafts in coconut milk pressing machines remain limited, particularly those that combine analytical calculations of capacity, torque, and pressing pressure with numerical validation via finite element analysis (FEA) [18], [35], [36]. In fact, a two screw shafts configuration can provide a more uniform pressure distribution, reduce material slippage, and enable more effective coconut milk extraction in a single processing stage without increasing power consumption.

Therefore, this study proposes a design to analyze coconut milk pressing machine employing dual counter-rotating screw shafts through an integrated mechanical engineering approach. The main contributions of this research include: (1) the development of a two screw shafts-based coconut milk pressing machine design for single-stage operation; (2) mechanical analysis encompassing the calculation of capacity, power, torque, and pressing pressure; and (3) structural safety evaluation using numerical simulations based on FEA as a foundation for prototype development. This research focuses on the design and technical analysis of two screw shafts in coconut milk pressing machine, using mechanical calculations and finite-element simulations. The proposed approach is expected to provide a more systematic, safe, and efficient design framework for coconut milk pressing machines suitable for MSMEs and small-to medium-scale food processing industries.

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2. Experimental Methods

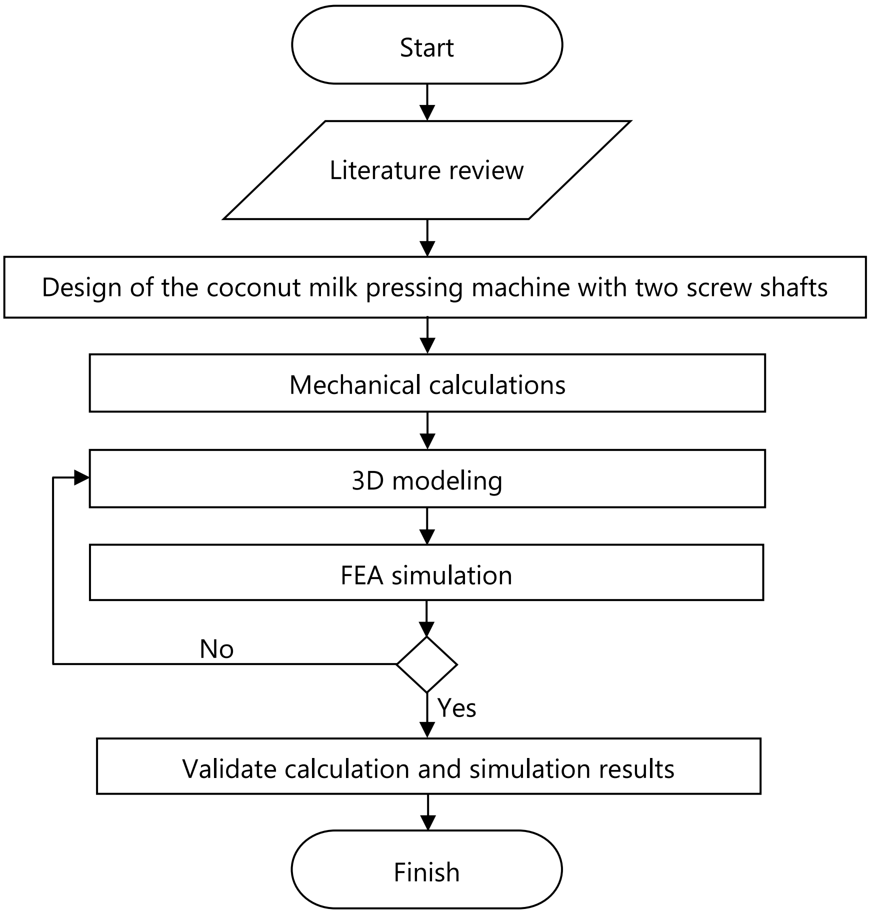

Figure 1. Research flow diagram

2.1. Literature Review

The first step in this study, as shown in Figure 1, is to conduct a literature review of various types of coconut milk extractors available on the market. This includes analyzing several studies on coconut milk extractors with screw press technology, whether using a single shaft or dual shafts. The purpose of this study is to evaluate existing designs and identify shortcomings as well as potential improvements. The insights gained from this literature review are expected to provide knowledge on the latest technology, materials used, and machine efficiency, which can enhance product quality and competitiveness.

2.2. Design Approach

The method used in the design of this coconut milk pressing machine is reverse engineering, also referred to as redesign. The redesign process involves analyzing existing machine designs and modifying them to improve the machine's efficiency and performance. Single-shaft screw press–type coconut milk pressing machines have been widely used and have proven capable of performing the basic pressing function effectively, particularly at the MSME scale. Therefore, this design is considered a functionally and technically relevant baseline. However, based on literature studies and design observations, single-shaft screw press machines exhibit limitations in pressure distribution and extraction efficiency. Consequently, the design is modified by developing two screw shafts to enhance effective pressing pressure and extraction consistency within a single processing stage, without significantly altering the machine's fundamental operating principle.

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This approach enables the use of proven designs while incorporating innovations to address existing limitations. These improvements include replacing the single-screw system with two screw shafts configuration to accelerate the pressing process and designing a more efficient drive system using energy-efficient electric motors. Material selection is crucial to the design of the coconut milk pressing machine. The materials used must exhibit high mechanical strength, corrosion resistance, and wear resistance. One of the most applied materials that come into direct contact with coconut milk is stainless steel, due to its excellent corrosion resistance and ease of cleaning.

2.3. Mechanical Calculations

2.3.1 Screw Pressing Capacity

The screw shaft is a key component in coconut milk pressing machine. In this design, the screw shaft features two shafts to enhance the efficiency of pressing process. Each screw shaft will work simultaneously to grind and press grated coconut, reducing the time required for pressing. The design of screw on the shaft must also consider factors such as material, screw dimensions, and rotational speed to achieve optimal pressing results.

The pressing capacity of screw is determined by a formula that combines diameter, pitch, and rotation to achieve the target capacity. Many researchers use an adapted screw conveyor capacity formula as follows.

$$Q = 60 \cdot \frac{\pi\left(D_s^2 - D_p^2\right)}{4} \cdot s \cdot n \cdot \eta_v \cdot \rho \cdot c \qquad (1)$$

where Q is the pressing capacity (kg/hour), D_s is the screw diameter (m), D_p is the shaft diameter (m), s is the pitch (m), n is the screw rotation speed (rpm), η_v is the volumetric filling/efficiency factor (for example, 0.3–0.5), ρ is the material density (kg/m^3), and c is the slope factor or other correction factors.

2.3.2 Power and Torque Calculations for the Screw Shaft

Calculating torque and twisting moment is crucial in the design of screw shaft. The torque generated by the motor must be able to rotate both screw shafts efficiently, while the twisting moment that occurs during the pressing process needs to be calculated to prevent failure of the shaft. Additionally, bending calculations are also necessary to ensure that the screw shaft does not experience deformation or damage due to forces acting on the shaft during the pressing process. All of these calculations must be performed carefully to ensure the machine operates stably and efficiently. The twisting moment on screw shaft can be calculated using the following formula [7].

$$T = \frac{P}{\omega} \qquad (2)$$

where T is the torque (Nm), P is the motor power (W), and ω represents the angular velocity of the motor shaft (rad/s).

Bending calculations are also necessary to ensure that the screw shaft does not experience deformation or damage due to forces acting on the shaft during the pressing process. Bending occurs due to the compressive force acting on the shaft when the coconut meat is pressed. To calculate the bending moment on the shaft, the following bending moment formula was used.

$$M = \frac{F \cdot L}{4} \qquad (3)$$

where M is the bending moment (Nm), F is the compressive force acting on the shaft (N), and L is the length of the shaft (m). This calculation ensures that the screw shaft can withstand the forces acting on it without experiencing damage or deformation.

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The planned power for screw shaft is generally calculated based on process requirements plus a correction factor, and then the torque is derived from the power. The planned power P_d is taken from the motor power multiplied by correction factor.

$$P_d = F_c \cdot P \quad (4)$$

where F_c is the correction factor (for example, 1.5) and P is the motor power (kW).

2.3.3 Pressing Pressure and Cone Screw Design

The pressing pressure of cone screw can be calculated by dividing total axial force by lateral surface area of the frustum of cone in contact with the material. In previous designs, the lateral surface area of the cone frustum was calculated using following expression.

$$A = \pi R l - \pi r l \quad (5)$$

where R is the large radius, r is the small radius, and l is the slant height of the cone, which is obtained through trigonometric calculations from the height and the difference in radii. Once A is obtained, the average pressure was found by the following formula [9].

$$p = \frac{F}{A} \quad (6)$$

where F is the compressive force related to the planned moment of shaft and screw geometry.

2.3.4 Gearbox and Pulley Calculations

The drive system of this coconut milk pressing machine uses an electric motor to transmit power to the screw shaft via a pulley and gearbox system. Gearbox calculations are necessary to determine the appropriate reduction ratio so that the screw shaft can rotate at correct speed to achieve optimal pressing. The selection of pulleys must also be done carefully, as the correct pulley will ensure efficient power transmission between the motor and the screw shaft. Additionally, the selection of pulley and belt materials must consider durability and resistance to wear during use.

The drive system of coconut milk pressing machine is designed with a single main speed transmission path comprising an electric motor, a gearbox, and a pulley–belt system. The electric motor serves as the primary power source. It operates at a high nominal speed, while the gearbox serves as the main reduction element, decreasing rotational speed and increasing torque to meet the requirements of pressing process.

After speed reduction through the gearbox, power is transmitted to the screw shafts via a pulley-and-belt system, which serves as a minor speed adjustment mechanism and provides layout flexibility rather than acting as the primary reduction stage. Accordingly, the pulley system is not designed to provide a large reduction ratio, but instead to facilitate shaft alignment, dampen vibrations, and simplify maintenance. The kinematic chain of the drive system can be summarized as follows: electric motor → gearbox (main reduction) → pulley and belt → dual screw shafts.

The gearbox ratio is selected based on the required screw rotational speed to achieve optimal pressing pressure. In contrast, the pulley ratio is determined with minor corrections to ensure practical, easy-to-manufacture pulley dimensions. This approach ensures the drive system operates efficiently, stably, and practically. The formula used for the gearbox calculation is as follows.

$$\text{Gearbox Ratio} = \frac{\text{Input Speed}}{\text{Output Speed}} \quad (7)$$

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Pulley selection is also a critical aspect of this system. Proper pulley selection ensures efficient power transmission between motor and screw shafts. The pulley sizes used in this design are determined by considering space constraints, the availability of standard components, and ease of maintenance. Therefore, the pulley ratio is kept relatively small to ensure that the pulley diameters remain realistic and practical for application.
To calculate the pulley dimensions, the following equation was used [34].

$$\frac{D_1}{D_2} = \frac{N_2}{N_1} \tag{8}$$

where D_1 is the diameter of the motor pulley, D_2 is the diameter of the pulley on the screw shaft, N_1 is the rotational speed of the motor, and N_2 is the rotational speed of the screw shaft.

The mechanical calculations in this study are conducted using defined input parameters and assumptions to ensure method reproducibility. The screw shaft and pressing barrel materials are assumed to be made of AISI 304 stainless steel, with a yield strength of 215 MPa and a modulus of elasticity of 193 GPa [34], [37], [38]. Grated coconut meat is assumed to have an average density of 600 kg/m^3 and to behave as a homogeneous soft plastic material [24], [39]. The screw channel filling factor (η_v) is taken in the range of 0.3–0.5, consistent with the characteristics of fibrous food materials, while the mechanical efficiency of system is assumed to be 0.85. A power correction factor of 1.5 is applied to account for load fluctuations during pressing [40].

2.4. 3D Modeling and FEA Analysis

Modeling is carried out using Autodesk Inventor Professional 2024 software, employing a parametric modeling approach that allows each primary dimension to be adjusted based on the results of previously determined calculations for capacity, pressure, torque, and power. This approach provides flexibility in the design optimization process and minimizes geometric errors before proceeding to further analysis. The selection of screw shape, shaft diameter, screw pitch, and effective length of the screw are determined based on the required pressing capacity and the optimal pressure needed to extract the coconut milk. The material for each component is specified at the modeling stage, particularly for components that come into direct contact with food, such as the screw shaft and pressing barrel, which are made from food-grade stainless steel. In contrast, the frame is constructed from low-carbon steel to ensure structural strength and ease of fabrication.

The next step is assembly modeling to ensure the integration of components and the functional validity of the design. The assembly process is performed by applying appropriate mechanical constraints, such as concentricity, mating, and insertion. Consequently, the relationships between shafts, bearings, pulleys, and frame function would be like in real conditions. This stage is also used to evaluate the component layout, the power transmission path from the motor to the screw shaft, and the ease of access for maintenance and cleaning. Therefore, 3D modeling serves not only as a design visualization tool but also as an early evaluation tool for ergonomics, workplace safety, and overall system efficiency.

FEA analysis is performed to evaluate the structural response of machine to the workload during coconut milk pressing process. The loading on the FEA model is adjusted to the operational conditions of the machine. The main loads applied include torque on the screw shaft originating from the motor power and transmission system, as well as axial force due to the pressing pressure of grated coconut inside the barrel.

FEA is conducted by defining boundary conditions and loading scenarios that represent the operating conditions of the coconut milk pressing machine. The screw shaft is modeled with fixed supports at the bearing locations to constrain translational and rotational degrees of freedom in accordance with actual operating conditions. The primary applied loads consist of torsional moments at the shaft end due to motor and transmission system, as well as axial forces representing the pressing force exerted by material inside the barrel. The contact between the screw shaft and the pressing barrel is assumed to be a bonded contact to evaluate the structural response under maximum loading conditions. This assumption is adopted to obtain conservative stress results and to avoid the complexity of nonlinear analysis during preliminary design stage.

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The FEA model employs three-dimensional solid tetrahedral elements, which are commonly used for structural analysis involving complex geometries such as screw shafts. The mesh size is defined adaptively, with local refinement applied to critical regions such as screw flights, shaft body, and geometric transitions to enhance simulation accuracy. A qualitative mesh convergence study is performed to ensure that the stress results do not change significantly with further mesh refinement.

The FEA analysis results observed include the distribution of Von Mises stress, total deformation, and safety factor. Von Mises stress is used as the primary parameter to evaluate material failure based on the distortion energy failure theory, which is commonly applied to ductile materials such as steel and stainless steel. Total deformation is analyzed to ensure that the deflection remains within acceptable limits and does not affect the performance of pressing mechanism. Meanwhile, the safety factor is calculated to assess the reliability of the design against potential structural failure during operation.

The final stage of 3D modeling and FEA analysis involves validating the simulation results against previously performed analytical calculations. This validation intends to ensure consistency between theoretical and numerical approaches. If the maximum stress from the simulation is below the material's allowable stress and the safety factor meets the established design criteria, the design is considered structurally safe and feasible. On the other hand, if critical areas with excessive stress or significant deformation are found, design revisions are made by adjusting dimensions, material selection, or structural configuration, followed by re-simulation until an optimal design is achieved. Through this iterative approach, 3D modeling and FEA analysis serve not only as verification tools but also as a means of comprehensive design optimization for the coconut milk pressing machine prior to fabrication and experimental testing stages.

3. Results and Discussion

3.1. Design

The design results of coconut milk pressing machine with two screw shafts are illustrated in the design diagram created using design software such as Autodesk Inventor. This design diagram tries to provide a detailed representation of the machine's main components and their interrelationships. The coconut milk press design and details of the pressing components, including the two screws, are shown in Figure 2.

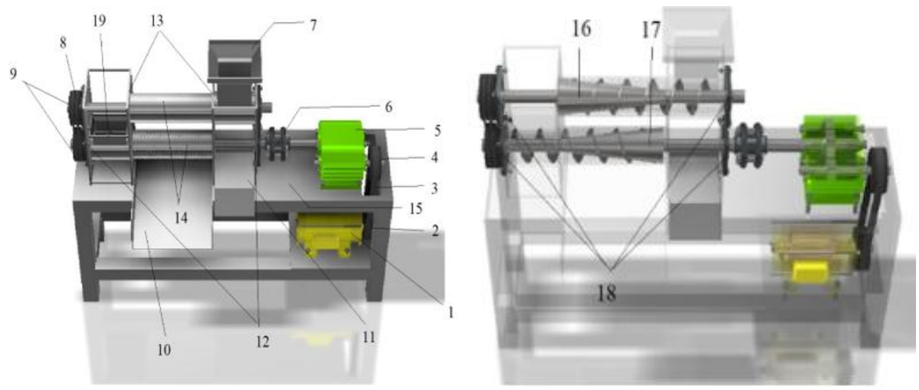

Figure 2. Design of the coconut milk pressing machine with two screw shafts

Figure 2 illustrates the design of coconut milk pressing machine, which is equipped with two screw shafts. This machine consists of various components that work together to process grated coconut into clean and efficient coconut milk. The design includes several key parts that are interconnected through the power transmission system (motor, pulley, and belt), aside from the pressing system with two screw shafts to produce an optimal amount of coconut milk.

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Table 1. Part description

No.	Part Name
1	Drive motor
2	Drive motor pulley
3	Belt
4	Gearbox input pulley
5	Gearbox
6	Shaft coupling
7	Upper hopper
8	Belt
9	Screw shaft pulley
10	Coconut milk collector
11	Coconut pulp output
12	Outer shaft support
13	Outer shaft support
14	Coconut milk filter tube
15	Frame and table
16	Upper screw shaft
17	Lower screw shaft
18	Pillow block bearing
19	Lower hopper

Table 1 provides an overview of various components in the design of two screw shafts coconut milk extractor machine. The machine starts with the drive motor (1), which provides power through the drive motor pulley (2) and belt (3) to connect to the other parts. The rotational motion is transmitted through the gearbox input pulley (4) and gearbox (5), which regulate the rotation speed, and then transferred to the shaft coupling (6) that connects the motor and gearbox. The upper hopper (7) serves as the point of introduction for grated coconut into the machine, which is then processed with the assistance of the belt (8) and screw shaft pulley (9). The coconut milk produced is directed into the coconut milk collector (10), while the coconut pulp output (11) serves as the outlet for the discarded coconut pulp. The machine is also equipped with two outer shaft supports (12 and 13) that maintain the stability of the screw shafts. The extraction process is achieved through the coconut milk filter tube (14), which separates the coconut milk from the pulp. All of these components are supported by the frame and table (15), which ensures the machine remains sturdy and stable. The upper screw shaft (16) and lower screw shaft (17) play a crucial role in rotating the grated coconut for extraction, assisted by the pillow block bearing (18), which facilitates smooth rotation. Finally, the lower hopper (19) functions as the place to collect the grated coconut before further processing. All these components work together to produce coconut milk efficiently and of high quality.

3.2. Modeling and Simulation

The design of two screw shafts coconut milk extractor machine involves two parallel shafts, each equipped with a screw thread that serves to grind and extract the coconut meat. Each screw shaft rotates in opposite directions to maximize the extraction process. The size and dimensions of screw shafts are carefully designed to match the desired extraction capacity. A detailed illustration of the screw shaft and its dimensions is shown in Figure 3.

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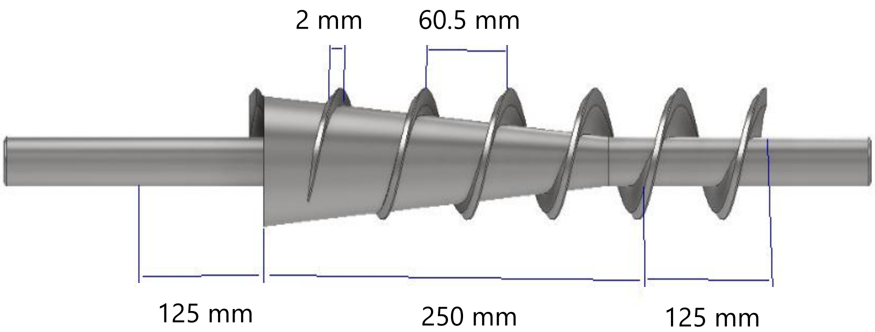

Figure 3. Screw shaft design

The two screw shafts system places both screws parallel within the filter tube, rotating in opposite directions, so that the grated coconut experiences a grinding and compacting effect along the length of the screw. This counter-rotating configuration enhances mixing, reduces material slip, and increases adequate pressure without excessively raising the rotational speed, thereby improving coconut milk extraction and resulting in relatively dry pulp. The screw threads are conically shaped, with a tapered end in the compression zone. The outer diameter of the screw increases from the input zone to the output zone, while the pitch remains either constant or slightly decreases. This design causes the volume of space between threads to shrink, creating a pressure gradient along the tube. In the existing design, shaft diameter is 30 mm, with outer screw diameter is 80 mm and compression zone length of approximately 250 mm. This setup has been proven to generate a pressure of 1.7 × 10^5 N/m² and a capacity of approximately 53 kg/h during the two-stage extraction process.

3.2.1 Von Mises Stress Analysis

This analysis is used to predict material failure under complex loading conditions. Von Mises stress combines various types of stresses acting on the material and provides a single value that indicates whether the material will fail or not. The results of this analysis are beneficial in ensuring that the screw can operate safely, without risk of damage or permanent deformation, under the given operating conditions. The results of Von Mises stress simulation on the screw are shown in Figure 4.

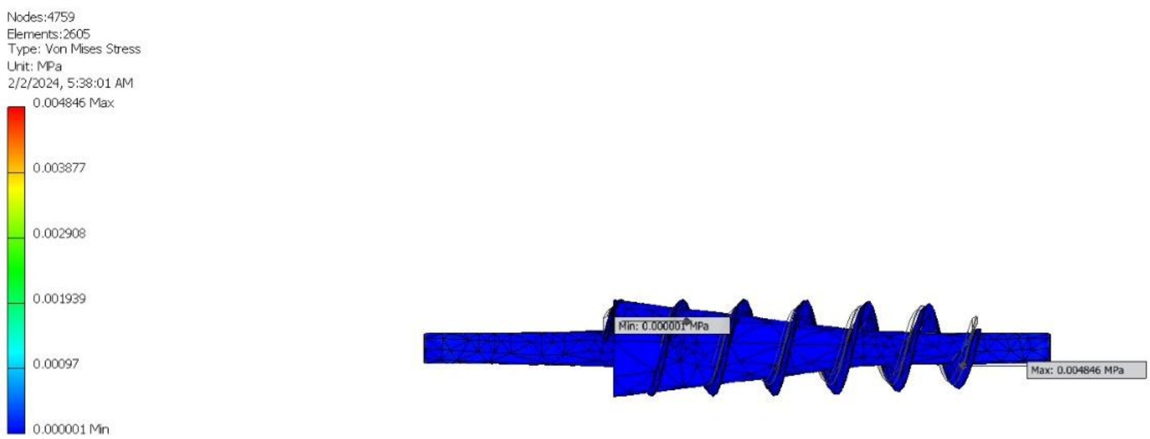

Figure 4. Von Mises stress analysis of the screw

Figure 4 shows the Von Mises stress analysis on the screw, depicted in blue. Von Mises stress is used to predict material failure under complex loading conditions. The color scale indicates the stress values, with darker areas (blue) representing lower stress and lighter areas (red or yellow) indicating higher stress. In this case, the

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maximum Von Mises stress is 0.004846 MPa, indicating that the screw design is safe under given load, as the stress is very low.

The simulation results indicate that the maximum von Mises stress is relatively low compared to the yield strength of stainless-steel material used. This condition is primarily attributed to a conservative design approach, selection of a material with high yield strength, and loading assumptions that represent nominal operating conditions. In addition, applying a power correction factor and safety factors during the preliminary calculation stage further contributes to the low stress levels throughout the structure. Therefore, the low stress values do not indicate a deficiency in the simulation; rather, they demonstrate that the structure possesses an adequate safety margin for machine operation.

The finite element simulation results show that the maximum Von Mises stress occurring on screw shaft is well below the yield strength of stainless-steel material used. This value yields a high safety factor, indicating that the shaft design is conservative and safe for long-term operation. The deformation that occurs is also minimal, ensuring that it does not affect the shaft's alignment or the extraction process's performance.

3.2.2 First Principal Stress Analysis

First principal stress measures the maximum tensile stress experienced by the screw. This is crucial for identifying any parts of the screw that may experience failure due to excessive tensile stress. In the design of coconut milk extractor machine, high tensile stress can cause the material to fracture or undergo permanent deformation, making this analysis essential for optimizing the design to prevent material failure. The results of the First Principal Stress simulation are shown in Figure 5.

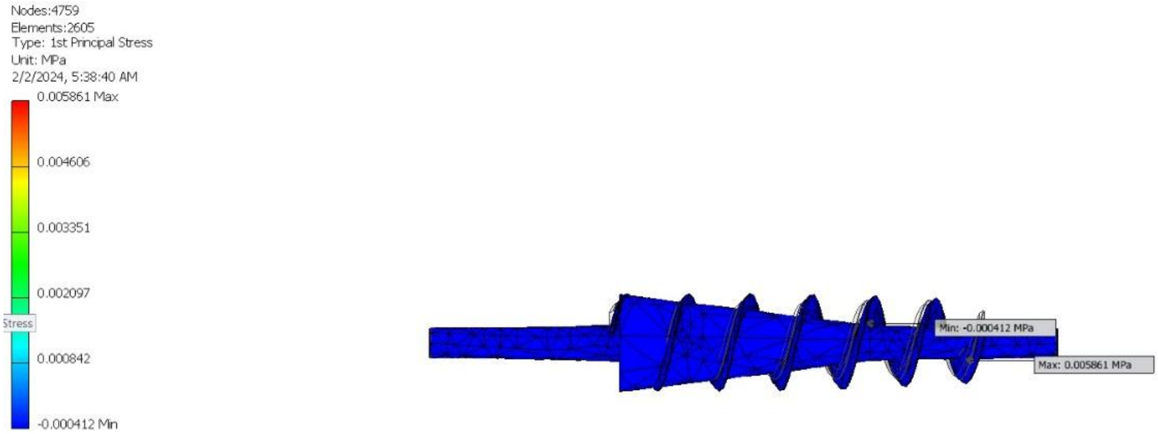

Figure 5. First principal stress analysis of the screw

Figure 5 displays the first principal stress analysis, which illustrates the maximum tensile stress applied to the screw. The first principal stress represents the highest stress experienced by the material and is used to assess the material's potential to fail due to tensile forces. In this image, the stress values range from -0.000412 MPa to 0.005861 MPa. Darker areas (green and blue) indicate regions with relatively low stress, while yellow and red areas show regions with higher tensile stress. High tensile stress has the potential to cause deformation or damage to the screw if it exceeds the material's strength limits. Thus, this first principal stress analysis helps identify the most vulnerable points on the screw, which are critical for recognizing weak spots in the machine design that could be prone to tensile failure.

3.2.3 Force Distribution Analysis on the Screw

Force distribution analysis shows how forces act on the screw during the extraction process. By visualizing the forces applied to the screw, we can identify the points that experience the greatest concentration of force. This is crucial for designing the screw to withstand the pressure in specific areas and prevent wear or damage to those sections. The force distribution on the screw is shown in Figure 6.

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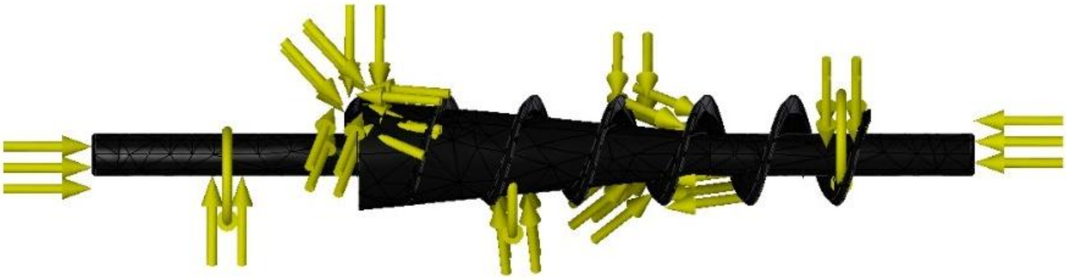

Figure 6. Force distribution on the screw

Figure 6 illustrates the force distribution acting on the screw. In this analysis, the applied forces on the screw are depicted by arrows that indicate both direction and magnitude of the force. The yellow areas represent regions with the highest concentration of forces, while darker areas indicate regions with smaller forces. These arrows demonstrate how the forces flow through the screw, with sections receiving higher forces tending to experience more pressure, which can lead to potential damage at specific points. In the coconut milk extractor machine, large forces are typically concentrated on the screw parts, which is responsible for squeezing the coconut and requires significant pressure. By visualizing these forces, designers can better understand the points of stress on the screw and improve the design to minimize the potential for material failure or operational issues.

3.2.4 Deformation Analysis

Displacement measures the extent to which the screw will deform when subjected to a load. While small deformations often have minimal impact on machine performance, excessive displacement can significantly affect the machine's function and efficiency. This displacement analysis helps verify that the screw will not undergo significant shape changes that could damage the extraction system.

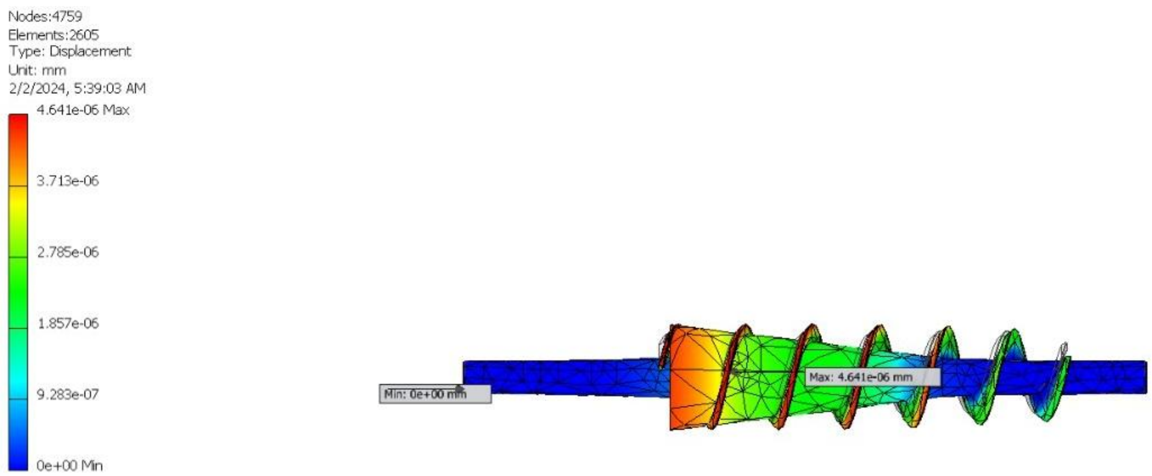

Figure 7. Deformation simulation results on the screw

Figure 7 presents the results of deformation analysis on the screw. Displacement illustrates the extent of shape change or movement that occurs in the screw when subjected to a load. This displacement often results from external forces applied to the material, causing it to move or distort. In this analysis, the color scale represents the displacement values in millimeters, with green indicating very small displacements while orange and red showing larger displacements. The maximum displacement detected is 4.64e-06 mm, which indicates that although the screw experiences pressure, the deformation is minimal and insignificant in affecting the machine's

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performance. This displacement analysis is crucial to ensure that the screw does not undergo excessive deformation impacting its function, such as wear or shape changes that could disrupt the extraction process.

3.2.5 Safety Factor Analysis

The safety factor describes how resistant the screw design is to failure. This analysis compares the material's strength with the load to which it is subjected. A safety factor greater than 1 indicates that the material can withstand more load before failing. With this analysis, we can ensure that the screw design is sufficiently strong to withstand extreme load conditions during operation, providing confidence in its durability and safety under stress.

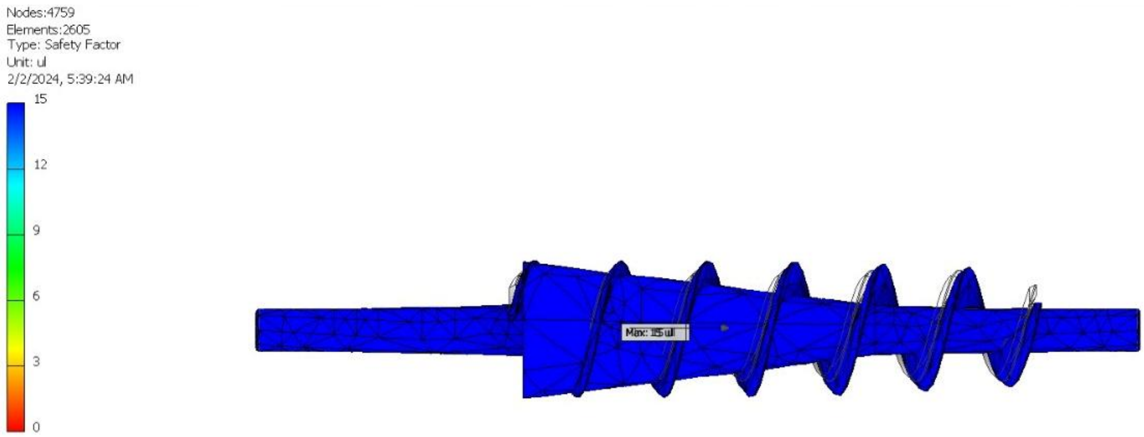

Figure 8. Safety factor displayed on the screw

Figure 8 shows the results of the safety factor analysis on the screw. The safety factor is the ratio between the material's strength and the load it experiences. A safety factor greater than 1 indicates that the material is safe to use under the analyzed conditions. In this analysis, the safety factor on the screw ranges from 0 to 15. The red areas represent regions with the highest safety factor, meaning these areas can withstand more load without the risk of failure. With a maximum safety factor of 15, this screw design indicates that the machine is very safe to operate under the given load conditions. This safety factor analysis is crucial as it provides a clear picture of how much additional load the machine can accept before the material starts to fail. In this case, the high safety factor indicates that the screw design is sufficiently strong and durable.

3.3. Drive Motor

An electric motor is used as the primary power source for the machine. The motor is connected to the screw shaft via a pulley and belt system, which transmits power from the motor to the screw shaft. In this design, the motor will be positioned in a location that is easily accessible and in line with the machine layout, ensuring optimal space efficiency.

Figure 9. Electric motor for coconut milk extractor

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Figure 9 shows the electric motor in coconut milk extractor machine, which plays a crucial role in coconut extraction process. This motor drives the screw shaft to provide necessary pressure to separate the coconut milk from the pulp in the extraction system.

a) The motor speed of 1460 rpm indicates that the motor operates at standard rotational speed for light industrial applications, ensuring efficient extraction without compromising the quality of the coconut milk produced.
b) A power usage of 1.5 HP (1.11 kW) is sufficient to run the coconut milk extractor at the desired capacity, offering a balance between energy efficiency and optimal output.
c) The motor operates on 220 V, making it compatible with mostly used household or small industrial power sources.

The motor's efficiency is crucial, as choosing a motor with either too large or too small power rating can affect operational efficiency. A motor with too high-power rating will consume more electricity without improving output, while a too small power motor may reduce the extraction speed and lower the machine's production capacity.

3.4. Gearbox and Pulley

The gearbox is used to adjust the speed ratio between the motor and the screw shaft, ensuring that the screw shaft rotates at the appropriate speed for optimal extraction. The design diagram will show the relationship between motor, gearbox, and pulley, as well as how power is transmitted from the motor to the screw shaft. The calculations related to the power transmission system in the coconut milk extractor machine include the gearbox ratio and pulley diameter, ensuring that the high motor speed can be converted into optimal speed for the screw shaft. These calculations use motor specifications (1460 rpm) and the desired screw shaft speed (146 rpm), along with the selection of pulley sizes to achieve correct ratio. The results of gearbox ratio calculations are shown in Table 2.

Table 2. Gearbox ratio and pulley diameter calculation results

No.	Description	Value
1	Motor speed	1460 rpm
2	Screw shaft speed	146 rpm
3	Gearbox ratio	10
4	Motor pulley diameter	100 mm
5	Gearbox pulley diameter	10 mm

Table 2 shows the calculation results related to the power transmission system in the coconut milk extractor machine, specifically for the gearbox ratio and pulley diameter calculations. In this system, the motor operates at 1460 rpm, while the desired speed for the screw shaft is 146 rpm. To achieve the correct speed ratio between the motor and the screw shaft, the gearbox ratio is calculated to be 1:10, meaning the motor rotates ten times faster than the screw shaft. This ratio ensures that the screw shaft rotates at the correct speed for optimal extraction of coconut milk.

Next, the motor pulley diameter is chosen to be 100 mm, which functions to transmit power from the motor to other transmission system components. The gearbox pulley, which reduces speed, is calculated to have a diameter of 10 mm. This indicates that the gearbox pulley is smaller than the motor pulley, as required for the specified transmission ratio. With these calculations, the motor's power can be efficiently transmitted, resulting in the correct screw shaft speed for effective extraction.

Overall, these gearbox ratio calculations and pulley sizes ensure that the high-speed motor operates efficiently, generating sufficient torque on the screw shaft, which is crucial for achieving maximum coconut milk extraction results.

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3.5. Extraction Capacity and Parameters of Power, Torque, and Pressure

The theoretical capacity and parameters, including power, torque, and pressure, are calculated for the coconut milk extractor machine. These parameters are essential for designing and optimizing the machine's performance in efficiently extracting coconut milk. With these values, we can evaluate the machine's performance based on the power required, the torque generated, and the pressure applied to the grated coconut during the extraction process.

The calculations of power, torque, pressing pressure, and theoretical capacity in this study are performed based on several design assumptions to simplify the analysis at the preliminary design stage. The machine is assumed to operate under steady-state conditions, with a continuous and homogeneous flow of grated coconut material throughout the pressing zone. The pressure distribution within the screw compression zone is assumed uniform, following a common approach used in the initial analysis of screw press–based machines.

The effects of load fluctuations due to variations in particle size, moisture content, and rheological properties of grated coconut are not explicitly considered at this stage. This approach directs to provide conservative estimates of required power and torque, which can subsequently be validated through prototype testing in future studies.

Table 3. Theoretical capacity, power, torque, and pressure calculations

No.	Parameter	Value
1	Extraction capacity (Q)	53 kg/hour
2	Planned power at shaft	1.11 kW
3	Planned screw shaft torque	7.3×10^4 N·mm
4	Extraction pressure	1.67×10^5 N/m^2

Table 3 shows the calculated extraction capacity, power, torque, and pressure for the coconut milk extractor machine, which are used to evaluate the machine's performance in processing grated coconut. The theoretical extraction capacity (Q) of 53 kg/hour indicates the amount of grated coconut which machine can process in one hour, providing insight into the machine's production capacity under theoretical conditions. The planned power at the shaft of 1.11 kW indicates the amount of power required by the drive motor to operate the machine optimally. This power is used to generate the required speed and torque at the screw shaft, enabling efficient extraction of coconut milk. The planned screw shaft torque of 7.3×10^4 Nmm represents the rotational force needed to rotate the screw shaft, creating sufficient pressure on the grated coconut, which aids in extracting the coconut milk. Finally, the calculated extraction pressure of 1.67×10^5 N/m^2 shows the amount of pressure applied by the screw shaft on the coconut during extraction, ensuring optimal separation of coconut milk from the pulp without compromising the milk's quality. All these parameters are interrelated to create an efficient and effective machine design that generates coconut milk with optimal capacity and quality.

The theoretical extraction capacity of 53 kg/hour implies the amount of grated coconut that the machine can process in one hour, which is sufficient to overcome material resistance during the extraction process without requiring an increase in motor power. This capacity is calculated based on the power supplied by the motor, the torque generated, and the pressure applied to coconut to separate milk from pulp. With this capacity, the machine can produce a significant amount of coconut milk in a relatively short time, making it efficient for small to medium-scale production.

The motor power required is 1.11 kW, which is designed to ensure the machine operates efficiently. This power is used to generate the necessary torque at the screw shaft, enabling the effective extraction of coconut milk. The torque of 7.3×10^4 Nmm represents a substantial rotational force on the screw shaft, enabling it to compress grated coconut with required pressure. This torque is critical because the greater the torque, the more force is applied to the coconut, resulting in more efficient extraction of coconut milk. With sufficient torque, the machine can overcome the resistance of grated coconut and optimize the extraction process.

The extraction pressure of 1.67×10^5 N/m^2 applied to coconut during extraction process ensures that the pressure is sufficient to separate coconut milk from pulp effectively without damaging the milk's quality. The

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pressure generated by the two screw shafts system is highly efficient because the screw configuration is designed with a conical shape in the compression zone, resulting in a high-pressure gradient along the machine. This enables more effective milk extraction and drier pulp. All these parameters support each other in creating an efficient coconut milk extractor machine with optimal capacity and quality.

The transmission system efficiency and power correction factor are applied to account for mechanical losses occurring in the gearbox, bearings, and frictional contacts during operation [41]. At the preliminary design stage for small- to medium-scale industrial machines, the mechanical efficiency of gearboxes is commonly assumed to range from 0.85 to 0.95, depending on the gearbox type and operating conditions [18], [38], [42].

The power correction factor is applied as a conservative approach to accommodate uncertainties in actual loading and variations in operating conditions, as recommended in the literature on machine element design and power transmission systems [43]. This approach is widely used to ensure that the motor and transmission components possess adequate safety margins before experimental validation.

The design, which includes key components such as motor, gearbox, pulleys, and screw shafts, contributes significantly to the machine's performance. The analysis of power, torque, and pressure shows that the machine is capable of producing sufficient power to rotate the screw shaft at the correct speed, generating adequate torque, and applying the appropriate pressure on the grated coconut. The calculations for the theoretical extraction capacity, required power, resulting torque and pressure ensure that the machine operates efficiently to produce coconut milk in large quantities with good quality. Through simulations and analyses such as Von Mises stress, first principal stress, and safety factor analysis, it is ensured that the machine design is safe and can be operated long-term without the risk of material failure. Thus, this coconut milk extractor machine provides an ideal solution for the coconut processing industry, particularly in terms of energy efficiency and maximum extraction yield. Compared to the single-screw machine design reported in previous studies, the two screw shafts system provides a more uniform pressure distribution without significantly increasing power consumption. This highlights the potential for improved efficiency in the extraction process within a single operational stage.

4. Conclusion

The design of a coconut milk pressing machine is a crucial stage in improving the efficiency of extraction process in coconut processing industry, particularly at the small- to medium-scale level. Based on this principle, this study focuses on the development of a two screw shafts coconut milk pressing machine design using a reverse engineering approach combined with numerical analysis. The design of two screw shafts coconut milk pressing machine delivers efficient and optimal performance in producing coconut milk. Based on the capacity analysis, the machine has a theoretical capacity of 53 kg/h, which is sufficient to meet production requirements for small- to medium-scale industries. The required 1.11 kW of power is designed with energy efficiency in mind, allowing the machine to operate optimally without excessive power consumption. In addition, the torque generated at the screw shafts, amounting to 7.3×10^4 N·mm, provides sufficient pressing force on the coconut material, enabling effective extraction and the production of high-quality coconut milk at a pressing pressure of 1.67×10^5 N/m^2.

The results of the capacity, power, torque, and pressure calculations indicate that the two screw shafts configuration is theoretically capable of providing a more uniform pressure distribution without a significant increase in power requirements. FEA further confirms that the machine's main structural components operate within safe stress and deformation limits. The machine design, which incorporates a gearbox and pulley system, also plays a significant role in maintaining operational efficiency. The gearbox system's speed ratio ensures the motor operates at high speed, while the screw shafts rotate at an appropriate speed for optimal pressing. All components function harmoniously to achieve maximum performance by appropriately balancing speed, torque, and pressure requirements during the pressing process.

Furthermore, the stress analysis and safety factor results indicate that the machine is safe for long-term operation, with minimal risk of material failure. The two screw shafts coconut milk pressing machine offers an efficient, practical, and durable solution for the coconut processing industry. With adequate production capacity, efficient power usage, and optimal coconut milk quality, this machine has the potential to enhance productivity

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and product quality, making it a competitive option for meeting the demands of modern coconut processing industry.

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