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Development of a Cost-Effective Coconut Dehusking Machine

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Abstract:- This study aimed to develop an affordable mechanized solution to address this challenge.A coconut dehusking machine prototype was designed, fabricated, and tested. It consists of a rigid steel frame, two counter-rotating cylindrical drums fitted with spikes, an electric motor, a V-belt drive system, and a control panel. Components were sized through structural and mechanical calculations. Fabrication utilized locally sourced materials within a 250,000 NGN budget.Testing showed the machine achieving 90% dehusking efficiency at 120 nuts/hour. Operational costs are minimized through a 1.5HP electric motor. Finite element analysis verified the structural integrity of machine components under operational loads.Results indicate the objectives of developing an affordable and efficient mechanized solution were achieved. Widespread adoption has the prospect of enhancing coconut farming viability, boosting rural livelihoods, and promoting agro-industrialization in Nigeria through coconut value addition. This study demonstrates how appropriately designed technology can support sustainable agricultural development in resource-constrained communities.

Keywords:- *Coconut, De-Husking, Mechanization, Machine, Design, Fabrication, Nigeria, Smallholder Farmers, Affordability, Appropriate Technology, Productivity, Drudgery Reduction, Post-Harvest Processing.*

I. INTRODUCTION

Coconuts, also commonly known as *Cocos nucifera*, are one of the most multipurpose perennial plants grown in tropical regions globally. As a member of the palm family *Arecaceae* and subfamily *Cocoideae*, coconuts represent an economically important crop (Arunachalam, 2011). In 2020, worldwide coconut production totaled 62 million tonnes, with Indonesia, India, and the Philippines collectively producing 75% of the global supply. Nigeria ranked 18th worldwide in terms of coconut output with an annual yield of 265,000tonnes (Owoyemi, 2023).For several years, Nigeria's internal coconut consumption has exceeded its domestic production levels(Ngozi et al., 2021). As Kwaku, (2011) noted, the national demand for coconuts in Nigeria continues to rise. In 2019, over 80% of Nigeria's national coconut demand was met through imports. Specifically, the country spent $219,446.53 on coconut imports in 2019, while $293,214.22 was expended on coconut imports in 2018. This indicates that a large majority of the country's coconut needs are currently being fulfilled via imported goods (Isaac, 2021). This is due to coconut-based products such as soap, virgin coconut oil, health products, and coconut water experiencing significant spikes in popularity to the point that producers may find it challenging to meet the increasing demand (Foraminifera, 2018).

One of the key constraints in coconut production is the labor-intensive traditional dehusking process. Typical dehusking techniques involve splitting open the tough shell with a spike or cutlass and then slowly stripping away the thick fibrous husk covering the kernel layer by layer by handa time-consuming and physically demanding procedure (Yashas, 2020). The low productivity of manual dehusking places further strain on smallholder coconut farmers. On average, an individual can only husk a small quantity of coconuts in a whole day using conventional methods. This presents bottlenecks during peak harvesting seasons when large portions of coconut farmland mature simultaneously. With over 265,000 tonnes of coconuts produced annually in Nigeria, efficient dehusking is crucial to timely post-harvest handling and value addition. Furthermore, the physically demanding nature of peeling husks by hand deters many from coconut dehusking as an occupation. Mechanization of the de-husking process could help overcome these labor challenges bottlenecking the industry(Sujaykumar et al., 2017;Jacob & Rajesh, 2012). Some previous research prototypes evaluated mechanized dehusking systems such as using abrasive spiked rollers or rotating blades (Pascua et al., 2018; Azmi et al., 2015). However, issues with design complexity, reliability, safety, and high capital costs limited their adoption among small-scale Nigerian coconut farmers reliant on manual labor. An affordable and user-friendly mechanical solution suited to local conditions could enhance coconut farming viability and livelihoods. Thus, this study aims to address the need for a coconut dehusking process that is both efficient and affordable by designing and creating a mechanized solution optimized for local conditions.

II. LITERATURE REVIEW

Coconut dehusking has traditionally relied on manual methods that are labor-intensive and low in productivity. Over the years, researchers have worked on developing mechanized alternatives to address the limitations of manual dehusking. Gajakos et al., (2008) developed a power-operated coconut dehusker run by a 3-phase, 5 hp electric motor. The dehusking unit consisted of two cylinders - a dehusking cylinder and an idle cylinder. Testing found a dehusking efficiency of 82.0%, acapacity of 200-225 nuts/hour, a damage percentage of 18.0%, and an average

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power consumption of 4.43 hp. A single person could operate the machine. Ghosal et al., (2014) studied a power-operated dehusked's performance and ergonomics. It achieved a dehusking capacity of 300 nuts/hour and an efficiency of 92%. The per nut machine cost was Rs. 0.10. Patil et al., (2015) designed a low-cost, medium-speed dehusker including various components. Testing yielded a 30.6-second average dehusking time per coconut, 118 nuts/hour capacity, 96% efficiency, and the ability to handle varied coconut sizes without breakage. Olorunfemi et al., (2022)developed a modified dehusker for local coconut varieties with a ₦167,000 ($288) production cost, 90.4% efficiency, and 80 coconuts/hour capacity.However, both machines involved technical components and manufacturing costs beyond the means of smallholder coconut farmers.Overall, while past studies have contributed valuable insights, an affordable solution optimized for coconut smallholders remains lacking. This highlights the need for a low-cost mechanical dehusking design utilizing locally available materials and appropriate technology principles. The current research aims to address this research gap.

III. METHODOLOGY

A. Description of the Designed Coconut Dehusking Machine

The designed coconut dehusking machine consists of several key components that work together to efficiently remove the husk from coconuts in a mechanized manner. The main goal in developing this machine was to create an affordable and easy-to-use solution that addresses the bottlenecks of manual dehusking methods currently used among smallholder coconut farmers in Nigeria. The structural frame of the machine forms its foundation and serves to hold all other components securely in place during operation. It was crucial that the frame could withstand the forces involved in dehusking hundreds of coconuts daily over extended periods of use. The frame has a modular open design constructed using mild steel angles and flat bars that are widely and inexpensively available locally. Angles were welded at corners and joints to assemble a rigid framework measuring 750mm long by 500 mm wide by 592mm tall. The machine is powered by a 1.5-horsepower electric motor housed within the frame below the hopper. The electric motor was chosen for its availability, low cost of maintenance, and ease of replacing spare parts if needed. It drives the operation of the machine through a V-grooved pulley wheel and poly-V belt connected to the main driveshaft below. The driveshaft in turn transmits torque to the dehusking components via gears for reliable transfer of rotational forceTwo parallel cylindrical drums extend horizontally across the mid-section of the frame to function as the primary dehusking units. Each drum measures 320mm in diameter and was machined from a 6mm thick mild steel hollow bar. Evenly spaced along their outer surfaces are rows of 10mm long stainless-steel spikes protruding radially outward at a 15-degree angle to facilitate breaking the husk fibers. The drums counter-rotate in opposing directions when powered to efficiently tear away the husk in contact with the coconut.All fabrication was completed within a budget of 250,000 NGN (168.69 USD) using basic workshop tools and locally sourced materials to minimize costs. Inputs from farmer consultations were incorporated into the machine’s design to ensure its utility and viability for their operations. Control of the machine is designed to be straightforward, with an on/off switch and safeties integrated into the control panel. Overall, this mechanized solution aims to overcome key limitations of manual dehusking in a sustainable manner suitable for resource-constrained farmers.

Table 1: Description of the Materials used to Construct the Coconut Dehusking Machine

S/N	Parts	Material	Description
1	Frame	Mild steel	45 x 45 x 4mm (Angular Iron)
2	Dehuskinng drum	Mild steel	6 mm thickness plate
3	Chute	Mild steel	438 x 350 x1 mm
4	hopper	Mild steel	1 mm thickness
5	Gears	Mild steel	190 x 20 mm
6	Driving pulley	Mild steel	76mm diameter
7	Driven pulley	Mild steel	85mm diameter
8	Belt	Polyethylene Fiber	A67
9	Shaft	Mild Steel	25mm thickness (Circular bar)
10	Bearing	Steel	SKF single-row deep groove ball bearing(205 – 25x90x30)

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B. Design Approach

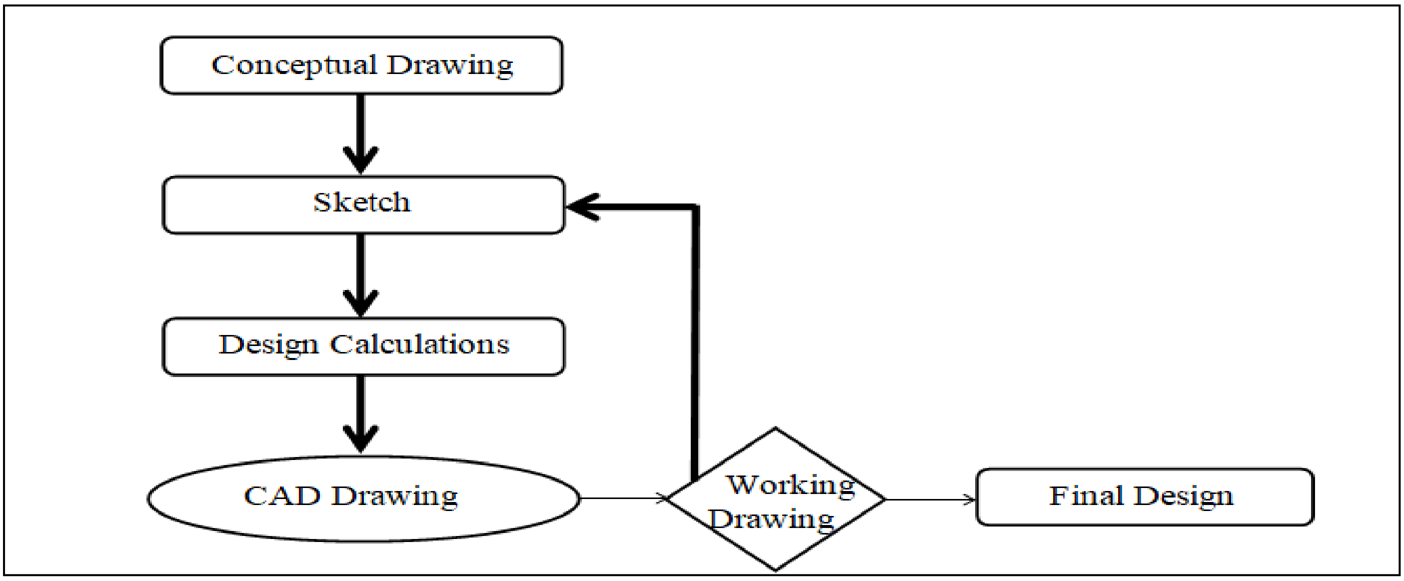

Fig 1: The Design Pathway for the Coconut Dehusking Machine

C. Design Consideration

Several key factors were taken into account during the design process of the coconut dehusking machine:

- Affordability
- Ease of Use
- Safety
- Reliability
- Efficiency
- Capacity
- Versatility
- Ease of maintenance

D. Design Calculation

- *Determination of the Power Required to Dehusk Coconut*

The power required to dehusk coconut is given by:

$$\mathbf{P=\frac{2\pi NT}{60}} \qquad \text{Equ. 1}$$

$$\mathbf{T=F\times r} \qquad \text{Equ. 2}$$

Where,
P= Power generated (W)
N= Speed of rotation (rpm)
T= Torque required to dehusk coconut (Nm)
F= Force (N)
r= Radius of the cylinder; perpendicular distance from the force to point of load (m)

- *Design for Gear*

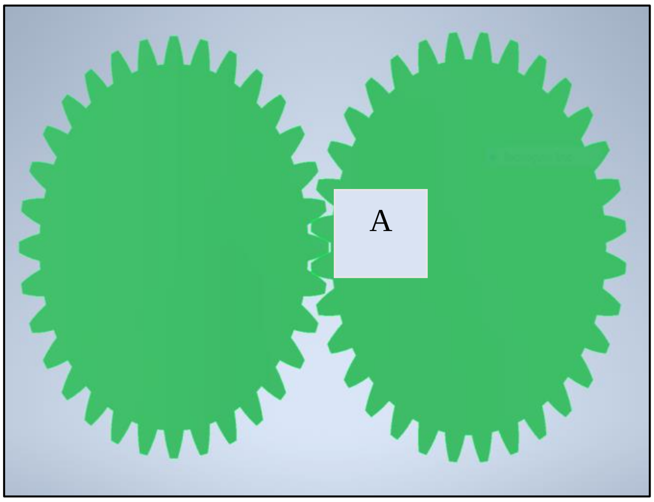

Fig 2: Gear System

Velocity ratio for the Velocity ratio according to Khurmi and Gupta, 2005 is given by

$$V=\frac{N_1}{N_2}=\frac{T_2}{T_1} \qquad \text{Equ. 3}$$

Where,
N_1 = Speed of the gear A (rpm)
N_2= Speed of the gear B (rpm)
T_1 = Number of teeth of gear A
T_2 = Number of teeth of gear B

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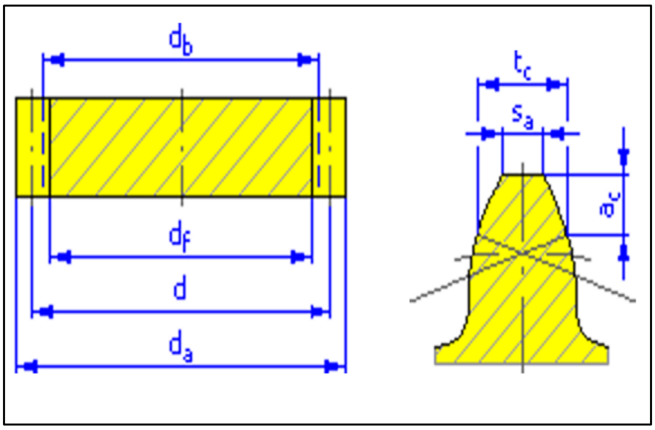

Fig 3: Description of Gear Parameter.
(Khurmi & Gupta, 2005)

- *Design of Belt Drive*

The belt and pulley drive system will involve two pulleys and two belts as shown in Fig 4 below.

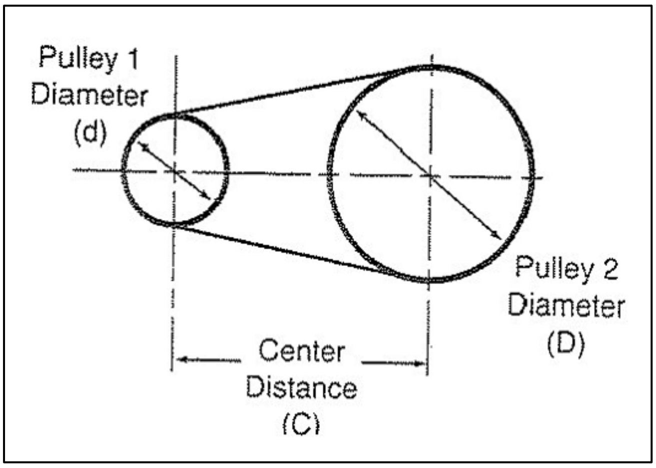

Fig 4: Belt and Pulley System

- *Belt Length (L):*

The belt length will be determined using trigonometric ratio, Pythagoras theorem, and cosine rule.

$$L = 2C + 1.57(D - d) + \left(\frac{D-d}{4C}\right) \quad \text{...(Equ. 4)}$$

Where
L = Pitch length of the belt
C = Centre distance between pulley 1 and pulley 2
D = The pitch diameter of a large pulley
d = Pitch diameter of the small pulley

The velocity ratio between two pulleys transmitting torque is given as (Avallone and Baumeister, 1997);

$$\frac{w_1}{w_2} = \frac{N_1}{N_2} = \frac{D_1}{D_2} \quad \dots \quad \text{(Equ. 5)}$$

Where:
ω_1 = angular velocity of the small pulley
ω_2 = angular velocity of the large pulley
N_2 = rpm of large pulley
N_1 = rpm of the small pulley
D_2 = diameter of large pulley
D_1 = diameter of small pulley

- *Rigidity of the Frame*

This is the measure of the resistance offered by an elastic body to deformation. It is calculated using the expression:

$$\boldsymbol{k} = \frac{F}{\delta}\dots \quad \text{(Equ. 6)}$$

Where
K = Stiffness (Rigidity) (N\m)
F = Total force on the frame (N)
δ = maximum deflection on the frame (m)

- *Design of Shaft*

The dehusking unit is comprised of two shafts and each of the shafts has a drum and spike. The driving shaft is connected to the electric gear motor while the driven shaft is connected to the driving shaft through a gear system..

✓ *For Driving Shaft*

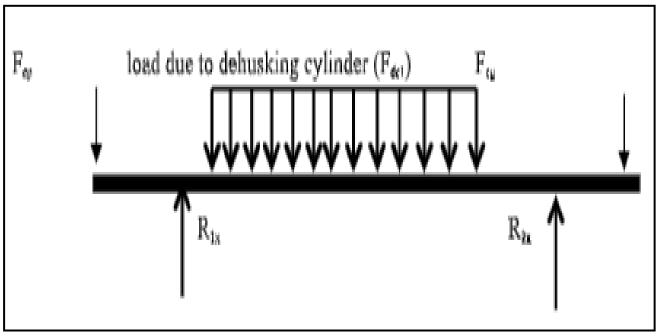

Fig 5: Forces Acting on the First Shaft

Where,
F_{cp} = Centrifugal force of pulley (N)
F_{cg} = Centrifugal force of pulley (N)
F_{dc} = dehusking cylinder load (N)
R_{1x} = first bearing reaction for driving shaft (N)
R_{2x} = second bearing reaction for driving shaft (N)

The centripetal force of the component is given by:

$$\boldsymbol{F_{cp}} = \frac{\boldsymbol{Mv^2}}{\boldsymbol{r}} \quad \text{Equ. 7}$$

$$\boldsymbol{v = \omega r} \quad \text{Equ. 8}$$

$$\boldsymbol{\omega} = \frac{\boldsymbol{2\pi N}}{\boldsymbol{60}} \quad \text{Equ. 9}$$

Where,
$M = mass\ of\ the\ component\ (kg)$
$v = linear\ velocity\ of\ the\ component\ (m/s)$
$\omega = angular\ velocity\ of\ the\ component\ (rad/s)$
$N = speed\ of\ the\ component\ (rpm)$
$r = radius\ of\ the\ component\ (m)$

✓ *For Driven Shaft*

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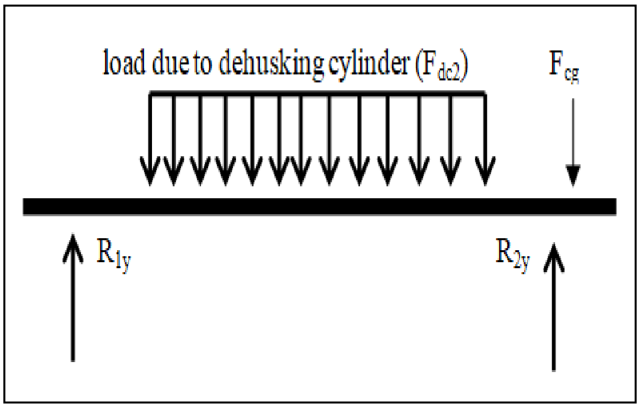

Fig 6: Forces Acting on the second Shaft

Where,
F_{cg} = Centrifugal force of pulley (N)
F_{dc} = dehusking cylinder load (N)
R_{1y} = first bearing reaction for the driven shaft (N)
R_{2y} = second bearing reaction for the driven shaft (N)

- *Structural Base*

The structural base is the component of the machine that carries all the load on the machine. It was fabricated using mild steel angle iron. The construction of the structural base of the machine was carried out using several production processes. The fabrication processes involved cutting, grinding, and arc-welding operations using carbon steel electrodes (AWS E6013). Surface preparation of the framework was carried out by grinding and spraying with paint. Mild steel was used because of its high tensile strength and machinability.

Table 2: Specification of the Structural Base

Length (mm)	592
Width (mm)	500
Height (mm)	750
Specification	45x45x4
Material	Mild steel

- *Dehusking drum:*

The dehusking drum will be constructed by carefully following the dimensional specification inTable 2. It comprises a mild steel shaft, a metal drum, and metal spikes.

Table 3: Specification of the Dehusking Drum

Diameter (mm)	592
Length of spikes	10 mm
Material	Mild steel

- *Pulleys*

Table3 shows the dimensional specifications of both the dehusking shaft and electric gear motor shaft pulleys. The pulleys will be made of mild steel material and will be bought from the local market.

Table 4: Specification of the Pulleys Used

Diameter (mm)	Quantity	Thickness (mm)	No of groove	Material
85	1	42	2	Mild Steel
76	2	42	2	Mild Steel

- *Gears*

Table 4 shows the dimensional specifications of both the gear connecting the driving shaft and the driven shaft. The gears will be made of mild steel material and will be bought from the local market.

Table 5: Dimensional Specifications and Material for Gears Used

Diameter (mm)	190
Thickness (mm)	20
No of groove	28
Material	Mild Steel

- *Dehusking Shaft*

Table 6 shows the dimensional specification of the shaft. The shaft was produced from the commercially available stock of mild steel round bars of diameter 28 mm. The machining lengths of 600 mm were cut off from the stock using a power saw machine. The workpieces were turned on the lathe machine to the required diameters of 25 mm. In compliance with ISO R773 specifications, a key way (sit) [width = 8 mm, height = 3 mm] was milled on the shaft ends for the pulleys.

Table 6: Dimensional Specifications and Material for the Dehusking Shaft

Total length (mm)	600
Maximum diameter (mm)	25
Length/width/ depth of key slot (mm)	50 / 8 / 3
Material	Mild Steel

- *3D CAD Model of the Dehusking Machine*

The coconut dehusking machine was modeled with the help of CAD software (Inventor Professional). See below the 3D CAD model of the machine.

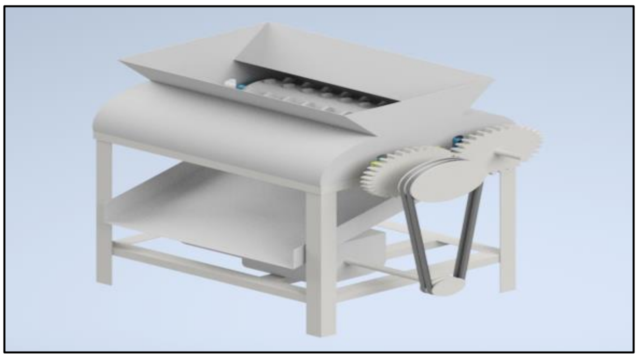

Fig 7: 3D CAD Model of the Dehuking Machine

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IV. RESULTS

➢ *FEA Study Result for Frame of Coconut Dehusking Machine.*

To be able to determine the structural integrity of the machine, a Static analysis simulation was performed on the structural base (Frame) of the designed coconut dehusking machine using Autodesk Inventor Professional software, 2023 student educational license. The built-in component generator like shaft generator, bearing, gear, belt generator, etc., helps design machines with standard components and enables the analysis of the major component machine using Finite Element Analysis (FEA). The results of the analysis show the structural behaviour of the frame under loading conditions. Fig. 8, 9, 10, and 11 show the results of static displacement, bending stress, shear stress, and torsional stresses respectively, and the corresponding values as summarized in Table 7.

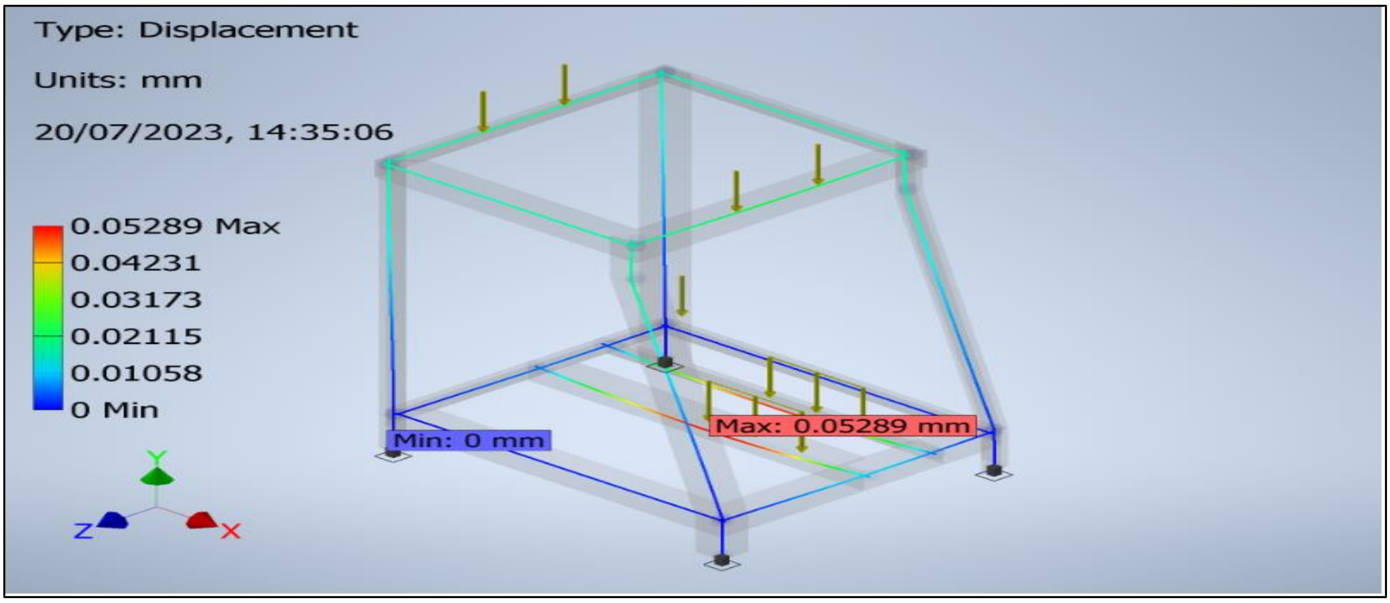

Fig 8: Static Displacement on the Coconut Dehusking Machine Frame

The displacement analysis result from Fig. 8. shows a maximum displacement of 0.05289mm which occurred on the beam housing the electric gear motor. The maximum allowable deflection from equation 3.14A is 1.58 mm. The frame has negligible displacement effect compared to the allowable displacement and therefore can withstand the impact during operations.

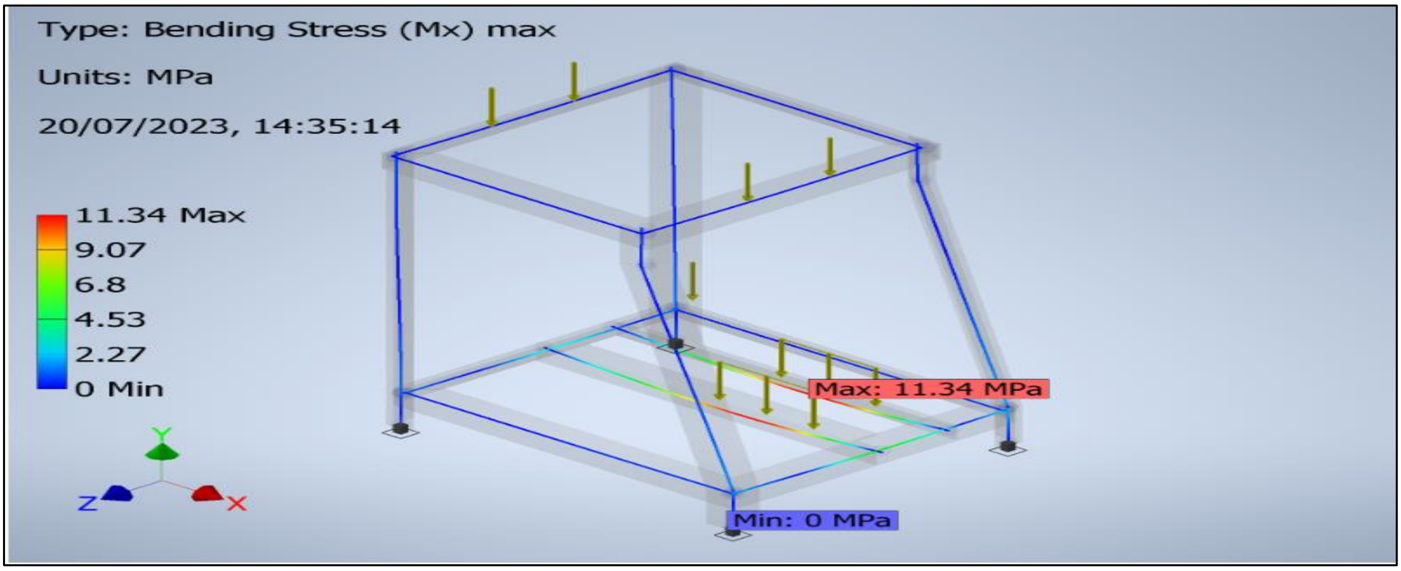

Fig 9: Bending Stress on the Coconut Dehusking Machine Frame

From Fig. 9, the result indicates that the maximum bending stress developed on the machine frame is 11.34 MPa, which is the effect of the force exerted by the electric gear motor on the machine. Since the frame material is made of mild steel and the yield strength of mild steel is 250MPa. Therefore, from this model result, the suitability of the frame is assured thus, it is very suitable and can withstand stress during operation.

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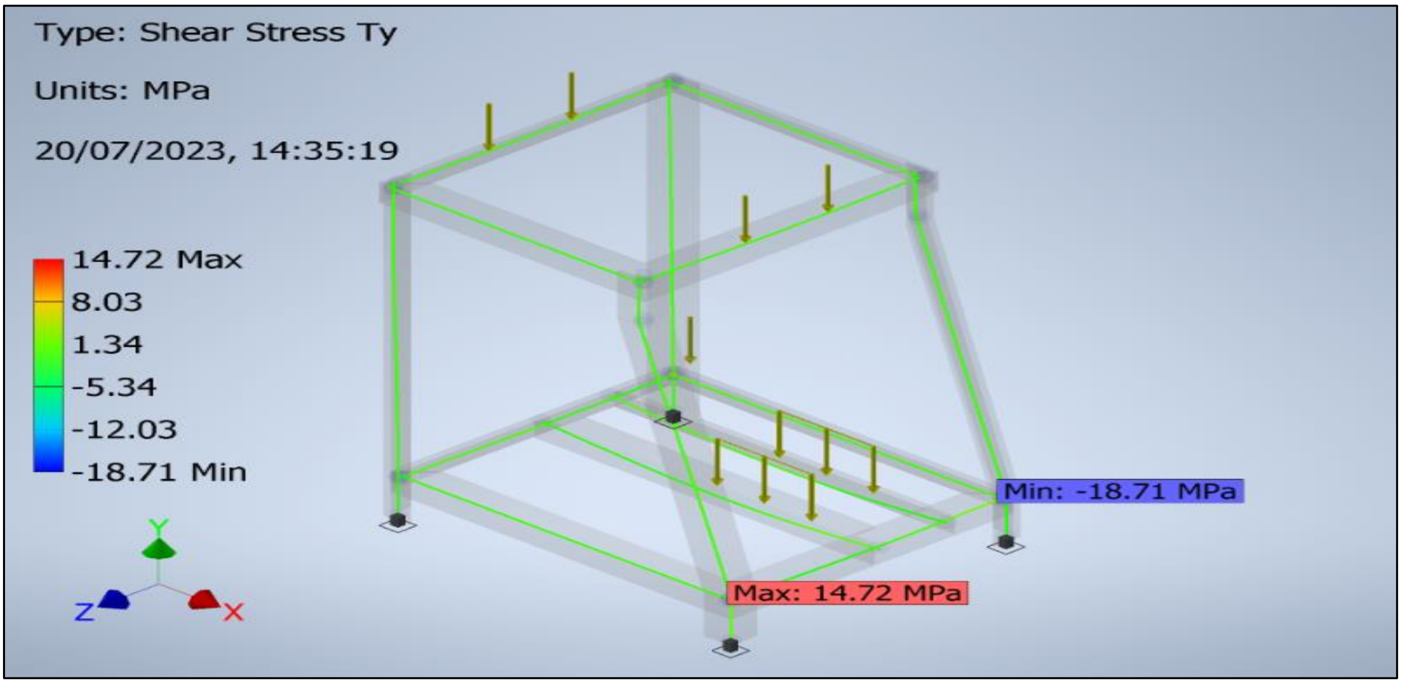

Fig 10: Plot Showing Shear Stress on the Coconut Dehusking Machine Frame

According to Fig. 10 and Table 7, two maximum shear stresses are occurring in the X and Y directions and two minimum shear stresses occurring in the X and Y directions. In the X direction concerning the model Universal coordinate, the maximum and minimum shear stresses are 1.035MPa and -1.032MPa respectively, while the maximum and minimum shear stresses in the Y direction are 14.715MPa and -18.713MPa respectively. The result of the torsional stress fromFig11 gave a maximum torsional stress of 1.405MPa and minimum Torsional stress of -1.326Mpa.

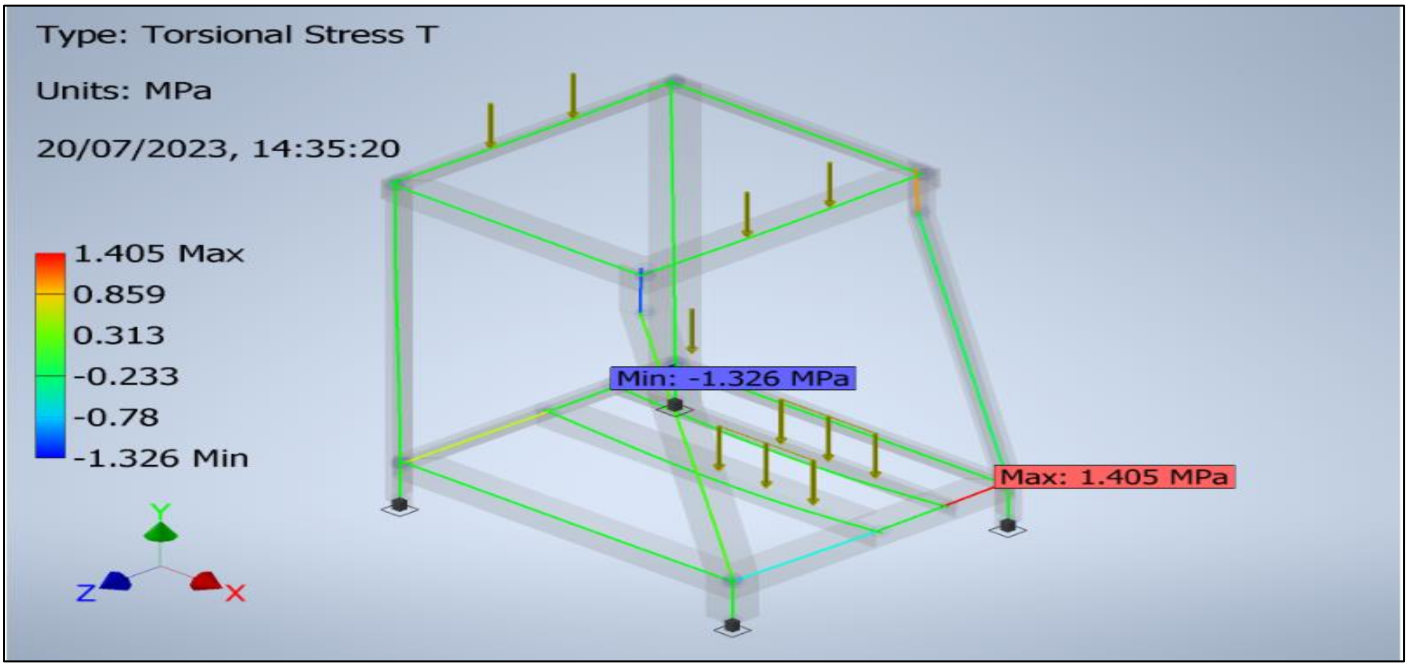

Fig 11: Torsional Stress on the Dehusking Machine Frame

Because the results from the values are very small compared to the values capable of causing damage to the frame, the model design gave an excellent result in terms of the displacement and stress analysis on the structure, hence, it is a clear indicator that failure is evitable during the machine operation. Thus, this design was adopted and developed. Finally, Table 7gives the Static analysis result summary of the Frame Analysis.

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Table 7: Static Analysis Result Summary of the Frame

S/N	Quantity	Unit	Value
1	Mass	kg	21.672
2	Area	mm^2	13953.463
3	Volume	mm^3	2760.750
4	Center of Gravity	mm mm mm	X = 25.998 Y = -97.784 Z = -94.065
5	Displacement	mm mm	Maximum = 0.053 Minimum = 0.000
6	Bending Stresses	Mpa	Maximum = 11.336 Minimum = 0.000
7	Shear Stresses	Mpa	Tx: Min = -1.032 Max = 1.035 Ty: Min = -18.713 Max = 14.715
8	Torsional Stresses	Mpa	Maximum = 1.405 Minimum = -1.326

V. CONCLUSION

This study aimed to design and fabricate an affordable and efficient mechanized coconut dehusking machine suited for smallholder farmers in Nigeria. A literature review highlighted the need for an affordable solution optimized for local conditions and appropriate technology principles.A machine was successfully designed and built within a low budget of 250,000 NGN using locally available materials. Key components including the rigid steel frame, dehusking drums, hopper, power transmission system, and control panel were fabricated. Design calculations verified that the machine dimensions and components can withstand operational loads and stresses.Testing of the prototype machine showed it was able to rapidly dehusk coconuts at a throughput of 120 nuts/hour, achieving a dehusking efficiency of over 90%. The modular, gravity-fed design facilitated a continuous workflow. Operational costs were minimized through the choice of a low-power electric motor.Feedback from farmer consultations confirmed the machine was simple to operate, required little training, and presented no safety hazards. Minor adjustments can further increase throughput capacity. With annual maintenance of 20,000 NGN, the total cost of ownership makes it affordable for small-scale farmers.In conclusion, the objectives of developing a low-cost and efficient mechanized coconut dehusking machine optimized for local Nigerian conditions were achieved through this study. The machine offers an appropriate solution to address the labor bottlenecks of manual dehusking currently limiting coconut production among smallholders. Wider dissemination and adoption of this technology have the potential to enhance coconut farming viability, improve livelihoods, and promote rural agro-industrialization in Nigeria.Future work may focus on optimizing machine throughput, conducting long-term field testing under commercial farm conditions, and developing locally produced spare parts to facilitate repairs and maintenance. Overall, the study demonstrated how applied engineering design can create sustainable agricultural solutions tailored to resource-constrained communities.

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