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DEVELOPMENT OF INDIGENOUS MOTORIZED COCONUT (*COCOS NUCIFERA*) DEHUSKING MACHINE

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ABSTRACT

Nigeria is one of the countries of the world with large coconut plantation. One of the problems encountered during the process of coconut is dehusking which majorly is carried out manually. With the drive to encourage the youths and women into processing of coconut fruit, an indigenous motorized dehusking machine was developed consisting of hopper, spur gears, spiked roller, and reduction gear following engineering design principle. Preliminary test was carried out by using the machine for dehusking coconut fruit was successful without breaking or distorting the coconut fruit

KEYWORDS: coconut, dehusking, testing.

1. INTRODUCTION

Coconut (***cocos nucifera***) is a drupe fruit produced by the coconut palm tree belong to member of a family ***Arecaceae*** and one of living species of a genus ***cocoe***. Among the world top producers of coconut, Indonesia is the largest ranked coconut manufacturer (Salman, 2020). But in Nigeria, Lagos state is the highest rated producer of coconut among other 22 producing states (FDC, 2018).

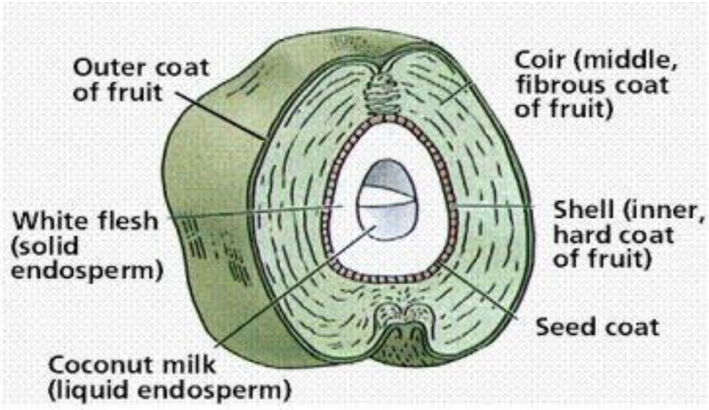

Figure 1: Structure of a Coconut fruit *(Source Nwankwoji et al., 2012)*

The coconut fruit (Figure 1) consists of an outer coat (***exocarp)*** called the husk followed by the middle fibrous coat (**coir**) then a hard-protective endocarp or shell (Faola et al., 2005). The edible part of the coconut is a whitey thin fleshy layer (**coconut meat**). Its inner part contains watery liquid (**coconut milk**) which its volume reduces as it grows. The oil in the milk depend on the volume of the milk on the mature nut. Coconut milk and its oil has economic importance for example the milk is used for refreshing and nutritious drink, while the oil is used in soap production, cooking and making margarine. The shell in the nut can be used as alternative source of heat energy. Virtually every coconut parts have significant importance in socio-economic development especially its husk as a domestic used to replace wood and other traditional fuel source (Nwankwoji et al., 2012).

Coconut dehusking operation is the first stage of coconut production after harvesting. This method involved removal of husk from the coconut by shearing force (**tearing**). Sujaykumar et al., 2017 reported that the binding force between fibre in the husk is greater than that between husk and the shell; therefore, detaching takes place between the husk and the shell interface.

Coconut is dehusked manually with simple hand tools like cutlass and axe. This is done by using cutlass or axe to strike the coconut at the top, down to the bottom thereby loosening the husk and detaching the shell (Roopasshree, 2017). This process of separations remained usual means of dehusking within our farmers in Nigeria despite the risk involved. Some risk and challenges of manual dehusking are, human energy is required for dehusking, Low productivity, Breakage of coconut shell during dehusking, incomplete dehusking, Low efficiency, and Time consuming.

However, having considered the fast growing coconut plantation in the country due to suitable ecological factor and demand for coconut fruit as raw material for other products, a motorized coconut dehusking machine that will completely separate the fibre from the shell was developed. This machine is operated by a prime mover in kilowatt (kW) because it provides less human interaction and increase rate of coconut production in our country where coconut production is higher, at the same time suit the demand in commercialized large-scale production in the world at large.

2. MATERIALS AND METHODS

Description of the machine

The NCAM motorized coconut dehusking machine (Figure 2) can dehusk any size and shape of coconut. The machine consists of the following major parts: hopper, frame, drive shaft, roller spike, husk outlet, coconut outlet and spur gear.

1. **Hopper:** the hopper has the diameter of 252 mm and height of 25 mm and was made from a 2 mm mild steel sheet. This unit is connected to the dehusking drum that accommodates coconut into the dehusking chamber.
2. **Frame:** the frame is a welded structure that gives support to the entire components of the machine. It is constructed from 50 mm $\times$ 50 mm $\times$5 mm angle iron with dimension of 750 mm length, 610 mm width and 845.3 mm height.
3. **Spikes**: The spike are designed from 12 mm diameter, cut into smaller pieces, sharp edge are formed based on the average thickness of the coconut husk. The spikes are sharpened and welded to the pipe at a measurable distance from one another for penetration and easy tearing of the husk. It is welded along the circumference of cylinder pipe in a predetermined arrangement.
4. **Drive shaft:** A mild steel shaft is held by two pillow bearings from both sides. It supports the dehusking mechanism because it is attached directly to the cylinder pipe. Each has a length of 850 mm with 30 mm diameter.
5. **Coconut outlet:** this outlet is made of mild steel and designed at an angle 30^0 to the dehusking unit where coconut move out of machine during operation.
6. **Husk outlet:** husk outlet is also attached to the dehusking unit which allow the husk to move out from the machine at inclination angle of 60^0.
7. **Spur gear:** this are circular tooth gear welded to the output shaft of spike drum that aids opposite rotation of the two spike drums. It is a simple gear with inner Ø30 and

outer Ø148. It is best use to transmit rotary motion between shafts that rotate in opposite direction.

Figure 2: Pictorial View of the NCAM Coconut Dehusking Machine.

Working principle of the machine

The principle used by this machine (Figure 3) to achieve the coconut de-husking is rubbing action (peeling) between the roller spikes and coconut fruit. The roller spikes rotate in the opposite direction and controlled to move clockwise or anti-clockwise. When coconuts are fed into the hopper, the rolling spikes grip the husks by shearing force and tear the husks from nut. After the separation, the nut moves to the outlet chute and rolls out of the machine, while the husks drop by gravitational force from the rolling spike to the husk outlet chute.

This operation continues until the coconut fruit is completely dehusked. The detached husk can be used for other viable products like rope, brush, tile, upholstery, etc.

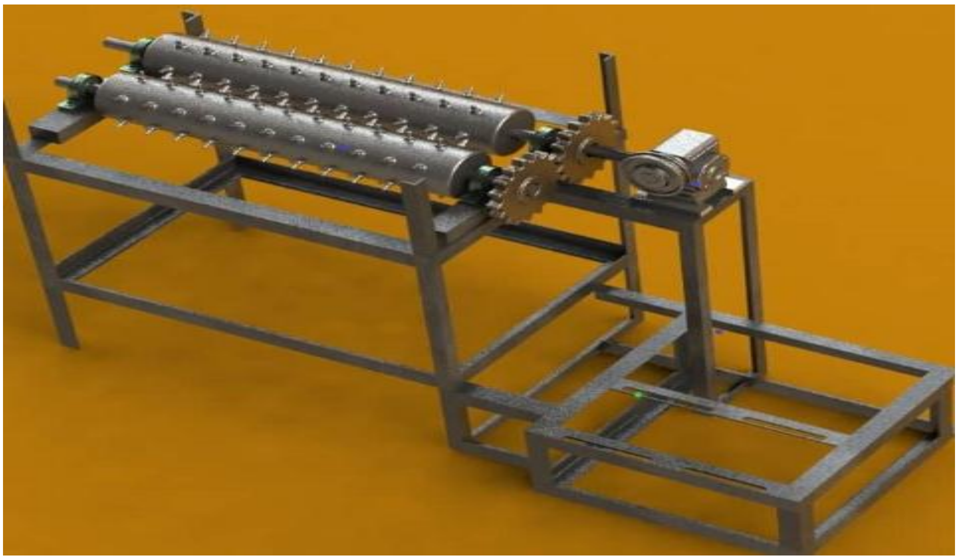

Figure 3: Picture of skeletal dehusking mechanism.

3. DESIGN ANALYSIS

Design consideration: the following factors are considered for the design of coconut dehusking machine.

i. Availability of the construction materials
ii. Durability
iii. Cost

Availability of the construction

The materials used for most parts of the machine were mild steel which is locally available in the market.

Durability

It expected to experience wear and tear on usage, thus the design caters for by using thick metal materials.

Cost

Considering the importance of the fruit processed by this machine (i.e. coconut) amongst the people of Nigeria, there is need to keep the cost of owing the machine down. Therefore, durable low-cost materials were used in the fabrication of the machine.

4. Design Calculations

Determination of the volume of the hopper

To determine the volume of the hopper for the dehusking machine, the hopper has a circular shape and the volume is calculated.

Using

$V = \pi r^2 h$..................(1)

Where $v = volume\left(m^3\right)$

Let the height of the hopper be taken as $110mm$

$\pi = 3.142$

$h = 110mm = 0.11m$

$r^2 = 253mm = 0.253m$

Volume of the hopper $v = 3.142 \times 0.11 \times 0.253 = 0.0794926m^3$

To determine revolution per minute (RPM) of the reduction gear

Assuming a revolution of 2600 rpm on prime mover, a pulley diameter of 100mm on the prime mover, and a pulley diameter of 80mm on the reduction gear.

Using

$\frac{N_1}{N_2} = \frac{D_2}{D_1}(Shigley, 1985)$..............(2)

Where,

N_1 = Rpm of the prime mover

N_2 = Rpm at gear reduction

D_1 = Diameter of pulley on the prime mover

D_2 = Diameter of pulley on the gear reduction (mm)

$$\frac{2600}{N_2} = \frac{30}{100}$$

Therefore, revolution per minute of reduction gear $N_2 = 3,250rpm$

Note: Reduction gear ratio of $60:1$ was used in the design

So, Speed of the reduction gear is,

$$\frac{3250}{60} = 54.3rpm$$

Torque required for dehusking coconut

To calculate the torque of the dehusker, the total forces acting on the roller shaft must be estimated.

For the spike

Length of the spike $l = 30mm$

Sharpened length of the spike at the end of the rod $12.5mm$

Angle of the sharpened edge $= 135^0$

Force required by rotating spikes

Number of spikes on each pipe $= 55$

Diameter of the spike $D = 15mm$

Volume of the solid rod

$$V = \pi \frac{d^2}{4} L ....(3)$$

$$= 3.142 \times 0.015^2 \times \frac{0.03}{4} = 5.4 \times 10^{-6} m^3$$

$$m = \rho \times v = 7850 \times 5.4 \times 10^{-6} = 0.042kg$$

Weight of the spike is

$$= 0.042 \times 9.81 = 0.4083087N \times 55 = 22.4 \times 2 = 44.91N$$

For cylindrical pipe

Volume of a cylinder is

$$V = \pi r^2 h$$

$$= 3.142 \times 0.02 \times 0.02 \times 0.25 = 0.0003142m^3$$

$$m = \rho \times v = 7850 \times 0.0003142 = 2.46647kg$$

Weight of the hollow pipe is

$$W = 2.46647 \times 9.81 = 24.2 \times 2 = 48.4N$$

Total force acting on a rolling shaft is

$= 44.9 + 48.4 = 93.3N$

Therefore, torque is

$$= F_\gamma (\frac{D-d}{2}) ....(5)$$

Where,

$F\gamma =$ Total force acting on the rolling shaft

$D =$ Diameter of pulley in the prime mover

$d =$ Considering factor of safety of 1.8

Torque $(T) = 93.3 \times 100 - \frac{30}{2} = 3.3 \times 1.8 = 5.94hp$; $6N$

To determine the power required by the dehusker

$P = F_\gamma V$..........(6) (Khurmi & Ghupta, 2004)

Where,

P = power required (W)

F_γ = Total force to be overcome (N)

V = Velocity of the mechanism (mls)

But $V = \frac{\pi ND}{60}$............(7)

Where,

N = rpm of the mechanism

Assume a diameter of $30mm$ for the shaft,

$$V = \frac{3.142 \times 54.17 \times 0.03}{60} = 0.8510107m^2$$

But, $F_\gamma = F_m + F_c$ (8)

F_m = Force to overcome the weight of mechanism (N)

F_c = Force to overcome the weight of the coconut (N)

To determine F_m we must evaluate weight of all the components of the mechanism:

Note: Density of mild steel $= 7850kg/m^3$

For bearing

Mass $= 1.2kg$ (determined)

Total bearing mass is:

$= 1.2 \times 4 = 10kg$

Weight of bearing

$= 1.2 \times 9.81 = 47.1N$

For shaft

Volume of solid shaft

$$V = \frac{\pi d^2}{4} l(9) ....(9)$$

Where,

V = volume (m^3)

D = diameter of shaft $= 30mm$

Volume of the shaft is

$$V = \frac{3.142 \times d^2}{4} = 3.142 \times 0.03^2 \times \frac{0.85}{4} = 0.0006009m^3$$

Density of the shaft is

$$\rho = \frac{m}{v} ....(10)$$ And

$m = 7850 \times 0.0006009 = 4.7171239kg$

Therefore, Weight of the shaft is

$= 4.71 \times 9.81 = 46.3N$

For spikes specification

Assume total length of the spike $= 30mm$

Sharpened length of the spike at the end of the rod $=$ $12.5mm$

Angle of the sharpened edge is 135^0

Number of spikes on each pipe = 55

D =diameter of spike $= 15m$

Force required by rotating spikes is

Volume of the solid rod is

$V = \frac{\pi d^2 l}{4}$.............(11)

$= 3.142 \times 0.015^2 \times \frac{0.03}{4} = 5.4 \times 10^{-6} m^3$

Mass of the spike is

$m = \rho \times v = 7850 \times 5.4 \times 10^{-6} = 0.042kg$

Therefore, Weight of the spike is

$= 0.042 \times 9.81 = 0.4083087N \times 55 = 22.4 \times 2 = 44.91N$

For cylindrical pipe

Volume of cylinder, $V = \pi r^2 h$(12)

$= 3.142 \times 0.02 \times 0.02 \times 0.25 = 0.0003142m^3$

Mass of the cylinder is

$m = \rho \times v = 7850 \times 0.0003142 = 2.46647kg$

Weight of the hollow pipe is

$W = 246647 \times 9.81 = 24.2 \times 2 = 48.4N$

For circular disc

Volume of a cylinder is

$V = \pi r^2 h$.........(13)

$= 3.142 \times 0.02 \times 0.02 \times 0.05 = 0.0000628m^3$

Mass of the circular disc is

$m = \rho \times v = 7850 \times 0.0000628 = 0.49kg$

Therefore, Weight of the disc is

$= 0.49 \times 9.81 = 4.84N$ Multiply by the number of disc (4)

$= 19.36N$

For spur gear

Mass of the spur gear is

$= 2kg$ (Determined)

Weight of the gear

$= 2\times 9.81 = 19.6N$ Multiply by $2 = 39.24N$

For reduction gear

Mass of reduction gear is

$= 1.8kg$ (Determined)

Weight of reduction gear is

$= 1.8\times 9.81 = 17.7N$

For reduction pulley weight

Mass of the pulley is

$= 1.2kg$ (Determined)

Weight of the pulley is

$= 1.2\times 9.81 = 11.772N$

F_m Equal the sum of the weight of the components

$F_m = (46.3+44.9+48.4+19.4+39.2+17.7+11.7) = 274.4N$

$F_c =$ Average shear force required to dehusk coconut of various sizes and shapes using universal testing machine was determined as $1500N$ (Sujay Kumar et al 2017)

Therefore,

$F_\gamma = F_m + F_c$...........(14)

$F_\gamma = 274.4 + 1500 = 1774.4N$

Power required todehusk coconut fruit (P)

$P = F_\gamma V$ (15)

Using a factor of safety of 1.8

$= 1774.4\times 0.8510107\times (1.8) = 2,718.060094944$

$P = 2,718.060094944$

But $748w = 1hp$

$2,718.060094944w$ to $1hp$

$\frac{2,718.060094944}{748} = 3.633\ ;\ \ 4hp$

Therefore, if a calculated 4.0 hp was gotten, then, a 5.0 hp prime mover would be suitable for operating the machine.

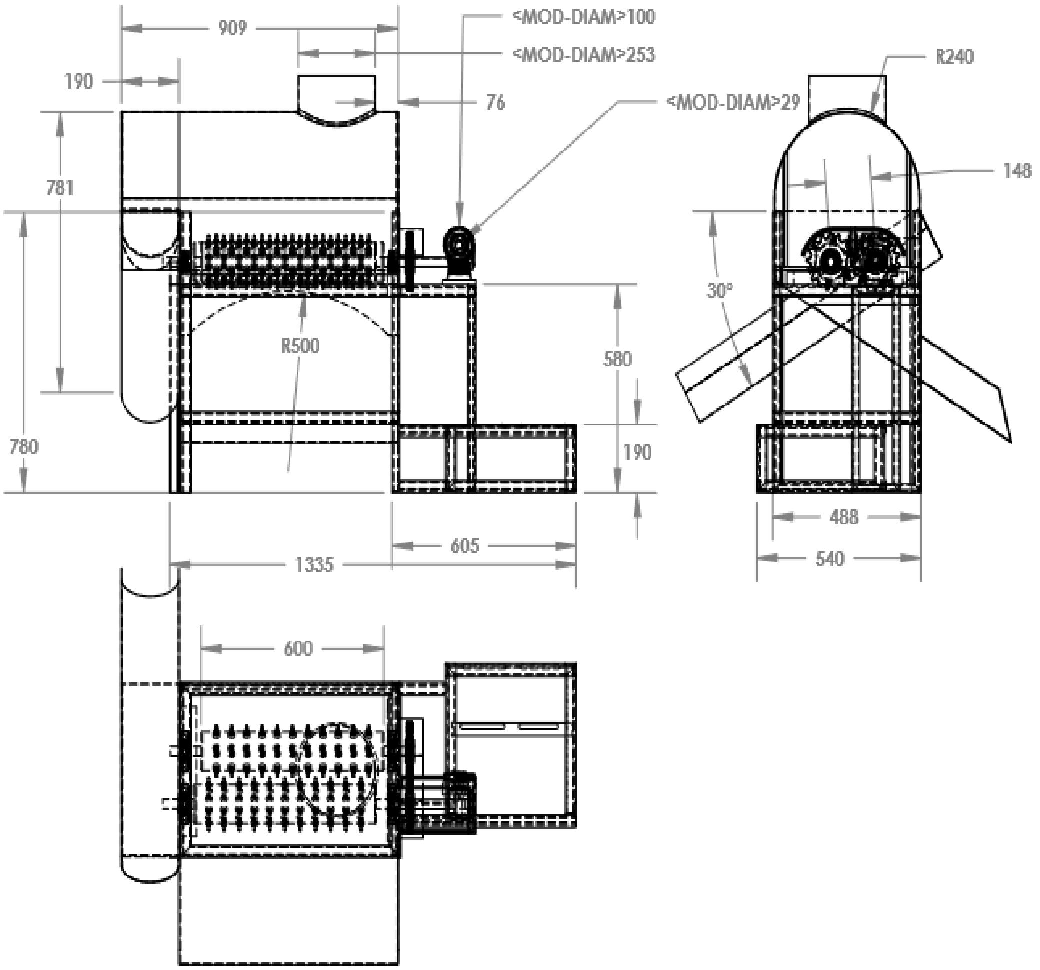

Figure 6: Orthographic view of the machine.

5. Preliminary Test

Procedure

The machine was tested for efficiency by loading a mature coconut fruit through the hopper in to the dehusking chamber. The average time utilized by the machine to fully dehusk a coconut is 10 seconds. This operation was repeated for different shapes and sizes of coconut and the result proved that it can effectively dehusk any varieties of coconut. However, a comprehensive performance evaluation would be carried out to scientifically report its performance. The pictorial views of coconut before operation and after were shown in Figure 5 below.

Figure 5: Pictorial view of before and after dehusking of coconut fruit.

6. CONCLUSION

A reliable dehusker was fabricated, using locally source materials. The machine is equipped with spikes for dehusking of the coconut fruit is achieved. The cost of maintenance is very low and the machine can be transported from one place to another due to its design portability. The machine has removed the challenges encountered in manual dehusking like incomplete dehusking and shell breakage during dehusking.

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