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DESIGN AND DEVELOPMENT OF A MOBILE POWER OPERATED COCONUT DEHUSKING AND CLEANING MACHINE

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Abstract

Coconut (Cocos nucifera L.) is a perennial tree crop. Nut is the most important economical part in a coconut palm. Fruit has to be de-husked and deshell before any production process. Coconut is a fruit of great value as every part of the fruit is commercially viable. To utilize coconut fruit and its parts, it is necessary to remove the coconut husk and to break the coconut shell. Coconut dehusking and shell breaking are traditionally labour-intensive operations. Shape and size characteristics data of coconut were collected. Based on the survey the maximum and minimum sizes of the coconut were determined. The machine was designed to accommodate the different sizes of the coconut irrespective of where there are cultivated around the world. Generally, coconuts are dehusked manually using a machete. These methods require skilled labour and are laborious to use often resulting to injuries to the Farmers when done manually. However, in this present work a mobile coconut dehusking and cleaning was designed and developed for the Coconut farmers. The unique features of this machine are its ability to dehusk and clean the nut completely and being moved to any location with ease and its increased efficiency when compared to other machines.

1. Introduction

Coconut (Cocos nucifera L.) is a versatile palm tree because most of the parts can be used for different purposes. The coconut fruit is a fibrous drupe. From outside in, the coconut consists of a thin hard exocarp, a thicker layer of fibrous mesocarp (husk), the hard endocarp (shell), the white endosperm (kernel), and a large cavity filled with liquid (water). When immature, the exocarp or outer skin is usually green or sometimes bronze. Wide variation in fruit shape and size exists within types and populations. Fruit shapes vary from elongated to almost spherical. Coconut tree can produce fruits throughout the year and onetreemayyieldaround50-80fruitsperyear [1] and [2].

It is well known that coconut fruit can be used for different purposes. This include being used of coco nut as food, fodder, fuel, in apiculture and for fiber, in construction works, lipids, alcohol, for creation ornamental products etc. Coconut used as food include copra, edible cooking oil, coconut chips,coconuthoney,coconutjamfromtendercoconut,coconutcandy,coconutmilk,virgincoconutoil,milkandcoconutsweet,defattedcoconutmeatasanimalfeed.Therearemany industrial uses of coconut fruit like fibres of coconut husk used in making ropes and other kinds of useful articles, coconut oil can beusedinsoaps,detergents,shampoos,cosmetics,pharmaceuticalsandexplosives,coconut-shell charcoal's activated carbon can beusedingeneralwaterpurification,crystallinesuga rpreparationandgoldpurification[3, 4, 5 and 6].

The shell is used for fuel purpose, shell gasifier as an alternate source of heat energy. The husk yields fibres used in the manufacture of coir products such as coir carpets, coir geo-textile, coir composite, coir safety belts, coir boards, coir asbestos and coir pith. Coir is a versatile natural fibre extracted from mesocarp tissue, or husk of the coconut fruit. Generally, fibre is of golden colour when cleaned after removing from coconut husk. Coir is the fibrous husk of the coconut shell. Being tough and naturally resistant to seawater, the coir protects the fruit enough to survive months floating on ocean currents to be washed up on a sandy shore where it may sprout and grow into a tree, If it has enough fresh water, because all the other nutrients it needs have been carried along with the seed.

The size of nut varies from 147 to196 mm in diameter and 245 to 294 mm long. The coconut fruit should be dehusked prior to any postharvest application on flesh. Prevailing de-husking techniques in Nigeria are risky and subject the Farmer to accident.

The whole coconut fruit is composed of several different layers, mesocarp. husk, shell, peel and coconut meat. Coconut meat and coconut water are financially important part of coconut fruit. Coconut meat and coconut water are found at centre most part of the fruit. Coconut husk is composed of many fibrous layers and are woven tightly with each other. Coconut shell is single hard sphere covering coconut meat. Removal of husk and shell are most time consuming, repetitive, labour-intensive fatiguing, tedious and angerous works in coconut processing. Traditionally and also till date, removal of husk and shell are performed largely by manual force using machete. The workers are faced with minor/ major injury resulting slash or wound in hand, palm, thigh and upper body. The bending posture they adopt during local method of dehusking is tiresome and prone to hazard. The manual coconut processing involves a lot of risk and requires precaution against injury. The average dehusking capacity in traditional practices is about 60-70nuts/h[7 and 8].

There are different types of coconut dehusking machines with different mechanisms and operational principles. The following are some of the mechanisms that defines the coconut dehusking machine

Hydraulically operated coconut dehusking machine; General purpose coconut dehusking machine; Triangular teeth roller coconut dehusker; Twin blade type powered coconut husking machine; Cam and follower type coconut dehusker; Coconut dehusking machine (Two spiked rolls); Continuous power operated coconut dehusking machine; Petrol engine powered coconut dehusking machine; Automated coconut ehusking and crown removal machine; Powero perated dehusker; Coconut de-husking, cutting and grating machine; Single spiked roll type coconut dehusking machine; Economical coconut dehusking machine; Coconut dehusking machine with flywheel; Electric coconut husk remover; Spiked and rollers type coconut dehusking machine; Auger-assisted semi-automatic coconut husking machine; TNA Udeveloped power operated coconut dehusker; Coconut dehusking machine(Model:COM11)[9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22 and 23].

Though, several studies on coconut de-husking machines have been carried out, most are not popular among coconut producers due to their complexity in operation and low efficiency. This research was conducted to design and develop a mobile power operated coconut de-husking and deshelling machine for medium scale farm holders which make their coconut de-husking operation efficient, safe and cheaper in order to increase profits in this particular aspect of the coconut industry in Nigeria with added advantage of moving it to different locations of choice and using relatively cheaper power source.

2. Materials and methodology

The study was conducted at the Faculty of Engineering, Cross River University of Technology, Calabar, Nigeria. A preliminary survey was carried out with different coconuts selected from different coconut plantations and locations in order to find out the average dimensions such as height, diameter and thickness of the husk at stalk end, to guide the determination of the design of the machine components.

2.1 Components and Description of machine parts

[1] Dehusking shaft with strippers
[2] Control paddle
[3] Machine frame
[4] Gearbox
[5] BearingwithBearingCap
[6] Petrol generator
[7] Inlet tray
[8] Pulley
[9] Polishing chamber
[10] V-belt
[11] Helical gears
[12] Sprocket
[13] Chain

2.2 Description of some machine parts

Dehusking shaft with strippers

A shaft is a rotating machine element which is used to transmit power from the driver to the driven or one place to another. The power is delivered to the shaft by some tangential force and the resultant torque (or twisting moment) set up within the shaft permits the power from the engine to be transferred to various machines linked up to the shaft. In order to transfer the power from one shaft to another, the various members such as pulleys, gears etc., are mounted on it. These members along with the forces exerted upon them causes the shaft to bending. In other words, we may say that a shaft is used for the transmission of torque and bending moment. The various members are mounted on the shaft by means of keys or splines.

The adhesion between fibers in the husk is greater than that between the shell and the husk, hence separation occurs at the husk-shell interface. The thickness of fiber is in the range of 20 to 40mm. The dimension of the strippers was selected to get effective penetration with coconut forced to them by the rotation of the control paddle. The strippers are attached dehusking roller shaft by welding.

2.3 Gearbox

A gearbox designed using a worm and worm-wheel is considerably smaller than one made from plain spur gears, and has its drive axes at 90° to each other. With a single start worm, for each 360° turn of the worm, the worm-gear advances only one tooth of the gear. Therefore, regardless of the worm's size (sensible engineering limits not withstanding), Given a single start worm, a 20-toothworm gear reduces the speed by the ratio of 20:1. With spur gears, a gear of 12 teeth must match with a 240-tooth gear to achieve the same 20:1 ratio Therefore, if the diametrical pitch (DP) of each gear is the same, then, in terms of the physical size of the 240-toothgeartothat of the 20-toothgear, the worm arrangement is considerably smaller in volume.

Gears are commonly used to transmit rotational motion between machinery shafts. The spur gears, which are designed to transmit motion and power between parallel shafts, are the most economical gears in the power transmission industry. The internal gears are spur gears turned "inside out". In other words, the teeth are cut into the inside diameter while the outside diameter is kept smooth. This design allows for the driving pinion to rotate internal to the gear, which, in turn, allows for cleaning operation. Intended for light duty applications, these gears are available only in brass. When choosing a mating spur gear, always remember that the difference in the number of teeth between the internal gear and pinion should notbelessthan15 or 12 [25].

The gear box used in this machine has a speed ratio of 48:1. This reduces the speed from 1440 rpm to 30rpm. The worm gear mechanism is used in the designed gear box for reducing he output speed. Reducing the output speed, increases the torque produced from the petrol generator.

2.4 Belts and Chains

Belts and ropes drive could slip and strain hence there are not preferred. Chain and gear drives are preferably used for small distance power transmission (Wadile1). The power from the chain is transmitted to the shaft by means of sprocket.

- No of teeth in the sprocket attached to the gearbox=18
- No of teeth in the chain pulley attached to the spur gear=40
- Total length of the chain=2400mm

2.5 v-belts

The V-belts are made of fabric and cords moulded in rubber and covered with fabric and rubber. These belts are moulded to a trapezoidal shape in cross-section and are made endless. These are particularly suitable for short drives. The included angle for the V-belt is usually from 30° to 40°.

The chains are mostly used to transmit motion and power from one shaft to another, when the centre distance between their shafts is short such as in bicycles, motor cycles, agricultural machinery, conveyors, rolling mills, road rollers etc. The chains may also be used for long centre distance of up to 8 metres. The chains are used for velocities up to 25 m/s and for power up to 110 kW. In some cases, higher power transmission is also possible [23].

2.5 Bearing

A ball bearing is a type of rolling-element bearing that uses balls to maintain the separation between the bearing races. Thepurposeofaballbearingistoreducerotational frictionandsupportradialandaxialloads.Itachie vesthisbyusingatleasttworaces to contain the balls and transmit the loads through the balls. In most applications, one race is stationary and the other is attached to the rotating assembly (e.g., a hub or shaft). As one of the bearing races rotates it causes the balls to rotate as well. Because the balls are rolling, they have a much lower coefficient of friction than if two flat surfaces were sliding against each other. Ball bearings tend to have lower load capacity for their size than other kinds of rolling-element bearings due to the smaller contact area between the balls and races. However, they can tolerate some misalignment of the inner and outer races.

The bearings were pressed smoothly to fit into the shafts because if hammered the bearing may develop cracks. Bearing is made up of steel material and bearing cap is mild steel. Ball and roller bearings are used widely in instruments and machines in order to minimize friction and power loss. Bearing Specification

- Bearing series=6200 series
- Bearing Number=6202
- Diameter of the bearing=20mm [24].

2.7 Pulley

The pulleys are used to transmit power from one shaft to another by means of flat belts, V-belts or ropes. Since the velocity ratio is the inverse ratio of the diameters of driving and driven pulleys, therefore the pulley diameters should be carefully selected in order to have a desired velocity ratio. The pulleys must be in perfect alignment in order to allow the belt to travel in a line normal to the pulley faces. The pulleys may be made of cast iron, cast steel or pressed steel, wood and paper. The cast materials should have good friction and wear characteristics. The pulleys made of pressed steel are lighter than cast pulleys, but in many cases, they have lower friction and may produce excessive wear.

2.8 Helical gears

A helical gear has teeth in form of helix around the gear. Two such gears may be used to connect two parallel shafts in place of spur gears. The helices may be right-handed on one gear and left-handed on the other. The pitch surfaces are cylindrical as in spur gearing, but the teeth instead of being parallel to the axis, wind around the cylinders circumferentially like screw threads. The teeth of helical gears with parallel axis have line contact, as in spur gearing. This provides gradual engagement and continuous contact of the engaging teeth. Hence helical gears give smooth drive with a high efficiency of transmission and less noise compared to other gears

2.9 Design Consideration

The coconut dehusking machine was designed and fabricated based on the following considerations:

1. The availability of materials locally to reduce cost of production and maintenance of the machine.

2. It is desired that there should be no husk on the nut.

3.No nut breakage and the removed husk should have its full length in place. Hence, the electric motor, gears, pulley and speed reducer were selected to meet the required speed of the dehusking and polishing units of the machine to achieve these objectives.

2.10 Design Analysis of Major Components

Some data on the forces acting on the coconut to dehusk are required. The husk is removed from the machine through the shear force exerted by the stripper dehusking roller shafts in the machine. Based on that, the amount of shear load required to dehusk the coconuts have been determined. Both dry and mature coconuts of various sizes are tested experimentally in the Standard Universal Testing Machine (UTM) [25].

The shear yield strength of coconut fruit was determined using the following equation,

$$\tau_{yt} = 0.577\,\sigma_{yt} \quad \text{(i)}$$

Where: τ_{yt} is the shear yield strength.

σ_{yt} is the tensile yield strength $=175\text{N/mm}^2$ for coconut fruit [17 and 26].

Therefore, the tangential force acting on the strippers during dehusking process was determined [27].

$$F_t = \tau A \quad \text{(ii)}$$

Where: τ =shear stress of coconut fibre

F_t = the tangential force on the strippers

2.11 Determination of Power required by the Dehusking machine

The power, required for the dehusking of one coconut by the machine was determined to be 0.75KW [23]. Service factor for difficult drive = 1.8. From the following relation given below:

∴Design power = power to be transmitted × service factor

$$P = F \times V \quad \text{(iii)}$$

Where: F, is the force required to grip and tear the husk

V= the peripheral velocity of the driving gear

Hence, for a machine transmitting less than 3.75 kW, the design power is within the range of 0.7-3.5 kW, [23].

For the purpose of this design, a petrol generator with output of 4kwwas chosen to drive the machine.

2.12 Selection of belt and pulley

The machine requires two pulleys and a V-belt for its drives. Due to the availability, cost and performance, mild steel pulley with groove angle of 38^0 was selected. Type A V-belt with thickness (t) 8 mm was chosen, [23].

The minimum outside diameter of the driver pulley, D_0 =78 mm.

But pitch diameter of the driver pulley,

$D = D_0 - t$

But the pitch diameter of the driven pulley,

$D = D_0 + t$

D_A, pitch diameter of the driving pulley, and

D_B, pitch diameter of the driven pulley

Speed of electric motor, N_A

From the relation, [23].

$$N_A D_A = N_B D_B \quad \ldots \text{(iv)}$$

$$N_B = \frac{NA \times DA}{DB}$$

Speed ratio between the two pulleys

$$= \frac{NA}{NB}$$

The distance between the drive and the driven shaft can be estimated as

$$X = \left(\frac{3DA + DB}{2}\right) \quad \ldots\ldots \text{(v)}$$

According to the Indian standard pitch length of V-belt, a type A V-belt with a standard pitch length of 747mm which is the closest value to 758.16mm was selected for the design, due to the power to be transmitted [23].

Belt tension;

The angle of lap for the smaller pulley (since both pulleys are made of the same material),

$$\theta = (180^0 - 2\alpha)\frac{\pi}{180} \text{ rad} \ldots\ldots\ldots\ldots \text{(vi)}$$

Where: θ is the angle of lap (contact) and value for $\pi = 3.142$[23].

$$\sin\alpha = \frac{D_B - D_A}{2x}$$

The centrifugal tension on the belt was determined using equation (vii) according to [23].

$$T_C = MV^2 \ldots\ldots\ldots\ldots\ldots\ldots \text{(vii)}$$

Where: T_C, is the centrifugal tension on the belt

M, is the mass of the belt $\frac{w}{g}$

V, is the peripheral velocity of the belt =?

Therefore, solving for the peripheral velocity we have,

$$V = \frac{\pi D_A N_A}{60}$$

From the dimensions of standard V-belts according to ISO: 2494-1974, [26] for a belt transmitting less than 3.75 kW.

Tension in the tight and slack side of the belt was determined using equation (viii)

$$P = (T_1 - T_2) V \ldots\ldots\ldots\ldots \text{(viii)}$$

Where: P, is the power transmitted by the belt

T_1, is the tension in the tight side of the belt

T_2, is the tension in the slack side of the belt

V, is the peripheral velocity of the belt,

$$P = T_1 (1 - T_2/T_1) V$$

Also, $\frac{T1}{T2} = e^{\mu\theta}$

Therefore, $P = T_1 \{1 - \frac{1}{e^{\mu\theta}}\} V$

$$\frac{T_1 - T_2}{T_2 - Tc} = e^{\mu\theta cosec\beta} \ldots\ldots\ldots\ldots\ldots \text{(ix)}$$

$$T_2 = \frac{(T_1 + T_C e^{\mu\theta cosec\beta})}{(1 + e^{\mu\theta cosec\beta})}$$

Determination of speed of the Driving Roller shaft

Number of teeth on the speed reducer pinion, T_{SP}=9

$$\frac{N_{Sp}}{N_{Sg}} = \frac{D_{Sg}}{D_{Sp}}$$

$N_{Sp}D_{Sp} = N_{Sg}D_{Sg}$…………… (x)

$$N_{Sg} = \frac{N_{Sp} \times D_{Sp}}{D_{Sg}}$$

$$N_{g2} = = \frac{D_{g1} \times N_{g1}}{D_{g2}}$$

$$N_{g4} = \frac{D_{g3} \times N_{g3}}{D_{g4}}$$

$$N_{g4} = \frac{36 \times 56}{46}$$

For the driving roller gear (gear 5);

$$N_{g5} = \frac{T_{g4} \times N_{g4}}{D_{g5}}$$

2.13 Design of the Diameter of Driving Roller Shaft

Due to the configuration of spur gear on the driving roller shaft, the tangential load acting on the gear teeth was computed using equation (xi), [26].

$$F_t = \frac{P}{V} \times C_s \text{…………… (xi)}$$

Where: F_t, is the tangential load acting the driving gear teeth.
P, is the power transmitted by the driving roller shaft
V is the peripheral velocity of the driving gear =?
C_S is the service factor =1.8.
Assuming steady load conditions [23].

$$\text{But } V = \frac{\pi D_{g5} \times N_{g5}}{60}$$

But the normal force F_N, which is acting on the driving gear, was computed as;

$$F_N = \frac{F_t}{\cos \emptyset} \text{………………………………………………………………………… (xii)}$$

Where: ∅ is the pressure angle =20°, (Khurmi and Gupta, 2005).
The resultant load acting on the driving gear was computed using equation (iv) by [23].

,

$$F_R = [(F_N)^2 + (W_G)^2 + 2F_N \times \cos \emptyset]^{\frac{1}{2}} \text{……… (xiii)}$$

2.14 Fabrication of the machine

As shown in Figures 1.0, the coconut de-husking machine was fabricated in the department of Mechanical Engineering Workshop, Cross River University of Technology, Calabar. It consists of the frame structure which is the main supporting structure upon which other components of the machine were mounted. The frame is a welded structure constructed from mild steel angle iron. The de-husking unit consists of two rollers with strippers and shafts. Both rollers are solid mild steel of known diameters. The strippers were formed by welding mild steel flat bars on the rollers. The dehusking shafts are supported at both ends by ball bearings. Some of the machine parts were bought out after due consideration of their design and functions from relevant design texts. The components bought out included; the gear box, the pulley, the GX 200 petrol generator and V-belt. The control paddle was constructed using rubber of 102mmx50mmx15mm dimension. The rubber was bolted to a shaft of 100mmx50mm. Eight plates of 30mmx20mmx15mm were welded to the shaft and the rubber was fastened to the plates. The function of the control paddle is to roll the coconut fruit gradually into the dehusking chamber. Like the dehusking stripper roller shafts, the control paddle is held at the two ends by bearings that ensures their efficient rotation during dehusking. The drive unit guards and the inlet tray plates were constructed by cutting 4 mm mild steel plate, shaped according to the design requirements and were fastened on the frame structure after the assembly of the major component parts.

When the petrol generator is turned on by pulling outward the starter rope, the generator starts running and power is transmitted through the gearing arrangement to the dehusking rollers shafts with the strippers via the gearbox and rotate them in counter directions towards the center thereby causing both the gripping and tearing of the husk when coconut is rolled in between the rollers by the aid of the control paddle. While the rollers rotate, control paddle continues to exert pressure on the coconut as the control paddle continues to rotate clockwise feeding the coconut fruit in the de-husking unit until the coconut is completely dehusked and moves to the cleaning chamber by the Operator.

Figure 1.0: A fabricated coconut dehusking machine

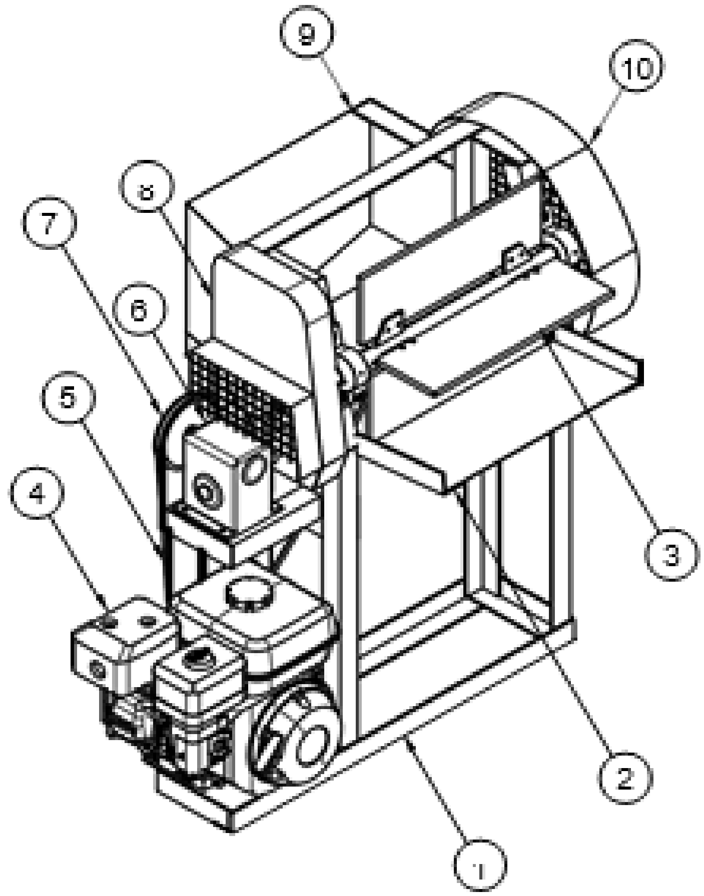

Figure 1.2 Shows the Assembly drawing of the developed machine

Table 1.0Shows the part list of the developed machine

S/N	ITEM	DESCRIPTION
10	TRANSMISSION DRIVE UNIT GUARD	MILD STEEL
9	POLISHING CHAMBER	MILD STEEL
8	MAIN DRIVE UNIT GUARD	MILD STEEL
7	PULLEY	BOUGHT OUT
6	GEARBOX	BOUGHT OUT
5	V-BELT	BOUGHT OUT
4	GX-200 ENGINE	BOUGHT OUT
3	CONTROL PADDLE	RUBBER
2	INLET TRAY	MILD STEEL
1	MACHINE FRAME	MILD STEEL

PARTS LIST

PROJ. TITLE	COCONUT DEHUSKING MACHINE	
DATE	MAY, 2023	
SCALE	1:10	ALL DIMENSIONS IN mm

3. Principles of Operation

The coconut dehusking machine is driven by a GX-200 petrol engine. Power is transmitted from a 4kW petrol engine to the speed reduction gearbox. The gearbox increases the torque while reducing the speed of the drive. Using a chain drive, power is transmitted from the gearbox to the stripping rollers. The stripping rollers operate in a contra-rotating direction. The contra-rotation is also facilitated by a chain-sprocket drive arrangement on the opposite end of the drive input. A set of control paddles is used to facilitate effective stripping of the coconut. The machine also incorporates a polishing unit, which facilitates further surface finishing on the dehusked coconut.

During operation, the coconut to be dehusked is fed into the machine through the inlet tray. The control paddle feeds the coconut to the stripping rollers for the dehusking process. When the dehusking process is completed, the control paddle ejects the coconut into the polishing unit, where a rotating metallic brush further processes the dehusked coconut to give it better surface finish. When the desired level of polishing is attained, the coconut is removed by the operator.

Thespeedofrotationoftheoutputshaftofthemotoris 1440rpm.Thegenerator output shaft is connected to the gear box using a V-belt which completely reduces the transmission losses. The generator is mounted at the base of the machine frame while the gearbox is mounted on the machine frame but at a higher position relative to the generator for the purpose of complete alignment. Care was taken to ensure that the generator pulley and the gear box input shaft were in straight line alignment to minimize the vibration and completely utilize the power of the motor.

4. Results and discussion

Twenty samples of coconut of various sizes and shapes were used to test the machine having been fully fabricated and tested without load. The coconuts were periodically loaded one after the other while the machine was running. The time taken to dehusk and clean each coconut was recorded as shown in Table 1.1.

Table1.1: Results of Dehusking Process

Sample	NUMBER OF COCONUT DEHUSKED	TIME(SECONDS)	COMPLETELY DEHUSKED	POLISHING TIME (SECONDS)
1	1	31	YES	YES
2	1	30	YES	YES
3	1	28	YES	YES
4	1	27	YES	YES
5	1	31	YES	YES
6	1	30	YES	YES
7	1	30	YES	YES
8	1	30	YES	YES
9	1	28	YES	YES
10	1	30	YES	YES
11	1	27	NO	NO

12	1	29	YES	YES
13	1	29	YES	YES
14	1	27	NO	NO
15	1	28	YES	YES
16	1	29	YES	YES
17	1	30	YES	YES
18	1	30	YES	YES
19	1	26	NO	NO
20	1	28	YES	YES

5. Discussion

From Table 1.1, the coconut dehusking machine was tested with coconut samples. Twenty different samples were loaded at different times. The dehusking time for each coconut was recorded. A total of twenty number of coconuts that were subjected to dehusking, seventeen number coconut were completely dehusked and cleaned with the corresponding time (seconds) as shown in the table. Three coconuts were not completely dehusked and cleaned. This implies that, eighty-five percent of the nuts were completely dehusked while fifteen percent of the nuts were incompletely dehusked. This shows that, the efficiency of the machine designed and tested is above eighty-five percent. This efficiency can be compared to some of the coconut dehusking machine already developed by; [11, 21, 12, 27, 9, and 26].

6. Conclusion

A mobile power operated coconut dehusking machine was successfully developed in the department of Mechanical Engineering, Cross River University of Technology, Calabar. The machine is unique because it dehusk and at the same time clean the nut by completely removing the fibre from it. It is cheap to acquire, easy to operate and maintain. The machine has a very high efficiency and economical to operate when compared to existing coconut dehusking machines. With the deployment of this machine in the coconut processing, higher output of coconut products will be achieved.

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