Original Research Article

Design and Development of an Improved Palm Kernel Shelling Machine and Separator

ABSTRACT

A palm kernel processing (Cracking and Separating) unit was developed to crack effectively various sizes/diameters of palm kernel as well as to separate the palm kernel from the shell with the aim of reducing the challenges encountered during the production of palm kernel Oil,. This machine was fabricated and designed with locally available materials for the ease of maintenance and it was designed the the aims of easing the pain, stress involved, intensive labour, time consuming, unduly cost and cumbersome operation encountered in the traditional/existing process of manually cracking and separating palm kernel from the nut. After the fabrication of this machine, the machine was tested to ascertain its performance and efficiency. The efficiency of the machine was discovered to be 98%with a processing rate of 95 nuts per second. This is an improvement over existing ordinary palm kernel machine that has an efficiency of 90% with a processing rate of 87 nuts per second wiithout separation. A 5hp Prime mover was selcted based on the power that was needed to effectively operate the machine. This project has catered for the various challenges encountered in the manual process of shelling palm kernen and separating the kernel from the shell.

Keywords: Palm kernel, Shelling, Sorting, Separator, Improved

INTRODUCTION

Taking into cognisance the Importance and advantages of Palm kernels, there is an increasing demand for it in World markets daily. Palm kernel from the cracked palm nuts are crushed in the Palm kernel mill to get Palm kernel oil that has many uses like Oil Paint, Polish, Candle and Medicine. Cake gotten during the milling is used as ingredient for livestock feeds and widely used in livestock industries, the oil is used for the production of fuel and biodiesel while the fibres are used in boiler as fuel.

During the years, extraction of oil from oil seeds involves a wide range of processes (Traditional, Chemical and Mechanical). Palm kernels are of more use when oil is extracted from it. Oil extraction is such a vital part of processing palm kernel and a whole lot of development has gone into palm kernel oil production. Production process begins with separating the palm nuts from the fibre. Palm oil is extracted from the pulp while the kernel produces the kernel oil. A critical step that affects the kernel oil quality is the release of kernels by cracking the palm nuts. The Traditional means of separating nuts from the fibre involves the use of a woven basket to bring out the nut/fibre mixture from the bottom of the processing pit. The basket is then rocked back and forth to facilitate the movement of the fibre to the top of the nuts. The fibre moves to the top of the nuts because it has a lower density than the nuts. The fibre are packed out of the basket to separate them from the nuts. Peasant farmers in the past broke the nuts one at a time between two stones by the magnitude of applied force. Experience was used to determine the magnitude of the applied force. This method is dangerous because the person cracking has a high probability of hitting their fingers with the cracking stone. Apart from the drudgery, health hazards and high time consumption are associated with this process and additional winnowing may be deemed important as there are still few quantity of fibre retained in the nuts. This method

also involves the preservation of the kernel embedded in the palm nut when cracking to enhance the quality of the palm kernel oil. This traditional method of cracking and separating palm kernel is also the manual method used for palm kernel cracking. Local youths and old women is the class that has taken this up as a business venture. This method is cumbersome, labour intensive and time consuming to meet the demands of the growing industry.
Another traditional method is by handpicking, the separation processes involves using a pot containing viscous mixture of water and clay. The purpose of the clay is to aid the shells to sink while the kernels float on top of the water clay mixture. This method consumes a lot of time in washing and drying the kernel and make the palm kernels to be liable to quick infection of fungal thereby reduced the quality of oil produced (Oke P. K., (2007)). The second mode of nut cracking is the Semi-mechanised modes which involves the use of hand-operated levers especially for Dika-nuts. Conventional mechanical nutcrackers are often of the centrifugal type. This mechanical nut crackers are designed such that the nuts are fed into a slot on a rotor turning at a very high speed or nuts are either fed into a cracking chamber where they are impacted upon by metal beaters turning at high speeds thereby throwing the nuts against a cracking ring. The nuts impinge the wall at random orientations but with repeated impact due to bouncing until they are discharged cracked or uncracked albeit with much kernel breakage. The machines are designed for adjustment in speed for acceptable cracking efficiency. Knowledge of the force required for nut cracking to achieve minimum impact is important for improvement of the existing semi-mechanised nut crackers.
Having understudied the challenges encountered during cracking and separation in the aforementioned methods, there is a need to design a palm kernel dual processing (Cracking and Separator unit) that is fabricated from local available raw materials such as discarded automobile spare parts, with relatively less production cost and time and also evaluate its performance for optimisation. Another mechanized wet method of separation is the hydro cyclone where the principle of flow resistance is applied. This method of separation has wide industrial applications but is capital intensive. Therefore, this work is of vital importance because it will proffer solution to the drudgery, health hazard and the inefficiency of traditional palm kernel shelling and sorting.
The challenge of actualising this type of machine and also achieving an equivalent purpose as does the existing ones cannot be over-emphasised. The benefits derivable from the development of this machine for efficient shelling and separation after cracking especially to countries with a far greater reliance on agriculture is worthy of acceptance by investors and professionals. Two basic mechanical actions are used to crack palm kernel; shock caused by an impact against a hard object/surface and the direct mechanical pressure to crush, cut or shear through the shell (Oke P. K., (2007)).

Mechanised palm kernel cracking machines are developed on the principle of throwing the palm nuts at a fairly low speed against a stationery hard surface. Two types of nut crackers are used in palm oil mills; **roller crackers and centrifugal impact crackers.** In **roller cracker**, the nuts are cracked in between two fluted rollers revolving in opposite directions. The clearance between the rollers is invariable but the nuts are of different sizes, which make the machine to be operating at reduced efficiency. The other cracker is a **centrifugal impact cracker** that uses the principle of centrifugal force to flap the palm kernel nuts on the walls of the hopper. This method involves using a shock caused by an impact against hard objects to shear, crush and cut through the shell. Mechanical method will only crack the nuts and leave the product as a mixture of shells and kernels, which needs to be separated before it can become a useful product. Taking into considerations the cost of the imported palm kernel crackers, there is an urgent need to design a machine from locally available materials for easy maintenance, lesser downtime, reduces cost without compromising the efficiency of the Machine (Oke P. K., (2007)).

OBJECTIVES OF THE PROJECT

The Objective of this project is to design a Palm kernel shelling/separating Machine with new features and simplifying the machine for one man operation in order to reduce operational cost and maximize the production rate.

MATERIALS AND METHODS

The selection of materials for various parts of machine is based on the following factors. Strength of the material and rigidity of the machine, Availability of the material locally and ease of obtaining them, durability, corrosion under various uses and weather condition to which its exposed, Economy / feasibility, the cost of material and hence production cost with consumer in view, Ease of fabrication: the choice of type size or thinness of the metal are based on the ease of machining, threading, welding, Cost of material and its properties (Eric, K. G. (2009)).

Table 1: Table showing the various machine components and the materials selected for use

S/No.	Machine Component	Criteria for Selection	Most Suitable Materials	Materials actually Selected	Reason for Selection
1	Hopper, Entry regulator, Body frame, Separator barrel and cover	Strength, machine, surface finish, weight, cost, availability.	Mild steel, cast iron	Mild steel	High strength and light weight
2	Shaft	Strength, machine, surface finish, weight, cost,	Mild steel, cast iron	Mild steel	High strength and light weight
3	key	Strength, machinability, surface finish,	Mild steel, carbon steel, cast iron	Mild steel	Surface finish, light weight
4	Gear	Weight, good wearing property, availability	Mild steel, cast iron	Cast Iron	Availability and weight
5	Hammer Mill	Strength, machinability, surface finish,	Mild steel, carbon steel, cast iron	Mild steel	Surface finish, light weight

The slippage has been a common phenomenon in the transmission of motion or power between two shafts which reduces the velocity ratio of the system. In precision machine in which a definite velocity ratio is of importance only positive drive by gears or toothed wheels (Ogunsina, B. S., (2008))

A gear drive is also provided, when the distance between the driver and the follower is very small. The power transmitted by gear is kinematically equivalent to that transmitted by frictional wheel or discs. Consequently, a gear drive was chosen for this project work because it suits the consideration given above (Khurmi and Gupta (2004).

In the existing cracking machine, the different sizes of nut were not put into consideration. When a mixture of different nuts are fed into the existing cracking machines, some are too small or too big to be cracked which was a major reason for low efficiency of the machine. Based on the above findings, an experiment was carried out to determine the physical properties like average size, average mass, moisture content, strength and coefficient of friction of shell and kernel to aid in the design and fabrication of the machine (Ologunagba, F. O.et. al. (2010)).

Physical characteristic of shell and kernel: The physical characteristics of palm kernel that need to be taken into account include: size of palm kernel nut, hell and kernel, mass of palm kernel and coefficient of friction for shell and kernel with respect to steel (Manuwa, S. I. (2007)).

Size of palm kernel nut, shell and kernel:

Measurement of sizes of the nuts was taken from Five (5) samples of 500 dura-nuts. Fifty nuts were measured in each sample, the average size of diameter of the palm kernel nuts ranged from 11.00 to 29.60mm and the size of shell thickness ranged from 2.20 to 8.60mm. The size of kernel ranged from 9.7 to 17.00mm (Stephen, K.A. and Emmanuel, S. (2009)).

Mass of palm kernel: measurement of mass of the nuts was also taken from five (5) samples of 500nuts. Fifty (50) nuts were weighed in each sample. The mass of the nuts ranged from 2.4 to 10.8g (Badmus, G. A., 1990).

Coefficient of friction: the coefficient of friction for shell and kernel with respect to steel were determined experimentally. The coefficient of friction for shell and kernel was 0.50 and 0.26, respectively. The shell has higher coefficient of friction than kernel with respect to steel surface. This is an important parameter in designing the separating unit of palm kernel processing machine (Okoli, J. U., 1997).

ASSEMBLY OF THE MACHINE

The Primary base frame sub-assembly is arranged first by welding the vertical and horizontal angle iron to form the desired dimensions followed by the secondary base frame sub-assembly. The secondary base frame sub-assembly stands on the primary base frame sub-assembly with the use of bolts and nuts at the four (4) vertical stands. The cracked kernel free fall control is then welded to the secondary base frame sub-assembly. The gear box housing unit is then positioned in between the two base frame sub-assemblies. The separating unit, its shaft and pulleys are then positioned before the hammer mill is joined to the secondary base frame at the top. The hammer mill sub-assembly is then covered with the hopper unit (Ryder, 2001)

HOW IT WORKS

The operation of the machine is automated, as the nut with its handles being released, the spring, flat bar and brush are as well automatically released; as the handles to the pinion gear is engaged in a rotary motion, the brush is being released down to the base of the tank and the handle attached to the sprocket is simultaneously rotating the brush, thereby washing the walls of the cylindrical tank.

MAINTENANCE

The machine should be properly used as specified by the designer, all the moving parts should be greased to prevent rusting, friction and wearing. The machine should be covered when not in use to avoid dirt and anything that can make it unhygienic from having contact with it

Design procedure and machine development: palm kernel dual processing machine has two (2) distinct parts and the parts include the Cracking unit and separating unit (Oke P. K., (2007)).

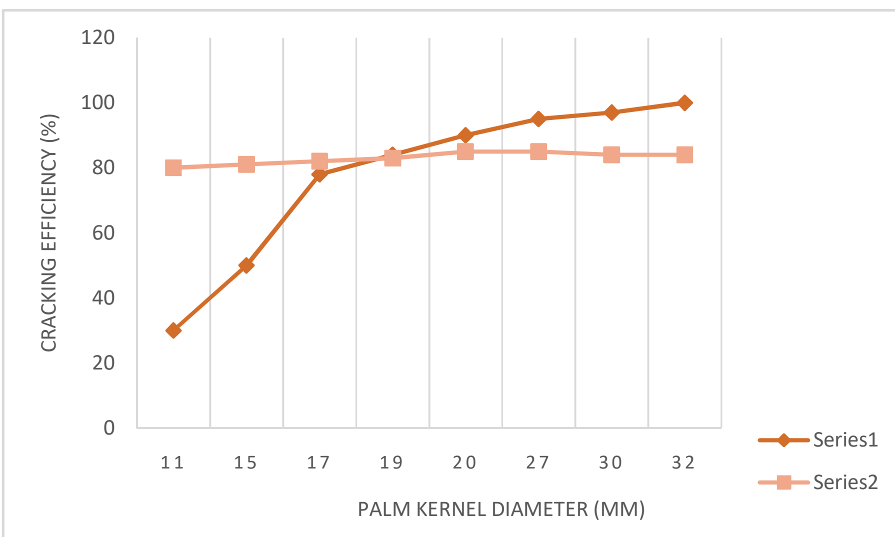
Below is a list of parameters and the values;

Table 2: List of calculated parameters and the values

S/NO	CALCULATED PARAMETER	VALUE OF CALCULATED PARAMETER
1.	$breadth\ of\ the\ hammer\ mill\ (b)$	$45mm$
2.	$radius\ of\ the\ hammer\ mill\ (r)$	35MM
3.	Thickness of the hammer mill (t)	6mm
4.	Length of the hammer mill (l)	103mm
5.	Angular Speed of the disk (N)	600rpm
6.	Angular velocity of the disk (ω)	62.83rad/s
7.	$Density\ of\ mild\ steel\ (\rho)$	$7.85x10^3\ kg/m^3$
8.	$Peripheral\ velocity\ of\ the\ hammer\ mill\ (V_c)$	$9.4245m/s$
9.	Force to crack palm kernel nut (F_c)	$1.20N$
10.	Area of palm kernel (A_{pk})	$0.000843m^2$
11.	Cracking Strength of Palm Kernel (S)	$1423.25N/m^2$
12.	Power required to drive the shaft of cracking unit (P_c)	$4.01hp$
13.	centrifugal force (F_c)	$307.38KN$
14.	Volume of the hammer mill (V_H)	$28.08m^3$
15.	$Weight\ of\ the\ pulley\ (w_p)$	$12N$

16.	Angle of repose (ϕ)	
17.	*Coefficient of Friction* (μ)	
18.	*Angle of repose of the shell* (ϕ_s)	26.6^0
19.	*Angle of repose of the shell* (ϕ_k)	14.57^0
20.	*Coefficient of Friction of the Shell* (μ_s)	0.50
21.	*Coefficient of Friction of the Kernel* (μ_k)	0.26
22.	The disturbing force, (F_t)	$382.64N$
23.	Stiffness of the Spring (Sx)	2N/mm
24.	Mass of screening tray ($M_{st)}$	24kg
25.	Angular speed of the screening (N_{sc})	69rpm
26.	Angular velocity of separator vibration (ω_s)	7.23rad/s
27.	radius of the pulley rotating the camshaft (r_c)	305mm
28.	Amplitude (x)	40mm
29.	*Weight of the Pulley* (wp_v)	$27N$
30.	Power required to vibrate the Separating Unit, (P_t)	$0.46hp$
31.	Total power required to drive the palm kernel processing machine(P_T):	$4.473hp$

Fig. 1: Graph of Cracking Efficiency (%) vs Palm Kernel Diameter (mm)
(Where Series 1 is the efficiency of the existing Machine and Series 2 is the



efficiency of the developed Machine)

Fig. 1 above shows that the developed machine is more efficient at a diameter of 19mm and above. This is justified because the most common diameters are ata diamteter of 20mm and above

MACHINE DEVELOPMENT: The palm kernel dual processing machine is made up of two (2) units namely:

1. Cracking Unit
2. Separating Unit

The Cracking Unit: this is made up of feed hopper, feed gate, impeller shaft, cracking drum and the impeller blade. The nut falls by gravity with the hopper channel into the cracking drum where the cracking process takes place with the help of the impeller blade (hammer mill) that flaps the palm kernel nut against the walls of the cylindrical cracking drum. The three blades are at 120^o to each other and the blades have clearance of 15mm from the cracking drum. As per design calculation, the impellers are made up of mild steel and are removable to ensure adequate maintenance and replacement in case of wears after being used for long period.

The Separating Unit: This unit is made up of camshaft, separating barrel, returning spring. The separating barrel is tilted at an angle of 20^o which is less than the angle of response of shell and greater than that of kernel, to enhance free fall of the kernel. The separating barrel separates by vibration and during this process, the kernel pass through the slots on the barrel while the nuts cannot pass through as a result of the nut diameter been greater than that of the slots. The separating barrel is subjected to vibration with the aid of three (3) camshaft rotated with a 5hp Prime mover with 2500rev/min. One of the pulleys is connected to the cracking unit while the other is connected to the separating unit

PERFORMANCE EVALUATION

The performance evaluation of the Machine is determined by evaluating the efficiency of the developed machine.

Machine Efficiency: Comparative evaluation was done between developed palm kernel cracking machine and manual way of cracking and separation. Six (6) samples were prepared for evaluation and each sample contains 2000 pieces of palm kernel nut. Each sample was poured into the palm kernel shelling machine and separator and the record of the cracked and un-cracked palm kernel nuts with time of processing were taken. The same thing was repeated for existing cracking machine. Six (6) other samples containing 2000 pieces of palm kernel nuts were prepared for manual cracking and seperating process for Six persons.

The results were recorded to compare the efficiency of the palm kernel shelling and separating machine, existing and manual processing operation.

Moreover, the efficiency of machine was determined relative to diameter of the palm kernel. Two thousand palm kernel nuts of the same size were sorted out for different diameter and used for the analysis of the existing and fabricated machine. Each sample containing the same size was poured into the machine to know the effect of kernel size on machine efficiency and same was done for existing palm kernel machine

RESULTS AND DISCUSSION

The evaluation results for the performance efficiency and rate for the developed Palm kernel shelling machine and separator are shown in Table 2. The existing machine can only crack and has a wet method for separation of the shell from its nut. This type of separation is faster than the manual method of separation but it exposes the nut to fungal infections due to longer drying period. The longer drying period has adverse effect on the quality of oil produced. The developed machine reduces the risk of fungal and insects attack due to low breakage and the dry method of separation immediately after the cracking process. The quality of oil in this case is not affected.

The machine evaluation results shows that this machine is faster with an average of 95nuts/sec with 98% efficiency (cracking and separating) than the existing machine that has an average of 87 nuts/sec with 90% efficiency. The developed machine

S/N	No. of nuts introduced into the Machine (N_1)	No. of processed palm kernel Nut (N_2)	Time Taken (s)	Performance Eff. (%)	Performance Rate (N_2s^{-1})	No. of cracked palm kernel nut (N_3)	Time Taken (s)	Performance Eff. (%)	Performance Rate (N_3s^{-1})

simultaneously separates the nut from the shell, which is not available in the existing machine. It can also be seen that the size of the nut has little or no effect on the efficiency of the developed machine which makes it an improved version of the existing machine.

			Palm kernel shelling machine and separator			Existing Machine			
1	2000	1897	52	97.88	94.00	1500	50	90.00	90.00
2	2000	1905	51	98.10	96.00	1520	51	90.10	88.33
3	2000	1903	51	98.06	95.00	1490	50	90.06	90.60
4	2000	1901	52	98.12	96.00	1480	51	90.08	88.31
5	2000	1907	52	97.90	95.00	1510	51	89.90	90.08
6	2000	1906	51	98.80	96.00	1490	51	89.94	88.24

CONCLUSION BASED ON THE ANALYSIS

The Hammer mill of the Palm kernel cracker can carry a load to the tune of 5N which was further confirmed from the analysis ran on the Hammer Mill. With this analysis work, we have been able to confirm that the Palm kernel cracker is an efficient machine with less probability of failure at its most usable part (Hammer Mill) and to show that less maintenance job will be done at the hammer mill since it can withstand a load of

5N.

Table 3: Machine Performance and comparative tests data (Oke P. K., (2007))

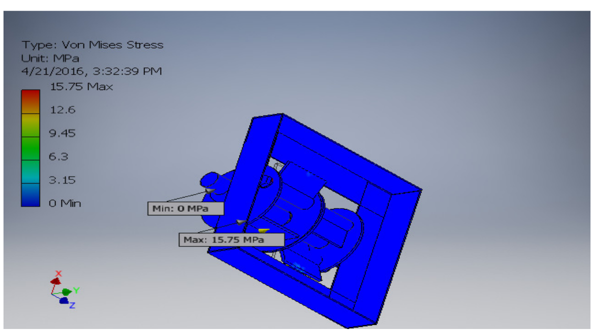


Fig. 2: Von Mises analysis of the Hammer Mill

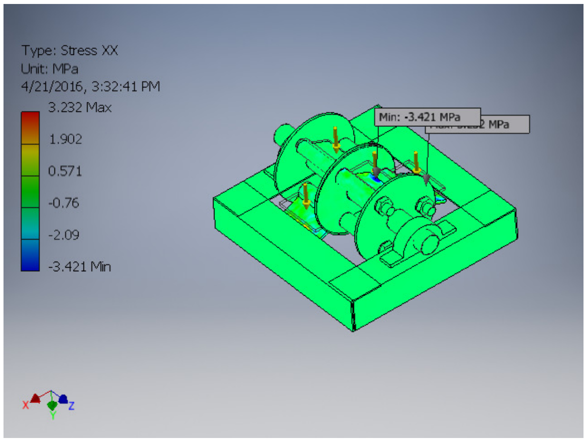


Fig. 3: Displacement analysis of the Hammer Mill

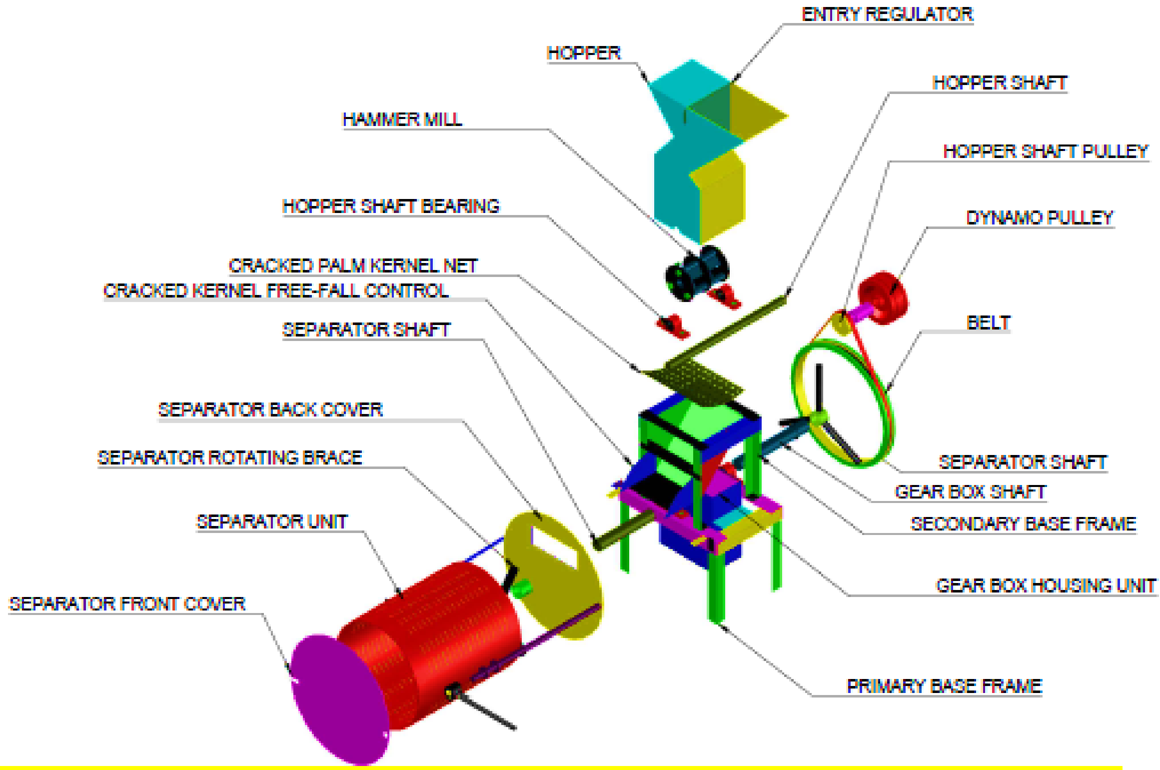


Figure 3 above is the analysis of how the Hammer mill which does the cracking by hitting palm kernel on the walls of the Hopper. The analysis was carried out under a load of 5N and there was no sign of fracture

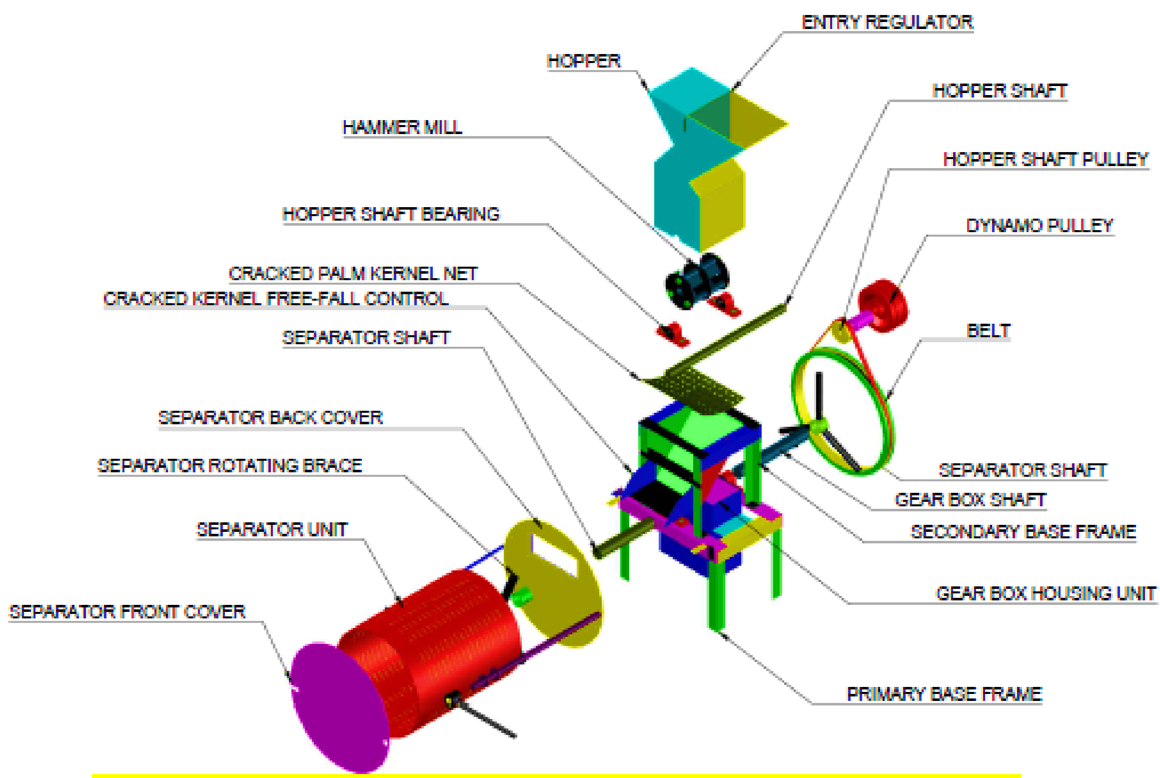


Fig. 4: Exploded view of the Fabricated Palm Kernel Cracking and Shelling Machine

Fig 5: Picture of the Fabricated Palm Kernel Shelling Machine

CONCLUSION

The results obtained have shown that there is a tremendous improvement over the existing shelling/separating machine and the manual method of processing palm kernel. The developed machine uses a prime mover to serve two processes thereby saving cost, energy and time over the existing kernel-cracking/separating machine. This developed machine is easy to operate, efficient and affordable for most Nigerians because of the materials used and its cost of production.

The affordability of this machine makes it good to meet the growing demand of the Nigerian industries for further development of the economy.

The development of a palm kernel shelling and sorting machine with improved qualities is a major addition to the agricultural production field of study. The newly designed and developed machine was made of locally available materials so as to reduce the cost of production of this machine to the barest minimum for its major, both for peasant farmers and large scale processing industries. The efficiency range and throughput capacity of the machine are satisfactory to ensure its usage and easy integration into the processing industries. In addition, this fabricated machine requires little or no expertise or training for its operation and maintenance.

CONSENT

All authors declare that ‘written informed consent was obtained for publication of this case report and accompanying images. A copy of the written consent is available for review by the editorial office/chief editor/editorial board members of this journal.

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