Original Research Article

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

ABSTRACT

In an attempt to ease the production of palm kernel Oil, a palm kernel processing (Cracking and Separating) unit has been developed to crack effectively various sizes as well as to separate the palm kernel from the shell. This palm kernel dual processing machine was fabricated and designed with locally available materials from the opinion of a new idea which aims at easing the pain, stress, intensive labour, time consuming, unduly cost and cumbersome operation encountered in the traditional/existing process of cracking and separating palm kernel from the nut. The machine was tested to ascertain its performance and efficiency of 98%with a processing rate of 95 nuts per second with just 5hp prime mover which 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. This project is a result of the various challenges encountered in the manual process of shelling palm kernen and separating the kernel from the shell.

Keywords: Palm kernel, Design and development, Shelling, Sorting, Efficiency, Separator

INTRODUCTION

The oil palm tree, known as *Elaeis guineensis Jacq.*is a great economic asset. The oil palm tree is aperennial plant which is indigenous to tropical areas. It is acclaimed to be the richest vegetable oil plant (Kheiri, M. S. A. (1985)).The plant which originated from Africa, mostly in the southern parts of Ghana and Nigeria, but grown inplantations in Southeast Asia and Southern America, has different varieties (Tang, T. S., (1985)), with many products derivable from the plant, some of which are palm oil, palm kernel oil, palm kernel cake, fibre, palm wine,fatty alcohol, broom and wood plank. Within the pulp or mesocarp lies a hard-shelled nut containing thepalm kernel. The palm tree grows in warm climates at altitudes within 500m above sea level, and bears itsfruits in bunches which vary in weight from 10 to 40kg. The individual fruit weighing from 60 to 70gms, ismade up of an outer skin (exocarp), a pulp (mesocarp) containing the palm oil in a fibrous matrix, a centralnut consisting of a shell (endocarp) and the kernel which itself contains an oil, quite different from palm oil,resembling coconut oil (Hartmann, T. H., (1993)). The fruit of the oil palm is well known for its economic importance and nutritivevalues. Harvested palm bunches undergo processing stages of sterilisation, stripping, digestion and palm oilextraction. Palm nuts and fibres are left as residue [4]. The nuts are dried and cracked into palm kernel andshell and subsequently it is separated into palm kernel oil (PKO), palm kernel meal (PKM) and water.

The three main varieties of the oil palm distinguished by their fruits characteristics are dura, pisifera and tenera (Adebayo, A. A. (2004)).

- **Dura:** this has a very thin pericarp, 40 -70% of fruit weight with very little and a very big shell of about 2-5mm thickness. The kernel size is generally bigger than other varieties.
- **Tenera:** this has a thick pericarp of about 60% fruit weight containing very high oil and thick shell (1-2.5mm) which promotes easy cracking.
- **Pisifera**: this has a thicker pericarp with higher oil yield with little or no kernel.

With respect to the importance and merits posed by palm kernels, the demand for it in the world markets isincreasing daily (Gbadamosi, L. (2006)).

Palm kernel from the cracked palm nuts are crushed in the palm kernel mill to get the palmkernel oil that is useful in making soap, glycerin, margarine, candle, pomade, oil paint, polish andmedicine. The palm kernel oil is also used in the production of fuel and biodiesel. The kernel cake on theother hand serve as ingredient for livestock feeds and it is widely used in livestock industries while the fibresare used in the boiler as fuel.Over the years, extracting and expression of oil from oil seeds involve a wide range of traditional, chemicaland mechanical processes. Extraction of oil from palm kernels is such an important aspect of palm kernelprocessing, and as the palm oil production stages in the processing line had undergone a great deal ofmechanical development, the palm kernel oil production is still less mechanized and this production processactually begin with the separation of the palm nuts from the fibre. Palm oil is extracted from the pulp and thekernel oil from the kernel. Cracking palm nuts to release the kernels is therefore a critical step that affectsthe quality of kernel oil. Traditionally, the separation of nuts from fibre is by using a woven basket to bringout the mixture of nuts and fibre from the bottom of the processing pit, and rocking the basket back andforth to facilitate the movement of the fibre (with lower density) to the top of the nuts (with higher density)after which the fibre are packed out of the basket, thus separating the nuts from the fibre. Not quite longago, peasant farmers who abound in the trade broke the nuts, one at a time between two stones judging themagnitude of the applied force by experience. This method is slow and in addition the person cracking wasin constant danger of inadvertently hitting their fingers with the stones. Preserving the kernel embedded inthe palm nut when cracking the nutshell is important in the subsequent palm kernel and shell separation and,in enhancing the quality of the palm kernel oil. Apart from the drudgery, time consumption and healthhazards that are likewise associated with this process, addition winnowing may be necessary as sizeablequantity of fibre is still retained in the nuts. Peasant farmers break the nuts one at a time between two stonesby experience (Emeka, V. E., & Olomu, J. M. (2007)).

The semi-mechanized modes of nuts cracking takes the form of hand-operated levers, as reported for Dikanuts. Conventional mechanical nutcrackers are often of the centrifugal type. The nuts are either fed intoa slot on a rotor turning at a very high speed or are fed into a cracking chamber where they are impactedupon by metal beaters turning at a high speed which throws the nuts against a cracking ring. The speed isadjusted for acceptable cracking efficiency. The nuts impinge the wall at random orientations but withrepeated impact due to bouncing until they are discharged cracked or uncracked albeit with much kernelbreakage Palm nut in a natural rest position lies longitudinally so that the impact is applied along the lateralaxis. The knowledge of minimum impact force required for nut cracking is therefore paramount todesign improvement of the existing mechanical nutcrackers. The challenge of designing and actualizing the successful fabrication of a motorized palm kernel Sheller with lesser production time and cost, and alsoachieving an equivalent purpose as does the existing ones cannot just be over-emphasized. This development is worthy of acceptance by engineers and investors as a result of the benefits derivable from the successfulshelling and sorting of palm kernels, especially to countries with greater reliance on agriculture as theireconomy's main stay. Therefore, this work is of vital importance because it will proffer solution to thedrudgery, health hazard and the inefficiency of traditional palm kernel shelling and sorting. The mainrationale behind this work is to design and construct a motorized palm kernel processing (nut shelling andsorting) machine with relatively lesser production cost and time, and evaluate its performance for optimization (Obiakor, S. I., & Babatunde, O. O. (1999)).

AIM AND OBJECTIVES OF THE PROJECT

The Aim of the work is to develop a Low Cost Palm kernel shelling/separating Machine that can work at a high efficiency with locally available materials and an affordable cost of production. This is a unique design because it has been developed to have a performance rate and efficiency than the existing (imported) machines.

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. Furthermore, the purpose of this is to design the Palm kernel shelling/separating Machine that is affordable and suitable for SME entrepreneurs.

SIGNIFICANCE OF THE PROJECT

This project work seeks to proffer assistance to the teeming population of local palm kernel and medium scale industries involved in palm kernel business in their quest for a convenient, available and cheap method of cracking their Palm nuts which in most cases are still being done manually due to either very high cost or unavailability of cracking machines.

DESIGN CONSIDERATIONS

Some of the factors which were taken into account while designing the palm nut cracker as described by (Koya, O. A. (2005)) are:

i. Machine factors such as rigidity, durability, strength, vibration and stability were considered in the selection of appropriate materials for the various machine components to ensure reliability.
ii. Machine was constructed out of locally available material to enhance the possibility of replacing damaged parts with less expensive but equivalently satisfactory parts that is readily available.
iii. The ease of fabrication of machine components was considered, bearing in mind, the use of temporary fasteners to facilitate easy disassembling during transportation, cleaning and maintenance.
iv. The overall cost was considered through critical value analysis in the phases of design, material selection and production which at the end would make it affordable by farmers and intending users.
v. Operating features of the machine were well located on the basis of convenient handling and safety of the operator and those within the zone of the machine during operation.

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)).

S/N	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, weight	Mild steel, carbon steel, cast iron	Mild steel	Surface finish, light weight
4	Gear	Weight, good wearing property, availability	Mild steel cast iron	Mild steel	Availability and weight
5	Hammer Mill	Strength, machinability, surface finish, weight	Mild steel, carbon steel, cast iron	Mild steel	Surface finish, light weight

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

The slipping of the belt or rope has been a common phenomenon in the transmission of motion or power between two shafts. The effect of slipping is to reduce the velocity ratio of the system. In precision machine in which a definite velocity ratio is of importance the only positive drive is 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).

More so, the following are the advantages of the gear drive as compared with other drives like belt, rope and chain drives:

i. Transmits exact velocity ratio;
ii. May be use to transmit large power
iii. May be use for small center distance of shaft
iv. Has high efficiency, reliable service and compact layout

According to Sanni, L. A., & Adegbenjo, A. O. (2002), the following parameters are usually known in design of a gear drive:

(i) The power to be transmitted,
(ii) The speed of driving gear,
(iii) The speed of driver gear of the velocity ratio
(iv) The center distance.

Moreover, the following are as well needed for the perfect design of a gear drive;

i. Gear teeth should have sufficient strength so that they will not fail under static loading or dynamic loading during normal running condition
ii. Gear teeth should name wear characteristics so that their life is satisfactory

iii. Used of space and material should be economical
iv. Alignment of the gears and deflection of the shaft must be considered because they effect on the performance of the gears; and
v. Lubrication of the gear must be satisfactory.

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, as experimental was carried out to determine the 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)).

Apparatus and experimental procedure: Apparatus that were used in the experimental are weighing balance, Vernier caliper, pins, standard masses, flexible cord, meter rule, scissors, resort stand and palm kernel shells of different sizes. The masses of palm kernel nut were measured and the major and minor diameters were also determined. The strength of palm kernel nut was also determined by allowing a kilogram weight to fall from varying elevated height on palm kernel until the weight actually cracked the palm kernel nut by cutting cord with a scissors (Poku, K. (2002)).

Physical characteristic of shell and kernel: The physical characteristic of palm kernel that needs 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 masses of the nuts was taken also from five (5) samples of 500nuts. Fifty (50) nuts were weighed in each sample. The masses 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 pf friction for shell and kernel is 0.50 and 0.26 respectively. The shell has higher coefficient of friction than kernel with respect to steel surface. This is an important in designing the separating unit of palm kernel processing machine (Okoli, J. U., 1997).

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)).

Cracking unit:

$\mathrm{b} = breadth\ of\ the\ hammer\ mill = 45mm$

$\boldsymbol{r} = radius\ of\ the\ hammer\ mill = 35mm$

$\boldsymbol{t} = thickness\ \ of\ the\ hammer\ mill = 6mm$

$\boldsymbol{l} = length\ of\ the\ hammer\ mill = 103mm$

$\boldsymbol{N} = Angular\ speed\ of\ the\ disk = 600rpm$

$\boldsymbol{\omega} = \frac{2\pi N}{60} = angular\ velocity\ of\ the\ disk$

$$= \boldsymbol{62.83 rad/s}$$

$$\boldsymbol{\rho} = Density\ of\ steel = \boldsymbol{7.85x10^3\ kg/m^3}$$

$$\boldsymbol{F_c = 337.49N}$$

$V_c = Peripheral\ velocity\ of\ the\ hammer\ mill$

$$V_c = \omega\ x\ r = 62.83\ x\ 0.15$$

$$\boldsymbol{V_c = 9.4245 m/s}$$

Force to crack palm kernel nut (F): The cracking strength of palm kernel as determined from an experiment was 1423.25N/m^2(Oguoma, O. N., Onwuzurigbo, C. C., 1993)

$$F = A\ x\ S$$

Where A= Area of palm kernel = 0.000843m^2

S = Strength

$$F = 1423.25\ x\ 0.000843$$

$$\boldsymbol{F = 1.20N}$$

Power required to drive the shaft of cracking unit (P$_c$):

$$Power = (f_c + w_p)V_c$$

In the design of palm nut cracker of horizontal shaft type, the following were considered in the design, material selection and construction of palm nut cracker viz: Impinging velocity of palm nut with which it strikes the drum, sizes of palm nuts, moisturecontent of palm nut and clearance between rotor and cracking drum (Olakanmi, E. O., 2004)

Cracking force of the impeller blade: Basically, there are two forces that exist on hammer mills which depends on its state of motion. These include the centrifugal force on the roller associated with the dynamic motion of mills and weight of the hammer mill in association with the static state of the hammer mills (Olakanmi, 2004). But the one that's available for cracking is centrifugal force (F_c)

$$F_c = M\omega^2 r$$

$$F_c = \rho V\omega^2 r$$

Where,

V = Volume of the hammer mill

$$V_H = \mathrm{Vr} + \mathrm{Vc} = (\pi r^2 h) + (l * b * h)$$

$$= (\pi r^2 h) + (l * b * h)$$

$$= (\pi * 4.5^2 * 103) + (104 * 45 * 6)$$

$$= (6.55E - 6) + (28.08)$$

$$V_H = 28.08\mathrm{m}^3$$

$$F_c = \rho V\omega^2 r$$

$$F_c = 7.85 * 28.08 * 62.83^2 * 0.35$$

$$F_c = 307380.34N$$

$$\boldsymbol{F_c = 307.38KN}$$

$$Power(\mathrm{P}_c) = (f_c + w_p)V_c$$

$w_p\ is\ the\ Weight\ of\ the\ pulley = 12N$

$$Power = (307.38 + 20)9.4245$$

$$Power = 3010.20W$$

$$\boldsymbol{Power(\mathrm{P}_c) = 3.01KW = 4.01hp}$$

Separating Unit:

Differences in the sizes and coefficient of friction of the shells and kernels as determined in the experiment were exploited in the design, material selection and development of palm kernel separator unit.

Angle of repose (ϕ) of shells and kernels: Angle of repose (ϕ) is the angle at which the separating tray is tilted for kernel and shell to move down with uniform velocity.

Where,

$$\mu = \tan \phi$$

$$\mu = \boldsymbol{Coefficient\ of\ Friction},\ \phi = \text{Angle of repose}$$

$$\phi_s\ is\ the\ Angle\ of\ repose\ of\ the\ shell \phi_k\ is\ the\ Angle\ of\ repose\ of\ the\ shell$$

$$\mu_s = Coefficient\ of\ Friction\ of\ the\ Shell = 0.50$$

$$\mu_k = Coefficient\ of\ Friction\ of\ the\ Kernel = 0.26$$

$$\phi_s = \tan^{-1} \mu_s = \tan^{-1} 0.50$$

$$\boldsymbol{\phi_s = 26.6^0}$$

$$\phi_k = \tan^{-1} \mu_k = \tan^{-1} 0.26$$

$$\boldsymbol{\phi_k = 14.57^0}$$

Vibration force: The vibration of screening tray is result of periodic disturbing force, F_t applied to the screening tray by mean of camshaft and returning spring. The disturbing force, F_t is therefore

$$F_t = Sx + M\omega^2 r$$

Where S = Stiffness of spring = 2N/mm, M = Mass of screening tray = 24kg, N = Angular speed of the screening = 69rpm, ω_t = Angular velocity of separator vibration = 7.23rad/s, r = radius of the pulley rotating the camshaft = 305mm and x = Amplitude = 40mm

$$\boldsymbol{F_t = 382.64N}$$

Power required to vibrate the Separating Unit, P_t

$$P_t = (F_t + wp_v)V_t \text{(Khurmi and Gupta, 2003)}$$

Where,

$$wp_v = Weight\ of\ the\ Pulley = 27N$$

$$V_t = \omega_t$$

r = Peripheral velocity of the camshaft

$$F_t = Vibrating\ force$$

$$P_t = (382.64 + 12) * 0.876$$

$$P_t = 345.70W = 0.345KW$$

$$\boldsymbol{P_t = 0.46hp}$$

Total power required to drive the palm kernel processing machine(P_T): power required to vibrate the separating tray (P_t) + Power required to vibrate the cracking unit (P_c)

$$P_T = P_c + P_t \quad \text{(Khurmi and Gupta, 2004)}$$

$$P_T = 4.013 + 0.46$$
$$\mathbf{P_T = 4.473}\boldsymbol{hp}$$

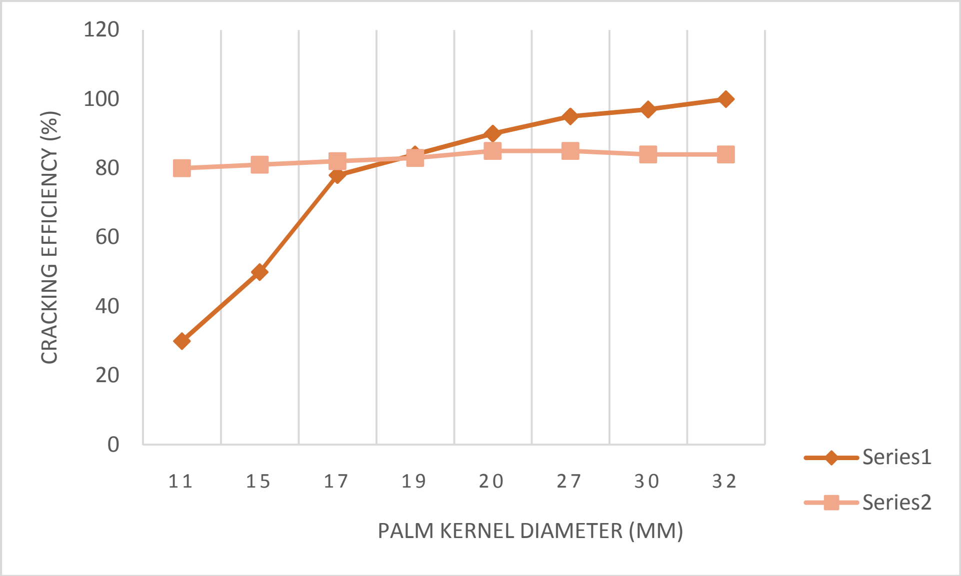

Fig. 1: Graph of Cracking Efficiency (%) vs Palm Kernel Diameter (mm)

(Where Series 1 is the efficiency of the existing Machine and Series 2 is the efficiency of the developed Machine)

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 through the hopper channel into the cracking drum where the cracking process takes place through 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 ccracking drum. This is based on the result of 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 20o which is less than the angle of response of shell but is far 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. Process efficiency ((P_e(%))) was calculated as follows:

$$P_E(\%) = \left[{(P-K)}/{P}\right] x\ 100$$ (Khurmi and Gupta, 2004)

Where $P = Total\ number\ of\ palm\ kernel\ in\ the\ sample$

$K = Total\ number\ of\ processes\ palm\ kernel\ nuts$

$$P_E\ is\ the\ Processing\ rate\ (kernel/sec) and\ is\ calculated\ as\ follows = \frac{T_c}{t_c}$$

$$Where\ T_c\ is\ the\ total\ number\ of\ processed\ palm\ kernel$$

$$and\ t_c\ is\ the\ time\ taken\ to\ process\ palm\ kernel$$

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. 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

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})
			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

Fig. 2: Machine Performance and comparative tests data (Oke P. K., (2007))

RESULTS AND DISCUSSION

The evaluation results for the performance efficiency and rate for the developed Palm kernel shelling machine and separator are shown above. The existing type of this machine can only crack and it 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. This longer drying period has adverse effect on the quality of oil produced. The developed machine reduces the tendency of fungal and insects attack due to low percentage of broken nut and the dry method of separation immediatelt 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 palm kernel shelling and separating machine simultaneously separates the nut from the shell, which is not applicable to the existing machine. It can also be seen that the size of the nut has little or no effect on the efficiency of the newly developed machine which makes it an improved version of the existing machine.

ASSEMBLY OF THE MACHINE

The Primary base frame sub-assemblyis arranged first by welding the vertical and horizontal angle iron to form the desired dimensions followed by the secondary base framesub-assembly. The secondary base framesub-assembly stands on the primary base framesub-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

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. This developed machine uses a prime mover to serve two processes thereby saving cost, energy and time than 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 product of this machine is more hygienic than the existing machine. The affordability of this machine makes it good to meet the growing demand of the Nigerian industries for further development of the economy.

The innovation of a palm kernel shelling and sorting machine with improved qualities is a major addition to the agricultural production field of study. The machine designed and fabricated in this research was made of locally available materials, as this limited the cost of production of this machine to the barest minimum, both for peasant farmers and large scale processing industries. Moreso, the efficiency range and throughput capacity of the machine are satisfactory enough to ensure its adoption in the processing industries. In addition, this fabricated machine requires little or no training for its operation and maintenance.

RECOMMENDATION

The design and design analysis of this project is an interesting project which further research should be carried out time to time because of the benefit of the machine.

LIMITATIONS

The following Limitations were encountered:

1. Power Failure was continually encountered and as a result led to more production downtime and increase in the cost of fabrication. The amount used for fuel consumption led to an increase in cost of fabrication.

2. There were few challenges in getting the Machine to the End users but this was later achieved with marketing strategies and there is sufficient demand for the Machine.

PLANS FOR FURTHER WORK

1. Steps are been taken to increase the efficiency of the Machine
2. Steps have been taken to reduce production downtime thus making it more affordable for Small and Medium Entrepreneurs'.

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.

APPENDIX

1. Abstract
2. Keyword
3. Introduction
4. Material Selection
5. Design Considerations and Calculations
6. Result and Discussion
7. Assembly of Machine
8. How it works

9. Maintenance
10. Conclusion
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Analysis Result:

Below is the analysis result carried out on the Hammer mill of the Palm kernel cracker. A force of 5N was used to simulate the process on the Hammer mill.

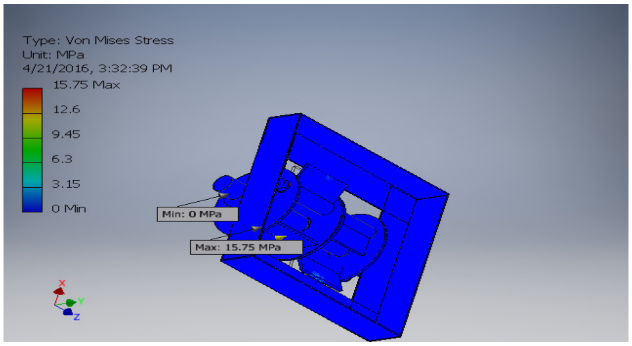


Fig. 3: Von Mises analysis of the Hammer Mill

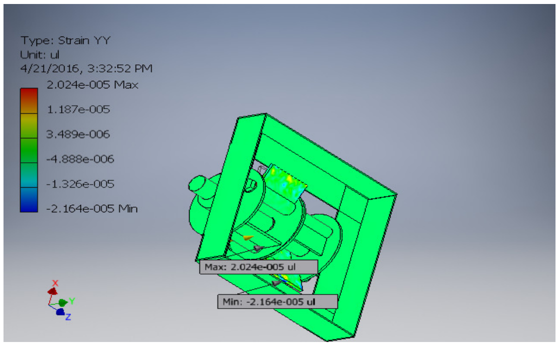


Fig. 4: Strain YY analysis of the Hammer Mill

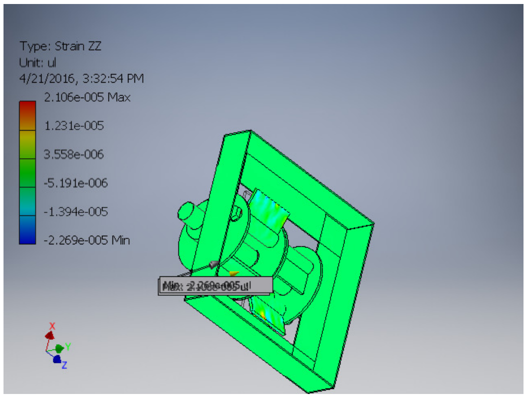
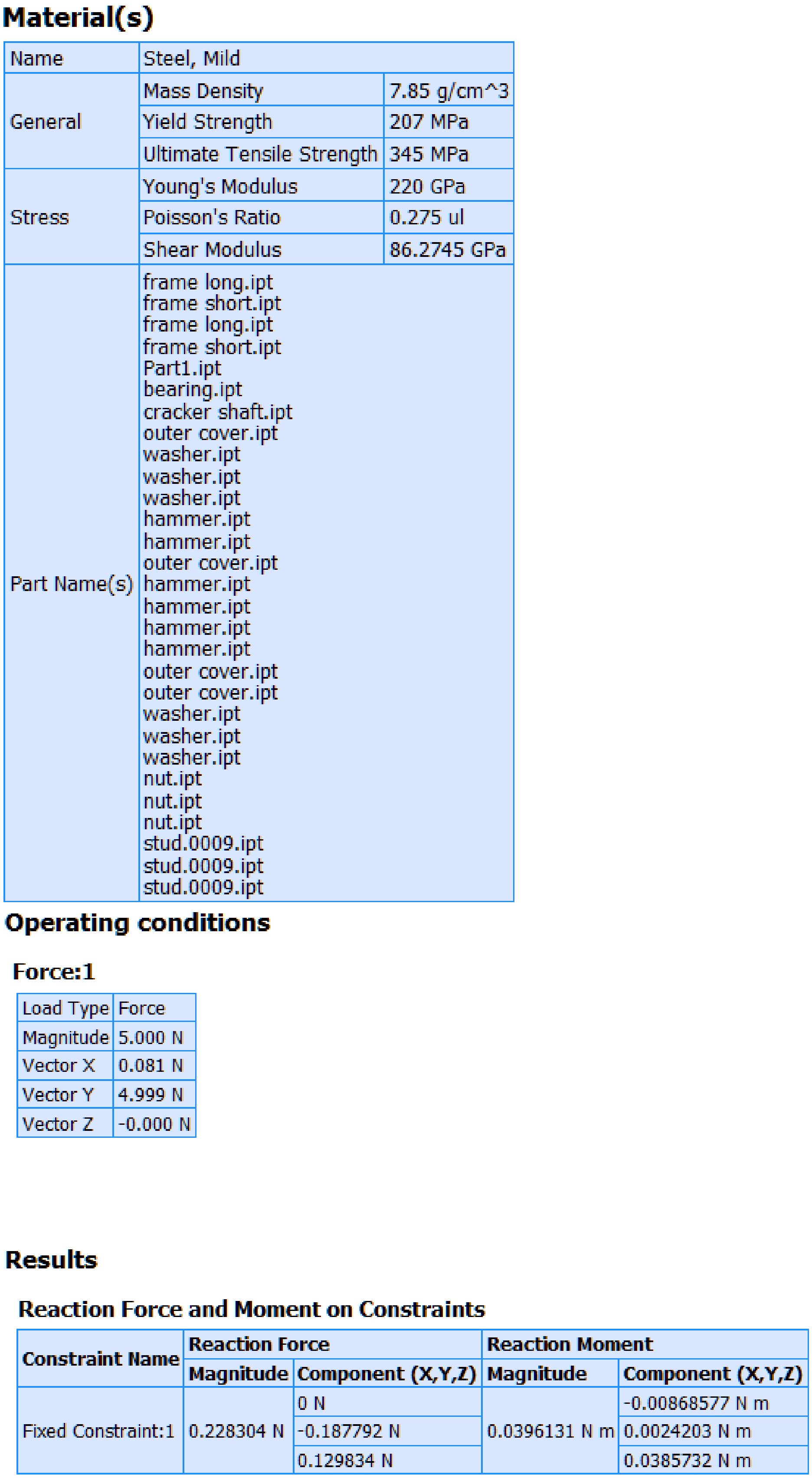


Fig. 5: Strain ZZ analysis of the Hammer Mill



Material(s)

Name	Steel, Mild	
General	Mass Density	7.85 g/cm^3
	Yield Strength	207 MPa
	Ultimate Tensile Strength	345 MPa
Stress	Young's Modulus	220 GPa
	Poisson's Ratio	0.275 ul
	Shear Modulus	86.2745 GPa
Part Name(s)	frame long.ipt frame short.ipt frame long.ipt frame short.ipt Part1.ipt bearing.ipt cracker shaft.ipt outer cover.ipt washer.ipt washer.ipt washer.ipt hammer.ipt hammer.ipt outer cover.ipt hammer.ipt hammer.ipt hammer.ipt hammer.ipt outer cover.ipt outer cover.ipt washer.ipt washer.ipt washer.ipt nut.ipt nut.ipt nut.ipt stud.0009.ipt stud.0009.ipt stud.0009.ipt	

Operating conditions

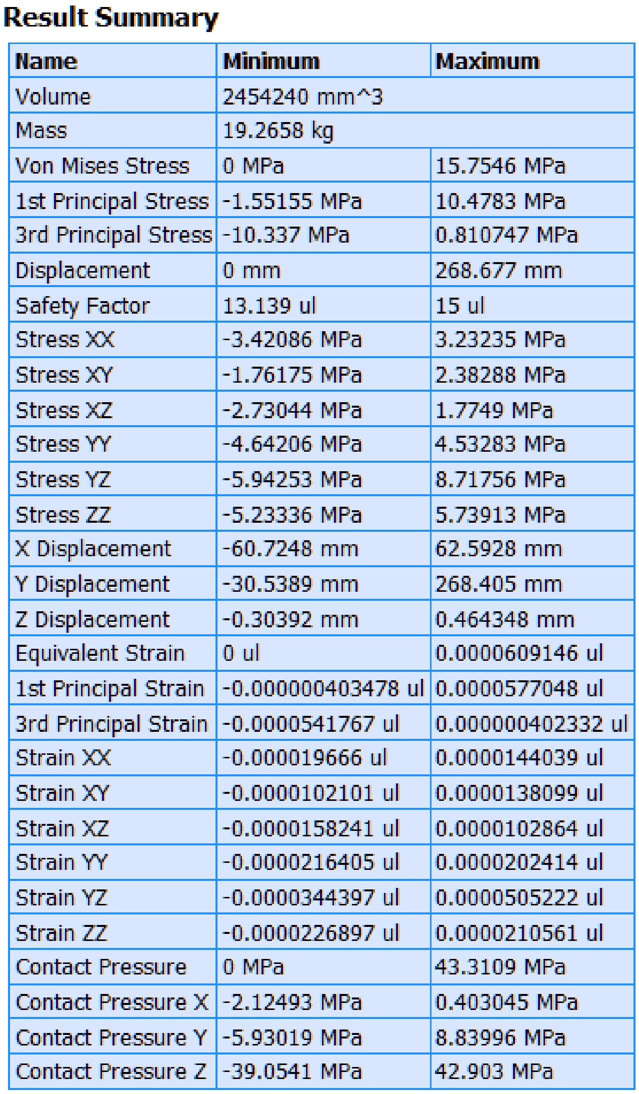
Force:1

Load Type	Force
Magnitude	5.000 N
Vector X	0.081 N
Vector Y	4.999 N
Vector Z	-0.000 N

Results

Reaction Force and Moment on Constraints

Constraint Name	Reaction Force		Reaction Moment	
	Magnitude	Component (X,Y,Z)	Magnitude	Component (X,Y,Z)
Fixed Constraint:1	0.228304 N	0 N	0.0396131 N m	-0.00868577 N m
		-0.187792 N		0.0024203 N m
		0.129834 N		0.0385732 N m



Result Summary

Name	Minimum	Maximum
Volume	2454240 mm^3	
Mass	19.2658 kg	
Von Mises Stress	0 MPa	15.7546 MPa
1st Principal Stress	-1.55155 MPa	10.4783 MPa
3rd Principal Stress	-10.337 MPa	0.810747 MPa
Displacement	0 mm	268.677 mm
Safety Factor	13.139 ul	15 ul
Stress XX	-3.42086 MPa	3.23235 MPa
Stress XY	-1.76175 MPa	2.38288 MPa
Stress XZ	-2.73044 MPa	1.7749 MPa
Stress YY	-4.64206 MPa	4.53283 MPa
Stress YZ	-5.94253 MPa	8.71756 MPa
Stress ZZ	-5.23336 MPa	5.73913 MPa
X Displacement	-60.7248 mm	62.5928 mm
Y Displacement	-30.5389 mm	268.405 mm
Z Displacement	-0.30392 mm	0.464348 mm
Equivalent Strain	0 ul	0.0000609146 ul
1st Principal Strain	-0.000000403478 ul	0.0000577048 ul
3rd Principal Strain	-0.0000541767 ul	0.000000402332 ul
Strain XX	-0.000019666 ul	0.0000144039 ul
Strain XY	-0.0000102101 ul	0.0000138099 ul
Strain XZ	-0.0000158241 ul	0.0000102864 ul
Strain YY	-0.0000216405 ul	0.0000202414 ul
Strain YZ	-0.0000344397 ul	0.0000505222 ul
Strain ZZ	-0.0000226897 ul	0.0000210561 ul
Contact Pressure	0 MPa	43.3109 MPa
Contact Pressure X	-2.12493 MPa	0.403045 MPa
Contact Pressure Y	-5.93019 MPa	8.83996 MPa
Contact Pressure Z	-39.0541 MPa	42.903 MPa

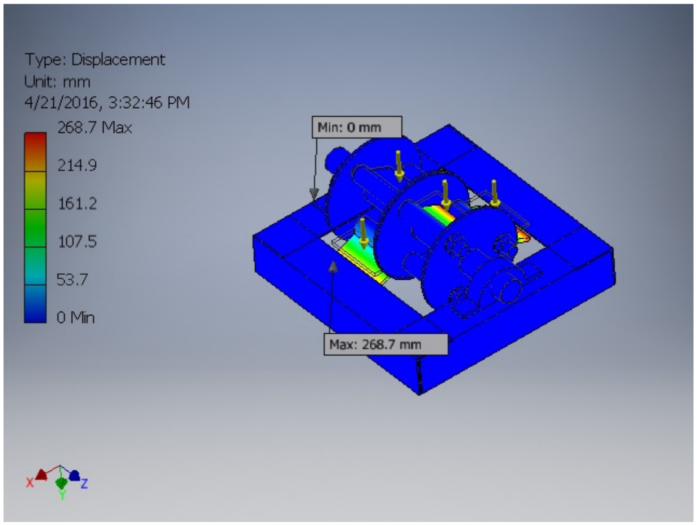


Fig. 6: Displacement analysis of the Hammer Mill

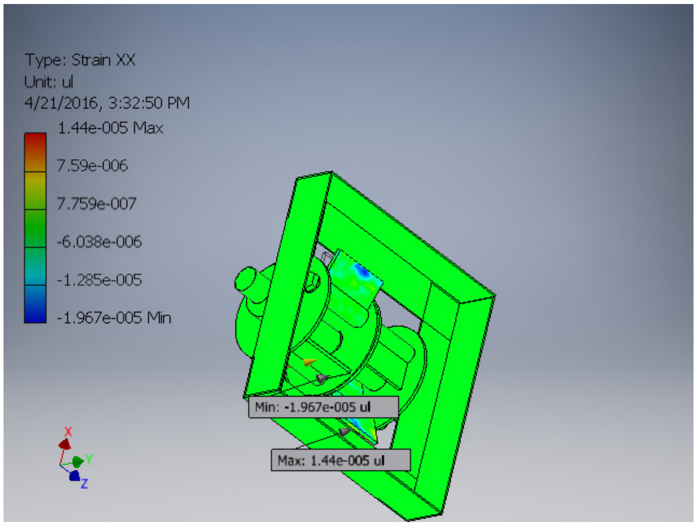


Fig. 7: Strain XX analysis of the Hammer Mill

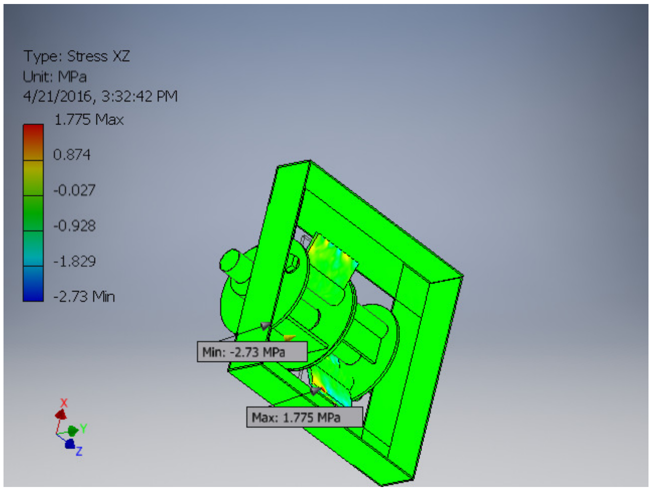


Fig. 8: Stress XZ analysis of the Hammer Mill

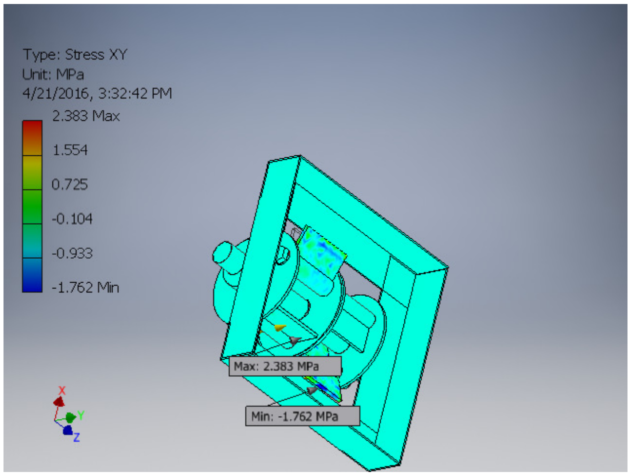


Fig. 9: Stress XY analysis of the Hammer Mill

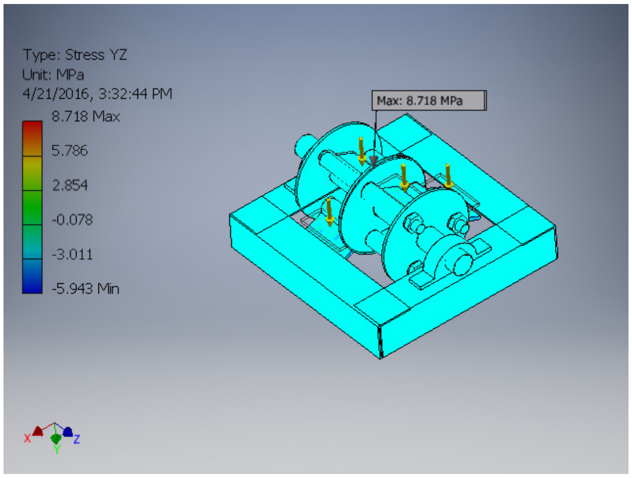


Fig. 10: Stress YZ analysis of the Hammer Mill

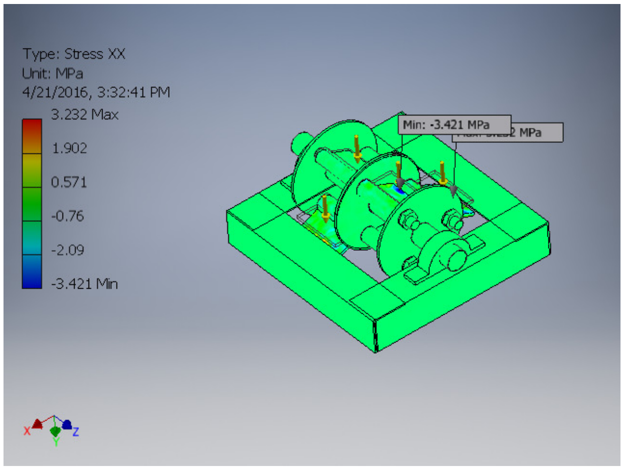


Fig. 11: Stress XX analysis of the Hammer Mill

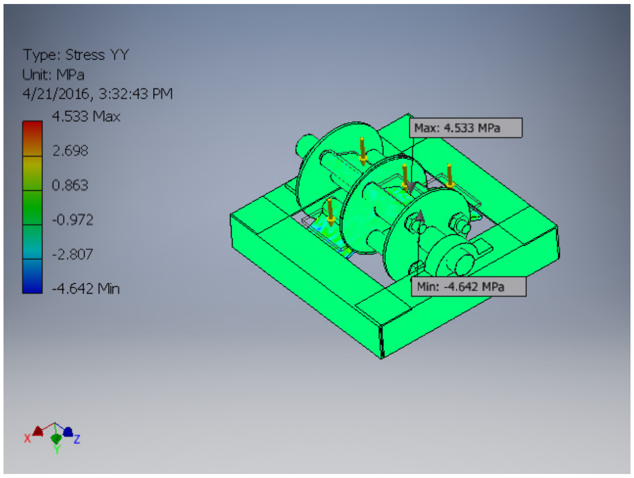


Fig. 12: Stress YY analysis of the Hammer Mill

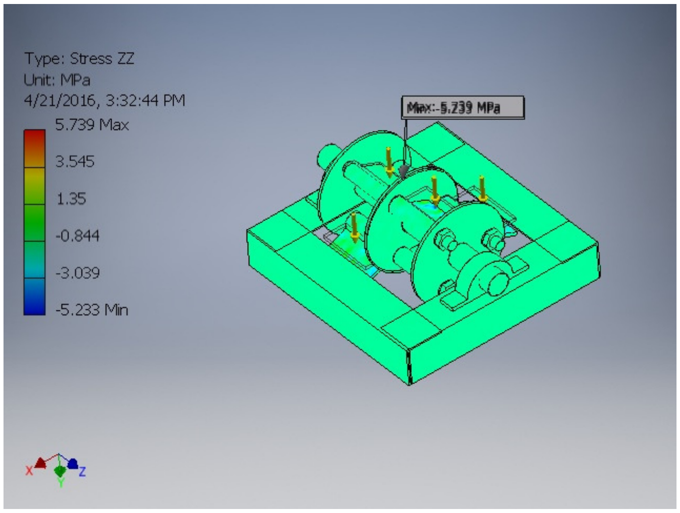


Fig. 13: Stress ZZ analysis of the Hammer Mill

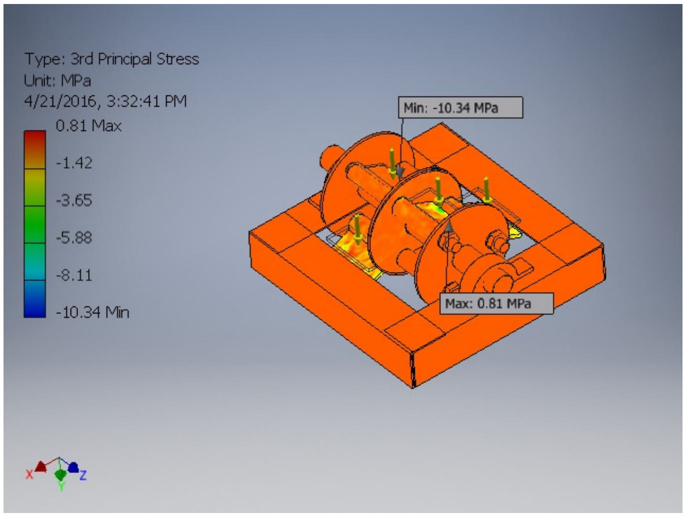


Fig. 14: 3rd Principal Stress analysis of the Hammer Mill

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

Fig 15: Picture of the Fabricated Palm Kernel Shelling Machine

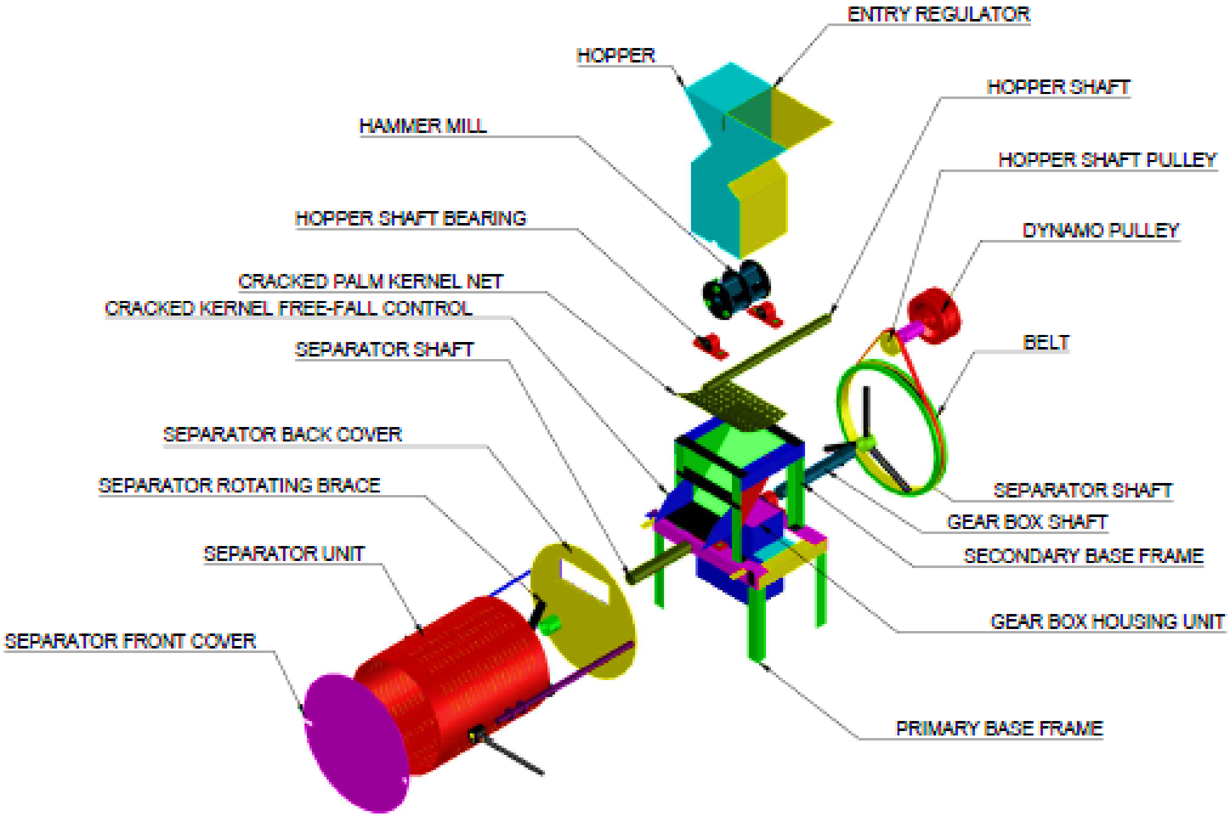


Fig 16: 3D Exploded CAD view of the Modeled Palm Kernel Shelling Machine

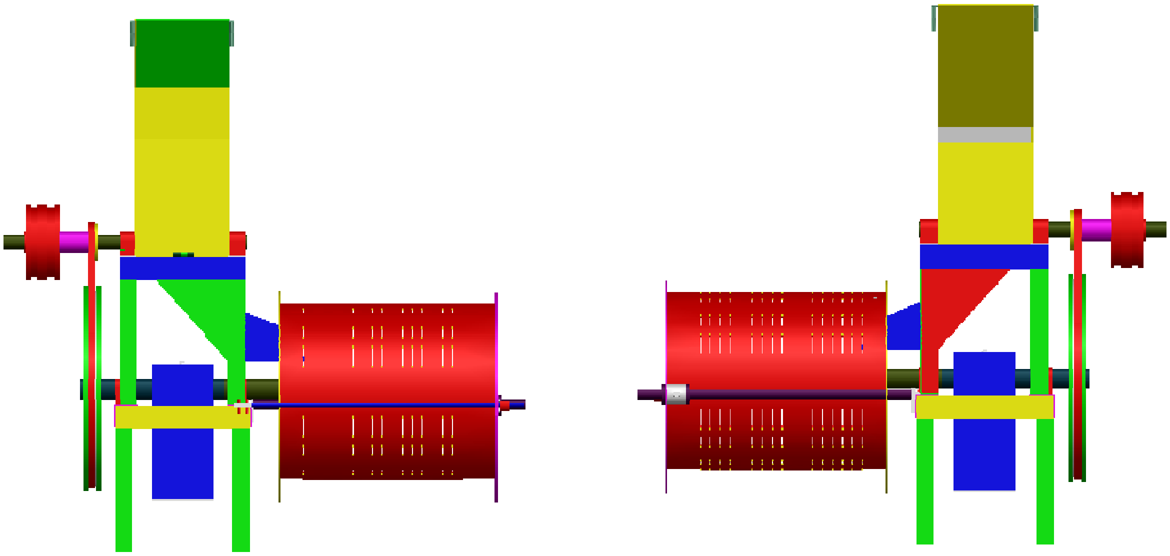


Fig. 17: Side Views of the Modeled Palm Kernel Shelling Machine

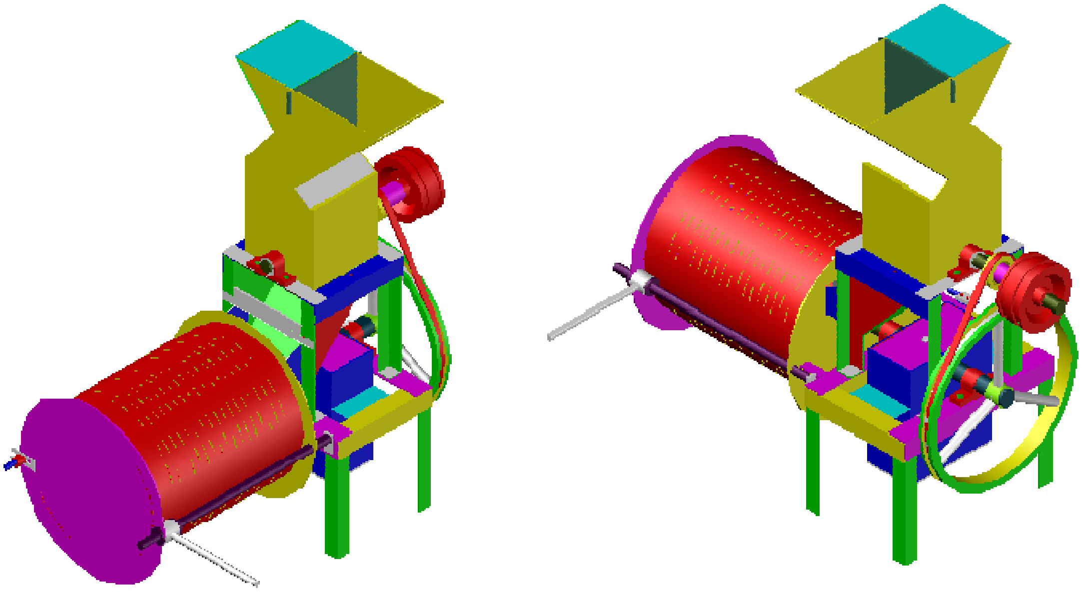


Fig 18: 3D CAD Views of the Modeled Palm Kernel Shelling Machine