DESIGN AND PRODUCTION OF PALM NUT AND FIBRE SEPARATING MACHINE.

ABSTRACT

Palm nut and fibre separating machine has been designed, constructed and tested. The basic features of the separator are feeding chute, pulverizing unit, separating unit, discharge outlets for nut and fibre, and the prime mover. The power required for operation of the machine is 2.86kW. The machine was tested with two different levels of moisture content termed (dry and wet) for three different runs and the average gotten and tabulated. The test results showed that the machine gave its best work performance with dry mixture at the throughput capacity, separating efficiency and quality performance efficiency of 0.155kg/sec, 89.7% and 82.3% respectively. However, the throughput capacity, separating efficiency and quality performance efficiency with the wet mixture gave 0.144kg/sec, 79.3% and 80.1% respectively.

Keywords; Separator, machine, palm nut, motor, auger, equipment.

1.0 INTRODUCTION

Traditional palm kernels extraction process involves sun drying of nuts for days and cracking of the nuts using stones or any other hard objects. This is followed by separation of the kernels from their shells by hand picking and drying of the extracted kernels under the sun for about two to four days before storage or sale (Oke, 2007). The production of palm oil in West Africa and most especially Nigeria, has proven difficult over the years due to the use of crude implements. This difficulty has made it paramount that existing palm oil production be modified

The design of more efficient equipment will create favourable conditions for the processing of palm fronts. These conditions will attract the peasant farmers who produce the oil manually as well as investors to have a keen interest in investing in palm oil production.

In as much as Palm oil production has been a target for small and large scale investors, we are still running a deficit in its production due to poor equipment. This makes it imperative that existing palm-nut fibre separator machine must be improved. Hence, this research aimed at designing and constructing an efficient palm nut fibre separator using locally sourced materials that will be affordable for low and medium scale investors in the rural areas.

2.1 **Design Considerations**

For an efficient design the following factors were considered:

i. Physical factors such as size, shape, surface texture and moisture content.
ii. Mechanical factors such as rigidity, deflection, wear; corrosion, vibration and stability were considered for appropriate material selection.
iii. Provision of different chutes for the discharge of nuts and fibres so as to have complete separation.
iv. The fibrous oil rich digested pulp can pass through narrow slits (dimension<3mm) but palm nuts cannot, and also that the cake from the digestion process is fairly compacted which must be thoroughly slacked before effective separation of the pulp and nuts will be possible.
v. The hopper arrangement to prevent the splash off of nuts, oil and fibre during cake break down.

2.2 Machine Description

The machine (palm nut and fibre separator) consists of six basic units; the frame, the feeding unit, pulverizing unit, the separating unit, the discharge outlets and the prime mover. The frame is made with 2" angular bar with 3mm thickness. The frame measures 380mm x 980mm x 1200mm with v-shaped leg extending the width to 600mm for rigidity. The clogged mixture of palm nuts and fibre obtained from the palm fruit expeller are fed through the hopper into the machine (Ologunagba et al, 2010). The hopper is made from 16-gauge mild steel sheet formed into a square shape with a top opening of 600mm x 360mm, a bottom opening of 280mm x 360mm and a height of 100mm with a top cover directly on top of the bottom opening to avoid flash off of nut and fibres as it approaches the beater inside the pulverizing unit. The pulverizing unit is where the clogged mixture is been broken into smaller particle sizes to release the entangled nuts within the fibre. The unit consists of a shaft, 1300mm length made up of 25mm mild steel rod and a 75mm diameter pipe. Attached to the shaft are beaters made of 12mm diameter mild steel rods which are arranged alternately at spacing of 100mm from one another so as to produce the necessary effect of breaking the clogged mixture, thereby detaching the nuts from the fibre. Underneath the pulverizing unit is the separating unit which can also be referred to as the nibbling unit. It is where the actual separation of the palm nuts and fibre takes place. The unit also consists of a shaft, 1300mm length made up of 25mm mild steel rod and 75mm diameter pipe, but with flat bars of 2mm thickness and 900mm length attached parallel to the shaft at 40mm spacing. The shaft is strategically positioned to give an adjustable fibre discharge opening (also referred to as fibre discharge outlet). The fibre is discharged through the opening while the palm nuts are conveyed to the other end of the machine to be discharged at the nut discharge outlet. The machine is powered by a 3.33KW (4hp) electric motor with the aid of belt and pulley arrangement which has 175mm diameter driven pulley and 75mm diameter driver pulley.

3.1 Design Analysis

3.1.1 Volume Capacity

The effective volume, V_{eff} of this separator that can be occupied by the digested palm fruit mash depends on the part of its trough that constitutes upper chamber where the mash from the hopper is slacked before feeding to separating unit at the lower chamber. Therefore V_{eff} is given by the volume (V) of the separator that can be occupied by the digested palm fruit mash and 50%

of V head space (Nwankwojioke etal, 2012). The volume of the digested palm fruit mashwas calculated using equation 1.

$$W = V \rho g \quad (1)$$

Where: W is maximum weight the machine was designed to carry at every point in time which is designed to be 98.1N, ρ is the bulk density of digested palm fruit cake, given by (Muthurajah, 2002) as 1060 kg/m^3, g is acceleration due to gravity and V is the volume occupied by the digested palm fruit. Hence the effective volume of the machine was determined as 0.045m^3 using equation (2);

$$V_{eff} = V + 0.5V \quad (2)$$

3.1.2 Selection of Pulleys

The machine requires four pulleys for its drives, one mounted on the electric motor shaft, one each at both ends of the auger shaft and the remaining one mounted at left end of the cake breaker shaft. Due to its availability, cost and performance; cast iron pulleys were selected. The intended ratio of the speed of the driven pulley to that of the driver is 2:3. Therefore, equation (3) was used to determine the diameter and speed of the pulleys.

$$\frac{n_2}{n_1} = \frac{D_1}{D_2} = \frac{2}{3} \quad (3)$$

Where n_2 and n_1 are the speed of the driven and driver pulleys respectively and D_1 and D_2 are the diameters of the driver and driven pulleys respectively. Hence we design the machine to run at the speed of 1000rpm for effective pulverization and separation. If small driver pulley is used assume 100mm diameter, therefore, n_1= 1500rpm, n_2= 1000 rpm, D_1 = 100mm and $D_2 = D_3 = D_4$ = 150mm.

3.1.3 Design for Belt

Equation (4) was used to determine the length of belt as given by (Khurmi and Gupta, 2005) as;

$$L = 2C + 1.57(D_2 + D_1) + \frac{(D_2 - D_1)^2}{4C} \quad (4)$$

Where L is the length of the belt, D_1 and D_2 are the diameters of the driver and driven pulleys, and C is the centre to centre distance of the two pulleys, and is given by equation (5) (Sharma and Aggarwal, 2006);

$$c = \frac{(D_1 + D_2)}{2} + D_1 \quad (5)$$

The centre distances, C between the adjacent pulleys were determined using equation (5) as 225mm and 300mm for the motor/auger and auger/cake breaker drives respectively. Substituting D_1, D_2, and C into equation (4), gives the length of the V-belts required as 845mm and 450mm for the motor/auger and auger/cake breaker drives respectively. Since each of the drives transmits less than 3.5kW, V-belt of type "A" is required for both drives (Khurmi and Gupta, 2005; Sharma and Aggarwal, 2006).

3.1.4 Shaft Design

Equation (6) gives the maximum stress relations for determining the diameters, d of the auger shaft and cake breaker shaft given as;

$$d = \left[\frac{16}{\pi\tau}\sqrt{(k_b M_b)^2 + (k_t M_t)^2}\right]^{1/2} \quad (6)$$

Where: τ is the allowable stress for steel shaft with provision for key ways, and is given as 42N/mm^2. M_t is the maximum twisting moment on the shafts (N-mm). M_b is the maximum bending moment on the shafts (N-mm). k_b is the combined shock and fatigue factor for bending. And k_t is the combined shock and fatigue factor for twisting. Note that Bending and twisting moments occur on shafts as a result of applied loads and belt tensions. The maximum twisting moment on each of the shafts was determined using the relationship given by Khurmi and Gupta (2005), as;

$$M_t = (T_i - T_j)\frac{D_2}{2} \quad (7)$$

Where T_i for the motor/auger and auger/cake breaker drives was determined using equation (8), given by Khurmi and Gupta (2005), as;

$$T_i = T_{max} - T_c \quad (8)$$

Where T_c and T_{max} are the centrifugal and maximum tension of the belts, and is given as;

$$T_{max} = \sigma a \quad (9)$$

And

$$T_c = mv^2 \quad (10)$$

The coefficient of friction, μ between the pulleys and the belts, mass per unit length m, maximum safe stress σ, and cross sectional area a, of the belts were obtained from standard tables as 0.3, 0.108kg/m, 2.1N/mm^2 and 81mm^2respectively (IS: 2494-1974-Khurmi and Gupta, 2005; Sharma and Aggarwal, 2006). Then the belt speeds,v for the motor/auger and auger/cake breaker drives were computed as 7.84m/s and 5.82m/s respectively from the relation;

$$v = \frac{n_2 \pi D_2}{60} \quad (11)$$

Therefore, substituting the values of equations (9, 10 and 11) into equation (8) gives the tension on the tight side for the motor/auger and auger/cake breaker drives as 163.79N and 168.52N respectively.

Consequently, the tension on slack side of each belt, T_j was determined using equation (12) as stated below;

$$2.3 log\frac{T_i}{T_j} = \mu\theta cosec\beta \quad (12)$$

The groove angle (2β) of each of the pulleys is 38^0 (thus, $\beta = 19^0$), while the angles of lap θ were determined as 2.74rad and 3.14rad for the motor/auger and the auger/cake breaker drives using equation (13) given by (Khurmi and Gupta, 2005) as;

$$\theta = 180 - 2\left[sin^{-1}(\frac{D_2+D_1}{2C})\right] \qquad (13)$$

Therefore substituting the values of equation (13) into equation (12) gives 13.08N and 9.29N as the tension on the slack side for the motor/auger and auger/cake breaker drives respectively. Hence substituting the values of T_i, T_j, and D_2 from equations (8, 12 and 3) respectively into equation (7) gives the maximum twisting moments on the shafts as 7462.50N-mm and 145031N-mm for the cake breaker and auger respectively.

For the bending moment on the cake breaker shaft, consider the line diagram of the shaft as shown in figure 1;

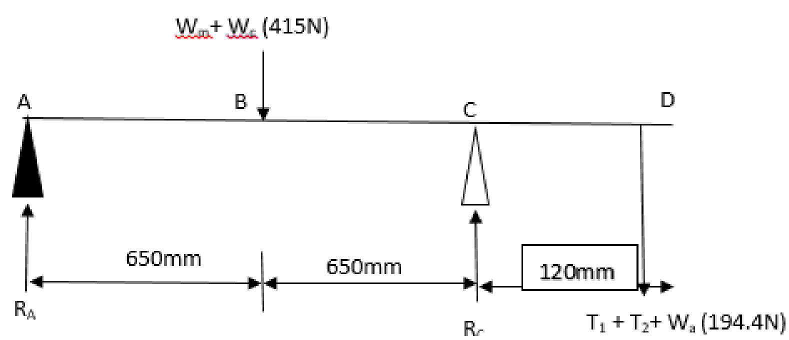

Figure 1: The cake breaker shaft showing forces acting on it.

Where: W_c is the weight of the cake breaker = 29.43N

W_{cp} is the weight of the auger/cake breaker shafts driven pulley = 16.73N.

T_1 is the auger/cake breaker drive belts tight side tension = 168.52N.

T_2 is the auger/cake breaker drive belts slack side tension = 9.29N.

Therefore the reactions, R_A and R_c were determined by taking moment about A (chukwulozie et al, 2015);

$$\sum M_A = 0$$

$$:.\ R_C(1300) = 194.4(1420) + 415(650)$$

$$:.R_C = 414.47N$$

Also $\sum F_y = 0$

$$:.414.47 + 194.4 = 415 + R_A$$

$$:.R_A = 174.6N$$

Thus, the bending moments on this shaft were computed as follows; B.M. at A and D = 0N-mm

B.M. at B = 120755.25N-mm; B.M. at C = 25535.60N-mm

Thus, the maximum bending moment on the cake breaker shaft is 120755.25N-mm and since the feeding of the fairly compacted digested palm fruit cake from hopper into the upper chamber of the machine is partially sudden, then K_b and K_t = 1.5. The maximum twisting moments on this shaft was also computed from equation (7) as 7462.50N-mm. Thus, the shaft diameter was calculated as 43.31mm using equation (6). Hence, a standard 45mm diameter solid shaft was selected for the operation of the cake breaking unit.Consequently, for the bending moment on the auger shaft, consider the line diagram of the shaft as shown in figure 2.

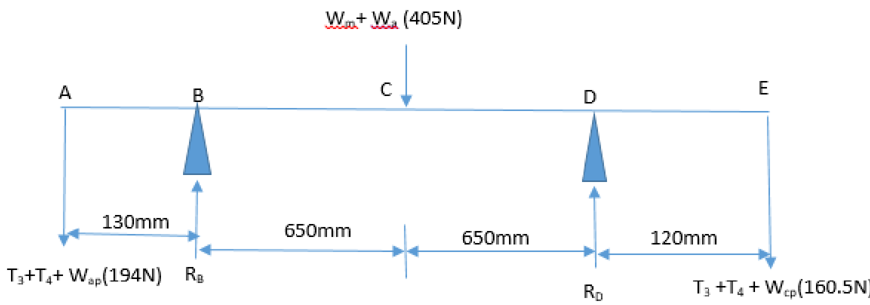

Figure 2: The auger shaft showing forces acting on it.

Where: W_a is the auger weight = 40N

W_{ap} is the weight of the motor/auger shafts driven pulley = 17.13N

$W_{cp}$is the weight of the auger/cake breaker shafts driving pulley = 16.73N.

T_3 is the auger/cake breaker belts tight side tension = 163.79N

T_4 is the auger/cake breaker belts slack side tension = 13.08N.

The reactions of the bearings, R_B and R_D were determined by taking moment about B;

$$\sum M_B = 0$$

$$:.170.8(1420) + R_D(1300) + 160(120) = 405(650)$$

$$:.R_D = 5.05N$$

Also $\sum F_y = 0$

$$:.405 + 194 = 170.8 + 5.05 + R_B$$

$$:. R_B = 450.40\text{N}$$

Thus, the resultant bending moments on this shaft are as follows;

B.M. at A and E = 0N-mm

B.M. at B = 29000N-mm

B.M. at C = 135189.05N-mm

B.M. at D = 22500.20 N-mm

Therefore, the maximum bending moment on the auger shaft is 135189.05N-mm. The maximum twisting moment on this shaft was also determined from equation (7)as 145031N-mm. Since the feeding of the slacked digested palm fruit cake fro into the auger separator is gradual and steady, K_b = 1.5, andK_t = 1.0 (Khurmi and Gupta, 2005) and also the shaft diameter determined using equation (6) is 44.15mm. Consequently, a standard 45mm diameter solid shaft was selected as auger shaft.

3.1.5 Design for Prime Mover

The power required for the operation of this machine is the total sum of the power required to drive its units and the power required to overcome the drives friction. The power, P required in the cake breaking and separating units were determined as 1.05kW and 1.55kW respectively using equation (14);

$$P = (T_i - T_j)v \qquad (14)$$

Taking care of 10% possible power loss due to friction, the total power required to drive the developed palm nut-pulp separating machine was computed as 2.86kW (3.80HP). Therefore a 4HP electric motor was selected for the operation of this machine.

Fig. 3: Picture of the constructed machine

4.0 Result and Analysis

4.1 Test Procedure

The machine was set up and operated with no load for five minutes to ensure that the various components were functioning properly. The separator was evaluated at two levels of moisture content (dry and wet) and the separating efficiency, quality performance efficiency and throughput capacity were evaluated at each level. In each of the test, 10kg sample was randomly fed through the hopper into the machine and the time taken for the nut fibre mixture to be completely separated was taken using the stop watch. After each operation, the separated and unseparated nuts and fibre from the two outlets were carefully sorted out and weighed, and the machine performances such as throughput capacity, separation efficiency, and quality performance efficiency were computed using equations (15, 16, and 17) respectively.

Throughput capacity (C_t) was expressed as

$$C_t = \frac{(W_n + W_f)}{t} \qquad (15)$$

Where W_n is the weight of nuts collected after separation (kg),

W_f is the weight of fibre collected after separation (kg)

The average separation time (sec).

Separation Efficiency (E_s) as;

$$E_s = \frac{(W_n + W_f)}{W_m} x\ 100 \quad (16)$$

Where W_m is the weight of nut/fibre mixture sample fed into the machine (kg)

Quality Performance Efficiency (E_Q)as;

$$E_Q = \left[\frac{W_{nn}}{(W_{nn} + W_{nf})}\right] x \left[\frac{W_{ff}}{(W_{ff} + W_{fn})}\right] \quad (17)$$

Where W_{nn} is the weight of separated nuts at the nut discharge outlet (kg), W_{nf} is the weight of nuts at the fibre discharge outlet (kg), W_{ff} is the weight of separated fibre at fibre discharge outlet (kg) and W_{fn} is the weight of fibre at nut discharge outlet (kg).This procedure was replicated three times for each level and the average taken and result is presented in tables 1 and 2.

Table 1: The Test Result of the Developed Machine Using Dry Digested Palm Fruit

S/N	**W_n (kg)**	**W_f (kg)**	**W_{nn} (kg)**	**W_{fn} (kg)**	**W_{ff} (kg)**	**W_{nf} (kg)**	**t (sec)**	**C_t (kg/sec)**	**E_s (%)**	**E_Q (%)**
1	3.6	5.4	3.1	0.5	5.1	0.3	58	0.155	90	83.1
2	3.7	5.2	3.3	0.4	4.7	0.5	60	0.148	89	80
3	3.5	5.5	3.2	0.3	5.1	0.4	55	0.163	90	83.9
average	3.6	5.3	3.2	0.4	5.0	0.4	58	0.155	89.7	82.3

Table 2: The Test Result of the Developed Machine Using Wet Digested Palm Fruit

S/N	W_n (kg)	W_f (kg)	W_{nn} (kg)	W_{fn} (kg)	W_{ff} (kg)	W_{nf} (kg)	t (sec)	C_t (kg/sec)	E_s (%)	E_Q (%)
1	3.5	4.5	3.0	0.5	4.2	0.3	55	0.145	80	81.3
2	3.4	4.6	3.0	0.4	4.1	0.5	52	0.153	80	78.1
3	3.4	4.4	2.9	0.5	4.1	0.3	53	0.134	78	80.7
average	3.4	4.5	3.0	0.5	4.1	0.4	53	0.144	79.3	80.1

4.2 Throughput Capacity

The throughput capacity is the rate at which the developed machine completely discharge the sample fed into it. This was calculated using equation (15), for each of the runs and the average values were obtained as 0.155kg/sec and 0.144 kg/sec for dry and wet sample respectively. The difference in the values of throughput capacity for dry and wet sample was because the wet sample is sticky and some quantity of the fed sample sticks to the shafts and inner walls of both breaking and separating chambers. It was also seen that the time for complete separation reduced for wet sample.

4.3 Separation Efficiency

The separation efficiency of the machine is the ratio of the total weight of the separated sample to the weight of the sample fed into the machine. This was calculated using equation (16) for the three runs and the average values obtained as 89.7% and 79.3% for the dry and wet sample respectively. This shows that the machine is quit efficient for both small and medium palm oil production.

Also the difference in the values for both dry and wet sample is still attributed to the sticky nature of the wet sample.

4.4 Quality Performance Efficiency

The quality performance efficiency is the product of the ratio of the weight of the nut discharged at the nut discharge unit after sorting to the total weight of the nut discharged at both nut and fibre discharge unit after sorting, and the ratio of the weight of the fibre at the fibre discharge unit after sorting to the total weight of fibre discharged at both unit after sorting. Simply put, it is the product of the separating efficiency for nut and separating efficiency for fibre. This was computed using equation (17) above for the three runs and the average obtained as 82.3% and 80.1% for dry and wet sample respectively. The reduction in the values was because, the wet sample test, greater percentage of the fibre went with the nuts to be discharge at the nut discharge outlet, as some of the fibres were trapped in the fibre discharge opening thus causing a partial blockage of the opening. This was caused by the sticky nature of the wet sample.

Conclusion

In this work, a palm nut and fibre separating machine was designed and developed through detailed design considerations and proper material selection to ensure smooth operation. The performance of the separator was quite appreciable in many of the test cases. However, the performance of the machine is directly proportional to the dryness of the mix. Optimally, the machine gave a throughput capacity of 0.155kg/sec, separating efficiency of 89.73% and quality performance efficiency of 82.3%. However the throughput capacity, separating efficiency and quality performance efficiency for wet mixture gave 0.144kg/sec, 79.3% and 80.1% respectively. With this performance, the machine will culminate the associated problems and difficulties in the traditional method of separation. Hence the Separation of digested palm fruit mash into palm nut and pulp before pressing of the pulp is mechanized, thereby improving the quantity of palm oil produced, by eliminating drudgery, nut breakage, and excessive loss of palm oil to pressed fibre, nut-fibre separation and second pressing operations.

REFERENCES

Khurimi, R.S., Gupta, J.K. 2005. A *Textbook of Machine Design. S.I. Units. Eurasis Publishing House (PVT) Limited*, New Delhi. pp. 16-52,120-180,509-557,624-758 and 962-1020.

Muthurajah, R. N. 2002. *Palm Oil Factory Hand Book, Palm Oil Res*. Institute New Delhi. pp: 35-56

Nwankwojike, B. N., Odukwe, A. O. and Agunwamba, J. C. (2012); "Design, Fabrication and Evaluation of Palm Nut-Pulp Separator",*Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS)*, vol. 3 iss. 1,pp. 144-151.

Sharma, P.C., Aggarwal, D.K. (2006). "Machine Design". *S.K. Katariaand Sons, NaiSarakDechi*; pp. 19-58, 483-839.

AdegokeOke, (2007); "Innovation Types and Innovation Management Practices in Service Companies", *International Jourtnal of Operations and Production Management,* vol. 27, iss. 6, pp. 564-567.

Ologunagba F. O., Olutayo L. A. and Ale M. O., (2010); "Development of Palm Nut and Fibre Separator, *Journal of Engineering and Applied Sciences,* vol. 5, no. 12, pp 10-15.

Okolie Paul Chukwulozie, Obika Echezona Nnaemeka, Azaka Onyemazuwa Andrew and Sinebe Jude Ebieladoh (2015) "Steel Work Design and Analysis of a Mobile Floor Crane" *British Journal of Applied Science and Technology,* Vol.13, Iss.3, pp. 1-9.