Motorization of Palm oil Extraction Process: Evidence from ManuelSpindle Press

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Abstract- *The importance of Palm tree in any economy cannot be forgotten in a hurry. It's a very economic tree and every part of it is useful to the society. A large percentage of the palm oil produced by small-scale processors cannot be utilized by the larger scale industries in Nigeria or outside the country because of its poor quality. The processing of the palm fruit locally is crude and tedious for the local and middle class dwellers in palm oil producing communities in Nigeria. The drudgery and time spent in extracting palm oil discourages the youth and affect the productivity of palm oil in our rural communities. The main objective of this study therefore was to re-design/motorize and test the performance evaluation of a manual spindle press palm oil processing machine which is commonly use in these communities. The existing spindle press was modified to incorporate an electric motor. The major components of the machine were standing frame, threaded shaft, speed reduction gear motor, driving and driven pulley and discharge outlet. The motorized machine was tested and was observed to replace the human energy needed in operation and also improved timeliness in operation and production was enhanced. From the quantity of oil produced, the performance efficiency of the machine was recorded as 79.78 percent both in timing and production output. The time taken to extract palm oil dropped from the usual 15 – 20mins used during human operation to 3 – 5mins using the modified motorized spindle press.*

Keywords — *Extraction Process, Motorization, Manual Spindle, Palm Oil, Electric Motor, Performance Evaluation.*

I. INTRODUCTION

It is certain that there is a universal demand for palm oil due to its use in domestic cooking as an ingredient for other food products like baking and frying of snack foods and as a raw material for the manufacture of soap, body/hair oils and detergents [1].Palm oil tree (*Elaeis guineensis*), the source of edible vegetable, is an important economic tree in Africa, Asia, and South America. About 90 percent of the palm oil produced from this tree ends in food products, while the remaining 10 percent is used for industrial production. Palm oil extract and palm oil manufacturing represent one of the most effective methods of ensuring food security and providing employment opportunities for millions of unskilled, semi-skilled and skilled workers in Nigeria. [2]Its numerous uses and demands increase as the world's population increases and standards of living upsurges. Palm oil accounts for 34 percent of the world's annual production of vegetable oil and 63 percent of the global exports of vegetable oils [3 - 5] Nigeria was once ranked 5th among palm oil producing countries of the world. This lost premier position on the world list of palm oil producers were attributed to neglect of the agricultural sector because of the then oil boom. Study by [6] reported that the decline in agricultural production in Nigeria was not statistically attributable to neglect of the agricultural sector during the oil boom period, but may be for some other reason else. In view of palm oil production, the predominant traditional method of oil processing which is time consuming, laborious, with low production output could be one of the other reasons mentioned.

Challenges due to Lack of appropriate processing technologies constitutes the major obstacle to palm oil production in Nigeria. Over the years attempts have been made to mechanize and automate the various operations involved in palm oil processing. Extraction (pressing) hasreceived the greatest attention for mechanization and automation. Presses developed over the years have included models such as: Manual vertical screw-press, Stork hydraulic hand press, Motor-jack press, Motor-jack/cantilever press, NIFOR hydraulic hand press, combined screw/hydraulic hand press, Mechanical screw-press [7 – 11]. The importation of screw press machines for oil palm are very expensive and not readily affordable by small and medium scale processors who form the majority of the processors in Nigeria. Moreover, industries established with imported technology do not function for a long period due to lack of spare parts, inadequate maintenance and inability to satisfy some local factors. It is therefore essential to evolve indigenous technology so as to address the issue of palm oil processing in Nigeria.

The manual screw press was a major breakthrough in palm oil production but there need to address some of its shortcomings, like drudgery in extraction of oil,

loss of oil in the process of extraction and poor or low quality yield of oil [12, 13].
This paper therefore aimed reviewing and automating the manual screw/ spindle press so as to achieve optimum efficiency in small - medium scale palm oil production in our local villages.

II. METHODOLOGY

A study of the existing method of palm oil extraction in some community in Southeastern Nigeria was examined. Figure 1. Shows the most common traditional and mechanized methods used in the visited communities.
There are different methods of extracting palm oil locally like the manual screw press, a long manual screw press, crude ways, and the manual spindle press as shown in Fig. I(i). The traditional method of extracting palm oil by villages involves washing pounded fruit mash in warm water and hand squeezing to separate fiber and nuts from the oil/water mixture.

Much quantity of water is used in washing the pulp hence this procedure is called the 'wet' method [14].Oil extraction processes from the palm-nut was a process that span approximately 21 days for the farm family due to the required human efforts, and it involves the cooperation of the man, his wife and children, and in some cases, members of the extended family [14]. An improved method was also observed with manual spindle press, hydraulic press and screw press as shown in Fig 1. The manual spindle press was observed to be a good alternative to the traditional manual method of oil extraction in the community. Moderately, it is economical and also conserves energy and time with respect to the traditional method of extracting palm oil. However, in spite of its successes in processing palm oil, setback such as drudgery involved in its operation, and loss of oil due to inadequate pressure application by an operator were observed.

a) Manual Spindle Press Modification.

Manual spindle press was redesigned and automated by adding some required electrical components like, round gear to the upward end of the shaft and fixing a thrust bearing to the downward end. A flange bearing, along the shaft was tightened to the frame of the machine for stability. The shaft used was threaded in a trapezoid form to offer high strength during pressing. The circular plate responsible for the compression was designed in such a way that it was attached to the shaft through the hole created on the plate[15].

(i) A manual spindle press.

(ii) A manual screw press Method

(iii) A long manual screw press Method.

(iv) Crude way Traditional method

(iv) Crude way/Traditional method

Fig 1: Methods of Processing Palm Oil in Most Community

The plate was designed in such a way that the hole created will be threaded to allow upwards and downwards movement of the plate during the rotation of the shaft. Gears were attached to the rotating spindle of the electric motor and that of the shaft to reduce the speed of the motor and increase the torque. The reduction of the speed of the rotating shaft will give the pressing plate greater torque to be able to compress the palm mash. Finally, the electric motor with electrical circuit diagram presented in Fig. 2 was introduced with a gear at the end of it to be able to match the gear on the spindle for proper rotation. It is relevant to note that the size of shaft and the thickness of pressing plate used are 120mm and 40mm. The thickness of the circular/pressing plate was selected by using the initial measurement for thickness of circular plate for the already existing machine which is 40mm.

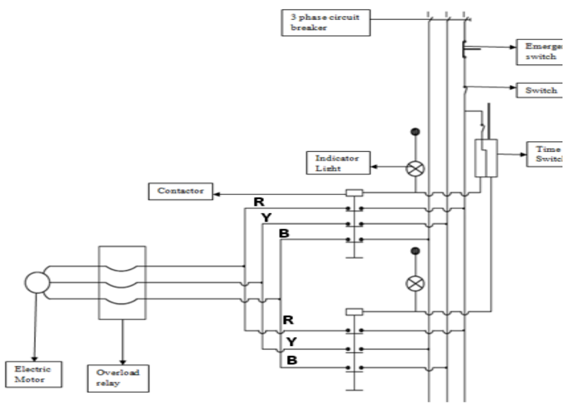

Fig. 2: Electrical Circuit Diagram

III. DESIGN CALCULATIONS

A 5hp, 750rpm motor was selected and connected to the shaft or spindle.A 5hp, 1750rpm electric motor is considered to be stable for the machine operation.

The shaft speed N_s, was calculated as follows;

$$Speed\ of\ driven\,(Ns) = \frac{speed\ of\ driver\,(Nm) \times Diameter\ of\ driver\,(Dm)}{Diameter\ of\ driven\,(Ds)} \qquad (1)$$

$$Ns = \frac{750 \times 70}{125} = \frac{52500}{125};\ Ns = 420 rpm$$

The motor starts using a star connection. Hence,

$$V_L \frac{V_{ph}}{\sqrt{3}} \qquad (2)$$

Rated current: $I = \frac{P}{V_L}$ (3)

where I = Current (Amps), P = Power (kW), V_{ph} phase Voltage (Volts), and V_L = Line Voltage

1 hp = 746watts, 5 hp = 3730watts = 3.73kw, $380V_{ph} = 219.39V_L$, so $I = \frac{5 \times 746}{219.39} = 17A$

i) ***Circuit Breaker Rating*:**

Since the rated current is equal to 17A, therefore, a circuit breaker of rating 20A was chosen. This prevents too much current entering the electric motor.

Torque transmitted by Motor (T_m):

$$Tm = \frac{Power\ transmitted\ by\ motor\ (P)}{Angular\ speed\ (\omega)} \qquad (4)$$

Power transmitted by Electric motor $V_C = \pi r^2 h$ (P),1hp = 0.746KW, 5hp = 5x0.746 = 3.73KW

Angular speed of motor

$$\omega,\ Angular\ speed\ (\omega)\ \frac{2\pi Nm}{60}\ (\omega), \qquad (5)$$

(N_m = Speed of electric motor)

$$\omega = \frac{2\pi \times 750}{60} = 78.54 rad/s,\ therefore,$$

$$T_m = \frac{3730}{78.54} = 47.50 N - m$$

ii) Stress built up in the cage

The cylindrical cage is subjected to two types of tensile stresses, viz: Circumferential stress, and longitudinal stress.

iii) Circumferential stress: This is as a result of the internal pressure in the cylinder that has the tendency to split up the cylinder into two troughs. Considering the cylinder specifications; Height of the cage 'H' = 650mm, Diameter of the cage 'D' = 400mm. Thickness of the cage 't' = 10mm.

Total pressure along the diameter of the cage.

We have that stress,

$$\sigma = \text{int}\,ensity\ of\ stress \times area = \sigma dl \qquad (4)$$

Circumferential stress in the shell,

$$\sigma_C = \frac{Total\ pressure}{\text{Re}\,sisting\ sec\,tion} = \frac{\sigma dl}{2tl}\ \frac{\sigma d}{2t} \qquad (5)$$

$$\text{Hoop stress} = \sigma h = \frac{\text{Pr}\,essure}{Thickness} = \frac{P}{t} \qquad (6)$$

Where P = 20psi (137.895KN/m^2), t = 5mm, ram diameter = 250mm.

$$\sigma h = \frac{137.895}{0.005} = 27579 KN/m^2$$

Hoop stress = Tensile stress across the diameter

$$\sigma c = \frac{\sigma hd}{2t}; d = 400mm = 0.4m$$

$$\sigma_C = \frac{27579 \times 0.4}{2 \times 0.005} = \frac{11031.6}{0.1} = 110316 KN/m^2$$

Volume of the cage: The volume of the cage is given by $V_C = \pi r^2 h$

(7)

Diameter (d) = 400mm, $r = \frac{d}{2} = 200mm = 0.2m,\ \pi = 3.142$ r = Height of the cage (h) = 650mm = 0.65m, and $V_C = 3.142 \times (0.2)^2 \times 0.65 = 0.083m^3 = 0.4m$ x

Area of pressing plates: $A_P = \pi r^2, \left[r = \frac{d}{2} \right],$

Diameter of pressing plate = 390mm

r = 390/2 = 195mm = 0.195m, Area = 3.142 × (0.195)2 = 0.12m2

Pressure on the cage:

Force = Ram pressure x Area of pressing plate

(8)

$$= 137.895 KN/m^2 \times 0.12 = 16.55\ KN$$

a) *The Rating of the Recommended Generator.*

Since a 5hp, 1750rpm electric motor was recommended and considered, the VA rating of the generator was calculated thus;

$$VA = \frac{W}{PF}; where, W = Load\ in\ watts;$$

$$PF = power\ \ factor$$

(9)

W = 5hp = 3730watts

$PF\ Cos\phi = 0.8$

$$VA = \frac{3730}{0.8}\ 4660VA = 4.66KVA$$

Hence, recommended generator rating will be a 6KVA three phase generator. To be installed for use in case of power outage during production.

The size of cable used to connect the electric motor was calculated as;

$$P = \sqrt{3}\, VI \cos\phi \qquad (10)$$

$V = 415, \cos\phi = 0.8,$

$P = 5hp = 3730 watts$

$$I = \frac{P}{\sqrt{3} \times V \times \cos\phi} = 6.486A, I \approx 6.5A$$

1mm^2 copper wire will carry an approximate current of 2.5A. Therefore, the required cable size for an electric motor current of 6.5A is 4mm^2, (or 2.5 mm^2) cable.

Fig.3 and Fig. 4 represent the sketch of modified manual spindle press and automated spindle press.

Fig. 4: A Section of the Mechanized Spindle

MODE OF OPERATION

The modified spindle press with flange bearing, electric motor etc., replaced the human energy required in extracting oil from the palm pulp. Its rotational movement, pulls up the pressing plate or thrusts it down, which was attached to the shaft in which the electric motor rotates. At clockwise movement, the plate is pushed down to make impact with the plate and on further clockwise movement it applies pressure on it. This pressure extract oil from the palm pulp. During anti-clockwise movement, the electric motor rotates in a reverse direction as a result of the interchange in phases i.e. RYB→RBY. The reversing of the motor comes to a halt immediately after the delay time has elapsed. This is to enable the operator remove the squeezed palm fruit mash. The time it takes to complete a squeezing operation is 3 minutes. Once this cycle has been completed, the time switch resets and begins another cycle at the command of the operator.

IV. RESULTS AND ANALYSIS

The results for the palm oil obtained for a particular quantity of palm fruits were as presented in Table 1. And the chart as shown in Fig. 5. *(Note that the evaluation was carried out on a small scale quantity, which can be extended to a larger scale pending on the availability of resources.)*

TABLE 1
QUANTITY OF OIL PRODUCED BY MANUAL AND MOTORIZED MACHINE

Quantity of Palm Fruits (kg)	Oil quantity (Litres) from Manual Operation	Oil quantity (Litres) Mechanized Machine
20	2.25	3.25
40	4.5	6.15
60	6.75	8.95
80	9	12.25
200	23.5	27.75

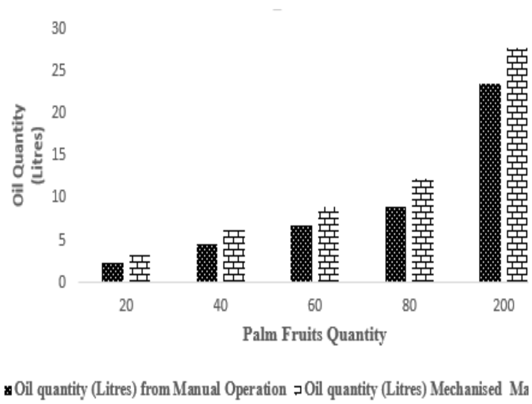

Fig. 5 Chart Showing Manual oil Quantity and Motorized Oil Quantity.

The expanded cage of the machine was loaded with palm fruit and an increased oil yield was observed. The incorporated electric motor on top of the frame replaced the need for human energy required in the extraction of the palm oil. The oil output and timing of operation was observed to be better than the manually operated spindle press. The time taken to extract palm oil dropped from the usual 15 – 20mins used during human operation to 3 – 5mins using the modified mechanized spindle press.Athorough performance evaluation of the modified motorized spindle press was carried out to ascertain the efficiency of the machine.Fourty (40) kg palm fruits produces 4.5 litres of palm oil using the manual method. But using the mechanized/motorized machine for the same quantity of palm fruits produces up to 6.15 litres of palm oil.The performance efficiency was recorded as 79.78 percent.

V. CONCLUSION AND ECOMMENDATIONS

The importance of palm oil in the Nigeria economy both local and internationally cannot be neglected, hence the need to ease the production and processing process/method mostly in our local villages. Manual spindle press which is commonly used in most local palm oil producing communities in Nigeria was improved by integrating an electric motor to solve the manual tedious labour involved in oil extraction and also increase the oil yield. The mechanized machine was observed to have increased the value of output per person per hour thereby increasing production. The processing time was reduces and also limit the requirement of more human labour in operating the machine, which they could channel to other aspect of the production in the industry. The mechanized press system therefore conserves more energy than the manual spindle press. Improving the refining efficiency, and the capacity of the processing equipment aids in much yield. *From the quantity of oil produced, the performance* *efficiency of the machine increased and was recorded as 79.78percent both in timing, and production output.*

Further research on performance evaluation is recommended for a much better increase production, and to improve on the design size. There is need also to carry out quality assessment for the palm oil produced to ensure that it is fit for human consumption. Appeal is therefore tendered to the government to come to our aid by giving financial assistance to peasant producers to motorize, automate and modernize most of the local manual spindle machines used in our local villages.

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