Journal of the Nigerian Association of Mathematical Physics
***Volume 31*, (July, *2015*), pp 191 – 194**
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Preliminary Design of a Small Scale Integrated System for Palm Oil Extraction

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Abstract

Small-scale agro-processing firms largely contribute to the production of palm oil in Nigeria. However, the traditional or manual method of palm oil extraction used by these firms has resulted in low sales and product stock in the agricultural market. As part to address these issues, it is imperative to pay attention to the sustainability and local technology improvement of this small scale agro processing firms. In this paper, a low cost integrated system for palm oil extraction was designed, fabricated and tested using locally sourced materials. Analyses was carried out on 5.2 kg of pre-boiled palm fruits and the result showed a time savings of 12 minutes when compared to the traditional method of palm oil extraction process.

Keywords: Palm oil, agro processing firms, extraction, design, product.

1.0 Introduction

Oil Palm *(Elaeisguineensis) was* originated in the tropical rain forest region of West Africa. The main belt runs through the southern latitudes of Cameroon, Côte d'Ivoire, Ghana, Liberia, Nigeria, Sierra Leone, Togo and into the equatorial region of Angola and the Congo. Processing oil palm fruits for edible oil has been practiced in Africa for thousands of years, and the oil produced which is highly coloured and flavoured, it is an essential ingredient in much of the traditional West African food [1].

Palm oil's unique composition makes it versatile in its application in food manufacturing and in chemical, cosmetics and pharmaceutical industries. Its semi-solid physical properties are needed in many application, its non cholesterol quality and superiority makes it a popular source of energy , while its technical and economic superiority makes it preferable as base materials in the manufacturing of various non-edible products [2]. It is also used to fuel liquid biomass plants in European countries. It is commonly used as cooking ingredients in Nigeria. It is used in the commercial food industry in other parts of the world.

International trade in palm oil began in the nineteenth century, while that of palm kernels developed after 1832. Palm oil became the principal cargo for slave ships after abolition of the slave trade. The establishment of trade in palm oil from West Africa was mainly the result of the industrial revolution in Europe [3]. As people in Europe began to take sanitation and hygiene seriously, demand for soap increased, resulting in the demand for vegetable oil suitable for soap manufacture and other technical uses. Tinplating required technical oil for which palm oil was found suitable. In the early 1870s exports of palm oil from the Niger Delta were 25,000 to 30,000 tonnes per annum and by 1911 the British West African territories exported 87,000 tonnes[4].

Before 1965, Nigeria was the world's leading producer and exporter of palm oil, and has since 1974 ceased to contribute to the export trade in the commodity, largely due to increased domestic demand/consumption that have not kept pace with the production [5]. During the past decade, Nigeria has become a net importer of palm oil. While in the early 1960's, Nigeria's palm oil production accounted for 43% of the world's production, currently, the country accounts for about 1.7% of the global palm oil production [6]. However, about 80% of these production comes from dispersed smallholders who use manual processing techniques. Also, Nigeria is now ranked fifth in the global crude palm oil production in the world, an enterprise that Nigeria once dominated. According to Aghalino [7] Nigeria lost her foremost place in oil export to Zaire and regained it only temporarily in 1964 – 1965. Nigeria lost to Malaysia and Indonesia, as the largest oil palm producer in the world today because of her poor commitment to oil palm production [8]. The drop in ranking is caused by the neglect of agriculture sector for petroleum products [9]. Azodo [10], designed and fabricated a motorized hydraulically operated palm oil press, which

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involved a single process of palm oil press. However, limited work has been done on machine design aspect to improve small scale palm oil extraction firm. There is a serious need for the encouragement of small-scale oil palm production in Nigeria to increase the domestic demand of palm oil since it has the ability of creating jobs for the teaming unemployed in the country [11]. Owing to the inefficient, strenuous and time consuming process of extracting palm oil in the small-scale processing firms, it is imperative to improve the processing units to achieve more product delivery in the Nigerian market. Hence this paper seeks to design an operational machine with integrated processing units.

2.0 Materials and Methods

The design factors considered most important for the development of the palm oil extraction machine includes: maintainability, affordability, reliability and safety. The model is made up of a motor which drives the entire process, an upper chamber where the digestion takes place and the lower chamber where the pressing is done, a shaft which runs through from the top to bottom of the machine, the beaters and conveyors welded to the shaft, and baffles on the body of the upper chamber. Figure 1.0 shows the picture of the fabricated design. The various components were designed as follows:

(a) The Digestion Chamber:

The digestion chamber was made with mild steel because it can withstand the pressure exerted by the process of the beating and also to save cost, as using a higher material would be of no effect. Baffles were welded to the internal of the chamber of inner diameter 200mm, outer diameter of 210mm and height of 500mm.The digestion is done by the action of the beaters on the fruits during the shaft rotation and is also aided by the baffles. The beaters were welded to the upper part of the shaft. Analyses for the design are as follows:

The volume of the chamber (V) is given by

$$V=\pi d^2h/4 \quad =\frac{\pi \text{ x } 0.22 \text{ x } 0.5}{4} = 0.01571m^3 \qquad (1)$$

Where h= height (m), d= diameter (m)

h =500mm=0.5m

d =200mm=0.2m

The maximum height (h_1) that the fruit will occupy is given by

h_1=h x $\frac{3}{4}$ = 0.5 x 0.75=0.375m

Maximum volume (V_1) the fruit would occupy is

V_1=0.01571m^3 x 0.75=0.01178m^3

Since a standard drum (200L) of palm fruit weighs 130kg

Hence, 200L ≈130kg

0.2m3 ≈ 130kg

0.01178m3 ≈ 0.01178 x 130/0.2 = 650kg

Thus the weight of palm fruit the chamber is expected to carry equals

W = 650 x 0.01178= 7.65kg

(b) Shaft diameter

The power is delivered to the shaft by some tangential force and the result torque set up within the shaft permits the power to be transferred to various parts linked up to the shaft. In order to transfer the power from one shaft to another, the various members such as pulleys gears are mounted on it. Thus, torque (T) transmitted is given by Equation (2)

$$T = \frac{Px\,60}{2\pi N} = \frac{2984\ x\ 60}{2\pi x\ 130} = 219.5Nm \qquad (2)$$

Where P = Power (W), N= Number of revolutions per minute

(c) Pulley

The pulley diameter was carefully selected in order to have the desired velocity ratio. The dimensions of pulley was analysed as follows:

Diameter of driver (d_1) =120mm

Diameter of driven (d_2) =90mm

Thickness of belt (t) =12mm

Density of the rim material (ρ)=7200kg/m^3

Velocity of the driver (v_1)

$$V_1 = \frac{\pi dN}{60} = \frac{\pi x\ 1.2\ x\ 100}{60} = 6.28m/s \qquad (3)$$

Centrifugal stress (σ_1) acting on the pulley is given by

$$\sigma_{1=}\ \rho \text{ x } v_1^2 = 7200 \text{ x } 6.28 = 2.84 \text{ x}10^5Pa \qquad (4)$$

Width of pulley = 1.25 x width of belt = 16mm

Coefficient of friction (µ) between driven pulley and belt µ

$$\mu=0.54-\frac{42.6}{152.6+6.28} =0.27$$

Using the velocity ratio from Equation (3), the number of revolution of the driven pully(N_2) is approximately equal to 130rpm

Therefore velocity of the drive pulley (V_2) is

$$v_2 = \frac{\pi \times 0.9 \times 130}{60} = 6.12\text{m/s} \quad (5)$$

$$\text{Length of belt } (L_b) = \pi(r_1+r_2) + \frac{2(r1+r2)2}{x} + 2x\frac{(r1-r2)2}{x} \quad (6)$$

Where $x$is the distance between the centre of the two pulleys and equals 381.5mm

$$L_b=\pi(45+60) + \frac{2(45+60)2}{381.5} + 2(381.5) - \frac{(60-45)2}{381.5}=1150\text{mm}$$

Figure 1.0: Fabricated palm oil extraction machine

Table 1: Summary of design specification of the machine

S/N	Part Name	Qty	Size	Material
1	Electric Motor	1	220volts, 4Hp	Cast iron
2	Digestion Chamber	1	Φ = 200mm, h = 700mm	Mild Steel
3	Extraction Chamber	1	Φ = 110mm, h = 700mm	Mild steel
4	Shaft	1	Φ = 40 mm	Carbon Steel
5	Cone	1	Φ_1 = 50mm, Φ_2 = 80mm	Mild Steel
6	Spring	1	----	High carbon Steel
7	v-belt	1	A 30	Rubber
8	Pulley	2	Φ_1 = 90mm, Φ_2 = 120mm	Cast iron
9	Bearing	2	Bearing No. 208	Galvanized Steel
10	Bolts and nuts		M8 x 40	Mild Steel
11	Beaters	6	Φ =10mm, L =60mm	Mild Steel
12	Screw Conveyor	1	-----	Galvanized Steel
13	Paint		4litres	

3.0 Test, Results and Discussions

The Palm fruits used for this experiment were boiled for exactly 45 minutes with an appropriate amount of water just before the analyses was carried out. The results gotten from the numerous tests are as follows:

TEST 1: NO LOAD TEST

The electric motor was switched on and the machine was allowed to run for ten minutes without loading the palm fruits. it was observed that the machine ran smoothly.

TEST 2: LOAD TEST

Before the machine was switched on, pre-boiled palm fruits were fed into the machine and thereafter the machine was turned on. It was observed that the motor was on but could not power the shaft, therefore it was safe to conclude that the machine cannot run pre-loaded.

TEST 3: LOAD TEST

The palm fruit was completely evacuated and the machine turned on to run for about 90 seconds, shortly after, the palm fruits were gradually poured in the digestion chamber. The machine ran smoothly and the palm began the digestion process until about 7 minutes when it was stopped abruptly. The digestion processes was successful and proceed to the extraction stage.

TEST 4: LOAD TEST

The machine was loaded with 5.2kg of palm and was digested for about 10mins after which it was transferred to the extraction chamber, after about a minute the extraction of oil began. The process was successful and was completed in 20mins, and 2litres of oil was extracted. The traditional method of extraction will produces an average of 1 litre per 22 minutes [3]. Thus, comparing the volume produced to the traditional method, the time savings through the production process is 12 minutes.

4.0 Conclusion

The integrated system for palm oil extraction was designed, fabricated and tested. Based on palm fruit load of 5.2kg, the machine was able to save about 12 minutes of the total process involved in palm oil extraction. However, further experimentations and investigations on the machine will be useful for further developing the machine intended for commercialization. This palm oil extraction machine has been able to reduce the tedious manual process following local production of oil palm. Thus, eliminating human fatigue and improving production output of oil palm.Due to profitability of the oil palm enterprise, the sector if adequately managed could assist in to solving unemployment challenges that Nigeria is currently facing. The sector could employ several people depending on the size of the enterprise. In order to speed up the net return of palm oil processing in Nigeria, the government should sensitize her populace on the profitability of the business while providing affordable technology to individual that are interested in the enterprise.

5.0 Acknowledgement

We would like to thank the following students: Y. Oloke-Ehisuan, R. Egwerome, V. Ohwofasa, and R. Olojeof the Department of Mechanical Engineering Department, University of Benin for their relentless support and co-operation toward the success of this research.

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