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Research Papers

Design and Construction of a Pneumatic Palm Kernel Shell Separator

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Abstract: Palm kernel is one of the products from palm oil mills. In kernels recovery plant, the separation of kernel and shell from cracked mixture is carried out using a combination of dry and wet separation. The separation device uses forced draught principle instead of usual induced draught. The air flow velocity in its separation column can be adjusted via the blower (damper) located at the ground or an elevated level. The effect of velocity and fan air speed in activity of separation must to be in consideration. The parameter that has been a monitored during the trials was dirt and shell content in production kernel, kernel loses and the effect of velocity on efficiency of separation. The system was capable to separate dried nuts and kernel shells. The total kernel from dry and wet separation also could be minimizing. This pneumatic or winnowing system also reduces the waste effluent from the mill promoting more environmental friendly technology for the oil palm industry.

Keywords: *Palm kernel, pneumatic separator, dry palm kernel shell, winnowing*

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INTRODUCTION

Palm oil kernel processing industry is very popular in the third world countries because of the dependency of many companies on palm kernel and palm oil as raw materials (Hartley 1987). The processing of the palm kernel entails cracking the shell to produce the nut for industrial use. Kernel produced much is separated from the shell to make it convenient for further processing in the industries. Separation of cracked mixture which results from the nut cracking stage and consists of kernels, broken shells, unbroken nuts and dusts required the recovery of each of these constituents of the mixture. It is a very important activity in the kernel recovery process of palms mills. In the developing countries small scale palm mills make use of manual labor for the separation of the kernels. The kernels are handpicked from the mixture and at the same time the broken nut are recovered and taken back to the mill for cracking. This method is slow, laborious and unsuitable for large scale mills; but modern method of cracked mixture separation have been devised which are classified into two namely: System based on density and System based on shaped. The Principle involved in the system based on density employs the difference in density between the kernel and the shells to chart part for their independent recovery. The relative density of palm kernel is about 1.07 and that of the shell ranges from 1.15 to 1.20. Clay- bath and hydro-cyclone are two methods devised for cracked mixture separations based on density. These methods of separation are usually known as wet processes since water is always involved and the kernels have to be dried at the end of the separation[1]. Over the years there have been a lot innovations geared towards improving the efficiency of these activities by way of reducing energy consumption, water usage and minimizing damage or rupture of the kernel, noise generation and generation of palm oil mill effluent (POME). Separation of cracked mixture is a challenging process especially to the small scale mill owners. Large scale mill have automated hydro-cyclone machines with high separation efficiency. However, clay-baths and hydro-cyclone are known for their high energy and water consumption making the application in small scale mills difficult[2]. On the other hand inefficient separation process could cause shells to be carried together with kernel to palm kernel expellers which could damage the crushing mechanisms. In other to enhance the recovery of dry shell and kernel in palm oil mills. We need to develop an improved dry separation system via a pneumatic separation technique[3].

There are two methods for net separation of palm kernel and palm oil shell. These are by using hydro-cyclone water bath. Clay water bath uses kaolin as a material to be mixed with water so that when the mixture of kernel and shell is introduced, the kernels will that which the shell will sink. The use of kaolin is expensive and it also produces a lot of waste after the separation was finished. Also it is a very difficult to get the right ratio of water and kaolin where perfects separations can be obtained in order to maximize the usage of operating conditions where maximize separation can be achieved of the pneumatic separation, since the current method used by the industry is trial and easor where the kaolin will be introduced little by little and the spealic gravity of this mixture will be tested. This will consume many working hours. Based on the commercial performance evaluation of the system in certain palm oil mills show the amount of cracked mixture for wet separation is about 60 to 80%. This shows that the system is inefficient based on the separation technique. Since the separation system available is inefficient, therefore there is need for a new technique required to improve the conventional method hence this study.

The aim of this study is to maximize the recovery of dried kernel and shell via a pneumatic separator. The objectives are to study the effect of velocity and fan air speed damper in activity of separation and to compare the old separation method with the new separation technique

2.0 LITERATURE REVIEW

2.1 Oil Palm

Oil Palm (Eleasis guineesis) is a perennial plant indigenous to tropical areas. It originated from Africa mostly in the southern parts of Ghana and Nigeria, but is grown in plantations in equatorial tropics in Southeast Asia and South America in different varieties (Hartman et al., 1993). The oil palm is cross pollinated and the main pollinating agent is the weevil, *Elaeidobius Kamerunicus* Faust, a type of insect. Harvesting can be done after 24-30 months after planting where each palm tree can produce up to 15 Fresh Fruit Bunch (FFB) per year. Each fruit weight an average of 20kg each.

Each FFB will contain around 1000 to 1200 fruit lets, each fruit lets consists of a fibrous monocarp layer, the endocarp (Shell) which contains the kernel. Present day planting materials are capable of producing 39 tons of FFB per year and 8.6 tons of palm oil and actual yields from good commercial plantings are about 30 tones FFB per year with 5.0 to 6.0 tones oil[4].

2.2 Types of Oil Palm

There are three main varieties of oil palm distinguished by their fruits characteristics. The most common palm oil used in the industries come from *Dura, Tenera* and *Pisifera* which can be differentiate according to the endocarp and medium mesocarp content ocarp and high mesocarp content of 60-95% and the *Pisifera* palms have no endocarp and about 95% mesocarp[5].

Dura: This has a thick shell separating the pulp from the kernel. The kernel tends to be large, comprising 7-20% fruit weight.

Tenera: This has a tin shell between pulp and kernel, together with a fibrous layer round the nut. The kernel is relatively small, comprising 3-15% fruit weight. The oil content is higher at 24-32%.

Pisifera: This has no shell and is very frequently female sterile. As a result of their very marked tendency to female sterility, pisifera palms are not used for commercial.

2.3 Palm Oil Fruit and Kernel Processing

The palm oil milling process starts by extracting the fruit of the oil palm to obtain the CPO. The process begins with the sterilization of Fresh Fruit Bunch (FFB) using steam up to 3 bars to stop the formation of Free Fatty Acid (FFA). The FFB then will be sent to a rotating drum thresher to separate the fruit with the Empty Fruit Bunch (EFB).

The fruit will be then later sent to the digester where it will be cooked using steam to loosen the oil-bearing msocarp from the nuts and thus break the oil cells present in the mesocarp[6].

The digested mash will then be later pressed to extract the oil using screw pressers. The press cake is then delivered to the kernel plant by conveyer to be further processed.

The oil from the press will be diluted and pump to vertical clarifier tanks. Impurities from this oil will be removed and dried using vacuum. This cleaned oil will then be later stored, ready for delivery. The sludge from the clarifier sediments is fed into the bowl centrifuges to recover more oil. The recovered oil is then recycled to the clarifier while the sludge mixture, referred to as Palm Oil Mill Effluent (POME) is then treated at the effluent treatment plant (ETP).

For the press cake, it will be delivered to the decipericarper where the fibre and nuts are separated. The fibre will be used to fire steam boilers whereas the nuts will be cracked, to obtain the palm kernel though, the nut of the fruit must be crushed first. This is usually achieved by the means of using the Rolek nut cracker[7]. And the shell and kernel will be separated by using a winnower (pneumatic separation) or a mixture of hydro cyclone and clay water bath.

2.3.1 Chemical Composition of Palm Kernel Shell

Palm kernel shell can be considered as pellet form because of its natural form, due to its high grade solid, high calorific value, low ash and low sulfur content. From biomass aspect, the calorific value 20100kj/kg and solid form has become one of the most favorable biomass media. It always mixes with EFB fiber in certain ratio to burn in the biomass boiler[8].

2.4 Separation of Cracked Mixture of Kernel and Nut

In food industry, there are basically two methods used to remove foreign particles, this systems are categorized as dry and wet system, these systems are used in other to achieve the desired purpose removing of (e.g. Straw, hull and chaff) or for classification purposes, these methods includes.

2.4.1 The Clay Bath

The Clay-Bath uses a clay solution that is maintained within a relative density of 1.12. When cracked mixture is admitted into the Clay-Bath, the denser shells will sink to the bottom while the less dense kernels will float[9].

2.4.2 The Vibrating Table

The vibrating table is a dry separation process. The table is supported by two steel leaf springs located at both sides of the table. An eccentric shaft driven by electric motor via lithe rubber coupling is used to create the vibrating motion. The cracked mixture from the cracker is poured on top of the table and as the table vibrates, the kernels are moved to one side of the table, while the shells move to the other side.

2.4.3 The Hydro Cyclone Separation

A hydro Cyclone assembly consists of two bottom cylindrical tanks with a conical base called baths, two overhead hydro cyclones called the kernel and shell hydro cyclones, two pumps, and two pairs of exit and over flow pipes. The size of the apertures at the bottom of the hydro cyclones is critical to their operation. The heights of the overflow pipes are adjustable as it is used to control the purity of the kernels.

The cracked mixture from the cracker is admitted into cracked mixture bath which is already filled with water. The pump powered by an electric motor is used to pump the cracked mixture together with water into the kernel hydro cyclone. At the entry of the cracked mixture into the hydro-cyclone, a helical motion is initiated by the tangential entry of the cracked mixture which causes the heavy particles to be thrown by centrifugal force to the wall of the cylinder and after tracing a helical path exits through the bottom of the cyclone.

By choosing the dimensions of the hydro cyclone and the pressure of the pump correctly, most of the shell pieces pass downwards and out through the bottom cone with small proportion of water flow. The larger part of the water together with most of the kernel after taking part in an initial down ward circular movement gradually move towards the center of the cylinder and start moving upwards leaving the hydro-cyclone via the overflow tube and exit pipe. In the kernel hydro-cyclone, the high overflow pipe is used to ensure that the kernels entering are sufficiently pure and ready for bagging. This high setting also causes some kernels to move downwards and exit with the shells through the exit pipes. The mixture (Containing shells and little proportion of kernels) leaving the exit pipe of the kernel hydro-cyclone is passed to another bath called the shell bath where a second pump is used to push the mixture to another hydro-cyclone known as the shell hydro-cyclone. The two baths are adjacent to each other with a perforated partition between them which allows the water levels to equalize. It is important to prevent the perforations from becoming so worn out that kernels can pass through into the shell fraction. In the shell hydro-cyclone, the overflow pipe is lowered sufficiently so that kernels together mixture bath. The lower overflow pipe ensures that the down flow is cleaner hence only shells move through the exit pipe of the shell hydro-cyclone.

2.4.4 Winnowing Column or Pneumatic Separation

The Winnowing column or Pneumatic separator uses air as the fluid for separation; the column consists of tall cylindrical or rectangular steel duct that is connected to a blower or suction fan. The Winnowing column is used in conjunction with either of the wet methods of separations-clay bath or Hydro- cyclone. The commercial Winnowing system uses force or induced draught[10].

Cracked mixture from the cracker is conveyed by a screw conveyor to some height along the column. As the mixture is poured inside the column, the air draught maintained by a suction pump sucks the fibres, dust and some shell pieces up the duct while the kernels, un-cracked nuts, and the remaining shells fall and are captured in another duct through the use of an air lock. In this way, up to about 30% to 40% of the shell present in the cracked mixture is removed without causing a loss exceeding 1% of the total kernel. This winnowed mixture is now dust free and can then be sent to the clay bath or hydro-cyclone separator.

3.0 MATERIALS AND METHOD

3.1 Materials

1. Electric blower
2.Air velocity meter
3.Weighing balance
4.Cracked mixture of palm kernel shell and nuts
5.Mild steel metal sheet

3.1.1 Design and Description of the Components of an Electric Powered Pneumatic Separator

.The Base Frame

The frame is welded to shape and provides support for other component parts of the pneumatic separator.

The Separating Column

The separating column is cuboidal in shape. It will be constructed with metal sheets. The selection of this material is due to its strength and cost effectiveness. Inside the separating column, two air vents exist at the upper side and the lower side of the machine. The vent at the lower side is where the air comes in from and the vent at the upper side is where the air escapes from with the cracked shell. Also a feed In-take hopper to the separating column was provided at the side of the separating column and discharging the air.

Electric Blower

Air Velocity Meter

This is a device used in measuring the air flow through a conduit or pipe per unit time.

Weighing Balance

This is a device used in determining the mass of the cracked palm kernel mixtures and also determining the weight of the separated shells and nuts.

Mild Steel

Mild Steel is used in design of the machine components and parts, the mild steel is a carbon steel typically with not more than 0.25 percent of carbon and cheaper steel compared to the rest of steel types in the family. Uncoated mild steel can easily form corrosion. Therefore, since the main body of the machine is made with mild steel, it will be coated with paint to avoid rusting.

The component of the machine to be made by using the mild steel are the pneumatic separation column, hopper, the nut and shell outlet because these parts are always busy with the movement of kernel and shell on them during operation and due to mild steel has an excellent surface finish. Mild steel is one of the most versatile and most widely used of all steel, available in a wider range of products, forms and finishes than any other, it has excellent forming and welding characteristics. Its chemical composition, mechanical properties, welds ability and corrosion resistance provides the best all round performance stainless steel at relatively low cost.

Cracked Mixture of Palm Kernel Shell and Nuts

This is a mixture of the various fractions of the cracked palm kernel nuts and shells gotten from the palm kernel nut cracking machine.

3.1.2 Principles of Operation of the Pneumatic Separator

The pneumatic system consists of a column in which the cracked samples are fed into for separation. Firstly, the air flow rate will be recorded before the cracked samples are loaded into the pneumatic separator. Air comes into the chamber from the bottom vent. The blower distributes air to the entire system. Thus the separation is by the differences in the terminal velocity of the cracked palm kernel shell and nuts. The air generated will be removed from the separating column through an opening at the top side of the separating column via a cyclon

3.2 METHODS

The principle of the separation is based on the airflow rate, which was calculated as follows:

$$\mathbf{VI} \qquad = \mathbf{VI \times Ai}$$

Where **Vi** is the volumetic air flow rate (M^3/Min), **Vi** is the air velocity (M/Min) and **Ai** is the throat area (M^2), for the respective column **i.** The performance of the machine was measured in terms of it's throughout capacity, separation efficiency, and the quality of the end product. The performance indices were defined as follow:[11].

3.2.1 Design Considerations

The design of the pneumatic cracked palm kernel nut and shell separator was develop on the following considerations

- Safety of the operator was put in consideration during
- The smoothness of the surface to be trailed by the kernel and shell particles where put in consideration by selecting the right metal
- The mass of kernel shell, nut and fibre was considered by designing the machine in such a way the blower could disperse them in their different outlets.
- Its designed in such a way the un- cracked nuts, and the remaining shells fall and are captured in another duct through the use of an air lock, in this way, up to about 30% to 40% of the shell present in the cracked mixture is removed without causing a loss exceeding 1% of the total kernel.
- It is designed in such a way that the air velocity in the separating column is adjusted to a suitable value to ensure removal of light shell without losing kernel and this is usually found to be in the range of 12.5m/s to 15m/s[12].

3.2.2 Throughput Capacity

The through put capacity was defined as the rate in kg/h at machine process the mixture for separation

3.2.3 Kernel Recovery

Kernel recovery was set to assess the percentage of the kernels which were recovered from the mixture introduced into the machine. It was expressed as

K_r = ( ) 100%

Where, C is the mass of kernels apparently lost (Discharged) with the shells, is the mass of separated kernels in Kg. Consequently, kernel loss defined the percentage of the kernels, which were discharged with the shell; so that it is a complement of the term kernel recovery[13].

Separation Efficiency

The separation efficiency ***ns*** of the separator was computed ***ns*** = ( )
Where, Kr is the percentage kernel recovery and Sr is the percentage shell recovery.
Now for a standard cyclone, the measurable pitch is 37.74mm and, the driving load W is 200N.
Using this information, the factor of safety is calculated
n = 106 x 37.74/2000 = 2.0 ……………… (1)
2000

Power Transmitted by cyclone:

The power transmitted by the cyclone is given by
$P = \frac{W_B.V/Nks}{Nks}$ …………………… (2)
Where V is the cyclone velocity given by Ad N/60
Where N = 500rpm
Substituting, Vc = .D. 50x 10^3m/s/60 =1.6mls
where d= 61.087
Where NB = Breaking load in new tons
V = Velocity of cyclone (M/S)
= Factor of safety
Ks = Service factor = K1, K2, K3= product of various factors such as load factor (K1), lubricating factor (K2), and rating factor (K3)

Therefore P = $\frac{W_B.\ V}{,\ k1,\ k2,\ k3}$ ……………4)
Substituting the values of W_B ,v,,k1,k2,k3 got from equs (1), (2), (3), (4)
P = $\frac{106x37.74x1.6}{2X1.25X1.5X1.0}$ = 1706.85W …………5)
Therefore the efficiency = $\frac{P_t\ x100\%}{Pi}$
= $\frac{1706.85w}{2000w}$ x100%
= **85.34%**

Kernel Purity

Kernel purity K_p defined as the percentage of the kernels in the mixture, which were actually discharged through the outlet meant for kernels.
Mathematically, kernel purity was expressed as, Kp = () 100%
Where, **a** is the mass of separated kernels in kg; and b*, mass in kg of the shells and impurities contained in the separated kernels

Shell Purity

Shell purity was defined as the percentage of the shell fragments in the mixture which were discharged through the appropriate outlets for shell particles.
Where, **b** is the mass in kg of shells and impurities discharged through the spout for shells[14].

4.0 TEST AND PERFORMANCE RESULT AND DISCUSSION

The results of the performance of the machine is expected to be 90% efficiency and above, so that the separation of both mixture is done in lesser time.
In order to evaluate the performance of the machine, different quantity of load were applied to it at differently recorded time. Each measure of load is repeated to get the average separation time.

Table 1; Details of the test and result.

S/N	LOAD Kg	TIME (SEC) T1	TIME (SEC) T2	AVERAGE TIME (SEC) T	DISTANCE OF SEPERATION (M)
•	Weight of arm with no load =20	13.83	13.82	13.825	
•	20+45=65	13.97	13.97	13.97	
•	20+90= 110	13.99	13.98	13.985	
•	20+40=420	13.01	13.05	13.03	1.24

DISCUSSION

The result shows that the time taken to separate the load to the maximum distance of 1.24m is above 13. 925sec (approximately 14 sec)

$$\text{The efficiency } E = \frac{Pt}{Pi} \times \frac{100\%}{1} = \frac{1706.85}{2000} \times 100\% = 85.34\%$$

CONCLUSION

It will guide the manufacturers to modify the components of the existing machine which entails promotion of technology transfer and adoption for the production of palm nut-shell separator from small to medium scale level, anticipating that the patronage by peasant farmers and other users of the new machine so modified will reduce drastically the labour, fatigue and cost involved in the production of palm kernel oil in a more hygienic way and under very conducive environmentally friendly conditions.

RECOMMENDATIONS

Agricultural sector in the West African sub-region and other parts of the world where palm trees are cultivated should make use of this modified machine in other to boost the production of agricultural product which aimed at adding values to very important agricultural product such as palm kernel nut, also national economy will be boosted since adoption of such machines will help in high productivity of quality palm kernel nut as one of the agricultural products which has been the bed rock of national economy through earning of more foreign exchange.

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