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Design, Fabrication and Testing of a Cocoa Depodding Machine

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***Abstract-* The project involves the design of a cocoa depodding machine, to eliminate drudgery experienced by local farmers using manual method of pod breaking. The basic features of the machine are the frame, feeding trough, shaft, stationary blade, rotating blade, rotating drum, chain, and electric motor. The machine operates on the principle of compressing the pods against the stationary blade to break it and separate the pods from the beans. As the blade rotates, it pushes the pods towards the stationary blade, which cuts the pods and transfers it to the separation chamber. As the drum rotates the beans are separated from the pods through the rotating sieve while the pod goes out through the discharge outlet. The machine is powered by 1hp three phase electric motor. The machine has an efficiency of 36%, a capacity of 500kg/hr. The depodding machine can be used by local farmers in rural areas for small scale cocoa processing.**

***Keywords*- Design, fabrication, thresher, cowpea, performance evaluation.**

I. INTRODUCTION

Background of the Study: Cocoa merit much economic significance in the producing countries the world over. Cocoa beans contain about 50% fat. It is useful in the production of lightning oil, ointments, candles, soaps and medicines (Opeke, 2004). Cocoa butter, made from the fat extracted from the beans, is a stable fat used in the production and pharmaceutical products. The beans are ground into powder for making beverages, chocolates, ice cream, soft drinks, cakes biscuits, flavoring agents and other confectionaries. Cocoa husks can be hydrolysed to produce fermentable sugar. Cocoa cake is used as part of feed ingredients for poultry, pig, sheep, goat, cattle and fish after removing the theobramine. The shell (pod) is a good source of potassium and can be used in the production of potash fertilizer, local soap, for biogas and particles boards (Opeke 2004). Considering all these benefits, cocoa production and processing must be mechanized and properly improved to aid profits of this concept of designing such a cocoa pod splitting machine, which has not been in existence in any part of the world.

One of the advantages of the primary processing of cocoa beans is that it is relatively inexpensive, and this gives good opportunities for small farm holders in Nigeria to use cocoa beans as a cash crop (Are & Gwynne-Jones, 1974). Added to this, small farm holders in Nigeria are aware of what characterizes good quality beans, and they know strategies for obtaining the good quality. Hence, the cocoa farmers in Nigeria produce very high quality cocoa beans which have given them premium prices on the world market. Traditionally, the process of breaking cocoa pods is done manually using wood and cutlass. This is an arduous task, apart from the large labour requirement and time consumed during the operation. Cocoa depodding machine will address the problems and drawbacks associated with the manual pod breaking such as; the number of labourers needed to break the pods is reduced, and the efficiency and reliability in production is increased. Human fatigues is also reduced, the manual method leads to high percentage of bean damage. Cocoa depodding machine is capable of breaking open cocoa pods and then separating the cocoa beans from the split-open cocoa pods without causing any damage to the cocoa beans. Safety issue is also a concern as the current manual pod breaking is entirely done by using knife. The application of cocoa depodding where the operator only needs to place the cocoa into the machine will definitely avoid accidents.

The Fabrication of a cocoa depodding will enhance, increase and boost productivity and enhance the quality of cocoa products to the highest possible level. The manual method of breaking cocoa which is one of the oldest methods makes the task greatly difficult as it requires large labour force. The cutlass used damages the beans, which makes some of the beans unsuitable for fermentation causing losses (Bamgboye, 2003). Also, the man-hours required for this manual operation vary and depend on crop factors such as variety and workers attitude and supervision (Opeke, 2004).

Hence the development of this concept of designing a cocoa depodding machine, which will massively improve cocoa production is designed. With this concept actualized it will greatly be beneficial to cocoa farmers.

II. MATERIALS AND METHODS

1. Design Considerations:

- The following factors were considered in the design of the cocoa depodding machine:
- Availability of local materials, selection of materials based on minimal cost, durability and aesthetics of the machine
- Geometric shape of the machine as well as the strength of the materials that would withstand vibration under different operating conditions
- The shape and size of the feeding trough that will allow for free flow of reasonable materials.
- The power requirement of the machine for effective depodding.
- The speed of operation of the machine
- The cost of materials

2. Component Parts of the Cocoa Depodding Machine:

The major components of the depodding machine are as follows:

2.1 Chain: The chain transmission provides a convenient means for transferring power from one shaft to another. The power is transmitted through friction between the chain and the sprocket.

2.2 Collecting Trough: This is where the cocoa beans from the depodding chamber are being collected.

2.3 Feeding trough: This is where the cocoa pods to be depodded are being fed.

2.4 Frame: The frame is a piece of angle iron welded together to carry the entire machine, it will be designed to carry the entire weight of the machine.

2.5 Residue Outlet: This was made of galvanized iron sheet of gauge. It is welded to the main frame and residue from the cocoa passed through it into the collection trough.

2.6 The Outlet: The outlet is rectangular in shape with dimension. This is where the depodded cocoa is collected.

2.7 Roller Bearings: The bearing was used in the fabrication of this work in other to remove friction between moving parts of machine.

2.8 Cleaning and separation unit: This is where the depodded cocoa beans is separated from the pods through the vibratory action of the attached sieve via a cam shaft.

3. Design Calculations of Component Parts:

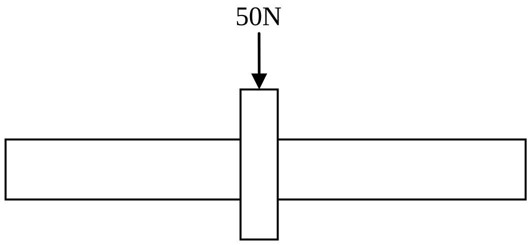
3.1 Bending Moment And Torsion Moment On Shaft

3.1.1 Torsion Moment

The torsion moment, mt acting on the shaft can be determine using,

$$m_t = \frac{kw \times 1000 \times 60}{2\pi N} \text{(Hannah, 1984)}$$

Where, kW = power in kilowatt
N = speed of shaft in rpm.
The electric motor to be used is 1 hp



L = 0.7m, w = 50N, d = ?

Allowable stress without keyway = 55MN/m2

$$z = \frac{\pi d}{32} = 0.098d^3$$

Max. moment at the center of the shaft

$$m = \frac{w.L}{4}$$

Where; W= force acting on the shaft,
L = length of the shaft

$$\frac{50 \text{ x } 0.7 \text{ x } 1000}{4}$$

$$\frac{35000}{4}$$

8750N/mm

Bending stress does not exceed 40mpa

$$\sigma_b = \frac{m}{z}$$

$$40 = \frac{8750}{z} = \frac{8750}{0.098d^3}$$

$$40 = \frac{8750}{0.098d^3}$$

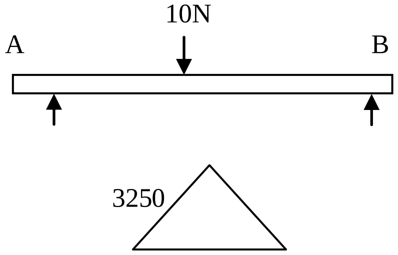
$$2.45d^3 = 8750$$

$$d^3 = \frac{8750}{2.45}$$

$$d = \sqrt[3]{2232.143}$$

d = 47.25mm

3.1.2 Second shaft design:



Vertical moment = 3250Nmm

$$M_b = \sqrt{3250^2 + 227500^2}$$

$$M_b = 227523.2\text{Nmm}$$

$$M_t = \frac{0.745 \text{ x } 9550}{x}$$

$$V.R = \frac{\text{no of teeth of the driven sprocket}}{\text{no of teeth ofthe drivings procket}}$$

$$V.R = \frac{55}{15} = 11:3$$

$$\text{output Torque} = 700\text{Nmm x } 37 = 2590\text{Nmm}$$

$$\text{output (RPM)} = \frac{1400}{37} = 378.4\text{RPM}$$

$$M_t = \frac{0.745 \text{ x } 9550}{378.4} = \frac{7114.75}{378.4}$$

$$M_t = 18.802\text{N/m}$$
$$M_b = 227.52\text{Nm}$$

The diameter of the shaft by A.S.M.E

$$d_s^3 = \frac{16}{\prod S_s}\sqrt{(K_b M_b)^2 + (K_t M_t)^2}$$

Based on the feeding rate, it is loaded suddenly (minor shock)

$K_t = 1.0 \quad k_b = 1.5$

$$d_s^3 = \frac{16}{\prod S_s}\sqrt{(1.5 \text{ x } 275.50)^2 + (1.0 \text{ x } 18.802)^2}$$

$$d^3 = 1.273\text{x}10^7\sqrt{171153.88}$$

d = 37.55mm

3.2 Bearing Selection:

These were based on ASAE (1972) standard. Factors considered are;

- Speed of shaft
- Size of shaft

A pillow bearing of 30mm diameter was selected for for the reciprocating shaft and a 40mm diameter pillow bearing selected for the separator shaft.

3.3 Power of chain:

Hp = 0.004N11.08 N10.9P3.0- 0.007p

At low speed

Hp = 0.004 x 1501.08 x 14000.9 x 0.63.0 – 0.007x 0.6
= 0.004 x 18.629 x678.45 x 0.21644
= 10.94W

At high speed

$$Hp = \frac{1000KN_1^{1.5}p^{0.8}}{N_1^{1.5}}$$

$$\frac{1000 \text{ x } 2.9 \text{ x } 15^{1.5} \text{ x } 0.6^{0.8}}{1400^{1.5}}$$

$$Hp = \frac{2900 \text{ x } 58.095 \text{ x } 6..65}{52383.20}$$

$$\frac{1120362.075}{52383.20}$$

Hp = 21.39 W

3.4 Working Principle of the Machine:

Once the machine is connected to the power source, power is transferred to the electric motor which provides power to the machine via the shaft. As the shaft rotates, it provides a turning effect for the hammer connected to beat the metal hitched to the feeding trough, this causes the feeding trough to tilt a little to allow a free flow of the cocoa to be fed into it. Once this is achieved, the cocoa is manually fed into the machine via the feeding trough.

The rotating spike connected to the shaft pushes the cocoa pods further towards the stationary blade which provides a compressive force to split the pods open. With the pods open, it is moved to the discharge outlet. Due to the vibrating action of the machine, the splitted pods are transferred to the cleaning and separating unit which comprises of a rotating drum with sieve.

The sieve are fabricated in such a way that only the beans can pass through it. As the rotating drum rotates at low speed, the beans passes through the sieve and it is separated from the pods while the pods are discharged through another outlet and gathered.

3.5 Methodology for Evaluation:

Freshly harvested cocoa pods were obtained from uchi market Auchi Edo state Nigeria.This pods were sorted and the bad and over ripe pods were separated from the rest. After sorting, the pods were weighed with a weighing balance and it's mid diameter were determined using a vernier caliper.The pods were grouped according to their mid diameter.

This experiment was carried out in the departmental workshop of Agricultural and bio environmental engineering Auchi. After which this pods were fed into the machine and the time of depodding was recorded. The depodded beans were weighed and its weight recorded. This parameters would help determine the machine efficiency and other various parameters.

3.6 Throughput Capacity

Throughput determines the input capacity of the depodding machine and it is expressed as:

$$\mathbf{T_p = \frac{W_1}{T}}$$

Where W_1 = Initial weight of the cocoa pod (kg),
T = Time of depodding (min)

$$t = \frac{72}{3600} = 0.02\text{hr}$$
$$t_p = \frac{10}{0.02} = 500\text{kg/hr}$$

3.7 Output Capacity:

Output Capacity (kg/hr) Qc: This determines the quantity of cocoa pod, depodded per unit time and is expressed as:

$$\mathbf{Q_c = \frac{W_2}{T}}$$

Where Q_c = Output Capacity (kg/hr)
W_2 = Weight of cocoa seed (kg)
T = Time of depodding (min)

$$q_c = \frac{3.6}{0.02} = 180\text{kg/hr}$$

3.8 Depodding Efficiency:

Depodding efficiency (%): This determines how efficiently the machine is, it is expressed as:

$$\mathbf{D_e = \left(\frac{W_2}{W_1}\right) \times 100\%}$$

Where D_e (%) = Depodding efficiency
W_2 = Weight of cocoa seed (kg)
W_1 = Initial weight of cocoa pod (kg)

$$D_e = \frac{3600}{10000} \text{ x } 100$$
$$D_e = 36\%$$

3.9 Cocoa Bean Damage:

$$\mathbf{B_d = \left(1 - \frac{M_{wb}}{M_t}\right) \times 100}$$

M_{wb} is the mass of whole bean, g;
M_t is the total mass of the pod and beans

$$B_d = \left(1 - \frac{3600}{10000}\right) \text{x } 100$$
$$B_d = (0.64)\text{x } 100$$
$$B_d = 64\%$$

3.10 Pictorial View of Mechanical Cocoa Depodding Machine:

The pictorial view, isometric and orthographic view of the mechanical cocoa depodding machine are presented in figures 3.1 -3.2.

Fig 1. Cocoa depodding machine (Plate1).

Fig 2. Front View of Cocoa Depodding Machine (Plate 2).

III. RESULTS AND DISCUSSION

1. Result

Testing was carried out on the machine as stated in the previous chapter and the following data were obtained. This would help us determine various parameters such as the depodding efficiency, the percentage of cocoa bean damaged etc.

Table 1. Results of testing carried out.

Mid diameter (mm)	Weight of cocoa (kg)	Time (sec)	Mass of bean (g)	Mass of losses (kg)
70-75	1.9	22	800	1
76-81	4	24	1300	1.3
82-87	4.1	28	1500	1.2
Total	10	72	3600	3.5

2. Discussion:
From the analysis carried out, it was discovered that the losses and percentage of cocoa bean damaged was more than the depodded bean. 64% 0f pods and beans were either damaged or not broken by the machine. It shows that adequate effort can be put in place to enhance the machine efficiency and minimize losses.

The table of analysis also shows that cocoa pods with 70-75mm diameter were the least depodded and the time of depodding is high when compared to others, as such the feeding trough can be designed in a way that would minimize losses of cocoa pods within this diameter.Generally, the time and rate of depodding is faster when compared to the manual method which is not just time consuming but also puts the farmer in greater of causing harm to himself and the cocoa beans if not careful.

IV. CONCLUSION

Based on the test carried out on the machine, it shows that the machine has a throughput capacity of 500 kg/hr. The machine is capable of depodding 500 pods/hr which justifies the design of the machine when compared to the traditional method of breaking pods, which has a capacity of 200-250 pods/hr. Though the rate of damage is high, the machine could be improved upon to minimize the losses and maximize efficiency.

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