Design and Fabrication of Motorized Maize Shelling Machine

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ABSTRACT

Majority of farmers who grow corn cannot afford the high cost of purchasing most of the available imported Shelling machine. Such farmers switch to manual hand shelling method which gives low efficiency, high level of wastage and high labour. This machine was fabricated from locally available material and to shell maize and separate the cob from the grain, at same time, blow the particle. Its cost is very low compared to the imported threshers. The machine was tested to establish the influence of moisture content levels, and the efficiency so as to reduce breakage and wastage during shelling operation. The machine has a power rating of 2.237KW and shelling capacity of 0.8 ton/hr with the shelling drum screw rotates at 60 revolutions per minute. This fabricated machine is capable of shelling maize efficiently and economically.

Keywords: Blower, breakage, capacity, drum, economical, hopper, shelling

1. INTRODUCTION

Grains are fruits of cultivated grasses belonging to the monocotyledonous family called Gramineae [2]. The most commonly found cereal grains in the world are wheat, barely, sorghum, rice and maize. Maize has become a principal commodity produced in West Africa. Maize contains about 10% proteins, 4% oil, 70% carbohydrates, 2.3% crude fibre, 10.4% albuminoides and 1.4% ash. Maize has significant quantities of vitamin A, nicotinic acid, riboflavin and vitamin E [1].

In Nigeria maize is widely grown both in the Northern and southern parts of the country. This is due to the fact that the climate in the south allows for it to be planted twice in the year. After the harvesting, 40% of harvested maize is lost every year due to the limitations posed for the farmers by the gross inadequacy of the right equipment for processing after harvest in Nigeria. [4] In some cases most at times, the required agricultural machines are out of reach of the peasant farmers [5].

Traditionally most of the shelling work was done by hand and hand operated maize shelling machine [8]. These two methods were cumbersome for large scale farming because it causes fatigue. There are machines which can shell maize, but these are too expensive for rural farmers. The need of less expensive, eco-friendly solution for shelling maize becomes necessary [4].

After studying existing practices of maize shelling and finding the need of maize Sheller with better performance and customized features, the problem statement has been formed. Traditional shelling is time consuming and there is a problem of labourers and their wages [6]. Hand shelling machine apart from its low cost, its major problem is limitation to output which makes it more less important for a farmer practicing large scale farming as the number of maize to be shelled are numerous [11]. More so, the maize shelling hand device is very slow compare to the motorized shelling machine because, it can only take a maize per operation [7].

2. LITERATURE SURVEY

Maize (Zeamas) belongs to the grass family. It is grown everywhere in the world and requires plenty of rainfall and sun for optimum yield. It can be grown throughout the year where farming is mechanized with efficient irrigation system [9].

Maize (Zea mays) is an important cereals crop which belongs to a grass family (Gramineae) producing small edible seeds which was said to have originated from Mexico over years [20]. It is the world's best adapted crop, growing between latitudes 580N and 400S of the equator. It is a versatile grain crop and commonly known as corn

in America. The natural endowment of high rainfall, high light intensities, and favourable temperature in the cultivation of maize make it to be one of the world's most versatile seed crops [21]. Maize production in Nigeria is of great

Maize shelling is a post-harvest operation which involves the removal of maize from the cob. Maize shelling therefore is an important step toward the processing of maize to various finished products like flour [18-19].

Maize (Zee mays) also known as corn is one of the most important staple crops in the world. In Kenya, for example, 45% of the population considers Ugali (maize meal) to be their survival food making it most consumed food of the country. [12] Maize also account for 43% of the Latin American diet. In Asia, maize production is over 200 billion kilograms a year and it is expected that the total maize production in developing countries will eventually overtake production in industrialization countries. [8]

[13-14] Damage free shelling was attempted using a high speed cutter for milling the cob out of the ear. The corn ears were fed axially against the cutter by a feeding mechanism

According to [15, 22], the performance of a thresher depends upon its size, cylinder speed, cylinder concave clearance, fan speed and the sieve shaker speed.

3. DESIGN AND CONSTRUCTION ANALYSIS

3.1 Load Analysis

The shelling machine has a rotating shaft which will transfer torque or tangential force and in its application for shelling, bending loads are often superimposed on the torsion loads [3].

The shaft for the shelling element is a ductile material. It will support blades and driven pulley. The limiting condition will thus be yielding under static load. If the bending moment, torsion moment and axial force are designated with M , T , and F respectively, the diameter of the shaft necessary to prevent shaft failure can be determined. The maximum shear stress theory 'Tresca' is used. The AISI table is used in selecting the alloy ductile material for the application [10].

3.2 Design and Stress Concentration Factor

Some factors are important in design problems and are thus treated as factors which reduce the strength of the member or compensate uncertainties in load and strength [16]. The design factor n_s is such factor whose value depends on the type of material and the mode of loading. The value of n_s is selected from the standard table. It is sometimes convenient to define two factors of safety. n_s which is one of them is in this case used to account for uncertainties in the strength while the other n_L accounts for the uncertainties with regards to load. Thus the total factor of safety could be obtained as;

$$F_s = n_s + n_L \quad (1)$$

Where F_s is applied to strength, we have

$$F_s = \frac{S_y}{S_p} \quad (2)$$

S_y is the yield strength and S_p is the permissible (design) stress. By rearranging the equation above, the design stress is determined by

$$S_p = \frac{S_y}{F_s} \quad (3)$$

Where S_p is applied to the limiting load F_u (maximum load), we have

$$S_p = \frac{F_u}{F_p} \quad (4)$$

F_p is the permissible load.

Stress concentration effects The stress concentration effects are consequence of holes' grooves, notches or other kinds of discontinuities which alter the stress distribution. It is usually stress that the stress concentration in static loading is very high in brittle materials and less serious in ductile material owing to the relief of stress concentration by plastic flow in the latter. However, it is not generally true that ductility is full insurance against stress concentration. Reduction of concentration is necessary wherever possible without regards to the type of material of which the member is made from.

The value of bending moment K_b and Torsion moment factor K_t are gotten from the American Society of Mechanical Engineers (ASME) table.

3.3 Machine Components Design

The Main Frame: The main frame supports the entire weight of the machine. The total weights carried by the main frame are: - weight of the hopper and housing; - weight of the shelling chamber; - the collector and pot; and - the bearings and pulleys. The two design factors considered in determining the material required for the frame are weight and strength. In this work, angle steel bar of 35 by 35mm and 2mm thickness is used to give the required rigidity.

Fig. 1: Support Frame.

Fig. 2: Hopper

The Hopper: The design of the hopper was made only to be filled in a vertical position only. Its shape is like a frustum of a pyramid truncated at the top. The top and the bottom both have a rectangular shape. The material used for the construction is mild steel sheet metal, which is readily available in the market and relatively affordable.

Shelling Pegs and Housing: The pegs are arranged to form a spiral shape (inform of screw conveyor) and are spaced at regular interval so as to ensure the removal of all maize from the smallest cobs.

For this design and purpose, the pegs are vertical and are called blades for design analysis. The more the number of blades, the more is the loss within the blades due to vertex action. Thus, the most appreciable number in design is three, as used in this design having an angle of 120° to each other and inclination of 45° to the centre line.

The housing on the other hand is another important part of the shelling unit. The pegs with high speed hit the maize carrying cobs against the housing causing shelling. The housing is best made of metal sheet or mild steel plate of about 3mm. the bottom part of the housing is flat and contains perforations. The clearance over the bottom part is 15mm for the pegs

Fig. 3: Upper and Lower Housing

Fig. 4: Blower

Blower: A mechanical blower is used to blow the shaft away from the cobs. It uses high speed blades to impart velocity to air hence, increasing the speed and the volume. The shaft is attached with a pulley connected to the motor with a belt.

Bearing Selection: Bearing must be selected based on its load carrying capacity, life expectancy and reliability [17]. For selection and determination of bearing for any installation, the following are considered; Radial Load, Thrust Load, Speed and Diameter of the shaft and Desired life bearing.

The equivalent Radial Load defined for rating purpose is expressed as

$$S_e = aS_r + bS_t \quad (5)$$

Where S_e is the equivalent radial load, S_r is the radial load, S_t is the thrust load, a is the radial factor, and b is the thrust factor.

The life of bearing, L , expressed in millions of revolutions is as given in equation (6)

$$L = (C/P)^n \quad (6)$$

Where L = life of bearing, C = Load Capacity, P = equivalent Load., $n = 3$ for ball bearings and $10/3$ for roller bearing.

The SKF guide was used to value the nominal life, L_n , and life design of maize Sheller falls between 4000 to 8000 hours. For this design, the maximum value is taken.

Hours of Service $L = 8000$ hrs.

Speed of shaft $N_s = 400$ rpm

Hence, the number of revolutions $= 192 \times 10^6$ revs.

The capacity of the ball bearings can be obtained as expressed in equation (7).

$$C = n\sqrt{L} \cdot P \quad (7)$$

Such that at point A, $C = 349.786$ kN and at point B, $C = 444.32$ kN

According to SKF catalogue the ball bearing that would support this load is Deep Grove ball bearing. Alternatively, Journal bearing could be used if deep Grove ball bearing is not available.

3.4 Power Transmission Components

Belt Selection: Belt drive was employed for the transfer of power from the motor to the shaft because of its low cost and flexibility. Belts are frequently necessary to reduce the higher rotational speeds of electric motors to lower values required by mechanical equipment [16].

Fig. 5: Tight and slack side Belt tension with pulley

Fig. 6: V belt pulley angles

$$T_m = T_o = \frac{1}{2} (T_1 + T_2) \quad (8)$$

$$T_1 = e^{u a^i}$$

$$U = \frac{\mu}{\sin r} \quad (\mu \text{ for V groove belt is } 0.14)$$

Assume r is 18° , total groove angle = 36°

T_m = mean effective tension, T_1 = effective tension on tight side of the belt, T_2 = effective tension on slack side of the belt, μ = coefficient of friction, a^i = angle of lap (radian) of the belt.

Pulley Design: For a V- grooved pulley, the normal force between the belt and the pulley is increased since the radial component of the force must equal R , if the semi angle of the groove is β .

$$N = R / 2 \operatorname{cosec} \beta \quad (9)$$

$$\text{Functional resistance } R = 2\mu R / 2 \operatorname{cosec} \beta$$

Fig. 7: V section of the Pulley

Fig. 8: Belts and Pulleys

If X is the distance of the neutral axis from the edge 0 – 0 of the belt cross section

$$\text{Area } ade = \frac{1}{2} \times bh \text{ and area } bcf = \frac{1}{2} \times bh$$

$$\text{Area } abcd = L \times B \text{ and area } abfe = \frac{1}{2} (a + b)h$$

Taking moment

$$\text{Area } abfe \times X = \text{area } abcd \times X$$

Machine pulley speed

$$= \text{motor pulley speed} \times \frac{\text{pitch dia. of motor pulley}}{\text{pitch dia. of M/C pulley}} \quad (10)$$

Shaft Design: In shaft design, the load to be carried by the shaft and the reactions at the supports are first established. The loads are:

$$\text{Weight of driven pulley} = 1 \text{ kg}$$

$$= (1 \times 9.81) \text{ N} = 9.81 \text{ N.}$$

Weight of flat shelling pegs using iron bar,

For each peg, $L=55\text{mm}$, $T=6\text{mm}$ $B=15\text{mm}$

Therefore, for shaft having 800mm length, the number of pegs required is

$$\frac{800}{55} = 14.55.$$

15 pegs were chosen per roll because of clearance on the shaft. These 15 pegs are expected to complete one length roll of the shaft when staggered. Therefore, to complete the 3 rows expected of the design, the number of pegs required is:

$$15 \times 3 = 45 \text{ pegs}$$

But the length of each peg = 55mm. The total length of bar is $55 \times 45 = 2475\text{mm} = 2.48\text{m}$.

Volume of Iron bar required is given as:

$$V = \text{Area} \times \text{Length}$$

$$V = 0.055 \times .015 \times 2.48 = 2.046 \times 10^{-3} \text{m}^3$$

Mass is given as the product of volume and density.

$$\text{Mass} = (7680 \times 2.046 \times 10^{-3}) = 15.7133 \text{ kg.}$$

This mass form a uniformly distributed load of 154.15 N

$$\frac{154.15}{0.8} = 192.68 \text{ N/m}$$

Calculating for the reaction we have, 9.81N

Figure 9

Taking moment around C

$$0.9R_A + 9.81 \times 0.1 = 192.68 \times 0.4 \quad (11)$$

$$0.9R_A = 76.089$$

$$R_A = \frac{76.089}{0.9} = 84.54 \text{ N}$$

Therefore, R_c is calculated as

$$\begin{aligned} \text{Total load} - R_A &= (9.81 \times 192.68) - 84.54 \\ &= 1805.65 \text{ N} \end{aligned}$$

As follows:

The bending moment at B

$$M_B = 0.1 R_A = 0.1 \times 84.54 = 8.454 \text{ Nm} \quad (12)$$

The bending moment at C

$$M_C = - (9.81 \times 0.1) = -0.981 \text{ Nm} \quad (13)$$

Referring to the shear force diagram at B, the shear force rises to 8.454 NM, then falls at mid-point. Hence the point P, at which it is Zero, is distant

$$= \frac{8.454}{1708.4} = 0.3549 \text{ from}$$

At P considering forces to the left

$$M_P = 168.22 \text{ N} \quad (14)$$

Point A and C are the bearing supports length B and C carry the shelling pegs point D has driven pulley.

The maximum bending moment = 168.22 Nm

R_A due to bearing support at A = 606.32N

R_C due to bearing support at C = 770.19N

P_2 due to the weight of the pulley at D = 9.81N

Total uniformly distributed load = 1366.7N

The yield strength (σ_y) of the shaft of 40mm diameter can be obtained from the AISI series

Fig. 10: Vertical load, Shear Force and bending moment diagram

The maximum bending moment is determined for this design. The shaft is neglected.

Recalling Tresca Theory of Failure

$$T_d = \frac{16}{d^3} (M^2 + T^2)^{\frac{1}{2}} \quad (15)$$

And introducing the fatigue factors

$$T_d = \frac{16}{d^3} (KbM^2 + KtT^2)^{\frac{1}{2}} \quad (16)$$

Where

D = diameter of the shaft

M = Maximum bending moment

T = Torque transmitted by the belt drive

T_d = Design shear stress

The power delivered to the shaft could be obtained as expressed in equation (17)

$$\text{Power} = (T_1 - T_2) V \times \text{no of belt} \quad (17)$$

$$V = \omega r \quad (18)$$

Where ω = angular velocity, r = radius of the machine

Horse power rating of the Electric motor

$$3 \text{ h.p} = (3 \times 746) \text{ watts} = 2.238 \text{ Kw}$$

Speed of the driven pulley is expected to 400 rpm. $N_s = 400 \text{ rpm}$

Power = Torque x Angular velocity in rad/s

$$P = T\omega \quad (19)$$

$$T = 53.42 \text{ N.m} \quad (20)$$

The maximum shear theory of static failure state

$$T_m = \frac{\sigma_y}{2} \quad (21)$$

$$\text{But } \sigma_y = 207 \times 10^6 \text{ N/m}^2$$

$$T_m = \frac{207 \times 10^6}{2} = 103.5 \times 10^6 \text{ N/m}^2 \quad (22)$$

$$\text{Also, } n_s \times n_l = 1.5 \times 4 = 6$$

$$T_d = \frac{T_m}{6} = \frac{16}{d^3} (KbM^2 + K_E t T^2)^{\frac{1}{2}} \quad (23)$$

The value of the diameter d as obtained is 39.8 mm. A shaft of diameter 40 mm is thus selected

For the most efficient shelling, the pegs are employed and pegs assists the progression of the cobs along the cylinder and ensure the removal of all maize from the smallest cobs. They are spaced at regular intervals. The pegs are arranged to form spiral shape or inform of screw conveyor to take the cobs into right hand side.

Fig. 11: Shelling drum

Fig. 12: Motorized Maize Sheller

4. PERFORMANCE TEST

The shelling machine was subjected to test and it was discovered to thresh maize very effectively having negligible Losses and breakages. The estimated capacity of the machine is about 0.6 – 0.8 ton per hour. The efficiency of the machine was calculated from the equation below to be equal to 99.2%:

$$Efficiency = \{(W_1 - W_2)/W_1\} \times 100 \quad (24)$$

Where W_1 is the weight of unthreshed cobs and W_2 = weight of cobs not well threshed

5. CONCLUSION

From the result above, the machine was successfully designed with the throughput capacity (600 – 800 kg/hr.) which is far better than the actual human throughput capacity determined to be 21kg/hr. It could be concluded that this project is of the best interest of the agricultural productivity and well reducing the force exerted on the shelling of maize by relieving the stress on the labour.

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