DESIGN AND FABRICATION OF A MAIZE SHELLING MACHINE

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ABSTRACT
Maize (Zea mays) is one of the major cereal crops that had contributed greatly into the development of the world agricultural economy. Farmers in developing countries used the traditional methods, due to inaccessibility of suitable machinery for maize shelling. The time required to shell maize from traditional method is more which in turn results in increased cost of production. This research work focuses on solving the problem faced by the farmers in separating the maize cobs from its kernel. The maize shelling unit operates on the principle of impact force. The cylinder is made up of 2 mm thick mild steel of size 200 mm diameter and length 660 mm. Several beaters were coupled to the cylinder which rotates along the cylinder and helped in the separation of grains from the cobs. It was observed that the maize sheller shelled maize at an average shelling efficiency and cob outlet loss of 89.3% and 10.7% respectively at 13% wb moisture content and minimal grain damage of 2.45% with an average shelling capacity of 108.57 kg/h at a rotational speed of 600 rpm. The output capacity of the shelling machine is 108.57 kg/h while the output capacity of hand shelling gives 6.40 kg/h. This shows that the machine shells 17 times as fast as shelling manually with hands. The blower shaft rotates at a speed of 1400 rpm to allow for maximum cleaning efficiency of the shelled maize.

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1.0 INTRODUCTION

Shelling, also known as threshing is the process of breaking the attaching bond between a seed and separating it from the other plant parts. The machine parameters that affect the efficiency of maize shelling machine are the rational speed of shaft and types of threshing cylinder (Al Sharifi, 2019; Chilur et al., 2014). Al Sharifi (2019) carried out a study to determine the influence of machine type, rotational speed and moisture grain on the grain damage percentage. The research outcome showed that the rotational speed has direct relation with the grain damage percentage, and the results recorded were 1.668, 2.216 and 2.445% respectively for different levels of rotational speed. This is as a result of low impact of the spikes on the grains when the rotational speed of the shaft decreased hence decreasing the grain damage percentage. These findings are agreement with the results that were recorded by Chilur et al. (2014) at varying moisture content levels where the lowest grain damage percentage of 1.712% was obtained at the moisture content of 16% and the highest grain damage percentage (2.606%) was obtained at the moisture content of
20%. When grain moisture increased, it leads to adhesion of the grains to the cobs resulted in grain damage with beating inside the machine. This also is in line with the results of Naveenkumar and Rajshekarappa (2012). Abu Al Khair et al. in 2005 confirmed that the interaction among the machine parameters; moisture content of 16% and the rotational speed 200 rpm caused the best result (1.091%).

Shelling is the process of removing seed or grain from their respective cobs for both human and industrial use (Mali et al., 2015). This separation which could be done by hand or machine, is obtained by threshing, by friction or by shaking the products. The difficulty encountered during the process depends largely on the varieties seed grown, the moisture content and the degree of maturity of the grain. The shelling operation can be carried out in the field as well as at the storage environment (Mali et al., 2015). The existing methods of maize shelling can be categorized based on the various mechanization technology used. These includes: hand-tool-technology, animal technology, and engine power technology (Amirmudin and Victor, 2012). In the ancient days and in rural communities, shelling was dominated by; beating with stick, crushing with mortar and pestle, hand shelling and therefore consume much human energy and time (Adewole et al., 2015; Abdulkadir et al., 2009). The only existing maize shellers at those periods and places are normally large and heavy, require high power input to operate and produce low product quality in terms of percentage seed breakage and purity (Patil et al., 2014).

Manual shellers come in several models, some of these models are equipped to take a motor and are generally driven by a handle or a pedal (CIGR, 1999; Igbinoba et al., 2020). The use of manual shellers generally requires a single worker (Figure 1). The major disadvantages peculiar with these shellers are that their threshing capacities are low. Also their operational mode is too cumbersome from the fact that the crank handle is directly connected to the shelling chamber and therefore the effect of friction is too pronounced during the operation (Bako and Bature, 2017).

![Figure 1: Manually Operated Maize sheller (Bako and Bature, 2017)](image)

2.0 MATERIALS AND METHODS

2.1 Materials

Adequate care was taken in the selection of the materials for maize shelling machine. The best materials for each of the shelling components with minimum cost were considered. Materials were selected locally to make the material sourcing easier bearings and other components that are vital to the design were careful selected.

2.2 Methodology

2.2.1 Design consideration

The following criterial and methods were considered in the designing of the shelling machine;

1. Use of locally available materials with cost affordability.
2. Weight of the equipment for portability.
3. Ease of operation and low maintenance cost.
4. Maximum Force required to crush Corn.
5. Considered shelling speed (velocity ratio).

2.2.2 Design analysis

The design analysis of various components of the shelling machine was carried out to ascertain the...
evaluation of the necessary design parameters; strength, size and material selection for the various machine parts in such that the failure by excessive yielding and fatigue during the required working life of the machine could be avoided.

2.2.2.1 Hopper

The feeding hopper was developed from a steel metal plate forming a hollow frustum of a trapezoidal prism with bottom base area of 180 mm × 120 mm and top area of 460 mm × 250 mm, the height was 460 mm while the slant height was 412 mm as shown in Figure 2. Angle of repose is the maximum slope at which a heap of any loose material will stand without sliding (Bako and Bature, 2017). The angle of repose of 27° was selected for maize (Aremu et al., 2015).

The hopper volume \( V_h \) was calculated as

\[
V_h = \left[ \frac{1}{2} (0.2 \times 0.36) + (0.26 \times 0.25) + 2(0.04 \times 0.1) + (0.18 \times 0.12) \right] 0.36
\]

follows

2.2.2.2 Frame

The frame provides support to all components of the maize shelling machine. Angle iron 40 mm x 40 mm x 5 mm was measured, cut to sizes and welded together to make a stand of length 1154 mm, width 310 mm and height 607 mm; brazed at different points for rigidity as shown in Figure 3.

![Figure 3: Frame Support and Engine Seat](image)

2.2.2.3 The shelling housing

These were made from mild steel sheet and was bent to semicircular shape of diameter 220 mm and was rigidly bolted to the frame support to give protection to the cylinder and to avoid grains from spilling out. The top concave has a provision for the attachment to the hopper. Holes of 10 mm diameter were drilled on the bottom concave for the passage of the shelled maize grains. Each hole has distance of 20 mm from each other. The rear side of the concave was cut for the fixing of cob outlet (Figures 4 and 5).

2.2.2.4 The shelling chamber

The shelling mechanism comprises of the pipe on which several spikes were arranged. The shelling compartment accommodates the shelling drum, pulley and shelling shaft. The calculated weight of the shelling device is the addition of the weight of the shelling drum and the total weight of all the spikes. According to (Akor et al., 2004), the number of spikes on the shelling cylinder was calculated using equation 1;
\[ N_s = \frac{\pi DL}{SrSc} \]

where; \( N_s \) is the number of spikes on shelling cylinder, \( L \) the length of cylinder, \( S_r \) is the spike spacing on row, \( S_c \) is the spike spacing on the cylinder and \( D \) is the diameter of shelling cylinder.

\[ N_s = \frac{\pi \times 92 \times 650}{50 \times 80} \]

\( N_s \) was calculated to be 46.97; therefore; the number of spikes on shelling cylinder is 47.

The weight of the shelling mechanism \( (W_{SM}) \) was calculated using equation 2;

\[ W_{SM} = W_d + W_s \]

where; \( W_s \) is the weight of drum, \( W_s \) is the weight of spikes

The weight of shelling drum, \((W_d)\) was determined using equations 3 and 4

\[ W_d = \rho V_d g \]

\[ V_d = \pi (R - r)^2 h \]

where; \( \rho \) is the density of steel, \( V_d \) is the volume of drum, \( g \) is the gravitational acceleration, \( R \) is the outer radius of the cylinder, \( d \) is inner radius

of cylinder and \( L \) is the total length of the drum.

The volume of the shelling drum was calculated

\[ W_s = N_s \rho V_s g \]

\[ V_s = \pi r^2 h \]

\( W_s \) to be

Where; \( V_s \) is the volume of each spike, \( N_s \) is the number of spikes, \( r \) is the radius of each spike and \( h \) is the length of each spike.

The volume of the shelling spike was calculated as:

\[ V_s = 3.93 \times 10^{-3} m^3 \]

\[ W_s = 14.23 N \]

The total weight of the shelling mechanism was calculated as:

\[ W_{SM} = 171.47 + 14.23 = 185.7 N \]

2.2.2.5 Power requirement

The power transmitted by shaft, angular speed and torque was determined using equations 7, 8 and 9;

\[ P = \frac{2\pi N}{60} \times T \]

\[ \omega = \frac{2\pi N}{60} \]

\[ P = T \times \omega \]
Where; $P$ is the power required, $\omega$, is the angular speed, $T$ is the torque developed and $N$ is the speed of shaft in revolution per minute. According to Ugwu and Omoruyi (2016), speed of 600 rpm is efficient to thresh the maize. Then, the angular speed of the drum can be calculated as:

$$\omega = \frac{2 \times \pi \times 600}{60}$$

$$\omega = 62.83 \text{ rad/sec}$$

Again, the torque is also given in equation 10 as;

$$T = W_{SM} \times r$$

where: $W_{SM} =$ Weight of threshing bars and $r$ is the radial distance between spikes

Therefore, a 1 hp electric motor is needed to drive the thresher shaft.

$$T = 185.7 \times 0.05 = 9.26 \text{ Nm}$$

$$P = 9.26 \times 62.83 = 583.38 \text{ W}$$

$$= 0.583 \text{ kW} \approx 1 \text{ hp}$$

2.2.2.6 Shaft design

The allowable shear stress ($S_s$), which is the resulting stress in which the external force acting on the component tends to slide the adjacent planes with respect to each other (Pavasiya et al., 2018) was determined using equation 11.

$$S_s = \frac{\text{Ultimate Shear Stress}}{\text{Factor of Safety}}$$

To calculate for the diameter of the shaft, the forces acting on the shaft as to be determined. The beater, shaft and the pulley are shown with respect to the force acting on the shaft as shown in Figure 5.

$$\sum M_c = 0$$

$$(375mm \times 185.70N) - (50mm \times 34.84N) - (R_D \times 750mm)$$

$$R_D = 90.53 \text{ N}$$

$\text{Upward forces } = \text{ Downward forces}$

$$34.84N + 185.7N = 90.53 + R_C$$

$$R_C = 130.01 \text{ N}$$

The maximum bending moment will occur at B which is calculated as

$$Bending \text{ Moment} = \frac{\text{Force} \times \text{Perpendicular distance}}{\text{Distance}}$$

$$M_s = 69637.52 \text{ Nmm}$$

The angular speed of the shaft is 600 rpm with a power of 0.583 kW and torsional moment of 9.26 Nm. The shaft diameter was calculated using equation 12;

$$d^3 = \frac{16}{\pi S_s} \sqrt{(K_b \times M_b)^2 + (K_t \times M_t)^2}$$

where; $d$ is the shaft diameter, $M_t$ is the torsional moment, $M_b$ is the bending moment, $K_b$ and $K_t$ are the combined shock and fatigue factor applied to bending and torsional moments respectively and $S_s$ is the allowable stress.

The diameter of the shaft was calculated to be 25 mm.

2.2.3 Description of the shelling machine

The maize shelling machine designed works on the principle of impact force; an application of beating the maize to the confining wall. Motion from the electric motor through the driving pulley
provides an angular velocity that is translated to the driven pulley that is fixed on the primary shaft which is supported by pillow bearing on both ends. The generated power on the driven pulley provides rotary motion of the beater which pulls and shells the maize cobs by friction and shearing action against the confining walls. The power generated from the primary shaft is transmitted to the secondary shaft, via belt and pulley arrangement. This secondary shaft transmits rotary motion to the fan blades. The fan blades blow away the cob, chaff and other impurities pass them out through the cob’s outlet while the clean grains pass through the screen to the grain outlet (Figure 1). The configuration of the spike teeth is in such a way that the maize cob are conveyed to the cob outlet as it is being shelled.

### 2.2.4 Fabrication and Assembly of Machine Components

The designed components of the maize sheller were fabricated independently (Figure 7). In this phase, the frame is the motherboard of all the machine components. The shelling mechanism (drum and spike) was fixed to the shaft supported by the pillow bearing which was mounted on the frame. The top concave and bottom concave were tightly bolted to the frame support to reduce noise and prevent vibration. The blower and its components (fan blade, blower shaft and casing) was also mounted to the frame support. The body parts (outlets) were permanently welded to the frame support. Similarly, the electric motor was mounted and bolted on the engine seat.

### 2.2.5 Evaluation of the shelling machine

The machine testing was carried out at the Agricultural and Environmental Engineering Departmental workshop of the Federal University of Technology Akure, using a 1 hp, 1400 rev/min electric motor as the source of power (Figure 8). The following parameters were determined from the data collected:

\[
\text{Shelling capacity} = \frac{\text{Mass of shelled grains (kg)}}{\text{Time taken (hr)}}
\]

\[
\text{Shelling efficiency} = \frac{\text{Mass of shelled grains}}{\text{Total mass of grain (shelled+unshelled)}} \times 100
\]

\[
\text{Grain damage} = \frac{\text{Mass of damaged grains}}{\text{Mass of shelled grain}} \times 100
\]

The evaluation was ascertained at three (3) trials.
3.0 RESULTS AND DISCUSSION

3.1 Results

Three trials were carried out in evaluating the shelling rate of the maize sheller. This was also adopted for the hand shelling method of which both results were compared and evaluated as shown in Tables 1 to 5.

Table 1: Shelling capacity with the use of maize sheller

<table>
<thead>
<tr>
<th>Trial</th>
<th>Mass of grain (kg)</th>
<th>Time taken (s)</th>
<th>Rate of shelling Expression (kg/h)</th>
<th>Rate of Shelling (kg/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.30</td>
<td>43</td>
<td>$1.30 \times 3600$</td>
<td>108.84</td>
</tr>
<tr>
<td>2</td>
<td>1.26</td>
<td>42</td>
<td>$1.26 \times 3600$</td>
<td>108.00</td>
</tr>
<tr>
<td>3</td>
<td>1.27</td>
<td>42</td>
<td>$1.27 \times 3600$</td>
<td>108.86</td>
</tr>
<tr>
<td>Mean Shelling Rate</td>
<td></td>
<td></td>
<td></td>
<td>108.57</td>
</tr>
</tbody>
</table>

Table 2: Shelling capacity with the use of hand

<table>
<thead>
<tr>
<th>Trial</th>
<th>Mass of grain (kg)</th>
<th>Time taken (s)</th>
<th>Rate of shelling Expression (kg/h)</th>
<th>Rate of Shelling (kg/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.874</td>
<td>485</td>
<td>$0.874 \times 3600$</td>
<td>6.49</td>
</tr>
<tr>
<td>2</td>
<td>0.742</td>
<td>420</td>
<td>$0.742 \times 3600$</td>
<td>6.36</td>
</tr>
<tr>
<td>3</td>
<td>1.280</td>
<td>726</td>
<td>$1.280 \times 3600$</td>
<td>6.35</td>
</tr>
<tr>
<td>Mean Shelling Rate</td>
<td></td>
<td></td>
<td></td>
<td>6.40</td>
</tr>
</tbody>
</table>
Table 3: Comparison of the two shelling methods

<table>
<thead>
<tr>
<th>Trials</th>
<th>Time (s)</th>
<th>Mass of grain (kg)</th>
<th>Output (kg/h)</th>
<th>Time (s)</th>
<th>Mass of grain (kg)</th>
<th>Output (kg/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>43</td>
<td>1.30</td>
<td>108.84</td>
<td>485</td>
<td>0.874</td>
<td>6.49</td>
</tr>
<tr>
<td>2</td>
<td>42</td>
<td>1.26</td>
<td>108.00</td>
<td>420</td>
<td>0.742</td>
<td>6.36</td>
</tr>
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<td>3</td>
<td>43</td>
<td>1.27</td>
<td>108.86</td>
<td>726</td>
<td>1.280</td>
<td>6.35</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>108.57</td>
<td></td>
<td>Mean</td>
<td></td>
<td>6.40</td>
</tr>
</tbody>
</table>

Table 4: Shelling efficiency

<table>
<thead>
<tr>
<th>Trials</th>
<th>Mass of shelled grain (kg)</th>
<th>Mass of unshelled grain (kg)</th>
<th>Total mass of fed grain (kg)</th>
<th>Shelling efficiency (%)</th>
<th>Shelling efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.30</td>
<td>0.17</td>
<td>1.47</td>
<td>$\frac{1.30}{1.47} \times 100$</td>
<td>88.44</td>
</tr>
<tr>
<td>2</td>
<td>1.26</td>
<td>0.14</td>
<td>1.40</td>
<td>$\frac{1.26}{1.40} \times 100$</td>
<td>90.00</td>
</tr>
<tr>
<td>3</td>
<td>1.27</td>
<td>0.15</td>
<td>1.42</td>
<td>$\frac{1.27}{1.42} \times 100$</td>
<td>89.44</td>
</tr>
<tr>
<td>Percentage mean efficiency</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>89.29</strong></td>
</tr>
</tbody>
</table>

Table 5: Grain damage with the use of maize sheller

<table>
<thead>
<tr>
<th>Trials</th>
<th>Mass of shelled grains(kg)</th>
<th>Mass of damage grains (kg)</th>
<th>Percentage of damaged grains %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.30</td>
<td>0.033</td>
<td>$\frac{0.033}{1.30} \times 100 = 2.54$</td>
</tr>
<tr>
<td>2</td>
<td>1.26</td>
<td>0.029</td>
<td>$\frac{0.029}{1.26} \times 100 = 2.30$</td>
</tr>
<tr>
<td>3</td>
<td>1.27</td>
<td>0.032</td>
<td>$\frac{0.032}{1.27} \times 100 = 2.52$</td>
</tr>
<tr>
<td>Percentage mean grain damage</td>
<td></td>
<td></td>
<td><strong>2.45</strong></td>
</tr>
</tbody>
</table>

3.2 Discussion

From the performance evaluation of the maize sheller, the shelling rates displayed in Tables 1 and 2 indicated that the shelling capacity using hand is 6.4 kg/h which is extremely low compared to a high shelling capacity of 108.57 kg/h of the maize sheller at 13% wb moisture contents of maize and at a shelling speed of 600 rpm. The mean shelling efficiency of the maize sheller was 89.3% while the cob outlet loss obtained was 10.7% as shown in Table 4. These results show that both the threshing and separation were achieved satisfactorily with the shelling machine designed. The machine also has a minimal grain damage of 2.45% as indicated in Table 5. Comparing the machine shelling capacity with
hand shelling method, it shells 17 times as fast as manual shelling as shown in Table 3. The blower shaft was regulated to rotate at a speed of 1400 rpm to allow for maximum cleaning efficiency of the shelled maize. The machine is also detachable so as to make assembling and dissembling easy, also to help detect faults and fix them quickly.

4.0 CONCLUSION

A simple, efficient, less tedious machine for shelling maize has been developed. Materials used in fabricating the machine are affordable and locally available. The machine can shell maize at an average shelling efficiency of 89.3 %, minimal grain damage of 2.45% with an average shelling capacity of 108.57 kg/h. The machine operates smoothly and efficiently when in operation. The shelled grains flow freely through the grain outlet, the chaffs are being blown off in opposite direction by the blower while the cobs are discharged easily through the cob outlet. It's less bulky and the user-friendly considerations in the design allowed for its comfortable use in a standing posture for it can easily be operated. The machine can help to significantly reduce the human labour and stress involved in shelling maize at an affordable cost and also reduces the time used for shelling operation. There is no doubt that the machine will ease the long-term problem of maize shelling especially for the farmers in rural areas where the supply of electricity is in abundance.

REFERENCE


