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Research Article

Design and Fabrication of Maize Sheller

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Abstract

Maize *(Zea mays L.)* is one of the most important cereal crops in the world agricultural economy. It is originated from Mexico several thousand years back, even before Columbus landed in South America. In Nigeria, Corn is one of the most important crops and it has a source of a large number of industrial products besides its use as human food and animal feed. The processing of agricultural product into quality forms not only prolongs the useful life of these products but also increases the net profit farmers make from such products. In this work, a simple commercial Maize Sheller was designed and fabricated to solve the problem of associated with shelling maize. Performance test carried out on Maize Sheller showed that the speed of 800 rpm was very effective in shelling compared with other speed of 600 rpm and 1000 rpm used for test. The shelling efficiency is 94.12% and a cleaning efficiency is 97.43%. The machine is simple to operate and maintain.

Keywords: Sheller; Threshing; Maize; Design; Processing.

Introduction

Maize *(Zea mays L.)*, the American Indian word for corn, means literally that which sustains life. It is, after wheat and rice, the most important cereal grain in the world, providing nutrients for humans and animals and serving as a basic raw material for the production of starch, oil and protein, alcoholic beverages, food sweeteners and, more recently, fuel [1]. In Africa, maize has become a staple food crop that is known to the poorest family. It is used in various forms to alleviate hunger, and such forms include pap or Ogi, maize flour, and etc. It is because of the importance place of maize that it's processing and preservation to an optimal condition must be analyzed.

Maize production in Nigeria is of great importance. With the increase in population and use of maize grain, the market demand for maize grain also increased. However, maize shelling in developing and under-developed countries has been and remains a serious problem to its processing as it is tedious and often require considerable labour hours [5]. As the ear of the maize reaches maturity, the individual grain swells and then harden to form a closely-packed cylindrical cob. The kernels on the cob are within the husks which endowed it for some degree of protection from damage caused by insects, fungi and the ambient climate. Recovery of the grains requires the removal of the husks, a moisture reduction in the field, shelling and cleaning. Shelling is therefore one of the essential processes in maize production [7]. In recent years, farmers in Nigeria have been faced with difficulty in substantial production of maize among which is shelling. Most farmers in the country still operate at subsistence level whereby shelling is done traditionally at farm level by hand or by beating sacks stuffed with cobs. These are time wasting and energy consuming, not only this, but also the hand may get bruised while shelling. The demand for maize as major raw materials in most industries requires that production must be stepped up. Hence, need therefore, to develop a method of shelling maize properly with minimal seed damaged.

Materials and methods

Design considerations

Different design factors were taken into consideration. These are as follows.

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Durability

The parts of machine are chosen that they may last for longer period before any sign of damage may be noticed.

Strength

Before any construction work could be done, the behaviour of stress action on the machine parts should depend on the load that machine is to carry and this is very essential.

Corrosiveness

Machine parts must be prevented from moisture as to prevent corrosion of the machine. This is achieved by painting the machine parts.

Availability

This is one of the most important factors to be considered when selecting materials. The materials must be readily available at low cost to ease the construction work and maintenance. In respect of the above fact, the materials used in the production of this machine were sourced for locally in Owode Onirin market in Lagos, Nigeria.

Design analysis and fabrication

Design of hopper

Hopper design is based on a common criterion for it to function. The criterion is called the "Angle of repose". Angle of repose is the maximum slope at which a heap of any loose or fragmented bulk material will stand without sliding. It can also be called the angle of friction of rest [3]. This type of hopper is a gravity discharge one and the recommended angle of inclination of hopper for agricultural materials is 8^{o} or more, higher than the angle of repose [6]. The angle of repose of maize is 270 [2]. This hopper has a shape of a truncated prism (Fig. 1).

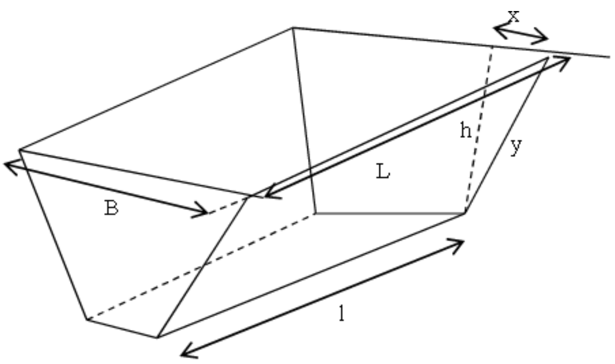

Fig. 1. The hopper (Scale 1:9)

In the fig. 1, B = Width of hopper top= 228 mm (chosen), L = Length of hopper top = 516 mm (chosen), b = Width of hopper bottom = 114 mm (chosen), l= Length of hopper bottom = 258 mm (chosen), h= Vertical height of hopper = 400 mm (chosen), y = Slant height of hopper and Ø = Angle of inclination of hopper. Plan view of the hopper is shown in fig. 2. The right angled triangle of the hopper is shown in fig. 3.

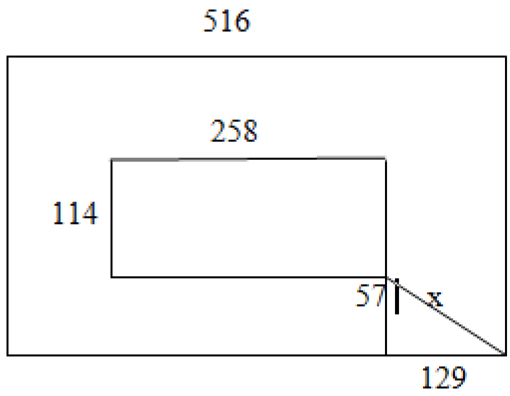

Fig. 2. Plan view of the hopper

Where, $\chi = \sqrt{(1292 + 572}$

$\chi =$ 141.03 mm

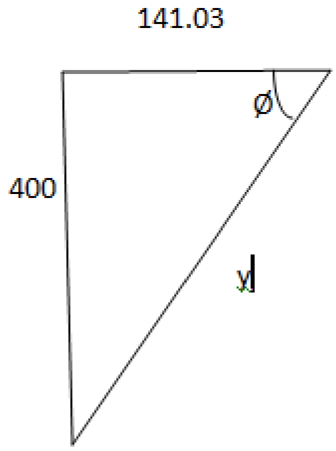

Fig. 3. Right angled triangle in the hopper

Therefore, from the right angled triangle (Fig. 3)

$$\text{Tan } Ø = \frac{400}{141.03} \quad (1)$$

Tan Ø = 2.85^{o}

Ø = 70.6^{o}

Therefore, since the angle of inclination of hopper, Ø is greater than the angle of repose of maize plus 80; the hopper will do the required job.

The volume of hopper

The volume of hopper can be calculated using eq. (2).

$$Vn = \frac{(Vct - Vcb)}{2} + Vcb \quad (2)$$

Where Vct = Volume of cuboid having the hopper top, has its length and breadth.
Vcb= Volume of cuboid having the hopper, bottom has its length and breadth.
Note: The height of cuboid for calculating Vct and Vcb is the vertical height of the hopper (400 mm).
Therefore, Vct = 516 x 228 x 400
= 47.059.200mm³
Vct = 0.0470m³
Vcb = 258 x 114 x 400
=11.764.800 mm³
Vcb = 0.0117 m³
Therefore,
Volume of hopper = Vh = $\frac{(0.0470-0.0117)}{2}$ + 0.0117

$= \frac{(0.035)}{2} + 0.0117$
$= 0.0175 + 0.0117$
$= 0.0292\ m^3$

Determination of number of spikes on the shelling cylinder, Np

The number of spikes on the shelling cylinder is given by

$$Np = \frac{Lc}{SSr} \times \frac{\pi d}{SSc}\ \pi d \qquad (3)$$

Where, Np = Number of spikes on shelling cylinder
Lc= Length of shelling cylinder = 1,180 mm
Ssr= Spike spacing on row = 60 mm
Ssc = Spike spacing on circle = 100 mm
d = Diameter of shelling cylinder = 114 mm
Therefore Np = $\frac{1180}{100} \times \frac{\pi 114}{60}$
= (11.80) χ (5.9690)
= 70.43
= 71

The total number of spikes on the shelling cylinder, Np = 71

Determination of pulley diameter of cylinder shaft

Horizontal bending movement diagram is shown in fig. 4.
The diameter, D_2 is given by the eq. (4).

$$D_2 = (D_1 \times n_1)/\ n_2)\eta \qquad (4)$$

Where n_1= electric motor speed = 1400 rpm
D_1 = diameter of electric pulley = 0.125 mm
D_2 = diameter of driven pulley = ?
n_2 = shelling speed = 800 rpm
η = efficiency = 96% = 0.96
D_2 = ((0.125 x 1400)/800) x 0.96
= 0.21875 χ 0.98
D_2= 0.214 m
Pulley diameter of shelling cylinder shaft for the speed of 1000 rpm

$$D_2 = \frac{n_1 D_1}{n_2} \qquad (5)$$

D_2 = (1440 x 0.214)/1000
Therefore D_2 = 308 mm
Pulley diameter of shelling cylinder shaft for the speed of 600 rpm

$$D_2 = \frac{n_1 D_1}{n_2} \qquad (6)$$

D_2 = (1440 x 0.125)/600
D_2 = 300 mm
(d) Pulley diameter of blower shaft is kept constant to get the constant blowing speed as calculated below

$$n_2 = \frac{n_1 D_1}{D_2} \qquad (7)$$

n_2= (1440 χ 0.125)/ 0.214
n_2 = 841.12 mm

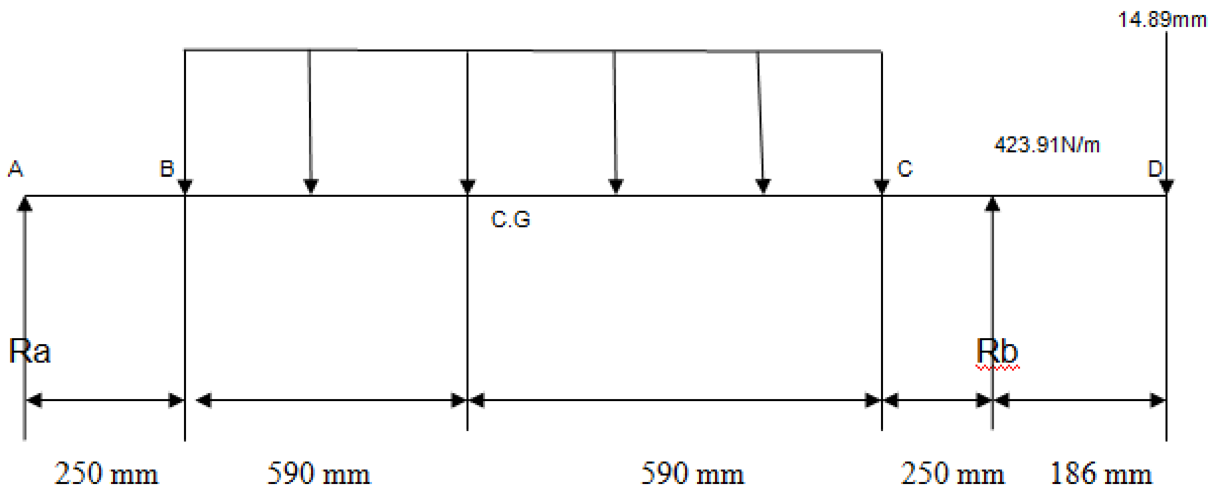

Fig. 4. Horizontal bending movement diagram

For stability, Ra + Rb = 14.89 N
Taking moment about a
Ra x 0 – 14.89 x 1416 + Rb x 1230 = 0
-14.89 x 1416 + 1230Rb = 0
1230Rb = 21,084.24N
Rb = 21,084.24/1230
Rb = 17.14N
Ra + Rb = 14.89N
Ra = 14.89N – Rb
= 14.89 – 17.14
Ra = -2.25N (in opposite direction to Ra in the fig. 4)

Vertical bending moment diagram is shown in fig. 5. Bending moment at B

= Rb x 1230 mm
= 17.14 x 1230
= 21,082.2 Nm
= 21.08 Nm
Maximum bending moment is given by
Mb = ωl^2/8 (uniformly distributed load) (8)
Where, l= length of uniformly distributed load = 1.180 m
ω = uniformly distributed load = 423.91 N/m
Mb = 423.91 x $(1.180)^2$/8
= 590.25/8
Mb = 73.78 Nm

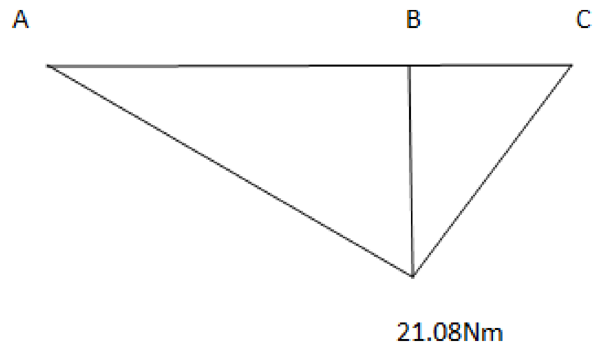

Fig. 5. Vertical bending moment diagram

Determination of shaft diameter

The required diameter for a solid shaft having combined bending and torsional loads is obtained from ASME code eq. [4].

$$d^3 = \frac{16}{\pi s_s}\sqrt{(k_b m_b)^2 + (k_t m_t)^2} \quad (9)$$

Where d = diameter of shaft
k_b = combined shock and fatigue factor applied to bending = 1.5
k_t= combined shock and fatigue factor applied to torsion = 1.0
s_s= allowable shear stress = 55 x 10^6 N/m (without key ways)

M_b = Maximum bending moment = 101.98 Nm
M_t = Maximum torsional moment = 59.57 Nm
d^3 = 9.26 x 10^{-8} ((1.5 x $101.98)^2$ + (1.0 x $59.57)^2)^{½}$
= 9.26 x 10^{-8} ((23,399.8209) + (3,548.5849)) ½
= 9.26 x 10^{-8} (26,948.4058) ½
= 9.26 x 10^{-8} (164.1597)
= 1.5201 x 10^{-5}
= 0.0248 m

= 24.8 mm

Result and discussion

The performance of the maize Sheller was tested using a variety of maize in Nigeria. The maize has a moisture content of 14.0% after the testing; samples of maize grain were collected at the clean grain outlet (chute), cob outlet and chaffed-straw outlet. Data collected are given in table 1 to 3.

Shelling efficiency

Shelling efficiency = $\frac{x}{y}$ x 100% (10)

Where, x = weight of clean shelled grains collected at all outlets = 9,978 g
Y = weight of maize cob with grain at input = 10,601 g
Therefore, shelling efficiency = $\frac{9,978}{10,601}$ x 100%
= 94.12%

Cleaning efficiency

Cleaning efficiency = $\frac{E}{F}$ x 100% (11)

Where, E = weight of clean shelled grains collected at the grain outlet = 9,860 g
F= weight of grain mixture (clean grain + foreign particles) collected at grain outlet = 10,120 g
Therefore, cleaning efficiency = $\frac{9860}{10120}$ x 100%
= 97.43%

Percentage grain damage

Percentage grain damage = $\frac{a}{y}$ x 100% (12)

Where, a = weight of damaged grains at all outlet = 53 g
Y = weight of shelled grains collected at all outlet = 9,978 g
Therefore, percentage grain damage = $\frac{53}{9978}$ x 100%
= 0.53%

Table 1. Performance evaluation of sheller at 600 rpm

Mass of maize cob with grain (g)	Mass of broken cobs (g)	Mass of unshelled (g)	Mass of clean shelled grain (g)	Mass of damaged/cracked grain (g)	Mass of grain loss (g)
3298	625	1525	994	98	56
4717	680	3516	389	106	28
2586	350	1974	180	63	19

Table 2. Performance evaluation of sheller at 800 rpm

Mass of maize cob with grain (g)	Mass of broken cobs (g)	Mass of unshelled (g)	Mass of clean shelled grain (g)	Mass of damaged/cracked grain (g)	Mass of grain loss (g)
3298	752	168	2351	-	27
4717	760	42	3892	-	23
2586	985	40	1545	-	15

Table 3. Performance evaluation of sheller at 1000 rpm

Mass of maize cob with grain (g)	Mass of broken cobs (g)	Mass of unshelled (g)	Mass of clean shelled grain (g)	Mass of damaged/cracked grain (g)	Mass of grain loss (g)
3298	1208	40	1921	110	19
4717	1400	54	3014	132	63
2586	1112	32	1339	88	15

Percentage of grain loss

Percentage of grain loss = $\frac{c}{y}$ x 100% (13)

Where, c = The total weight of grain loss = 65g

y = weight of clean shelled grains collected at all outlets = 9,978g

Therefore, percentage of grain loss = $\frac{65}{9978}$ x 100%

= 0.65%

A comparative study with an already existing maize Sheller shows the following for this new designed maize Sheller.

Table 4. Comparison between newly designed Sheller and existing sheller

	Existing maize sheller, %	Newly designed maize sheller, %
Total grain loss	0.94	0.65
Grain damage	0.72	0.53
Shelling efficiency	91.0	94.12
Cleaning efficiency	96.0	97.43

Conclusions

A maize Sheller was designed and fabricated for effective removal of dried grains from maize cob, having tested the performance of the fabricated machine, it could be concluded that the shelling efficiency, cleaning efficiency, grain damage, total grain losses are 94.12, 97.43, 0.53 and 0.65% respectively at moisture content between 12.5 – 14.0% dry basis and the best shelling speed is 800 rpm. The machine is able to remove the tedious parts of operation involved in hand shelling and manually. The Sheller is suitable to de-husked maize cobs.

Conflict of interest

Authors declared no conflict of interests.

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