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Development of a Medium Scale Motorized Maize Shelling Machine

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ABSTRACT

Maize is becoming the third major crop of the country after rice and wheat. Shelling of maize cob is done mostly by farmers in the country by the traditional methods while available motorised shellers are expensive. To provide for the income level of small and medium farmers a maize Sheller was developed and fabricated in NCAM. The maize shelling machine was developed to shell maize and separate the cob, and the chaffs from the grains by a shaker and suction fan of appropriate engineering design factors. The shelling machine was powered by a 6.5hp diesel engine; it has an average shelling capacity of 274.04 kg/h and a shelling efficiency of 97.85%. The breakage level was an average of 1.64%. The machine developed has the capacity to shell maize efficiently and economically with an appreciable level of cleaning.

Introduction

Maize is the American Indian word for maize which literally means, that which endures life. After wheat and rice, it is the most important cereal grain, providing nutrients for both humans and animals. Maize is widely used as a major basic raw material for the production of starch, oil, protein, alcoholic beverages, food sweeteners and recently, fuel (FAO, 1992).
Maize shelling a post-harvest operation which is the removal of the maize seeds from the cob, is an important step towards the processing of maize to its various finished products like flour. Shelling can be achieved by friction or by shaking the products. The difficulty of the operation depends on the varieties grown, the moisture content and the degree of maturity of the crop.

Maize is shelled traditionally by hands. This is done in such a way that maize is rubbed against another until the grains are removed from the cob. Likewise the grain can be detached from the cob with the use of pestle and mortal. But this traditional method of shelling is highly tedious, inefficient and time consuming with low productivity (FAO, 2005). However, the modern way of shelling is by the use of mechanical means, which can be driven by prime movers or tractors. Akubuo, (2002)observed that manual shelling of maize is a time-consuming and tedious operation and the few existing mechanized shellers on Nigerian farms are imported and these imported shellers are out of reach for rural peasant farmers that are characterized by small holding and low income. However, to enable fast shelling of maize in order to reduce post-harvest deterioration, mechanical shellers are recommended. This is because hand shelling methods cannot support commercialized large scale production.
With the fast growing increase in cultivation of maize resulting from its rapidly growing use as industrial raw materials a medium scale maize shelling machine was developed in NCAM to enhance processing of maize, small enough for an average Nigerian farmer to afford.

Materials and Methods

Description of Machine

The maize shelling machine can shell maize of different size. The machine consist of the following main parts; hopper, frame, chaff outlet, cob outlet, and drive shaft.

a. **Hopper:** The hopper of the machine has the length of 660mm and width of 390mm and was made from a 2mm thick mild steel sheet. The hopper unit is connected to the cover of the shelling drum and it accommodates the maize before gradually moving to the shelling drum.
b. **Frame:** The frame of the machine is 1020mm high and 660mm wide. It was made from a 45mm x 45mm angle iron. The frame supports all components of the machine.
c. **Chaff Outlet:** The chaff outlet allows the chaffs to move out of the machine while in operation. It is attached to the shelling drum cover and is made from mild steel with 110 mm width and 2mm thick.
d. **Cob Outlet:** The cob outlet is also attached to the shelling drum cover but on the opposite side of the chaff outlet. It is an opening for the passage of the broken cobs out of the machine during operation. It has a width of 136mm and made from a 2mm thick mild steel sheet.

e. Drive Shaft: The shaft has the length of 1425 mm with 30mm diameter. It is held by two pillow bearings from both sides, the shaft support the shelling drum because is directly attached to it, is also made from mild steel

Fig. 1: Pictorial view of Maize Shelling Machine

Working principle of the Machine

The maize shelling machine operates continuously and is powered by a 6.5hp diesel engine. It is operated by loading dry maize crop into the hopper from where it drops into the shelling drum. The shelling drum rotate in circular motion beating the maize to separate its grains from the cob with the help of power transmitted by the prime mover to the shelling drum. From the shelling drum the shelled grain, broken cob and the chaff fall on the shaker where a suction fan sucks away the chaff separating it from the grains. The shaker agitates continuously to separate the maize grains from cob particles and other dirt. It has a tray made of a wire mesh with holes just big enough to allow maize grains fall through it into the grain collector from where clean maize grains can be collected using a sack or bowl.

Design considerations

In the design of the maize Sheller, several factors were considered to achieve a desirable level of efficiency and reliability. These include:

i. Effective shelling capacity and rate with minimal loss of useful grain.
ii. The quality of food to be handled, hence material that will not contaminate it
iii. Affordability, availability, workability and strength of materials used for construction
iv. Physical properties of materials to be handled
v. Overall cost and capacity of machine putting it within the reach of a medium scale farmer or processor.

Design Analysis

Volume of Hopper

The volume of the hopper is given by the expression;

$$V = \frac{B \times H}{3} \quad (1)$$

Where, V *= volume of the hopper,* H *= height of the hopper,* $B = L \times W$, L *= length of the base and* W *= width of the base.*

Force required to thresh along the shelling drum

The shelling drum is connected to the shaft, hence it rotates with it resulting to a centripetal driving force. The force required for shelling is therefore equivalent to the force due to centripetal action of the rotating shelling drum which is given as;

$$F = m\omega^2 r \quad (2)$$

Where; F *= centripetal force,* m *= mass of shelling drum,* ω *= angular velocity,* r *= radius of the shelling drum arm.*

Angular velocity

The angular velocity is given by;

$$\omega = \frac{2\pi N}{60} \quad (3)$$

Where, N *= speed of the shaft (rpm)*

Threshing torque

The torque is given by the following expression;

$$T = F \times r \quad (4)$$

Where; F *= force along the shelling drum,* r *= shelling radius.*

Shaft design

The shaft design considered the maximum shear and bending stresses acting on the shaft due to the twist and bending moment it is subjected to. The shaft diameter d, was given by the expression;

$$d^3 = \frac{16}{\pi \delta_{sy}}[(K_b M_b)^2 + (K_t M_t)^2]^{\frac{1}{2}}$$ (Khunmi, R.J and Gupta, J.K., (2005) (5)

Where; d *= diameter of shaft,* K_b *= combined shock and fatigue factor for bending moment,* K_t *= combined shock and fatigue for torsional moment,* M_b *= resultant bending moment (Nm),* M_t *= resultant torsional moment (Nm),* δ_{sy} *= allowable shear stress (MN/m^2).*

Length of belt

The length of the belt used was determined by the equation;

$$L = \frac{\pi}{2}(d_1 + d_2) + 2x + \frac{(d_1 - d_2)^2}{4x}$$

Srivastava et al. (2006) (6)

Where, L = *length of belt;* d_1 = *diameter of prime mover pulley;* d_2 = *diameter of driven pulley;* x = *centre distance between the two pulley*

Construction/Fabrication of maize Sheller

Construction of the maize Sheller was carried out at the fabrication workshop of the National Centre for Agricultural Mechanization (NCAM), Ilorin. The machines, equipment and tools used for the fabrication of the maize shelling machine are include; lathe machine, drilling machine, filing machine, arc and gas welding machine , measuring tape, measuring rule and scriber. Different drawings of the shelling machine presenting various views of the machine are shown in the appendix. The major Parts of the machine of and their function and materials include;

1. Hopper: The hopper serves as storage for the maize to move into the shelling drum, it is made up of mild steel.
2. Shelling drum: is to shell and give out grain, and is made from mild steel.
3. Cob outlets: It is an opening where the broken cobs move out from the machine after Shelling, is made from mild steel.
4. Chaff outlets: It allows the chaff to move out after shelling with the help of a suctioning mechanism.
5. Fan: It suction the chaff from the grain on the shaker to the chaff outlets, is made from mild steel.
6. Shaker: It accommodate both the grain and the chaff after shelling, the shaker move in a reciprocating motion to allow the grain to fall into a grain collector through a mesh attached to it, is made from mild steel.
7. Grain outlets: Is where the clean grain comes out after shelling, is made from mild steel.
8. Shaft: It transmits torque and motion generated by prime mover to turn the shelling drum; it is also made up of mild steel.
9. Frame: It support and allows the body to rest firmly and absorb vibration, it is made from angle iron.
10. Prime Mover: It generates a torque to the system, R175 diesel engine.
11. Bearing: It allow free movement of the shaft, it is made up of cast iron.
12. Belt: To transmit the torque from the prime mover to the pulley, it is made from a fabric cord.

Performance Test

A preliminary test of the maize shelling machine was carried out at the National Centre for Agricultural Mechanization, Ilorin. Dry maize harvested from NCAM research farm was loaded into the maize shelling machine in three replicates to evaluate it capacity and efficiency. The following performance parameters were determine from data collected

1. $$Shelling\ rate = \frac{mass\ of\ shelled\ grain \times 3600}{time\ taken} (kg/h)$$
2. $$Shelling\ efficiency = \frac{mass\ of\ shelled\ grains}{total\ mass\ of\ grain(shelled + unshelled)} \times 100$$
3. $$Grain\ damage = \frac{mass\ of\ damage\ grain}{mass\ of\ shelled\ grain} \times 100$$

Table 1: Shelling capacity with the use of developed machine

Replicate	Mass of feed (kg)	Mass of shelled grain (kg)	Time taken(s)	Rate of shelling (kg/hr)
1	25	24.47	328.8	267.92
2	25	24.42	326.4	269.34
3	25	24.50	309.6	284.88

Table 2: Shelling efficiency

Replicate	Mass of shelled grain(kg)	Mass of unshelled grain(kg)	Shelling Efficiency (%)
1	24.47	0.53	97.88
2	24.42	0.58	97.68
3	24.50	0.50	98.0

Table 3: Grain damage

Replicate	Mass of shelled grain(kg)	Mass of damage grains(kg)	Percentage of damage grains %
1	24.47	0.3	1.23
2	24.42	0.5	2.05
3	24.50	0.4	1.63

Result and Discussion

The maize Shelling machine was developed and evaluated, results of the preliminary test carried out on the shelling machine showed that it has a shelling efficiency of 97.85%. The machine shelled at an average rate of 274.04kg/h of maize grain and grain damage level of 1.64%.

Conclusion and Recommendations

A high efficient and less monotonous machine for shelling maize has been developed materials used in fabricating the machines are cheap and locally available, NCAM maize Shelling machine can shell maize of various sizes and has a shelling efficiency 93.02% and minimal grain damage with an average Shelling capacity of 1tones per 2hrs. The machine operates smoothly and efficiently when in operation. The Shelled grains flow freely from the Shelling drum to the shaker and thereafter falls on the grain outlet, the chaffs are being suction in the opposite direction by the suctioning mechanism while the cobs are discharge easily through the cob outlet.

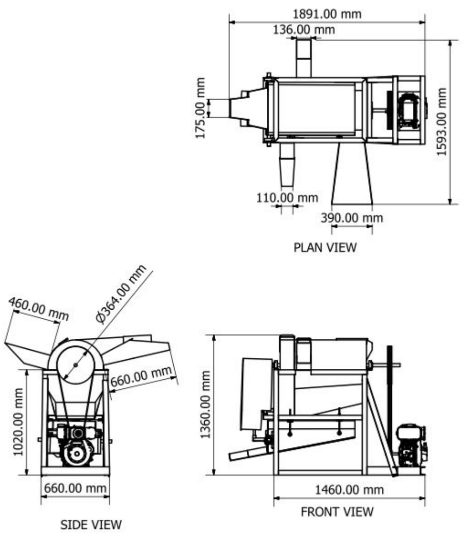


Fig. 2: Orthographic view of maize shelling machine

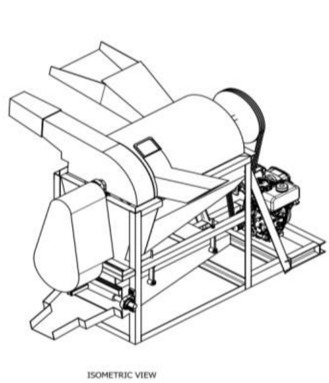
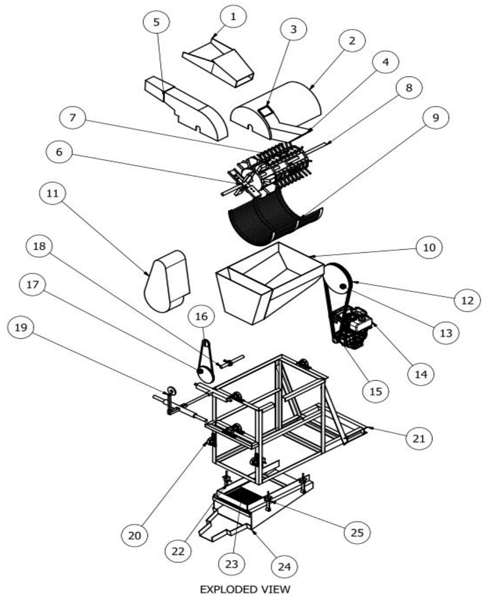


Fig. 3: Isometric view of maize shelling machine



PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	feeding shute	
2	1	cover	
3	1	curb outlet cover	
4	1	curb outlet	
5	1	shaft oulet/fan cover	
6	1	fan	
7	1	beating drum	
8	1	drum shaft	
9	1	seive(screen)	
10	1	base	
11	1	pulley cover	
12	4	V-Belt	
13	2	Grooved Pulley1	
14	1	YANMAR L48	
15	1	generator pulley	
16	3	vibrator pulley	
17	2	Grooved Pulley2	
18	1	shaft	
19	1	arm	
20	8	Pillow Bearing	
21	1	FRAME	
22	4	collector holder arm	
23	1	outlet sieve	
24	1	seed outlet	
25	8	bolt	ISO metric machine screws

Fig. 4: Assembly Drawing of Maize shelling Machine

The machine can help substantially reduce human fatigue involved during Shelling maize at an affordable cost and also reduces time consumed for shelling operation on big and small farms. There is no doubt that the machine will alleviate the rate of challenges attached to maize shelling in urban and rural areas. It is recommended that an optimization analysis is carried out on the machine to determine its best operating parameters.

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