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DEVELOPMENT OF A MAIZE SHELLING MACHINE: A REWIEW

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ABSTRACT

Maize production in Nigeria is of great importance with the increase in population and the use of maize grain, the market demand for maize also increased. However, maize shelling in developing and under-developed nations has been and remains a serious problem to its processing as it is tedious and often requires considerable labour hours, as such the Non availability of maize processing machines, especially Maize Sheller, has become a major problem of Maize production. This paper reviews from past literature the research-work for design, fabricate, and performance evaluation of a Maize Shelling machine which includes the design of various components of the machine using different methodology. The machine could be operated continuously if well fabricated for a comparatively long time with high shelling rate without causing damage to maize. It was recommended that the shelling unit should be incorporated with a long shelling cylinder to ensure proper shelling before reaching the stalk outlet, and a vacuum evacuating device should be made available for the removal of large broken and crushed maize stalks from the shelling chamber when necessary.

Keywords: *Maize, shelling, threshing, grains,machines,labor*

INTRODUCTION

Maize sheller is a machine which threshes out maize grains from its cob. It comprises a frame, hopper, beater teeth, blower, concave sieve, blower housing and a motor. It seperates the grains from the cobs at higher speed than manual beating. Maize (*Zea mays*) is an important cereals crop which belongs to a grass family (Graminae) producing small edible seeds which was said to have originated from Mexico over the years (Iwena, 2002). It is the world's best adapted crop, growing between latitudes 58^0N and 40^0S of the equator. The natural endowment of high rainfall, high light intensities, and favorable temperature in the cultivation of maize make it to be one of the world's most versatile seed crops (Kay, 1987).

Maize production in Nigeria is of great importance with the increase in population and the use of maize grain, the market demand for maize also increased. However, maize shelling in developing and under-developed nations has been and remains a serious problem to its processing as it is tedious and often requires considerable labour hours (Abdullahi et al, 1979). In industrialized countries, maize is largely used as livestock feeds and as a raw material for industrial products, while in low income countries; it is mainly used for human consumption (Ndirika, 1995). In Sub-Saharan Africa, maize is a staple food for an estimated 50% of the population (IITA, 1996). Maize is an important source of carbohydrate, protein, iron, vitamin B and minerals. In Africa, maize is consumed as a starchy base in wide variety of porridges and pastes. Green maize (fresh on the cob) is eaten parched, baked, roasted or boiled which play an important role in filling the huge gap after dry season (IITA, 1996).

Maize is a vital raw material in industry. Maize starch, maize oil, maize syrup and maize sugar are the chief industrial products obtained from maize. Maize starch is used for starching clothes. The starch is also employed in the manufacture of asbestos, ceramics, dykes, plastics, oil cloth and linoleum. Maize syrup is used in shoe polish, glassine paper and rayon in tobacco industries. Maize sugar finds their use in the manufacture of chemicals, leather preparation, dykes and explosives. The maize when cooked under acids produces furfural, a compound used in the production of adipontrile (nylon) in the restringing of diesel and lubricating oils. The stalks and leaves are sometimes used for making paper, paper board and wall board. Pulverized maize cobs are used extensively for removing carbon from airplane motors. (I.O. Adewumi, 2015).

Shelling of Maize

Shelling is the process of removing seed or grain from their respective cobs for both human and industrial use. Shelling is best attained when the moisture content is as low as 13% (ASHRAE, 1998). In the olden days and rural communities, primitive method of shelling maize included, beating with stick, crushing with mortar and pestle, hand shelling and therefore consumed much human energy and time (Sunghal and Thierstein, 1987).

Shelling is an indispensable process which is undertaken to maximize space and promote the easy handling of grains. Maize shelling, if done manually is one of the most labour consuming processes in maize post-harvest handling. The existing maize shellers are normally large and heavy, require high power input to operate and produce low product quality in term of percentage seed breakage and purity (Wagami, 1997). Damaged kernels are susceptible to insect and moulds thereby increasing the incidence of aflatoxin contamination. Thus, there is a need to develop a maize sheller with higher efficiency, better grain quality and higher power with small engine demand.

The Pedal Operated Energized Flywheel Motor has been adopted for many design of rural Applications in the last two decades In recent past a pedal powered process machines has been developed for wood turning (Modak and Bapat, 1993), washing (Dhakate,1995), brick making (Modak and Moghe, 1998). The main objective to design and develop a machine, which uses the Pedal, operated energized flywheel motor as an energy source, consisting of a bicycle mechanism, use of non-conventional energy as source Non availability of power in Interior areas and large scale unemployment of semi-skilled worker. In the context of the present condition in India of Power shortage and exhaustion of coal reserves and unemployment, it is felt that "Pedal Operated Maize Thresher" for Maize Threshing is very necessary. This machine is environment friendly i.e. nonpollutant. It will bring innovation and mechanization in agricultural engineering. Unskilled women may also get employment. Development of such energy source which has tremendous utility in energizing many rural based process machines in places where reliability of availability of electric energy is much low. The average work rate of a Any manufacturing process requiring more than 75W and which can be operated intermittently without affecting end product can also be man powered. Such man powered manufacturing process can be based on the following concept. In this processes a flywheel is used as a source of power. Manpower is used to energize the flywheel at an energy input rate, which is convenient for a man. After maximum possible energy is stored in flywheel it is supplied through suitable drive (Gupta, 1997) and gearing system to a shaft, which operates the process unit. The flywheel will decelerate at a rate dependent on load torque. Larger the resisting torque larger will be the deceleration. Thus theoretical a load torque of even infinite magnitude could be overturn by this man- flywheel system. Pedal driven Maize Thresher operates on the basis of above principle. If such machine is developed it will be great help to farmers of rural area because it does not need conventional energy. It is environment friendly machine

METHODOLOGY

The method and principle used to conduct this project involves the modification of the blower and the finishing of the component parts which take into account the design consideration.

Design Consideration

The design of any engineering component begins as a mere imagination and before it is actualized so many factors have been taken into consideration.
The following criteria were used:
I. The mechanical properties of the material
II. Machinability and Formability
III. Availability of material
IV. Choice of material
V. Cost of material

The Design of the Component

The main features of the sheller include;

I. Prime mover (Internal combustion engine) ICE
II. Hopper
III. Shelling unit
IV. Transmission unit
V. Frame

VI. Concave sieve
VII. Blower's casing.

The sheller works based on the principle of rotary impact. The selection of some of the parameters were in accordance with the works of Ahaneku I.E (2002) on "*Design, construction and performance evaluation of a multi crop sheller"*. Some physical and engineering properties of the grain were examined, this includes moisture content, bulk density and size of the grain. The following design parameters were established after measuring the physical properties of the maize grain.

I. Length of Shelling area
II. Cylinder speed
III. Fan speed
IV. Feed rate
V. Cylinder concave clearance
VI. Power requirement.

Physical and Engineering Properties of the Grain

I. Appropriate moisture content for maize is 15%
II. Bulk density of maize ranges from 695 to 802kg/m^2 [Russel, (1998)]

The Shelling Unit

The shelling unit consists of a cylinder, beater and perforated concave plate made of mild steel metal (400x250x2)mm and formed into a semi-circle with 10mm diameter holes spaced all over the surface of the cylinder in an helical manner. This orientation is to aid the conveyance of the chaff to the chaff outlet. The spikes are made from flat bar (25x45x2)mm. In each row, the beaters are spaced at 100mm from each other. Clearance between the surface and the concave sieve is maintained at 28mm. The shelling unit is covered with semicircular steel plate (250x400x0.5) to prevent loss of grains through scattering.

The Transmission Unit

The transmission unit consists of two pulleys, bearings, shaft and V-belt. One pulley is mounted on the cylinder shaft while the other single pulley was mounted on the prime mover.

Design of Shaft

A solid shaft of length 733mm rotating at 2000rpm was made of mild steel. The shaft here was subjected to both bending moment and torsion stresses. The ultimate shear stress of a mild steel shaft from design data was 265Mpa. The safe load was 300N (Approx 30kg).

Design of pulley

Length of belt between driving shaft and driven shaft
d = diameter of driving pulley = 80mm
D = diameter of driven pulley = 180mm
C = Central distance between driving and driven pulley = 460mm

Design of Bearing

Depending upon the nature of contact the antifriction bearing has been chosen.

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 (Eugene and Theodore, 1986).

This type of hopper is a gravity discharge one and the recommended angle of inclination of hopper for agricultural materials is at least 80^0 higher than the angle of repose (Micheal and Ojha, 1987). The angle of repose of maize is 270^0 (Richey, 1982). This hopper has the shape of a truncated prism.

Cleaning Unit

The cleaning unit of the sheller consists of three fan blades made of mild steel. The blades are equally spaced at 120^0 to each other. It is stationed at a distance of 150mm below the perforated concave behind the chaff outlet giving a windowing effect.

The Frame

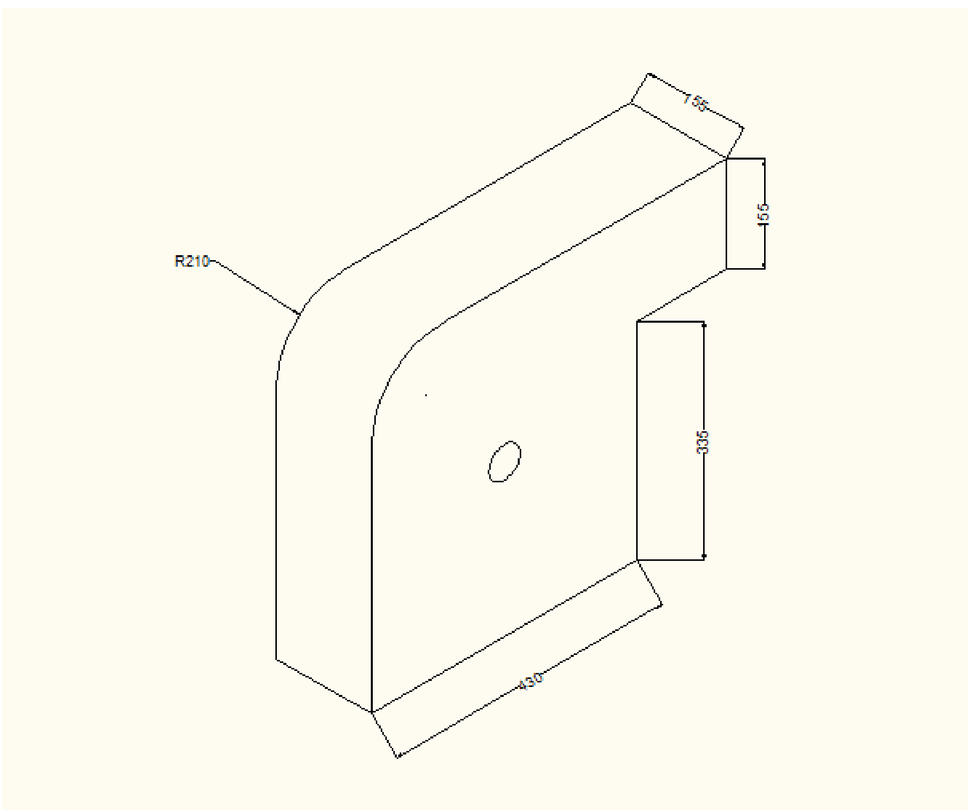
The frame forms the mounting support of all other units of the sheller and it is made of angle iron. The overall dimension is $(240x600x400)mm^2$.

The Concave Sieve

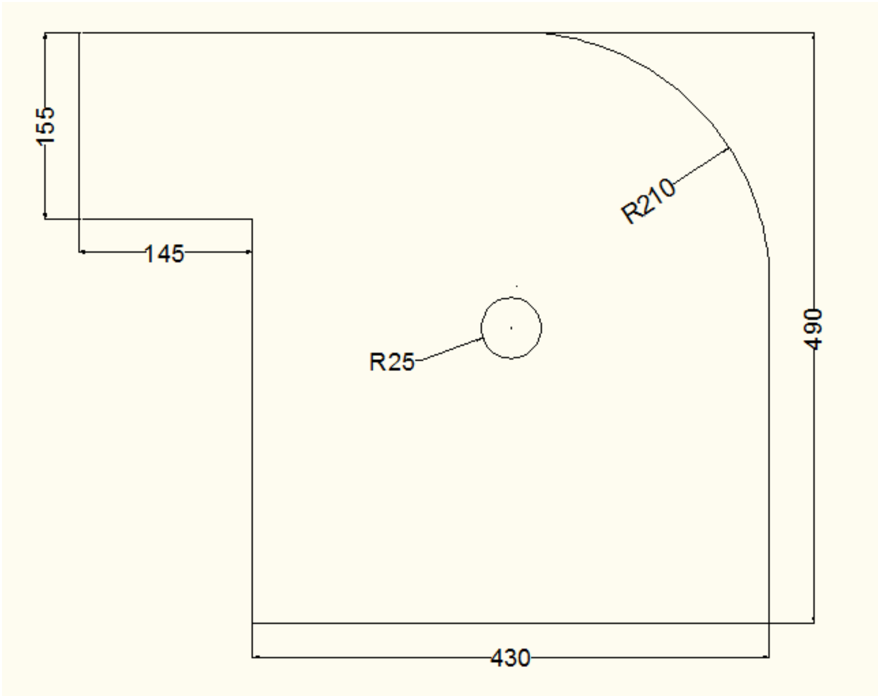
The grain outlet is steel sheet (400x250x3)mm is positioned below the shelling cylinder with 8mm diameter hole spaced all over the surface below the sieve plate. The concave sieve plate is constructed with mild steel.

Design of Blower Casing

The blower Casing is designed to support the blower end of the shaft, therefore constituting the maize sheller cleaning unit. It is made of mild steel metal (575x490x2)mmand (1630x155x1)mm. It has an edge fillet radius of 210mm and a center hole bore of diameter 50mm. The outlet aperture is designed to have a square dimension of 155mm per side.



3D representation of blower showing dimensions



2D representation of blower showing dimensions

Material Selection

In the selection of the material for engineering component care has to be taken in the choice based on the function of the parts and the working environment. This is determined by the mechanical properties, availability of material and cost of material.

FABRICATED MATERIALS

S/NO	COMPONENT PARTS	MATERIALS
1	Shaft	Mild steel
2	Shelling cylinder	Mild steel
3	Casing (sheet metal)	Mild steel
4	Spike (Beater bars)	Mild steel
5	Frame (angle iron)	Mild steel
6	Prime mover seating (angle iron)	Mild steel
7	Concave sieve (screener)	Mild steel
8	Hopper	Mild steel
9	Chaff outlet	Mild steel

10	Blower	Mild steel

Construction and Assembly of Component Parts

Following the determination of various parameters and selection of materials, the blower housing was constructed using the following procedures;

I. Mild steel sheet were cut to dimension using cutting disc and shearing machine
II. Themiddle casing sheet was bent using a rolling machine.
III. Side casing sheets were drilled using a drilling machine.
IV. The steel sheets were joined together using a welding machine.
V. Rough surfaces were grinded using a hand grinder.
VI. Burrs were removed using emery cloth
VII. The component was painted using a spray paint.

Performance Test

During the shelling exercise the total weight of shelled grain is 250kg and the corresponding time taken was 11 minutes as observed using a stop watch.

Before starting maize shelling exercise, the fuel tank was filled to maximum tank capacity (4 Litres) and level marked. After shelling for 11 minutes, a known quantity of fuel (0.5 litre) was used to re-fill the engine fuel tank to the original fuel level. The quantity of refilled fuel was considered equal to the fuel consumed by the sheller to shell the corresponding quantity of shelled maize.

RESULTS AND DISCUSSION

The results obtained from the observation of the project takes into consideration the fabrication, operation and cost of the maize sheller.

3.1 Result

From the performance test carried out on the machine, the coefficient of performance of the maize sheller is obtained as computed below:

$$C.O.P = \frac{Desired\ Output}{Required\ input}$$

$$= \frac{A+B}{P_{in}}$$

Where C.O.P = Coefficient of performance

A = mass of clean grains collected, (230kg)

B = mass of cracked/broken grains collected, (20kg)

P_{in} = fuel consumed in liter, (0.5ltr)

$$C.O.P = \frac{230+20}{0.5}$$

$$= \frac{250}{0.5}$$

= 500kg of grains/ litre of petrol

Discussion

As observed from the performance test carried out on the machine, the machine has higher coefficient as recorded in kg/litre. The quantity of petrol required to shell 500kg of grain is 1 litre. As reported by the performance test on the previous chapter, the sheller can shell 250kg of grains in 11 minutes. This simply implies that the machine can shell at least 1300kg of grain in 60 minutes. The higher the moisture content of the maize, the lower the shelling efficiency of the machine. (Adewole, 1994).

Maize grains of higher moisture contents are not easily detached from the cobs by the rolling and crushing action of the spike teeth against the concave. Instead of shelling, maize gtrains of higher moisture content may be grinded or masticated. Hence, shelling efficiency is reduced by higher moisture content of maize.

The higher the shelling speed, the higher the shelling efficiency and output capacity. The average shelling capacity of machine is 1400 kg/hrs.

The Modified Sheller

The vibration produced from the components of the original model which might accelerate rates of wear, create noise which cause safety problems and lead to damage in product quality, was reduced by the fiber padding attached to the detachable components of the machine to absorb oscillation. The finishing operations such as grinding, and the complete refurbishing of the blower casing has enhanced the operational, aesthetic (beautification), safety (accident reduction due to smoothened surfaces) and maintenance qualities of the maize sheller to the operator. However, since the design of the parts of the sheller remained unchanged, the pictorial look of the original model and the modified model are alike.

Operation of the Sheller

When turned on by starting the engine, the maize sheller separates the maize cobs and chaff from the grain. It delivers clean grains, maize cobs and chaff through different outlets. This enables the farmer to obtain clean grain and maize cobs for other uses at the same time and without additional labour.

Sheller Output

The high output of the sheller is due to the design of its concave that contributes to the removal of grains from cobs. The maize grain is removed by impact of the shelling drum and the rubbing action of the concave. The design of the concave also makes grain to drop off the shelling unit as soon as it is removed from the cob, thus reducing resistive forces in the shelling unit. The output of the sheller increases with an increase in shelling speed. At high shelling speed the rate of removal of grain from the cobs is high due to the increased force of impact on the grain.

Shelling Efficiency

Maize shelling in the sheller is both by impact force of the shelling drum and rubbing effect of the concave. Due to the increased force of impact at higher shelling speeds, the sheller showed an increased shelling efficiency with increasing shelling speed. Shelling efficiency reduces as the moisture content increases. By adding fibre pads, we were able to reduce the gyration of the beater and give even rubbing effect on the concave.

Cleaning Efficiency

The cleaning efficiency was found to increase due to increase in the rotational speed of the blower and the design of the blower casing. As observed from the test carried out on the 250kg of grains collected, the mass of clean grains was 230kg. Thus, the cleaning efficiency of the machine is estimated to be 92%.

Broken grains

From the performance test, the mass of the broken grain was 20kg. When compared to the total grains shelled (250kg), it amounts to only 8%. This simply implies that variations in the broken grains with the increasing shelling speed were negligible.

Grain Loss

There is a reduction in grain loss due to increase in the speed of the sheller and reduction in moisture content of the grains.

CONCLUSION AND RECOMMENDATION

The review of the development of a maize shelling machine has been discussed, A motorized corn sheller mode of design and operation was also discussed as studied from related literature. A well fabricated machine should be designed with lower vibration and better finishing to enhance user friendliness and machine maintenance.

From a related literature the result of the test conducted on the sheller showed no significant difference in performance when shelling varieties of maize. When the prime mover (I.C.E) is filled to the required gauge of 4 litres, it can shell at least 4000kg of maize grains.

Shelling maize is best at low moisture content of the crop when the stalk is brittle and grain size is of no significant difference across different maize varieties.

The noted problems associated with shelling of maize in the machine are;

I. Maize is not fully shelled before reaching the stalk outlet
II. Maize from stalk outlet exits with high speed which could be hazardous to the operator.
III. Evacuation of large broken and crushed stalks from the shelling chamber is only possible by dismantling which is cumbersome and time consuming.
IV. The maize stalks spread over a wide area which could litter the floor of a plant.

RECOMMENDATIONS

To minimize problems encountered during operation, the following recommendations are offered:

I. The shelling unit should be incorporated with a long shelling cylinder to ensure proper shelling before reaching the stalk outlet.
II. A vacuum evacuating device should be made available for the removal of large broken and crushed maize stalks from the shelling chamber when necessary.
III. An outlet guide should be placed at the blower outlet for the control of the stalk speed and direction.

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