Design, Fabrication and Performance Evaluation of a Hand Operated Maize Sheller

Tanko Bako[1*], Boman James Bature[2]

[1,] Department of Agricultural and Environmental Engineering, University of Agriculture, Makurdi, Nigeria.
[2,] Department of Agricultural and Bio-Environmental Engineering, Nuhu Bamalli Polytechnic, Zaria, Nigeria
engbako@gmail.com

Abstract: Maize (Zea mays) is one of the most important cereal crops in the world agricultural economy. It is known as queen of cereals and king of fodder due to its great importance in human and animal diet. Many farmers grow maize but could not afford the cost of acquiring some of the imported shelling machines because of their cost. Such people resort to traditional means of shelling. The traditional shelling methods are rubbing the maize cobs against each another, rubbing on bricks or stone and by using iron cylinder consisting of wire mesh inside. These methods are time consuming and result to low efficiency, high level of wastage and exerting of much labour. In view of this, the study was undertaken to design, fabricate and evaluate a hand operated maize sheller that is low cost and efficient. The maize sheller consisted of a cylinder and a concave. The cylinder made up of mild steel of size diameter 20 cm. The cylinder length 86 cm, having beaters which rotates along the cylinder and separates grains from the cobs. While the concave was fabricated using 2mm size mild steel sheets. The length of concave was 86cm with opening size of 13mm diameter. It was observed that for hand operated maize sheller at a moisture content of 16 % w.b., the shelling efficiency, cobs outlet loss and visible damage was found to be 75.03 %, 24.97 % and 1.3 %, respectively.

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1. Introduction

Maize is a staple food for an estimated 50 % of the population in Sub-Saharan Africa. 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 (Aremu *et al*., 2015). 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. In rural communities, the dwellers use maize in production of porridge (fura) and "Tuwo". Owning to demand for maize to human diet, its shelling and cleaning has been and remains a serious problem to local dwellers in their communities (Nwakaire *et al*., 2011).

Maize is a vital raw material in industry. Corn starch, corn oil, corn syrup and sugar are the chief industrial products obtained from maize. Corn starch is used for starching clothes. The starch is also employed in the manufacture of asbestos, ceramics, dykes, plastics, oil cloth and linoleum. Corn syrup is used in shoe polish, glassine paper and rayon in tobacco industries. Corn 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 restinging of diesel and lubricating oils. The stalks and leaves are sometimes used for making paper, paper board and wall board. Pulverised maize cobs are used extensively for removing carbon from airplane motors (Kareem, 2011).

Shelling is the process of removing seed or grain from their respective cobs for both human and industrial use. This separation, done by hand or machine, is obtained by threshing, by friction or by shaking the products. The difficulty of the process depends on the varieties grown, and on the moisture content as well as the degree of maturity of the grain. Maize shelling operation can be carried out in the field or at the storage environment (Mali *et al*., 2015). The different methods of maize shelling can be categorized based on various mechanization technology used. These includes: hand-tool-technology, animal technology, and engine power technology (Amirmudin and Victor, 2012).

Shelling is an indispensable process which is undertaken to maximize space and promote the easy handling of grains. In the olden days and in rural communities, primitive method of shelling includes, beating with stick, crushing with mortar and pestle, hand shelling and therefore consume much human energy and time (Adewole *et al*., 2015). The existing maize shellers are normally large and heavy, require high power input to operate and produce low product quality in terms of percentage seed breakage and purity. Besides, the cost of purchasing such shellers are high for the rural farmer and therefore call for the need of a relatively low cost maize shelling mechanism that will be affordable to such farmers not only to meet their shelling requirement but also to improve the threshing efficiency and reduce damage to the seed (Patil *et al*., 2014).

Rural areas require a conventional maize shelling technique that would significantly cater for the farmers harvest capacity and which many households can afford. This is with due consideration to the following reasons:

i. Most of the maize grown by such rural farmers is for food rather than for commercial purpose.

ii. Industrial maize shellers are too expensive to be purchased by such rural farmers.

iii. For most of the farmers, the cost of hiring the service of industrial shellers is high with respect to the amount of grain output at the end of the farming season.

2. Materials and Methods

The machine is to be operated by applying force to rotate the crank handle (Figure 1). As the maize cobs are being fed into the threshing drum through the hopper, the grains are beaten out of the cobs and separated from the bulk of the cobs. This is done by a cylinder fitted with beater pegs that rotates above a stationary grid known as a concave. Motion of the handle provides an angular velocity that transmits power to the shaft hence providing rotary motion of the beater discs which pull and shell the maize cobs by friction and shearing action against the spiked iron projections on the threshing drum. The empty cobs will pass out through the cobs outlet opening and are thrown out by the force of rotation of the Shelling discs, and then grain will spread through the grain outlet.

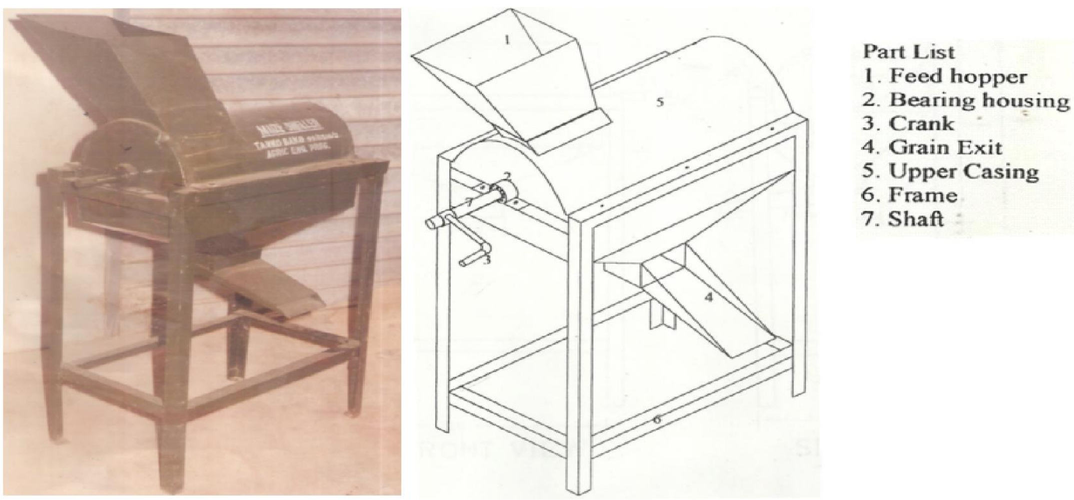

Fig. 1: Pictorial drawing of the hand operated maize sheller

2.1 Engineering properties of maize

Engineering properties are useful and necessary in the design and operation of various equipments used for agricultural operations. The engineering properties such as physical, aerodynamic and frictional properties of maize were determined. The physical properties including dimensions of the maize cobs were determined using standard procedure stated by Tarighi et al. (2011). The aerodynamic and frictional properties were determined using the procedures described by El Fawal et al. (2009).

2.2 Design analysis

The design analysis was carried out with a view to evaluate the necessary design parameters, strength and size of materials for consideration in the selection of the various machine parts in order to avoid failure by excessive yielding and fatigue during the required working life of the machine.

2.2.1 Selection of the design

i. There is no power consumption as it works on human power and hence suitable for remote areas.

ii. Suitable for small scale industries as the investment is low.

iii. Maintenance cost is low.

2.2.2 Machine components design

I. 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 (Aremu *et al*., 2015). This type of hopper is a gravity discharge one and the recommended angle of inclination of hopper for agricultural materials is 8^0 or more, higher than the angle of repose. The angle of repose of maize is 27^0 (Aremu *et al.*, 2015).

The hopper was designed to be a frustum, trapezoidal in shape and has the following dimensions that were chosen based on proportionality and aestatics. The larger part of the frustum is a rectangle of 270 mm by 160 mm while the smaller part of the frustum is a rectangle of 200 mm by 110 mm. The height of the frustum is 400 mm. The angle of the base to the vertical is α which is the measured angle of repose or angle of friction of maize. The minimum angle of inclination was calculated to be 85^0. Hence, since the angle of inclination of hopper, α is greater than the angle of repose of maize plus 8^0; the hopper will do the required job.

The Volumetric and gravimetric Capacities of the hopper were determined. The volumetric capacity of the hopper, V_h was determined from the equation by *Eric* et al., *1982*;

$$V_h = \frac{h}{3}\left(A_1 + A_2 + \sqrt{A_1 A_2}\right) \quad 1$$

Where; A_1 = Area of the hopper top (270mm×160mm), A_2 = Area of the hopper bottom (200mm×110mm). Therefore; $V_h = 0.0128\ m^3$

The gravimetric capacity of the hopper, G_h is related to the volumetric capacity of the hopper, V_h using the Equation;

$$G_h = \rho V_h \quad 2$$

Where; ρ=density of maize cobs = 415 kg/m^3, V=volume of hopper = 0.0128 m^3

G_h = 5.312 kg = 52.11 N

II. Shelling mechanism

The shelling mechanism consists of the drum, conveyor and spikes.

Determination of number of spikes on the shelling cylinder, Ns: The number of spikes on the shelling cylinder is given by;

$$N_s = \frac{\pi DL}{S_r S_c} \text{ (Eric } et\ al., \text{ 1982)} \quad 3$$

Where, N_s = Number of spikes on shelling cylinder, L= Length of cylinder area with spikes = 40cm, Sr= Spike spacing on row = 5cm, Sc = Spike spacing on circle = 8cm, D = Diameter of shelling cylinder = 20cm. Therefore; N_s = 63

Weight of shelling mechanism: The weight of the shelling mechanism is calculated as;

$$W_{TS} = W_d + W_c + W_s \quad 4$$

Where; W_d = weight of drum, W_c = weight of conveyor, W_s = weight of spikes

The weight of shelling drum, W_d;

$$W_d = \rho V_d g \quad 5$$

$$V_d = \pi DLt \quad 6$$

Where; ρ = density = 7860kg/m^3, V_d = volume of drum, g = gravitational acceleration,

D = diameter = 20cm, L = length = 58.5cm and t = thickness = 0.2cm. W_d = 56.70 N

The weight of conveyor, W_c;

$$W_c = N_c \rho LBHg \quad 7$$

Where; N_c = number of conveyors = 7, B = breadth = 1cm, H = height = 2.5cm, L = 24cm; W_c = 32.40N

The weight of spikes, W_s;

$$W_s = N_s \rho A_s L g \quad 8$$

$$A_s = \frac{\pi D}{4} \quad 9$$

Where; N_s=63, D=1cm, L=2.5cm; W_s = 9.54N

The total weight of the shelling mechanism,

W_{TS} = 56.70+32.40+9.54 = 98.64N

III. Design for sieve

Total area of sieve,

$$A = \frac{2\pi rL}{2} = \pi rL \quad 10$$

r = 16 cm, L = 61.5cm and A = 0.31m^2

Diameter of each hole = 13 mm, Area of each hole in a column (circular)

$$A = \pi r^2 \quad 11$$

r = 6.5mm and A = 1.327×10^{-4}m^2

Total numbers of column = 20, Total area of column = $20\times1.327\times10^{-4} = 2.65\times10^{-3}$m^2

Area of sieve under stress = Total area of sieve minus total area of column

Area of sieve under stress

= $0.31 - 2.65\times10^{-3}$ = 0.307m^2

Area of sieve A

$$A = \frac{\text{Force of grain on sieve}(F_g)}{\text{Area of sieve under stress }(A_S)} \quad 12$$

F_g = 0.319N

Stress on sieve = 1.039N/m^2

IV. Flow of grain between the drum and the sieve

The force of grain depends largely on the speed with which each spike throws the grain onto the sieve and also the drag force on the grain without taking effect of axial air into consideration, taking distance between drum and sieve to be 6cm then speed of grains.

$$Vg(X) = 2gx, \text{ and } Vg = 2gx \quad 13$$

x = 6cm. therefore; Vg = 1.18m/s

But force on each spike, $Fs = \frac{\text{drum torque}}{\text{radius of drum}}$

$$Fs = \frac{T_d}{R_d} \quad 14$$

T_d = 287.5Nm, R_d = 12.5cm and F_S = 2312N

Number of grains inside the shelling unit is;

$$Ng = \frac{V_c}{V_g} \quad 15$$

Where; V_c = Volume of available space between the drums, V_g = Volume of each grain (main)

$$\text{But } V_c = \frac{\pi(D^2 - d^2)L}{4} \quad 16$$

D = 31cm, d = 20cm, L = 58.5cm and V_c = 0.0258m^3

$$\text{Volume of grain, } V_g = \frac{4}{3}\pi r_g^3 \quad 17$$

Where r_g = 1cm. Therefore; $V_g = 4.188\times10^{-6}$ m^3

Number of grains, $N_g = \frac{V_c}{V_g}$ 18

N_g = 6160 grains

Time taken to fall onto the sieve,

$S = Ut + \frac{1}{2}gt^2$ 19

Assume that U = 0, $S = \frac{1}{2}gt^2$ and $t = \sqrt{\frac{2S}{g}}$

S = 6cm. Therefore; t = 0.111 sec

Mass flow rate, $M = \frac{M_g}{t}$ 20

Where; M_g = 0.03kg; therefore Mass flow rate, M = 0.27kg/s

Hence force of grain, $F_g = V_g \times M$ 21

F_g = 0.319N

V. Drag force

The drag force, F_D is given by;

$F_D = \frac{C_D U^2 A_g \rho_g}{2}$ 22

Where; C_D = Coefficient of drag (0.6), U = Velocity of grain = 1.18m/s, A_g = Area of grain, ρ_g = Density of grain = 1.18kg/m^3, r = Radius of grain = 1cm. Hence F_D= 0.000155N

Since $F_g$is greater than $F_D$it implies that the grain will not fall on the sieve always without being dragged behind by the drag force.

VI. Hand crank

The crank is the mechanical means of rotating the shaft during manual operation. The design of the crank bar is based on the strength. It is required that the crank bar has enough strength to be able to resist failure due to tension or shear.

For suitability, comfort and optimum operation of the shelling machine a length of 0.8257m was chosen for the crank which is a mild steel rod of 20mm diameter. Assuming the weights of the handle and boss of the crank are negligible. Then the weight of the crank, W_k;

$W_k = \rho ALg$ 23

$A = \frac{\pi D^2}{4}$ 24

W_k = 20N

The direct stress on crank is;

$$S_d = \frac{\text{Axial Force}}{\text{Cross} - \text{sectional Area}} = \frac{4F}{\pi d^2} = 2.55 \times 10^5 \text{N/m}^2$$

Where; S_d = Direct stress (N/m^2), F = Axial force (N) = 80 N, d = Diameter of crank bar (m)

The shear stress in the crank is determined from;

$\tau = \frac{\text{Axial Force}}{\text{Shear area}} = \frac{4F}{\pi d^2}$ 25

The perpendicular distance, R from the applied force to the line of action of the crank is given by;

$R = \frac{T}{F}$ 26

Where; T = Torque required of the crank = 11.96Nm, F = Axial force = 80N. Hence R=0.15m

VII. Power requirement of the machine

The total power requirement of the machine is the sum of the power to drive the threshing drum (P_D) and the power to thresh grain from the cobs (P_T).

$P = P_D + P_T$ 27

Power to drive threshing drum;

$P_D = T\omega$ 28

Where; T = Drum torque, Nm; ω = Angular velocity, rad/s

$T = Wr$ 29

$\omega = \frac{2\pi N}{60}$ 30

Where; W = Weight of threshing drum = 150.75 N; r = Distance of point of force application from axis of rotation = 0.125 m; N = speed of the threshing drum = 50 rpm. Hence P_D = 98.705 watts

The power required to thresh grains from the maize cobs is expressed as: $P_T = T\omega$

$T = Fr$ 31

Where; F = Impact force required to thresh maize, N

$F = F_S N_S$ 32

Where F_S = shelling force = 0.687 N, N_S = number of spikes = 63. Hence P_T = 28.339 watts

Total power P = 98.705+28.339 = 127.044 watts

Assuming that the input torque that an individual will be willing to apply easily is 30 Nm and input speed is 50 rpm. Total input power P will be; $P = T\omega = \frac{2\pi NT}{60}$ = 157 watts

Since the power requirement of the machine is less than the input power, an average man/woman or even below can operate the machine effectively.

VIII. Design of shaft

Design of shafts of ductile materials based on strength is controlled by maximum shear stress theory while that of brittle materials is by maximum normal stress theory. In practice shafts are usually subjected to fluctuating torque and bending moments. In order to design such shafts like line shafts the combine shock and fatigue factors must be taken into account. For a solid shaft made from ductile material

having little or no axial loading, the shaft diameter is obtained from ASME code equation according to Khurmi and Gupta, 2008.

$d^3 = \frac{16}{\pi Ss}\sqrt{(K_b M_b)^2 + (K_t M_t)^2}$ 33

Where; K_b = Combined shock and fatigue factor applied to bending moment, K_t = Combined shock and fatigue factor applied to torsional moment, M_b = Maximum bending moment, Nm, M_t = Torsional moment, Nm. Maximum permissible shear stress;

$$Ss = \frac{\text{Ultimate Strength in Shear}}{\text{Factor of Safety, FS}}$$

The bending moment of the shaft will be the resultant of the vertial and horizontal bending moments (Figure 2).

$M_b = \sqrt{MV^2 + MH^2}$ 34

MV = 25.56 Nm and MH = 2.4 Nm,
therefore $M_b = 25.67$ Nm

Torsional moment; $M_t = Fr$ 35

F = 150.75 N and r = 0.25 m, hence M_t = 37.69Nm

For shaft having key way and load gradually applied:

K_b= 1.5, K_t =1.0 (Khurmi and Gupta, 2008)

Assuming a factor of safety (F.S) of 1.5, the working stresses for shaft with key is;

$$\sigma_w = \frac{\sigma_u}{F.S} = \frac{84\ \text{Mpa}}{1.5} = 56\ \text{Mpa}$$

$$\tau_w = \frac{\tau_u}{F.S} = \frac{42\ \text{Mpa}}{1.5} = 28\ \text{Mpa}$$

d = 21.40mm

In order to satisfy all conditions of design, a nominal shaft diameter of 25.00 mm is chosen.

2.3 Fabrication of the machine

The parts of the machine include; transmission shaft, shelling drum, spikes, conveyor, sieve, upper casing, feed hopper, exit chute, frame and hand crank.

Shaft: A mild steel rod of 30mm diameter was machined to 25mm diameter and was used as the power transmission shaft. The operations carried out was mainly facing and turning while the work piece was held between centers on the lathe machine.

Drum: The drum was made from a mild steel of 628mm by 585mm cross-section. The metal sheet was rolled with the rolling machine to form a drum of length; 585mm and diameter, 200mm. Faceplates were marked out as 200mm circles and cut out. They were then welded to the drum and the right centers were drilled to accommodate the shaft.

Spikes: They were made from a mild steel rod of 10mm diameter. They were cut to give 50mm length and were welded unto the drum. The spikes cover 2/3 of the drum.

Conveyor: This is made of a 25mm by 10mm mild steel bar and designed to push the maize cobs to the shelling unit. It covers 1/3 of the drum.

Sieve: The sieve was made from a mild steel plate of 615 by 567mm. Holes of 13mm were drilled using 13mm drill bit. The plate was rolled using rolling machine to form a curved surface and both sides were bent using the bending machine and holes were drilled to permit bolting of the sieve to the frame. A face plate was marked out and cut to give 310mm diameter which was divided into two halves and were welded to both sides of the cylinder giving space for the shaft to pass through. Provision was also made at one side of the face plates for the cobs to pass out. The sieve was designed to screen the seeds and the cobs of maize during shelling.

Upper Casing: This was made of a 2mm thick mild steel sheet of 615mm by 567mm. It was rolled to form a half cylinder of 315mm diameter, both sides were bent and holes were drilled to permit bolting to the frame. A face plate was marked out and cut to give 315mm diameter which was divided into two halves and were welded to both sides of the cylinder giving space for the shaft to pass through. The upper casing was designed to cover the upper part of the shelling drum and to support the feed hopper.

Hopper: This was made of mild steel sheet of 2mm thickness. The hopper of dimension 160×270mm at the top and 110×200 mm at the bottom was designed to aid conveyance, reduce the labour of constant feed and allows for continuous feeding.

Exit Chute: This was also made of mild steel plates. The operations here are cutting, welding and drilling. The exit chute is designed to collect all the grains from the sieve and direct into a receiver.

Frame: This was made from angle bars from mild steel of 40mm. Operations are cutting, welding and drilling. It is designed to carry the rotating mechanism, crank, casings and the shaft.

Crank: This was made of mild steel rod of 20mm diameter. A pipe of 25mm internal diameter was used as was used as the boss of the crank. The operations involved here were cutting, machining and welding.

2.4 Machine evaluation

Machine evaluation refers to the performance of the machine in terms of output, efficiency, comparative performance, economic cost and a host of others. However, while some of these can be quantitatively expressed others may have to be qualitatively analyzed.

2.4.1 Cost analysis

The material costs are based on the current market price, labour cost is assumed to be 20% of the material cost and overhead cost is assumed to be 15% of the material cost.

2.4.2 Machine performance test

The testing of the maize sheller was carried out in order to ascertain whether there is conformance of its performance to its design specifications. Samples of maize varieties were obtained from a storage unit in Bauchi where they have been stored in a crib. The cobs were pre-inspected to ensure uniformity of size and quality; the cobs had an average length of 150mm. before operating the machine, the bearings were lubricated. Parts of the samples were shelled with the machine manually operated by the use of a hand crank at 50 rpm.

After each shelling session quantity of shelled grains, cobs and shelling duration were noted. The grains that fell on the ground close to the sheller were swept up and included in the shelled grain sample while those that were thrown very far away from the work place were classified as ‘unrecovered material’

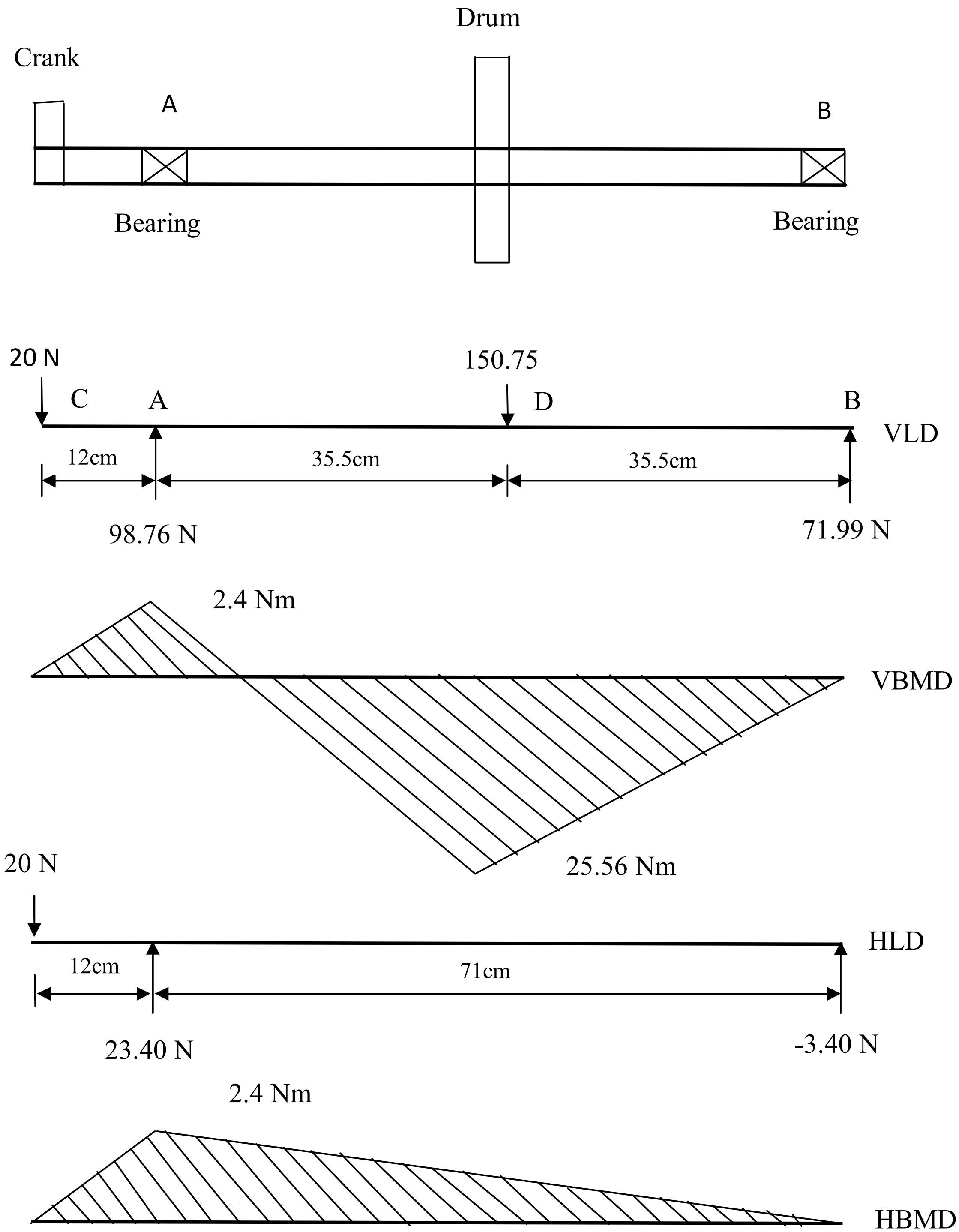

Fig. 2: Shaft loading and bending moment diagrams

and grouped with the unstripped grain to reflect the inefficiency of the system. Unshelled grains were removed by hand from each cob. Randomly picking 1500 grains from each shelled sample and visually examining each one of them carefully to assess damage to grains caused by the sheller. All broken, chipped and craked grains were classified as damaged grains. Kernels that had freshly made readily observable slight surface scratches were also regarded as being damaged. The definitions and calculations of these parameters are as below.

Throughput capacity: The weight of the maize cobs with kernels attached attempted by the machine in unit time was taken as rate of throughput and it was calculated as; throughput capacity, c

$$C = \frac{\text{Total weight of cobs with kernels attached,kg}}{\text{Time,hr}} \quad 36$$

Shelling rate: The weight of the maize kernels (whole + broken) detached from the cobs in unit time was taken as shelling rate. It was calculated as:

$$SR = \frac{\text{Weight of shelled grains,kg}}{\text{Time,hr}} \quad 37$$

Theoretical efficiency: The efficiency of the maize sheller can be estimated theoritically from the input and output powers. Losses in the machine during operation in the various components can be determined. The efficiency can be found by finding the efficiency of various machine elements involved in the power transmission. The major power transmission elements in this machine are the bearings.

The efficiency of a ball bearing standard is given to be 99% (Eric *et al*., 1982)

Loss in bearing = 100 – 99 = 1%

Since we have 2 bearings;

total loss in bearings = 1 x 2 = 2%

The total power loss in the machine = total loss in bearings

Efficiency of machine = 100 – total loss in machine

= 100 – 2 = 98 %

Shelling efficiency: It is the percentage by weight of shelled kernels from all outlets of the sheller with respect to total kernel input. It was calculated as:

$$E = \frac{\text{Wt of shelled grains}}{\text{Wt of shelled +Wt of unshelled}} \times 100\ \% \quad 38$$

Cobs outlet loss: This is the percentage by weight of shelled grains passing through the cobs outlet plus the weight of unshelled grains still attached to the cobs that were hand stripped with respect to total grain input and was calculated as:

$$L = \frac{\text{Wt of cobs outlet +Wt of unshelled}}{\text{Wt of shelled +Wt of unshelled}} \times 100\ \% \quad 39$$

Percentage grain damage: It is the percentage by weight of damaged shelled kernels from all outlets of the sheller with respect to total kernel output. It was calculated as:

$$d = \frac{\text{Weight of damaged grains}}{\text{Weight of shelled grains}} \times 100\ \% \quad 40$$

3. Results and Discussion

The results pertaining to engineering properties of maize, development and performance evaluation of the maize sheller are presented and discussed below.

3.1 Engineering properties of maize

The different engineering properties of most commonly grown maize variety are presented in the Table 1. The mean moisture content of the maize grains during the study was found to be 14 % (w. b.) with standard deviation of 1.9 %. The mean length of undehusked cob was of 183.25 mm with standard deviation of 29.56 mm while mean diameter of undehusked cob was of 54.21 mm with standard deviation of 4.37. The sphericity of the grain was found to be 0.71 with a deviation of 0.04. The minimum diameter of cob without grains was found to be 24.25 mm with standard deviation of 2.10 mm whereas the maximum diameter of cob without grains was 28.56 mm with standard deviation of 2.72 mm. The average length of the shelled maize cob of 150.00 mm was noticed with a deviation of 11.02 mm. The test weight of the maize grain was noticed as 249.77 g with deviation of 46.96 g. The grain to dry matter ratio was recorded as 3.29 with deviation of 0.41. The mean terminal velocity of maize husk was found to be 1.24 ms^{-1} with a deviation of 0.05 ms^{-1} whereas it was 14.58 ms^{-1} with a deviation of 0.41 $ms^{-1}$for maize grains. The maximum angle of repose was found to be 24.32^0 with a deviation of 1.16^0 for maize grains.

Table 1 Parameters and properties of maize variety selected for the study

Properties	Parameters	Mean	SD
Physical properties	Length of un-dehusked cob, mm	183.25	29.56
	Diameter of un-dehusked cob	54.21	4.37
	Sphericity	0.71	0.04
	Minimum diameter of cob without grains, mm	24.25	2.10
	Maximum diameter of cob without grains, mm	28.56	2.72
	Average length of shelled cob, mm	150.00	11.02
	Test weight, g	249.77	46.96
	Grain to dry matter ratio	3.29	0.41
	Moisture content, %	14	1.9
Aerodynamic properties	Husk terminal velocity, ms^{-1}	1.24	0.05
	Grain terminal velocity, ms^{-1}	14.58	0.41
Frictional property	Angle of repose, degree	24.32	1.16

Table 2: Materials, specification and costing for the maize sheller

Component	Material	Specification (mm)	Quantity	Unit price (₦)	Amount (₦)
Material Cost					
Hopper	Mild steel	270×160×400	1	1,000.00	1,000.00
Cylinder	Mild steel	Ø200×590	1	2,500.00	2,500.00
Conveyors	Mild steel	240×10×25	7	100.00	700.00
Spikes	Mild steel	Ø10×25	63	30.00	1,890.00
Screen	Mild steel	Ø310×615	1	1,500.00	1,500.00
Top cover	Mild steel	Ø310×615	1	1,500.00	1,500.00
Down cover	Mild steel	620×310×310	1	2,000.00	2,000.00
Shaft	Mild steel	Ø30×850	1	1,000.00	1,000.00
Crank	Mild steel	Ø20×830	1	700.00	700.00
Bolts and Nuts	Mild steel	M12	13	20.00	260.00
Ball bearings			2	500.00	1,000.00
Frame	Mild steel	720×410×940	1	2,000.00	2,000.00
Electrodes		Gauge 10	2 packs	900.00	1,800.00
Abrasives		2 mm Thick	1	1,000.00	1,000.00
Paint			1 Tin	1,000.00	1,000.00
Sub-Total					**19,850.00**
Labour cost	**20 % of material cost**				**3,970.00**
Overhead cost	**15 % of material cost**				**2,977.50**
Grand Total					**26,797.50**

Table 3: Machine performance test

Feed mass (kg)	Time (mins)	Grain output (kg)	Cobs output (kg)	Unshelled grain (kg)	Throughput capacity (kg/hr)	Shelling rate (kg/hr)	Shelling efficiency (%)	Cobs outlet loss %	Grain damage (%)
12.00	20.00	7.500	1.500	2.500	36.00	22.50	75.00	25.00	1.31
12.00	20.75	7.470	1.702	2.618	34.70	21.60	74.05	25.95	1.27
12.00	20.50	7.544	1.845	2.378	35.12	22.08	76.03	23.97	1.32
Mean	20.42	7.505	1.682	2.499	35.27	22.06	75.03	24.97	1.30
SD	0.38	0.037	0.173	0.120	0.66	0.45	0.99	0.99	0.026

3.2 Cost analysis

The materials, specification and costing for the maize sheller is shown in Table 2. Based on material cost alone, the machine will cost ₦19,850.00. The labour and overhead costs of the machine were assumed to be 20% and 15% of the material cost respectively. The total cost of the

machine will be N26,797.50. This is based on current market price.

3.3 Shelling performance of the machine

This device as previously stated was designed and constructed for shelling of maize, which is operated manually. A man or woman with an average height or even below can operate this device conveniently through turning of the crank. Table 3 is the result of the machine performance test.

From the analysis, 12kg of maize fed at each session of operation had an average shelling duration of 20.42 minutes with a standard deviation of 0.38 minutes. The results also showed mean grain output, mean cobs output and mean unshelled grain output of 7.505±0.037 kg, 1.682±0.173 kg and 2.499±0.120 kg respectively.

The machine cannot attain 100 % efficiency, which is true for all machines, because of many factors such as material selection, design and so forth. However, this machine could be said to be satisfactory with the theoretical efficiency of 98%. The mean shelling efficiency obtained is 75.03 % with standard deviation of 0.99 % while the mean cob outlet loss is 24.97 % with a deviation of 0.99 %.

A relatively low mean grain damage of 1.3±0.026 % that was obtained is an indication that the crop moisture content, feed rate, cylinder/concave clearance and the shelling speed of 50 rpm of the machine were all within acceptable limits as all these factors affect the degree of grain damage (Aremu *et al.*, 2001). The optimum moisture content for shelling maize is around 20 % while typical peripheral speed and cylinder/concave clearance are 13-22 m/s and 22-29 mm respectively for rasp-bar or spike-tooth cylinders.

The mean throughput capacity of the sheller is 35.27±0.66 kg/hr while the mean shelling rate of 22.06±0.45 kg/hr was obtained indicating that the machine is only fit for small scale shelling since more sophisticated power-driven shellers used for large scale shelling usually have throughputs varying from 1000 to 3500 kg/hr (Aremu *et al.*, 2001). The aim of this work is to shell maize. From the results obtained, the maize grains were actually shelled from the cobs. That is to say that the machine was able to perform its function.

4. Conclusion and Recommendation

4.1 Conclusion

The average kernel shelling capacity and shelling efficiency of the sheller was 22.06 kg/hr and 75.03 % is better than the conventional finger palm shelling method which has been reported to have 12.63 kg/hr average kernel shelling capacity and 100 % shelling efficiency. The average level of visible grain damage to the detached kernels recorded was 1.3 %. Thus the sheller seems to solve the problem that rural and small scale farmers regarding maize shelling.

4.2 Recommendation

In comparison with conventional finger palm shelling method, the sheller has a better output capacity, reasonable shelling efficiency and kernel damage. It is therefore recommended to demonstrate and pre-scale it up to solve the problem rural and small scale farmers are facing for maize shelling at small scale levels.

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