DESIGN AND CONSTRUCTION OF A MANUALLY OPERATED COWPEA DEHULLER WITH GRINDER

BY

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NOVEMBER, 2006.

DECLARATION

I hereby declare that this project is a record of a research work that was undertaken and written by me. It has not been presented before for any degree or diploma or certificate at any University or Institution. Information derived from personal communications, published and unpublished works of others were duly referenced in the text.

Zubairu Abdulmalik

10/11/06

Date

CERTIFICA TION

This project entitled "Design and Construction of a Manually Operated Cowpea Dehuller with Grinder" by Zubairu Abdulmalik meets the regulations governing the award of the degree of Bachelor of Engineering (B.ENG) of the Federal University of Technology, Minna and it is approved for its contribution to scientific knowledge and literary presentation.

....10/11/06.....

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DEDICATION

This project is dedicated to my parents Mallam Zubairu and Mallama Ayishat and to all the Zubairu's family and friends.

ABSTRACT

The extraction of cowpea seeds in the preparation of various food items for domestic use or by food vendors as remained a tedious operation up till now. A manually operated cowpea dehuller with grinder was designed with mild steel shafts, auger housing, grinding disc, hopper, spault, stand and crank handle which was substituted for the dehulling with hand, grinding stone and mortar that are labourious, time consuming and higher in losses. The dehulling unit composed of a screw conveyor, which consists of a shaft that carries helicoids flighting on its outer surface, was used, and this was enclosed in a horizontal cylindrical tube. The volumetric efficiency of the screw conveyor was determined to be 98%. The dehulling efficiency of the machine at soaking time of cowpea seeds of 10 and 15minites were obtained to be 98.04% and 87.30% with grain recovery range of 99.5% and 96.73% respectively. A grinding efficiency of 94% was also obtained with 10minites soaked cowpea seeds.

AKNOWLEDGMENT

My profound gratitude goes to Almighty ALLAH the existence of the universe. And also to His prophet Muhammad (SAW).

My sincere appreciation goes to my supervisor Engr. A. C. Onuachu for his encouragement, love, moral and technical advice to make me successful in the project. My thanks also goes to Head of department Agricultural Engineering department Engr. Dr. (Mrs.) Z. D. Osunde, my lecturers in the department, Prof. Akin Ajisegiri, Engr. Dr. M. G Yisa, Dr. Adgidzi, Dr. Egharavba, Dr. Alabadan, Dr. O. Chukwu, Engr. Adewoye and the rest for their physical and spiritual support.

I acknowledged the love, care, attention and the guidance of my parents Mallam Zubairu and Mallama Ayishat and Mallama Fatima, I am grateful. I am thankful to my brothers and sister for standing by me throughout my program. I pray that Almighty Allah should reward you abundantly. The same thank goes to my spiritual father Sheik Yahaya and Sheik Usman. I also appreciate the effort of my uncle mall Yakubu I.T.E department FUT Minna, for his financial and moral support.

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NOMENCLATURES

ROMAN LETTER

SYMBOL	MEANING
d	Diameter
e	Distance
F	Force
g	Torsional modulus of elasticity
H	Height
h	Truncated height
K	Combined shock and fatigue factor
L	Length
M	Moment
m	Mass
n	Angular speed
Q	Capacity
R	Reaction
S	Stress
T	Time
V	Volume
w	Load
X	Distance

GREEK LETTERS

ρ	Density
Θ	Angle of twist
μ_1	Material-metal friction
μ_2	Material-material friction
η	Efficiency
N	Diameter

SUBSCRIPT

a	Actual
b	Bending
sf	Screw flighting
ss	Screw shaft
t	Torsion
v	volume

OPERATORS

$\frac{d}{dx}$	Differentiation

ABBREVIATIONS

B.M	Bending Moment
G.R.R	Grain Recovery Range
N.C.A.M	National Center for Agricultural Mechanization
S.F	Shear Force
T.D	Time of Dehulling
W.B.S	Weight of Broken Seed
W.S.C	Weight of Seed Coat
W.S.D	Weight of Seed Dehulled
W.S.I	Weight of Seed Introduced
W.S.N.D	Weight of Seed Not Dehulled

CHAPTER ONE

INTRODUCTION

1.1 Relevance and importance of dehuller

Cowpea dehuller with grinder is a machine that removes the outer layer that covers the cowpea seed and also capable of grinding the seeds after it have been separated from the seed coat. This machine is designed to reduce the energy and time wastage experienced by the Africa woman during the process of dehulling. Traditionally, it is either done by hand through rubbing the palms together so that the soaked beans in between the palms is dehulled or by pounding the soaked cowpea in mortar and later adding excess water sinks the cowpea seed down and the coats stay on the surface, the two are then separated using a sieve. These two methods are good means of dehulling, but they consume a lot of energy and waste time.

In recent times, the Nigerian housewife, especially workingwomen in urban areas, are getting used to mechanical aids in the kitchen. Such operations like flower mills for cassava and yam flour, melon and pepper grinding and boiled yam pounding for Iyan are now mechanized, hence, the evolution of mechanical aids for dehulling of beans becomes essential.

Cowpeas are mostly used as consumed food crop as in bean soup "Gbegiri" also called "sansany" in Nupe land (Nigeria). It is also used in preparation of other dishes such as "adayi" (Ghana), "awalowalo" (Senegal) and in Indian; they are commonly used for "dhal" (Macmillan 1991). In other to process cowpea into these edible forms, the cowpea seed need to be dehulled and this machine makes that easy and faster with less labour. Cowpea dehuller with grinder is designed to encourage those who are interested in preparing either steamed cake "Moin-moin" or fried bean cake "Akara" all in Nigeria, but are scaring because of the labour involved in dehulling and looking for grinder for grinding the beans after dehulling and separation

Attention is given to only cowpea in this design because they are of the most important crops in Africa, which produces over 95percent of the world crops. Nigeria is the biggest producer in Africa. She produces about 850,000 tones in 1975; Brazil is the largest producer in Latin America producing 1meter per year. In this report, an attempt is made to improve the existing methods of dehulling and time waste in going for grinder by replacing those methods with a manually operated cowpea dehuller with grinder.

1.2. Existing methods of dehulling

Generally there are three common methods of dehulling cowpea, and these are;

1. The use of grinding stone
2. Use of hand
3. Use of mortar and pestle

The operation generally requires soaking the beans in water for some minutes, prior to dehulling for any of the above methods. Housewives and food vendors carry out these operations daily.

1.2.1 The use of grinding stone

Soaked cowpea seeds are placed on the wider stone with the smaller stone allows resting on top of them. The smaller stone is then moved continuously forward and backward pressing the cowpea seeds until the seeds in between the stones are dehulled. This method wastes a lot of cowpea and is unhygienic.

1.2.2 Use of hand

This is done through rubbing the palms together so that the soaked cowpea seed in between the palms are dehulled. This process requires a lot of human labour, time waste and it is of less sanity

1.2.3 Use of mortar and pestle

Mortar and pestle is also used for dehulling cowpea it is done by pounding the soaked cowpea seeds inside the mortal. This pounding process remove the coat from cowpea seed while some cowpea seeds are grinded together during the process and that result to less efficiency of this method apart from its being energy and time consumable

1.3 Types of cowpea

Cowpea, which is also known as vigna unguiculata (botanically), is one of the most important legumes grown in West Africa. It is an annual crop and is one of the major sources of protein in the West African diet. Cowpeas are grown mainly for food. The seeds may be white, red, brown or mottled, and the size of seeds is also variable. It is of different variety; we have cherry bean which is an annual grassy plant, low gravity, bushy or slightly climbing and tap roots

Another variety of cowpea is the black-eye pea it is cheaply cultivated in Africa. The plant is erect or trailing with climbing top. The asparagus pea, which is annual climbing with long stem, is also another variety of cowpea.

1.3.1 Vegetative and ecological requirement

The earliest ripening varieties of cowpea vegetates within 60 to 80 days, 80 to 120 days is the medium ripening and 120 to 150 days is the late ripening varieties.

The ecological requirements of cowpea are in many ways similar to those of cereals. An important different however lies in its higher protein content a factor which makes future expansion of its cultivation highly desirable.

1.4 Statement of research problem

Dehulling of cowpea is supposed to be in a hygienic condition to protect human health. Therefore the existing method of dehulling cowpea may have the following disadvantages:

1. The cowpeas during those processes are not to certain extent free from germ and disease attack.
2. Women drudgery in the field of processing (Stanton, 1962)
3. Low dehulling efficiency resulting from losses during the process
4. High labour and time involve, reduce the use of cowpea in many homes.

From the problems stated above, it is true that most of these problems are put to nearest minimum by the use of dehuller with grinder.

Stanton (1962) stated that the care for the crop in many Nigeria agriculture is assigned to women while Holfen (1981), indicated that generally, separation of shaft and husk from grains present a difficult problem as the operation depends on aero or hydro dynamic properties of the product of dehulling or threshing.

1.5 Objectives

The main objective of this project is to design and construct a cowpea-dehulling machine. The specific objectives of the project are as follows:

a. To construct a manually operated cowpea dehuller with grinder.

b. To design an auger as the conveying mechanism and dehulling device for production of the dehulled cowpea.

c. To carryout performance evaluation test on the constructed machine.

1.6 Justification of the project

As discussed earlier, cowpea seed can be removed by the use of hand, grinding stone or mortar but the labour, time and losses experienced during any of these methods is high and the process is less of hygiene.

The other method is the use of dehuller with grinder, which makes dehulling easier compared to the traditional methods. Dehuller with grinder tends to reduce losses, save time and energy, eliminates backaches and improve the hygienic condition under which cowpea is being dehulled. Dehuller with grinder reduces the labour involved in preparing steamed cake "moin-moin", fried bean cake "Akara" and bean soup "sansany" in Nupe land, all in Nigeria. Also, cowpea dehuller with grinder add to the numerous contribution of modern technology to agriculture especially in the aspect of food processing and, encourage the planting of more cowpea since there is an easier and cheaper way of dehulling in order to process it into any edible form.

CHAPTER TWO

LITERATURE REVIEW

2.1 Concept of seed dehulling

Basically, the dehulling of cowpea is the removal of its seed coat (outer layer). The care for the crop in much Nigeria agriculture is assigned to women (Stanton, 1962).

According to Sefa-Dedeh *et al.* (1979), the ease of wet dehulling of cowpea is with absorbed moisture. The apparent modulus of elasticity and deformity reduces with increase in Kernel moisture content for maize (Mosheim, 1979). Reigher *et al.* (1979) reported that the ease of dehulling increases with soaking time for maize. These are applicable to cowpea as it composed of an endosperm and seed coat like maize.

Holfen (1981) concluded that generally, separation of chaff or husk from grains present a difficult problem as the operation depends on aero or hydro-dynamic properties of the product of threshing or dehulling. Oladoja (1990), worked on the development of cowpea dehuller/cleaner based on the compression and shear in an off-center drum for dehulling, friction on belt separation and a dehulling efficiency of less than 50% for 2-5 minutes of soaking was observed for the machine. Olufeagba (1991) carried out the same work and reported about 80% dehulling efficiency with a manual dehulling machine.

Also, in India, Sun drying or perching method is used. In this method, the seeds are mixed with small quantity of oil and the sun dried to loosen the seed coat on a large scale. Passing the seed through coated rollers to scratch the surface facilitates penetration of the oil. After two to five days sun drying, the seed coats are removed by roller or hard operated "chalalas" (horizontal mill) at this stage, about half of the seeds are dehulled and most are split.

The process of sun drying and oiling is repeated until all the beans are milled into "dhal" (Macmillan, 1991)

2.2 Basic principles of dehulling

According to chakraverty (1988), the principle of dehulling may be described as depending on one or a combination of the following factors:

1) The compression and shear used in splitting and removing the husk from grain concave types of dehulling machines or rubber rolls employ these principles.

2) Abrasion and friction.

3) Impact and friction that are used. With varying results. Hahn (1970) described the used of roller mills for sorghum but with limited usefulness. Impact machines are useful for dry milling like maize.

2.3 Cowpea dehulling machine

According to olufeagba (1991), oladoja (1990), developed cowpea dehuller based on the compression and shear in an off-center drum. NCAM Ilorin, Nigeria, worked on seed testa dehuller using screw conveyor as the dehulling mechanism.

2.3.1 Cowpea dehuller based on the compression and shear in an off-center Drum

Oladoja (1990) and Olufeagba (1991), worked on the development of cowpea dehuller/cleaner based on the compression and shear in an off-center drum for dehulling and friction on belt separation. A dehulling efficiency of less than50% for 2-5 minutes of soaking was observed for the machine, while about 80% dehulling efficiency was obtained with a manual dehulling machine (Olufeagba, 1990).

2.3.2 NCAM seed testa dehuller

National center for Agricultural Mechanization Ilorin, Nigeria (NCAM), worked on seed testa dehuller with 25-30kg soaked seed/hr capacity. It uses screw conveyor as the dehulling mechanism. The screw conveyor consists of a shaft, which carries helicoids flightings on its outer surface.

2.4 Method and equipment of screw conveyor

According to Ajit *et al.* (1993), the auger length is defined as the length of the tube assembly including any intake but not including the intake hopper and/or the head drive. The intake length is the visible flighting at the intake of the auger. The outside diameter of the tube is referred to as the auger size. A standard pitch auger is the one whose pitch is approximately equal to outside diameter of the helicoidal flighting. Generally, the pitch is not less than 0.9 and not more than 1.5times the outside diameter. Standard pitch augers are used for horizontal and up to 20^0 inclination angles. For inclination angles greater than 20^0, half standard pitch screws are used.

2.4.1 Performance

The performance of a screw conveyor, as characterized by its capacity, volumetric efficiency and power requirements, is affected by the conveyor geometry and size, the properties of the material being conveyed, and the conveyor operating parameters such as the screw speed and the angle of inclination (Ajit *et al.,* 1993).

2.4.2 Capacity

Screw length has no effect on the capacity. There is a limiting value of speed beyond which the capacity does not increase. Infact it may even decrease beyond a certain speed. The capacity decreases as the angle of inclination increases. The limiting value of speed is independent of the angle of inclination. It has been suggested that there may be two factors responsible for this behaviour;

a) The maximum possible rate of grain flow through an orifice; and

b) The centrifugal force due to the rotation of grain mass. If the speed is increased sufficiently, the centrifugal force may become so restrictive as to cause a decline in the capacity.

2.4.3 Volumetric efficiency

Brusewitz and Persson (1969), reported that the screw clearance affects the volumetric efficiency. The dimentral clearance p to 5-7% have little effect on the volumetric efficiency but a drop in efficiency of 0.7% per 1% increase in clearance can be expected. No interaction of the conveyor inclination, volumetric efficiency decreases as the screw speed and the angle of inclination increases.

2.4.4 Power requirement

The effect of screw diameter on specific power as defined earlier is dependent on the speed. At low speed there is a decrease in the specific power with increase in the screw diameter. The trends reverse with higher speeds. Screw length has no effect on specific power. There is slight effect of the pitch on the specific power. For horizontal augers an increase in the dimentral clearance causes a slight decline in a general increase in power.

An increase in screw speed result in the increase in the required power. Increasing the angle of inclination causes the power to increase initially but a decrease follows beyond a certain angle. This is due to decline in the volumetric efficiency. Moisture content, which is associated with increase in friction, causes the power to increase significantly (Brusewitz and person, 1969)

CHAPTER THREE

DESIGN ANALYSIS AND DESIGN CALCULATION

3.1 Design analysis

For this manually operated cowpea dehuller with grinder a shaft is incorporated in the design. This shaft carries helicoid flighting on its outer surface, and transmitting power to the mill. The means of power transmission is through the use of crank, using an average human horsepower of 0.08kw.

3.1.1 Volume of hopper

The formula for caculating the volume of pyramid is shown below.

Where V is the volume.

V = ⅓ area of the base x height (3.1)

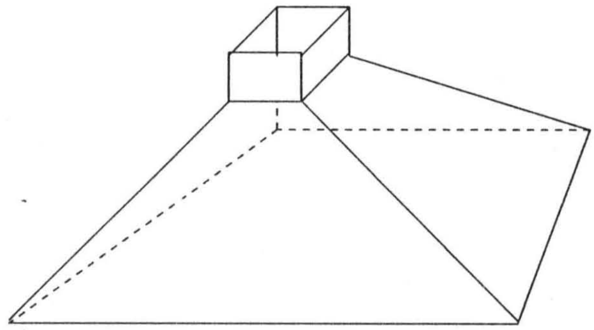


Fig 3.0 The Hopper

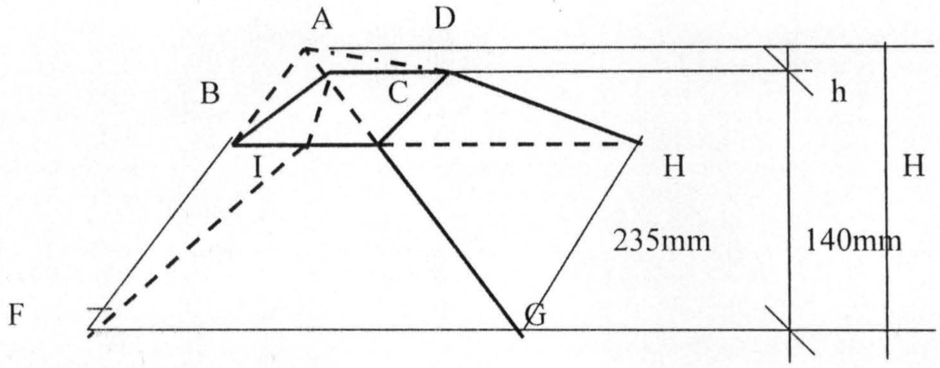


Fig 3.1 frustrum of pyramid

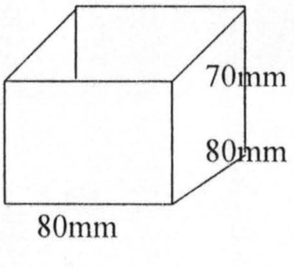


Fig 3 .2 Cuboid

Where H is the full height.

h is the truncated height.

The height can be calculated by using similar triangle.

Theorem $$\frac{h}{BC} = \frac{H}{FG} \quad (3.2)$$

Where H= h +140

Volume of the whole pyramid can be calculated using the formula.

V_L = ⅓area of base x height (3.3)

Where , V_L is the volume of whole pyramid (AFGHI). Volume of truncated pyramid can also be calculated using the formula

V_s = ⅓area of base x height (3.4)

Where Vs is the volume of truncated pyramid (ABCDE) and the volume of fig 3.2 on the frustrum can be calculated using the formula

V_c =Area of base x height (3.5)

Where V_c is the volume of fig 3.2

The total volume of hopper is calculated using the formula

$$V_T = (V_L - V_s) + V_c \quad (3.6)$$

Where V_T is total volume

V_L is volume of whole hopper.

V_s is volume of truncated hopper.

V_c is volume of fig 3.2

3.1.2 Mass of seed the hopper can accommodate

Mass of seed the hoper can accommodate can be calculated from the formula

$$m = \rho \times V \quad (3.7)$$

Where, m is the mass of seeds

ρ is the wet density of seeds

V is the volume of seeds

3.1.3 Determination of the reaction forces on the shaft

Fig 3.3 represents forces acting on the shaft with reaction at point A and

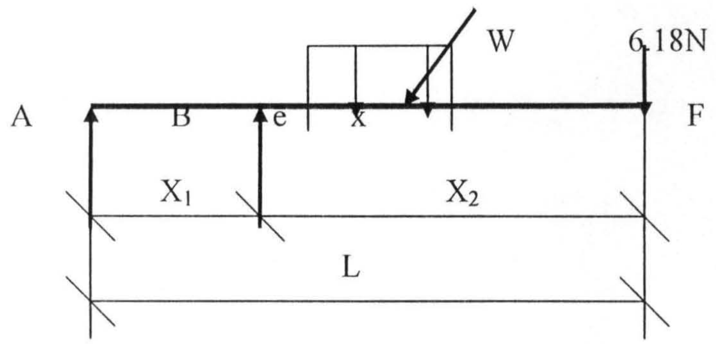


Fig 3.3 Reaction at points A and B of the shaft.

Taking moment about A, we have

$$R_B \times X_1 = WX \times (X_1 + e + X/2) + 6.18(X_1 + X_2) \quad (3.8)$$

And $$R_A + R_B = WX + 6.18 \quad (3.9)$$

Where, R_A is reaction at point A

R_B is reaction at point B

W and F are acting forces

X, X_1 and X_2 are distance of application

3.1.4 Determination of bending moment and shear force

All the forces acting on the shaft are presented in figure 3.4

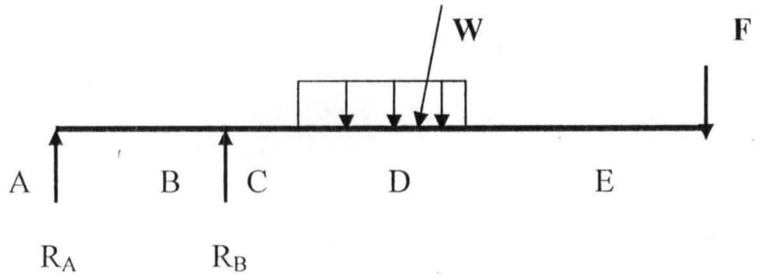
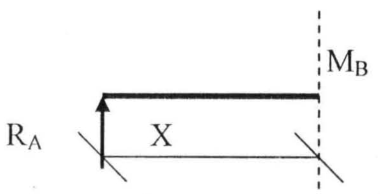


Fig 3.4 Sectioning of the shaft

Bending moment at B



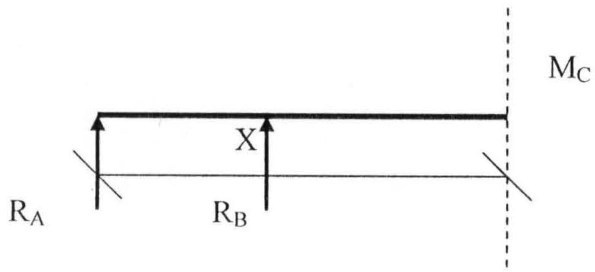
$M_B = R_A$ (3.10)

Where M_B is the bending moment at point B

R_A is the reaction at point A

X is the distance of application of force

Bending moment at C:



$$Mc = R_A X + R_B (X - X_1) \qquad (3.11)$$

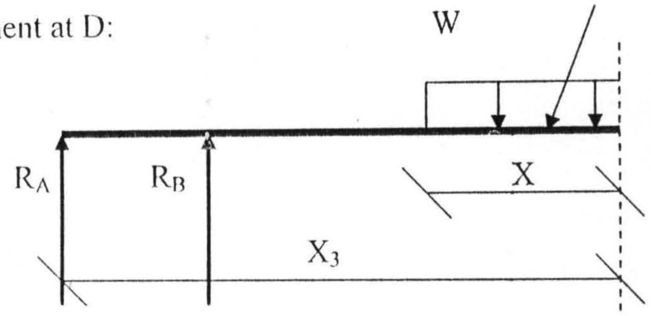
Where Mc is bending moment at point C

R_A and R_B are reaction at points A and B.

X is distance of application of reaction at point A.

X_1 is the distance between reaction R_A and R_B.

Bending moment at D:



$$M_D = R_A X_3 + R_B (X_3 - X_1) - WX (X_3 - (X_1 + e + X/2) \qquad (3.12)$$

Where, M_D is the bending moment at point D.

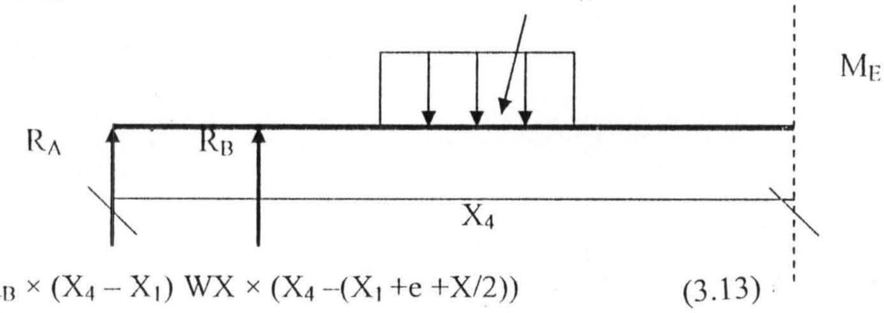
R_A and R_B are reaction at point A and B.

X_3 is distance of application of reaction A.

X_1 is distance between reaction A and B

X is the distance of application of load W

Bending moment at E:



$$M_E = R_A \times X_4 + R_B \times (X_4 - X_1)\ WX \times (X_4 - (X_1 + e + X/2)) \qquad (3.13)$$

$$M_E = R_A \times X_4 + R_B \times (X_4 - X_1)\ WX \times (X_4 - (X_1 + e + X/2)) \qquad (3.13)$$

Where, M_E is the bending moment at point E.

X_4 is the distance of application of reaction at A

R_A is the reaction at point A

W is the load acting on the shaft

X_1 is the distance between the two reaction forces

X is the distance of distribution of load.

Shear force can be calculated using the formula.

$$S.F = \frac{d\,(M_x)}{dx} \qquad (3.14)$$

Where S.F is the shear force

d/dx is differentiation

M_x is the bending moment of the section under consideration.

3.1.5 Determination of the diameter of the shaft.

Diameter of the shaft is calculated by the formula.

$$d^3 = 16/\pi Ss\sqrt{(K_bM_b)^2 + (K_tM_t)^2} \qquad (3.15)$$

Where d is the diameter of the shaft.

Ss is the allowable stress.

M_t is the torsional moment.

M_b is the bending moment.

K_b is the combined shock and fatigue factor applied to bending moment.

K_t is the combined shock and fatigue factor applied to torsional moment.

3.1.6 Torsional deflection

The torsional deflection of the solid circular shaft can be calculated using the formula

$$\Theta = 584 M_t L / G d^4 \qquad (3.16)$$

Where Θ is the torsional deflection or angle of twist

M_t is the torsional moment.

L is the length of the shaft.

G is the torsional modulus of elasticity.

d is the shaft diameter.

3.1.7 Volumetric efficiency of the screw conveyor

The volumetric efficiency of screw conveyor (auger) can be calculated using the Buckingham's π- theorem (Ajit et al., 1993)

$$\eta_v = 432 \times 10^{-6} (2\, \pi n \sqrt{l_p/g})^{-0.44} (l_i/l_p)^{0.31} [f_1 (\Theta)]^{1.35} (\mu_1)^{-4.59} (\mu_2)^{-3.72} \qquad (3.17)$$

Where, η_v is the volumetric efficiency.

n is the angular speed in rev/s.

l_p is the exposed screw intake length (m) or pitch length (m).

g is the acceleration due to gravity (m/s^2).

l_i is the intake length.

Θ is the angle of conveyor inclination (degree).

μ_1 is the material-metal friction.

μ_2 is the material-material friction, $f_1 (\Theta) = 1 + \cos^2 \Theta$

3.1.8 Volumetric capacity of screw conveyor.

The capacity of the screw (auger) conveyor can be calculated from Buckingham's π-theorem (Ajit et al., 1993)

$$Q_a = \eta_v \times \pi/4\ (d^2_{sf} - d^2_{ss})\ l_p n \qquad (3.18)$$

Where Q_a is the volumetric capacity of the screw conveyor.

η_v is the volumetric efficiency.

d_{sf} is the outside screw diameter (m).

d_{ss} is the screw shaft diameter (m).

l_p is the exposed screw intake length (m).

n is the angular speed (rev/s).

3.1.9 Power require of screw conveyor

According to Rehkugler and Boyd (1962), power requirement can be calculated as

$$P = 3.54\ (2\pi n\sqrt{l_p/g})^{0.14}(d_{sf}/l_p)^{0.11}\ [f_2\ (\Theta)](\mu_2)^{2.05}\ Q_a\rho_b gL \qquad (3.19)$$

Where, P is the power requirement (watt).

n is the angular speed (rev/s).

l_p is the exposed screw intake length (m).

g is the acceleration due to gravity (m/s^2)

d_{sf} is the outside screw diameter (m).

Θ is the angle of conveyor inclination (degree)

$f_2(\Theta) = 6.94(1.3 - \cos^2 \Theta)$

μ_2 is the material-material function.

Q_a is the volumetric capacity.

ρ_b is the material bulk density.

3.2 Design calculation.

3.21 Determination of volume of hopper.

The height of truncated pyramid can be calculated using equation 3.1

h/BC = H/FG

Where H = h+140

h = 140BC/FG-BC

Where BC=80m

FG=235mm

h=140 x80/235-80

h=72.26mm

From equation 3.2 volume of whole pyramid is given as

V_L=⅓ area of base × height.

Where area of base =235 x235=55225mm^2

height (H)=72.26+140=212.26mm

V_L=⅓ x 55225x 212.26

V_L=3907352.80mm^3.

Volume of truncated pyramid can be calculated from equation 3.3

V_s =⅓ × area of base × height

Area of base=80 × 80 = 6400mm^2

Height =h=72.26mm

V_s=⅓ × 6400 × 72.26

V_s =154514.67mm^3

From the equation 3.4, volume of cuboid can be calculated

V_c =Area of base × height

Where area of base =80 × 80 =6400mm^2

Height = 70mm

V_c = 44800mm^3

From equation 3.5, the total volume of hopper is given as

$V_T = (V_L - V_S) + V_C$

Where $V_L = 3907352.80mm^3$

$V_S = 154154.67mm^3$

$V_C = 448000mm^3$

$V_T = (3907352.80 - 154154.67) + 44800$

$V_T = 4201198.13mm^3$

3.2.2 Determination of mass of seed the hopper can accommodate

Dry cowpea seed 0.1kg occupies $155862.27mm^3$

Dry density = mass/volume

Where mass =0.1kg

Volume $=155862.27mm^3$

Dry density= $0.1/155862.27 \times 10^{-9}$

Dry density = 641.59kg/m

Choosing a moisture content of 50%wet basis,

$M_w = 50\%$ of $M_i + M_i$

Where M_w = mass of the seed after soaked

M_i = mass of dry seeds

M_w = 50% of 0.1+0.1

M_w = 0.15kg

Wet density = $0.1/155862.27 \times 10^{-9}$

Wet density = 962kg/m^3

From the equation 3.6 mass of the fluid is given as

$m = \rho \times v$

Where ρ = 962kg/m^3

V = 4201198.13mm^3

m = 4.04kg

3.2.3 Determination of the reaction forces on the shaft

Reaction at point B can be calculated using equation 3.7

$R_B \times X_1 = WX \times (X_1+e+X/2) + 6.18 \times (X_1+X_2)$

Where X_1= 0.13m

e = 0.02m

X = 0.08m

$X_2 = 0.21m$

$W = 39.63N/m$

$0.13R_B = (3.17 \times 0.19) + (6.18 + 0.34)$

$R_B = 2.7N$

From the equation 3.8 reactions at point A can be calculated

$R_A + R_B = WX + 6.18$

$R_A = WX + 6.18 - R_B$

Where $WX = 3.17N$

$R_B = 2.7N$

$R_A = 3.17 + 6.18 - 2.7$

$R_A = 6.65N$

3.2.4 Determination of bending moment and shear force

Bending moment at point B can calculated using equation 3.9

$M_B = R_A X$

Where $R_A = 6.65N$

$X = 0.13m$

$M_B = 6.65 \times 0.13$

$M_B = 0.8645Nm$

Bending moment at point C can be calculated using equation 3.10

$M_C = R_A X + R_B (X - X_1)$

Where $R_A = 6.65N$

$R_B = 2.7N$

$X = 0.15m$

$X_1 = 0.13m$

$M_C = (6.65 \times 0.15) + (2.7 \times 0.02)$

$Mc = 1.0515Nm$

Bending moment at point D can be calculated using equation 3.11

$M_D = R_A X_3 + R_B (X_3 - X_1) - WX [X_3 - (X_1 + e + X/2)]$

Where $R_A = 6.65N$

$R_B = 2.7N$

$X = 0.08m$

$X_1 = 0.13m$

$X_2 = 0.21m$

$e = 0.02m$

$X_3 = 0.23m$

$M_D = 1.5295+0.27-0.1268$

$M_D = 1.6727Nm$

Bending moment at point E can be calculated using equation 3.12

$M_E = R_A X_4 + R_B (X_4-X_1) - WX [X_4 - (X_1+e+x/2)]$

Where $R_A = 6.65N$

$R_B = 2.7N$

$X_1 = 0.13m$

$X_4 = 0.34m$

$e = 0.02m$

$WX = 3.17m$

$M_E = 2.261+0.567-0.15$

$M_E = 2.678Nm$

Shear force at each point can be calculated using equation 3.13

$S.F = d(Mx)/dx$

At point B,

$M_B = R_A X$

$S.F_B = R_A$

$S.F_B = 6.65N$

At point C,

$Mc = R_A X + R_B (X - X_1)$

$S.Fc = R_A + R_B$

Where $R_A = 6.65N$

$R_B = 2.7N$

$S.Fc = 6.65+2.7$

$S.Fc = 9.35N$

At point D

$M_D = R_A X_3 + R_B (X_3 - X_1) - WX [X_3 - (X_1 + c + X/2)]$

$S.F_D = R_A + R_B - WX$

Where $R_A = 6.65N$

$R_B = 2.7N$

$WX = 3.17N$

$S.F_D = 6.65+2.7-3.17$

$S.F_D = 6.18N$

At point E,

$M_E = R_A X_4 + R_B (X_4 - X_1) - WX [X_4 - (X_1 + c + X/2)]$

$S.F_E = R_A + R_B - WX$

Where

$R_A = 6.65N$

$R_B = 2.7N$

$WX = 3.17N$

$S.F_E = 6.65+2.7-3.17$

$S.F_E = 6.18N$

3.2.5 Determination of torsional moment.

Torsional moment (torque) can be determine using the formula

$M_t = 60P/2\pi N$

Where

M_t is the torsional moment

P is the power

P is 0.08KW [Human factor in engineering] and

N (revolution/min) is 30

$M_t = 60 \times 0.08 \times 03/(2\times \pi\times 30)$

$M_t = 25.47Nm$

3.2.6 The diameter of the shaft

The diameter of the shaft can be calculated from equation 3.14

$d^3 = 16/\pi Ss\sqrt{(K_bM_b)^2 + (K_tM_t)^2}$

Where

$Ss = 40MN/m^2$

$K_b = 1.5$

$K_t = 1.0$ [Theory and problem of machine design SI (metric edition)]

$M_t = 25.47Nm$ and $Mb = ME = 2.678Nm$ (calculated)

$d^3 = 16/\pi \ x40\ x10^6 \sqrt{(1.5\ x\ 2.678)^2 + (1.0\ x\ 25.47)^2}$

$d^3 = 3.283\ x10^{-6}$

$d = 0.01486m$

$d = 14.86mm$

Choosing the standard diameter d=15mm

3.2.7 Torsional deflection of the shaft

The torsional deflection of the shaft is calculated using equation 3.15

$\Theta = 584MtL/Gd^4$

Where

Mt = 25.47Nm

$G = 80 \times 109 N/m^2$ [SI (metric edition)]

L = 0.34m

$\Theta = 584 \times 25.47 \times 0.34/80 \times 109 \times (0.015)^4$

Θ=1.25degree

3.2.8 Screw conveyor design

3.2.8.1 Volumetric efficiency of the screw conveyor

The volumetric efficiency of the screw conveyor can be calculated using the formula

$\eta_v = 432 \times 10^{-6}(2\ \pi n\sqrt{l_p/g})^{-0.44}\ (l_i/l_p)^{0.31}[f_1(\Theta)]^{1.35}\ (\mu_1)^{-4.59}\ (\mu_2)^{-3.72}$

Where

$n = 3rev/s$ (from table)

$l_p = 0.018m$

$g = 9.81m/s^2$

$\Theta = 0^0$

$l_i = 0.08m$

$\mu_1 = 0.414$

$\mu_2 = 0.554$ [principle of agricultural machines]

The dimensionless groups are calculated as follows:

$2\pi n\sqrt{l_p/g} = 0.81$

$l_i/l_p = 4.44$

$f_1 (\Theta) = 1+\cos^2 \Theta = 2$

$\eta_v = (432 \times 10^{-6})(0.81)^{-0.44}(4.44)^{0.31} (2)^{1.35} (0.414)^{-4.59} (0.554)^{-3.72}$

$\eta_v = 0.98$

$\eta_v = 98\%$

3.2.8.2 Volumetric capacity of screw conveyor

Volumetric capacity of screw conveyor can be calculated from equation 3.17

$Q_a = \eta_v \times \pi/4(d^2_{sf}-d^2_{ss})l_p n$

Where

$\eta_v = 0.98$

$d_{sf} = 0.036m$

$d_{ss} = 0.03m$

$l_p = 0.018m$

$n = 3rev/s$

$Q_a = 0.98\pi/4(0.036^2-0.03^2) \times 0.018 \times 3$

$Q_a = 1.65 \times 10^{-5} m^3/s$

3.2.8.3 Power requirement of screw conveyor

Using equation 3.18

$P = 3.54(2\pi n\sqrt{l_p/g})^{0.14} (d_{sf}/l_p)^{0.11}[f_2 (\Theta)](\mu_2)^{2.05} Q_a \rho_b g L$

Where

$l_p = 0.018m$

$g = 9.81m/s^2$

$n = 3rev/s$

$d_{sf} = 0.036m$

$\mu_2 = 0.554$

$Q_a = 1.65 \times 10^{-5} m^3/s$

$\rho_b = 962kg/m^3$

$L = 0.34m$

The dimensionless groups are determine as

$2\pi n\sqrt{l_p/g} = 0.81$

$d_{sf}/l_p = 2.$

$f_2(\Theta) = 6.94(1.3-\cos^2 \Theta) = 2.1$

$P = (3.54)(0.81)^{0.14}(2)^{0.11}(2.1)(0.554)^{2.05}(1.65 \times 10^{-5})(962)(9.81)(0.34)$

$P = 0.123W$

Converting the required power to kilowatts

1kW=1000W

0.123W=0.123/1000

P=0.000123W

The machine requires 0.000123kW that is smaller than the average human horse power, 0.08kW, therefore, human being will be able to efficiently supply the power required without much stress

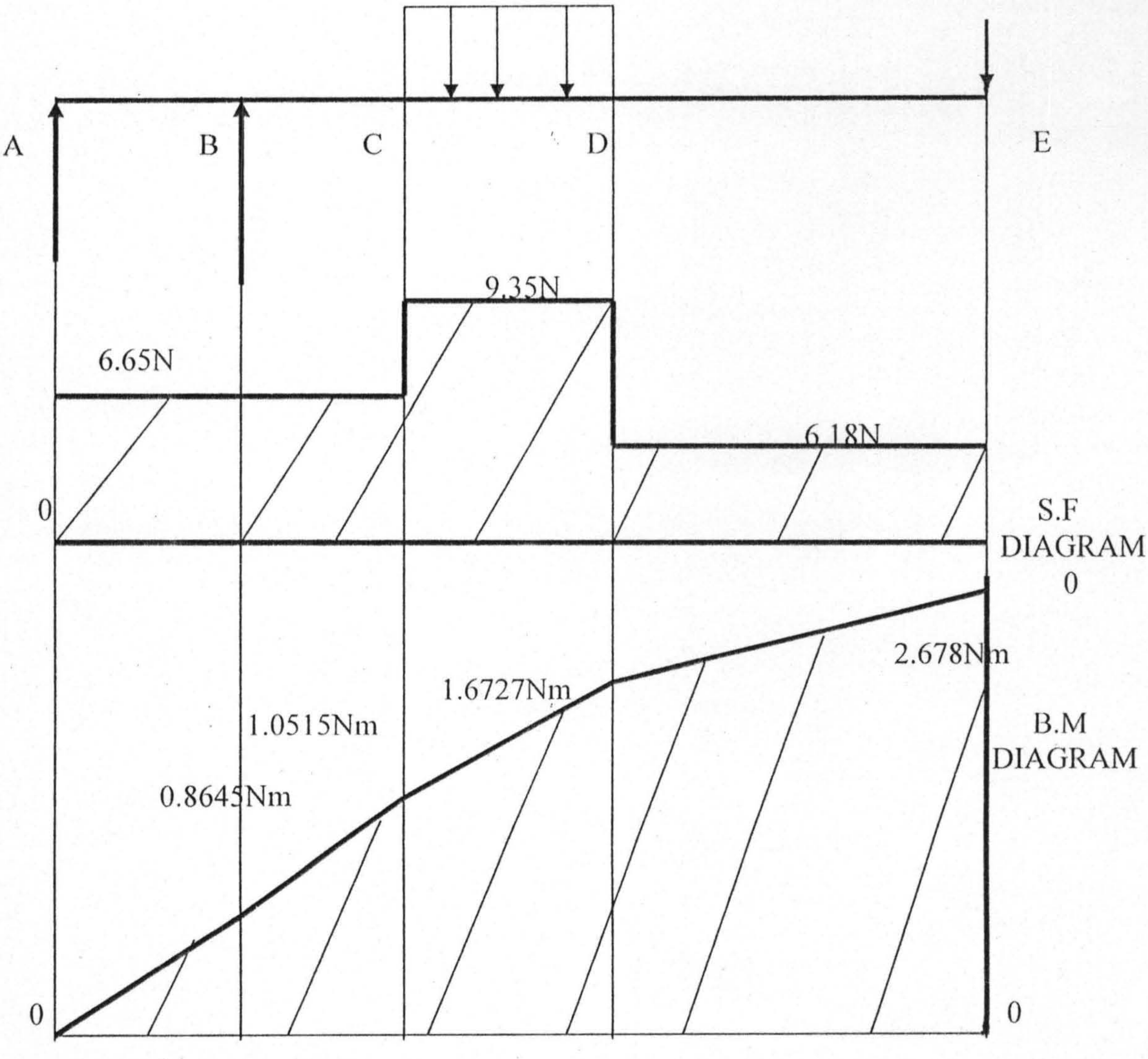


Fig 3.5 shear force and bending moment diagram of the shaft.

CHAPTER FOUR

MATERIAL SELECTION, CONSTRUCTION METHODS AND TEST PERFORMANCE

4.1 Material Selection.

Accessibility and availability of the material designed for, must be strictly considered for effective and resourceful design and susceptibility of the machine to various climatic condition.

Material selected for manufacturing different components of the machine will eventually influence the weight; portability, strength, and cost manufacture, it also influence the manufacturing process, and conditions in which the machine will be exposed without damage.

4.1.1 Factors affecting selection of materials

Factors taken into consideration in selecting the material for construction include

a. Cost of production:

Relatively cheap and available materials with close substitute were carefully chosen to reduce the cost of production, which is considered eventually to reduce the price of the machine by prospective buyer.

b. Cost of operation and operation safety:

The machine is designed for manure operation; the cost of operation is considerably minimized, except for the replacement and lubrication of bearing used.

c. Cost of maintenance:

Effective maintenance prolongs the useful life of the machine, the machine designed is of a low cost maintenance, the principle of operation is simple, and the main working component are bolted together to allow for easy removal during maintenance. The moving parts are exposed for easy lubrication.

d. Portability:

The compact configuration of the machine is an advantage for it easy transportation without much stress, and material with less weight were designed for to reduce the overall weight of the machine

e. Simplicity:

The machine is made simple to operate, so that a rural man or woman can operate it easily without having to learn much skill.

4.2 Material Selected for the Machine Parts

Table 4.1 contains material selected for the machine parts

Table 4.1 Materials selected

S/No	*Name of Component*	*Number of Required*	*Selected Materials*
1	Hopper and spault	1	Mild seed metal sheet (700 x 700 x 2mm)
2	Base	1	Angle bar ($1^1/_2$ x 600mm)
3	Sand	1	Angle bar (25 x 25mm half of full length; 18ft/2)
4	Angle Housing	1	Cylindrical mild steel pipe ϕ40 x 185mm)
5	Main Shaft	1	Mild steel shaft (ϕ30 x 500mm)
6	Conveyor shaft	1	Mild steel rod (ϕ5 x 900mm)
7	Grinding disc	2	Cast iron (ϕ120mm)
8	Crank handle	1	12mm mild steel rod

4.3 Construction Methods

4.3.1 The Grinding Unit

This unit consists of the grinding stone or disc, one fixed and the other rotating with the aid of the grinding plate. The construction of the driving plate of about 116mm diameter is cut and three holes equal diameter of 8mm and at equal interval is drilled on it, where the rotating grinding wheel will be fixed. The two grinding disc made of cast iron with high temperature.

4.3.2 The collecting unit

A spault is constructed on the grinding cover through which the grinded stuff is collected.

4.3.3 The hopper unit

The construction of the hopper unit is to serve as the housing to contain the material to be grinded to prevent wastage. It also directs the material into the dehulling unit.

Mild steel sheet of 2mm thickness is the material used for the construction of the hopper. This material was cut with shear to form trapezoidal like shape to make the direction for the foodstuff into the dehulling unit for each dehulling.

4.3.4 The dehulling unit

This unit consists of a main shaft, which carries conveying shaft (auger) on its outer surface. The auger is enclosed in a cylinder. The main shaft is made of a rod of 15mm thickness with length 500mm.

Conveyor shaft is a mild steel rod of diameter 5mm and 990mm in length. While the cylinder, which is the auger, housing is made of a 40mm diameter pipe of length 185mm.

4.3.5 operation of the machine

The soaked beans is fed into hopper while the crank handle is being turned. The turning of the crank rotates the auger, which moves and packs the soaked beans with its loose coats to the far side and discharge part of the dehulling unit

The dehulling is achieved by slight compression to the soaked beans. The combined axial and rotating motion imposed on the beans ensuring peeling off of the beans seed coat by abrasion through frictional contact.

4.4 Cost analysis

Cost estimation is the determination of the total manufacturing cost and consists of material cost, labour cost and some miscellaneous expenses. Cost of construction is greatly influenced by the present economic recession, which leads to exuberant rise in prices of materials.

In the construction of this machine, relatively cheap and available materials with its close of substitutes were carefully chosen to reduce the cost of production.

Table 4.2: Bill of material for the machine

S/No	*Material Description*	*Material Specification*	*Quantity*	*Unit Cost (₦)*	*Total Cost (₦)*
1	Mild Steel metal sheet	700 x700 x2.0mm	1	2500	2500
2	Steering	ϕ12 x 125mm	1	150	150
3	Solid shaft	ϕ 30 x 500mm	1	200	200
4	Cylindrical pipe	ϕ 40 x 185	1	300	300
5	Grinding disc	ϕ120mm	2	200	400
6	Bushing	ϕ20mm	2	100	200
7	Angle bar base	$1^1/_2$ x 600mm	1	250	250
8	Angle bar stand	25 x 25 x 5700mm	1	550	550
9	Electrode	Mild Steel electrode	2 dozens	100	200
10	Paint	Green	1 tin	250	250
11	Labour cost			1000	1000
12	Miscellaneous			500	500
		Total Cost			6500

4.5 Test Performance

4.5.1 Test Procedure

The performance test of the machine was carried out to evaluate its efficiency based on dehulling efficiency, breakage percentage, losses percentage, as well as the grain recovery range.

300g of soaked cowpea seed (black – eye pea) for 10 minutes was introduced into the hopper of the machine the cowpea was dehulled, and seeds separated from seed coat. Time taken for dehulling was noted. The output from the outlet were collected and analyzed. The procedure was repeated for one more time.

The same quantity of soaked cowpea seed at 15minutes soaked was taken and the above procedure repeated. The results of the test performance are as shown in table 4.3 and 4.4, and used to determine dehulling efficiency, percentage breakage and percentage losses.

a) Dehulling efficiency $= \frac{\text{weight of dehulled cowpea seeds x 100}}{\text{sum of weight of dehulled, not dehulled\& broken cowpea seed}}$

b) Percentage breakage $= \frac{\text{weight of broken seeds x 100}}{\text{Sum of weight of dehulled, not dehulled \&broken seeds}}$

c) Percentage losses $= \frac{\text{W.S.I- (W.S.D+W.S.N.D+W.B.S+W.S.C) x100}}{\text{W.S.I}}$

c) Grain recovery (GRR) This is expressed as the difference between 100 percent and percentage total loss (Isyaku, 2005)

d) GRR = 100 -% Total losses

e) Grinding efficiency $= \frac{\text{mass of material after grinding x 100}}{\text{mass of material before grinding}}$

4.5.2 Test results

Table 4.3: Performance Data of the Dehuller at 10 minutes Soaked

W. S. I. (g)	*W. S. D. (g)*	*W. S. N. D (g)*	*W. B. S.(g)*	*W. S. C. (g)*	*T. D. (s)*
A	B	C	D	E	T
300	250	0	5	43.5	128

$$\text{Dehulling Efficiency} = \left[\frac{B}{(B+C+D)}\right]\times 100 = \left[\frac{250}{255}\right]\times 100 = 98.04\%`$$

$$\text{Percentage breakage} = \left[\frac{D}{(B+C+D)}\right]\times 100 = \left[\frac{5}{255}\right]\times 100 = 1.964\%$$

$$\text{Percentage losses} = \left[\frac{A-(B+C+D+E)}{(A)}\right]\times 100 = \left[\frac{1.5}{300}\right]\times 100 = 0.5\%$$

GRR = 100 - % TOTAL LOSSES = 100 – 0.5% = 99.5%

$$\text{Mass Flow Rate} = \frac{A}{T} = \frac{300}{128} = 2.34\text{g/S} \ (8.42\text{kg/hr})$$

Table 4.4: Performance data of the dehuller at 15 minutes soaked

W. S. I. (g)	*W. S. D. (g)*	*W. S. N. D (g)*	*W. B. S.(g)*	*W. S. C. (g)*	*T. D. (s)*
A	B	C	D	E	T
300	220	2	30	38.2	125

$$\text{Dehulling Efficiency} = \left[\frac{B}{(B+C+D)}\right]\times 100 = \left[\frac{220}{252}\right]\times 100 = 87.30\%$$

$$\text{Percentage breakage} = \left[\frac{D}{(B+C+D)}\right]\times 100 = \left[\frac{30}{252}\right]\times 100 = 11.90\%$$

$$\text{Percentage losses} = \left[\frac{A-(B+C+D+E)}{(A)}\right]\times 100 = \left[\frac{9.8}{300}\right]\times 100 = 3.27\%$$

GRR = 100 - % TOTAL LOSSES = 100 – 3.27% = 96.73%

$$\text{Mass Flow Rate} = \frac{A}{T} = \frac{300}{125} = 2.4\text{g/S (8.64kg/hr)}$$

$$\text{Grinding Efficiency} = \left[\frac{m_2}{m_1}\right]\times 100`$$

Where:

m_1 is the mass of dehulled material (10 minutes soaked) before grinding = 220g

m_2 is the dehulled material (10 minutes soaked)after grinding = 207g

$$\text{Grinding Efficiency} = \frac{207}{220}\times 100 = 94\%$$

$$\text{Mass flow for grinding} = \frac{m_1}{Time} = \frac{220}{120} = 1.83\text{g/s (6.58kg/hr)}$$

4.5.3 Discussion

Cowpea seed of variety black-eye pea (which is cheaply cultivated in Africa), direct from the market, when soaked for 10 and 15 minute in water were used to determine the various parameter of dehulling. The performance data of the dehuller at 10 and 15 minute soak are shown on the table 4.3 and 4.4 respectively.

The dehulling efficiency of about 98.04% was achieved when the seeds were soaked for 10 minutes, and percentage breakage, percentage losses and grain recovery range were found to be 1.96% and 99.5% respectively. For 15minites of seed soaked, the efficiency of dehulling was noted to be 87.30%, less than when the seed were soaked for 10minites. 11.90%, 3.27% and 96.73% were achieved for percentage breakage; percentage loses and grain recovery range.

From the above, the machine dehulled black-eye pea at 10minites soaked. That is seeds soaked for about 10minites will produce a better dehulling product.

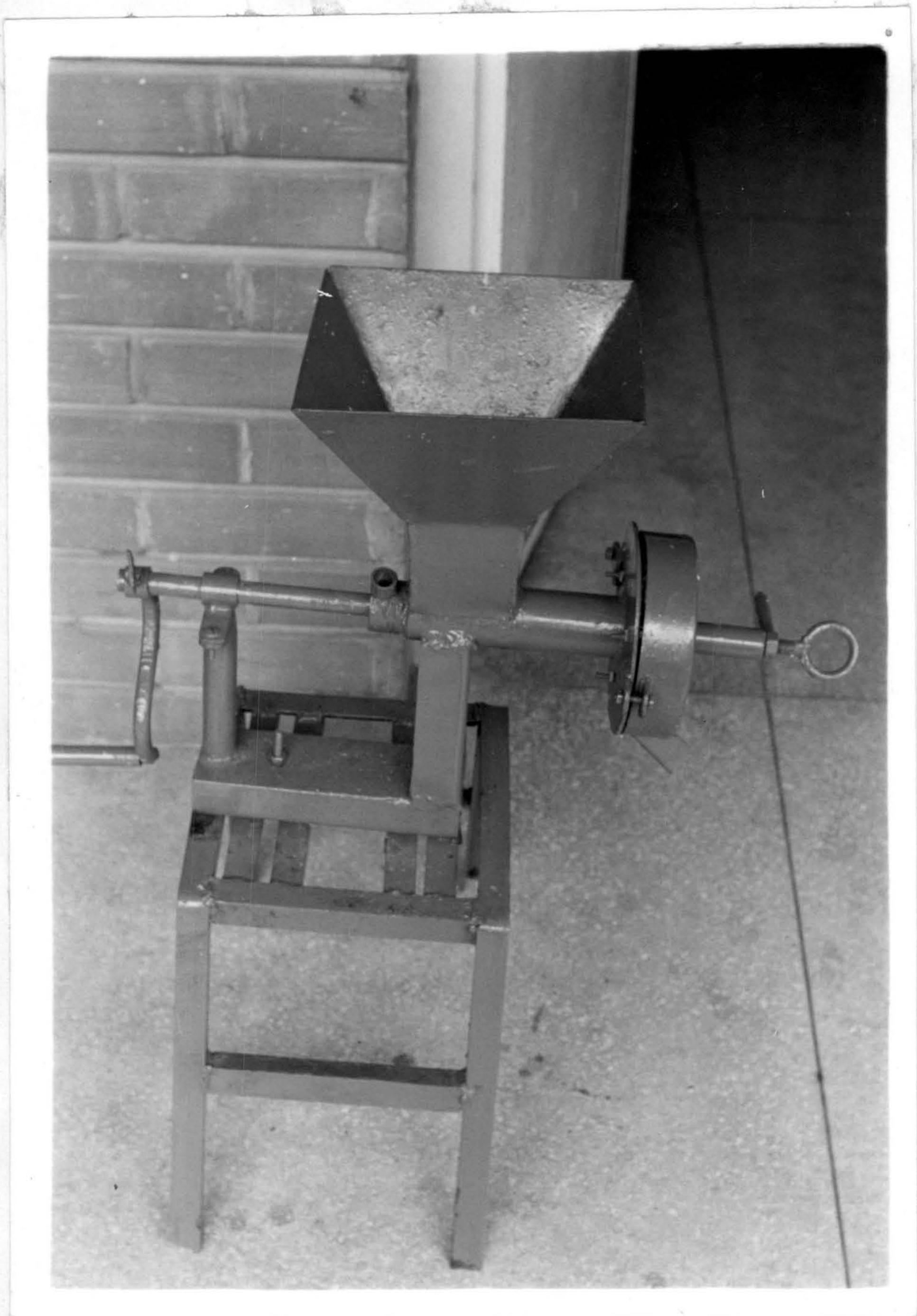


Plate1: Manually operated cowpea testa dehuller with grinder

Plate2: Samples of dehulled and grinded cowpea

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The machine was designed from local available materials to reduce the energy and time wastage experience by African women during the process of dehulling, since the care for the crop is assigned to women. From the design consideration and analysis, portability, simplicity of operation by a rural man or woman, cost of construction and power required for operating the machine were given favourable consideration during the design and fabrication process. The volumetric efficiency of the auger had been determined to be 96%, while dehulling efficiency and grinding efficiency were found to be 98.04% and 94% when the machine was subjected to test with 10 minutes of soaked cowpea seeds.

5.2 Recommendations

To improve upon the performance of the machine the following recommendations are to be considered for further work.

. Proper maintenance of the machine can be ensured by timely lubrication of the bearing, steering and dismantling of the machine for cleaning the barrel to prolong the useful life of the machine.

. Efficiency of the dehulling operation can be increased by using the steering to reduce the distance between the two discs.

. A separate unit where the seeds will be separated from their coats can be incorporate into the machine for further design.

. A separate power unit such as electric motor can be attached to promote the efficiency of the machine and increase the rate of work.

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