

## **Design and Fabrication of Groundnut Shelling and Separating Machine**

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**ABSTRACT :** *This work focused on the design and fabrication of a groundnut shelling and separating machine electrically powered by a 1hp motor. The machine has the capacity of shelling 400kg of groundnut per hour with a shelling and separating efficiencies of 95.25% and 91.67% respectively. The machine was fabricated from locally sourced materials, which makes it cheap and easily affordable and also easy and cheaper to maintain. It is also of light weight and comprises of the hopper, crushing chamber, separation chamber and the blower unit. During the process of testing, it was observed that majority of the groundnut pods that came out unshelled or partially shelled were the ones with one seed per pod and those with two small seeds in their pods.*

**KEYWORDS:** *Design and fabrication, groundnut shelling, separating machine, locally sourced materials.*

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### **I. INTRODUCTION**

Groundnut is the sixth most important oilseed crop in the world. It contains 48-50% oil and 26-28% protein, and is a rich source of dietary fiber, minerals and vitamins. It grows best on soils that are well drained, loosely textured and well supplied with calcium, potassium and phosphorus. Over 100 countries worldwide grow groundnut. Developing countries constitute 97% of the global area and 94% of the global production of this crop. The production of groundnut is concentrated in Asia and Africa (56% and 40% of the global area and 68% and 25% of the global production, respectively) [1]. Shelling is the removal of grains from their stalk, pod or cub, either by stripping, impact action and rubbing or any combination of these methods. The most popular method of shelling which is still widely used in the northern part of Nigeria is the method of crushing or pressing the pods between the thumb and the finger to break off the pods and release the seed. This method has low efficiency, it is time consuming, and has high demand of energy. In addition, the output per-man hour is as low as 1-2.5kg of groundnut.

There are different methods of shelling and different machines have been fabricated and used to shell wide variety of crops under different conditions ([2]; [3]; [4]; [5])). The peasant farmer cannot afford these machines because they are too costly and complex in operation and maintenance. Also the operator had to be trained and spare parts imported. These factors increase the overall cost of production which does not make any economic sense to the farmer. Hand operated shelling machine which is of concave or semi-rotary design is widely used locally. It had no expelling unit; hence separation is achieved by winnowing. A simple hand operated groundnut Sheller has a semi-cylindrical screen closed on both sides. A shaft carrying a lever at one end is fixed across the centre of the semi-cylinder. On the lever is a pair of plate with shoes or beater bars, having blunts on their undersides. For successful operation of the machine, the operator stands by the side, then holding the operating lever (handle) and swinging it by pushing to and fro to provide shelling action on the shoes assembly. The semi-rotary, action of the shoes shells the pods against the screen. The major short coming of this machine is that it is labour intensive and consumes lots of time. Output is about 60-80kg/hour. This particular design overcomes all those short comings and also has an improved efficiency. It comprises the hopper, crushing chamber, separation chamber and the blower unit. It is also powered electrically, which saves time and with a well improved shelling capacity. The machine is also light weight and easy to operate and maintain, the spare parts are also available locally.

## II. DESIGN ANALYSIS AND CALCULATIONS

### Determination of Power Required to Break the Groundnut Pods.

Considering a single spike, the torque required to drive the system may be obtained from the following expression:

$$T = n_a \times n_s \times F \times r \quad (1)$$

Where,

$n_a$  = number of active anchor at a time = 5

$n_s$  = number of spike per anchor = 7

$F$  = force per spike required to break the groundnut pod

$r$  = distance from the axis of rotation to the point of action of the force = 0.11m

The average force required to break the groundnut pod is 2N. From equation (1), we get

$$T = 5 \times 7 \times 2 \times 0.11 = 7.7 Nm$$

The power required in breaking the pods in the shelling chamber may be obtained from

$$P = T \times \omega_2 = T \times \left( \frac{\pi \times N_2}{30} \right) \quad (2)$$

Where,

$N_2$  = speed of rotation of the driven shaft = 240rpm

From equation (2), we get

$$P = 7.7 \times \left( \frac{\pi \times 240}{30} \right) = 193.52 W$$

### Determination of Spike Diameter

The loading on each spike is taken to be that of a concentrated intermediate load on a cantilever. Hence the deflection on it is

$$y = \frac{F \times a^4}{8 \times E \times I} (a - 3 \times l) = \frac{64 \times F \times a^4}{8 \times E \times \pi \times d^4} (a - 3 \times l) \quad (3)$$

From equation (3), we get

$$d = \sqrt[4]{\frac{8 \times F \times a^4}{E \times \pi \times y} (a - 3 \times l)} \quad (4)$$

Where

$d$  = spike diameter

$y$  = deflection =  $-5 \times 10^{-10}$  m

$E$  = modulus of elasticity =  $200 \times 10^9$  N/m<sup>2</sup>

$a$  = radius of the spike = 0.01

$l$  = length of the spike = 0.02m

$$d = \sqrt[4]{\frac{8 \times 2 \times 0.01^4}{200 \times 10^9 \times \pi \times (-5 \times 10^{-10})} (0.01 - 3 \times 0.02)} = 2.99 m$$

A diameter of 4mm was selected for use.

### Determination of Pulley Diameters

The diameters of the pulleys may be determined from the relation

$$N_1 D_1 = N_2 D_2 \Rightarrow \frac{N_1}{N_2} = \frac{D_2}{D_1} \quad (5)$$

Where,

$N_1$  = speed of driving pulley = 1440rpm

$N_2$  = speed of driven pulley

$D_1$  = diameter of driving pulley = 0.04m

$D_2$  = diameter of driven pulley

From equation (5), we get

$$D_2 = \frac{N_1 D_1}{N_2} = \frac{1440 \times 0.04}{240} = 0.24 \text{ m}$$

**Determination of Tension in the Belt.**

For a v-belt, the relationship between tension  $T_1$  and  $T_2$  is given by [6]

$$2.3 \log \left( \frac{T_1}{T_2} \right) = \mu \theta \cos ec \beta \tag{6}$$

Where,

$\mu$  = coefficient of friction between the belt and side of groove = 0.25

$\theta$  = angle of contact on the smaller pulley = 2.75rad

$\beta$  = half angle of groove = 17.5°

$T_1$  = tension on the tight side

$T_2$  = tension on the slack side

From equation (6), we get

$$\frac{T_1}{T_2} = \log^{-1} \left( \frac{\mu \theta \cos ec \beta}{2.3} \right) = \log^{-1} \left( \frac{0.25 \times 2.75 \times \cos ec 17.5}{2.3} \right) = 9.86 \Rightarrow T_1 = 9.86 \times T_2 \tag{7}$$

Torque transmitted is given by

$$T = (T_1 - T_2) \times R_1 \tag{8}$$

Where,

T = torque transmitted

R = radius of pulley = 0.12m

From equation (8), we get

$$\frac{T}{R_1} = 8.86 \times T_2 \Rightarrow T_2 = \frac{T}{8.86 \times R_1} = \frac{7.7}{8.86 \times 0.12} = 7.24 \text{ N} \tag{9}$$

Substituting equation (9) into equation (7), we get

$$T_1 = 9.86 \times T_2 = 9.86 \times 7.24 = 71.39 \text{ N} \tag{10}$$

**Determination of Bending Moments acting on the Shaft**

The forces acting on the shaft include: the weight of the crushing drum = 20N, the weight of the pulley attached to the shaft which drives the crushing drum, the resultant force effect of the belt tensions and the reactions at the bearings support. Fig. 1 shows the belt drive assembly.

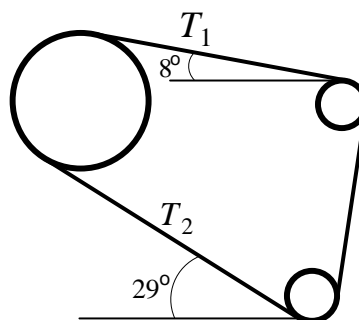


Figure 1: Belt drive assembly

$$F_V = T_1 \times \sin 8 + T_2 \times \sin 29 + W_p = 17.45 N \quad (11)$$

$$F_H = T_1 \times \cos 8 + T_2 \times \cos 29 = 77.03 N \quad (12)$$

Where,

$F_V$  = vertical load effect of the belt drive assembly

$F_H$  = horizontal load effect of the belt drive assembly

$W_p$  = weight of the crusher pulley = 4N

Fig.2 shows the vertical load diagram.

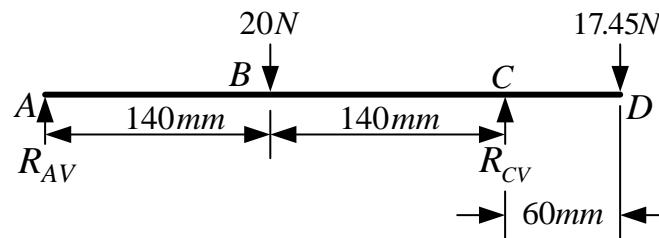


Figure 2: Vertical load diagram

Summing forces in the vertical direction gives:

$$R_{AV} + R_{CV} = 20 + 17.45 = 37.45 N \quad (13)$$

Taking moment about A, we get

$$R_{CV} \times 0.28 = 17.45 \times 0.34 + 20 \times 0.14 \Rightarrow R_{CV} = 31.19 N$$

From equation (13), we get

$$R_{AV} = 37.45 - R_{CV} = 6.26 N$$

From fig.2,

$$M_{AV} = 0 Nm$$

$$M_{BV} = 6.26 \times 0.14 = 0.88 Nm$$

$$M_{CV} = 6.26 \times 0.28 - 20 \times 0.14 = -1.05 Nm$$

$$M_{DV} = 6.26 \times 0.34 - 20 \times 0.20 + 31.19 \times 0.06 = 0 Nm$$

Fig.3 shows the horizontal load diagram.

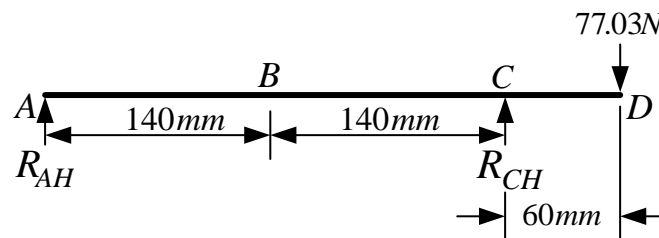


Figure 3: Horizontal load diagram

Summing forces in the horizontal direction gives:

$$R_{AH} + R_{CH} = 77.03 N \quad (14)$$

Taking moment about A, we get

$$R_{CH} \times 0.28 = 77.03 \times 0.34 \Rightarrow R_{CH} = 93.54 N$$

From equation (14),

$$R_{AH} = 77.03 - R_{CH} = -16.51 N$$

From fig.3,

$$M_{AH} = 0 Nm$$

$$M_{BH} = -16.51 \times 0.14 = -2.31 Nm$$

$$M_{CH} = -16.51 \times 0.28 = -4.62 \text{ Nm}$$

$$M_{DH} = -16.51 \times 0.34 + 93.54 \times 0.06 = 0 \text{ Nm}$$

Resultant bending moment at A

$$M_A = \sqrt{(M_{AV})^2 + (M_{AH})^2} = 0 \text{ Nm} \quad (15)$$

Resultant bending moment at B

$$M_B = \sqrt{(M_{BV})^2 + (M_{BH})^2} = 2.47 \text{ Nm} \quad (16)$$

Resultant bending moment at C

$$M_C = \sqrt{(M_{CV})^2 + (M_{CH})^2} = 4.74 \text{ Nm} \quad (17)$$

Resultant bending moment at D

$$M_D = \sqrt{(M_{DV})^2 + (M_{DH})^2} = 0 \text{ Nm} \quad (18)$$

From equation (17), the maximum bending moment occurs at C with a value of 4.74Nm

### Determination of shaft diameter

For a solid shaft having little or no axial loading, the shaft diameter may be determined from the following ASME code equation [7]:

$$D^3 = \frac{16}{\pi \tau_{\max}} \sqrt{(k_b M_b)^2 + (k_t M_t)^2} \quad (19)$$

Where,

$D$  = Shaft diameter

$\tau_{\max}$  = Permissible shear stress

$M_b$  = Maximum value of bending moment

$M_t$  = Maximum value of twisting moment

$k_b$  = Combined shock and fatigue factor applied to bending moment

$k_t$  = Combined shock and fatigue factor applied to twisting moment

The maximum permissible shear stress may be taken as 42 MPa for shafts with allowance for keyways [6]. For suddenly applied load,  $k_b = 2.0$  and  $k_t = 1.5$ . From equation (19), we get

$$D = \sqrt[3]{\frac{16}{\pi \times 42 \times 10^6} \sqrt{(2.0 \times 4.74)^2 + (1.5 \times 7.7)^2}} = 12.19 \text{ mm}$$

A standard size of 25mm was selected [6].

### Determination of Power to Drive the Fan

The power required to drive the fan may be obtained from the following expression:

$$P_F = \frac{Q \times P_s}{\eta} \quad (20)$$

Where,

$P_F$  = power required to drive the fan

$Q$  = fan flow rate =  $0.11 \text{ m}^3/\text{s}$

$P_s$  = static pressure of fan =  $336 \text{ N/m}^2$

$\eta$  = static efficiency of fan = 75%

From equation (20), we get

$$P_F = \frac{Q \times P_s}{\eta} = \frac{0.11 \times 336}{0.75} = 49.28 \text{ W} \quad (21)$$

The total power required by the machine =  $193.52 + 49.28 = 242.8 \text{ W}$ , a 1hp electric motor was selected.

### III. TESTING

The various parts of the machine were assembled, after which the electric motor was mounted, the machine was then test run without groundnut poured into the hopper. This was done to study the behavior of the machine. Fig. 4 shows the electrically powered groundnut shelling and separating machine. Test was then carried out to evaluate the performance of machine based on its shelling efficiency, the time taken to shell a known weight of groundnut pods and the capacity of the machine. The shelling efficiency was assessed by taking four separate experimental samples of 100 groundnut seed poured into the hopper while the machine was running. After each group was passed through the machine, the output was analyzed by physically counting the shelled, unshelled, partially shelled, broken or shattered groundnut. The sum of the shelled and shattered groundnuts makes up the shelling efficiency. Table 1 shows the test results for the shelling efficiency.

TABLE 1 Test results for shelling efficiency

Test	Shelled	Unshelled	Partially	Shattered	% Shelled
1	77	2	4	17	94
2	80	1	1	16	96
3	75	3	5	18	93
4	80	0	2	18	98

The shelling efficiency of the machine was calculated as follows:

$$\text{Average number of groundnut shelled} = \frac{77 + 80 + 75 + 80}{4} = 78$$

$$\text{Average number of groundnut shattered} = \frac{17 + 16 + 18 + 18}{4} = 17.25$$

$$\text{Therefore, shelling efficiency of the machine} = \left( \frac{78}{100} + \frac{17.25}{100} \right) \times 100 = 95.25 \%$$

The separation efficiency was determined by shelling two sets of groundnut and re-weighing after shelling. Table 2 shows the test results for the separation efficiencies.

TABLE 2 Test results for separation efficiency

Test	Initial weight(kg)	Final weight(kg)	Loss weight(kg)	Separating efficiency (%)
1	0.6	0.52	0.08	$\frac{0.52}{0.6} \times 100 = 86.67$
2	0.6	0.58	0.02	$\frac{0.58}{0.6} \times 100 = 96.67$

$$\text{Therefore, separation efficiency} = \frac{86.67 + 96.67}{2} = 91.67 \%$$

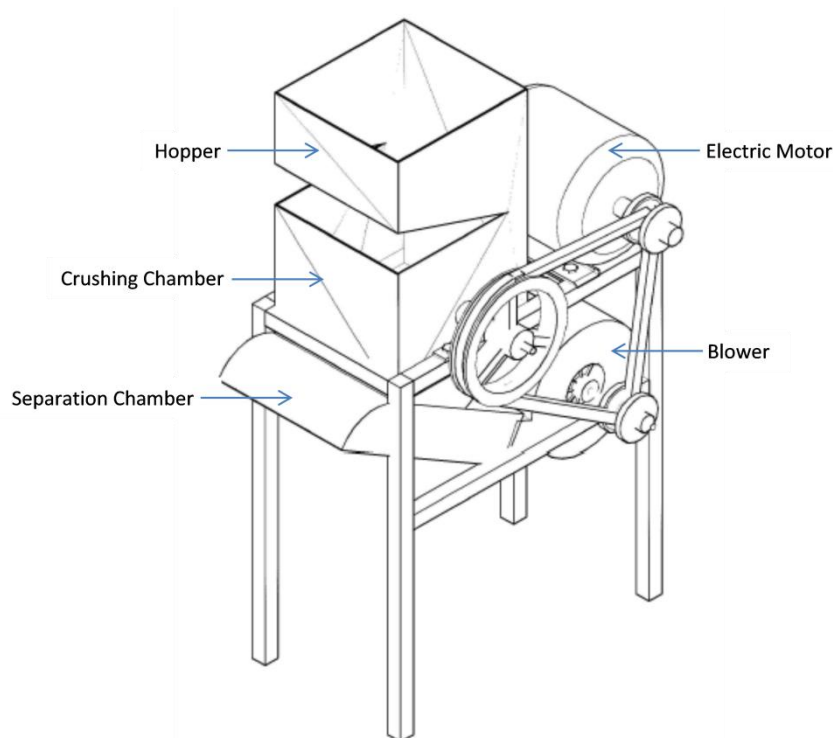


Figure 4: Groundnut shelling and separating machine

During the test, to determine the capacity of the machine, it was observed that it took 54 seconds to shell 6kg of groundnut. It then means that in one minute, one can shell a total of 6.7kg of groundnut and in 1 hour, a total of 400kg of groundnut can be shelled. It was also observed that groundnut with one seed per pod were the ones that came out unshelled or partially shelled. Others that also came out unshelled or partially shelled were the ones that had two small seeds in their pods.

#### IV. CONCLUSION

This work presents the design of an electrically powered groundnut shelling machine. The machine was fabricated using materials that were sourced locally. It can be used for both domestic and industrial purposes. The advantage to be derived from the use of this machine far outweighs its shortcomings. The test result showed that the machine can shell a total of 400kg of groundnut in an hour. It was also observed that groundnut with one seed per pod and those with two small seeds in their pods were the ones that came out unshelled or partially shelled.

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