International Journal of Advances in Engineering and Management (IJAEM)
Volume 6, Issue 09 Sep. 2024, pp: 352-358 www.ijaem.net ISSN: 2395-5252

Design and Implementation of an Automated Groundnut Shelling Machine

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Date of Submission: 10-09-2024 Date of Acceptance: 20-09-2024

ABSTRACT: Groundnut shelling is done manually in some parts of African Countries, especially Nigeria, which is laborious, time consuming and expensive. Temperature is very high during the harvesting period and people find it very difficult to work comfortably. Some developed Groundnut shelling machines had no cleaning compartments and has high mechanical damages. y. In Nigeria available groundnut threshing machine couldn't overcome the challenges of high rate of mechanical damage of the groundnut seeds. However, in order to address these problems, physical and engineering properties of various varieties of groundnuts were determined and each variety has its own concave for threshing with regulated speed. This s research work focused on the design and implementation of an automated groundnut shelling machine, where the application of control system was achieved. The circuit was designed and simulated using proteus software and were properly mounted on the printed circuit board (PCB). The DC motor model was simulated using MATLAB/SIMULINK software which showed signals responses rise time of 0.394 seconds, settling time of 1.37 seconds and overshoot of 9.48%. The cylinder speed levels are 160, 170 180 and 190 rpm and the groundnut variety with speed of 190 rpm, feed rate of 71g/s and 12mm concave clearance had threshing efficiency 97.6%, mechanical damaged 2.1%, and unshelled 0.3% respectively.

KEYWORDS: Groundnut, shelling, DC Motor, MATLAB/SIMULINK, PCB.

I. INTRODUCTION

Groundnut with botanical name, Arachis hypogea belongs to the Leguminosae family. China is the largest producer of Groundnut, followed by India. One of the important processes involved in the production of groundnut is shelling and separation. Shelling is the removal of the groundnut seed from its pod by stripping, by impact action, rubbing, compression and shearing etc. This crop is best grown on loamy soil that is rich in Calcium (Ca), Potassium (K) and Phosphorus (P). Over a hundred countries worldwide grow groundnuts such as Nigeria, China, Sudan, India, Israel, USA, etc. (Agidi et al., 2014).In Nigeria, the product is predominantly cultivated in the northern part of the country such as Sokoto, Gombe, Kano, Borno, Bauchi and Kaduna States (Ani et al., 2013). However, because of its value it is the 13th most important crop and the 4th most important oilseed crop of the world (Abdul-Rahman and Daniel, 2014). The major groundnuts producing countries are China (41.1%), India (16.4%), Nigeria (8.2%), USA (5.9%), and Indonesia (4.1%). Before the World War II, Nigeria's groundnut took a position prominently in the world trade which account for 29% of Africa's export and 12% of the world's export. When oil was not discovered between 1950s and 1970s, Nigeria contributed 50% to African export and 30% to world export (Ani et al., 2013).

Due to crude oil discovery Nigeria's groundnuts production started declined because of lack of organized input procurement, government attention, marketing the product both locally and internationally and difficulty in obtaining the seed. Statistic has shown that the production of groundnut was left in the hand of average farmer that are technically inefficient and cannot afford modern mechanization, the production of groundnut become labour intensive and could not compete with the other crop both local and international markets. Threshing can generally be done by traditional method (hand) and machine method under different conditions. Traditional method is the process in which the pod is pressed with thumb and the first finger so that the

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groundnut seed can be released, it could also be used by stick beating, animal trampling etc. The most popular method of groundnut threshing widely used in Nigeria is by pressing the pod with thumb and finger which has a very low percentage of groundnuts breakage, time wastage, high energy requirement, high labour intensive, fatigue also with sore thumb syndrome when large quantity are handled with low productivity. The time require for an average man to produce at least 1kg to 1.5kg of a groundnut seeds from its pod is between 1 to 2 hours while a day's work will be an average of 15kg.

II. RELATED WORKS

Atiku et al. (2004) evaluated a groundnut sheller and reported that the moisture content, material feed and the interaction between them had significant effect on the quantity of shelled, unshelled and partially shelled pods as well as that of damaged seeds.

Huynh et al., (2015) Stated that the seed separation from stalks and passage of seed through the concave gate is a function of some variables such as feed rate, threshing speed, concave length, cylinder diameter and concave clearance.

Dauda (2001) designed, constructed and evaluated the performance of a manually operated cowpea thresher for small scale farmers in Northern Nigeria. Results obtained gave a threshing effectiveness of 85.9, 84.6 and 84.1% for Kanannado, Borno Brown and Aloka local, respectively. Seed damage was 1.8, 2.3 and 1.9% for Kanannado, Borno Brown and Aloka local, respectively.

Sudajan, et al., (2005) investigated the effect of concave aperture on performance of a sunflower threshing machine. It was reported that the concave aperture significantly affected the capacity, grain damage, grain losses, and the total grain-MOG separated by the concave, but did not affect the threshing efficiency.

Makanjuola (1975) investigated the impact of moisture content on shelling effectiveness of a melon shelling machine which revealed that the kernels could be separated more easily from the shells at low moisture contents. At low moisture content, the kernels do not fill completely the internal space of the shells and it is the little clearance between the kernels and the shells that facilitate the separation.

III. DESIGN OF THE SYSTEM

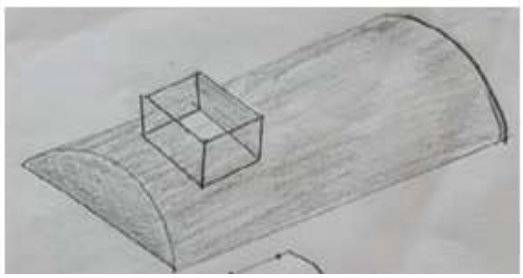
Component of Groundnut Shelling Machine

The component used in our groundnut Shelling machine are:

2. Feeder
3. Threshing Drum
4. Plumber block
5. Perforated sheet
6. Fan and Blower
7. Motor

3.1 Feeder

The Groundnut legume is fed through the feeder, as shown above:



3.2 Shelling Drum

It is the active or rotating portion of the machine. It consist of the cylindrical drum which is spirally bolted with bolts and it also consist of Shaft and two covering plate.

3.3 Motor

Motors are used to convert the electrical energy to mechanical energy. It is used as the driver. It rotate the threshing drum through the chain transmission. The sprocket is provided with required ratio.

3.4 Fan and Blower

It is used for blowing away the dust and other plants parts. The air flow is maintained in such a speed that the groundnut pod will fall to ground and the dust particle will flow away from the groundnut falling area. Such that only clean pod we can get easily thus removing the cleaning process.

3.5 Perforated Sheet

With the help of this sheet the groundnut pod and plant get separated.

IV. DESIGN OF THE SYSTEM

The system consists of the shelling unit, the prime mover, control unit and weighing balance. The components of the threshing unit are;

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frame, hopper, threshing chamber and separation chamber. The prime mover is an induction motor with 1.52 hp. The weighing unit are conveyor and load cell. The frame acts as a support for all the machine components, the hopper is where the groundnut pods is been fed into, with flow rate control device and a line of sight (LOS) sensor i.e IR. The threshing chamber consists of threshing cylinder and removable concave (screen) also the separation chamber consists of chaffs outlet and seed collector also an axial flow fan powered by the prime mover connected by means of shaft, pulleys and belt. Collection unit consists of conveyor driven by a dc motor and weighing balance and when the cylinder is rotating the spike tooth bars rub the groundnut pods against the concave to effect the breaking of the pods and release the groundnut seeds with minimal damage also when the blower is rotating it generates a stream of air current which blow off the chaffs through chaff outlet and the threshed seeds fall freely on the seed collector. The threshed seeds were being conveyed by a conveyor for collection and weighing the quantity of the seed with the help of weighing balance.

4.1 Design of Frame

The frame is trapezoidal in shape with a size of 420 mm by 365 mm at the top and angle bar iron was used for construction. The frame was welded that provided support for other components parts. It has a height of 460mm, width of 420mm and breath of 365mm

$$\text{Stress} = \frac{\text{Force}}{\text{Area}}$$

The following are the loads on the frame. (Bhandari , 2010)

I. Weight of shelling cylinder $Wc = mg$ ... (1)

$m = \rho v$

II. Pulley $Wp = mg$

$m = \rho v$

$V = A \times Lp$

$A = \pi d^2/4$

$Wp = \rho \times \pi d^2/4\ Lp \times g$ ... …….(2)

III. Weight of Shaft

$Ws = mg$

$m = \rho v$

V = A x Ls

$A = \pi d^2/4$

ds = 16 $\pi\tau s$ $\sqrt{(KbMb)\ 2 + (KtBt)\ 2}$ (Abayinah, 2015)

Ws = ρ x πd^2 /4 x Ls x g … (3)

IV. Others are prime movers (20kg), conveyor

Area of the frame (trapezoidal in shape) A = $\frac{1}{2}$ (a + b) h

Stress of frame= $\frac{\text{Total load}}{\frac{1}{2}(a+b)\ h\ N/m2}$..... (4)

Where:

W = the weight (N)

m = mass of threshing drum (kg)

g= acceleration due to gravity (m/s2)

ρ= the density of the (kg/m3)

V = the volume of the (m3)

ds= Shaft diameter (mm)

Kb = Shock and fatigue factor applied to bending moment

Kt = Shock and fatigue factor applied to torsional moment

Mb= Bending moments

Mt= Torsional moments

τ s= Allowable stress of the steel shaft.

4.2 Design of Hopper

Upper hopper Area = length x width (mm^2) ……... (5)

Volume =$\frac{1}{3}$ (area x height) (mm^3) ..... (6)

Lower hopper Area = base x width (mm^2)

Volume = $\frac{1}{3}$ (area x height) (mm^3)

Volume of hopper = upper hopper–lower hopper (mm^3) ……. (7)

4.3 Design of Shelling Unit

(i) Concave

The concave has a diameter of beater 2.5mm with a plate connected to it of 6/150mm thickness and diameter mounted on the shaft.

rc = rd + hp + Cc (Khabbabetal) ….. (8)

Where: rc = Concave radius (mm)

rd = Radius of cylinder drums (mm)

h p = Peg height above the drum (mm)

Cc = Concave clearance (mm)

(ii) Rupture force

The rupture force and power require was determined using equation 9 and 10 was adopted from Akintayo, 2015

FR = $\frac{F}{A}$ N ……. (9)

A = Area of peanut mm

(iii) Power required for shelling, P = W x x FR x log $\frac{L_1}{L_2}$ ……..…….. (10)

FR = Rupture force of groundnut (N/mm)

W = Average weight of unshelled groundnut (kg)

L_1 = Average length of unshelled groundnut (m)

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L_2 = Average length of shelled groundnut (m)
(iv) Shaft, Pulley and Belt
The shaft for shelling has a diameter of 28mm with internal diameter of 25mm for bearing and was step down to 22mm for its pulley.
$N_1D_1 = N_2D_2$ ……(11)
Where:
N_1 = Speed of driving pulley (rpm)
N_2 = Speed of driven pulley (rpm)
D_1 = Diameter of driving pulley (mm)
D_2 = Diameter of driven pulley (mm).
D. Design of separation unit
The major components of this unit is fan which is driven by belt and pulley
(i) FAN
The air discharge is given as:
$Q = (V \times A)$ (Khabbab, 2015) ……(12)
Q = Air flow rate m^3 /s
A = Outlet cross-section area m^2
V = Air velocity m/s
(ii) Belt length: The effective belts length of conveyor
$Lb = \frac{\pi}{2}(D_1 + D_2) + \frac{(D_1 - D_2)}{4x} + 2x$ (arjun etal, 2015) ……. (13)
D_1 = Diameter of driving pulley (mm)
D_2 = Diameter of driven pulley (mm)
x = Centre distance between driving and driven pulley mm.

4.4 Design of Drive system
Considering the pulley of radius (r) in meter acted upon a circumferential force (F) in Newton which causes it to rotate at N rpm and generate a torque (τ) in Nm was adopted from khumi and Gupta (2005) from equations 14 to 19
$\tau = F \times r$ (Nm) ... (14)
The work done, W by this force for one revolution can be shown in (15)
$W = F \times d = F \times 2\pi r$ Joule …... (15)
Therefore, for N- number of revolution, the work done can be expressed as
$W = F \times 2\pi r \times N$ Joule …….. (16)
The power developed, P has be determined from
$P = \tau \times \omega$ Watt …….. (17)
Where
ω = Angular velocity (rad/s) But
$\omega = \frac{2\pi N}{60}$rad/s ……..... (18)

Therefore,
$P = \tau \times \frac{2\pi N}{60}$ watt ……..... (19)
F. Design of the Conveyor system
The conveyor belt speed and its capacity were adopted from Daniyan et al., (2014).
$V = d \times \pi$…….. (20)
Belt capacity (kg/sec) is given as B.
$C = 3.6 \times A \times \rho \times V$ ……..... (21)
Where
C = conveyor capacity (kg/m)
V = Belt speed (m/s).
A = Belt sectional area (m^2)
d = Roller diameter
ρ = Material density (kg/m^3)

4.5 Design of the prime mover system
An electric inductor motor will serve as a prime mover to the entire system such as belt, pulley drive, shelling mechanism etc.
(i) Determination of torque transmitted and power consumption of the prime mover was adopted from Aladeji (2013) both equations 22 to 25 Torque = 9.55 pn ... (22)
Where
P = electric motor power
n = The number of revolution per minute of the electric motor

(ii) Power consumption
$P = \frac{2\pi NTa}{60}$ watt …….. (23)
N = Speed of tool shaft in rpm
Ta = Torque required at tool shaft

(iii) Design of belt and pulley from prime mover
The length of belt from the motor to shelling drum is determine in order to know the actual belt size that is needed to transfer power from the electric motor to the shelling drum.
$Lb = 2c + \frac{\pi}{2}(D_1 + D_2) + (\frac{(D_1 - D_1)^2}{4C})$
$C = (\frac{D_1 + D_2}{2}) + D_1$ ..... (25)
D_1 = Diameter of the motor pulley (mm) which is 45mm
D_2= Diameter of the threshing drum pulley (mm) which is 210mm
C = The centre distance between the motor pulley and the shelling drum shaft pulley. To obtain speed of driving and driven pulley
$V_1 = \frac{\pi D_{1N_1}}{60}$ ..... (26)
$V_2 = \frac{\pi D_{2N_2}}{60}$ ..... (27)

Where N_1 and N_2 are in (rpm) for the driving pulley and driven pulley respectively.

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V. RESULTS

Fig. 2: Fabricated Ground

Fig. 3: Fabricated Automated shelling Machine

The automated shelling machine is powered by electrical energy through an effective controlled medium which comprises of microcontroller, sensor and other electronic components. The initials start up the blower will start in order to generate a full air current that will be able to blow off the groundnut chaff, after ten (10) seconds the thresher (cylinder) prime mover will ON which will transmit motion via pulley, shaft and belt to rotate the threshing unit also after another ten seconds the conveyor motor will be ON in order to set the conveyor in motion, LCD is there to display the operation when a row materials (groundnuts) was not introduce the control unit switched off the system. However, when groundnut was introduce to the machine via the hopper there is line of side sensor at the hopper the moment they are breach the microcontroller sense it and start the blower immediately after ten seconds the cylinder will start and the control flow rate will open and the groundnut will go down to the thresher where the pike and concave will thresh the ground at controlled speed the groundnuts seeds and the chaffs will fall freely at the separation chamber where the chaffs will be blow off through the chaffs outlet and the seeds will be collected at the seed collection unit where they will fall freely on the moving conveyor to the collection point. These operation continue until when the groundnut was no longer introduce then the microcontroller will now sense that the sensor are seen them self it will give a command for the prime mover of the cylinder to stop, after ten seconds the blower will now stop and at last after another ten seconds the conveyor will now stop. The operation is done automatically apart of introducing the groundnuts into the machine.

5.1 Microcontroller

Control algorithm program code was implemented on the controller that executed all given command. Also in this research work microcontroller was used as the central control interface. The choice of ATmega328 microcontroller is due to its availability, high efficiency, it is also user friendly.

Fig. 4: AT Mega 328 microcontroller

5.2 Simulation Results

This automation process, simulation results of the dc motor were made possible at aiming to address one of the objectives of this project. The model was created, verified and validated. The simulation was conducted with the following results, where input and output responses from the model in figure 4 were obtained. The automation operation was process from the control unit, where the circuit drawn using proteus step 8 professional software diagram as shown in figure 4, and the following components such as capacitors, diodes, resistors, relays, transformer, LCD, transistors, motors, jumpers wire, potentiometer and ATmega 328P etc. were properly arranged on the printed circuit board (PCB). Also programmed

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microcontroller was run and all the motors and other unit was tested okay as shown in figure 5.

The performance of the prototype of automated groundnut shelling machine was clearly indicated through the evaluation of its shelling efficiency, mechanical damage, unthreshed of the groundnut, which was carry out at different quantities of different variety of groundnuts.

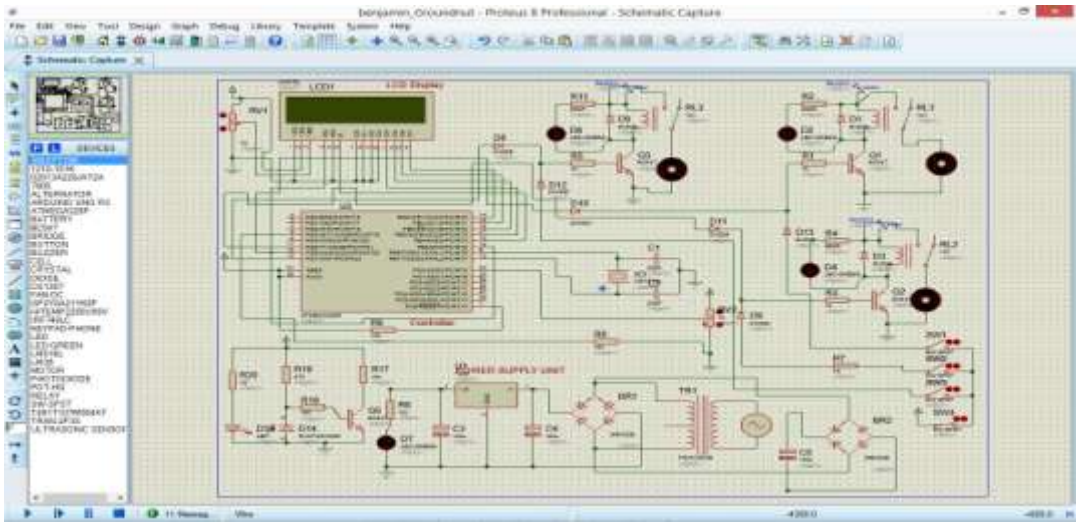

Fig. 4: Circuit Diagram

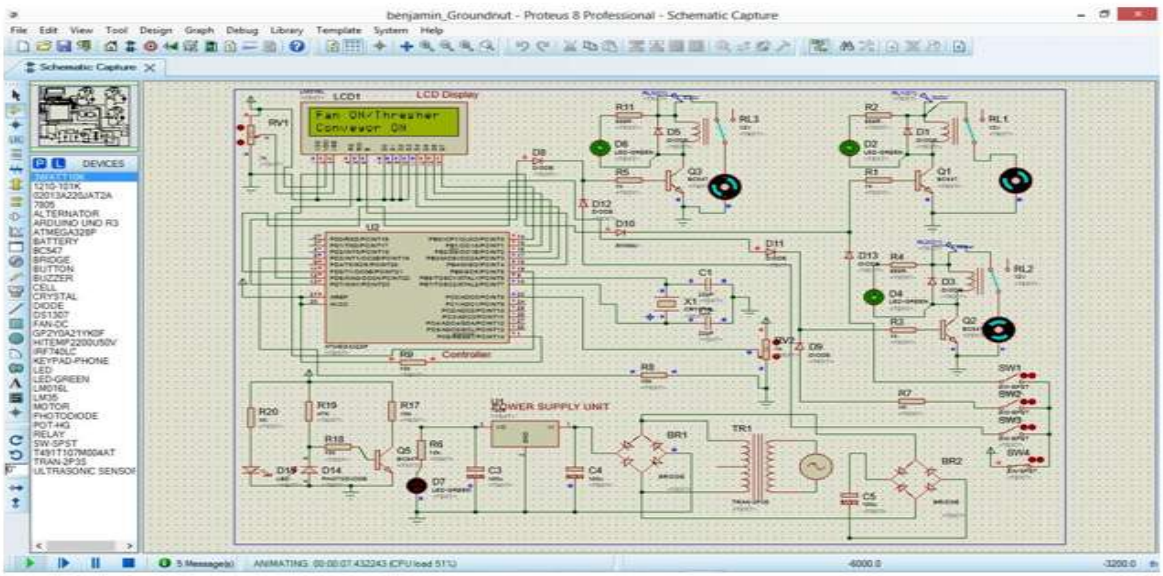

Fig. 5: Automation Code Tested

5.3 Conclusion

Proper evaluation of the control circuit for the automation system was designed with the printed circuit board (PCB) for the components layout using proteus professional step 8 software, where a programmed microcontroller (ATmega 328p) was used. Also a SIMULINK Model Plant was achieved and simulating with effective response result. An automated shelling machine was developed with effective automation algorithms and the performance was evaluated using groundnut. Shelling performance of the Groundnut with speed of 160rpm with feed rate of 53g/s and 9mm of concave clearance, also have the following results the threshing efficiency,

mechanical damaged, and unthreshed of 98%, 1.6 %, and 0.4 %, respectively.

The performance of the automated shelling machine was quite better which called for more production for agriculture and economic sustainability.

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