ABSTRACT: This research work focuses on the design and fabrication of an automated groundnut threshing and weighing machine, where the application of control system was achieved through the use of Arduino(Uno) software and the programmed microcontroller (ATmega 328p). The control circuit was designed and simulated using proteus 8 professional software and were properly arranged on the printed circuit board (PCB). The equivalent DC motor model was simulated using MATLAB/SIMULINK software which showed signals responses rise time of 0.376 seconds, settling time of 1.26 seconds and overshoot of 9.23%. The prototype cylinder speed levels are 140, 150 160 and 170 rpm and the groundnut variety Jarma variety with speed of 170 rpm, feed rate of 69g/s and 10mm concave clearance had threshing efficiency 98.5%, mechanical damaged 1.4%, and unthreshed 0.2% respectively. 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 minimise 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.

Key words: Microcontroller (ATmega 328p), Groundnuts, Threshing, Separation, Arduino uno.

I. INTRODUCTION

One of the important processes involved in the production of groundnut is threshing and separation. Threshing 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 [1]. In Nigeria, the product is predominantly cultivated in the northern part of the country such as Sokoto, Gombe, Kano, Borno, Bauchi and Kaduna States [2]. However, because of its value it is the 13th most important crop and the 4th most important oilseed crop of the world [3],[4]. 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 [2]. Due to crude oil discovery Nigeria’s groundnuts production started declined because of lack of organised 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. [5]

Threshing can generally be done by traditional method (hand) and machine method under different conditions [6-10] Traditional method is the process in which the pod is pressed with thumb and the first finger so that the 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 [11]. 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 [4]. However this research was aimed to design and fabricate an automated groundnut threshing and weighing machine that will reduce human effort and wastages, and also enhance good quality production and increase high productivity

II. SYSTEM STRUCTURE AND DESIGN

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

A. 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

\[
\text{Stress} = \frac{\text{Load}}{\text{Area}}
\]

The following are the loads on the frame. (Bhandari , 2010)
i. Weight of threshing cylinder

\[ W_c = mg \]  \hspace{1cm} \text{... (1)}

\[ m = \rho V \]

ii. Pulley

\[ W_p = mg \]

\[ m = \rho V \]

\[ V = A \times L_p \]

\[ A = \frac{\pi d^2}{4} \]

\[ W_p = \rho \times \frac{\pi d^2}{4} \times L_p \times g \]  \hspace{1cm} \text{... (2)}

iii. Weight of Shaft

\[ W_s = mg \]

\[ m = \rho V \]

\[ V = A \times L_s \]

\[ A = \frac{\pi d^2}{4} \]

\[ ds = \frac{16}{\pi \tau_s} \sqrt{(K_b M_b)^2 + (K_t B_t)^2} \] \hspace{1cm} (Abayinah, 2015)

\[ W_s = \rho \times \frac{\pi d^2}{4} \times L_s \times g \]  \hspace{1cm} \text{... (3)}

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

Area of the frame (trapezoidal in shape)

\[ A = \frac{1}{2} (a + b) \times h \]

Stress of frame = \( \frac{\text{total load}}{\frac{1}{2} (a + b) \times h} \) \( \text{N/m}^2 \)  \hspace{1cm} \text{... (4)}

Where:

- \( W \) = the weight (N)
- \( m \) = mass of threshing drum (kg)
- \( g \) = acceleration due to gravity (m/s\(^2\))
- \( \rho \) = the density of the (kg/m\(^3\))
- \( V \) = the volume of the (m\(^3\))
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

τs = Allowable stress of the steel shaft

**Figure 1: Frame**

**B. DESIGN OF HOPPER**

Upper hopper

Area = length x width (mm²)

Volume = \( \frac{1}{3} \) (area x height) (mm³)

Lower hopper

Area = base x width (mm²)

Volume = \( \frac{1}{3} \) (area x height) (mm³)

Volume of hopper = upper hopper – lower hopper (mm³) 

... (5) 

... (6) 

... (7)
C. Design of Threshing 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.

\[ rc = rd + hp + Cc \]  \hspace{1cm} \text{(Khabbab et al., 2015)} \hspace{1cm} \text{... (8)}

Where:
- \( rc \) = Concave radius (mm)
- \( rd \) = Radius of cylinder drums (mm)
- \( hp \) = 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.
\[ FR = \frac{F}{A} \text{ N} \] ... (9)

\[ A = \text{Area of peanut mm} \]

(iii) Power required for threshing

\[ P = W \times x FR \times \log \frac{L_1}{L_1} \] ... (10)

\[ FR = \text{Rupture force of groundnut (N/mm)} \]

\[ W = \text{Average weight of unshelled groundnut (kg)} \]

\[ L_1 = \text{Average length of unshelled groundnut (m)} \]

\[ L_2 = \text{Average length of shelled groundnut (m)} \]

(iv) Shaft, Pulley and Belt

The shaft for threshing has a diameter of 28mm with internal diameter of 25mm for bearing and was step down to 22mm for its pulley.

\[ N_1 D_1 = N_2 D_2 \] ... (11)

Where:

\[ N_1 = \text{Speed of driving pulley (rpm)} \]

\[ N_2 = \text{Speed of driven pulley (rpm)} \]

\[ D_1 = \text{Diameter of driving pulley (mm)} \]

\[ D_2 = \text{Diameter of driven pulley (mm)} \]

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)

\[ Q = \text{Air flow rate m}^3/\text{s} \]

\[ A = \text{Outlet cross-section area m}^2 \]

\[ V = \text{Air velocity m/s} \]

(iii) Belt length:

The effective belts length of conveyor

\[ L_b = \frac{\pi}{2} (D_1 + D_2) + \frac{(D_1 - D_2)^2}{4x} + 2x \] (arjun et al, 2015) ... (13)

\[ D_1 = \text{Diameter of driving pulley (mm)} \]
D2 = Diameter of driven pulley (mm)

\( x = \text{Centre distance between driving and driven pulley mm.} \)

**E. 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 \((\tau)\) in Nm was adopted from Khumi and Gupta (2005) from equations 14 to 19

\[
\tau = F \times r \text{ (Nm)} \quad \ldots \ (14)
\]

The work done, \(W\) by this force for one revolution can be shown in (15)

\[
W = F \times d = F \times 2\pi r \text{ Joule} \quad \ldots \ (15)
\]

Therefore, for \(N\)- number of revolution, the work done can be expressed as

\[
W = F \times 2\pi r \times N \text{ Joule} \quad \ldots \ (16)
\]

The power developed, \(P\) has be determined from

\[
P = \tau \times \omega \text{ Watt} \quad \ldots \ (17)
\]

Where \(\omega = \text{Angular velocity (rad/s)}\)

But \(\omega = \frac{2\pi N}{60} \text{ rad/s} \quad \ldots \ (18)\)

Therefore \(P = \tau \times \frac{2\pi N}{60} \text{ watt} \quad \ldots \ (19)\)

**F. Design of the Conveyor system**

The conveyor belt speed and its capacity were adopted from Daniyan *et al.* (2014).

\[
V = d \times \pi \quad \ldots \ (20)
\]

Belt capacity (kg/sec) is given as

\[
\text{B. C} = 3.6 \times A \times \rho \times V \quad \ldots \ (21)
\]

Where \(C = \text{conveyor capacity (kg/m)}\)

\(V = \text{Belt speed (m/s)}\)

\(A = \text{Belt sectional area (m}^2)\)

\(d = \text{Roller diameter}\)

\(\rho = \text{Material density (kg/m}^3)\)
G. 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

\[
\text{Torque} = 9.55 \frac{P}{n} \quad \text{... (22)}
\]

Where \( P \) = electric motor power

\( n \) = The number of revolution per minute of the electric motor

(ii) Power consumption

\[
P = \frac{2\pi NTa}{60} \text{ watt} \quad \text{... (23)}
\]

\( N \) = Speed of tool shaft in rpm

\( Ta \) = Torque required at tool shaft

(ii) Design of belt and pulley from prime mover

The length of belt from the motor to threshing drum is determine in order to know the actual belt size that is needed to transfer power from the electric motor to the threshing drum.

\[
Lb = 2c + \frac{\pi}{2} (D_1 + D_2) + \frac{(D_1-D_2)^2}{4c} \quad \text{... (24)}
\]

\[
C = \left( \frac{D_2+D_1}{2} \right) + D_1 \quad \text{... (25)}
\]

\( D_1 \) = 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 threshing drum shaft pulley.

To obtain speed of driving and driven pulley
\[ V_1 = \frac{\pi D_1 N_1}{60} \quad \ldots (26) \]
\[ V_2 = \frac{\pi D_2 N_2}{60} \quad \ldots (27) \]

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

![Figure 5A Fabricated thresher machine](image)
![Figure 5B Fabricated automated machine](image)

Figure 5A showed the fabricated groundnut thresher while figure 5B shown an automated thresher with control box mounted on it for operation.

**III. WORKING PRINCIPLE OF THE MACHINE**

The automated threshing machine is powered by electricity through an effective controlled box which comprises of microcontroller, sensor and others electronic component. 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.

Figure 6: A complete automated groundnut thresher

IV. CONTROL SYSTEMS

To have a desire output of a system there is need to regulate speed of the motor given the motor equivalent circuit shown in figure 7, and assuming the constants $K_t$ and $K_e$ are equal, the equations for the transfer function of the system can be derived using Newton’s second law and Kirchhoff’s voltage law. Considering the torque and the returned magnetic field,

$$T = K_t i \quad \ldots (28)$$

$$e = K_e \frac{d\theta}{dt} \quad \ldots (29)$$

But $K_t = K_e = K$

Applying Newton’s second law, $s$
\[ J \frac{d^2 \theta}{dt^2} + b \frac{d \theta}{dt} = K_i(t) \]  

... (30)

Applying Kirchhoff's voltage law,

\[ L \frac{di(t)}{dt} + Ri(t) = V(t) - K \frac{d \theta}{dt} \]  

... (31)

Applying Laplace transform to equations 30 and 31,

\[ s(Js + b)\theta(s) = KI(s) \]  

... (32)

\[ (Ls + R)I(s) = V(s) - Ks\theta(s) \]  

... (33)

From equation 32,

\[ I(s) = \frac{s(Js+b)\theta(s)}{K} \]  

... (34)

Equation 33 becomes

\[ \frac{s(Ls+R)(Js+b)\theta(s)}{K} = V(s) - Ks\theta(s) \]  

... (35)

Re-arranging, the transfer function is

\[ \frac{\dot{\theta}}{V(s)} = \frac{K}{(Ls+R)(Js+b)+K^2} \]  

... (36)

Considering the general equation of PID to obtained the transfer function

\[ U(t) \propto e(t) + \int e(t) + \frac{d}{dt} e(t) \]  

... (37)

\[ U(t) = K_p e(t) + K_i \int e(t) + K_d \frac{d}{dt} e(t) \]  

... (38)

Taking Laplace transform of both side \( T_D \)

\[ U(s) = K_p E(s) + \frac{K_i}{s} E(s) + K D S E(s) \]  

... (39)

Re-arranging, the transfer function is

\[ \frac{U(s)}{E(s)} = K_p E(s) + \frac{K_i}{s} E(s) + K D S \]  

... (40)

\[ \frac{U(s)}{E(s)} = K_p (1 + \frac{1}{K_i s} + TD S) \]  

... (41)
The tuning rule was applied to the proportional-Integral-Derivative controller (PID) and the process plant model parameters as shown in figure 8. Where

\[ Ra = 1.0 \quad La = 0.5 \text{ H} \quad J = 0.01 \text{ Nm}^2/\text{rad} \]

\[ Ke = 0.01 \text{ nm/A} \quad b = 0.1 \text{ Nm} \]

Figure 8 (a, b) : Control model

Figure 9: SIMULINK Model Plant
A. 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.

![ATmega328 Microcontroller](image)

**Figure 10: ATmega328 Microcontroller**

V. SIMULATION RESULTS

With this automation process, simulation results of equivalent dc motor were made possible at aiming to address one of the objectives of this project. The model has been created verified and validated the simulation was conducted with the following results, where input and output responses from the model in figure 9 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 plate 1 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 microcontroller was run and all the motors and other unit was tested okay as shown in plate 2.
However, plate 1 shown the circuit diagram drawn using proteus step 8 professional software used for the control box while plate 2 indicate the functionality of the circuit after being run with code.
A. RESPONSE FROM DC MOTOR EQUIVALENT CIRCUIT

The step response of the system model without controller in figure 13 showed when a unit step voltage was applied at the input, the rise time was 1.5 seconds and the settling time was 2 seconds while the steady stage error was approximately 90% of its final value, and the system proves to be stable. When turning method was applied to the system in figure 14 as showed, that the system is linear when the input increases the output also increases, the responses illustrated that the system was stable based on its behaviour while the dotted line at the horizontal axis was the block response.

Figure 13: Open loop of dc motor without a controller
Figure 14: Open loop response with PID controller

Figure 15: Reference tracking response using PID controller

Figure 15 demonstrate the effect of controller on the signal response to reduce the time taken for the response to settle, the tracking response signal was stable at 1.5 second. Figure 16 illustrate the functionality of controller by minimizing the disturbance rejection an input signal was injected into the system and there was a rapid overshoot the controller
minimize the overshoot to 0.03 and stabilized the system at 1.9 second while the block response rise to 0.084 with long time taken to stabilize.

![Figure 16: Input disturbance rejection response](image)

Table 1: Controller parameters

<table>
<thead>
<tr>
<th></th>
<th>Tuned</th>
<th>Block</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proportional (P)</td>
<td>17.937</td>
<td>1</td>
</tr>
<tr>
<td>Integral (I)</td>
<td>43.4548</td>
<td>1</td>
</tr>
<tr>
<td>Derivative (D)</td>
<td>-0.77687</td>
<td>0</td>
</tr>
<tr>
<td>N</td>
<td>4.2202</td>
<td>100</td>
</tr>
</tbody>
</table>

The parameters display in table 2 shows that, all the response values are acceptable and conform to the characteristics and properties of a stable system.
Table 2: Performance and Robustness

<table>
<thead>
<tr>
<th></th>
<th>Tuned</th>
<th>Block</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rise time</td>
<td>0.376 seconds</td>
<td>22.8 seconds</td>
</tr>
<tr>
<td>Settling time</td>
<td>1.26</td>
<td>40.4 seconds</td>
</tr>
<tr>
<td>Overshoot</td>
<td>9.23%</td>
<td>0%</td>
</tr>
<tr>
<td>Peak</td>
<td>1.09</td>
<td>1</td>
</tr>
<tr>
<td>Closed-loop stability</td>
<td>Stable</td>
<td>Stable</td>
</tr>
</tbody>
</table>

B. Stability test

Root locus was used for stability test where the location of the poles in the plot as they move across the s-plane are in the negative part ranging from -2 to -10 as indicated in the figure 17 and the breakaway point as they leave the imaginary axis is perpendicular to real axis of the negative part of the plane this phenomenon confirm that the system stable.

![Root Locus](image)

**Figure 17: Stability test using Root Locus**
The frequency analysis response test using bode plot where The phase crossover frequency have reaches $180^0$ and is at the positive phase margin and also the gain crossover margin have pass the zero(0)dB of the positive gain margin of the bode plot shown in figure 18. This means that the system is stable.

![Bode Diagram](image)

**Figure 18: Bode plot showing the stability of the system**

**VI. EXPERIMENTAL RESULT**

The performance of the prototype of automated groundnut threshing machine was clearly indicated through the evaluation of its threshing efficiency, mechanical damage, unthreshed of the groundnut, which was carry out at different quantities of different variety of groundnuts these are Ex-dakar, SAMNUT 26, Jarma and Nasarawa. Each variety of groundnuts has its own separate concave (component of threshing) base on the physical properties.
A. THRESHING EFFICIENCY

The highest threshing efficiency of various varieties is as follows Ex-dakar was 98%, SAMNUT 26 was 97%, Jarma was 98.4%, and Nasarawa was 97%. While Jarma variety was ranked the best in threshing with feed rate of 69g/s. As shown in figure 19. While Ikechukwu et al (2014) got their threshing efficiency to be 95.25% and Ashish and Handa (2014) got their threshing efficiency to be 81.2%. Therefore automated threshing machine proves to be the best in operation.

![Figure 19: The effect of different feed rate on the performance of the machine on threshing efficiency](image)

B. MECHANICAL DAMAGE

A range of 1.4% to 4.2% groundnut seed damage was obtained from all the various varieties of groundnut where Nasarawa variety with 4.2% damage, feed rate of 20g/s was ranked the highest to be damage as indicated in figure 20. These showed that this automated thresher was better compare to the result obtained by Ashish and Handa (2014) with mechanical damage of 20.07%.
C. UNTHRESHED GROUNDNUT

During the threshing process it was observed that there were some groundnuts that were not threshed at every operation on different feed rate, the percentage of unthreshed of each varieties ranging from 0.2 to 2.5%. Jarma variety has the less unthreshed of 0.2% at feed rate of 69/s while SAMNUT 26 has the highest not threshed with 2.5% at feed rate of 20g/s. These unthreshed groundnuts are as a result of immature groundnuts which are very small in size.
Figure 21: The effect of different feed rate on the performance of the machine on unthresh efficiency

VI. 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 simulated with effective response result. An automated threshing machine was developed with effective automation algorithms and the performance was evaluated using groundnut. Threshing performance of Ex-dakar 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. SAMNUT 26 with the speed of 170rpm, feed rate of 63g/s, and concave clearance of 12mm had the threshing efficiency, mechanical damaged, and unthreshed of 97, 2.5 %, and 0.5 %, and The Jarma variety with speed of 170 rpm, feed rate of 69g/s and 10mm concave clearance had threshing efficiency, mechanical damaged, and unthreshed of 98.5%, 1.4 %, and 0.2 %, respectively. And Nasarawa with speed of 170rpm, feed rate of 65g/s, and concave clearance of 12mm had the threshing efficiency, mechanical damaged, and unthreshed of 97%, 2.6 %, and 0.4 %. The performance of the automated threshing machine was much better which called for more production for agriculture and economic sustainability.

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REFERENCE


