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Study and design of solar powered economical groundnut decorticating and separating machine in Eastern province of Rwanda

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Abstract

World is mostly concentrating on new inventions and running with updated technology. Farmers are back bone for every country in the world. Without farmer's livelihood is difficult. Groundnuts is grown on a small scale by farmer. The major problem in groundnut production in country like Rwanda is the lack of groundnut processing machines available to farmers. In the beginning the peanuts were separated from its shells by the workers. The output from this method was very less and could not satisfy the market demand as it was very time-consuming process. Lack of groundnut processing machines at affordable cost, especially groundnut Sheller, is a major problem of groundnut production. The groundnut Sheller machines available in the market are large in size and costly and not suitable for domestic purpose. The machine is designed for locally sourced materials. The major parts of machine are Hopper, Crushing Chamber, Separating Chamber and Blower. This project is mainly about to remove the barriers while removing the groundnuts. In this rotational mechanism is used. With the help this instrument the time gap reduces from removing of groundnut from plant and also the labor required reduces. This project makes the farmer to work easy and can save more time and investment. It is more efficient and can be available to all at minimum cost. With this mechanism the final outcome is nut from the shell. This work is dedicated to the designing of machine with more production capacity &operating on less power input like 1/2 HP than manual work. This machine will be helpful for the small and medium scale farmers as well as new star ups by investing less capital.

Keywords: Groundnut, Battery, Solar panel, Pulley & belt drives, Collector.

INTRODUCTION

Groundnut (Arachis Hypogea) originated from Latin America (Brazil) and was introduced into West Africa by Portuguese traders in the 16th century, Groundnut is the sixth most important oilseed crop in the world. It contains 46-50% oil and 25-28% 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 phosphorous.

Decorticating is the removal of grains from their pod either by stripping, impact action and rubbing or any combination of these methods. The most popular method of groundnut shelling, which is still widely used is the method of crushing or pressing the pods in between the thumb and the first finger to break off the pods and release the seed(Vernekar, 2018). This method has low efficiency, it is time consuming, and has high demand of energy. Groundnut Decorticating machine is a machine used to remove the shell of groundnut so as to obtain the groundnut seeds. There are different methods of shelling and different machines have been fabricated and used to shell wide variety of crops under different conditions (Ravindra et al., 2017). 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(No, n.d.). 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 center 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 shoe's assembly(MADNAIK et al., 2017). The semi-rotary, action of the shoes shells the pods against the screen. The major short coming of this machine is that it is labor 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(Maduako & Hamman, 2005).

Theoretical perspectives

This groundnut decorticator can be described as a household, industrial and institution machine used for decorticating large quantity of groundnuts. It is an electromechanical machine and may have different controls to suit the users' needs.

This decorticator uses standard mechanism. Motor torque is at required speed to shell large quantity as well as small quantity of groundnuts, even the stating torque is enough for starting to produce the reciprocating motion to the roller shaft.

Fundamental goal in study and design of this decorticator is to meet the required production, operate competitively but all this being affordable to the population from rural region at low price.

Design and Calculations

PV system sizing

A solar cell, or photovoltaic cell, is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect, which is a physical and chemical phenomenon. It is a form of photoelectric cell, defined as a device whose electrical characteristics, such as current, voltage, or resistance, vary when exposed to light. Individual solar cell devices can be combined to form modules, otherwise known as solar panels.

- Important formulas

Current (I) = Power/ Voltage = P/V

Unit:(A)

Voltage (V) = Power/Current = P/I

Unit :(V)

Power (P) = Voltage x Current = V x I

Unit: (W)

Energy (E) = Power x time = P x t = V x I xt

Unit :(W h or J)

The current to be generated by the solar module is given by using the following equation

IM=E:(HP*BV*DF)

IM: is the module current

E= is the total energy

HP= is peak sun, peak sun is different with the location. In Rwanda the peak sun is 5 hours/day.

B_V= is the battery voltage.

DF= is the derating factor and always is 0.9

IM= 3728.5Wh :(5*24*0.9) =34.5A

WP=Watt peak or Peak power

WP= V_{max}*I_{max}= 24V*34.5A= 828 wp

Number of PV=828Wp/250W=3.3

Actual requirement= 3 solar modules, so this system should be powered by at least 3modules of 250 Wp PV module.

Motor sizing

This is the DC motor with type of Bus Wiper Motors (0.5HP /24v). This DC motor is used to rotate the roller shaft and Fan shaft by using belt and pulley.

The motor used to drive a roller shaft should have an efficiency of 88%

- The output power of electric motor should be equal to 1/2HP

  1/2HP=0.5HP so, 0.5HP=0 .37285Kw

  0.37285Kw=372.85W

- Voltage will be U=24V, then Current will be I=372.85/24=15.5A

Energy required for an electric motor:

$E = P\,t$ Where t = 10Hours

E= 372.85W X10= 3728.5wh means 3.7285Kwh

This is the main part of our project because this project is constructed on the rotation of some parts that comes from motors, it is better for using DC motors to make this decorticator at low cost and make it accessible to many people as many citizens live in sunny region where sun lights is abundant.

Pulley

Pulley is used to transmit the torque of motor to the roller. One pulley is directly mounted over the prime mover and for fan shaft, another pulley mounted on the roller shaft. And both the pulleys are connected with the help of V-belt.

Fig 3. 1 : V groove pulley

V-Belt

V-Belt is used to transmit rotary motion for motor to the roller shaft and fan shaft.

Material of the belt is rubber or polymer for strength and reinforcement. This type of V-

belt should be used to transmit power from the prime mover to the roller shaft and the fan shaft for decorticating the groundnuts.

Fig 3. 2 : V belt

- Selected motor 1/2HP, 30rpm
- Speed of main shaft = N2
- Motor pulley diameter= D1, so $\frac{D1}{2} = R1$
- Roll shaft pulley diameter=D2, so $D2/_2 = R2$
- Fan shaft pulley diameter= D3, so $D3/2 = R3$
- Number of belts required= 2

  - ✓ Length of the belt L_1 for roller shaft pulley and prime mover shaft pulley will be calculated as follow:

$$L1 = 2C1 + \pi(R1 + R2) + \frac{(R2 - R1)^2}{C1}$$

  - ✓ Length of the belt L_2 for fan shaft pulley and prime mover shaft pulley will be calculated as follow:

$$L2 = 2C2 + \pi(R1 + R3) + \frac{(R3-R1)^2}{C2}$$

Where,

R1= radius of the prime mover shaft pulley

R2= radius of the roller shaft pulley

R3= radius of the fan shaft pulley

L1= total length of the belt for prime mover pulley to roll shaft pulley

L2= total length of the belt for prime mover pulley to fan shaft pulley

C1= center distance between centers for motor shaft pulley and roll shaft pulley

C2= center distance between centers for motor shaft pulley and fan shaft pulley

Keys

In mechanical engineering, a key is a machine element used to connect a rotating machine element to a shaft. The key prevents relative rotation between the two parts and may enable torque transmission. For a key to function, the shaft and rotating machine element must have a keyway and key seat, which is a slot and pocket in which the key fits. The whole system is called a keyed joint. A keyed joint may allow relative movement between the parts.

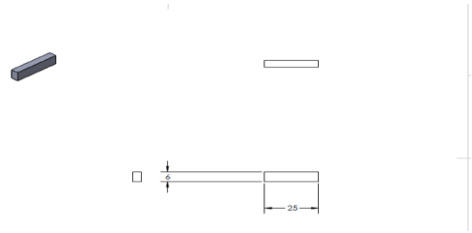

Fig 3. 3 : Key design

Hopper

It contains the unshelled groundnut before and during the shelling operation. It must be able to withstand the vibration loads and stresses, have good strength and good corrosion resistance.

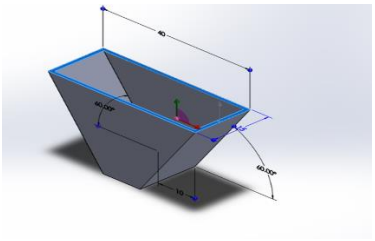

Fig 3. 4 : Hopper design

Roll Shaft

This the shaft at which the shelling bar is connected.

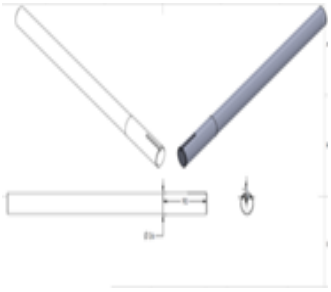

Fig 3. 5 : shaft

- selected motor: 1/2HP, 30Rpm, single phase DC
- The diameter, D_2 of the auger (roll shaft) pulley may be determined from the relation: $N_1*N_2=D_1*D_2$ then $D_2=\frac{N1*N2}{D1}$
- Speed of roll shaft (auger) pulley will be:

$$N2 = \frac{D1*D2}{N1}$$

- Center distance (from prime mover shaft center to roll shaft center):

$$C1 = \frac{D1+D2}{2}$$

Where N_1= speed of prime mover
N_2=speed of driven pulley (auger or roll shaft),
D_1=diameter of prime mover pulley
D_2=diameter of the driven pulley (roll shaft)

✓ The diameter, D_2 of the auger (roll shaft) pulley may be determined from the relation: $N1 * N3 = D1 * D3$, So $D3 = \frac{N1*N3}{D1}$

✓ Speed of roll shaft (auger) pulley will be: $N3 = \frac{D1*D3}{N1}$

✓ Center distance (From prime mover shaft center to fan shaft center)

$$C2 = \frac{D1+D3}{2}$$

Where N1= speed of prime mover
N3=speed of fan shaft pulley,

D1=diameter of prime mover pulley

D3=diameter of the fan shaft pulley

Fan

Fan is mounted on the shaft of the motor just in front of pulley at some distance. This fan separates the shell and the peanuts. It should be made from aluminum due to its light weight**.**

Fig 3. 6 : Fan

Fan cover

Fan cover is for covering the fan and directing the wind at the desired area.

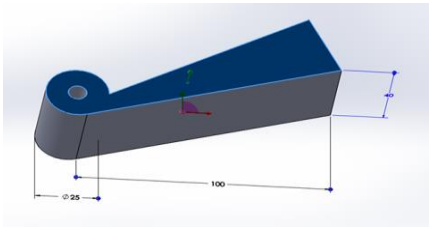

Fig 3. 7 : Fan cover

Semicircular Net

This semicircular net is fitted beside the roller at very small distance so that shell of groundnut should be easily cracked and peanuts remain uncracked.

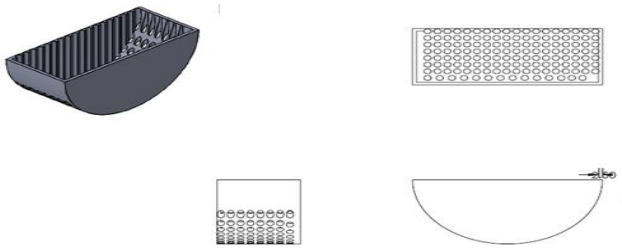

Fig 3. 8 : Semicircular Net

Frame

It holds the solar module, hopper, shelling, and separating unit as well as the prime mover (electric motor). Being the main support for the machine, it must be able to withstand stresses and loads and have good welding properties. Hence, mild steel in form of angle bar should be used.

Sizing of battery storage

DC produces a steady current that is easily depleted. Although it can be restored, the loss of power is significant. This is the effect that can be seen in batteries over time; they gradually lose power until they stop working.

Battery nominal Capacity (BNC) is given by the following formulae:

BNC= (Nr * AUT)/ Beff*DOD*U

Where, AUT: Autonomy in days

DOD: Authorized depth of Discharge

U= System Voltage

Nr = 3728.5 Wh

DOD=50%=0.5

Beff=Battery efficiency (normally is0.8-0.9)

For minimization of the cost of batteries, AUT= 1day

U= 24 V

BNC = (3728.5x1)/0.5*0.85*24= 365.53Ah

So, the battery should be rated 24V 400 Ah for 1-day autonomy.

Charge controller sizing

A Charge Controller is needed to prevent overcharging of the batteries. Proper charging will prevent damage and increase the life and performance of the batteries. Charge controllers (or often called charge regulator) are rated based on the amount of amperage they can process from a solar array.

If a controller is rated at 20 amps it means that you can connect up to 20 amps of solar panel output current to this one controller. The most advanced charge controllers utilize a charging principal referred to as Pulse-Width-Modulation (PWM) - which insures the most efficient battery charging and extends the life of the battery.

Charge controller should be able to with stand short circuit current (Isc) of the module and maximum battery to load current (ILmax). Load current can be calculated by using following equation.

ILmax=Pt/Bv

ILmax=Maximum battery to load current

Pt=Total power

Bv=Battery voltage.

ILmax=750W/24V=**31.25A**

Block Diagram of solar powered decorticator

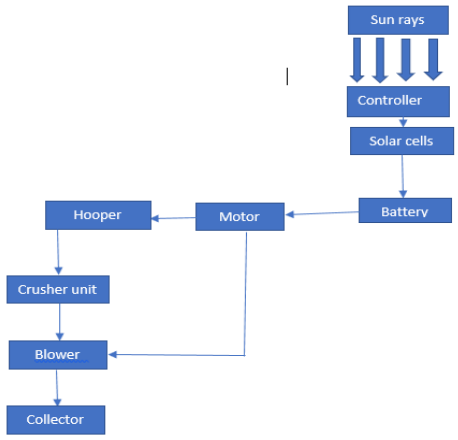

Fig 3. 9 : Block Diagram of solar powered decorticator

Working principle

Solar Powered economical groundnut decorticator and separating machine is operated on the action of shearing & separating the groundnut. At first the raw groundnuts are supplied through a hopper.

Then raw pods of nut are fed to the semicircular net and shaft of the roller. The net is stationary while shaft is reciprocating element. As raw groundnut passes over the stationary net and rotating shaft shearing of ground nut begins. Because of crushing, the groundnuts are sheared into the peanut and outer shell. Between the net and roller shaft the clearance is provided to decide the size and shape of groundnut to be decorticated. After decorticating the nut and shells gets dropped in downward direction from the semicircular net, later the blow of fan is imparted on the mixture of peanut and shell due to uneasiness of shell, nuts are thrown and can be collected in the collector. due to less weight of the husks, they were blown away from the machine which are collected from the backside of the machine. From the shelling chamber the unshelled groundnuts also get dropped in the tray (7% to 10%). In this way the "SOLAR POWERED ECONOMICAL GROUNDNUT DECORTICATOR & SEPARATING MACHINE" performs the work.

METHODS

Introduction

The aim of this modelling research project is to study and design of solar powered economical groundnut decorticator and separating machine for better efficiency and labor power reduction. Here, Groundnut decorticating machine is operated on the action of shearing & separating the groundnut. At first the raw groundnuts are supplied through a hopper. Then raw pods of nut are fed to these semicircular net and shaft of the roller. The net is stationary while shaft is revolving element. As raw groundnut passes over the stationary net and rotating shaft shearing of ground nut begins. For achieving this aim, various works have been done in this chapter, so this chapter presents research design, local of study, population of study, sample size and sampling procedure, method of data collection, source of data, research instrument, reliability and validity of the research instrument, procedure of data collection and method of data processing and analysis.

Research design

In the case study, the research has to take time to understand better the problem or area of study in preliminary way and relate the variables of the study. This approach often relies on direct research of a limited number of respondents of what is to be studied. The study will be important in describing the characteristics of a large population.

Study setting

This study is directly related with current technology development in every farming

areas in Rwanda especially in the district of Bugesera, Ngoma, Nyagatare, and Gatsibo where, the groundnuts farming is abundant and these areas are very sunny.

Study population

The population of the study participants are all comprehensive group of individuals in eastern province of Rwanda especially in the Districts of Bugesera, Ngoma, Nyagatare and Gatsibo where the groundnuts farming is abundant.

Data collection procedures

Studying and Designing a simple system that can decorticate the groundnuts is not easy, without having complete information about the structure of the recording and some communication systems and components to be used. To do this, it was necessary to use different methods to collect the necessary information coming from different institution and other online resources. In my research I have used three process of data collection: Documentation, on-site visit and Observation.

Ethical considerations

Ethical Consideration Researchers have ethical obligations to take into account when conducting research. Therefore, the use of a systematic process to collect data without interfering or harming your subjects (research participants) is very important. The following were taken into consideration when performing this research. Privacy is one of the most important aspects with regard to ethics. In collecting data, the researcher was conscious of breech of research participants‟ privacy. Another ethical concern the researcher left out were bias and misrepresentation of information. Therefore, only the facts concerning the financing implication of going study and design of solar powered economical groundnut decorticator and separator were analyzed and reported in this research work.

For research respondents of the study (humans/individuals who have answered the questionnaire); after doing observations, the researcher wrote and distributed the questionnaires to the population and done interviews with them. After this, the collection has been done of those questionnaires and finally put the review in percentage whereby shown the review in form of different charts and the privacy, anonymity for the participants was respected.

Basic concept of machine design

Study and design of this decorticator is based on different concepts, I as designer, there are a lot of factors to consider for getting an optimum design. Firstly, once conduct a market survey this gives a picture of really what people around need and according to what I learnt in entrepreneurship course

stated that a successful business is created based on customer's needs. All designer's consideration should meet the desired design because once mistaken lead to poor design.

RESULTS

Introduction

The main objective of this project is to study and design a solar powered economical groundnut and separating machine using solar power sources that is regenerative circuit in which electricity is produced and consumed simultaneously to adopt this machine for small application in rural areas. Apart from this, the machine is designed to have good decorticating efficiency and low percentage breakage of peanuts.

Performance evaluation

Capacity:

C=W/t

Where:

C= capacity of the machine, kg/hr

W= weight of groundnut pods machine, kg

t= time taken for decortication, hr

Decorticating Efficiency:

Efficiency = $1 - \frac{Wu}{W} * 100$

Where:

Wu= weight of unpeeled pods, kg

w = total weight of pods fed in the machine, kg

Breakage:

Breakage, percent = $\frac{Wb*100}{Wg+Wb}$

Where:

Wb = weight of broken kernels,

Wg = weight of good kernels, kg.

DISCUSSION

Limitations of the study

- Inadequate finances and time to extensively collect data from each household and respondents.

-The researcher is a full-time employee with other responsibilities and had made a budget for the intended research within available means and permitted time.

- Unwillingness of respondent to answer the questionnaire.

-Sparse distribution of pastoralists was also a challenge due to the covid-19 worldwide pandemic regulations.

Conclusion

-This work presents the study and design of a solar powered economical groundnut decorticator and separating machine.

-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.

- Fundamental goal in study and design of this decorticator is to meet the required production, operate competitively but all this being affordable to the population from rural region at low price.

-The objective of this project is to be more efficient in decorticating the groundnuts.

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List of abbreviations

IST BURKINAFASO: Institut superieur de technologies de Burkina Faso

Wb: Weight of broken kernels

Wg: weight of good kernels

Wu: weight of unpeeled kernels

W: total weight of pods fed in the machine

C: capacity of the machine

T: time taken for decortication

NO: Normally open

NC: Normally closed

MINAGRI: Ministry of agriculture

AC: Alternative current

DC: Direct current

C: Center distance

D: Diameter (ϕ)

Fig: Figure

Hp: horse power (unit of power)

L: Length

n: number of belts

N: Rotation speed

R: Radius

Reg: Registration number

Rpm: Revolution per minute

Mm: Millimeter

BNC: Battery nominal capacity

Beff: Battery efficiency

AUT: Autonomy in day

DOD: Authorized depth of discharge

IM: Module current

Bv: Battery voltage

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