Development of a Cassava Grating Machine

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Abstract- Developing of a cassava grating machine is presented. This is a great boost in the development of local content and reduction of wastage in cassava produce in Africa. The use of internal combustion engine in powering the cassava grating machine makes the study unique as it goes a long way in eliminating the undue stress involved manual grating of cassava tubers. The developed machine is made up of components such as hopper, pulley belts, grating unit, internal combustion engine and shaft. Scientific formulae were employed to aid the design of the cassava grating machine. A detailed graphical modeling was done to serve as a guide for the fabrication of the machine. The developed grating machine had a volumetric capacity of hopper to be 50272000 mm^3. A power capacity of 1.715 KW was delivered to the solid shaft of 27.05 mm diameter to grate the peeled cassava tubers at a designed torque of 10.23 Nm.

Keywords: Cassava, Grating, Machine, Design, Internal combustion engine.

1. Introduction

Nigeria is one of the major producers of *Manihotesculenta* specie known as cassava with an average annual input of about 35 million tonnes. Cassava is known to be a tuberous crop of the plant family of *Euphorbiaceae* [1]. Africa is known for its significant progress in agricultural development. To continue standing out among leading nations, there is a crucial necessity to enhance its indigenous resources. The capacity to cultivate crops must be complemented by thorough technological expertise in processing agricultural products. [2].

In the past some researchers in Nigeria developed a manually powered cassava grating machine which had numerous limitations.The development of a cassava grating machine powered by an internal combustion engine for rural African communities embodies several layers of novelty. It addresses local agricultural needs, leverages appropriate technology for non-electrified regions, boosts productivity, and supports socio-economic development. By focusing on mechanical efficiency, portability, local manufacturing, and environmental sustainability, such innovations have the potential to transform rural agriculture, making it more efficient, profitable and sustainable.

In Africa, the cassava is mainly converted to sweet cream white flour known as garri. In a bid to increase this starchy crop production recourse has to be made to the deployment of modern machinery to the cultivating and processing of the crop.

Cassava processing has been in existence for a long time. Africans have been used to the traditional method in which mortar and pestle are applied to the crushing of dried peeled cassava tubers [5]. This method is laborious, time consuming and unhygienic. These deficiencies have led to the development of modern machinery. For a small scale farm the development of cassava processing machine is a welcomed course as a nonexistent of locally made cassava grating machine poses a huge challenge. Before now some researchers have fabricated manually operated cassava grating machine which was considered a bit more useful than the traditional mortar and pestle method. In a bid to bring about improvement in cassava processing an electric motor powered cassava grating machine was designed and constructed by [6].Rural areas often have limited or unreliable access to electricity. Using an internal combustion engine (ICE) as the power source makes the grating machine independent of the electrical grid, ensuring consistent operation even in remote locations. This adaptation is particularly suited to the energy realities of rural African communities [7].

This study is focused on development of cassava grating machine been powered by the internal combustion engine. The machine does not require any electrical power source. It may be used in any rural region without power.

2. Materials and Methods

2.1 Design Considerations

Some design parameters were determined in the course of conceptualizing the development of this machine. The designed parameters are shaft diameter, machine torque, power required, belt speed, length of belt, belt tensions and hopper capacity. In carrying out the parametric design of the grating machine recourse was made to some specifications as obtained from [7] and [8]. The specifications are:

i. Length and breadth of top hopper feature= 400 mm
ii. Length and breadth of bottom hopper feature= 200 mm
iii. Height of hopper=400 mm
iv. Shear stress of mild steel=450 Mpa
v. radius of small pulley=40 mm
vi. radius of large pulley=80 mm
vii. Centre to centre distance of pulleys, a=225 mm
viii. area of leather belt=90 mm^2
ix. length of shaft =350 mm
x. Modulus of rigidity for mild steel =80 GN/m^2
xi. Linear speed, N =1400 m/s
xii. shaft power = 1.5 Kw

2.1.1 Design of Hopper Capacity

The volumetric capacity of the hopper was determined by using equation (1) as obtained from [8].

$$V = \frac{1}{3}[(A_1^2) - (a_1^2)] \times h \qquad (1)$$

where V=volume of hopper

A_1= area of top feature

a_1= area of bottom feature

h = height between the top and bottom feature

$$V = \frac{1}{3}[(400^2) - (200^2)] \times 400 = 50272000\, mm^3$$

The volume of the hopper was calculated to be 50272000 mm^3.

2.1.2 Determination of Length of Belt

The length of open belt was determined by equation (2) obtained from [9].

$$L_b = \pi(R + r) + 2a + \frac{(R - r)^2}{a} \qquad (2)$$

where L_b= length of open belt

R= radius of large pulley

r = radius of small pulley

a = centre to centre distance

The length of belt was determined to be 834.15 mm

Also, the speed of the pulley was determined using equation (3)

$$\frac{N}{n} = \frac{d}{D} \qquad (3)$$

where n =speed of small pulley

d=diameter of small pulley

D=diameter of large pulley

The velocity of belt was determined by the application of equation (4) obtained from [9].

$$v = \omega R \quad (4)$$

v= velocity of belt

R= radius of large pulley

ω= angular speed

The angular speed of the belt was determined by equation (5) obtained from [10].

$$\omega = \frac{2\pi N}{60} \quad (5)$$

The angular speed was determined to be 146.63 rad/s for a linear speed of 1400 rpm. Also, the velocity of the belt was calculated to be 11.73 m/s.

2.1.3 Determination of Torque

The torque transmitted by the shaft was determined by equation (6) obtained from [10].

$$T = \frac{60 \times P_s}{2\pi N} \quad (6)$$

where P_s= Power transmitted by the shaft

T=Torque transmitted

The torque transmitted was determined to be 10.23Nm for a shaft power of 1.5 Kw

The centrifugal force was determined by equation (7) obtained from [10].

$$F = \frac{T}{r} \quad (7)$$

The centrifugal force was determined to be 255.75 N.

In addition, the stress acting on the leather belt was determined by equation (8).

$$\sigma_b = \frac{F}{A_b} \quad (8)$$

where σ_b =stress acting on the belt

A_b=area of leather belt

The stress on the belt was determined to be 2.842 N/mm^2.

2.1.4 Determination of Belt Tensions

Also, the maximum tension on the belt was calculated using equation (9) obtained from [11].

$$T = \sigma_b \times t \times b \quad (9)$$

where T= maximum tension

t= belt thickness

b =belt width

The maximum tension was determined to be 258.622 N from a belt width of 13 mm and thickness of 9 mm

The tension on the tight side was determined by using equation (10).

$$T_1 = T - T_{cf} \quad (10)$$

where T_1= tension on tight side of the belt in N

T_{cf}=centrifugal tension

Considering centrifugal tension to be negligible, the tension on tight side was determined to be equal to the maximum tension of the belt.

The tension on the slack side of the belt was calculated by the application of equation (11) as given in [11].

$$\frac{T_1}{T_2} = \ell^{\mu\theta} \quad (11)$$

where T_2=Tension on the slack side in Newton

θ =angle of contact of the smaller pulley in radians.

The angle of contact of the smaller pulley was determined by using equation (12) obtained from [12].

$$\theta = 180 - 2sin^{-1}(\frac{R-r}{a}) \quad (12)$$

The angle of contact of the smaller pulley was calculated to be 2.7786 radians.

By substitution of angle of contact and a coefficient of friction of 0.3 in equation (11) yielded a slack side tension o f 112.37 N.

2.1.5 Power Transmitted by the Belt

Power transmitted by the belt was determined by applying equation (13) obtained from [12].

$$P = (T_1 - T_2)v \quad (13)$$

where P= power transmitted in Watt

v=velocity of belt in m/s

$$P = (258.622 - 112.37)11.73 = 1715.54\ W$$

Power transmitted by the belt was calculated to be 1715.54 W by substituting for the belt tensions in equation (13).

2.1.6 Shaft Design

The shaft design was carried out based of rigidity. The polar moment and the shaft diameter of the cassava grating machine were determined by the application of equations (14) and (16) respectively obtained from [12] and [13].

$$\frac{T}{J} = \frac{G\theta_t}{L} \qquad (14)$$

where T =Torque in Nm

J=polar moment

G= Modulus of rigidity for mild steel taken to be 80 GN/m^2

θ_t=angle of twist taken to be 0.05°

L= length of shaft

The polar moment was calculated to be 0.0513 m^4 as shown in equation (15).

$$J = \frac{10.23 \times 0.35}{80 \times 10^9 \times \frac{0.05\times\pi}{180}} = 0.0513\ m^4 \qquad (15)$$

The diameter of the shaft was calculated by substituting for the polar moment in equation (16).

$$J = \frac{\pi d^4}{32} \qquad (16)$$

where d = diameter of shaft in mm

The shaft diameter was determined to be 27.05 mm.

In addition, the volume and weight of shaft were determined using equations (17) and (18) respectively.

$$V_s = \frac{\pi \times d^2 \times L}{4} \qquad (17)$$

Vs=volume of shaft in mm^3

$$V_s = \frac{\pi \times 27.05^2 \times 350}{4} = 201163.3\ mm^3$$

$$W_s = \rho_s \times g \times V_s \qquad (18)$$

where Ws= weight of shaft in N

g =acceleration due to gravity taken as 9.81 m/s^2

ρ_s=density of shaft taken to be 7850 kg/m^3

$$W_s = 7850 \times 9.81 \times 0.00020116 = 15.5\ N$$

The machine shaft had a volume and weight of 201163.3 mm^3 and 15.5 N respectively.

2.2 Machine Description

The developed cassava grating machine is comprised of components constructed with steel, including the hopper, internal combustion engine, pulley belt, solid shaft, main frame, and grating unit.

I. Hopper

The hopper shown in Fig. 2 had designed volumetric capacity of 50272000 mm^3. The hopper served as a housing for the peeled and washed cassava tubers as they entered the grating unit.

II. Internal Combustion Engine

The power supply used in the grating machine is by the internal combustion engine designed to have a capacity of 1715.54 Watt. The prime mover utilizes premium motor spirit as fuel.

III. Pulley Belt

The belt and pulley system of power transmission was utilized in this study. The leather belt had dimensions of 13 mm, 9 mm and 834.15 mm for the width, thickness and length respectively. The belt was designed to transmit a power capacity of 1.715 Kw.

IV. Solid Shaft

A solid shaft of 27.05 mm diameter and length of 350 mm was designed on the basis of rigidity to withstand power delivered from the internal combustion engine through pulley belt.

V. Main Frame

The main frame acted as structural support for the grating machine. The frame consists of 50.8 mm angle bar which enhances machine stability and structurally sustained the internal combustion engine, hopper and solid shaft.

VI. Grating Unit

The grating unit consists of perforated sheets, drum and circular discs. The drum is held by shaft and wrapped by perforated rolled cylindrical steel sheet.

3. Results and Discussion

The summary of the designed parameters and detailed graphical modeling are presented in this section.

3.1. Summary of the Designed Parametric Values of the Developed Cassava Grating Machine

The designed values of the Cassava grating machines are shown in Table 1.

Table 1. Summary of designed values of the grating machine

S/N	Machine parameter	Designed value
1	Volume of the hopper	50272000 mm^3
2	Length of belt	834.15 mm
3	Velocity of the belt	11.73 m/s
4	Torque transmitted	10.23 Nm
5	Centrifugal force	255.75 N
6	Stress on the belt	2.842 N/mm^2
7	Maximum tension	258.622 N
8	Power transmitted	1715.54 W
9	Shaft diameter	27.05 mm
10	Volume of shaft	201163.3 mm^3
11	Weight of shaft	15.5 N

The designed parametric values of the cassava grating machine were in agreement with the values of the cassava grating machine designed by [7] and [8].

3.2. Graphical Modelling of the Cassava Grating Machine

The graphical modeling of the developed Cassava grating machine showing the isometric drawing, third angle orthographic projection and the components drawing are shown in Figures 1, 2 and 3 respectively.

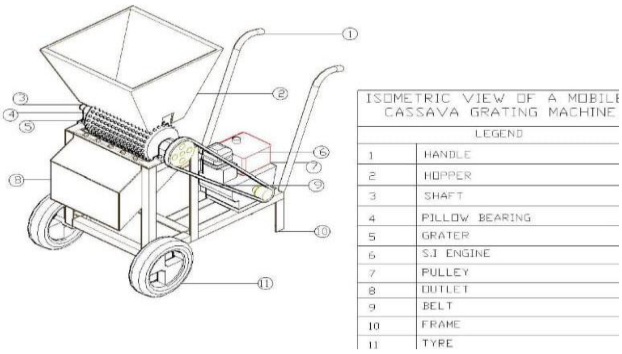

Fig. 1: Isometric drawing of the cassava machine

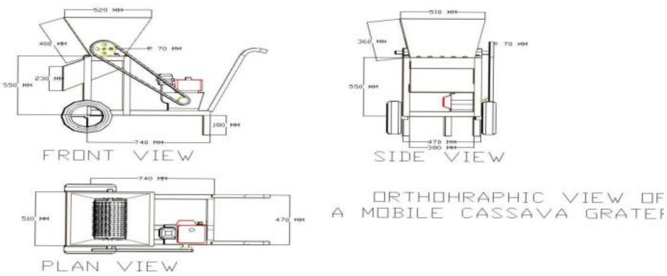

Fig. 2. Third angle orthographic projection of the cassava grating machine

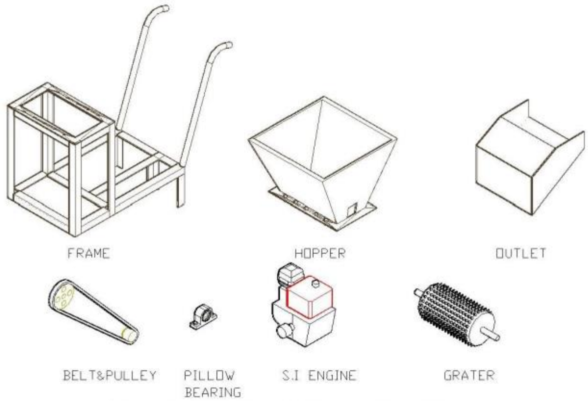

Fig. 3. Components parts of the machine

3.3. Construction of the cassava grating machine

The construction of the machine was carried out using joining processes like welding and riveting. A marking out of components on the main frame of the machine was carried out. The main frame which serves as base and major support for machine components such as hopper, internal combustion engine, grating unit, shaft and pulleys was first constructed using angle bars. Bolts and nuts were used to carry out temporary joining processes for components parts like the internal combustion engine and pulleys. A thorough finishing was done using filing machine in ensuring that every sharp and rough edge was made smooth. In addition, paints were applied to perform the final surface finishing. The developed cassava grating machine is shown in Figure 4.

Fig. 4. Developed cassava grating machine

4. Conclusion

Africa is reputed for its developmental strides in the field of agriculture. In order to remain relevant among the comity of great nations there is a great need to develop its local content. The ability to grow food crops must be matched with the requisite or in depth technological knowhow on processing of agricultural produce. This idea informed the development of cassava grating machine to help convert harvested tubers into various sizes of pellets and powdery form that are served as staple food in many homes across the globe. The cassava grating machine was successfully designed to provide various choices for cassava products. The developed grating machine had a hopper capacity of about 50272000 mm^3 which could contain cassava weight of 20 kg/m^3A power capacity of 1715.54 W was delivered to the solid shaft of 27.05 mm diameter to grate the peeled cassava tubers at a calculated torque of 10.23 Nm.

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