Design of an Improved Double Barrel Cassava Grating Machine

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***Abstract*— This work presents the design of an improved double barrel cassava grating machine. The need for ease and hygienic processing of cassava has made researchers sought for better and faster way in processing cassava. Hence, for a smooth cassava processing system, a proper design that can guarantee capacity and efficiency should be available for fabricators. Research so far have shown that there are more of single barrel cassava grating machine. In other to obtain the same quantity of grated cassava, an increased number of barrels have been designed. The design made use of Autodesk inventor professional software to produce the CAD model of the machine. Result of the fatigue simulation on the grater shows damage percentage of 1.667e-03 at a maximum 6.000e+07 life cycle. Statice analysis on the structural base shows a small deflection 0.01074 at the load of 1094N. Rigidity of the machine frame was found to be 104.7 × 10^{6}N\m**

Keywords—Cassava, Computer Aided Drafting (CAD), Grating

I. INTRODUCTION

In developing countries, cassava has become a major staple food providing the basic diet for over half a billion of world population (Grubben et al., 2014; Onokwai et al, 2019). The root starch for cassava which has been the core for its cultivation, is mainly used as food (48%) and feed (34%), feedstock (18%) and for biofuels and as well as biochemicals (FAO, 2008). Of all root tubers, cassava has been the most perishable and when the tubers are separated from the main plant and turns out to be unpleasant within two to three days after harvest thereby undergoing post-harvest physiological deterioration (Adjekum 2006; Okonkwo et. al, 2019). Hence, it is necessary to process the crops within three days after harvest. Processing the tubers into pulp form is known as grating (FAO 2005).

Various traditional methods of grating fresh cassava includes; pounding with pestle and mortar, and also the use of hand graters. Making use of hand graters is quite laborious, time-consuming and also dangerous. Cassava grating machines have been designed and also made available on the market. Some of these grating machines include pedal operated engine, dual operational mode machines, the International Institute of Tropical Agriculture (IITA) 202, the Jahn type grater, the GRATIS Foundation (GF) IITA 202- and the Double-barrel cassava grating machine, (FAO, 2005). However, these machines have been widely regarded as inefficient (Kolawale et al., 2010). Due to poor quality of the products, and low efficiency of the technologies which is a major constraint to the inefficiency of the machines (Quaye et al., 2009). A modern approach which responds quite well to the necessity of mankind is necessary for modern agriculture. This makes it necessary for an advanced mechanized grating machine which will really help in producing sufficient quantity and quality of cassava pulp that will meet market demands and standards.

This study was carried out in order to design and improve a double barrel cassava grating machine. The study was achieved through the study and developing a mechanism of a double barrel cassava grating machine and developing a 3D CAD Model of double barrel cassava grating machine using Autodesk Inventor Professional.

In this work, an improved double barrel cassava grating machine will be designed. The study will be achieved through the development of mechanism of a double barrel cassava grating machine and developing a 3D CAD Model of double barrel cassava grating machine using Autodesk Inventor Professional.

II. LITERATURE REVIEW

Over the years, the need to transform cassava root to pulp for garri production has led to invention of several cassava grating machines available today. Hence the trend of consistent research works has characterized the progressive development of the grating machine. This machine consists of machine frame, electric motor, Chute, Grater, pillow block bearing, hopper etc. These research works and investigations have the common objective of providing optimum cassava grating machine suited for garri processing and which offer the most favorable collection efficiencies at minimum cost.

In other cater for the group of garri producers who have no access to electricity and/or lack the resources or know-how, Odigboh (1984) designed A Manually Operated Cassava Grating Machine. Also, Ndaliman, (2006) focused on power failure problems by developing a grating machine that can be powered either electrically or manually. Adetunji, & Quadri, (2011) Design and Fabricated an Improved Cassava Grater. The work modified the design of the existing cassava grater (dimensions) to the home use-small scale sizes and to change the crude wooden drums used in cassava grating machines to lasting stainless steel and galvanized pipe.

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Ajao, et al. (2013) worked on Design and Fabrication of a Home Scale Pedal Powered Cassava Grater. Erratic power supply, scarcity and high cost of petroleum products necessitate the need to address the issue of cassava grating to a certain extent by developing a mechanism that will make life easier in food processing for rural dwellers and improve their economic wellbeing. With the concept of commercializing grating of cassava, Oriaku, et al. (2015) Design and Evaluateed the Performance of a Double Action Cassava Grating Machine, while Okonkwo et al. (2020), optimized a similar system with the aim of achieving a very high throughput in cassava grating and at a reduced grating time.

III. METHODOLOGY

Description of the designed Double Action Grating Machine:

The double barrel grating machine consists of; (1) Structural base, (2) Discharge chute, (3) Inlet hopper, (4) Bearing (Plummer block), (5) Grating Shaft, (6) V – Belts, (7) Pulleys and Idler, (8) Bolts and Nuts, (9) Electric motor, (10) Rivet pin, (11) Barrel, (12) Perforated stainless mesh. The overall length of the machine is 962.086mm, width of 520mm and height of 908.877mm. The large trapezoidal hopper has a large area of 330 x 963.622mm, the base area of 330 x 532mm and the height of 348.716mm. The grating barrel diameter 182mm and a length of 300mm. And the structural frame was made with 60 x 60 x 5mm thick angle iron of top length 528.493mm, base length 738.148mm, slant length 619.565mm, width of 450mm and height of 624.428mm.

Table 1: Materials used in the design of the Cassava Grater.

S/N	Name	Materials Used
1	Structural base	Mild Steel
2	Discharge chute	Stainless Steel
3	Inlet hopper	Stainless Steel
4	Bearing (Plummer Block)	Cast Iron
5	Grating Shaft	Cast Iron
6	V - Belts	Polyester Fibre
7	Pulleys and Idler	Mild Steel
8	Bolts and Nuts	Mild Steel
9	Electric motor	Cast Iron with windings
10	Rivet pin	Stainless Steel
11	Barrel	Oak Wood
12	Perforated Stainless Mesh	Stainless Steel

PRINCIPLE OF OPERATION

The primary rotation of the electric motor is essential for the powering of the grating machine. The two grating barrels rotate in the same direction which is clockwise. The motions of the grating barrels are transmitted through the V– belt, pulleys, shafts and bearings by the torque of the electric motor. The shaft is attached to the grating barrel and peeled cassava is fed into the machine through the hopper which makes contact with the rotating grater barrel. The rotating grater then reduces the cassava tuber into pulps. The grated pulp drops through the little gaps between the grating barrels and hopper plates through the inclined exit channel and then into the receiver.

DESIGN CONSIDERATIONS

The consideration for the design is to attain light weight with high rigidity, easy installation such as assembly, disassembly and operation, and cost reduction and also to achieve reduced grating time with high throughput.

DESIGN APPROACH

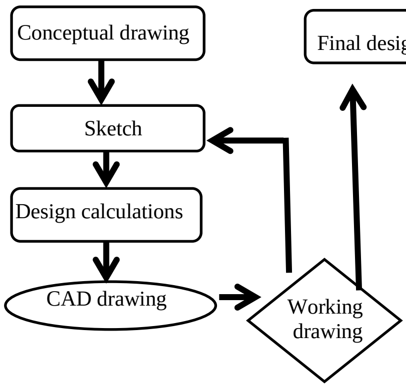


Fig 1: Design approach for double barrel cassava grating machine

Design OF Machine Components

Grating Barrel:

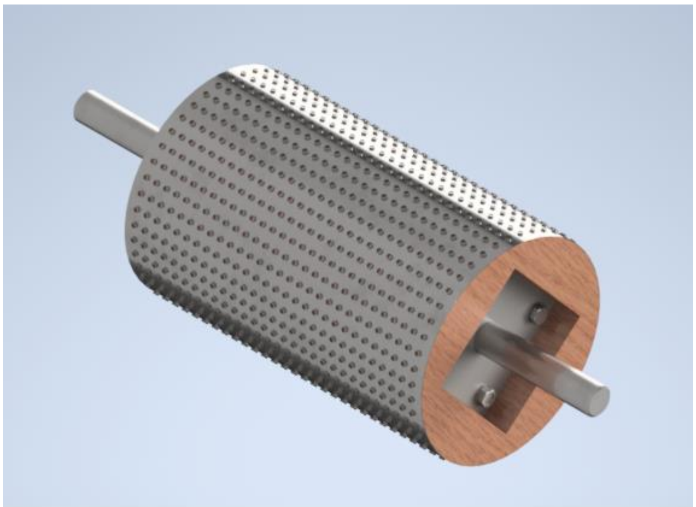


Fig 2: CAD model of the grating barrel (10.75kg)

Centrifugal Force (F_c) developed by the electric

$$F_c = M_b \omega^2 r \qquad (1)$$

Where, M_b = mass of belt used for the drive

r = Radius of pulley

Mass of Belt (M_b):

Mass = cross-sectional area of belt x density x belt length:

$$M_b = A_b \times \rho_b \times L_{b1}$$

Cross Sectional Area of Belt (A_c):

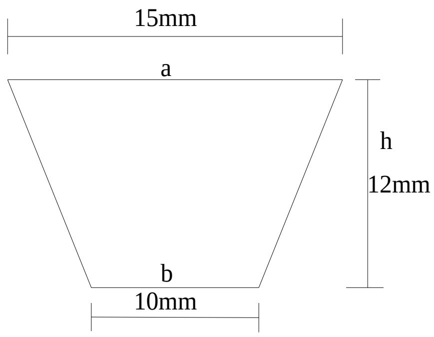


Fig 3: Cross sectional area of belt

The dimension of a section of the belt is shown above. The trapezoidal cross-sectional area is thus calculated as

$$A_b = \frac{1}{2}(a+b)h \qquad (2)$$

Angular Velocity (ω) of Rotation:

$$\omega = \frac{2\pi N}{60} \qquad (3)$$

Force due to grater F_g

$$F_g = M_g \times g$$

Force due to cassava loaded F_m

$$\mathbf{F_m} = M_m \times g$$

The total force F_b due to grater and cassava loaded into the machine is

$F_b = F_g + F_m = 354.5$ N

Bearing reactions on the shaft (R_1 and R_2)

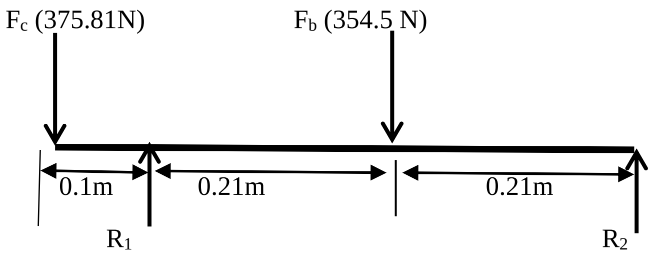
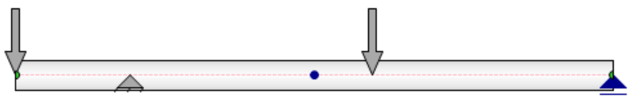


Figure 3.5: The schematic representation of forces acting on shaft.

From the evaluation of the forces, determination of the bearing reactions, maximum bending moments (Mmax) and others stress analysis of the shaft were performed using inventor professional software (educational license) and are shown in the figures below.



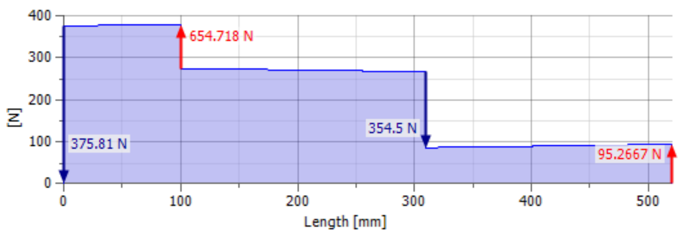


Fig 4: Shear force diagram

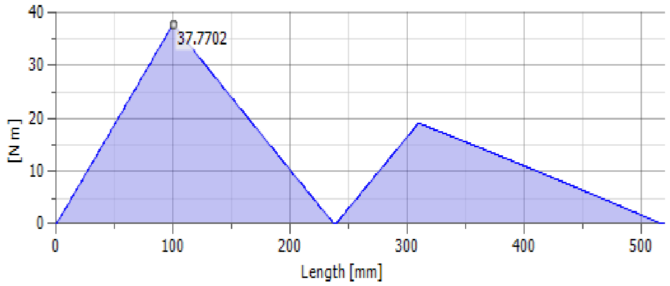


Fig 5: Bending moment diagram

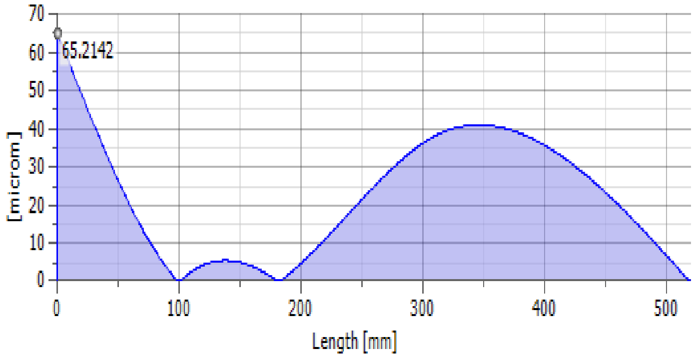


Fig 6: Deflection

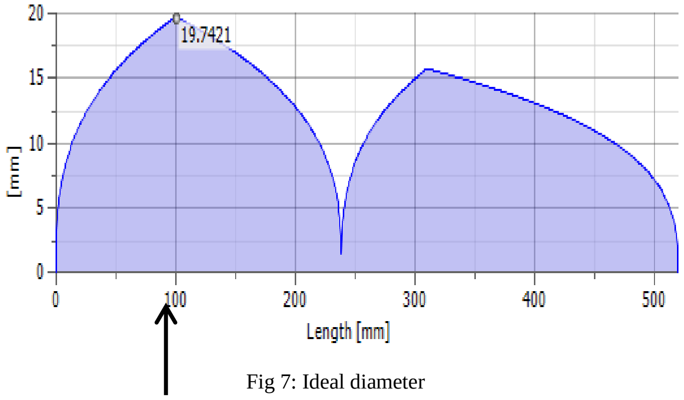


Fig 7: Ideal diameter

Design calculation and specification of inlet Hopper:

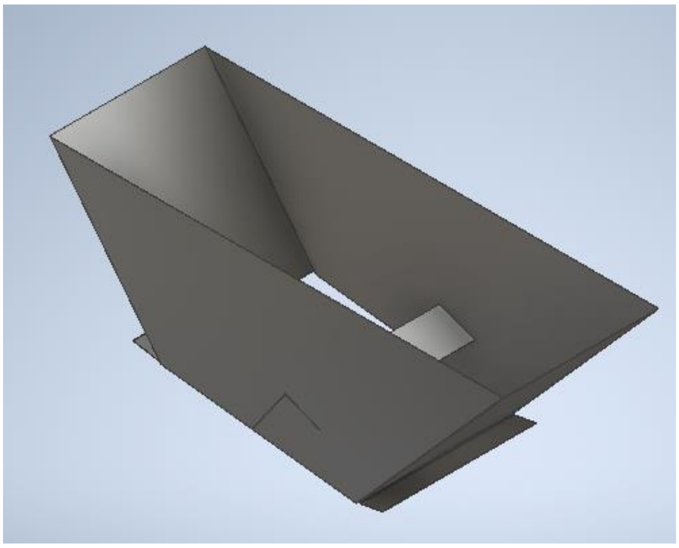


Fig 8: CAD Model of the Inlet Hopper

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$V = A \times b$

Where V = volume of the hopper
A = Area of trapezium + Area of triangle
b = breath of the hopper

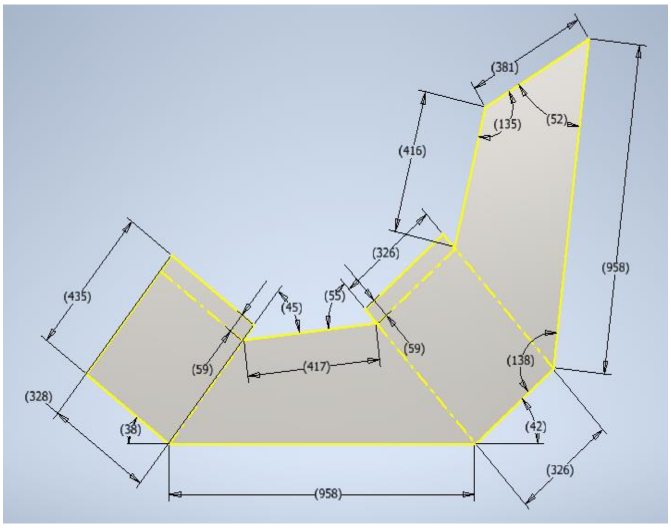

Fig 9: Sheet metal flat pattern of the inlet hopper

Structural Base:

Structural base was designer for high stability and rigidity using 60 x 60 x 6 mm Angle iron

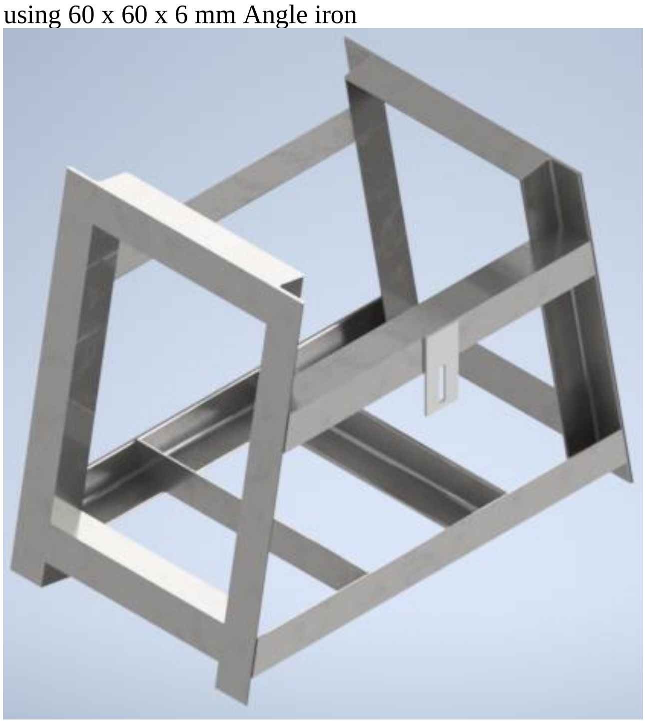

Fig 10: CAD Model of the Structural Base

Rigidity of the frame

This is the measure of the resistance offered by an elastic body to deformation. It is calculated using the expression:

$$k = \frac{F}{\delta} \quad (4)$$

Where K = Stiffness (Rigidity) (N\m)
F = Total force on the frame (N)
δ = maximum deflection on the frame (m)

Pulley and Belt Drive:

The belt and pulley drive system will involve four pulleys (3 pulleys and 1 idler pulley) and 2 belts.

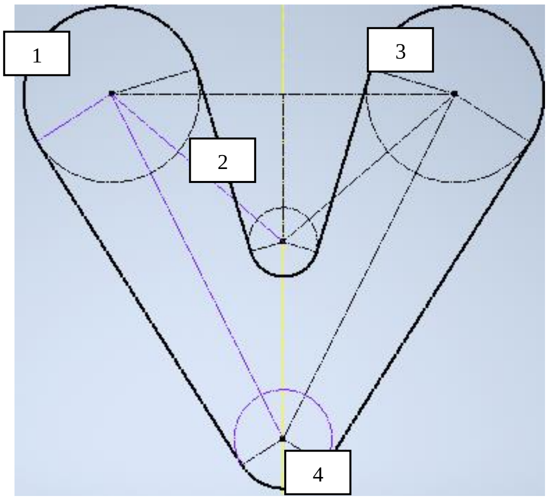

Figure 11: Pulleys connected by a belt.

The velocity ratio between two pulleys transmitting torque is given as (Avallone and Baumeister, 1997);

$$\frac{w_4}{w_1} = \frac{N_4}{N_1} = \frac{D_4}{D_1} \quad (5)$$

Where:
ω_1 = angular velocity of the last driven pulley
ω_4 = angular velocity of driver pulley
N_4 = rpm of driver pulley
N_1 = rpm of the last driven pulley
D_4 = diameter of driver pulley
D_1 = diameter of driven pulley
Θ = angle of lap between belt and pulley

- **Tensions on Belt (T_1 and T_2):-**

For belt transmission between two pulleys, the following equations by Hall et al., 1961 are used

$$T_1/T_2 = e^{\mu\Theta} \quad (6)$$

Also

$$\frac{T_1 - T_c}{T_2 - T_c} = e^{\mu\theta} \quad 3.11$$

And $T_c = mv^2$ 3.12

$T_c = T_1/3$ i.e. $3T_c = T_1$ 3.13

Where T_1 = tension on tight side of belt
T_2 = tension on slack side of belt
T_c = centrifugal tension
ω_1 = angular velocity of driver pulley
ω_2 = angular velocity of driven pulley
V = linear velocity of belt

The power transmitted with the belt is given as
$P = (T_1 - T_2)\, v$

In this equation the power (P) is in watts, when T_1 and T_2 are in Newton and belt velocity is in metre per second. When the tensions are in Newton and the velocity in metre per second,

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the horse power (HP) transmitted is given in watts or kilo watts.
1HP = 0.746 kw

Belt Length (L):-

The belt length will be determined using trigonometric ratio, Pythagoras theorem and cosine rule.

$$L = 2X_3 - \frac{(r_{1-r_4})^2}{X_3} + 2X_1 - \frac{(r_{1+r_2})^2}{X_1} +$$
$$2\left[2\pi - \arccos\left(\frac{X_1 + X_2 + X_3}{2X_1X_3}\right) - \arccos\left(\frac{r_1 + r_2}{X_1}\right) - \arccos\left(\frac{r_1 - r_4}{X_3}\right)\right] r_1 +$$
$$\left[2\pi - 2\arccos\left(\frac{r_1 + r_2}{X_1}\right) - \arccos\left(\frac{2X_1^2 - X^2}{2X_1^2}\right)\right] r_2 +$$
$$\left[\pi - \arccos\left(\frac{2X_3 - x^2}{2X_3^2}\right) - 2\arctan\left(\frac{r_1 - r_4}{X_3}\right)\right] r_4 \qquad (7)$$

Where:
L = length of belt
X_1 = centre distance between pulley 1 and pulley 2 (idler)
X_2 = centre distance between pulley 3 and pulley 2 (idler)
X_3 = centre distance between pulley 1 and pulley 4
r_1 = radius of pulley 1 r_2 = radius of pulley 2 (idler)
r_3 = radius of pulley 3 r_4 = radius of pulley 4

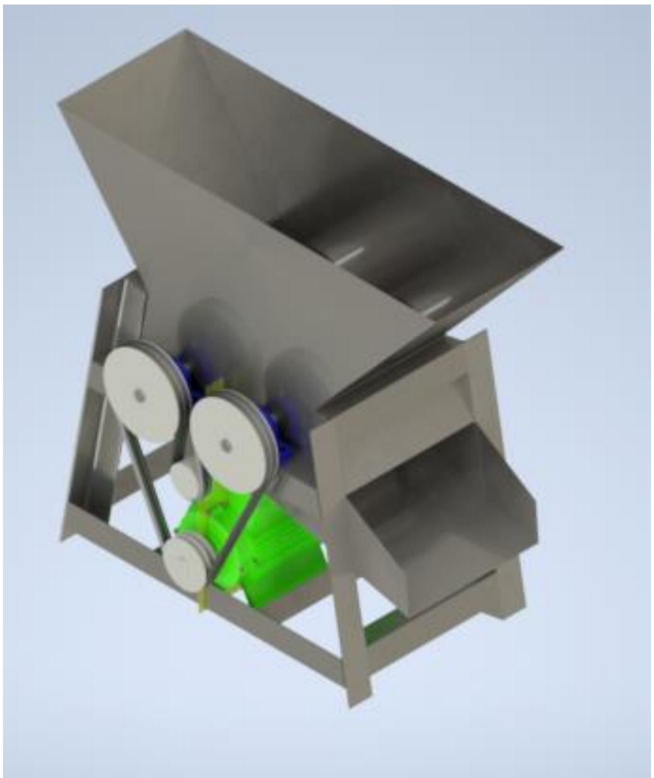

Fig 12: 3D CAD Model

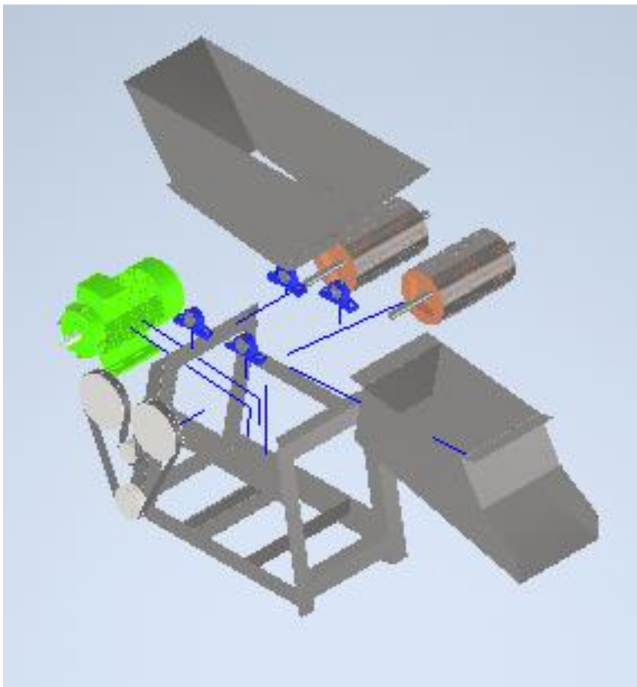

Fig 13: 3D Explosive CAD Model

DISCUSSION

Most mechanical systems have many standard components that makes up the machine. Hence, it becomes imperative to use Computer aided engineering software for the design and optimization of mechanical components. Autodesk Inventor professional which is equipped with component generators like Shafts, bearings, gears, belt and pulley. The use of such component generators aid in the proper designing of machines.

From the frame design, it was observed that the maximum load which can be loaded on the machine can have insignificant effect on the frame thereby making the machine to highly rigid and will minimum vibration effect.

Table 2: Technical specification of the machine

S/N	Component	Symbol	unit	Value
1	Electric motor Pulley diameter	d	100	mm
2	Cross-sectional area of belt	A	0.00015	m
3	Mass of belt	M_b	0.16296	Kg
4	Motor Speed	N	1450	Rpm
5	Angular velocity	w	151.86	rad/sec
6	Centrifugal force	F_c	375.81	N
7	Force due to grater	F_g	104.5	N
8	Force due to cassava load	F_m	250N	N
9	Total force	F_b	354.5	N
10	Volume of hopper	V	74,220,960	mm^3
11	Load overcome	F	1093	N
12	Targeted weight	W	74	kg

IV. CONCLUSION

In this study, an improved Double barrel cassava grating machine has been designed. Materials used were carefully selected with reference to the best global health practice. With the careful utilization of Autodesk inventor professional CAD Software, and application of the basic engineering design principle, the machine was design to grate cassava in minimum time with high throughput and also experience minimum vibration when in operation. The design also ensured easy of assembling and disassembling thereby making easy to be used.

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