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Design and Construction of Dried Cassava Pellets Grinding Machine

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ABSTRACT :*The use of grinding machine is one of the simplest methods of processing agricultural raw materials alternative to the traditional methods of using stone, mortar and pestle. Grinding process reduces the size of solid materials by mechanical action, and it achieves this by dividing them into smaller particles. Grinding of agricultural products is one of the oldest cultural techniques of humanity. In this research work,design and construction of dried cassava pellets grinding machine was carried out.The dried cassava grinding machine is made up of the following component parts; electric motor, main frame, pulley, transmission belt (V-belt), shaft, bearing, and vibratory tray sieve.The summary of results obtained from design calculation shown that; velocity of 5.54m/s, power of 1177.1W, torque of 10.16Nm were required for the operation of the machine. Also, the maximum deflection (0.00647mm) obtained is negligible relative to the length of belt (225mm) and the diameter of the shaft (25mm). This implies that the shaft will retain its ability to function optimally under the applied total transverse load (338.77N). Moreover, static failure analysis was carried out on the machine using SolidWorks CAD modeling. The results obtained show that the Von Mises stress is less than the stress required to cause yielding. Therefore, the design is safe*

KEYWORDS*-Design,construction, dried cassava,pellets, machine, torque, power*

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I. INTRODUCTION

Cassava, (Manihotesculenta, Crantz)is a tuberous starchy root crop of the family Euphorbiaceae [1]. It is a food crop, known worldwide for drought tolerance and for thriving well on marginal soils [2].Nigeria is presently the largest producer of cassava in the world with an annual output of over 34 million tonnesof tuberous roots [3]. It is majorly classified as sweet or bitter (manihotutilissimaormanihot palmate) cassava respectively [4]. According to Olukunle [5], cassavaproduction is needed in several areas; for enhanced food security, means of foreign exchange and tool for rapidindustrialization. However, the drudgery in processing cassava can be minimized or eliminated through adequate mechanical processing [6].

The use of grinding machine is one of the simplest methods of processing agricultural raw materials alternative tothe traditional methods of using stone, mortar and pestle [7].Grinding process reduces the size of solid materials by mechanical action, and it achieves this by dividing them into smaller particles [8]. Grinding of agricultural products is one of the oldest cultural techniques of humanity. As a result of size reduction, processing, and storage, farmers were forced to develop technology for grinding their produce. The most extensive application of grinding in the food industry is in the milling of the cassava pellets to make flour, but it is equally usedin many other processes, such as in the grinding of corn, for the manufacture of corn starch, grinding of millet, grinding of millet. There are usually two different methods used in effecting size reduction of dried cassava pellets. The grinding carried out by pounding via mortar and pestle,and the grinding done by crushing between two stones via grinding stone). The method of the pestle and mortar is widely used in the West-African country.However, the traditional method of grinding stone, pestle and mortar is time consuming and tasking. The traditional method is very laborious, and it is hard work for anyone to grind more useful quantity in a short period of time. To solve the problem of grinding dried cassava pellets traditionally, a mechanical method via the use of grinding machine was used in this research work. Grinding machines are machines that use the principles of abrasion, compression, attrition/shearing, impact or friction forces to effectsize reduction in Agricultural raw materials. The basic principle behind most of our local grinding machines is friction. In order to effect size reduction, the two frictional surfaces of the grinding machines have to come togetherto crush the material between them [9].

II. MATERIAL AND METHOD

The dried cassava grinding machine is made up of the following component parts, which includes:

(a) Electric motor
(b) Main frame
(c) Pulley
(d) Transmission belt (V-belt)
(e) The shaft
(f) The bearing
(g) Vibratory tray sieve

2.1 Design Calculation

2.1.1Speed Ratio of Belt Drive

Velocity ratio for belt drive is the ratio between the velocity of the driver and the driven. It may be expressed mathematically as:

$$\frac{N_2}{N_1} = \frac{D_1}{D_2} \qquad (1)$$

Where;
D_1 = diameter of the driver =75mm
D_2 = diameter of the follower = 150mm
N_1 = speed of the driver = 1440rpm
N_2 = speed of the follower =?
Therefore;

$$N_2 = \frac{(1440 \times 75)}{150} = 705rpm$$

2.1.2 Velocity of Belt

$$v = \frac{d_2}{2} \times \frac{2\pi N_2}{60} \qquad (2)$$

d_1 = 0.075m
N_1= 1410rpm

$$v = \frac{0.15}{2} \times \frac{2 \times \pi \times 705}{60}$$

v = 5.54m/s

2.1.3 Length of V-belt

r_1 = 37.5mm = 0.0375m
r_2 = 75mm = 0.075m
x = 225mm = 0.225m

$$L = \pi(r_2 + r_1) + 2x + \frac{(r_2 - r_1)^2}{x} \qquad (3)$$

$$L = \pi(0.0375 + 0.075) + 2(0.225) + \frac{(0.0375 - 0.075)^2}{x}$$

L = 0.8 m

2.1.4 Center to Center Distance between Pulleys

The centre to centre distance is given by Equation (4)

$$C = D_1 + D_2 \qquad (4)$$

Taking center to center as
C=150 + 75
C=225mm

2.1.5 Angle of Lap or Contact on Smaller Pulley

$\theta_1 = \pi - (\frac{D_2 - D_1}{C})$ (5)

$\theta_1 = \pi - \left(\frac{150-75}{225}\right) = 2.81rad = 160.98$degree

2.1.6 Angle of Lap or contact on Large Pulley

$\theta_1 = \pi + (\frac{D_2 - D_1}{C})$ (6)

$\theta_1 = \pi + \left(\frac{150-75}{225}\right) = 3.47rad = 198.79$degree

2.1.7 Cross-sectional Area of Belt

$A = \frac{1}{2}(X + Y)H$ (7)

X = 13mm

H = 8mm

Y =?

Q= $\tan 15 \times 8 = 2.14$

Y= X – 2(Q)

A = $\frac{1}{2}(13 + 8.72)8$

A = 86.88 mm^2

2.1.8Torque Transmitted by Shaft

$T = \frac{\boldsymbol{p \times 60}}{\boldsymbol{2 \times \pi \times N}}$ (8)

P = 1500W

N_1 = 1410rpm

T = $\frac{1136.59 \times 60}{2 \times \pi \times 1410}$

T = 10.16 Nm

2.1.9 Centrifugal Force

F = $\frac{T}{r}$ (9)

T = 10.16 Nm

R = 37.5mm = 0.0375

F = $\frac{10.16}{0.0375}$

F = 269.87N

2.1.10 Stress acting on belt

$\sigma = \frac{F}{A}$ (10)

F = 269.87N

A = 86.88mm^2

$\sigma = \frac{269.87}{86.88}$ = 3.15N/mm^2

2.1.11 Maximum Tension

T = $\sigma \times a$

a = 81.963×10^{-6}

σ = 3.15N/ mm^2

$T = 81.963 \times 10^{-6} \times$

T = 229.5N

2.1.12 Tension in Tight Side, T_1

$T_1 = T - T_c$ (2.12)
Centrifugal tension is neglected
Therefore $T_1 = 229.5N$

2.1.13 Belt Tension Ratio

$\frac{T_1}{T_2} = e^{\mu\theta 1 \mathrm{Cosec}\frac{\alpha}{2}}$ (2.13)

Where;
$\alpha = 32^0$
μ = Coefficient of friction = 0.22
T_1 = Tension in the tight side
T_2 = Tension in the slack side
θ_1 = 2.81rad

$\frac{T_1}{T_2} = e^{0.22 \times 2.81 \times Co\sec\left(\frac{32}{2}\right)}$

$\frac{T_1}{T_2} = e^{2.24}$
$\frac{T_1}{T_2} = 9.43N$

2.1.14 Tension of Slack Side, T_2

$\frac{T_1}{T_2} = 9.43N$
$T_1 = 229.5N$
$\frac{229.5}{T_2} = 9.43$
$T_2 = 24.34N$

2.1.15 Power Transmitted by v-belt
$P = (T_1 – T_2) V$ (2.14)
$V = 5.54m/s$
$T_1 = 229.5N$
$T_2 = 24.34N$
$P = (229.5 – 24.34)5.54$
$P = 1136.59W$

2.1.16 Shaft Design
A shaft is rotating device use to transmitting power and motion from one point to another. A solid shaft is used base on the following:
i. To obtain the maximum tensional rigidity possible for the minimal diameter
ii. Ensure that the shaft would withstand the applied transverse and axial loads without risk of failure
To this end, a mild steel solid shaft was selected.

2.1.16.1 Minimum Diameter of the Shaft
$\frac{T}{J} = \frac{G\theta}{L} = \frac{\tau}{r}$ (2.15)
Length = 300mm = 0.3m
G= (Modulus of rigidity) for mild steel =78GN/m^2 [10]
θ=Taking a minimum angle of twist of 0.05
T= Torque
J = second polar moment $=\frac{\pi D^4}{32}$
Ultimate tensile strength UTS = 440MPa

Torque (T) = 59.68Nm
Mathematically

$$\frac{T}{\frac{\pi D^4}{32}} = \frac{G\theta}{L} \quad (2.16)$$

Also,

$$d = \sqrt[4]{\frac{32TL}{\pi G\theta}} \quad (2.17)$$

$$\sqrt[4]{\frac{32\times 10.16\times 0.3}{3.142\times 78\times 10^{9}\times\frac{0.1\times 3.142}{180}}}$$

d = 0.025m = 25mm
Hence a diameter of 25mm was selected for the solid shaft in order to allow for extraneous torsional loads on the shaft and to obtain torsional shiftiness

2.1.16.2 Shaft Volume

$$V = \frac{\pi D^2}{4} \times L \quad (2.18)$$

$$V = \frac{3.142 \times 0.025^2}{4} \times 0.3$$

$V = 1.473\times 10^{-4}\ m^3$

2.1.16.3 The weight of the shaft

$W_S = \text{Density} \times Volume \times g$ (2.19)
Where density of mild steel = 7850 Kg/m^3 [10]
$7850 \times 3.865 \times 10^{-4} \times 9.81 = 29.76$

2.1.16.5 The Weight of the Grinding Plate Mounted on the Shaft

Grinding plate dimensions
Diameter (∅) = 150 mm
Thickness (t) = 20 mm

Volume of the grinding plates = $\frac{\pi D^2}{4} \times t \times n$

$$= \frac{3.142 \times 150^2}{4} \times 20 \times 2$$

$= 706950\ mm^3$
$= 7.0695 \times 10^{-4}\ m^3$
∴Weight of the grinding plate = Density ×Volume × 9.81
= 54.44N

Hence the total transverse load on the shaft = 254.57 + 29.76 + 54.44
= 338.77N

Assuming the total load is distributed evenly across the length of the shaft since the greatest transverse load is due to the weight of the loaded cassava to be ground

$$\frac{5\times W\times l^2}{384EI} \text{ [12]} \quad (2.20)$$

Where;
E= 200 GN/m^2
I= Moment of inertia

Maximum Deflection = $\frac{5\times 338.77\times (0.3)^2}{384\times 200\times 10^9\times I}$

$= \frac{1.985\times 10^{-12}}{I}$

But I= $\frac{\pi d^4}{64} = \frac{3.142\ \times 0.05^4}{64} = 3.068 \times 10^{-7}$

$$\therefore Maximumdeflection = \frac{1.985 \times 10^{-12}}{3.068\ \times 10^{-7}}$$

$= 6.47 \times 10^{-6} m = 0.00647\ mm$

2.1.17 Maximum Bending Moment of the Shaft (Load on bearing)

Distributed load per unit length $= \frac{255}{0.3} = 850N/m$

$R_A + R_B = 255 + 30 + 54 = 339$

$R_A + R_B = 339$

$EM_B = 0$

$(R_A + 300) – (30 \times 150) - (255 \times 150) = 0$

$R_A = \frac{(30 \times 150) - (255 \times 150)}{300} = 142.5$ N

$R_B = (339 – 142.5) = 196.5$ N

2.1.18 Volume of Hopper

$$\frac{1}{3}[(A_{base} \times H) - (a_{base} \times h)] \quad (2.21)$$

$$V_h = \frac{300}{400 + x} = \frac{100}{x}$$

$300x = (400+x)\ 100$

$300x= 40000 + 100x$

$200x = 40000$

$$x = \frac{40000}{200}$$

$x = 200\ mm$

Hence Volume $= \frac{1}{3}[(300^2 \times (400 + 200)) - (300^2 \times 200)]$

$= 17\ 333\ 333.\ 33\ mm^3$

$=0.0173\ m^3$

Density of dried cassava to be load ranges from 1239 to 1500 Kg/m^3 [11]

$\therefore maximummasstobeloadeedinthehopper = density \times volume$

m =Density $\times$Volume

$=1500 \times 0.0173 = 25.95$ Kg

Max Weight = mg = $25.93 \times 9.81 = 254.57$ N

2.1.19 Fabrication of the Machine

Frame

The stand of the machine was fabricated with angular mild steel bar of cross section 305mm x 760mm. the angular mild steel bar was chosen because of its rigidity, availability and relatively cheap. A mild steel sheet of 5mm x 305mm x 760mm was brushed. The angular bar was cut into four pieces to form the four Legs of the stand and welded to a frame to form a table stand. Two rollers were screwed to the legs for easy mobility of the machine

Shaft

A mild steel bar of 25mm x 300mm was mounted on the lathe chuck. Both ends were faced and then the rod turned into the designed diameter.

Hopper

The hopper is a truncated pyramid in shape. The truncated pyramid was constructed on drawing paper to hopper's specification. The shape was cut out and pasted on the galvanized steel sheet. Scriber was used to trace the shape on the steel sheet and snipers used to cut out the marked out shape. The cut out sheet was folded to the required shape and the lapping edges were welded to form a hopper

Vibratory Filtration Components

The basement of the filter was developed from 400mm x 400mm mild steel plate and was suspended on a spring which is vibrated by a shaft on load.

Figure 1 shows the isometric model view of the dried cassava pellets grinding machine.

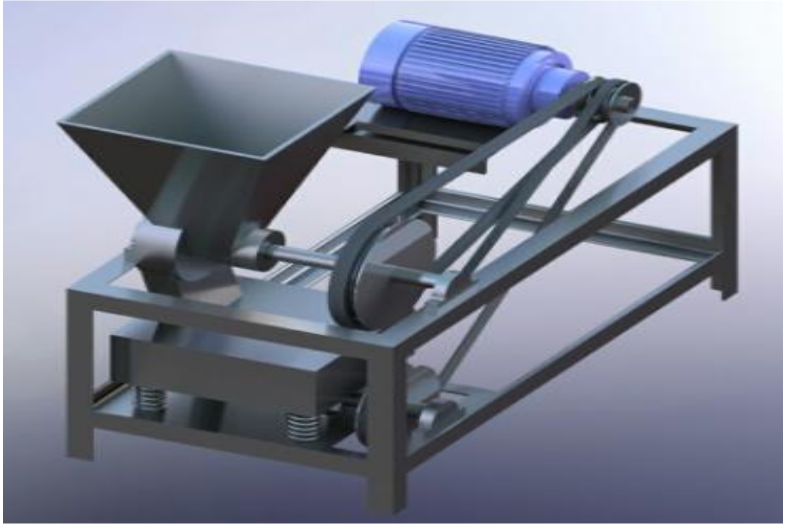


Figure 1: Isometric Model View of Dried Cassava Pellets Grinding Machine

III. RESULTS AND DISCUSSION

The summary of results obtained from design calculation is shown below.
Belt length = 225mm
Angle of lap on small pulley = 2.81rad
Angle of map on large pulley = 3.47rad
Tension on tight side = 273.6N
Tension of slack side = 25.2N
Peripheral Velocity = 5.54m/s
Power required by the machine = 1177.1W
Torque = 10.16Nm
Shaft diameter = 25mm
Shaft volume = 0.0001473m^3
Density of shaft = 29.76kg/m^3
Weight of grinding plate = 54.44N
Total transverse load on shaft = 338.77N
Maximum deflection = 0.00647mm
Volume of hopper = 0.0173m^3

The maximum deflection (0.00647mm) obtained is negligible relative to the length of belt (225mm) and the diameter of the shaft (25mm). This implies that the shaft will retain its ability to function optimally under the applied total transverse load (338.77N). The shaft is fixed between the bearings on both ends which are in turn fixed to the frame. Hence the axial loading on the shaft may be considered negligible.Thus, the shaft dimensions and material (50 mm solid mild steel shaft) was selected to provide optimum function under the expected axial, transverse and torsional loading condition.The performance test results obtained with the machine is shown in Table 3.1. The machine through put capacity is calculated from equation (1) [13].

$$MTC = \frac{M_1}{T} \tag{1}$$

The efficiency is given by equation (2)

$$Eff. = \frac{M_2}{M_1} \times 100 \tag{2}$$

The average efficiency is calculated from equation (3).

$$Ave. = \frac{\Sigma}{n} \tag{3}$$

Table 1: Performance Test Results

S/N	M_1 (Kg)	M_2 (kg)	T (min.)	MTC(kg/min)	Eff. (%)
1	30.00	25.01	8.00	3.75	83.37
2	28.45	20.85	6.45	4.41	73.29
3	25.05	15.45	5.05	4.96	61.68
4	23.20	14.20	4.45	5.21	61.20
5	20.45	12.25	4.00	5.11	59.90
Σ	127.15	87.76	27.95	23.44	339.44
Ave.	25.43	17.55	5.59	4.69	67.89

*M1 = Mass of dried cassava, M2 = Mass of properly grind cassava pellets

As shows in Table 1, performance test with the grinding machine was carried out five times with different masses of dried cassava that vary in weight. The average of mass of dried cassava pellets fed into the grinding machine and the mass of properly grind dried cassava to require sizes were calculated and it was used to determine the efficiency of the machine. An average efficiency of 67.89% was obtained and this shows that the machine is good and its performance was satisfactory. Figure 2 shows the graph of mass of dried cassava pellets, ground cassava pellets and efficiency. Figure 3 shows the graph of machine throughput capacity (MTC) and time of grinding. From the graph, the higher the mass, the longer the time of grinding. Also, the mass of cassava pellets is a function of the machine throughput capacity.

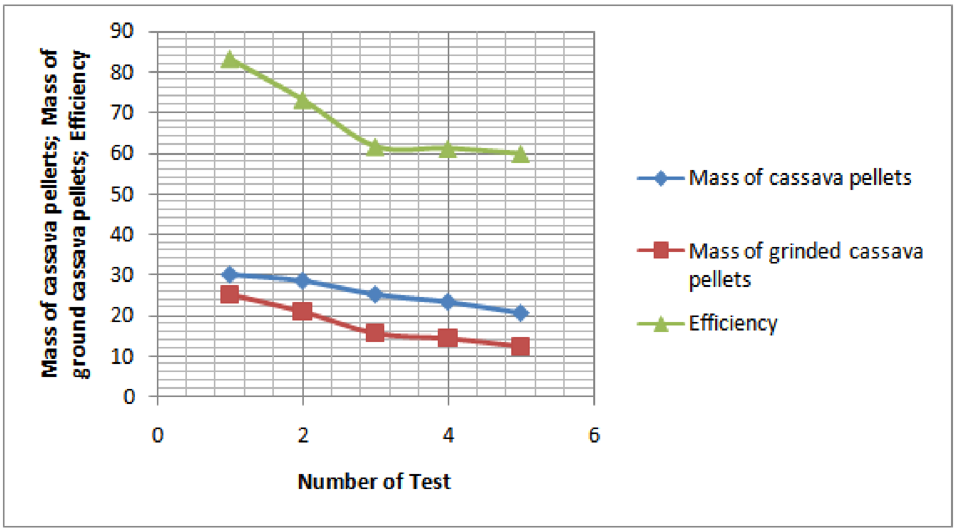


Figure 2: Plot of Mass of Cassava and Efficiency

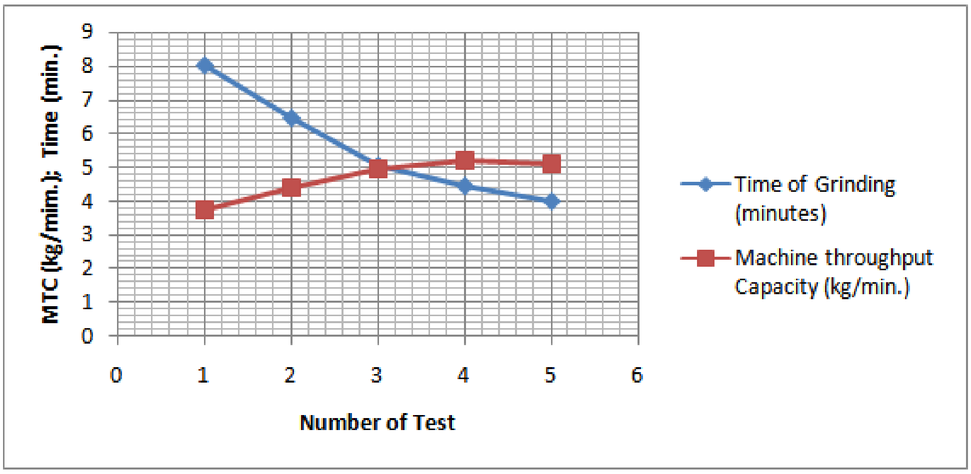
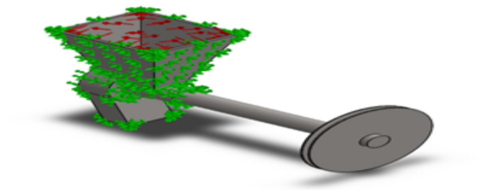


Figure 3: Plot of MTC and Time of Grinding

Static failure analysis was carried out using SolidWorks CAD modelling. Figure 4 shows the model information.



Model name: Cassava Pellets Machine Analysis

Current Configuration: Default

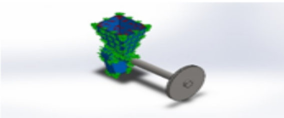
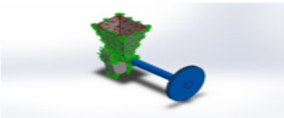
Solid Bodies			
Document Name and Reference	**Treated As**	**Volumetric Properties**	**Document Path/Date Modified**
Boss-Extrude2 	Solid Body	Mass:0.406501 kg Volume:5.21155e-005 m^3 Density:7800 kg/m^3 Weight:3.98371 N	C:\Users\Engr. Joe\Desktop\cassava grinding machine\cpmana.SLDPRT Feb 07 23:12:47 2018
Revolve2 	Solid Body	Mass:0.397277 kg Volume:5.09329e-005 m^3 Density:7800 kg/m^3 Weight:3.89331 N	C:\Users\Engr. Joe\Desktop\cassava grinding machine\cpmana.SLDPRT Feb 07 23:12:47 2018

Figure 4: Model Information

The material properties are shown in Table 2.

Table 2: Material Properties

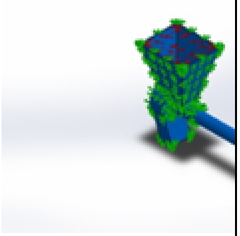
Model Reference	Properties		Components
	Name:	Plain Carbon Steel	SolidBody 1(Boss-Extrude2)(cpmana), SolidBody 2(Revolve2)(cpmana)
	Model type:	Linear Elastic Isotropic	
	Default failure criterion:	Max von Mises Stress	
	Yield strength:	2.20594e+008 N/m^2	
	Tensile strength:	3.99826e+008 N/m^2	
	Elastic modulus:	2.1e+011 N/m^2	
	Poisson's ratio:	0.28	
	Mass density:	7800 kg/m^3	
	Shear modulus:	7.9e+010 N/m^2	
	Thermal expansion coefficient:	1.3e-005 /Kelvin	

Figure 5 shows the static failure analysis using Von Mises criteria. The Von Mises stress is at maximum towards the fixed end of the shaft and hopper and the value obtained is lower than the yielding stress of the material. Therefore, the design is safe.

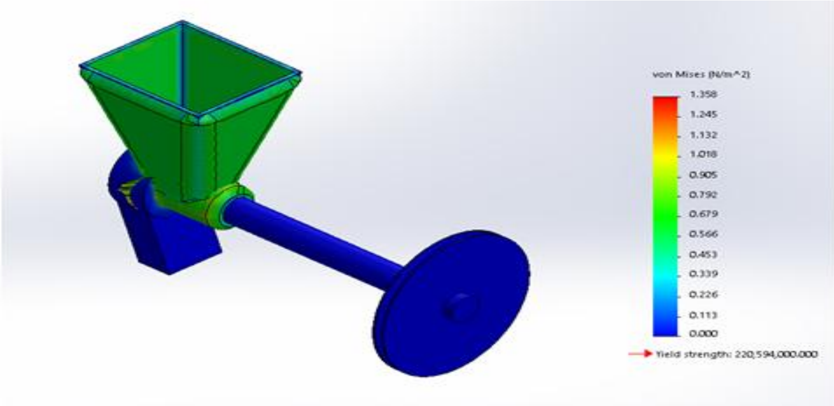


Figure 5: Static Failure Analysis

IV. CONCLUSION

Nigeria is presently the largest producer of cassava in the world with an annual output of over 34 million tonnesof tuberous roots. Processing of cassava for storage is usually done traditionally by average Nigerians. This research work focused on the designandconstruction of dried cassava pellets grindingmachine.The results obtained from the test performance analysis carried out on the machine design for domestic and commercial use in Nigeria show that the grinding machine was efficient and can be use across Nigeria towns and cities for processing of cassava tubers. This machine can replace the traditional method currently adopted by average Nigerian.

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