IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 12, Issue 4 Ver. II (Jul. - Aug. 2015), PP 07-15
www.iosrjournals.org

Design Analysis of a Reciprocating Cassava Sieving Machine

Stephen Tambari [1], Dan-orawari G.I [2], Aziaka D.S [3] Ayejah Victor [4]
[1,2,3,4] Department of Mechanical Engineering, Rivers State Polytechnic, P.M.B.20 Bori

Abstract: *The separation of course particles, big lumps or unwanted materials or impurities from grams (millets, rice, Soya beans, maize, dehydrated cassava etc) has always been a serious problem as it goes with massive/tremendous stress when done manually. This study is intended to case the stress involved in sieving grated dehydrated cassava using an electric motor as a source of power. This work uses the principle of slider crank mechanism which converts rotary motion of the pulleys to the reciprocating (sliding) movement of the sieving tray. The machine was tested and confirmed to have an output capacity of 100.59kg/hr and an efficiency of 75.7%, which makes it very adequate and capable for mass production.*
Keywords: *Reciprocating, Cassava, Sieving Machine*

I. Introduction

Energy is the driving force (power) that makes man, machines and systems work perfectly and efficiently. And food is the major source of energy that gives man the ability to work efficiently. In Africa, especially in Nigeria, Garri is the major staple food for man to be productive and as a result, the production processes need to be improved upon and to be taking seriously to enhance mass production in order to meet up the demand of the masses. The processed involved obtaining the final product called Garri includes, cultivation, tuber harvesting, peeling, grating, dewatering (squeezing), sieving and drying (frying). The sieving process which forms the basis of this study, involves the separation f coarse particles that is, ungraded portion of the cassava lumps from time and smoother ones. this is done after the moisture content of the meshed or pulp have been reduced to about 35% or 40% in the process of dewatering, a small lump is put on the palm and squeezed. If it is sufficiently dewatered, it will disintegrate that is break into smaller particles easily. Then it will be put on the local filter where little force and motion will be applied by hands to sieve and the smaller particles goes beneath the filter.

1.2 Purpose of the Study

This study is geared towards producing an end-product of better and more uniform quality and to reduce the drudgery and labour intensiveness involve when sieving manually.

1.3 Benefit of Study

This work will enhance and promote the establishment of economically viable small and medium scale cassava based industries that will mass produce garri (end product) and create new employment opportunities in rural areas.

1.4 Materials and Method

The first phase of the work was the design consisting of layout drawings as well as detailed production and assemble drawings. The fabricated parts are: the sieving tray, sieving chamber, collector which are made of Galarza steel, the frames and sieving table made of mild steel were welded. The sieving power comes from electric motor through v-belts on pulleys and transmitted to the connecting rod and the sieving tray.

II. Design Analysis

2.1 Design Considerations

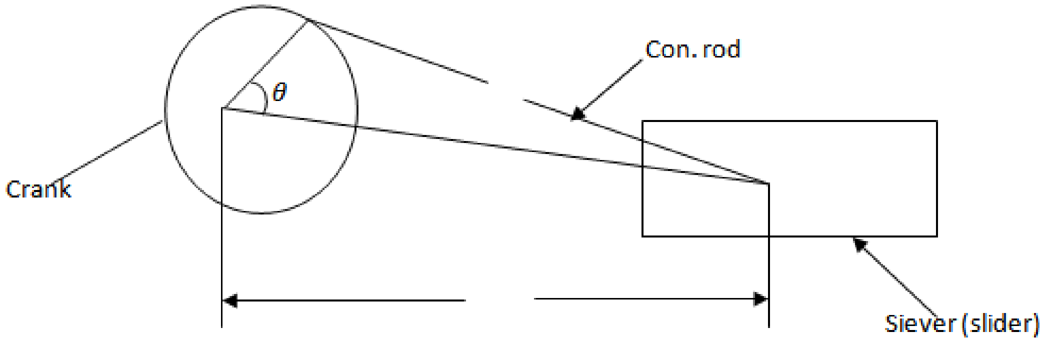
The following factors were considered during the design of this work. They are: strength of materials, wear, corrosion, moisture content, size and shape, and shape, cost/maintenance, power requirement etc.

III. Result and Discussion

The machine was tested for ten (10) different input values of dehydrated (squeezed) cassava and the time for each was taken and recorded.

Table 1 below shows he result. The output capacity of the machine was then calculated from the test to be 100.59kg/hr and efficiency is 75.7%. Which shows that the performance of the machine is high as compared to the manual method. And from all indications, the ratio of the performance of the manual method of sieving to this mechanized method is 1:7. This justifies the fact that the machine meets all design specifications, performs accurately with better efficiency, and so the results support the objective of the study.

2.2 Design Analysis/Calculations



1. The Maximum Displacement of the Siever (Slider)

The maximum displacement occurs when the crank is at an angle of 180^0 with the horizontal.

$So, r = 92mm, L = 435mm.$

$$X_{max} = r\,(1 - cos\theta) + \frac{r^2 sin\theta^{\,2}}{2L}$$

$$= 92\,(1 - cos180) + \frac{90^2 \times (sin\,180)^2}{2 \times 435}$$

$$= 92\,(1 + 1) = 184mm = 184mm$$

∴ The maximum displacement $X_{max} = 184mm$ @ 180^0

2. The Maximum Velocity of the Siever

The maximum velocity will occur when the acceleration $a_s = 0.$

Where

$$\Rightarrow a_s = w^2 r\left[cos\theta + \frac{cos\,2\theta}{n}\right]$$

So, since $a_s = 0$ (acceleration of siever).

$$O = w^2 r\left(cos\theta + \frac{cos\,2\theta}{n}\right)$$

$$\Rightarrow \quad O = ncos\theta + cos2\theta$$

But $cos2\theta = 2cos^2\theta - 1$

$$\Rightarrow O = ncos\theta + 2cos^2\theta - 1$$

So, Using Almighty Formula, and $n = \frac{L}{r} = \frac{435}{92}$

$$\Rightarrow \quad n = 4.728$$

$$\Rightarrow \quad 2cos^2\theta + 4.728cos\theta - 1 = \theta.$$

$$cos\theta = \frac{-4.728 \pm \sqrt{4.728^2 + 4 \times 2}}{2 \times 2}$$

$$= \frac{-4.728 \pm \sqrt{30.3539}}{4}$$

$$cos\theta = \frac{-4.728 \pm 5.5094}{4}$$

So, taking positive (+ve).

$$cos\theta = \frac{-4.728 + 5.5094}{4} = 0.1954$$

$$\theta_{max} = cos^{-1}\,0.1954 = 78.7^0$$

∴ The $V_{smax} = wr\left(sin\theta_{max} + \frac{sin\,2\theta max}{2n}\right)$

So, using N = 450 rpm (khurmi 2005)

$$\Rightarrow w = \frac{2\pi N}{60} = \frac{2 \times 3.142 \times 450}{60} = 47.13rad/s$$

$$\Rightarrow V_{smax} = 47.13 \times 0.092\left(sin78.7 + \frac{sin\,157.4}{2 \times 4.728}\right)$$

$$= 4.34\left(0.9806 + \frac{0.3842}{9.456}\right)$$

$$= 4.34m/s$$

∴ The maximum velocity of the siever (slider)

is $V_{smax} = 4.34m/s$

3. The Output Capacity (Kg/hr)

The output capacity, $Q_c = \frac{w_c}{t}$

Where: w_c = Total weight of the sifted mass (kg) and t = total time taken to sift (hr)

Table 1

Number of loading	Mass of cassava (kg) (sifted cassava)	Time taken (sec)
1	0.5	22
2	1.3	32
3	1.7	46
4	2.3	52
5	2.6	72
6	3.0	96
7	3.5	127
8	4.2	167
9	4.8	201
10	5.3	230
Total	29.20	1045

∴ The output capacity

$$Q_c = \frac{\text{Total mass of sifted dehydrated grated cassava}}{\text{Total time taken to sift}}$$

$$Q_c = \frac{29.20 \times 3600}{1045}$$

$$\therefore Q_c = 100.59 kg/hr$$

That is, the machine will be able to sift 100.59kg of dehydrated grated cassava in one hour.

4. The Sifting Efficiency (%)

Efficiency (%) = $\frac{w_2}{w_1} \times 100$

Where, W_2 = weight of the sifted mass (kg)

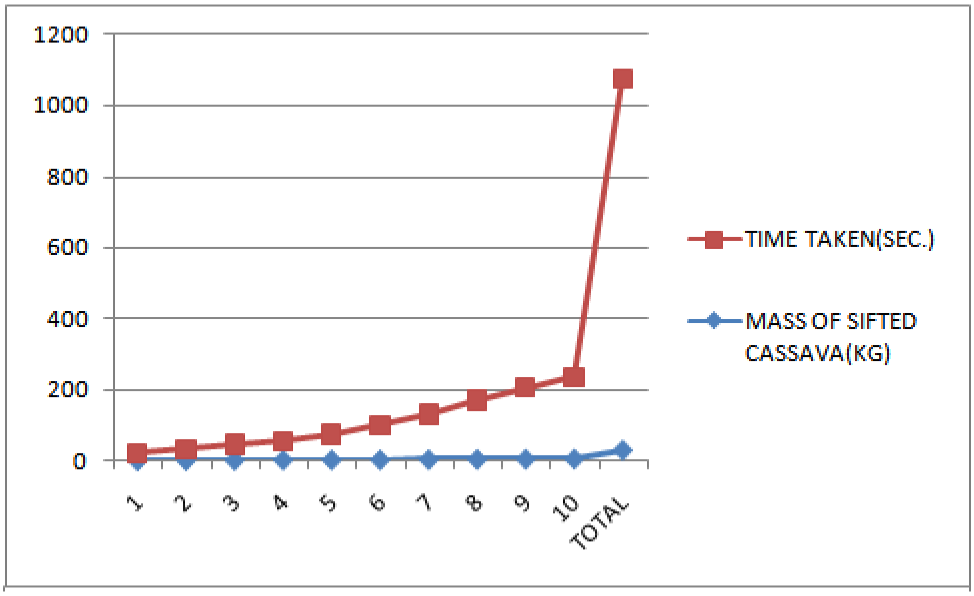
W_1 = Initial weight of the grated cassava mesh (kg)

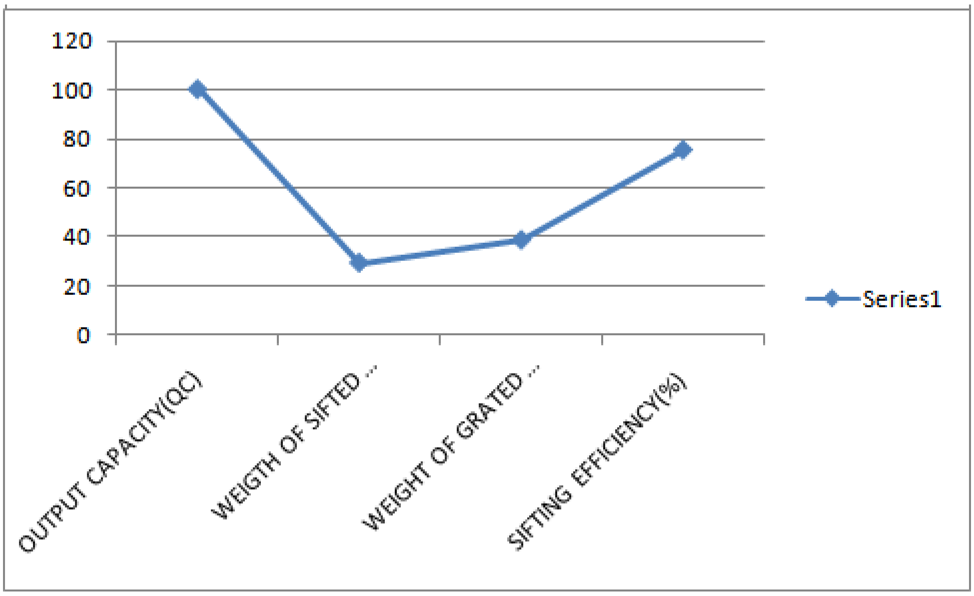
But W_2 = 29.20kg

W_1 = 38.6kg

∴ Efficiency = $\frac{29.20}{38.6} \times 100$

= 75.7%





5. The Total Load of the Siever Mechanism

The total load of the sieving mechanism consists of:

(a) Mass of sieve tray
(b) Mass of sieving chamber
(c) Mass of garri in container
(d) Mass of the screening material

(a) **Mass of Sieving Tray**

$M_{st} = T_{st} \times V_{st}$ ______ (1)

But $V_{st} = A_{st} \times T_{st}$ ______ (2)

Where; $A_{st} = 2(L_{st} \times H_{st}) + 2(B_{st} \times H_{st})$ __ (3)

Density of metal material, T_{st} = 7800kg/m^3 and L_{st} = 420mm, B_{st} = 310mm, H_{st} = 125mm and t = 2.0mm

So, substituting values,

$A_{st} = 2(0.42 \times 0.125) + 2(0.310 \times 0.125)$
= 0.105 + 0.0775 = 0.1825m^2

and $V_{sb} = 0.1825 \times 0.002$
= 3.65 × 10^{-4}m^3

$\therefore M_{sb} = 7800 \times 3.65 \times 10^{-4}$
= <u>2.85kg</u>

(b) **Mass of the Sieving Chamber**

$M_{sc} = T_{sc} \times V_{sc}$ ______ (4)

$V_{sc} = A_{sc} \times t_{sc}$ ______ (5)

and $A_{sc} = 2(L_{sc} \times H_{sc}) \times 2(B_{sc} \times H_{sc})$ ______ (6)

But the density of the metal material used is given as 7800kg/m^3 and $L_{sc} = 484mm$, B_{sc} = 475mm, t_{sc} = 2mm and H_{sc} = 75mm.

$A_{sc} = 2(0.484 \times 0.075) + 2(0.475 \times 0.075)$
= 0.0726 + 0.07125
= 0.1439m^2

and $V_{sc} = 0.1439 \times 0.002$
= 2.878 × 10^{-4} m^3

$\therefore M_{sc} = T_{sc} \times V_{sc}$
= 7800 × 2.878 × 10^{-4}
= <u>2.24kg</u>

(c) **Mass of Garri in the Container**

The mass of garri, $M_g = T_g V_g$ ______ (7)

and $V_g = L_g \times B_g \times H_g$ ______ (8)

For a dehydrated, grated cassava, the density is T_g = 563kg/m^3

Where; $L_g = L_{sc} = 484mm, B_g = B_{sc} = 475mm, H_g = H_{sc} = 75mm$

$\Rightarrow V_g = 0.484 \times 0.475 \times 0.075$

$= 0.0172m^3$

$\therefore M_g = T_g \times V_g$

$= 563 \times 0.0172$

= <u>9.71kg</u>

(d) **The Mass of the Screening Material**

The screening materials consist of the net and the net frame.

$M_{sm} = M_n + M_f$ ________________________ (9)

Where; M_{sm} = Mass of screening material

M_n = Mass of net

M_f = Mass of net frame

Where; M_n = 0.003kg and M_f = 0.45kg (Olawale J. Okegbile, Abdulkadir B, 2014).

$\therefore M_{sm}$ = 0.003 + 0.45

= <u>0.045kg</u>

$\therefore$ The total mass of the reciprocal sieve bed is:

$M_{rsb} = m_{st} + m_{sc} + m_g + m_{sm}$

= 2.85 + 2.24 + 9.71 + 0.45

= <u>15.25kg</u>

6. **Shaft Design**

(i) Minimum Shaft diameter

$d_s^3 = \frac{16}{\pi t_s} \sqrt{(k_b m_b)^2 + (k_t m_t)^2}$ ______________________ (k)

Where; m_t = torsional moment and m_b = bending moment

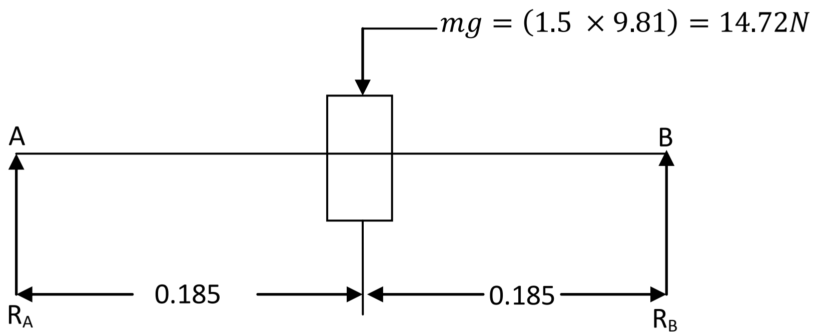
k_b = Combined shock and fatigue applied to bending moment.

k_t = Combined shock and fatigue applied to torsional moment

t_s = Allowable shear stress

k_t = 1.0 and k_b = 1.5 and $t_s = 40 \times 10^6 N/m^2$ (khurmi Design 2005).

But first, let us calculate the bending moment.



Calculating the Reactions

$R_A + R_B = 14.72$ _____________________ (1)

$\sum M_B = 0$

$R_A \times 0.37 = 14.72 \times 0.185$

$R_A = \frac{2.7232}{0.37} = 7.36N$

$\therefore R_A = R_B = 7.36N$

S.F Calculation

@ Pt. A: $S.F_A = R_A = +7.36N$

@ Pt. C: $S.F_C = R_A - 14.72 = 7.36 - 14.72 = -7.36N$

@ Pt. B: $S.F_B = R_A - 14.72 + R_B = 0$.

B.M Calculation

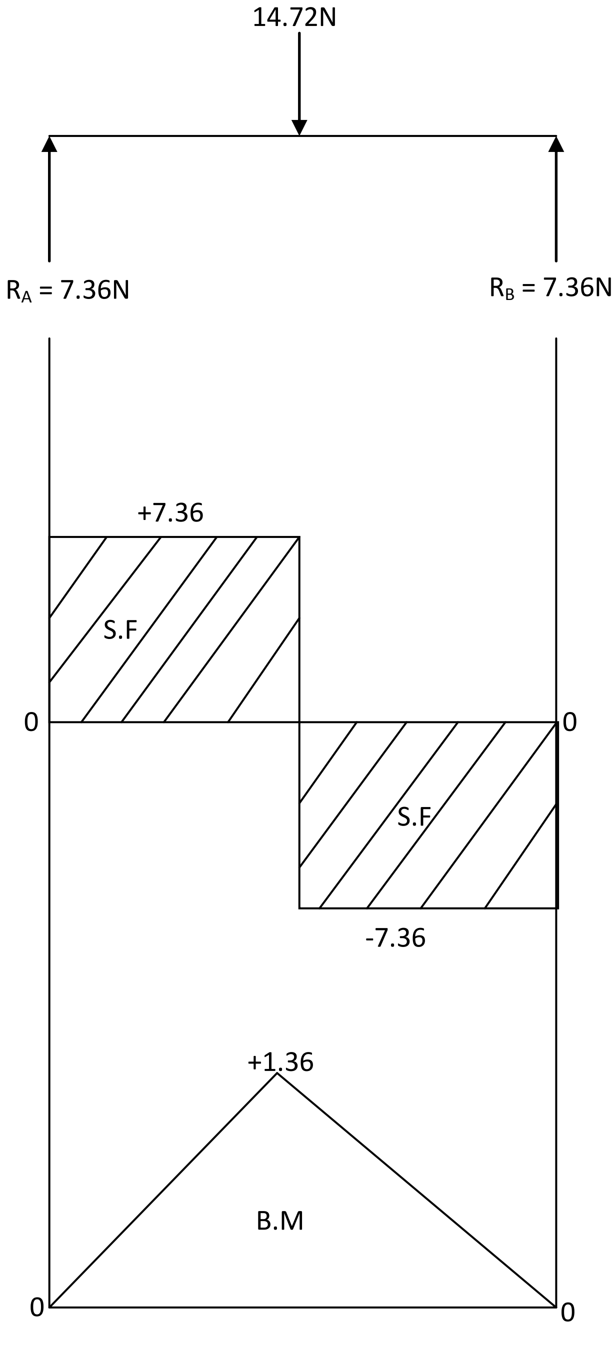
@ Pt. A: $B.M_A = 0$

@ Pt. C: $B.M_C = R_A \times 0.185 = 7.36 \times 0.185 = 1.36Nm$

@ Pt. B: $B.M_B = 7.36 \times 0.37 - 14.72 \times 0.185 = 0$

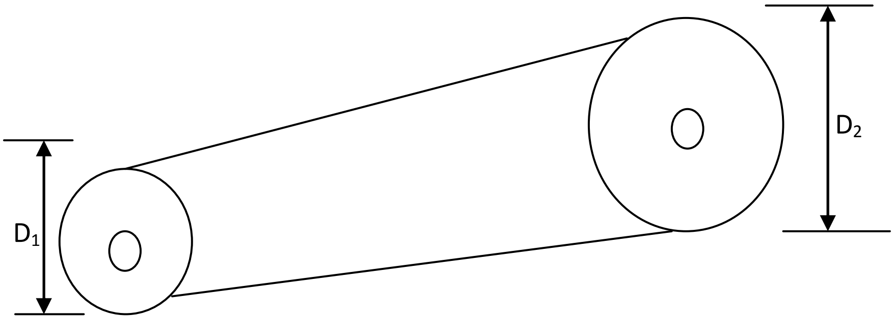
$\therefore$ The Maximum Bending moment is = 1.36Nm

S.F and B.M diagrams



So, M_b = 1.36Nm
and $M_t = \frac{power}{speed} = \frac{P}{V}$ ________________________ (m)

But P = $(T_1 - T_2)V$ = power to drive motor.
But Belt tensions T_1 and T_2 =?
Recall that, T_{AV} = Average torque on pulley = $(T_1 - T_2)\ \frac{D_1}{2}$



$\Rightarrow T_{AV} = (T_1 - T_2)\ \frac{D_1}{2}$ ________________________________ (a)
But T_{AV} = 31.05Nm (According to India standard)
and D_1 = 100mm and D_2 = 250mm (Khurmi and Gupta, 2005)
Where D_1 = Driver diameter
D_2 = Driven diameter
So, equation @ now becomes;

$31.05 = (T_1 - T_2)\ \frac{0.1}{2}$

$\Rightarrow T_1 - T_2 = 621$ ________________________________ (b)

Also, $\frac{T_1}{T_2} = \rho^{\mu\theta}$

$\Rightarrow T_1 = T_2\ \rho^{\mu\theta}$ ___________________________________ (c)

Where θ = 180 -2θ and groove angle varies between 32^0 to 40^0 (khurmi and Gupta, 2005)
So using $\theta = 32^0$

$\Rightarrow \theta = 180 - (2 \times 32) = 180 - 64 = 116^0$

$\therefore$ and $\mu = tan\theta$

$\Rightarrow \mu = tan32^0 = 0.66$

So, substituting values into ______________________ (c)

$T_1 = T_2\ \times\ 2.718^{\frac{0.66\ \times 116}{180}}$

$T_1 = T_2\ \times\ 2.718^{0.4253}$

$\Rightarrow T_1 = 1.5299\ T_2$ _____________________________ (d)

So, putting (d) into (b)

$\Rightarrow 1.5299T_2 - T_2 = 621$

$\Rightarrow 0.\ 5299T_2 = 621$

$\Rightarrow T_2 = \frac{621}{0.5299} = 1171.92N$

So, putting the value of T_2 into (d)

$\Rightarrow T_1 = 1.5299 \times 1171.92$
$= 1792.92N$

$\therefore T_1 = 1792.92$ and $T_2 = 1171.92N$
So, power $P = (T_1 - T_2)\ V$
But $V = w\ \times r$ and w = 47.13rad/s as calculated above.

$\therefore V = 47.13 \times 0.05$
$= 2.36m/s$

$\therefore$ Power, P = (1792.92 – 1171.92) 2.36
= 1465.56W
$\therefore$ P = 1.47KW
Also, from equation (m)

$M_t = \frac{P}{V} = \frac{1465.56}{2.36} = 621Nm$

So, substituting values into equation (k) to get the minimum diameter.

$$d_s^3 = \frac{16}{3.142 \times 40 \times 10^6} \sqrt{(1.5 \times 1.36)^2 + (1.0 \times 621)^2}$$

$$d_s^3 = \frac{16}{125680000} \sqrt{4.1616 + 385641}$$

$$\Rightarrow d_s = \sqrt[3]{(1.27 \times 10^{-7} \times 621)}$$

$$d_s = 0.0266m$$

$$\therefore d_s = 26.6mm$$

∴ We choose 25mm (standard diameter) as the shaft diameter.

IV. Recommendation

For further review, the following recommendations are hereby given:

1. This machine is highly recommended for domestic application especially for ruler dweller to boost the production of garri.
2. It is highly recommended that, the machine be modified so that it can also perform the functions of disintegrating the cassava particles as well as sieving it than using the hand manually.
3. This machines is recommended not only for grated and dehydrated cassava but also to sieve grains (maize, beans, soya beans, rice, millets etc).
4. It is recommended that, the grated cassava should be properly dehydrated to reduce the moisture content to about 60% in order to avoid slight resistance to push through the filter.
5. After sieving the fine particles from the larger (coarse) particles, it is highly recommended that further design should incorporate a method of discharging the undesired (coarse) particles automatically, instead of switching off the machines to remove these large particles before turning it on again for sieving.

V. Conclusion

Testing of the machine was done to evaluate the performance, and the results obtained showed that the study was successful as it was found to have an output capacity of 100.59kg/hr with an efficiency of 75.7%.

Therefore, the machine will absolutely facilitate the mass production of garri especially in rural areas and also overcome the massive/tremendous stress associated with the manual process.

Reference

[1]. Khurmi, R.S & Gupta, J.K (2008). A Textbook of Machine design (14th edition) New Delhi; Eurasia Publishing House, (chapter 14).

[2]. Onwuala, A.P, Akubuo, C.O & Ahaneku, I.F (2006) Fundamental of Engineering in Agriculture (1st edition) Lagos immaculate Publication Ltd.

[3]. Shigley, J.F & Mischke, C.R (2001) Mechanical Engineering design (1st edition) New York: McGraw-Hill Book of company, 1248 Pp.

[4]. Eugene, A.A, Theodore B (1996) Mechanical Engineering Research Publication, McGraw-Hill.

[5]. Yerxa, E.J Taylor and Francis "Occupational Science; a New Source of Power for participants in Occupational Theorapy"-Journal of Occupational Science ISSN 1442-5791 Volume: 13, Issue 1, April 1993 Pp154- 259.

[6]. Stephen, Tambari, Ibor Benjamin, Kanee Sorbari, Oruene W.D, Opuda Datonye (2014)-"Design Analysis of a Pedal Powered Cassava Grinding Machine – 10SR Journal of MECHINAL and Civil Engineering", e-ISSN: 2278-1684, p-ISSN: 2320-334X, volume 11, Issue 5 ver. IV.

[7]. Adetunji, O.R and A.H Quadric (2011) Design and Fabrication of an Improved Cassava Grater. Pacific Journal of Science and Technology. 12(120-129).

[8]. Oladele P.K, L Ayodeji, and S. Agbetoye (2007) Engineering Research of Improve Cassava Processing Technology. International Journal of Food Engineering, 3(6):9.

[9]. Zukbee, N.A, Festus, Chimezie, Kpabep M. Charity (2013), Design and Construction of a Dual Power Grain Grinding Machine. International Journal of Research and Advancement in Engineering Science, Volume 3.

[10]. Young, H.D and Freedom R.A (1996) University Physics (9th edition), Addison Westley Publishing CO. New York Pg 91.

[11]. Khurmi, R.S and Gupta J.K (2004) Theory of Machines and Mechanisms, S.C hand Publishers New Delhi.

[12]. Retsch, (2003): Basic Principles of Sieve Analysis: www.retsh.Com.