Computer Aided Design and Construction of Dewatered Cassava Mash Sieving Machine using Rotary Sweepers

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Abstract ***-*** *A cassava mash sieving machine with lump breaking device was designed using Computer Aided Design (CAD), and fabricated. The machine consists of a rotary sweeper with the sieve to sift the dewatered cassava mash poured into it through the hopper. The total mechanical power required for rotating screen is 3.746kW. It is designed to sieve 16.7kg of dewatered cassava mash in a batch and it is capable of producing 1.2tonnes/hr of sifted cassava mash. The machine is driven by a synchronous electric motor of 3.75kW with 1450 rpm, and has a sieving efficiency of 98%. The total cost of production is ₦139,100.00.*

Keywords: Cassava, gari, sieving machine, CAD

I. INTRODUCTION

Cassava (Manihot esculenta) is a woody shrub extensively cultivated as an annual crop in tropical and subtropical regions for its edible starch tuberous root. It is the third largest source of food carbohydrates in the tropics, after rice and maize, and a major staple food in the developing world. Cassava is rich in carbohydrates, calcium, vitamins B and C, and essential minerals. More than 228 Million Tons (MT) of cassava was produced in 2007, of which Africa accounted for 52% [1].

Nigeria is the largest producer of cassava worldwide producing 46 Million tons in 2007 and by 2012, Nigeria production increased to 54Million Metric Ton according to the Food and Agricultural Organization's corporate statistical database. Nigeria is the world's second largest consumer of cassava, after the Democratic Republic of Congo. Cassava can be cooked and eaten, processed into alcoholic beverages, biofuel, animal feed, laundry starch, and used for medicinal purposes etc. It is locally processed to gari, fufu, starch, lafun, abacha, etc for human consumption [2].

Gari is a creamy-white granular flour with a slightly fermented flavor and a slightly sour taste made from fermented, gelatinized fresh cassava tubers. It is widely known and consumed in Nigeria either by being soaked in water with sugar, coconut, roasted groundnut, dry fish, cooked beans, moinmoin or as eba, a pasted/semi solid material and food substance when poured into hot water and eaten with soup. Gari is rich in starch, has high fibre content, and contains protein and some essential minerals. When properly stored, gari has a shelf life of about six months. Processing of cassava to gari involves stages such as harvesting/sorting of cassava, peeling, washing, grating, fermentation, pressing or dewatering, sifting, drying, frying, cooling (to room temperature), sieving (optional) and packaging [3], [4].

The dewatered cassava mash is fermented under high pressure for 2-4 days in order to reduce the cyanide acid [5], the dehydrated cassava mash comes in form of cake that can be big as the size of the sacks in which they are packed and compressed. The cake formed from the cassava mash is a serious constraint to the granulation of gari, a necessary factor for efficient frying. This is because the caked cassava mash needs to be pulverized and sieved into granulets form with residual dods and fibres separated.

Sieving is a very important stage in the gari processing. It is the pulverization of pressed cassava mash carried out as necessary measure to achieve efficient heat transfer during the frying. It is equally important as it ensures the homogeneity of the finished product and reduces the energy required during the frying process. In addition, sieving will produce different grades of gari that will be suitable to different classes of consumers depending on local customers and traditions. The importance of sieving in the processing of cassava tubers to gari cannot be overemphasized, it includes:

i. Ensuring uniform frying of particles during garrification
ii. Removal of chaffs from the cassava mash before frying.
iii. Reduction of energy and time expended during frying.
iv. Ensuring the homogeneity of the dewatered cassava mash.
v. Ensuring the homogeneity of the finished products

II. LITERATURE REVIEW

From time immemorial, sieving has always been an important stage in the processing of cassava to gari. For example, before the advent of mechanization, gari processors, who are mainly women and young adults, had used the traditional method of sieving. The traditional or manual method involves the use of raffia sieve. The pulverization and sifting of cassava mash was carried out using a hand woven raffia sieve. (Approximately 450 x 450mm in size) and applying slightly pressure with both hands to rub the cassava mash against the sieve for some time. The sieved product is collected at the other side of the raffia sieve while the chaff is left and collected at the top of the sieve [6]. The traditional method of sieving has been found to be tedious, laborious, inefficient, time and energy consumption, unhygienic, prone to contamination of the cassava mash, and subject the operator to health hazards like back ache.

The mechanical or mechanized method of sieving involves the use of machine or mechanical devices in sieving cassava mash to solve the problems associated with the traditional or manual method. Over the years, various researchers have worked on producing various forms of sieving machine with varied degree of success. Fatusin and Sanni [7] fabricated and tested cassava mash sifter with lump breaking device driven by a 1.2kW, 1000rpm, 3phase electric motor. Igoh and Igoni, [5] constructed a continuous flow rotary gari siever with a moisture content of 7.6%. Jimoh and Oladipo also developed gari sift powered by a 1.2kW electric motor and a sieving capacity of 0.3kW [8]. All these efforts have been found to be with one shortcoming or the other. Also the design process had been too laborious and inaccurate due to the manual method of design employed.

This work uses the Computer Aided Design (CAD) 2000 version to design a dewatered cassava mash sieving machine using rotary sweepers.

III. DESIGN OF PARTS

A dewatered cassava mash sieving machine involves a lot of parts that require design. CAD has been employed to carry out the calculations, as well as the detailed drawings of the various parts making up the machine.

i. Design Shaft

Using Autodesk Inventor to design the main shaft of the machine, some input loads on the shaft have to be calculated. The loads on the shaft include the weight of cassava mash coming on the shaft from the hopper, the weight of the lump breaker spikes and the sweepers, belt tensions and reactions at the bearings

a. Calculation of the weight of the cassava mash

$$Weight of the cassava mash = Density of cassava mash \times Volume of the hopper \quad (1)$$

$$Volume of the hopper = \frac{1}{2}(a+b) \times h \times l \quad (2)$$

Since the hopper is of trapezoidal shape, from the equation, a = 370.4mm, b = 158mm, h = 272.3mm and l = 153.9mm

Therefore, $Volume of the hopper = \frac{1}{2} \times (370.4 + 158) \times 272.3 \times 153.9$

V = 11071821.47mm^3

= 0.01107m^3

Since the density of cassava mash is 1509kg, then weight of the cassava mash on the shaft =1509 x 0.01107

= 16.70kg =167N

b. Calculation of weight of lump breaker and sweeper

There are 15 lump breakers made of stainless steel rod and 10 sweepers made of stainless steel and rubber on the shaft

Weight of a breaker = 100g = 0.1kg

Therefore, total weight of the breakers = 15 x 0.1kg = 1.5kg = 15N

Weight of a sweeper = 70g = 0.07kg

Therefore, total weight of the sweepers = 10 x 0.07kg = 0.7kg = 7N

c. Calculation of belt tensions

Using an electric motor of 5hp and speed of 1450rpm,

The belt tension on both tight and slack sides, T_1 and T_2 respectively is given as:

$$T = (T_1 - T_2)r \quad (3)$$

Where T = Torque transmitted by electric motor and r = radius of electric motor pulley. If r = 30mm, the Torque transmitted is given as:

$$T = \frac{60P}{2\pi N} \quad (4)$$

Where P is electric motor power = 5hp = 3730Watts

N is speed of electric motor = 1450rpm

$$T = \frac{60 \times 3730}{2\pi \times 1450}$$

T = 24.56Nm

Assuming belt tensions ratio ≤ 3

i.e. $\frac{T_1}{T_2} \leq 3$

T_2 = 409.41N

and T_1 = 1228.241N

Total belt tension T = 1637.65N

d. Calculation of reactions at the bearing supports

The loads acting on the shaft are distributed on the shaft as shown in figure 1.

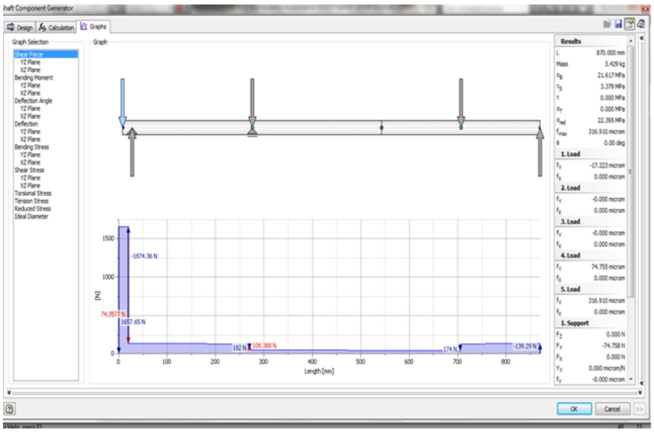


Fig 1: Computer aided design interface showing the loads acting on the shaft

Where:

W_p is Weight of the pulley = 2kg = 20N

T is Total belt tensions = 1637.65N

W_b is Weight of lump breakers = 15N

W_c is Weight of cassava mash = 167N

W_s is Weight of sweepers = 7N

R_1 and R_2 are reactions at the bearings

To find R_1 and R_2,

$R_1 + R_2 = W_p + T + W_b + W_c + W_s + W_c$
$R_1 = 1874.36N$
$R_2 = 139.29N$

ii. Design output

After inputting all the load data on the shaft, the program was then run to generate the output and the parameters for the design of the machine. Tables I, II, and III below show some of the design outputs generated through the Autodesk inventor, 2010.

Table I: Calculation of Loads

Index	Location, mm	Radial force		Size (N)	Y micron	Size micron	Direction (deg)	Deviation
		Y (N)	X (N)					
1	0	1657.650		1657.65	-17.223	17.223	180.00	0.05
2	20	-1874.360		-1874.36	-0.000	0.000	180.00	0.05
3	270	182.000		182.000	-0.000	0.000	180.00	0.02
4	705	174.000		174.000	74.755	74.755		0.06
5	870	-139.290		-139.290	316.910	316.910		0.09

Table II: Table showing the supports

Index	Type	Location (mm)	Reaction Force					Yielding	Type	Deflection				Deflection Angle (deg)
			Y		Size (N)	Direction (deg)	Axial Force			Y (micron)		Size (micron)	Direction (deg)	
1	Fixed	20	-74.758		74.758	180.00			User	-0.000		0.000	180.00	0.05
2	Free	270	108.388		108.388				User	-0.000		0.000	180.00	0.02

Table III: Table showing the force, stresses, and deflection

Length	L	870.000 mm
Mass	Mass	3.429 kg
Maximal Bending Stress	σ_B	21.617 MPa
Maximal Shear Stress	τ_S	3.379 MPa
Maximal Torsional Stress	T	0.000 MPa
Maximal Tension Stress	σ_T	0.000 MPa
Maximal Reduced Stress	σ_{red}	22.395 MPa
Maximal Deflection	f_{max}	316.910 microns
Angle of Twist	Φ	0.00 deg

IV. FABRICATION PROCEDURE

The fabrication of the cassava sieve was carried out with detailed design drawing and the machine was constructed with the locally available material. The fabrication procedures are as analyzed below:

A. THE FRAME

The frame was made of a 50x50x2mm mild steel angle bar as shown if figure 2. Four pieces of mild steel angle bar iron was cut to a length of 864mm and another 4 pieces of angle bar iron, two of it was cut to a length of 520mm and other two to a length of 485mm so that the longer angle will be placed vertical with slight bending for rigidity while the smaller one are welded at the top of the longer one to form a rectangular shape at the top. Another 4 pieces length of angle bar of 740mm long was used to braze it at a distance of 150mm to the base of the frame for rigidity. Another extension, of 3 pieces of angle bar of 260mm length, is cut and it is welded at 45mm distance to the two edges of the standing frame for the hopper of the machine and two pieces angle bar of length 570mm long cut at 45° angle at both side edges and welded from the extension to the standing frame to braze the two parts for erect standing and rigidity.

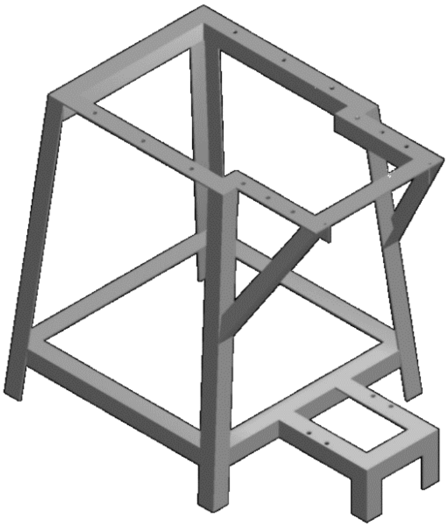


Fig. 2: Frame.

B. HOPPER

The hopper was made of stainless steel of 3mm thickness. The stainless steel plate was cut, folded, and joined as shown in figure 3 to achieve the hopper shown in figure 4. Trapezoidal plate is cut of length 365.9mm and height of the upper end is 150mm and the lower end 200mm and another plate is cut of 200mm length bent to form an angle of 149° with another plate of 150mm welded vertically to the 260mm length plate, then the 2 trapezoidal plates cut horizontally are welded at the ends of the same plate. Another plate of height 200mm is welder on a sector like shape of radius 34.4mm so all the parts are welded together to make it one unit. The purpose of the sector like shape is to prevent the de-watered cassava mash from escaping when feed vertically.

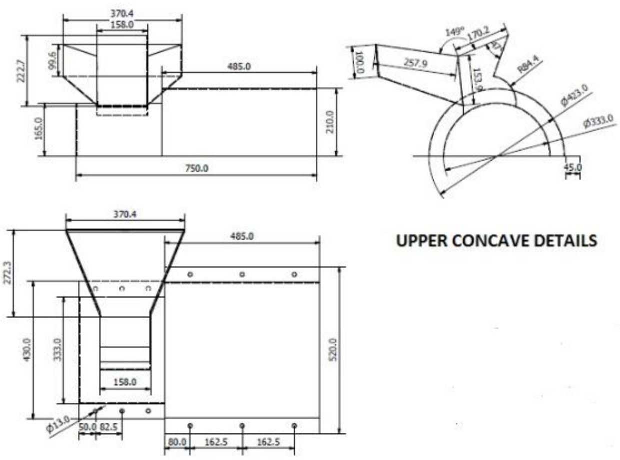


Fig. 3: Upper concave details

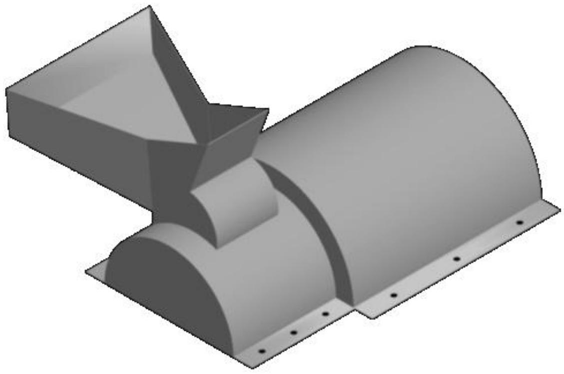


Fig. 4: Hopper with housing unit.

C. SIEVE

The sieve is made of stainless steel square mesh. The mesh is cut to a length of 495mm and width of 520mm which is then bent to form a cylindrical shape of radius 250mm; then, it is taped at ends to a length 70mm placed 20mm at the centre, and bent over it with the sieve right inside the plate. A plate of the same thickness and radius was cut and welded to a cylindrical shape to form the side of the same radius and an exit is cut off to allow the chaff to escape through. The taped end is bent to rest on the frame. One side of the sieve is cut to form a semi circle of a distance of 100mm to the base of the sieve. Then, a conical shape like plate is cut with length 268mm welded on the cut out parts of the sieve to make them a single unit as shown in figure 5.

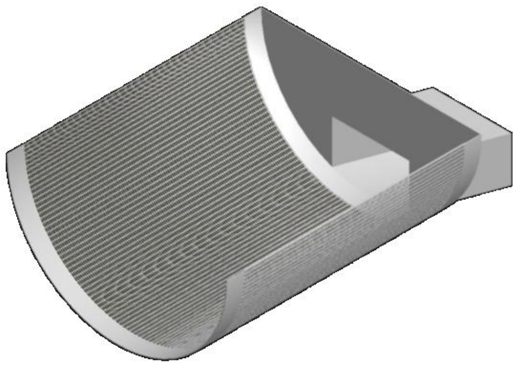


Fig. 5: Sieve.

D. HOUSING

The housing is made of stainless steel of 2.5mm thickness and it is splitted into two with one side bigger than the other side. The stainless steel plate is cut to length and breadth of 485mm and 520mm. The other smaller part is cut to length and breadth of 265mm and 165mm, the bigger one is folded to form a cylindrical shape with radius of 210mm while the smaller part is also folded to form cylindrical shape welded at 45mm distance to the top of the bigger housing. So a square hole is cut out of the smaller part where the hopper is welded together to make the housing and the hopper one unit. It is bent at 50mm on both sides to lie on the frame which afterwards was drilled to a diameter of 14mm with the sieve and the frame so they can be bolted together.

E. SHAFT

The shaft is made of stainless steel rod and of total length of 886mm. It is turned to a length of 6mm for pulley and 4mm on both sides of the bearing. It consists of breakers and sweepers. The breakers being 30mm wide each had 10mm bent at 90^o to give the breaker strength while the sweepers which are 50mm wide each are bent 20mm at 90^o to strengthen them. The shaft is provided with a cup where dunlop sweepers fixed to sweep the dewatered cassava mash when loaded in the machine. The sweepers and the breakers are arranged sinusoidally to be able to sweep out the chaffs through the exit.

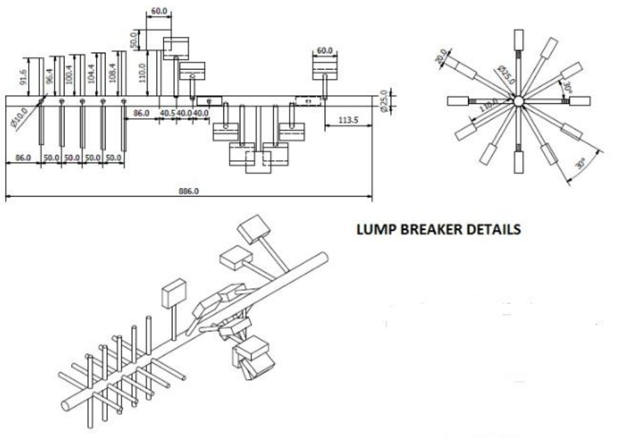


Fig. 6: Shaft with breakers and sweepers.

F. RECEIVING TRAY

The receiving tray or discharge outlet is made of stainless steel of 1.5mm thickness and aluminum 3mm thickness. The receiving tray was constructed using a total length of 730mm, with a breadth of 485mm. Thereafter 300mm was cut and was beveled on both sides to form an angle of 68^o, which consists of length of 322.2mm and width of 242.5mm. The part cut was welded to the standing frame and bent to an angle of 68^o. Another aluminum sheet was cut to a length of 728.5mm and divided into two of length 430mm and 298mm, the 430mm cut was used to form a semi circle at a radius of 208.5mm which is then riveted to the stainless part of the receiving tray on one side and the other side retain the normal length and it was riveted to the other side to prevent the sieved product. After all this, another aluminum plate was cut 121.25mm from both sides which was bend at both side to a length of 20mm to form 90^o so that it can lay on each other for riveting as shown in figure 7.

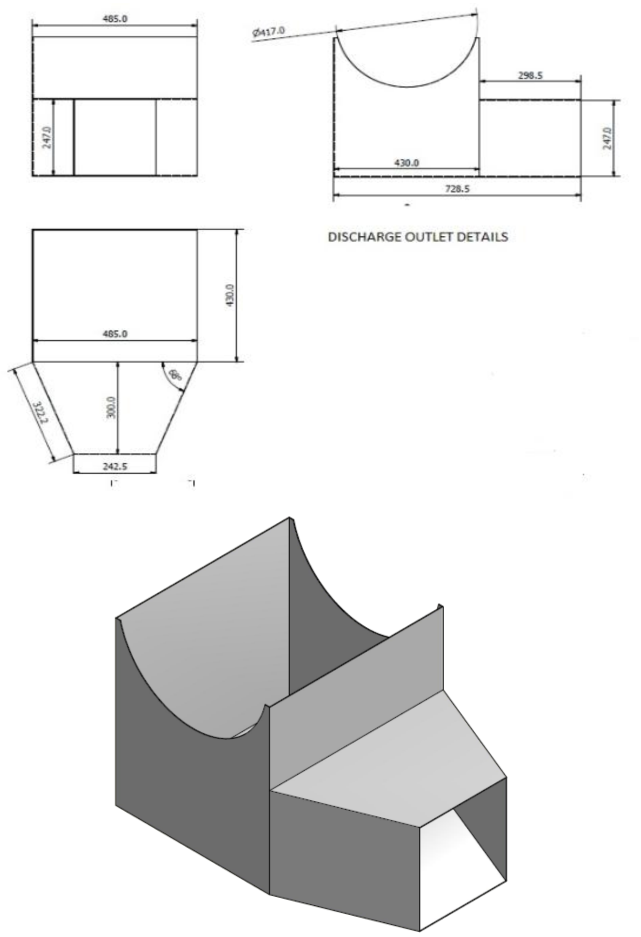


Fig. 7: Receiving tray or discharge outlet.

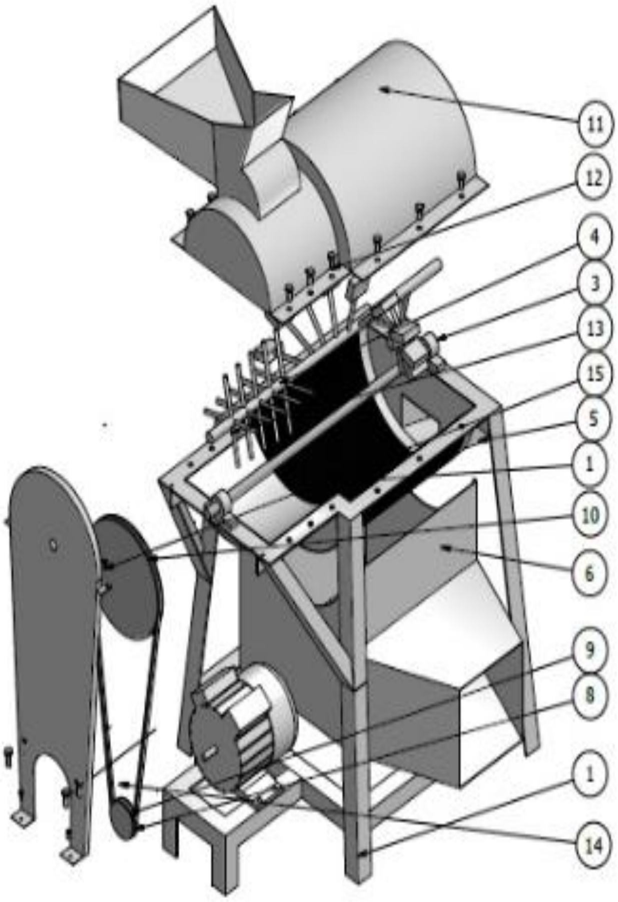
V. ASSEMBLYING PROCEDURE

The frame is placed on a level ground and the sieve is place inside the frame to seat properly on it.

A shaft of 25mm diameter was turned at both ends to reduce the diameter of the shaft to 20mm. The distance covered by the bearing at one end is 4mm and the other end is 10mm, including the distance of pulley (6mm) to the other end.

However, after the straight turning of the shaft at both ends, two pillow bearings of 20mm diameter were fixed into the shaft of the same diameter at both ends to allow the bearings unit to seat properly on the frame.

After the assembling of the sieve, the shaft (which is attached with the breakers and sweepers) bearings, and the hopper were then assembled with dampers attached around it to reduce excess vibration by bolting it firmly to the frame. The hopper was bolted for future, proper maintenance and replacement of any worn out parts of the machine. The motor seat was perfectly joined with the frame of the machine, where the motor (synchronous) was fixed and a belt connected to the pulley.



PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	FRAME	
2	1	LUMP BREAKER BOTTOM	
3	1	BEARING	
4	1	SHAFT AND BREAKER	
5	1	SIEVE	
6	1	DISCHARGE OUTLET	
8	1	V-Belt	
9	1	Grooved Pulley1	
10	1	Grooved Pulley2	
11	1	UPPER CONCAVE	
12	16	ISO 4014 - M12 x 50	Hexagon head bolt - product grades A and B
13	13	ISO 4032 - M12	Hexagon nuts, style 1 - Product grades A and B
14	1	BELT GUARD	
15	4	ISO 4014 - M6 x 30	Hexagon head bolt - product grades A and B
16	1	Shaft	
17	1	ELECTRIC MOTOR	

Fig. 8: Exploded drawing of the machine

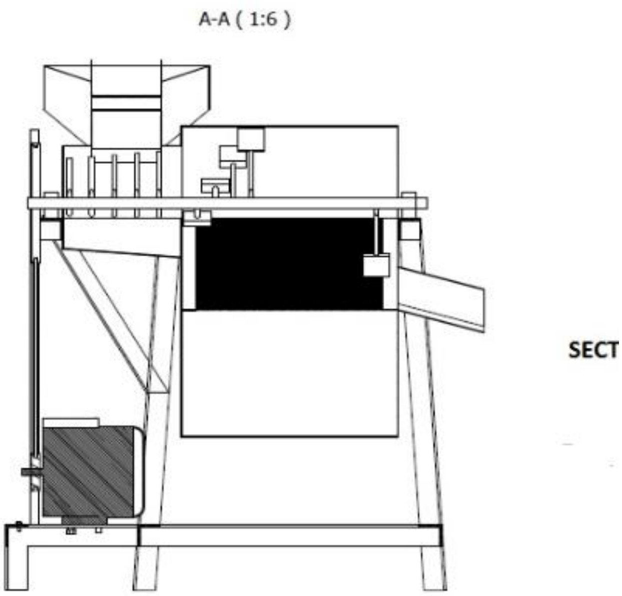


Fig. 9: Sectional view of the machine

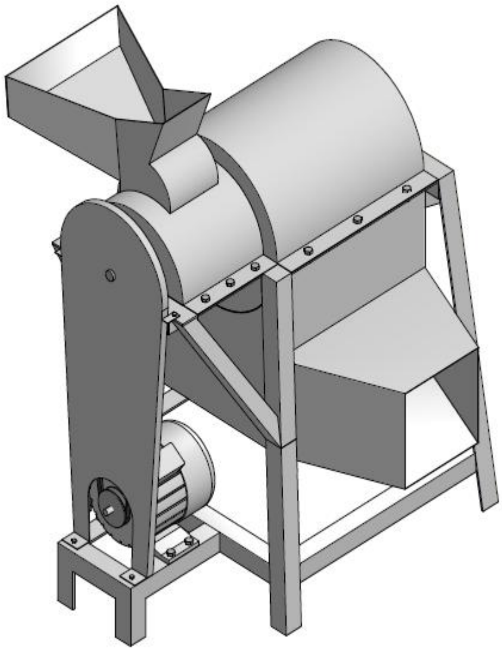


Fig. 10: An Assembled Machine.

VI. CONCLUSION

The problems associated with manual sieving of cassava mash have been solved by the design and fabrication of a dewatered cassava mash sieving machine using rotary sweepers. The design is simplified and made more accurate by the application of CAD to the design processes. The parts were carefully designed and the parts were selected from locally available materials in order to reduce the cost and adapt it to the local ecosystem.

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