Journal of Environmental Issues and Agriculture in Developing Countries
Volume 10, Number 3, December 2018
ISSN: 2141-2731

Development and Utilization of Mobile Cassava Grating Machines in Nigeria

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ABSTRACT

Garri and starch are staple food in Africa and Nigeria in particular, these and other numerous foods are by products of cassava. With the continued demand for these by products, the need to fabricate machines for easy grating of cassava becomes inevitable. A mobile cassava grating machine is designed, fabricated using locally sourced material and tested to determine its output capacity. The current design is an improvement to the other designs. It consists of a hopper unit, the grating drum and the delivery channel; it also consists of tyres for easy mobility. All these components are assembled on a frame made from angle bars. The machine is mechanically powered; the grating drum is also made of metallic cylinder that carries a perforated plate which served as the grater. The machine cost ₦42,000.00 to produce, with an output capacity of 55.79 kg/hr. The machine is economically affordable and used for both house hold and industrial purposes.

Keywords: *Cassava grater, cassava machine, mobile, development and utilization*

INTRODUCTION

Cassava *(manihotesculenta)* is a tuber plant that can be processed into food for human consumption, the uses of cassava are numerous, and it can be processed into garri, fat and even starch (Ndaliman, 2006). The tubers of cassava cannot be stored for long after harvest before decaying and so processing follows immediately after harvesting (Ndaliman, 2006). Cassava processing leading to size reduction includes peeling, grating, dehydrating, milling and sieving (Ndaliman, 2006). Cassava processing by grating is of main concern in this paper. Different types of graters have been used over the years with one short coming or the other. Oyesola (1981) reports in (Ndaliman,

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2006) that the traditional method of grating was first used, and this involves placing of the local grater, which is made of perforated metal sheet on the table when it is convenient for effective use and brushes sheet metal the cassava turns into pulp and drop into container that is being used to collect the grated pulp cassava. Many modifications have been introduced, Adejumo (1995) in Ndaliman, 2006) designed a wooden grater in which the cassava forced into a hopper is rubbed against the grater which is being electrically powered. Enhanced quality of cassava can be grated using this method (Ndaliman, 2006). However, the durability of the grater is low because of its wooden nature (Ndaliman, 2006). Ndaliman (2008) in Oriaku, Angulanna, Odenigbo and Adizue (2015) fabricated a pedal operated cassava grater which is powered by human efforts applied to pedal. The grinder pulverizes the cassava tubers into paste which can pass through a wire sieve. The effective performance of the design was at 60% (Ndaliman, 2006). Ndaliman (2006) also designed a double action grater; the machine assembly is powered mechanically or manually in case of electrical failure. Apart from faster grating rate, it required less time. The grating drum is made of metallic pipe that carries perforated plate which served as the grater. The main objective of this work is to design, fabricate and utilize a mobile cassava grating machine using locally sourced materials in Nigeria.

MATERIALS AND METHOD

Design consideration

In designing the cassava grater, certain considerations were put in place:

i. The machine should be portable and mobile so that it can be used for both household and industrial purposes.

ii. Another consideration is that cassava produces a large amount of cyanogenic glycosides so in selecting materials for construction adequate care was taken not to use materials that can corrode easily due to the acidic content in cassava (Adetunji and Quadri, 2011).

Design principles

The design principles adopted for this grater are as follows:

i. The gravitational dropping of the peeled cassava tubers from the loading platform to the grating point and exit of the pulp to the receiver.

ii. The continuous abrasive force (frictional force) delivered to the tubers by the rough surfaces of the rotating barrel which is achieved by the rotating barrel which is achieved by the rotating actions of the pulley, bearings, belt and shaft (Oriaku, Angulanna, Odenigbo and Adizue, 2015).

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Hopper Design

The hopper has the shape of the frustum of a pyramid

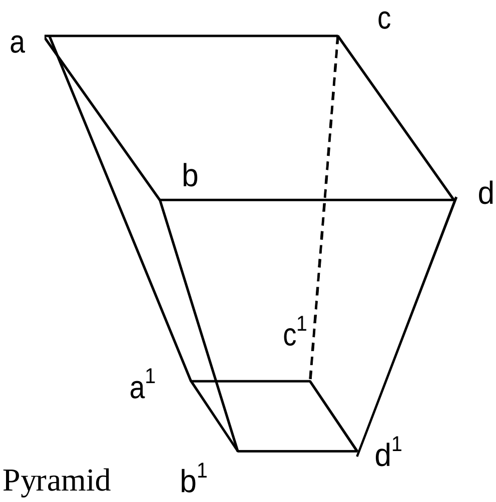

Figure 1: Frustum of Pyramid

Source: (Adu, 2004)

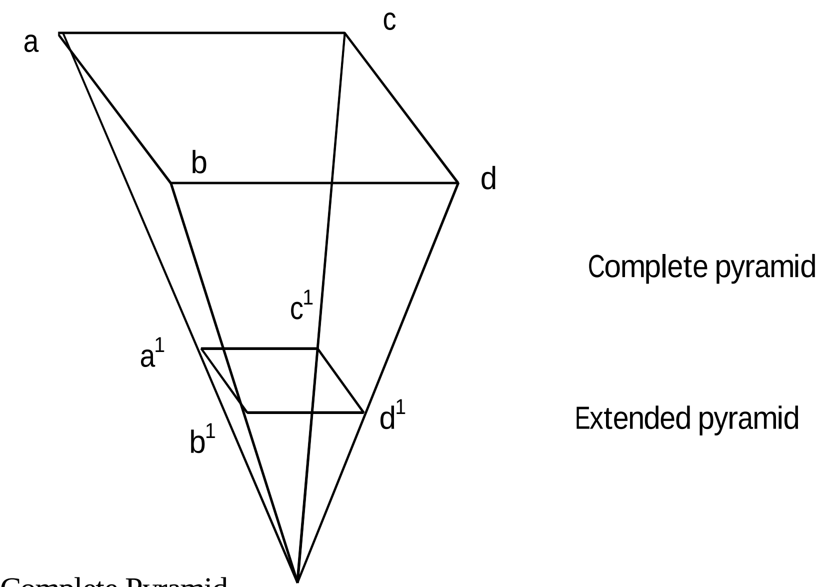

Figure 2 Complete Pyramid

The volume of the pyramid is given by:

$$V = \frac{1}{3} \text{base} \times \text{height} \qquad (1)$$

Volume of hoper = volume of complete pyramid – volume of extended pyramid (Adu, 2004).

$$= \frac{1}{3} B_1 \times H_1 - \frac{1}{3} b_1 \times h_1 \qquad (2)$$

Where:

V = volume of hopper
B_1 = Base of complete pyramid
b_1 = base of extended pyramid
H_1 = height of complete pyramid
h_1 = height of extended pyramid

Mass of hopper is given as:

$$M = \rho V (kg) \qquad (3)$$

Where

ρ = density of material

Grating drum design

The grating drum is cylindrical in shape. The volume of the grating drum is given as:

$$V_d = \pi r^2 L \qquad (4)$$

Where L = length of cylindrical drum
r = radius of cylindrical drum
V_d = volume of cylindrical drum.

The force acting on the cylindrical drum is given as:

$$F = mg \qquad (5)$$

Where

$$M = \rho . V$$

$$F = \rho V g \qquad \text{(Ryder, 1985)} \qquad (6)$$

Where F = force acting on cylindrical drum
g = acceleration due to gravity

Pulley Selection

Torque of motor shaft (driving shaft) can be obtained as:

$$\text{Motor power} (pm) = T_m W_m \qquad (7)$$

Where:

Pm = Motor power
T_m = motor torque
W_m = angular speed of motor

Angular velocity can be deduced using the motor rating as:

$$W_m = \frac{2\pi N}{60} \tag{8}$$

Where:

N = speed of motor in Rev/min

$$\text{Motor Torque}\left(T_m\right) = \frac{P_m}{W_m} \tag{9}$$

To prevent a belt drive due to loading from complete slipping, the motor pulley (Driving pulley) diameter D_1 is chosen as:

$$D_1 = 57\left(T_m\right)^{1/3} \quad \text{(Chernilesky, Lavrora and Thomas, 1994)} \tag{10}$$

Where D_1 = diameter of the motor pulley

Also, the diameter of the cylindrical drum pulley (driven pulley) can be calculated from:

$$D_2 = D_1 \times \frac{W_1}{W_2}(1-\varepsilon) \quad \text{(Hall, Holowenko and Laughlin, 1982)} \tag{11}$$

Where:

D_2 = diameter of cylindrical drum pulley
W_1 = angular velocity of driving shaft
W_2 = angular velocity of driven shaft
ε = slipping coefficient

Design for belt

Determination of centre distance (Cs)

The centre distance for a v – belt is obtained as:

Where: Cs = centre distance
T_B = Thickness of belt

Determination of Belt Length

For a v – belt the length between driving pulley and driven shaft pulley is given as:

$$L_B = \frac{\pi(R+R)+(R-r)^2+2C_2}{C_s} \tag{13}$$

Where:

L_B = length of belt
R = radius of driving pulley
r = radius of driven pulley

Design for angle of wrap for driving pulley and driven pulley
The angle of wrap for driving pulley and driven pulley is given as:

$$\alpha_1 = 180^o - 2\beta = 180^o - 2Sin^{-1}\frac{(R-r)}{C_s} \tag{14}$$

$$\alpha_2 = 180^o + 2\beta = 180^o + 2Sin^{-1}\frac{(R-r)}{C_s} \tag{15}$$

Where:

α_1 = angle of wrap for driving pulley
α_2 = angle of wrap for driven pulley

The smaller value of α_1 and α_2 governs the design

Shaft Design

The shaft used for this is a solid shaft subjected to combined torsional and bending stresses. The (ASME) code equation for a solid shaft having little or no axial loading has a maximum shearing stress given as (Paul, 1986).

$$Ss_{max} = \frac{16}{\pi d^3}\sqrt{(m_b k_b)+(m_t k_t)} \tag{16}$$

Where: Ss = shearing stress,
d = diameter of shaft,
m_b = bending moment,
m_t = torsional moment,
k_t = combined shock and fatigue applied to torsional moment (1.0),
k_b =combined shock and fatique applied to bending (1.5)

Determination of Torsional Moment (mt)

Since the shaft rotating horizontally both bending as well as torsional moment are the main factors influencing the shaft design, the torsional moment acting on a rotating shaft can be determined from the relation

$$m_t = \frac{\text{power}}{\text{angular speed}} \tag{17}$$

$$= \frac{kw}{\frac{2\pi N}{60}} \tag{18}$$

$$= \frac{kw \times 60}{2\pi N} \tag{19}$$

Equation (17) will be used to calculate the torsional moment

Shaft Loading

The solid shaft is loaded as shown in Fig 3:

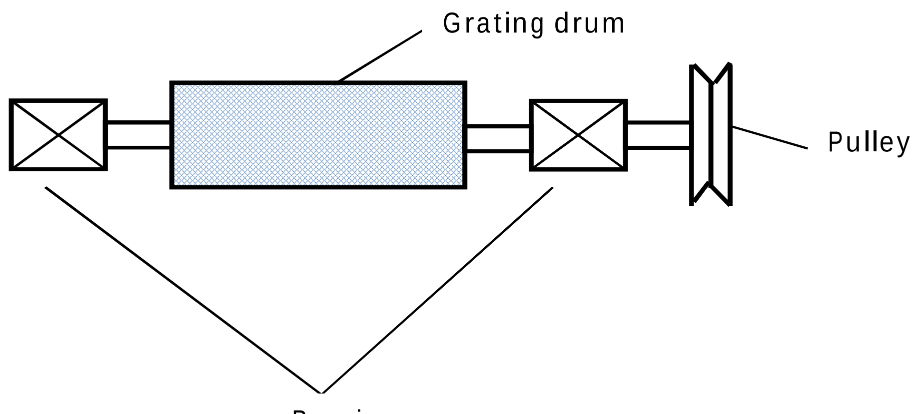

Fig. 3: Shaft loading of cassava grating machine.
Source: Researchers' representation (2018)

The solid shaft with forces acting on it is represented in Fig 4.

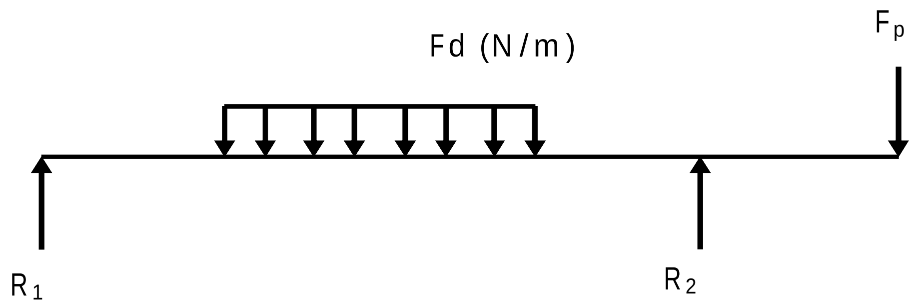

Fig 4: Reactions on the shaft due to vertical loading with uniformly distributed load
Source: Researchers' representation (2018)

Where

F_p = weight of pulley
R_1 and R_2 = Bearing reactions
F_d = Distributed load on grating drum

For ease of calculations, the uniformly distributed load is converted to a point load as shown in Fig 5.

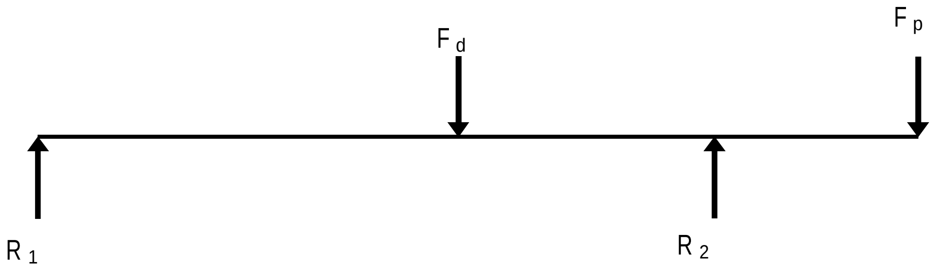

Fig 5: Reactions on the shaft due to vertical loading with uniformly distributed load converted to point load.
Source: Researchers' representation (2018)

From the evaluation of the forces and determination of the bearing reactions, the maximum bending moment Mb(max) for the shaft was determined. The shaft diameter d was calculated using (13) by changing subject of formula as:

$$d = \left(\frac{16}{\pi Ss_{max}} \sqrt{(m_b k_b) + (m_t k_t)} \right)^{1/3} \qquad (20)$$

Mode of Operation

The machine connected to a prime mover by a v – belt is set into action and allowed to run for some time to ensure smooth operation. Peeled cassava tubers are then introduced into the machine through the hopper these tubers come in contact with the grating drum, they are macerated into cassava pulp, this is achieved due to the perforations on the surface of the rotating grating drum. The pulps are collected through the discharge into a basin or small rubber plate.

Performance Evaluation

Tests were carried out using different weights of cassava for ten different batches. The time taken for each batch was accurately recorded. The results of the test are shown in table 1.

Table 1: Number of loading and time taken

Number of loading	Mass of cassava (kg)	Time taken to grate (sec)
1	0.6	32
2	1.0	81
3	1.5	96
4	2.0	121
5	2.5	149
6	3.1	182
7	3.4	214
8	4.0	242
9	4.4	280
10	4.9	371
TOTAL	**27.4**	**1768**

Source: Researchers

Therefore,

$$\text{Output capacity} = \frac{\text{Mass of cassava (kg)}}{\text{Time taken (hrs)}}$$ (Ajao, Ayilara and Usman, 2013)

Substituting values we have,

$$\text{Output capacity} = \frac{27.4 \times 3600}{1768} \qquad (21)$$

$$= 55.79\text{kg/hr}$$

CONCLUSION

A mobile cassava grating machine was designed, fabricated and tested. The machine is simple to operate. It can be used both for household and industrial purposes. It was found to be effective and efficient during operation and cold grate about 55.79kg/hr. The machine is readily affordable due to the fact that it was produced from locally sourced materials. The machine costs forty two thousand naira only (₦42,000) to produce.

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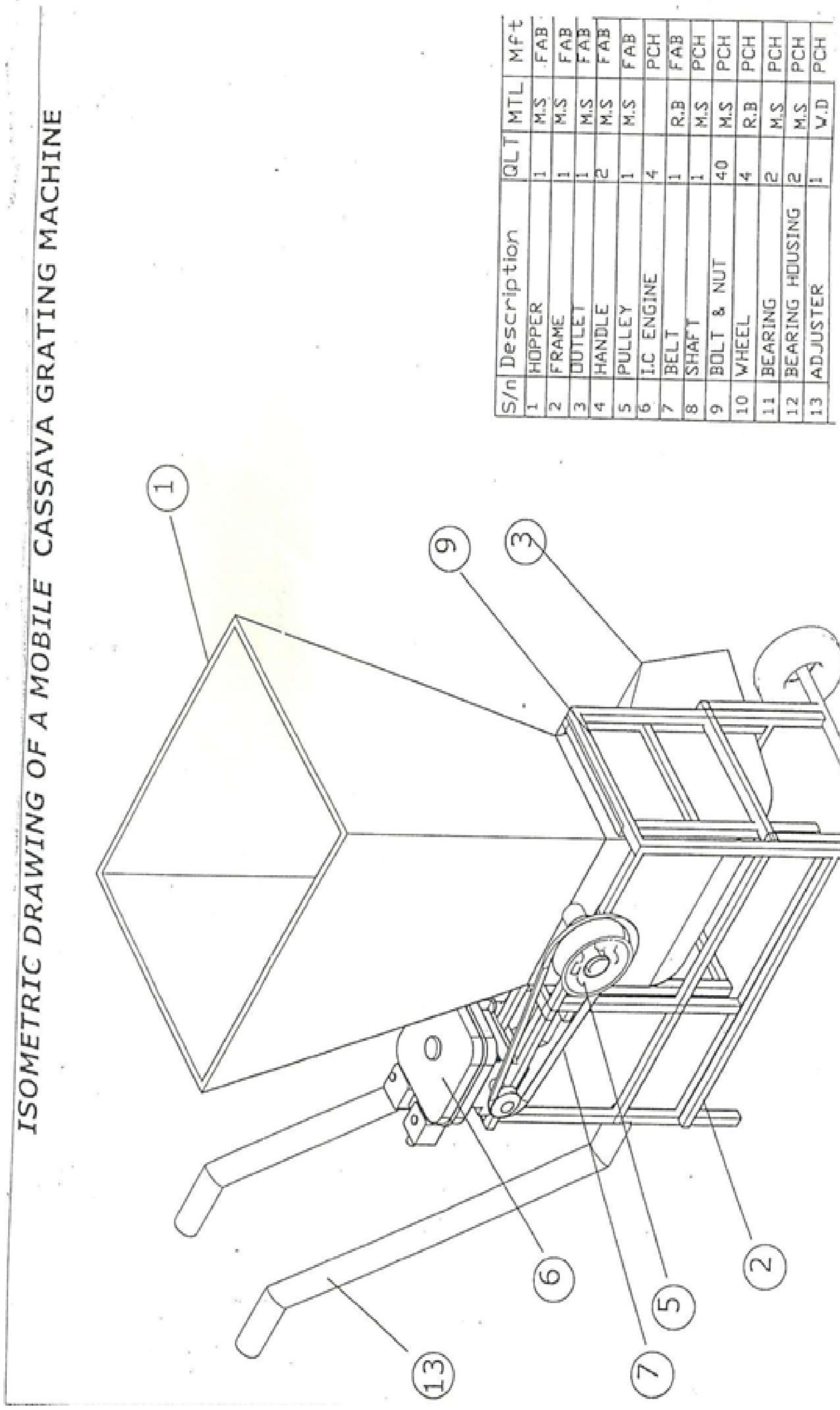
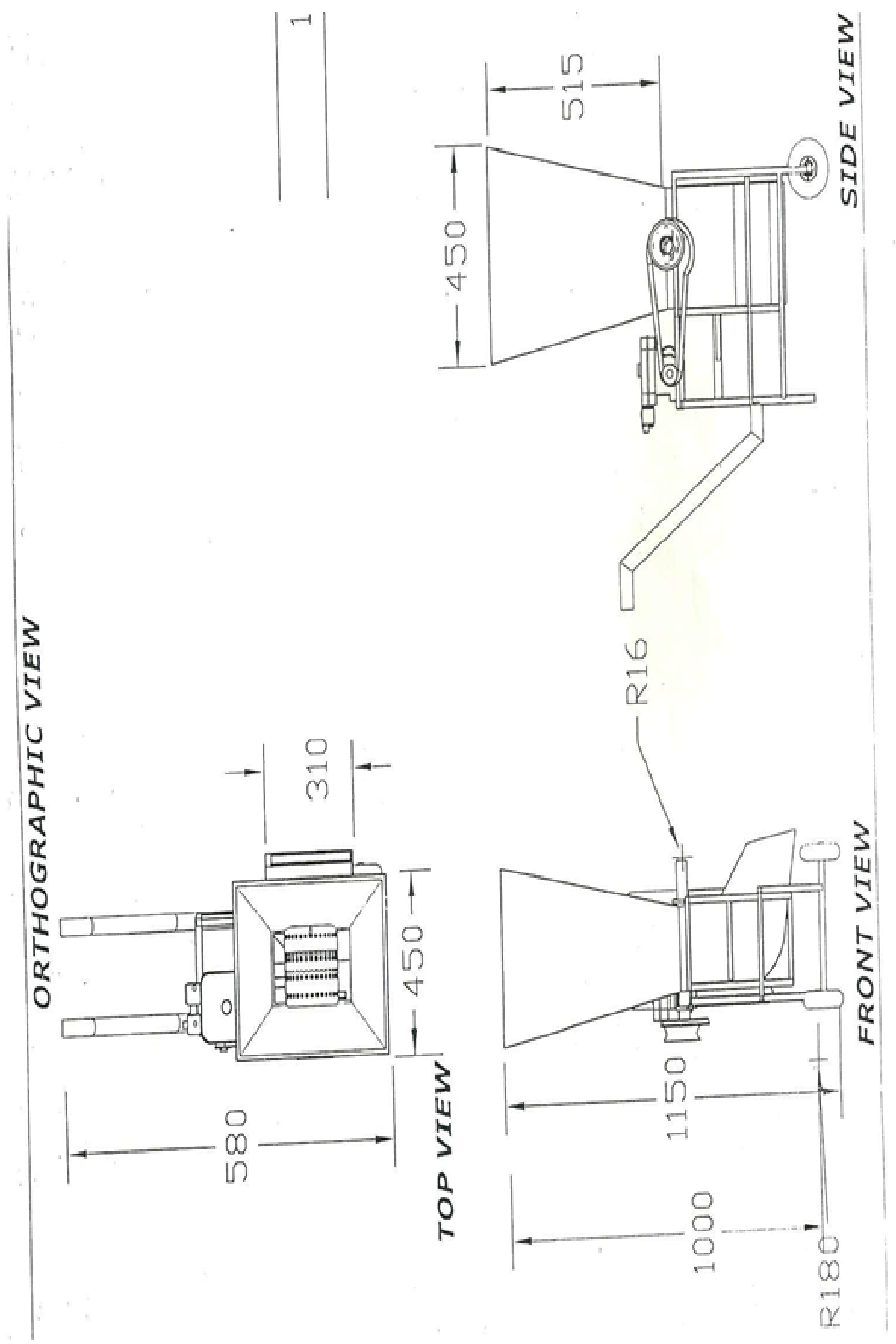
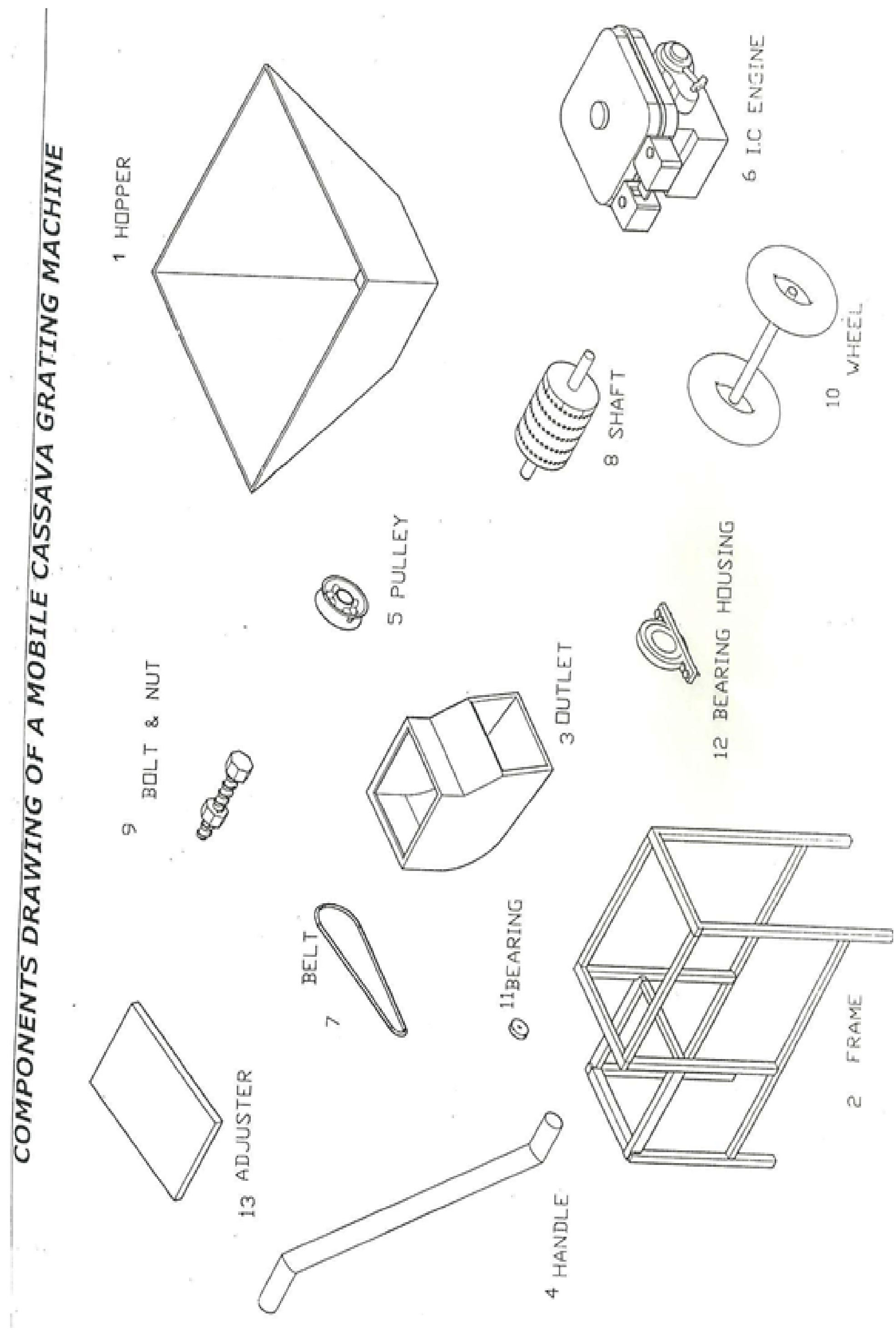


S/n	Description	QLT	MTL	Mft
1	HOPPER	1	M.S	FAB
2	FRAME	1	M.S	FAB
3	OUTLET	1	M.S	FAB
4	HANDLE	2	M.S	FAB
5	PULLEY	1	M.S	FAB
6	I.C ENGINE	4		PCH
7	BELT	1	R.B	FAB
8	SHAFT	1	M.S	PCH
9	BOLT & NUT	40	M.S	PCH
10	WHEEL	4	R.B	PCH
11	BEARING	2	M.S	PCH
12	BEARING HOUSING	2	M.S	PCH
13	ADJUSTER	1	V.D	PCH


ORTHOGRAPHIC VIEW
TOP VIEW
FRONT VIEW
SIDE VIEW
580
450
310
1150
1000
R16
R180
450
515


COMPONENTS DRAWING OF A MOBILE CASSAVA GRATING MACHINE
1 HOPPER
2 FRAME
3 OUTLET
4 HANDLE
5 PULLEY
6 I.C ENGINE
7 BELT
8 SHAFT
9 BOLT & NUT
10 WHEEL
11 BEARING
12 BEARING HOUSING
13 ADJUSTER