Design and Fabrication of a House-Hold instant Noodles Making Machine using Cassava Dough

C. C. Eze

Department of Mechanical Engineering, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.

ABSTRACT: An affordable instant noodles making machine was designed and fabricated using locally-sourced materials. The rolls were arranged in two pairs, one positioned upand having 5 mm gap between rolls to receive the incoming prepared cassava dough materials. The material rolling proceeds down into the second pair, also having the same gap between the rolls and installed directly below the upper pair. Roll 3, one of the lower pair was grooved to effect both shape forming and shredding of the dough, exiting slender noodles. Two V-belt-pulley systems were used for motion transmission to the rolls via four gears, powered by a 4.2 horse power electric motor. Every complete revolution of the lower pair of rolls exited 146 g of noodles. The machine cost was valued at N20,000 Nigerian Naira, an equivalent of $50 USD only.

Keywords: Noodles-making machine, Cassava, rolls, locally-sourced materials, affordable, dough.

I. INTRODUCTION

Noodles are a staple food in many cultures made from unleavened dough which is stretched, extruded, or rolled flat and cut into one of a variety of shapes [1]. Food noodles are usually starch-based fast food made from flours from grains. However, modern noodles may be compounded from pastas of other food types like cassava, yams, potatoes, tubers when they are processed into flours.

Cassava, a starchy tuber food is associated with the poisonous cyanide substance which must be removed or neutralized during processing to make it fit for human consumption. Thus to do this, the cassava tuber is soaked in water for four days to allow fermentation to take place. During fermentation, the poisonous substance is either neutralized or dissolved out leaving a soft mass which can be extracted, dried and ground into dust or flour. At this stage, the white flour is safe and may be prepared to be eaten in a variety of ways. The dough may be prepared by stirring in boiling water for ten minutes leading to a thick, elastic dough. Cassava dough is usually eaten as foo-foo with soup. However, the dough to be rolled into noodles may be allowed to rest or cool off before compounding and sheeting or slitting and waving for noodle rolling. This noodle making has become necessary to serve as fast food.

Cassava dough is turned into thin strips or sheets which when packaged may be available in shops, restaurants and homes. Users need only to parboil and steam for less than four minutes with ingredients of choice such as pepper, onion, salt, thyme, oils, etc. and served as delicious pastes. This is especially good as fast food for travelers and students on campuses. Noodle strands are usually processed according to noodle types, some adding eggs, fish, guar gum, sodium hydroxide, phosphates, etc.

The noodles making machines turn the dough into thin strips or sheets that are usually packaged when dried. Some noodle making machines serve multi-purpose operations-rolling, cutting, shredding, blade cleaning, folding, shaping components, etc. and have features that do these. Modern instant noodles making machines as patents-US 4083668 A, described by [2] incorporate many of these operational objects and features. All these multiple-operations end in transforming the dough into line, discrete ribbons of noodles. The machines, though fascinating, are usually so phiscated, costly and bulky, and could only be used on industrial purposes. These machine types would always demand for more than one operator. They are not fit for family and smaller unit use because they are not easily affordable, and the components are not locally available when there is a breakdown. For instance, the kingdoo noodles making machines from Wuhan G- young Industries, the Sk-8430,8-stages automatic machines from Jinan Sensi, China, are complex, need many hands to operate, and are very costly, costing in the range of $100,000-$150,000 for a unit [3]. Even the very simple types like the ordinary hand noodles making machine costs about $10, and even at that, a minimum quantity of 2 pieces must be ordered at a time. Thus, a simple, portable instant noodle making machine is the option. This is the type designed
and fabricated here, and is shown in figure 2. The machine components were all sourced locally and component replacement is relatively much easier.

II. MATERIALS AND METHODS

In this design, there are two pairs of rolls - the upper pair rolls UR bearing roll 1 or R1 and roll 2 or R2, and the lower pair rolls – LR bearing roll 3 or R3 and roll 4 or R4. The upper pair is smooth and receives the kneaded cassava dough, converts it to sheet and transmits it down to the lower pair. The lower pair has one of the rolls grooved into rectangular shape and it is this form that the noodle stripes take the form as they exit the pair.

It is meant to occupy a small space, which is taken by the size of the machine and electric motor. Power is transferred by means of pulleys to the lower pairs. The torque is also transferred from the lower rolls to the upper roll by means of pulleys.

All gears (aluminium alloy cast), G1, G2, G3, and G4, each has same dimensions - diameter = 70 mm, Length = 360 mm
All rolls (aluminium alloy pipes), R1, R2, R3 and R4, each has 60 mm diameter, Length = 360 mm
The rolls are all hollow aluminium material which allow for strength and light.
The surface area of each roll less the two end surfaces of the roll makes the rolling contact with the dough material.
The shafts are solid of steel having yield stress of 240 Mpa
The Beamboy software was used to obtain the relevant maximum reaction, moments and stresses acting on the four shafts of the machine.

<table>
<thead>
<tr>
<th>SN</th>
<th>NAME OF PART</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Frame work</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Roll 1</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Roll 2</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Roll 3</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Roll 4 (grooved)</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Shaft 1</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Shaft 2</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Shaft 3</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Shaft 4</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Gear 1</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Gear 2</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Roll 1</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Pulley 2</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Hopper</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Casing</td>
<td></td>
</tr>
</tbody>
</table>

Figures 1-Some components of the noodles making machine (numbered clockwise)

Figure 2- The noodle making machine assembly (wire view).
2.1 Forces involved in rolling

When the dough is fed into the receptacle at the top of the machine, the UR receives the in-coming dough sheet of 5mm. This is due to the gap allowed between roll 1, R1 and roll 2, R2. Two forces are involved in the rolling operation. They are the radial force $F_n$ and the tangential frictional force $F_T$. The cassava dough to be rolled is drawn into the gap of the rolls by means of friction. The normal component forces coming from the rolls reduce the thickness of the dough. The dough elongates in the rolling direction.

![Rolling profile](image)

2.2 Roll forces

In this drive, the tangential force $F_T$ provides the driving torque and the normal or radial force brings about the compressive and bending effect on the shaft. According to [4] and [5], the following roll operational forces and geometrical expressions were obtained:

\[ F = L_p w \sigma_{av} \quad (1) \]

where $F$ = roll force developed in operation

\[ L_p = \text{roll contact length} = \pi r \sqrt{h_0 - h_f} \quad (2) \]

and $r$ = radius of the rolls = 30 mm = 0.030 m.

\[ h_0 = \text{thickness of dough sheet before rolling} = 5 \text{mm} \]

\[ h_f = \text{thickness of dough after rolling} = 4 \text{mm} \]

\[ L_p = 5.5 \text{ mm} = 0.0055 \text{ m} \]

Mass of each roll = 1.2 kg

Now $w$ = width of the sheet dough being passed through the upper roll pair (UR) = 60 mm = 0.060 m (dough material to spread across the roll diameter).

\[ \sigma_{av} = \text{average stress of the sheet material passing through the rolls}. \]

\[ k = \text{consistency coefficient of dough at about 62.5% moisture content (assumed same with commercial baker’s dough/flour = 3.4 kPa.s).} \]

\[ n = \text{a regression constant (assumed same with wheat flour) = 0.34}. \]

So, from [4] and [5], the entire roll length the stress developed $\sigma_{av} = \frac{\int k \varepsilon^n d\varepsilon}{\varepsilon_f}$. (3)

Integrating eqn. (5) yields $\sigma_{AV} = \left[ \frac{k \varepsilon^{n+1}}{\varepsilon_f (n+1)} \right]_0^\varepsilon_f$, (4)
Where, \[ E_f = \ln \left( \frac{h_2}{h_1} \right) = \ln \left( \frac{5}{4} \right) = 0.097 \] (5)

\[ \sigma_{AV} = 0.0349 \left( \frac{0.097}{1.8125} \right) = 0.002 \text{ N/mm}^2 \] (6)

Required rolling force from upper roll (UR) in contact with the dough sheet according to equation (1):
\[ F = L_p w \sigma_{av} = 55 \text{ mm} \times 60 \text{ mm} \times 0.002 \text{ N/mm}^2 \]
This is the force required by the upper roll (UR) per revolution to turn out a sheet of 60 mm.

2.3 Motor torque requirement

2.3.1 Machine drives

An electric motor provides the driving power, which goes from motor pulley \( P_m \) to pulley \( P_4 \) of roll 4 via v-belt 1, at a pulley ratio of 1:2. Pulley 1(\( P_1 \)) is welded to Gear 1(\( G_1 \)) of the upper gear train. Motion enters the gear train via \( G_4 \).

The torque required in the machine drive takes care of the torque outputs arising from the (i) rolls(ii) the gear train and (iii) the force effect of rolls, gears, pulleys and belts.

(i) Torque generated by rolls 3 and 4

Since all rolls have the same parameters, the required rolling force for rolls 3 and 4 ie (LR), on dough may also be assumed to be \( F = L_p w \sigma_{av} = 6.6 \text{ N} \)

\[ = 13.2 \text{ N per revolution. Each of the four shafts bearing the four rolls will thus bear the load of } 1 \times \frac{2F}{4} \text{ or 3.3 N, } \]
actinging at the shaft centre 0.185 m from the left of each shaft.

This rolling operation force involves the tangential force \( F_T \) and the normal force \( F_n \). The tangential force accounts for the machine driving torque \( T_d \) and the normal or radial force \( F_n \) is responsible for the deflection of the rim and bending of the shaft. [8]

The force component associated with the machine drive ie the tangential force \( F_T = F \cos \alpha \) where \( \alpha = \) angle of contact between dough and each roller

and where \( \alpha = \cos^{-1} \left( 1 - \frac{h_n - h_f}{2r} \right) = 11.8^\circ \) (9)

\[ \Rightarrow \text{ for each shaft, the tangential load on it causing twisting } F_T = 3.3 \cos 11.8^\circ \text{ N} = 3.2 \text{ N} \]

Also, the force component responsible for bending ie the normal force \( F_n = F \sin \alpha \)

\[ : \text{ For each shaft, the normal load on it causing bending } F_n = 3.3 \sin 11.8^\circ = 0.67 \text{ N} \]

Torque requirement of roll 4

Torque on shaft arising from each roll causing twisting \( = F_T \times \text{ radius of roll} \)

\[ = 0.5 \times (3.2 \times 0.035) \text{ Nm} \] (11)

(ii) Gear torque

For the cassava dough to enter the throat of UR, frictional force component \( f \) must be equal to or greater than the horizontal component of the normal force \( F_n \), as shown in figure 4

![Fig.4- Rolling forces](image-url)
For rolling operation to occur, $F_T \cos \alpha \geq F_n \sin \alpha$

$F_T > F_n$ or $3.2 \text{ N} > 0.67 \text{ N}$, so that rolling is feasible [4].

Torque from meshed gears 4-3

The following parameters were considered:

(i) From figure 4, the angle the common normal to the base circle of wheel 4 makes with the pitch circle of wheel 3 or $\alpha$, according to [8], is $\alpha = 14^\circ$

(ii) Weight or load of gears 4 and 3 train or $2(0.74 \text{ kg} \times 9.81 \text{ m/s}^2)$

(iii) Vertical load components of meshed gears 4 and 3 ($V_{cg}$) i.e., wt. of gears 4 and 3 sin $14^\circ$

$\Rightarrow$ Total vertical load effect = wt. of (gear 4 + gear 3) + $V_{cg}$

$= (14.52 + 3.50)$.

Thus torque generated by gear 4 and 3 train $T_g = (18.02 \times 0.035) \text{ Nm}$

Since the radius of gears 4 or 3 = 35mm = 0.035 m,

The torque experienced by this gear 4 and 3 train = $(18.02 \times 0.035) \text{ Nm}$

The assumption is that one-half of this LR torque is associated with shaft 4, $T_p = 0.5(18.02 \times 0.035) = 0.32 \text{ Nm}$ (12)

(iii) Torque or force effect of pulleys and belts

2.4 Belt tensions

For Belt 1,

Motor speed $n_1 = 1000 \text{ rpm}$

Motor pulley radius $r_m = 0.02 \text{ m}$

Pulley 4 radius $r_4 = 0.04 \text{ m}$

Pulley 1 radius $r_1 = 0.06 \text{ m}$ since $d_1 = 120 \text{ mm}$

The relationship existing between the two tensions in a V-belt arrangement according to [8] is

$2.3 \log \left( \frac{T_1}{T_2} \right) = \mu \theta \csc \beta$  \hspace{1cm} (13)
Where \( T_1 \) and \( T_2 \) = tensions on the tight and slack sides of the belt respectively.
\[ \mu = \text{coefficient of friction between the belt and groove side} = 0.5123 \]
\[ \theta = \text{angle of contact on the motor pulley}. \alpha = x_1 + \sin^{-1} \left( \frac{r_2 - r_1}{x_1} \right) = 5.9^\circ, \text{and } x_1 = \text{centre distance between the two shafts centres} = 200 \text{mm} = 0.200 \text{m}. \]
\[ \Rightarrow \theta = 168.2^\circ \]
\( \beta = \frac{\theta}{2} = 33.4^\circ \)

From equation (9), \( \frac{T_1}{T_2} = \log^{-1} \left( \frac{\mu \theta \csc \beta}{2.3} \right) \Rightarrow \frac{T_1}{T_2} = \log^{-1}(2.376) = 237.68 \text{Nm}. \)

Again, the power transmitted by this V-belt is related to tensions in this expression [8]
\[ P = (T_1 - T_2) V_b \] (14)

Where \( P \) = motor power and \( V_b \) = belt velocity which is given as
\[ V_b = \left( \frac{\pi d_1 n_1}{60} \right) \text{ and } d_1, n_1 \text{ are diameter and speed of motor respectively.} \]

Thus from equation (9) and (10), \( T_1 \) and \( T_2 \) may be obtained.

Now, the torque required at this stage from equation (5) \( T = \left( \frac{9.554 P}{1000} \right) = 5.23 \text{Nm} \)

Length of belt 1 required, \( L_1 = \pi (r_2 + r_1) + 2x + \left( \frac{r_2 - r_1}{x} \right) \) (15)

Belt 2
Following the steps of belt 1 calculations,
The desired distance between \( P_1 \) and \( P_2 = x_2 = 300 \text{mm} \)
\[ \mu_2 = 0.5123 \]
\[ \alpha_2 = 12.6^\circ \]
\[ \beta_2 = 14^\circ \]

Again, From equation (9), \( \frac{T_3}{T_4} = \log^{-1} \left( \frac{\mu_2 \theta_2 \csc \beta_2}{2.3} \right) \Rightarrow \frac{T_3}{T_4} = \log^{-1}(2.486) = 306.13 \text{Nm}. \)
\[ T_3 = 306.13 T_4 \]

Since the motor power = 547.78.18 W, the Belt 2 speed \( V_2 = \left( \frac{\pi d_2 n_2}{60} \right) = \left( \frac{\pi x 0.08 \times 500}{60} \right) = 2.1 \text{m/s} \)

And since \( \frac{T_3}{T_4} = 306.13 \text{Nm} \), \( \Rightarrow T_3 = 306.13 T_4 \)

\[ . P = (306.13T_4 - T_4) \times V_2, \Rightarrow T_3 \text{ and } T_4 \text{ may be obtained.} = 0.86 \text{Nm}; = 261.71 \text{Nm} \]
From equation (5), the torque required at this second stage of pulley \( P_1 \),
\[ 9.554 \frac{P}{n_2} \] (16)

The total torque needed for the two belt-pulley stages is \( (5.23 + 10.47) = 15.70 \text{Nm} \)

Total torque required by the two belt systems \( Tb = (5.23 + 15.70) \text{Nm} \)

Thus, the total torque required of the machine = \( Tr + Tg + Tb = (0.06 + 0.32 + 15.70) \text{Nm} \)

2.5 Mass of dough per roll revolution
From fig. 4, since grooving was cut on R3, the sheet turned out from LR bears on one surface the desired slender noodles of rectangular shape. The tiny long rectangular grooves on the roll effect shredding the sheets into noodles.
Since the four rolls are of the same diameter and length, For LR,

The surface area of the roll $S_A$ is the surface area of a cylinder, less the area of the two ends which do not make contact with the dough material during rolling,

$$S_A = (2\pi r l + 2\pi r^2) - 2\pi r l$$

and where $r =$ roll radius = 30mm; $l =$ roll length = 360 mm.

The volume of dough produced per rev. of UR ($V_{UR}$) = volume of dough produced per rev. of LR ($V_{LR}$)

Thus, $V_{LR} =$ roll surface area x dough thickness = $67885.7 \text{mm}^2 \times 4 \text{mm} = 271542.8 \text{mm}^3$ where thickness of exiting dough sheet/noodles = 4 mm).

The volume of dough shaped, shredded and exited per rev of LR = 271542.8 mm3

Now, bulk density of cassava flour = $0.55 \frac{g}{m^3} = 550 \frac{kg}{m^3}$ [8]

Mass of cassava dough $M_d = 550 \times 0.000271542.8 = 0.14934854\text{kg} = 149\text{g}$

Thus, 271542.8 mm3 volume of cassava noodle which has a mass of 149g is produced per rev of LR.

2.6 Shaft diameter

The shaft is made of steel having a yield stress of 240 Mpa. ASME code was used to design the diameter of the shaft for suddenly applied load with combined fatigue and shock factors in bending and torsion. Subsequently, the bending and twisting factors are $k_b = 2.0$ and $k_t = 1.5$ respectively. The diameter of the shaft may therefore be determined using maximum shear stress theory [9]

$d^3 = \left(\frac{16}{\pi \tau_{\text{max}}}ight) \sqrt{((M_b k_b)^2 + (M_t k_t)^2}$

where

$d =$ shaft diameter

$\tau_{\text{max}} =$ permissible shear stress = 0.3 of the material yield stress or $0.3S_y$ [9]

$= 0.3 \times 240 = 72 \text{Mpa} ($x$)$

$M_b =$ maximum resultant bending moment = 5.2 Nm (The resultant maximum bending moment $M_b$ on shaft was obtained from this expression $M_b = \sqrt{(M_v)^2 + (M_h)^2}$ (20)

Where $M_v, M_h$ are the maximum vertical and horizontal bending moments respectively.

$M_t =$ maximum working stress in shear = 16.44 Nm i.e the total torque machine requirement.

$K_b =$ combined shock and fatigue factor for bending moment = 2.0

$K_t =$ combined shock and fatigue factor for torsion = 1.5

$= (\frac{\pi}{16}).\tau_{\text{max}}.d^3 = \sqrt{(M_b x k_b) + (M_t x k_t)}$

$\Rightarrow d^3 = \left(\frac{16 \sqrt{(5.2 \times 10^3 \times 2.0)^2 + (16.44 \times 10^3 \times 1.5)^2}}{\pi \times 72}\right) \Rightarrow d = 12.3 \text{mm}$

Since R4 bears the highest load, a standard shaft diameter of 13 mm was selected for each of the four rolls.

2.7 Loads on shafts

2.7.1 Vertical loads on shaft

From figure 2, it may be observed that roll 4 has the greatest number of external components attached to it than the other three rolls. Thus, its shaft, S4 should bear the highest load and suffer the greatest effect of torsion. The twisting on S4 is determined:
(1) Weight of roll 4, (1.2x9.81), a point load acting at the shaft centre, 0.185 m from the left.
(2) Weight of gear 4, (0.74 kg x 9.81 m/s²), a point load acting on shaft at 0.020 m from left
(3) Vertical load components of meshed gears 4 \( (V_{cg}) = 7.3 \sin 14^\circ \)
Total vertical load effect = wts of (gear 4) + \( V_{cg} = (7.3 +1.8) \).
(4) Weight of aluminum pulley P4, (0.11x9.81), a point load acting at 0.010 m from the left.
(5) Weight of belt 1, (0.29kg x 9.81) a point load also acting at the 0.010 m from the left.
(6) Vertical load components of belt 1, \( (V_{cb}) = T_1 \sin \theta + T_2 \sin \theta \), where \( \theta = \) angle of contact (14°) and \( T_1 \) and \( T_2 \)
= tight and slack tensions respectively in the belt 1 drive.
\[ \Rightarrow \text{total vertical load effect acting at 0.010 m} = \text{wts. of belt 1 + pulley + } V_{cb} \]
The loads on shaft 4 may be assumed to be the same loads on the other three.

2.7.2 Horizontal loads
Belt horizontal load effect may be obtained in this manner:
\[ F_{\text{HOR}} = \text{horizontal load effect (tension) of pulleys 4 & 1 and belts 1 & 2 systems} \]
\[ = T_1 \cos 5.9^\circ + T_2 \cos 5.9^\circ \text{(from belt 1), and} \]
\[ T_3 \cos 12.6^\circ + T_4 \cos 12.6^\circ \text{(from belt 2), acting at 0.010 m from the left of shaft.} \]
Also for gear G4, the normal force associated with the shaft bending = \( F_n \cos 14^\circ \) (14° being the angle of contact for all gear drive), acting at 0.020 m from the left of shaft.

III. RESULTS AND DISCUSSION

3.1 Results

![Fig. 7- The shaft free body diagram](image)

Table 1. The maximum stress values on shaft arising from vertical loads.
Fig. 8: The shaft free body diagram

Table 2. The maximum stress values on shaft arising from horizontal loads

<table>
<thead>
<tr>
<th>Maximum Values</th>
<th>Maximum Value</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bending Moment</td>
<td>5.03 N·m</td>
<td>0.01 m</td>
</tr>
<tr>
<td>Bending Stress</td>
<td>51200 MPa</td>
<td>0.01 m</td>
</tr>
<tr>
<td>Deflection</td>
<td>19700 mm</td>
<td>0.35 m</td>
</tr>
<tr>
<td>Slope</td>
<td>4300 degrees</td>
<td>0.35 m</td>
</tr>
</tbody>
</table>

Table 3. Forces and roll forces

<table>
<thead>
<tr>
<th>s/n</th>
<th>Force developed by each pair of rolls</th>
<th>6.6 N</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Tangential load component of each roll</td>
<td>3.2 N</td>
<td>N</td>
</tr>
<tr>
<td>3</td>
<td>Normal load component of roll</td>
<td>0.67 N</td>
<td>N</td>
</tr>
<tr>
<td>4</td>
<td>Angle of contact between dough and roll</td>
<td>11.8 Degree</td>
<td>Degree</td>
</tr>
<tr>
<td>5</td>
<td>Weight of roll 4 = 1.20 kg x 9.81 m/s² = 11.8 N, a point load acting at the shaft centre, 0.220 m from the left.</td>
<td>11.8 N</td>
<td>N</td>
</tr>
<tr>
<td>6</td>
<td>Torque requirement of roll 4</td>
<td>0.06 N·m</td>
<td>Nm</td>
</tr>
</tbody>
</table>

Table 4. The force and torque generated by the gear 4

<table>
<thead>
<tr>
<th>s/n</th>
<th>Angle θ the common normal to the base circle of wheel 4 makes with the pitch circle of wheel 3 = θ (khurmi, 2008)</th>
<th>14 Degree</th>
<th>Degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Weight or load of gear 4 = (0.74 kg x 9.81m/s²)</td>
<td>7.3 N</td>
<td>N</td>
</tr>
<tr>
<td>3</td>
<td>Vertical load components of gear 4 (Vₘₐ) = 7.3 sin 14°</td>
<td>1.8 N</td>
<td>N</td>
</tr>
<tr>
<td>4</td>
<td>Total vertical load effect = wts of (gear 4 + gear 3) + Vₘₐ = (7.3 + 1.8).</td>
<td>9.1 N</td>
<td>N</td>
</tr>
<tr>
<td>5</td>
<td>Driving force component of the gear mesh =18.02 cos 14°</td>
<td>28.2 N</td>
<td>N</td>
</tr>
<tr>
<td>6</td>
<td>Bending force component of gear mesh 18.02sin 14° causing bending on the shaft acting on the shaft at 0.015 from left where the gear is located on the shaft.</td>
<td>7.0 N</td>
<td>N</td>
</tr>
<tr>
<td>7</td>
<td>Torque generated by gear 4 T₄ = (18.02 x 0.035) Nm.</td>
<td>0.32 N·m</td>
<td>Nm</td>
</tr>
</tbody>
</table>

Table 5. Torques and point loads acting on the roll shaft

<table>
<thead>
<tr>
<th>s/n</th>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Angle</td>
<td>168.2 Degree</td>
<td>Degree</td>
</tr>
<tr>
<td>2</td>
<td>Weight of belt 1 = 9.81 x 0.029 kg = 0.28 N, a point load also acting at the 0.010 m from the left.</td>
<td>Wb1</td>
<td>0.28 N</td>
</tr>
<tr>
<td>3</td>
<td>Tensions on tight and slack sides of belt 1 T₁, T₂</td>
<td>262, 1.10</td>
<td>N</td>
</tr>
<tr>
<td>4</td>
<td>Vertical load components of belt 1, Vₐ = Tₛᵣ.sin θ + Tₛᵣ.sin θ</td>
<td>Vₛ</td>
<td>33.82 Nm</td>
</tr>
<tr>
<td>5</td>
<td>Total vertical load effect at 0.010 m = wts. of (belt 1 + pulley) + Vₐ = 1.1+0.28+33.82</td>
<td>Vₑ</td>
<td>35.2 Nm</td>
</tr>
<tr>
<td>6</td>
<td>Belt 1’s linear velocity</td>
<td>Vₑ</td>
<td>2.1 m/s</td>
</tr>
<tr>
<td>7</td>
<td>Torque requirement of belt 1 Tₑ, Tₑ</td>
<td>5.23 N·m</td>
<td>Nm</td>
</tr>
<tr>
<td>8</td>
<td>Length of belt(standard)</td>
<td>L</td>
<td>710 Mm</td>
</tr>
<tr>
<td>9</td>
<td>Tensions on tight and slack sides of belt 2 Tₑ₁, Tₑ₂</td>
<td>262, 0.86 N</td>
<td></td>
</tr>
</tbody>
</table>

Table 4: Machine design cost analysis as at July 2016

<table>
<thead>
<tr>
<th>S/no</th>
<th>Design variable</th>
<th>Quantity of material used</th>
<th>Cost of material used (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2mm thick mild steel sheet</td>
<td>2 sheets</td>
<td>4,000.00</td>
</tr>
<tr>
<td>2</td>
<td>4 sprocket gears</td>
<td>70 mm diameter, each</td>
<td>4000.00</td>
</tr>
<tr>
<td>3</td>
<td>60 mm diameter stainless steel pipes</td>
<td>4 pieces</td>
<td>3,200.00</td>
</tr>
<tr>
<td>4</td>
<td>20 mm aluminium alloy pulley</td>
<td>1 unit</td>
<td>300.00</td>
</tr>
<tr>
<td>5</td>
<td>100 mm aluminium alloy pulley</td>
<td>1 unit</td>
<td>500.00</td>
</tr>
</tbody>
</table>
The total weight arising in is relatively small, 0.63 Nm and, N, the total torque requirement needed to drive belt 1 is 5.23 N and that for belt 2 is 10.47 N, giving the belts driving torque demand as 15.70 N.

From Table 3, it can be shown that rolling operation can occur since the tangential force component involved in the operation 3.2 N is greater than the normal force component 0.97 N. The force delivered by each roll is 6.6 N and the torque developed in the rolling operation is 0.06 Nm.

Table 4 indicates that the torque requirement of the gear 3 and 4 train is relatively small, 0.63 Nm and that assumed to be on any one rolleg on roll 4 is 0.06 Nm.

From tables 3 and 5, the torques and point loads acting on the shaft are shown. The weight of roll 4, which is 11.77N, a point load acting on the shaft, 0.220 m from the left of shaft and that of aluminium pulley P4, 1.1 N, a point load acting at 0.010 m also from the left of the shaft are indicated. The total weight arising from pulley 4 and belt 1, jointly with their vertical load effects acting at 0.010 m (where they are located) is 35.2 N. The Torque requirement needed to drive belt 1 is 5.23 N and that for belt 2 is 10.47 N, giving the belts driving torque demand as 15.70 N.

The total torque requirement of the machine is thus the sum of the torques from the rolls, from the gear trains, from the pulleys, and from the two belts. The total torque is 16.08Nm. Using equation (12), the motor power requirement of the machine was obtained as 4.2 hp.

The resultant maximum bending moment M_B = 5.2 Nm, which together with the maximum stress in shear, 16.08 Nm, gave the shaft’s standard diameter of 13 mm. From equation (21), this machine is able to produce 146 g of cassava dough per revolution.

It can be shown from Table 4 that the total cost (current market price) of the measured 38 kg mass rolling machine is N20,000 Nigerian Naira or $50USD equivalence.

IV. CONCLUSION

ACKNOWLEDGMENT

I gratefully acknowledge the permission granted me by the Mechanical Engineering workshop (welding and fabrication unit), Department of Mechanical Engineering, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria.

REFERENCES

[6]. M.J. Patel, and S. Chakrabarti-bell, Flour quality and dough elasticity: Dough sheetability, Centre for Grain Food Innovation, (26 Dick Perry Avenue, Kensingston, WA 6151, Australia)