American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-5, Issue-10, pp-137-146
www.ajer.org
Research Paper Open Access

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

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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. The38 kg 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. Traditionally , in Nigeria, 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 multi-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 break-down. 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 samedimensions-diameter =70 mm, Length = 360 mm

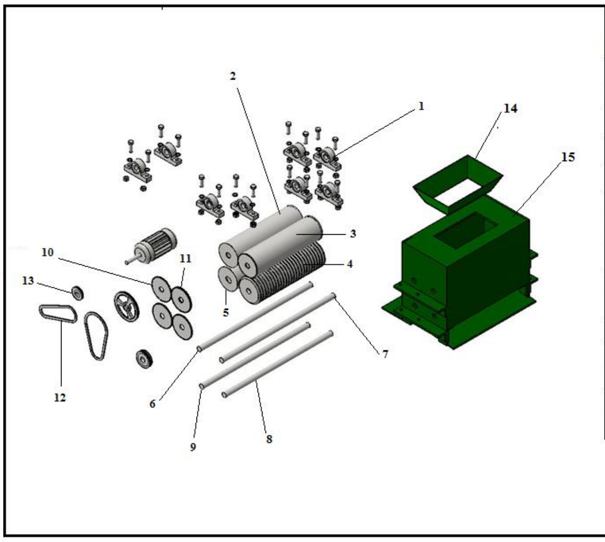
All rolls(aluminium alloy pipes), R1,R2, R3 and R4, each has 60 mm diameter, Length = 360 mm

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.



LEGEND

S/N	NAME OF PART
1	Plummer block
2	Roll 1
3	Roll 2
4	Roll 3
5	Roll 4 (grooved)
6	Shaft 1
7	Shaft 2
8	Shaft 3
9	Shaft 4
10	Gear 1
11	Gear 2
12	Belt 1
13	Pulley 2
14	Hopper
15	Casing

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

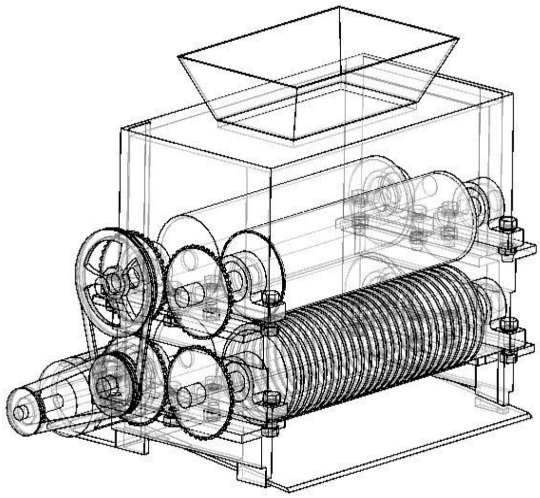


Figure 2- The noodle making machine assembly (wire view).

2.1Forces 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 roll2, 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.

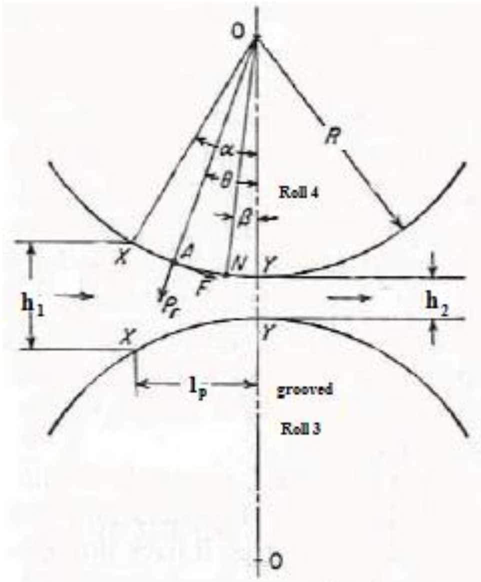


Fig.3- Rolling profile

2.2 Roll forces

In this drive, the tangential force F_T providesthe 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 operationalforces and geometrical expressionswere obtained

$F = L_p w \sigma_{av}$ (1)

whereF = roll force developed in operation

L_p = roll contact lengthcomputed as $r\sqrt{ho - hf}$ (2)

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

h_o = thickness of dough sheet before rolling = 5mm.

h_f = thickness of dough after rolling = 4mm

:. L_p= 5.5 mm = 0.0055 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).

σ_{av} =average stress of the sheet material passing through the rolls.

σ = sheet stress = $k\varepsilon^n$ (3)

k = consistency coefficient of doughat about 62.5% moisture content (assumed same with commercial baker's dough/flour = 3.4 kpa.s^n [6]

andn = a regression constant (assumed same with wheat flour) = 0.34 [7].

So, from [4] and [5], the entire roll length the stress developed $\sigma_{av} = \frac{\int_0^{\varepsilon_f} k\varepsilon^n d\varepsilon}{\varepsilon_f}$. $\frac{\int_0^{\varepsilon_f} k\varepsilon^n d\varepsilon}{\varepsilon_f}$ (3)

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

Where, $\varepsilon_f = \ln\left(\frac{h_1}{h_2}\right) = \ln\left(\frac{5}{4}\right) = 0.097$ (5)

$\Rightarrow \sigma_{AV} = 0.0349\left(\frac{0.097}{1.8125}\right) = 0.002$ N/mm2 (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 mmx 60 mm x 0.002 N/mm2
This is the force required by the upper roll (UR) per revolution to turn out a sheet of 60 mm.

2.3Motor torque requirement
2.3.1 Machine drives

An electric motor provides the driving power, which goes from motor pulley P_m to pulley 4, 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 N
$\Rightarrow$the total rolling force exerted by the action of both the UR and LR on the making of the sheet dough F_{TOT} = 2F (7)
= 13.2 N per revolution. Each of the four shafts bearing the four rolls will thus bear the load of l$s = \frac{2F}{4}$ or 3.3 N, acting at the shaft centre o.185 m from the left of each shaft.

This rolling operation force involves the tangential force F_T and the normal force Fn. The tangential force accounts for the machine driving torque T_d and the normal or radial force Fn 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 $F_T = F\cos\alpha$ (8)
where α = angle of contact between dough and each roller

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

$\Rightarrow$for each shaft, the tangential load on it causing twisting $F_T = 3.3\cos 11.8^o$ N = 3.2 N
Also, the force component responsible for bending ie the normal force $Fn = F\sin\alpha$ (10)
:. For each shaft, the normal load on it causing bending $Fn = 3.3\sin 11.8^o = 0.67$ N
Torque requirement of roll 4
Torque on shaft arising from each rollcausing twisting = F_T x radius of roll)= Tr
:.Torque experienced byroll4 is assumed to affect shaft 4=0.5(Tr) =0.5 (3.2 x 0.035) 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

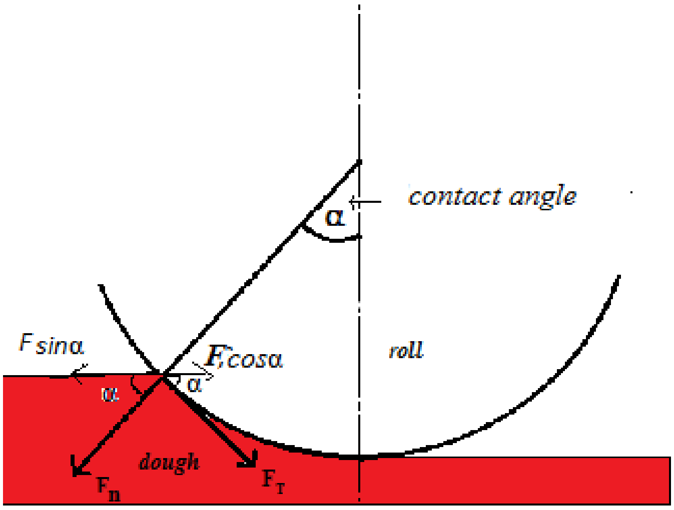


Fig.4- Rolling forces

For rolling operation to occur, $F_T\cos\alpha \geq F_n\sin\alpha$
:.F_T>Fn or 3.2 N > 0.67 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 α, according to [8],is α where $\alpha = 14^o$
(ii) Weight or load of gears 4 and3 train or 2(0.74 kg x 9.81m/s^2)
(iii) Vertical load components of meshed gears 4 and 3 ($V_{cg)}$ iewt. of gears 4 and 3 sin 14^o
⟹Total vertical load effect = wts of (gear 4 + gear 3) + V_{cg}
= (14.52 + 3.50).
Thus torque generated by gear 4 and 3 train T_g = (18.02 x 0.035) Nm

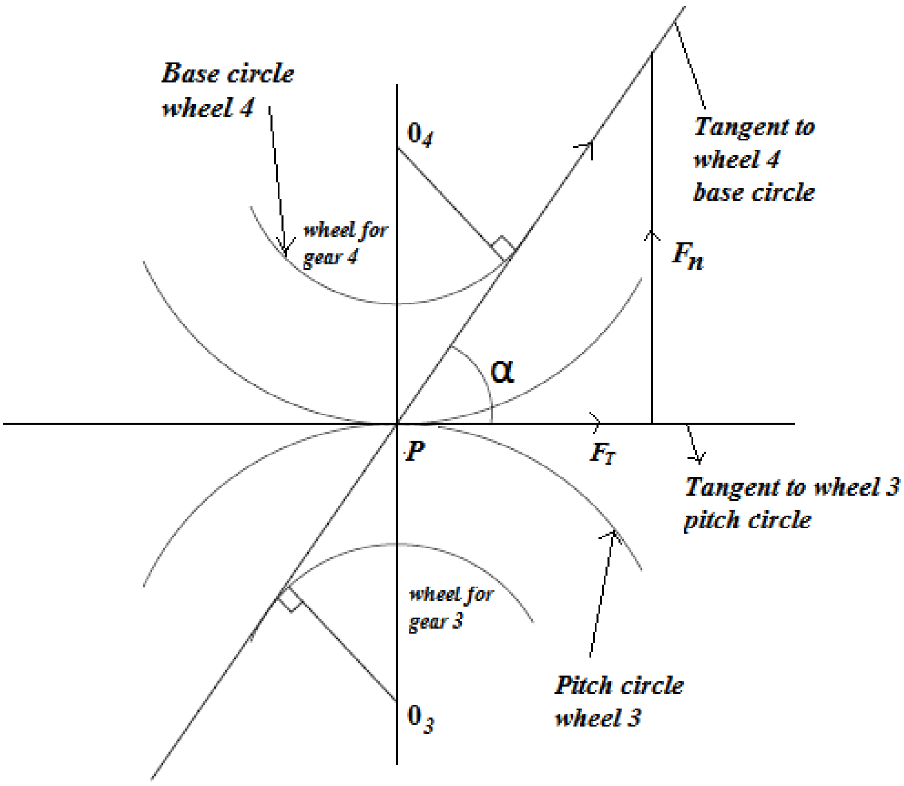


Figure 5- Gear drive profile

Since the radius of gears 4 or 3 = 35mm = 0.035 m,
The torque experienced by this gear 4 and 3 train = (18.02 x 0.035) Nm
The assumption is that one-half of this LR torque is associated with shaft 4,T_g =0.5(18.02 x 0.035) = 0.32 Nm (12)
(iii) Torque or force effect of pulleys and belts

2.4Belt tensions
For Belt 1,
Motor speed n_1 = 1000rpm
Motor pulley radius r_m = 0.02 m
Pulley 4 radius r_4 = 0.04 m
Pulley 1 radius r_1 = 0.06 m since d_1 = 120 mm
The relationship existing between the two tensions in a V-belt arrangement according to [8] is

$$2.3 \log \left(\frac{T_1}{T_2}\right) = \mu\theta\text{cosec}\beta \quad (13)$$

Where $T_1$and T_2= tensions on the tight and slack sides of the belt respectively.
μ = coefficient of friction between the belt and groove side = 0.5123

θ = angle of contact on the motor pulley. $\alpha = x_1 + \sin^{-1}(\frac{r_4 - r_m}{x_1})$ = 5.9°, and x_1 = centre distance between the two shafts centres= 200mm = 0.200m. Now θ = 180° - 2α = 180° – (2 x 5.9°) = 168.2°

$\Rightarrow \theta = 168.2 \text{ x } (\frac{\pi}{180})$ = 2.94 rads

β = half of the groove angle of the sheaves, where the full angle of groove is measured as 32°. Thus β = $(\frac{32^o}{2})$ = 16°

From equation (9), $(\frac{T_1}{T_2}) = \log^{-1}(\frac{\mu\,\theta \operatorname{cosec}\beta}{2.3}) \Rightarrow (\frac{T_1}{T_2}) = \log^{-1}(2.376)$ =237.68Nm.

Again, the power transmitted by this V-belt is related to tensions in this expression [8]
$P = (T_1\text{-}T_2)V_b$ (14)
Where P = motor power and V_b = belt velocity which is given as

$V_b = (\frac{\pi d_1 n_1}{60})$ and d_1, $n_1$are diameter and speed of motor respectively.

Thus from equation (9) and (10), T_1andT_2 may be obtained.

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

Length of belt 1 required, $L_1 = \pi(r_4 + r_1) + 2x + (\frac{r_4 - r_1}{x})^2$ (15)

Belt 2
Following the steps of belt 1 calculations,
The desired distance between P_4 and P_1 = x_2 = 300mm
μ2 = 0.5123
α2 = 12.6°
θ2 = 2.70 rads
β2 = 14°

Again, From equation (9), $(\frac{T_3}{T_4}) = \log^{-1}(\frac{\mu_2\theta_2 \operatorname{cosec}\beta_2}{2.3}) \Rightarrow (\frac{T_3}{T_4}) = \log^{-1}(2.486)$ = 306.13Nm.

$T_3 = 306.13T_4$

Since the motor power = 547.78.18 W, the Belt 2 speed $V_2 = (\frac{\pi d_4 n_2}{60}) = (\frac{\pi x 0.08\ x 500}{60})$ = 2.1 m/s

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

:. $P = (306.13T4 - T_4) \text{ x } V_2$,⇒ T_3 and T_4may be obtained.= 0.86 Nm; = 261.71 Nm
From equation (5), the torque required at this second stage of pulley P1,

$T = P \text{ x } \frac{9.554}{n_2}$ (16)

The total torque needed for the two belt-pulley stages is (5.23 + 10.47) = 15.70 Nm
Total torque required by the two belt systems Tb = (5.23 + 15.70) Nm
Thus, the total torque required of the machine = Tr + Tg + Tb = (0.06 + 0.32 + 15.70) 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.

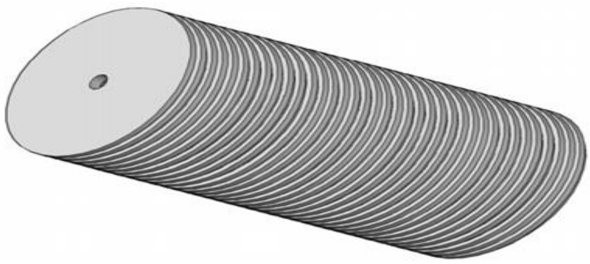


Fig. 6. Grooved roll

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,

$S_A= (2\pi r l + 2 \pi r^2) - 2 \pi r^2 = 2\pi r l$ (17)

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

:. Thesurface area of the sheet produced per roll revolution $A_s = S_A = 67885.7mm^2$

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 = 67885.7mm2 x 4 mm = 271542.8 mm^3 where thickness of exiting dough sheet/noodles = 4 mm).

:.$V_{LR\,=}$ volume of dough shaped, shredded and exited per rev of LR = 271542.8 mm3

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

:.Mass of cassava dough M_d= 550 x 0.000271542.8 = 0.14934854kg = 149g (18)

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 kb = 2.0 and kt = 1.5 respectively. The diameter of the shaft may therefore be determined using maximum shear stress theory [9]

$$d^3 = \left(\frac{16}{\pi\tau_{max}}\right)\sqrt{(M_b.k_t)^2 + (M_t.k_t)^2} \quad (19)$$

where

d = shaft diameter

τ_{max} = permissible shear stress = 0.3 of the material yield stress or $0.3S_{yt}$ [9]

= 0.3 x 240 = 72 Mpa (x)

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

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

Mt = maximum working stress in shear = 16.44 Nm ie the total torque machine requirement.

Kb = combined shock and fatigue factor for bending moment = 2.0

Kt = combined shock and fatigue factor for torsion =1.5

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

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

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 9.81m/s^2), 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^o
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 θ= angle of contact (14^o) and T_1 and T_2 = tight and slack tensions respectively in the belt 1 drive.
$\Longrightarrow$ total vertical load effect acting at 0.010 m = 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_{-HOR} = horizontal load effect (tension) of pulleys 4 & 1 and belts 1 & 2 systems
= $T_1\cos 5.9^o + T_2\cos 5.9^o$ (from belt 1), and
$T_3\cos 12.6^o + T_4\cos 12.6^o$ (from belt 2), acting at 0.010 m from the left of shaft.
Also for gear G_4, the normal force associated with the shaft bending = $F_n\cos 14^o$ (14^o 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

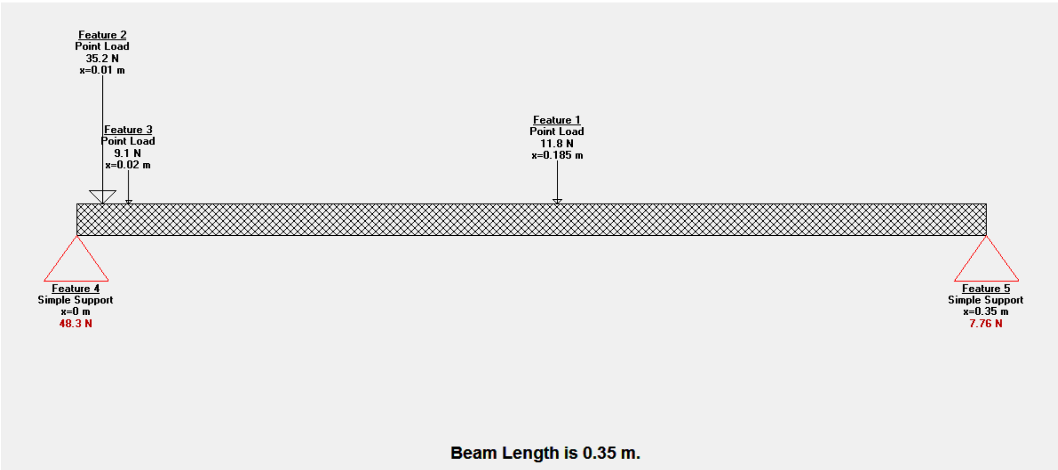


Fig. 7- The shaft free body diagram

Table 1. The maximum stress values on shaft arising from vertical loads.

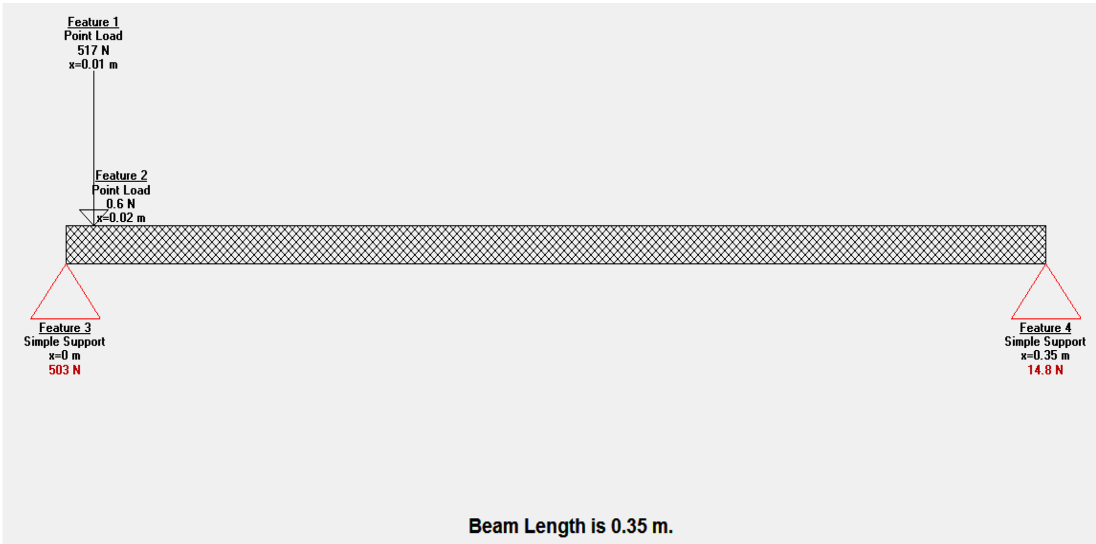


Fig. 8- The shaft free body diagram

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

Maximum Values

	Maximum Value	Location
Bending Moment	5.03 N-m	0.01 m
Bending Stress	51200 MPa	0.01 m
Deflection	19700 mm	0.35 m
Slope	4900 degrees	0.35 m

Close

Table 3. Forces and roll forces

1	Force developed by each pair of rolls	6.6	N
2	Tangential load component of each roll	3.2	N
3	Normal load component of roll	0.67	N
4	Angle of contact between dough and roll	11.8	Degree
1	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.	11.8	N
6	Torque requirement of roll 4	0.06	Nm

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

s/n	load components of the belt	Value	Unit
1	Angle θ the common normal to the base circle of wheel 4 makes with the pitch circle of wheel 3 = α (khurmi, 2008)	14	Degree
2	Weight or load of gear 4 =(0.74 kg x 9.81m/s^2)	7.3	N
3	Vertical load components of gear 4 ($V_{cg)}$ = 7.3 sin 14^o	1.8	N
4	Total vertical load effect = wts of (gear 4 + gear 3) + V_{cg} = (7.3 + 1.8).	9.1	N
5	Driving force component of the gear mesh =18,02 cos 14^o	28.2	N
5	Bending force component of gear mesh 18.02sin14^o causing bending on the shaft acting on the shaft at 0.015 from left where the gear is located on the shaft. .	7.0	N
6	Torque generated by gear 4T_g = (18.02 x 0.035) Nm	0.32	Nm

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

s/n		Symbol	Value	Unit
1	Weight of aluminium pulley P4 = 0.11 kg x 9.81 = 1.1 N, a point load acting at 0.010 m from the left.	Wa	1.1	N
2	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.	Wb1	0.28	N
3	Angle of contact on the motor pulley	θ	168.2	Degree
4	Tensions on tight and slack sides of belt 1	T_1, T_2	262, 1.10	N
5	Vertical load components of belt 1, V_{cb} = T_1sin θ+ T_2sin θ	V_{cb}	33.82	Nm
6	Total vertical load effect acting at 0.010 m = wts. of (belt 1 + pulley + V_{cb}) = 1.1+0.28+33.82	V_L	35.2	Nm
7	Belt 1's linear velocity	V_{b1}	2.1	m/s
8	Torque requirement of belt 1	T_{b1}	5.23	Nm
9	Length of belt1(standard)	L	710	Mm
10	Tensions on tight and slack sides of belt 2	T_3, T_4	262, 0.86	N
11	Torque on belt 2	T_{b2}	10.47	N
12	Total torque requirement of the machine	TT	16.08	Nm
13	Machine power demand	PT	1721	Kw
14	Motor horsepower requirement	hP	4.2	Hp
15	Resultant maximum bending moment$\sqrt{}$(Mv)^2 +($M_{h)}$^{2} = $\sqrt{}$ (1.28)^2 + (5.03)^2	Mb	5.2	Nm
16	Standard shaft diameter selected	ds	13	Mm

Table-4: Machine design cost analysis as at July 2016

S/no	Design variable	Quantity of material used	Cost of material used (N)
1	2mm thick mild steel sheet	2 sheets	4,000.00
2	4 sprocket gears	70 mm diameter, each	4000.00
3	60 mm diameter stainless steel pipes	4 pieces	3,200.00
4	20 mm aluminium alloy pulley	1 unit	300.00
5	100 mm aluminium alloy pulley	1 unit	500.00

6	V-belts	2 pieces	400.00
7	13 mm machined solid mild steel rods	4 pieces	2,000.00
8	Bolts and nut (assorted)	16 pieces, each	400.00
9	Plummer blocks	8 pieces	1,200.00
10	Electric motor-4.2 horse power	1 piece	5,000.00
Total cost of design materials used			N20,000.00 ($50)

3.2 Discussions

From Table 1, the maximum vertical bending moment is 1.28 Nm located at 0.185m of the shaft from the left. Reactions at points A and B are 48.3 N and 7.76 N respectively. It has the tendency of developing a bending stress of 13000 mPa at a location 0.185 m from the left.
Figure 7 gives the free body diagram of the vertical load effect on the shaft.

From Table2, the maximum horizontal bending moment is 5.03 Nm, located at 0.01 m on the shaft from the left. Reactions at points A and B are 503 N and 14.8 N respectively. The bending stress will develop with a value of 51200 MPa at a location of 0.01 m from the left.
Figure 8 also gives the free body diagram of the horizontal load effect on the shaft.

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 shaftare 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. CONCLLUSION

ACKNOWLEDGMENT

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

REFERENCES

[1]. Noodles-Wikipedia, https://en.wikipedia.org/wiki/Noodle. Retrieved on 04/07/2016

[2]. J.Bardwick, *Noodle making machine -Patents*,Patent US4083668, (2004).

[3]. Noodle-making machines, Sunseni.en.made-in-China.www.google.com/patents/US4083668 Retrieved on 14/11/2015.

[4]. Rolling of metals, Suranaree University of Technology.*http://eng.sut.ac.th/metal/images/stories/pdf/03_Rolling%20of%metals.pdf*. Retrieved on 13/6/2016

[5]. Metal rolling,*Thelibraryofmanufacturing.com/**metal_rolling**.html,*

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

[7]. N. Sharma, M.A. Hanna, and Y. R. Chen,Flow behaviour of wheat flour-water dough using a capillary rheometer 1.*Effect of capillary Geometry. Cereal chem 70(1): 59-63*

[8]. R. S. Khurmi, and J. K Gupta, *Theory of Machines* (Euresia Publishing House (PVT) ltd, Ram Nagar Delhi,2008)110,055

[9]. Cassava-Wikipedia,https://en.wikipedia.org/wiki/Cassava Retrieved on 17/2/16