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Geometric Design of a Table Top Palm Fruit Milling Machine (Ofe-Aku Machine)

Gabriel Oladeji Bolarinwa[1], Segun Agbadua[2], Jibrilla Abdulrahman[3], Zemoya Ogbemudia Ogbomida[4]
[1] National Engineering Design Development Institute (NEDDI), PMB 5082, Nnewi, Anambra State, Nigeria.
[2] National Engineering Design Development Institute (NEDDI), PMB 5082, Nnewi, Anambra State,
[3] Hydraulic Equipment Development Institute, (HEDI) Kano, Kano State,
[4] National Engineering Design Development Institute (NEDDI), PMB 5082, Nnewi, Anambra State.

Abstract: This paper shows the preliminary design of a table top palm fruit milling machine. It is observed that the palm kernel soup in Nigeria especially in the eastern part of the locally called "OFE AKWU" is very popular and it is commonly prepared both for domestic consumption and for commercial purposes by the food vendors. But owing to the stress required in this extraction process, we aim at alleviating this by designing this simple machine that could be easily operated by both the young and the adult, literate or illiterate. This is a simple device aimed at reducing drudgery and stress involved in milling digested palm nut (removing the flesh portion of the nut from the boiled palm nut). The removed flesh is then manually squeezed to extract the oil. Similarly, the nuts are separated manually from the chaff. It is expected that future modification will incorporate a digester, a press and a separating mechanism.
Keywords: Ofe-Aku, Table top, Palm fruit, threshing, drudgery

I. INTRODUCTION

It is observed that the palm kernel soup is a very popular and nutritious soup. It is very rich in vitamin A. it is called "OFE AKWU" in Igbo land, and it is commonly prepared both for domestic consumption and for commercial purposes by the food vendors. It is also prominent in Yoruba land where it is being referred to as "Obe Egboyin" and in the south-south region, Banga Soup .But owing to the stress required in the extraction process, (removal of flesh which contains the oil), we aim at alleviating this by designing this simple machine that could be easily operated by both the young and the adult, literate or illiterate, skilled and unskilled.

II. RIEF ABOUT PALM FRUIT

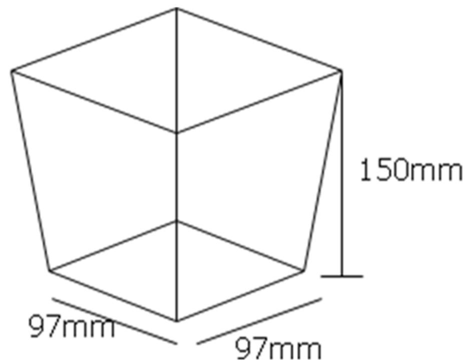
Oil Palm, common name for an ornamental and economically valuable palm tree, native to western Africa and widespread throughout the tropics. The oil palm grows up to 9 m (30 ft) in height. It has a crown of feathery leaves that are up to 5 m (15 ft) long. The flower cluster is on a short thick spike at the base of the leaves. Flowering is followed by the development of a cluster of egg-shaped, red, orange, or yellowish fruits. Each fruit is approximately 3 cm (1 in) long and contains from one to three seeds embedded in a reddish pulp.

Palm oil is extracted from the fruit pulp. This yellowish or reddish oil is used mostly in the manufacture of soap and candles. Palm oil is also the largest source of palmitic acid, a fatty acid used in numerous commercial processes. The more valuable palm kernel oil is obtained from the seed kernels of the fruit. This oil has a pleasant odour and nutty flavour and is used in making margarine as well as soap and candles. The kernels are shipped to mills where the oil is extracted with solvents or by hydraulic presses. After extraction, the oil cake that is left over is used as cattle feed.But it was observed that no machine or any other device is domestically available for achieving this extraction and this led to the design and fabrication of this very useful, portable, and efficient machine.

III. DESIGN CALCULATIONS

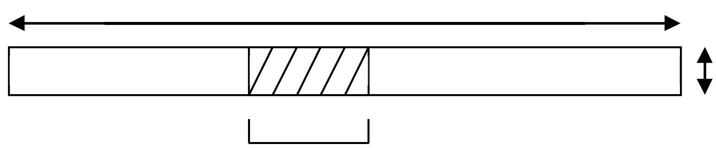
A. Design of the hopper

Height = altitude = h =150mm
Length of base, L = 97mm
Breath of base = b= 97mm
Area of the base = k= L x b
= 97 x 97
= 9409mm²
Maximum allowable volume of the hopper = V =1/3[h x k]
= 1/3 x 150 x 9409
= 470450mm³



B. Design of the working region

Working Volume = Volume of the pipe – Volume of the shaft
= V_p – Vs
Volume of the pipe $V_p = \pi rp^2L$
Where Rp = Outer radius of the pipe = 52mm
rp =Internal radius of the pipe = 50mm
L = Length of the pipe or shaft = 400mm
V_p =3.1416 *502 x 400
= 3141600mm^3
Volume of the shaft, Vs= πr_s^2L
Where r_s = radius of the shaft=20mm
= 3.1416x 202x400
= 502656 mm^3
Working volume = 3141600 - 502656
= 2638944mm3
Consider an elemental part of the pipe



Elemental circumferential area of the pipe = d A
$d A = 2\pi r_p dl$
Where r_p = inner radius of the pipe
Integrate both sides,
$\int d A = \int 2\pi r_p dl$
$\int d A = 2\pi r_p \int 400 dl$
$\int d A = 2 \pi r_p [L]\ 400$
$A = 2\pi rp [400] - 2\pi r_p$
$A = 800 \pi r_p$
A = 800 x 3.1416 x 50
=125664mm²
In finding the relative speed of the shaft to the worm, we can relate it to the wheel and axle principle

Volume 3 Issue VIII, August 2015
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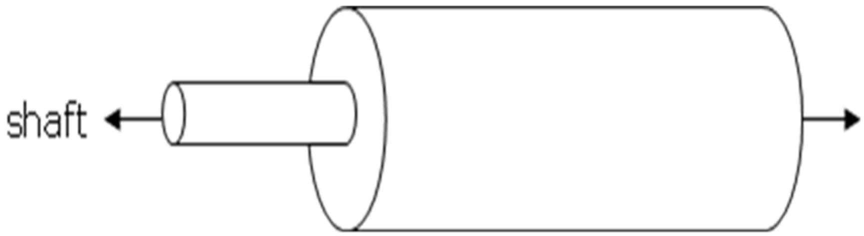
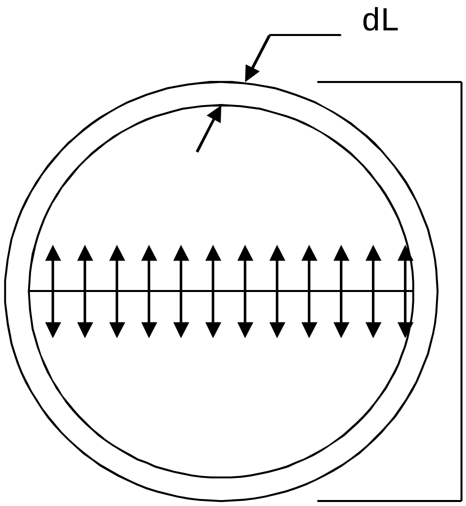
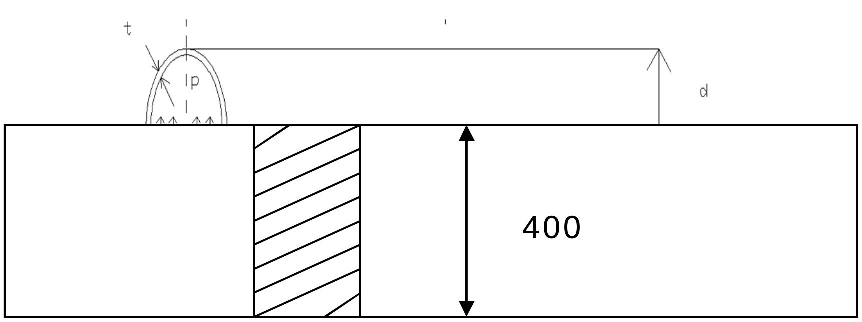


Speed = distance / time = d / t
Angular Speed = Velocity / radius = V / r
Taking ratios;
$w_s / W_w = 2\pi r_s \ / 2\pi r_w$
$w_s \ / w_w = r_s / r_w$
Where
w_s = angular speed of shaft
w_w = angular speed of worm
r_s = radius of shaft = 20 mm
r_w = radius of worm = 40mm
w_s / w_w =20/40
$w_s / w_w = ½$.
This implies that,
$2w_s = w_w$
w_s = ww / 2
w_s = 0.5ww

This implies that the shaft will cover twice the distance that the worm will cover at a given instant of time.
Circumferential or hoop stress, σ_h:
This is the stress that occurs as a result of the pressure exerted on the internal part of the pipe by the palm kernel = P x d / 2t where,
P= internal pressure
d= internal diameter
t= thickness of the pipe





Force acting on longitudinal section = p x d x L where dL is the projected area.
Force acting on the wall of the pipe
= σ_h x 2t x L

Volume 3 Issue VIII, August 2015
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Equating the two equations of forces,

$p \times d \times L = \sigma_h \times 2t \times L$

$t = Pd/\ 2\ \sigma_h$.

P = intensity of internal pressure.

d= internal diameter of the cylindrical shell.

l = length of the cylindrical shell

t = thickness of the cylindrical shell = 2.5mm

Q_l = loop stress/circumferential stress

$$Q_l = \frac{pxd}{2.t}$$

Circumfrential area = πdt

$A_c = 3.142 \times 40 \times 2.5 = 314.2mm^2$

$$P = \frac{F_c}{A_c}$$

$$= \frac{461}{314.2}$$

$P = 1.5N/mm^2$

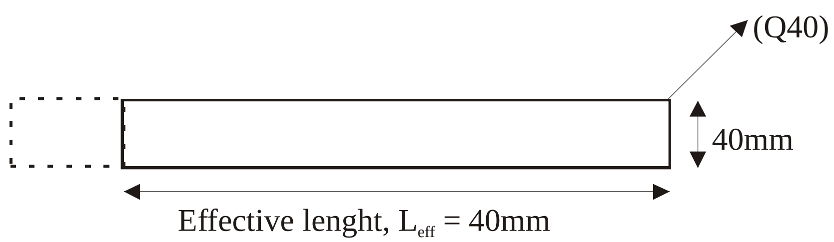
$$Q_l = \frac{pd}{2t}$$

$$= \frac{1.5 \times 40}{2 \times 2.5}$$

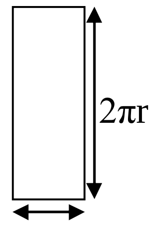
$Q_l = 12N/mm^2$

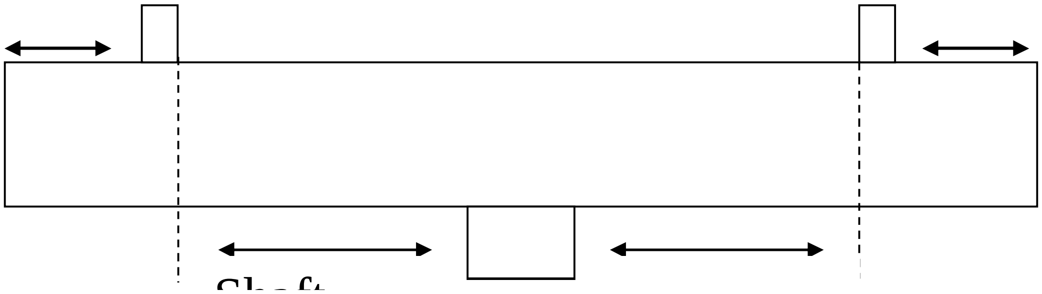
C. Shaft Design

(1)



Effective (cylindrical)





(1) Volume of the effective shaft

$L_{eff} = 40mm$

$D_{effective}$ = 40mm

$R_{eff} = 20mm$

$Volume_{eff} = \pi r_{eff}^2 L_{eff}$

$= \frac{22}{7} \times (20)^2 \times 400$

$= \frac{22}{7} \times 400 \times 400$

$=502720mm^2$

Volume of a spike =

$\ell_s = 20mm$

$D_s = 10mm$

$V_s = \frac{\pi D_o \ell_s}{4} = \pi r_s^2 \ell_s$

$= 3.142 \times (5)^2 \times 20$

$= 1571mm^2$

Total volume occupied by the spiked = 3 x 1571

= 4713mm3

ℓ_s = Length of the spike

D_s = Diameter of the spike

D_{EFF} = Effective diameter of the shaft.

ℓ_{ef} = Length of the effective parts on shaft.

Volume of the cylinder – (v_{reg}) working region.

V_{reg} = Volume of the working region

D_{reg} = 100mm

V_{reg} = 50m

$\ell_{reg} = L_{eff} = 400mm$

$V_{reg} = \pi r_{reg}^2 \ell_{eff}$

$= 3.142 \text{ x } (50)^2 \text{ x } 400s$

$=3145000mm^3$

Working Volume $_w$

$= V_{reg} - V_{eff} - V_s$

$= 3145000 – 502720 – 4713$

$= 2637567mm^3$

Mass of the Shaft,

The total length of the shaft = 550mm

Volume of the entire length of the shaft.

$Vt = \pi r_s^2 \ell_r$

$= 3.142 \text{ x } (20)^2 \text{ x}550$

$= 6912.40mm^2$

Density of ρ of stainless steel (Type 304)

$= 7.9g/m^3 = 7.9 \text{ x}10^{-3} g/mm^3$

$\rho_{s.s} =7.9 \text{ x}10^{-3} g/mm^{-3}$

From,

$\text{Density} = \frac{mass}{volume}$

Mass = Density x Volume.

$=7.9 \text{ x } 10^{-3} \text{ x } 691240$

M = 5460.796g.

M = 5.461kg

The mass of the entire shaft length

M shaft = 5.5kg.

The mass for pieces of the spikes

$= \rho_{s.s}$ x Volume of spike x3.

i.e

$= \rho_{s.s} \text{ x } V_s = 3$

$= 4713\text{x } 7.9\text{x}10^{-3} \text{ x}3$

= 111.7g.

Mspikes , mass of spikes

= 0.11kg.

Total mass, $M_T = M_{shaft} + M_{spikes}$

= 5.5 + 0.1

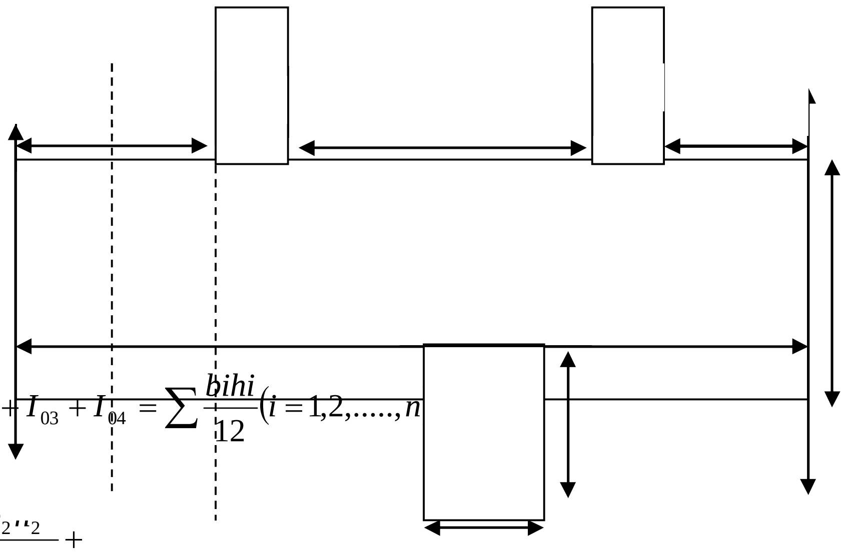
$M_t = 5.61kg \approx 6kg$

Volume 3 Issue VIII, August 2015
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Centripetal Force $= \dfrac{mv^2}{r}$

D. Moment of Inertia (composite body)

5+6+98-



$$I_0 = I_{01} + I_{02} + I_{03} + I_{04} = \sum \frac{bihi}{12}(i = 1,2,.....,n$$

$$= \frac{bihi^3}{12} + \frac{b_2 ..._2}{12} +$$

$$= \frac{bihi^3}{12} + \frac{3b_2 h_2^{\ 3}}{12}$$

$$= \frac{550 \times (40)^3}{12} + \frac{3 \times 10 \times (20)^3}{12}$$

$$I_0 = 2953333mm^4$$

$$I_{xx} = I_0 + \sum A_i d_i^2$$

$$d_1 = \frac{550}{2} = 275mm \qquad d_3 = 455\text{mm}$$

$$d_2 = 165mm \qquad d_4 = 310\text{mm}$$

$$\sum A_i d_i^{\ 2} = 55x40x(275)^2 + 200x(165)^2 + 200x(455)^2 + 200x(310)^2$$

=`166375000+5445000+41405000+19220000

= 232, 445, 000mm^4.

I_{xx} =2953333 + 232, 445, 000mm^4

=235398333mm^4

=235.4 x 10^{6}mm^4

≈235 x 10^{6}mm^4

Mass moment of inertia = MK^2

K = radius of gyration

K $= \sqrt{\dfrac{I}{A}}$

Area $_{of}$ the entire shaft

Volume 3 Issue VIII, August 2015
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

$$A_{shaft} = \frac{\pi D_5^2}{4} = \frac{3.142x(40)^2}{4}$$

$=1256.8mm^2$

$$A_{spikes} = \frac{3\pi D_{spikes}}{4} = \frac{3x3.142x(10)^2}{4}$$

$= 235.65mm^2$

Total area = 1256.8 = 235.65

= 1492.45mm2

$$K = \sqrt{\frac{235.4x10^6}{1492.45}}$$

K = 397mm

M ass moment = 16 x $(397)^2$

= 945654 $kgmm^2$

== 945.7 x $10^3 kgmm^2$

Assumed 1hp electric motor,

1.34hp = 746watts

$$1hp = \frac{746}{1.34} = 557watts$$

Power = $T_{w,}$

557 = T_w

but $T=F_r$

where F = Centripetal force,

r = radius of the shaft

557 = F x r x ω

$$\omega = \frac{557}{Fr}, \text{ but } f = mr\omega^2$$

$$\omega = \frac{557}{mr^2w^2}$$

$$\omega^3 = \frac{557}{mr^2} =$$

= 232083.33

$$\omega = \sqrt[3]{232083} = 61.45\,{}^{rad}\!/_{sec}$$

$$\approx 62\,{}^{rad}\!/_{sec}$$

$$\text{but } \omega = \frac{2\pi N}{60}$$

$$N = \frac{60\omega}{2\pi} = \frac{60x61.45}{2x3.142} = 587\,{}^{rad}\!/_{mm}$$

$$N = 587\,{}^{rad}\!/_{mm}$$

Volume 3 Issue VIII, August 2015
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Centripetal force f = $\dfrac{Mv^2}{r} = V = r_w$

$$f_e = \frac{M(r\omega)^2}{r} = \frac{m_r^2\omega^2}{r} = M_T r\omega^2$$

M_T = 6kg, r = 20mm = 0.02m

F_e = 6 x 0.02 x 3844 = 461.28N ≈ 46N

$R_A + R_B$ = (1.08 x 2) + 5.93

= 8..07N

$\sum M_{O1} R_A J + ve = O$

1.08 x 50 + 5.93 x 200 + 1.08 x 350

= 400R_B

5.4 + 1186 + 378 = 400R_B

400R_B = 1618

$R_B = \dfrac{1618}{400}$ = 4.05N

5.4 + 1186 + 378 = 400R_B

400R_B = $\dfrac{1618}{400}$ = 4.05N

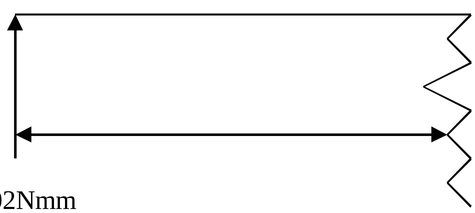
R_B = 4.05N

$R_A + R_B$ = 8.09

R_A =8.09 – 4.05

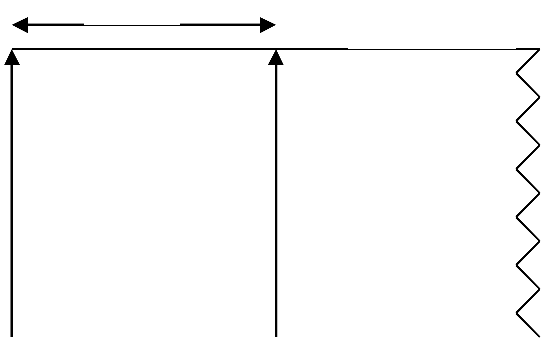
R_A =4.04N

1) X < 50



4.04 x 50 = 202Nmm

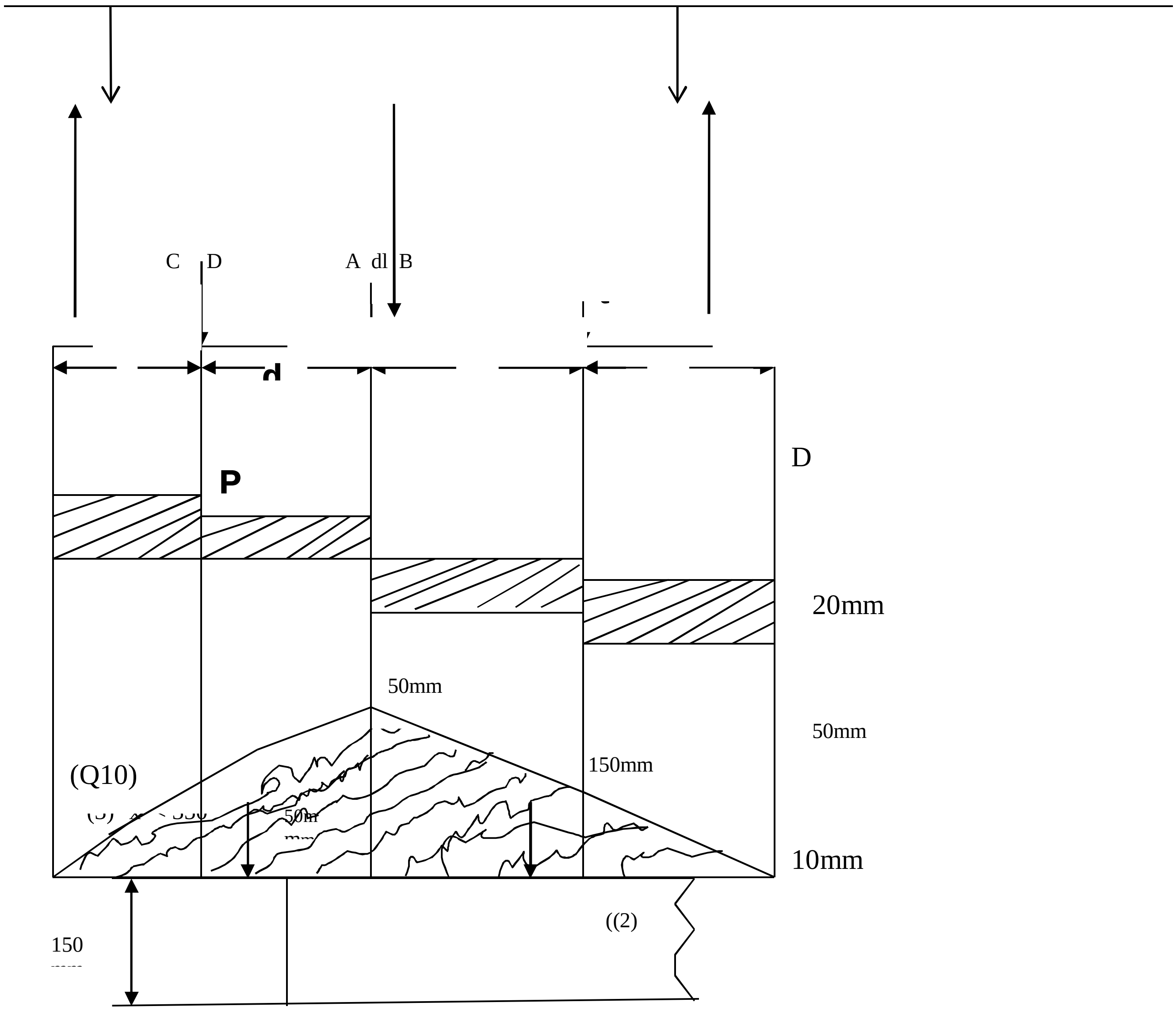
2) X < 200



4.04 x 200 – (150 x 1.08)

= 808 – 160

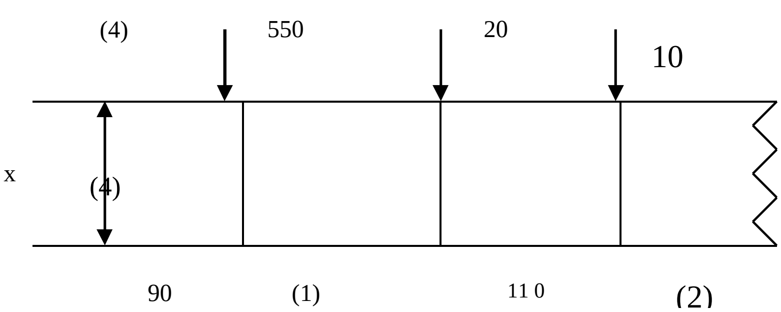
= 648Nmm



(3)

4.04 x 350 - 1.08 x 30(... 0

1414 - 324 - 889.5 = 200.5Nmm



4.04 x 400 – 1.08 x 350 – 5.93 x 200 – 1.08 x 50

1616 – 378 – 1186 – 54 = -2Nm.

E. Design of V – Belts and Pulleys

Specification

1) Electric motor 1 hp
2) Service factor 1.2
3) Belt type A

F. Belt Design

Selecting an appropriate belt involves calculating horsepower per belt as follows.

NH_r = (demanded hp x ks)/K_1K_2

Where H_r = hp/belt rating, either from ANSI formation above or from

Manufacturer's catalog

Demanded hp = horsepower required by the job at hand.

K_s = Service factor accounting for driver and driven characteristics regarding such things as shocks, torque level, and torque uniformity

K_1 = angle of contact correction factor

K_{2} = Length correction factor [ ]

N = Number of belts.

Data

$K_{s} = 1.2$

$K_{1} = 1$

$K_{2} = ?$

$N = 1$

K_{2} = length of correction factor.

Sheaves are specified by their pitch diameter, which are used for velocity ratio calculation in which case inside belt length must be converted to pitch length for computational purpose. Pitch length are calculated by adding a conversion factor to inside length i.e $L_p = L_s + \Delta$

$L_s = 660.4$

$\Delta = 1.3$

$L_p = 660.4 + 1.3$

K = 0.83

$$NHr = \frac{1x1.2}{1x0.83} = \frac{1.2}{0.83}$$

NHr = 1.45hp/belt.

From above we can see v – belt type A can served the purpose.

According to India standard (I_s : 2494 – 1974) v – belt of type A has a top width of 13mm and a minimum pitch diameter of pulley is 75 mm.

Since the width of the belt is known, then the width of pulley (B) is taken as 25% greater than the width of belt

i.e 1.25b where b = width of belt

B= 1.25 x 13 = 16.25mm

(ii) the thickness of the pulley rim (+) varies from

$$\frac{D}{300} + 2mm \text{ to } \frac{D}{200} + 3mm$$

where D = diameter of pulley

Volume 3 Issue VIII, August 2015
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$$\frac{100}{300}+2=2.3$$

$$\frac{100}{200}+3=3.5mm$$

(iii) Dimension of arms .

The number of arms may be taken as 4 for pulley diameter from 200mm to 600mm and 6 for diameter from 600mm to 1500mm.

Since the pulley less than200mm diameter are made with solid disk instead of arm.

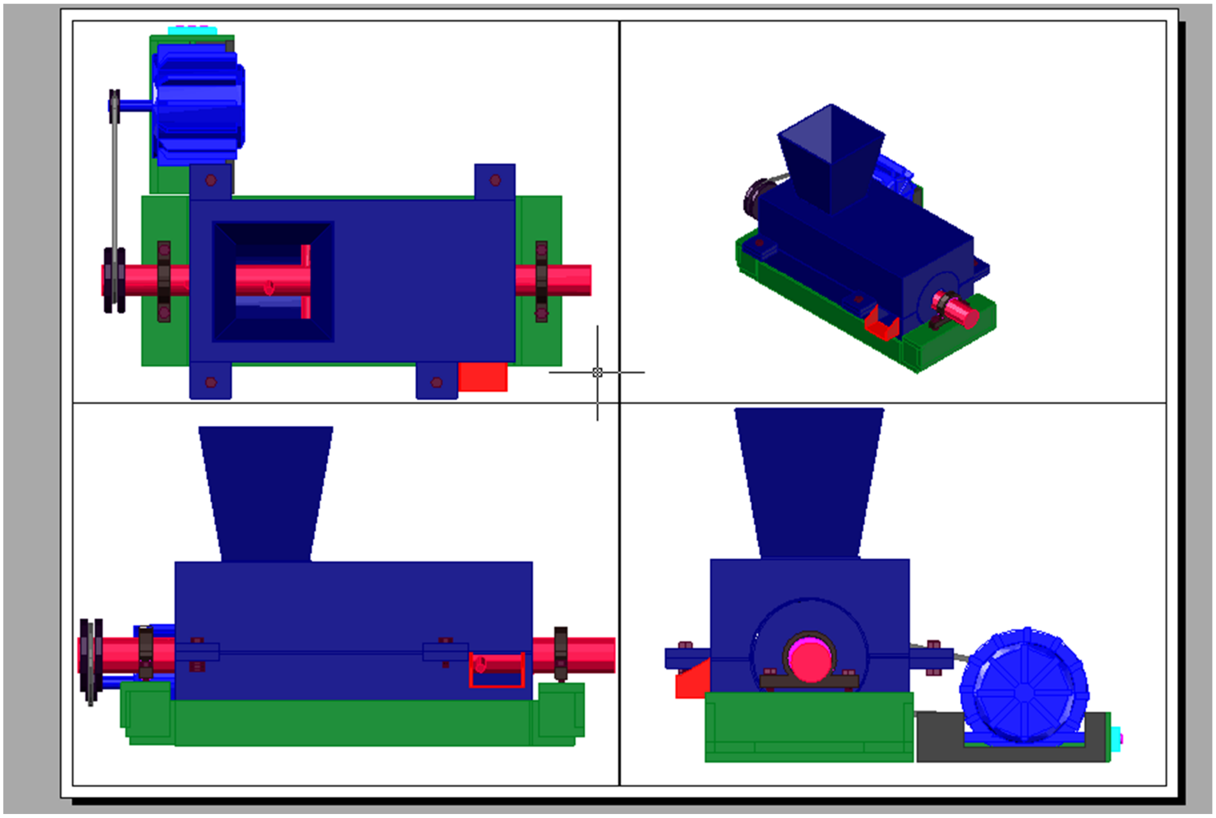

Fig. 1 Isometric and Orthographic views of the designed Table top palm fruit Milling Machine.

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