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DEPARTMENT: MECHANICAL ENGINEERING

MATRIC NO: 15/ENG06/030

COURSE TITLE: PRODUCT DESIGN

COURSE CODE: MEE 510

ASSIGNMENT 1

Project Topic: Design and Fabrication of a Pelletizer for agro based products

Material Selection, factors considered and reasons for selection

Table 1. Material selection S/N	**Machine components**	**Materials**	**Factor**	**Reason for selection**
1	Hopper	Mild Steel	Rigidity	Cheap, Available, Reliable and Durable
2	Support base	Mild Steel	Strength	Strong, Cheap, Available
3	Pulley	Mild Steel	Strong and Tough	Strong and not easily defected
4	Shaft	Stainless rod	Hard and Tough	Corrosion resistance, Strong, Availability and not easily deflected

5	Auger	Stainless Steel	Strong and ability to withstand impact stress	Corrosion resistance and Strength
6	Concave Drum	Stainless Steel	Hard and Tough	Very strong and Corrosion Resistance
7	2.5mm Die disc	Stainless Steel	Temperature resistance, machinability, strong and tough	Corrosion resistance, strong, ease of maintenance
8	V-belt	Rubber	Strength, tension	Economical, belt life duration

<u>Design specification</u>

Part no	Component parts	Qty	Dimension
1	V-belt	2	800mm dia
2	Pulley	2	100mm and 70mm dia
3	Gear motor	1	3hp
4	Shaft	1	40mm
5	Hopper	1	35 x 35
6	Barrel	1	50mmϴ x 660mm
7	Die disc	3	2.5ϴ,3ϴ,5ϴ,6ϴ (x 125ϴ)
8	Out let	1	7 x 7mm
9	Frame	1	183 x 115 x 38mm
10	Screw conveyor	1	40mmϴ x 655mm

i) The Frame

The frame is the support base for other components. It is rigid and designed to withstand dynamic stresses and it measures 183 x 115 x 38mm.

ii) The Barrel

This is a cylindrically shaped component with a 50mm diameter and 660mm length. It is made of stainless steel of thickness 2.5mm.

iii) The Screw Conveyor

This a stainless cylindrical screw shaft of 46mm external diameter and 660mm length, placed inside the barrel for the purpose of conveying feed components to the die at a constant rate. It is connected to an electric gear motor with a v-belt.

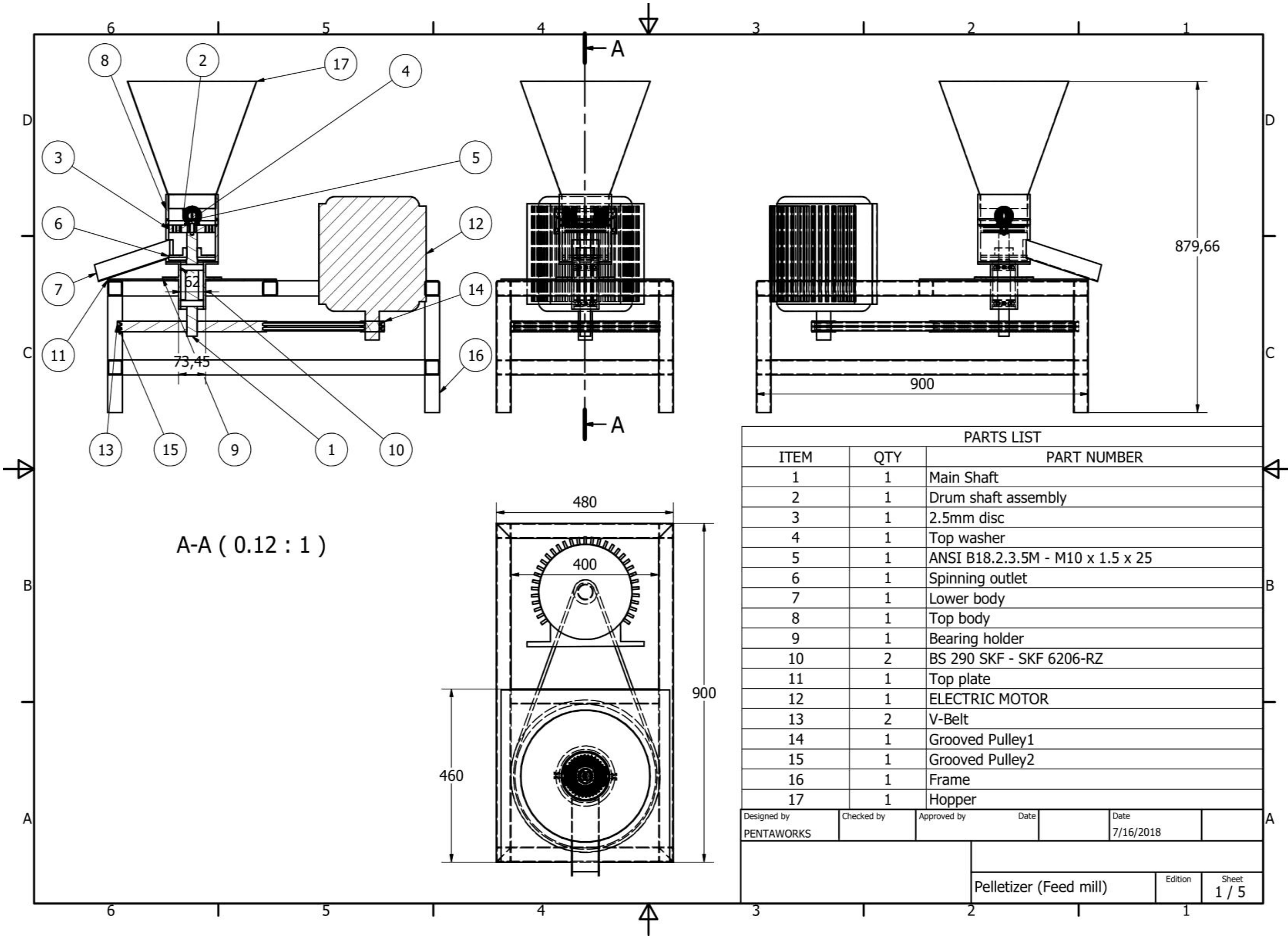
iv) The Die Plate

The die is a plate placed at the terminal of the screw, it is made of stainless steel and of 2.5mm thickness with holes of 2.5,3,5 and 6mm drilled onto it. Note that the die is of variable sizes depending on the size of the feed pellet required.

v) Feed Hopper.

Hopper is the input point for the feed components. The mixed feed is fed in through hopper and with the help of a feed conveyor attached to the hopper, the feeds are transferred to the barrel, from where it will be taken to the die for extrusion. It has an outer and inner dimension of 350 x 350mm and 210 x 210mm respectively, at an angle 90o. The dimension of the outlet of the hopper leading to the barrel is 40 x 40mm, with a height of 350mm. A gauge number 20 stainless steel was used to prevent sticking of feeds to the feed hopper and to allow easy cleaning.

Detailed Design and Specification of the Pelletizer



PARTS LIST		
ITEM	QTY	PART NUMBER
1	1	Main Shaft
2	1	Drum shaft assembly
3	1	2.5mm disc
4	1	Top washer
5	1	ANSI B18.2.3.5M - M10 x 1.5 x 25
6	1	Spinning outlet
7	1	Lower body
8	1	Top body
9	1	Bearing holder
10	2	BS 290 SKF - SKF 6206-RZ
11	1	Top plate
12	1	ELECTRIC MOTOR
13	2	V-Belt
14	1	Grooved Pulley1
15	1	Grooved Pulley2
16	1	Frame
17	1	Hopper

Figure 1: Detailed Design and Specification of the Pelletizer

Die Design

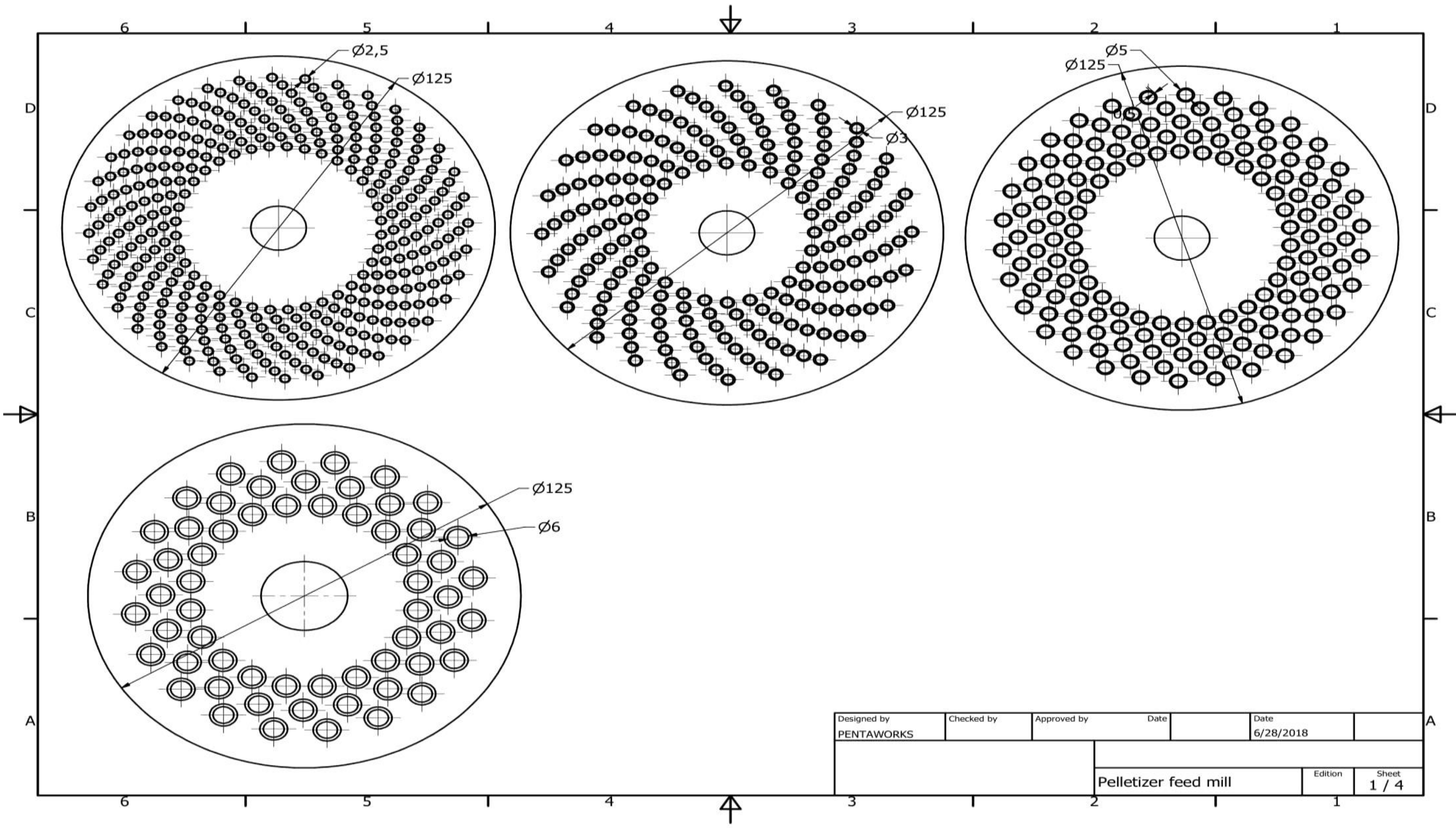


Figure 2: Shows the different dimensions of the die plates

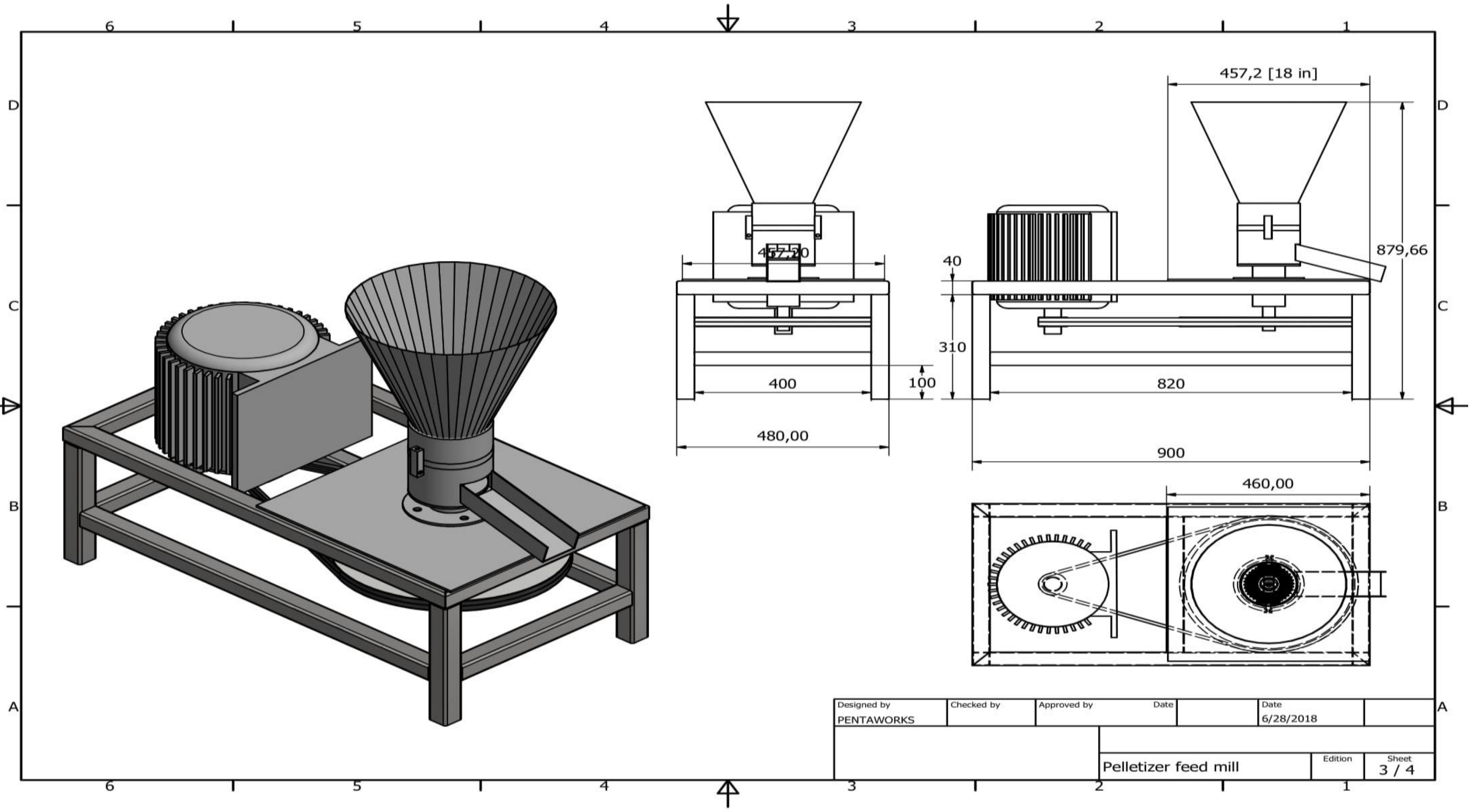


Figure 3: Shows the different views of the pelletizing machine

BEME (Bill of Engineering Measurement and Evaluation)

ITEM	QTY	PART NUMBER	Fabrication procedure.	Cost
1	1	Main Shaft	This part is machined on a lathe with turning , drilling and tapping procedures	NGN 12,500.00
2	1	Drum shaft assembly	This part is machined on a lathe with turning , drilling and tapping procedures. The rollers are also hardened.	NGN 28,500.00
3	3	2.5mm disc	This disc are drilled on a pillar drill, turned on a lathe, counter sunk and hardened.	NGN 17,500.00
4	1	Top washer	Bought over the shelf	NGN 600.00
5	1	ANSI B18.2.3.5M - M10 x 1.5 x 25	Bought over the shelf	NGN 250.00
6	1	Spinning outlet	Plasma cut, machined, welded and tapped	NGN 2,500.00
7	1	Lower body	Machined on a lathe and welded	NGN 17,000.00
8	1	Top body	Machined on a lathe	NGN 15,500.00
9	1	Bearing holder	Machined on a lathe	NGN 12,800.00
10	2	BS 290 SKF - SKF 6206-RZ	Bought over the shelf	NGN 2,000.00
11	1	Top plate	Plasma cut, and welded.	NGN 3,650.00
12	1	ELECTRIC MOTOR	Bought over the shelf	NGN 60,000.00

13	2	V-Belt	Bought over the shelf	NGN 850.00
14	1	Grooved Pulley1	Machined on a lathe	NGN 3,000.00
15	1	Grooved Pulley2	Machined on a lathe	NGN 4,250.00
16	1	Frame	Cut with a chop off saw and welded	NGN 8,950.00
17	1	Hopper	Cut out of a sheet, rolled and welded.	NGN 2,800.00
		Wiring and socket		NGN 6,250.00
		Consumable for finishing and painting		NGN 7,800.00
		Transportation of materials and machine		NGN 25,000.00
				NGN 231,700.00

Design Calculations

Hopper

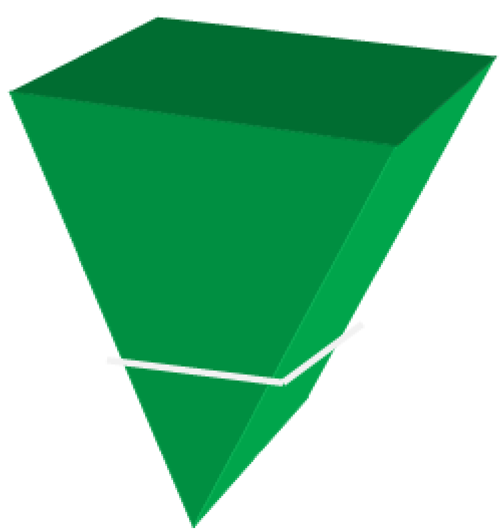


Fig A: Truncated pyramid

AB = 360mm

BC = 380mm

h = 350mm

FG = 135mm

EF = 120mm

The upper length AB of the hopper was calculated as;

/FG/: /AB/ = 1: 3

1:3 = 120 × AB

= 120 × 3

= 360mm

The height h, between the upper and the lower face of the hopper is calculated as;

Tan 680 = h/120

h = 120 × Tan 680

h = 297.010mm

h = 300mm

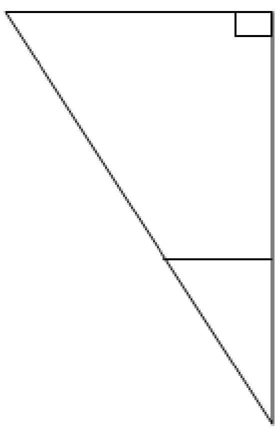


Fig.B: Sectional triangle of the hopper

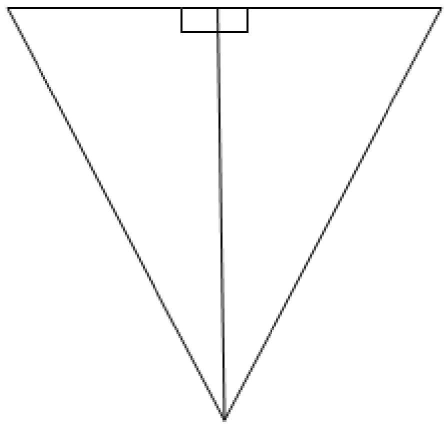


Fig C: Section of hopper plate

$H = h + H1$

$H = 300 + H1$

$FJ /DI = H1/h +H1$

$60/180 = H1/300 + H1$

$H1(180) = 60 (300 + H1)$

$180H1- 60H1 = 1800$

$H1 = 18-00/ 120$

$H1 = 150mm$

Therefore total height, $H = (300 + 150)$ mm

$H = 4$

Volume of hopper = Volume of larger pyramid – Volume of smaller pyramid

Volume of hopper = 1/3 base area × height

$= 1/3\ a2\ H – 1/3\ b2H1$ (1)

$= 1/3\ (a2H – b2H1)$

$= 1/3\ (3602 \times 450) – (1202 \times 150)$

$= 19440000 – 720000$

= 18720000mm3

= 18720000mm3

= 18.720000cm3

= 0.01872m3

Determination of the Driven Pulley Diameter

The diameter of motor is 65 mm = 6.5 cm and the motor speed chosen for electric motor is 1400 rpm.

Assuming the machine works averagely between 45% to 50% efficiency, the machine speed will be 650rpm [7].

Machine pulley diameter, D2 =?

Motor Pulley diameter, D1 = 6.5cm

Electric motor Speed, N1 = 1400 rpm

Machine speed, N2 = 650rpm

Therefore;

N1D1 = N2D2 (2)

D2 = (N1D1) / N2

= (1400 × 6.5) / 650

= 9100 / 650

D2 = 14 cm

Transmission ratio is given as D2/ D1

D2/ D1 =14/ 6.5

= 2.15

Therefore the transmission ration is calculated as;

1: 2.15

Determination of Belt Length

In determining the length of belt, the relation is given as;

Where;

$$L = 2C + 1.57\,(D + d) + \frac{(D + d)^2}{4C}$$

L = length of belt

C = centre distance between two pulleys

D = Larger pulley diameter

d = smaller puller diameter

For standard belt, Centre distance is given as 59cm = 590mm.

D = 14cm, previously calculated

d = 6.5cm, assumed

$$L = 2(59 + 1.57\,(14 + 6.5) + \frac{(14 + 6.5)^2}{4(59)}$$

$$L = 118 + 32.185 + \frac{56.25}{236} = 118 + 32.185 + 0.2383$$
$$= 150.42 \text{ cm}$$
$$= 150.42 \times 10^{-2}\text{m}$$

Shaft Design

For the rotating shaft, pure torsion is assumed. Hence, the maximum shear stress due to torsion and the angle of twist are considered.

$$P = T\omega = \frac{2\pi NT}{60}$$ (Burr, 1982; Khurmi and Gupta, 1979)

$$T = \frac{60P}{2\pi N}$$

$$T = 153.3 \text{ Nm}$$

Diameter of shaft = 0.025 m

Active length of shaft = 0.34 m

Maximum stress due to torsion is

$$\tau_{max} = \frac{Tr}{J}$$ (Burr, 1982; Khurmi and Gupta, 1979)

$$\tau_{max} = 50 \text{ MNm}^{-2}$$

Angle of twist of the shaft is

$$\theta = \frac{TL}{GJ}$$ (Burr, 1982; Khurmi and Gupta, 1979)

$$\theta = 0.92^o$$

Determination of Belt Speed

Belt speed is represented by;

Where;

$$V = \frac{\pi DN}{60}$$

V = speed of belt (m/s)

D = diameter of the smaller pulley (6.5cm = 6.5 × 10^{-2}); assumed.

N = number of revolution per minute

(Assuming the machine is to be operated at 90% maximum speed)

$$\text{Actual speed will be} = 1400 \times \frac{90}{100}$$
$$= 1260\text{rpm}$$

$$\text{Belt Speed; } V = \frac{\pi DN}{60}$$
$$V = \frac{3.142 \times 6.5 \times 1260}{60}$$
$$= 10^{-2} \times \frac{25732}{60}$$
$$= \frac{257.33}{60}$$
$$= 4.29\text{m/s}$$

Determination of Belt Tension

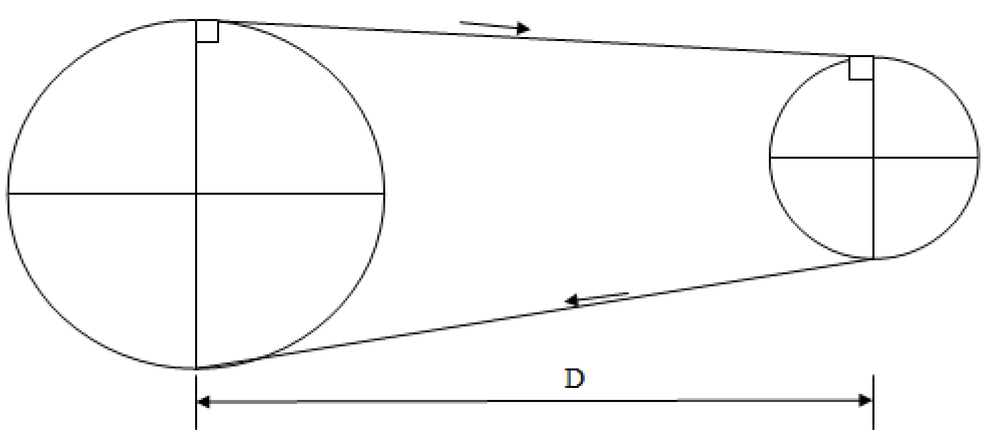


Fig D: The belt on the drive and driven pulley

Where,

T1 = Belt tension on the tight side

T2 = Belt tension on the slack side

ß = Angle of inclination of the belt

ϖß = Angle of wrap on the bigger pulley

ϖS = Angle of wrap on the smaller pulley

$\text{Sin ß} = \frac{R-r}{C}$

Where,

C = Centre distance

R = Radius of bigger pulley

$ϖS = 180^0 - 2\text{Sin}^{-1}\left(\frac{R-r}{C}\right)$

$ϖß = 180^0 + 2\text{Sin}^{-1}\left(\frac{R-r}{C}\right)$

$ϖS = 180^0 - 2\text{Sin}^{-1}\left(\frac{70-32.5}{590}\right)$

$= 180 – 7.3$

$= 172.7^0$

= 3.01 rad

$ϖß = 180^0 + 2\text{Sin}^{-1}\left(\frac{70-32.5}{590}\right)$

$= 180 + 7.3^0$

$= 187.3^0$

= 3.27 rad

For smaller pulley,

Since ϖS = 3.01 rad

Groove angle ‘θ’ = 35^0 for V-belt

Coefficient of friction ‘μ’ = 0.15

$= \frac{\ell \times \mu \times ϖ}{\frac{1}{2}\text{Sin}\,\theta}$

$= \frac{\ell \times 0.15 \times 3.01}{\frac{1}{2}\text{Sin } 35}$

$\ell^{0.15} = 4.49$

For larger pulley,

Since ϖß = 3.27 rad

Groove angle 'θ' = 350 for V-belt

Coefficient of friction 'μ' = 0.25

$$= \frac{\ell \times \mu \times \omega}{\frac{1}{2}\sin\theta}$$

$$= \frac{\ell \times 0.25 \times 3.27}{\frac{1}{2}\sin 35}$$

$$\ell^{0.25} = 15.16$$

The pulley that governs the design is the one with smallest angle of wrap [7].

$$\frac{W2}{W1} = \frac{h}{h+t}$$

Where,

W1 = Nominal top width of the belt

W2 = Nominal bottom width of the belt

t = Nominal height (thickness)

Groove angle = 35^o as earlier stated

For standard V-belt,

W1 = 3.125cm

Thickness = 1.875cm (assumed)

h = 1.5625 × 1/ (tan 17.5)

= 4.96cm

From the above equation,

$$\frac{W2}{W1} = \frac{h}{h+t}$$

W2 = W1h (h + t)

= 3.125 × 4.96 / (4.96 + 1.875)

= 15.488 / 6.831

= 2.27 cm

Area of the belt = width of the belt × thickness of the best

= 3.125 + 2.27 / (2× 1.875)

= 5.06cm2

= 5.06 × 10-4 m2

Density of rubber belt is 1250 Kg/m3 [7]

Mass of belt = Density × Area × Length

$= 1250 \times 5.06 \times 10^{-4} \times 150.42 \times 10^{-2}$

= 0.95 Kg

Belt tension can now be determined by using,

$$T_1 = \frac{MV2}{MV\,2} = \frac{\ell\mu\omega}{\sin\theta/2}$$

Where,

μ=coefficient of friction = 0.15

ωs=3.01rad

Mass per unit length $=1250x5.055x10^{-4}$

=0.63188kg/m

V= belt speed

= 4.29m/s

θ= angle of groove

$= 35^0$

T1= tension on the tight side of the belt (N)

T2= tension on the slack side of the belt (N)

Mass of belt per meter = Density x Area

$= 1250 \text{ x } 5.055\text{x } 10^{-4}$

= 0.63188kg/m

$$T_1 - \frac{MV2}{T2} - MV^2 \quad = \frac{\ell\mu\omega}{\sin\theta/2}$$

Recall

$$T_1 - \frac{0.63188 \text{ x } (4.29)\ 2}{T\,2} - 0.63188 \text{ x } (4.29)^2 = \frac{\ell 0.15\text{x}3.01}{\sin 1/2\ (35)}$$

$$T_1 - \frac{11.63}{T2} - 11.3 \quad = 4.49$$

$$4.49(T_2 - 11.3) = T_1 - 11.63$$

$$4.49(T_2 - 11.3) + 11.63 = T_1$$

$$4.49T_2 - 52.22 + 11.63 = T_1 \quad \text{.................................(i)}$$

Note, Power transmitted by motor, P is given as

P = (T1 – T2) V

For 5.5hp motor power transmitted will be 4.29kw

Since 1hp = 745.699872w

1hp = 0.74569kw

5.5hp = (0.74569 x 5.5) kW

= 4.29

4.29 = (T1 – T2)4.29

(4.29 x 1000) w = (T1 – T2)4.29

4290 = (T1 – T2)4.29

(T1 – T2) = 4290/4.29

T1 – T2 = 1000

T1 = 1000 + T2 ……………………………………(ii)

Putting Equation (ii) in (i) above

4.49T2 – 52.22 +11.63 =1000 T2

4.49T2 – 40.59 = 1000 + T2

4.49T2 – T2 – 40.59 = 1000

3.49T2 – 40.59 =1000

3.49T2 = 1000 + 40.59

= 1040.59

T2 = 1040.59

3.49

T2 = 298.16N

From equation (ii)

T1 = 1000 + T2

= 1000 + 298.16

= 1298.16N

Resultant belt tension; T1 + T2

= 1298.16 + 298.16

The resultant torque T, is given as

T = (T1 – T2) rp

Where rp is the radius of the bigger pulley (m)

$T = (1298.16 + 298.16)\ 7 \times 10^{-2}$

T = (1298.16 + 298.16) 0.07

T = 36.7 Nm

<u>Design Process/ Manufacturing</u>

Main Shaft	This part is machined on a lathe with turning , drilling and tapping procedures
Drum shaft assembly	This part is machined on a lathe with turning , drilling and tapping procedures. The rollers are also hardened.
2.5mm disc	This disc are drilled on a pillar drill, turned on a lathe, counter sunk and hardened.
Top washer	Bought over the shelf
ANSI B18.2.3.5M - M10 x 1.5 x 25	Bought over the shelf
Spinning outlet	Plasma cut, machined, welded and tapped
Lower body	Machined on a lathe and welded
Top body	Machined on a lathe
Bearing holder	Machined on a lathe
BS 290 SKF - SKF 6206-RZ	Bought over the shelf
Top plate	Plasma cut, and welded.
ELECTRIC MOTOR	Bought over the shelf
V-Belt	Bought over the shelf
Grooved Pulley1	Machined on a lathe
Grooved Pulley2	Machined on a lathe
Frame	Cut with a chop off saw and welded
Hopper	Cut out of a sheet, rolled and welded.