DHANALAKSHMI COLLEGE OF ENGINEERING

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DEPARTMENT OF MECHANICAL ENGINEERING

III YEAR MECHANICAL - VI SEMESTER

ME 6601 – DESIGN OF TRANSMISSION SYSTEMS

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UNIT - I
STUDY NOTES

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UNIT - I

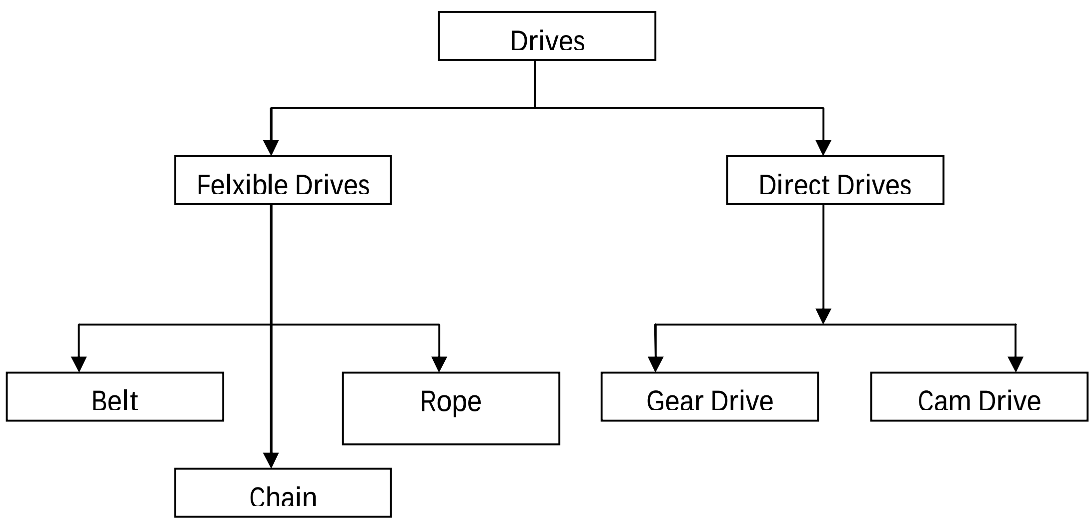
DESIGN OF TRANSMISSION SYSTEMS FOR FLEXIBLE ELEMENTS

Selection of V Belts and Pulleys – Selection of Flat belts and Pulleys –Wire ropes and pulleys – Selection of Transmission chains and Sprockets. Design of pulleys and sprockets.

Introduction

To transmit power, flexible elements such as belts chains and ropes are frequently used. Pullerys are mounted on a shaft and a continuous belt or rope is passed over them. In belt and ropes, power is transmitted due to friction between them and pulleys. In case of chain drives, sprocket wheels are used.

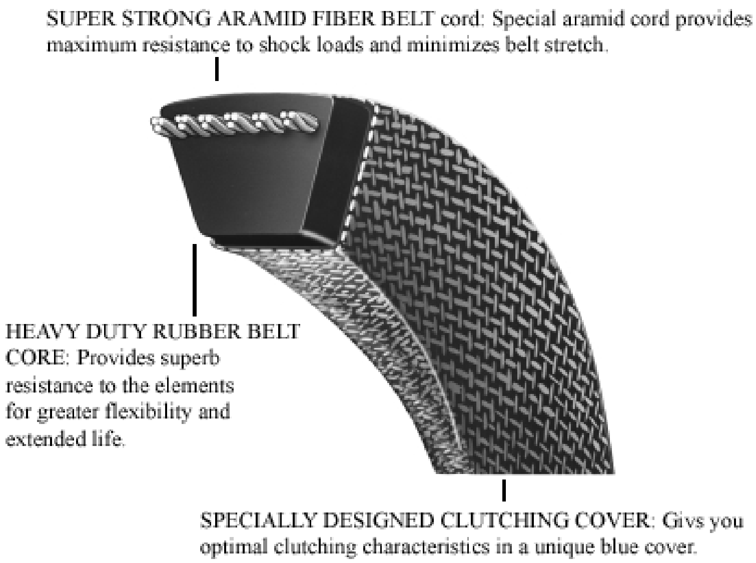
Classification of Drives



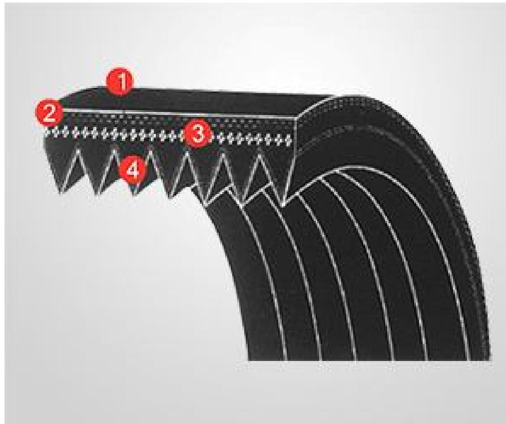
Types of Belts

1. Flat Belts
2. V – Belts
3. Ribbed Belts
4. Toothed or timing belts

FLAT BELTS



V-BELTS



RIBBED BELTS

TOOTHED OR TIMING BELTS

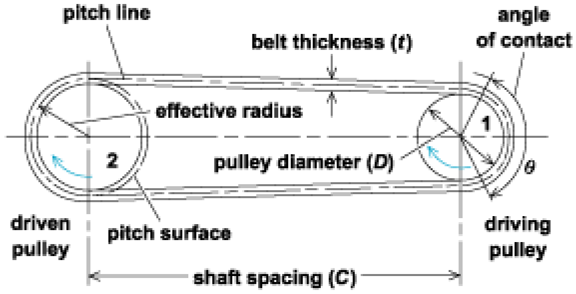
Selection of Flat Belt Drive

It depends on

- Power to be Transmitted
- Speed of Driver and Driven Shafts
- Shaft relationship
- Service conditions
- Speed reduction ratio
- Centre distance
- Positive drive requirement
- Space available

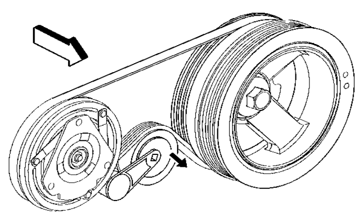
Types of Flat Belt Drives

1. **Open Belt Drive**



Used with shafts arranged parallel and rotating in same directions

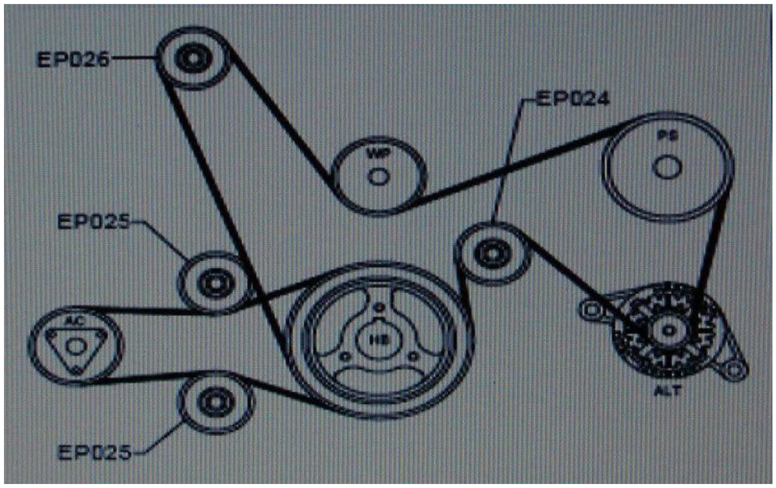
2. **Open Belt Drive with One Idler Pulley**



Used with shafts arranged parallel and when an open belt drive cannot be used due to small angle of contact on the smaller pulley.

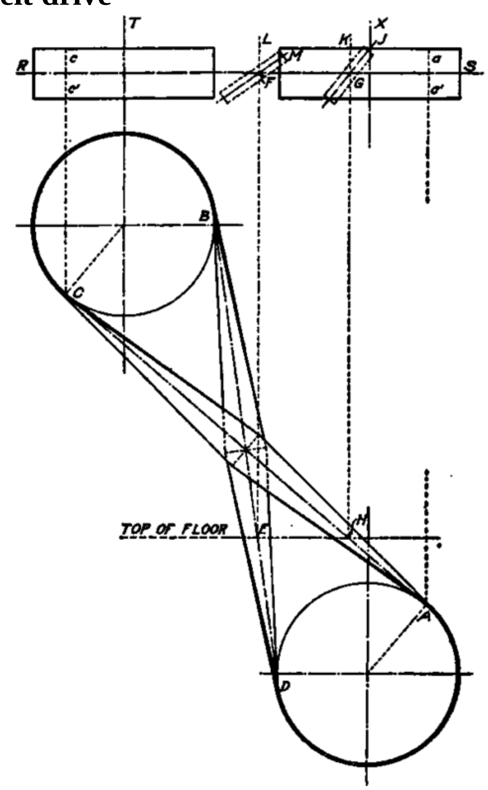
Idler pulleys also known as jockey pulleys are provided to obtain high velocity ratio and when the required belt tension can not be obtained by other means.

3. **Open belt drive with many idler pulley**



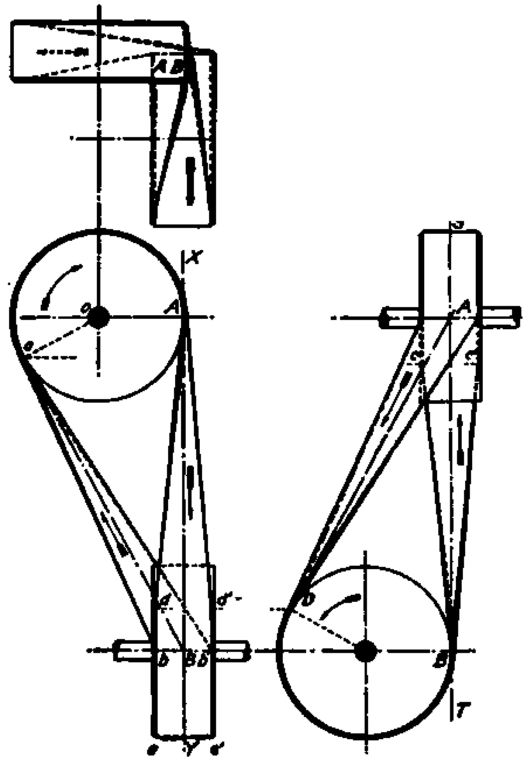
Used when it is desired to transmit motion from one shaft to several parallel shafts

4. Crossed or twisted belt drive



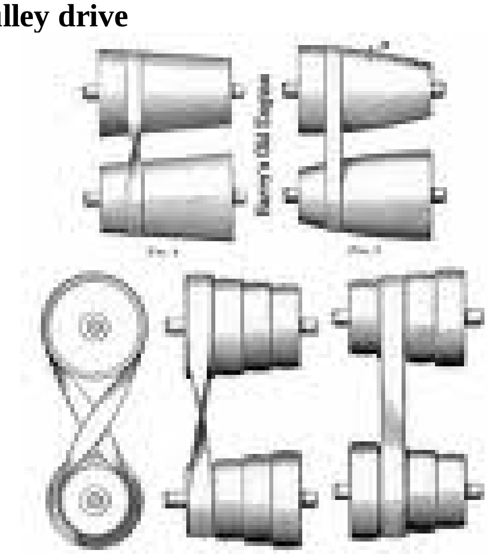
Used with shafts arranged parallel and rotating in the opposite directions.

5. **Quarted twist or Quarter turn drive**



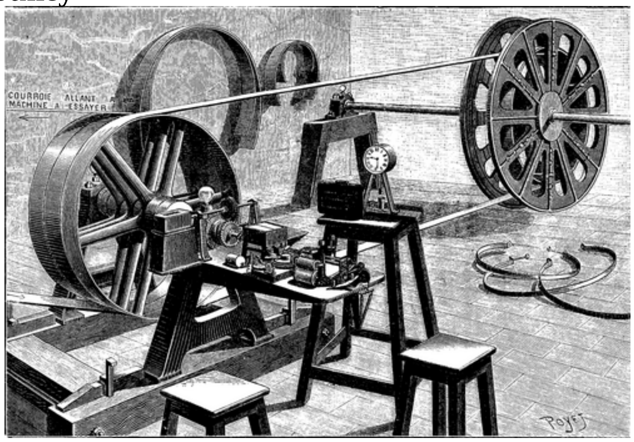
Used with shafts arranged at right angles and rotating in one definite directions

6. **Stepped or Cone pulley drive**



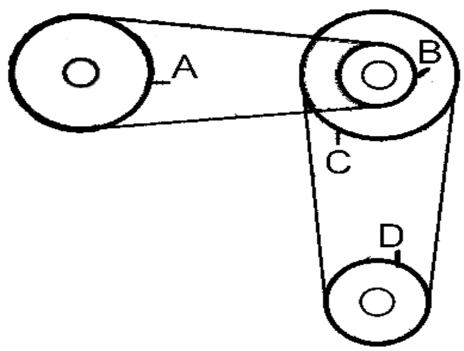
Used for changing the speed of the driven shaft while the main or driving shaft runs at constant speed.

7. **Fast and loose pulley**



Used when the driven shaft is to be started or stopped whenever desired without interfering with the driving shaft.

8. **Compound drive**



Used when several units are to be driven from one central shaft.

Belt Materials

The desirable properties of belt materials are

- High C.O.F
- Flexibility
- Durability
- Strength

1. Leather Belts

- made of animal hides
- Leathers for belting may be tanned with oak, or chrome salts.
- Oak tanned belt is fairly stiff
- Chrome tanned leather is soft and pliable

Belts specified according to number of layers as single ply, double ply or triple ply belts. Double belts or triple belts are made by cementing two or three strips together with hair sides outside.

2. Fabric & Cotton Belts

Obtained by stitching two or more plies of canvas or cotton duck. Treated with linseed oil to make it water proof. These belts are cheap and most suitable for farmwork, quarry and saw mills.

3. Rubber Belts

- These belts are made up of plies of fabric impregnated with vulcanized rubber or synthetic rubber.
- Easily made endless.
- Saw mills, creameries, chemical plants and paper mills largely use rubber belts

4. Balata Belts

Balata is gum similar to rubber. Balata belts are made in the same manner as the rubber belts made. They are acid proof and water proof. These belts cannot be used at temperatures above 40°C, because at this temperature it softens and became sticky.

5. Nylon Core Belts
6. Camel's Hair belts

Velocity ratio of belt drive

The ratio between the speeds of the driver and driven respectively.

Velocity ratio = $N_2/N_1 = \omega_2/\omega_1 = D/d$

Where D & d = diameter of driver and driven respectively

N_2 & N_1 = Speed of driven & driver respectively

ω_2 & ω_1 = Angular velocities of driven & driver respectively

Effect of belt thickness on velocity ratio

Considering the thickness of belt (t)

$N_2/N_1 = (D + t)/(d + t)$

Effect of slip on velocity ratio

Slip is defined as the relative motion between the belt and pulley.

The difference between the linear speed of the pulley rim and belt is the measure of slip.

The reason is, there is a tendency for the belt to carry with it on the underside between the pulley and the belt. The frictional grip between the pulley and the grip is insufficient.

The slip reduces the velocity ratio of the drive.

Slip can be reduced BY

- Roughening the belt by dressing
- By crowning the pulley

Let S_1 = Percentage slip between the driver and the belt.

S_2 = Percentage slip between the driven and the belt.

S = Total percentage slip = $S_1 + S_2$

Velocity ratio = N_2/N_1 = $D/d\ [1 - ((S_1 + S_2)/100)] = D/d\ [1 - (S/100)]$

If thickness of the belt (t) is considered, then

Velocity ratio = N_2/N_1 = $(D+t)/(d+t)\ [1 - ((S_1 + S_2)/100)]$

= $(D+t)/(d+t)\ [1 - (S/100)]$

Effect of creep on belt

Let σ_1 = stresses in the belt on tight side

σ_2 = stresses in the slack side

E = Young's modulus of belt material

Velocity ratio = N_2/N_1 = $(D)/(d)\ [[E + \sqrt{\sigma_1}\ ]/[E + \sqrt{\sigma_2}\ ]]$

Law of Belting

Lawof belting states that, the centre line of the belt, as it approaches the pulley, must lie in a plane perpendicular to the axis of that pulley or must lie in the plane of the pulley. Otherwise the belt will run off the pulley

Power Transmitted by the belt

$P = (T_1 - T_2)$ v watts

Where T_1 = tension in the tight side.

T_2 = tension in the slack side.

V = linear velocity of the belt in m/s

Centrifugal Tension (T_c)

As the belt moves round the pulley it would experience a centrifugal force which has the tendency to separate the belt from the pulley surface.

To maintain the contact between pulley and belt, the centrifugal force produce additional tension in the belt, this is known as the centrifugal tension.

T_c = waste load, increases the tension without increasing power capacity.

$\mathbf{T_c} = mV^2$

m = mass / unit length (Kg/m)

V = linear velocity (m/s)

Initial tension

$\mathbf{T_o = [T_1 + T_2]/2}$ **[neglecting centrifugal tension]**

$\mathbf{T_o = [T_1 + T_2 + 2T_c]/2}$ **[considering centrifugal tension]**

Maximum tension when the belt subjected to centrifugal tension

$T = \mathbf{T_1 + T_c}$

T = maximum stress X cross sectional area of the belt

= σ b t

σ = maximum stress in N/m²

b = width in m

t = thickness in m

When Centrifugal tension taken for consideration

Tension in tight side is $T_{t1} = T_1 + T_c$

Tension in tight side is $T_{t2} = T_2 + T_c$

Then Power Transmitted by the belt

$P = (T_{t1} - T_{t2})\ V$ watt

After simplification $P = (T_1 - T_2)\ V$ watt

It shows centrifugal tension doesn't have any effect on power transmission.

Ratio of driving tensions of flat belt drive.

$T_1/T_2 = e^{\mu\alpha}$

Considering centrifugal tension

Tension ratio = $T_{t1}/T_{t2} = (T_1 - mV^2)/(T_2 - mV^2) = e^{\mu\alpha}$

Where

μ = coefficient of friction between belt and pulley

α = angle of contact or angle of wrap

Condition for Maximum power transmission

The power transmitted is maximum when the centrifugal tension T_c is one third of the maximum tension (T).

(i.e) $T = 3\ T_c$

Maximum velocity $V = \sqrt{(T/3m)}$

Stresses in belt

1) **Due to maximum working tension**
   σ_t = Tight side tension/cross section area. = T_1 / (bxt)

2) **Due to bending**
   $\sigma_b = (E \times t)/d$.

3) **Due to centrifugal force**
   $\sigma_c = T_c / (bxt) = mv^2/(bxt) = \rho v^2$

   since $\rho = m/(bxt)$

4) **Maximum stress in tight side of smaller pulley**
   $\sigma_{max} = \sigma_t + \sigma_b + \sigma_c$

Design Procedure for flat belt drive using Manufactures Catalogue

Step 1 From the given data determine the design power using the following procedure

a. From the center distance and dia of pulley find speed ration (I) XI $\underline{+}$ i = dia of larger pulley / dia of smaller pulley.

$$i = \frac{\text{Speed of smaller pulley}}{\text{Speed of larger pulley}}$$

b. Calculate the velocity using the formula
$V = \pi dn / 60$ or $\pi DN / 60$

c. Determine the arc of contact from page 7.5A of data book and select the rating of the belt at 10 m/s and 180^o

d. Determine the power rating for the belt for the actual velocity and the actual arc of contact.

e. Fix the number of plies and calculate the rating of the belt.

f. Calculate the design power using the formula
Design power= Rated Power x K_s / K_c

Step 2 Determine the width of the belt using the formula width

$$\text{Width} = \frac{\text{Design power}}{\text{Load Rating}} \text{ and standardize it}$$

Step 3 Calculate the pulley width and length of the belt

Step 4 Write the specification

Step 5 Do the pulley design, Calculate the dia of pulley, width of the pulley and thickness of the pulley in from page No. 7.57

Step 6 Draw the neat diagram of pulley with dimensions.

PART – A

1. **How is V-belt specified?** **(M/J 2012)**

   V-belts are specified by its type and nominal inside length.

2. **Give the relationship of ratio of tensions in a V-belt drive.** **(A/M 2008)**

   $$\frac{T_1}{T_2} = e^{\mu\alpha . cosec\,\beta}$$

   Where T_1&T_2 = tensions in the tight and slack tensions respectively,

   2β = angle of groove, and

   μ = Co-efficient of friction between belt and sides of the grooves

3. **Define – maximum tension in a belt.** **(A/M 2008)**

   Maximum tension in a belt = Tension on tight side of the belt + Centrifugal tension.

4. **What are the five parts of roller chain?** **(A/M 2010)**

   i. Pin link or coupling link
   ii. Roller link
   iii. Pins
   iv. Bushes &
   v. Roller.

5. **Distinguish between open drive and cross drive of a belt drive.** **(A/M 2011)**

   Open Belt drive: Used with shafts arranged parallel and rotating in same direction.

   Cross Belt drive: Used with shafts arranged parallel and rotating in opposite direction.

6. **Give any three applications of chain drive. What are their limitations?** **(A/M 2011)**

   Chain drives are widely used in transportation industry, agricultural industry, metal and wood working machines.

   Limitations: Chain drives cannot be used for velocity ratio more than 10.

7. Mention the materials used for making belts. **(N/D 2011) (M/J 2013)**

i. Leather
ii. Fabric and cotton
iii. Rubber
iv. Balata and
v. Nylon

8. Give the advantages of chain drives over belt drives. **(M/J 2012)**

i. Chain drives can be used for long as well as short Centre distances.
ii. They are more compact than belt drive.
iii. There is no slip between chain and sprocket. So they provide positive drive.

9. Explain the term "crowing of pulley". **(M/J 2011)**

The pulley rims are tapered slightly towards the edges. This slight convexity is known as Crowning.

10. In what way silent chain is better than ordinary driving chain? **(M/J 2011)**

Silent chains are preferred for high-power, high-speed, and smooth operation.

PART - B

Problem 1

Design a flat belt to transmit 12 kw at 450 rpm for an engine to a shaft running at 1200 rpm the dia of engine pulley is 600 mm and centre distance 2 m

Given data

P = 12 kw

N = 450 rpm

n = 1200 rpm

D = 600 mm

CD = 2 m

Step 1: i

a. Speed ratio $i = \frac{n}{N} = \frac{1200}{450} = 2.667$

i = 2.667

$$i = \frac{D}{d} = 2.667 = \frac{600}{d}$$

d = 225 m

b. Velocity

$$V = \frac{\pi dn}{60} = \frac{\pi \times .225 \times 1200}{60} = 14.137 \text{ m/s}$$

V = 14.137 m/s

C. Arc of Contact 7.54(PSG Data Book)

$$\text{Arc of Contact } Q = 180 - \frac{D-d}{C} \times 60$$

$$= 180 - \frac{0.600 - 0.225}{2} \times 60$$

Arc of Contact Q = 168.75^{o}

Selecting high speed belt load rating of belt at 180^{o} and 10 m/s

Load rating at 180^{o} & 10 m/ac = 0.023 kw / mm / ply

d. Load rating at 168.75 arc of contact & V = 14.37 M/sec.

$$= 0.023 \times \frac{14.137}{10} \times \frac{168.78}{180}$$

Load Rating = 0.03048 kw/mm/ply

Step 1: i

a. Speed ratio $i = \dfrac{n}{N} = \dfrac{1200}{450} = 2.667$

i = 2.667

<u>Problem 2</u>

In electric motor drives the exhaust fan using flat belt design the belt drive as per the following specification a center distance between the pulley is 2.5 m. The permissible stress on the belt is 2.5 n/mm^2 the thickness of the belt is 5 mm and its able to transmit 22.5 kw check the width of the belt using standard formula .

Diameter (mm)	Driver (Motor Pulley)	Driven (Fan pulley)
θ (rod)	400	1600
μ	0.3	0.25
Speed (rpm)	700	?

Given

P = 225 kw

d = 400 rpm

D = 1600 mm

CD = 2.5 m

Step 1:

a. Speed ratio $i = \dfrac{D}{d} = \dfrac{1600}{400} = 4$

i = 4

$$i = \frac{n}{N} = \frac{700}{4} = 175 \text{ rpm}$$

2. Calculation of belt speed

$$V = \frac{\pi dn}{60} = \frac{\pi \times 0.4 \times 700}{60} = 14.66 \text{ m/s}$$

V = 14.66 m/s

C. Arc of Contact

$$\text{Arc of Contact } Q = 180 - \frac{D-d}{C} \times 60$$

$$= 180 - \frac{1.600 - 0.400}{2} \times 60$$

Arc of Contact Q = 151.2^{o}

Selecting high speed belt load rating of belt at 180^{o} and 10 m/s

0.023 kw / mm / ply

Load rating at 208.8^{o} arc of contact & Velocity = 14.66 m/sec.

$$= 0.023 \times \frac{14.66}{10} \times \frac{151.2}{180}$$

No. of plies = 8

Load Rating = 0.028 x 8 = 0.224 kw/mm

Design Power = Fatal Power x k_s / k_c

k_s = 1

k_c = 1.08

= 22.5 x 1 / 1.08 = 20.83 μv

Width = 20.83 / 0.224 = 93mm

Width = 200 mm

Pulley width = belt width + 25

= 200 + 25 = 225 mm

Length belt

$$L = 2c + \frac{\pi}{2}(D+d) + \frac{(D-d)^2}{4c}$$

$$L = 5 + \frac{\pi}{2}(2) + \frac{(1.5)^2}{10}$$

= 829m

The obtain initial tension 0.5 % of belt length should be shorten

Actual Length = (99.5 / 100) x c = 0.995 x 8.29 = 8.24 m

Specification

Belt width = 200 mm

No.of plies = 8

Width of pulley = 225 mm

Length of pulley = 8.24 mm

(a) No.of arm = 4 for driven pulley

= 6 for driver pulley

(b) U/s of arm elliptical

Thickness of arm near boss = $2.94 \sqrt{aD / 4n}$

Driver pulley = $2.94 \sqrt[3]{(22.5 \times 1600)/(4x6)}$

= 12.5 mm

Driven pulley = $2.94 \sqrt[3]{225 \times 400 / 24} = 45.68$ m

Thickness of arm near boss = 2/3 x breath of boss

Driver pulley = 2/3 x 72.5

= 48.33 mm

Driven pulley = 2/3 x 45.68 = 30.45 mm

Radius of C/s of arm = ¾ D

Driver pulley = (3 / 4) x 45.68

= 34.26 mm

Min Length of the bore l = (2/3) x a

= 2/3 x 225 = 150mm

Thickness of boss = $0.41^2 \sqrt{aD + 6}$

Driver pulley = $0.41^2 \sqrt{225 \times 1600 + 6}$

= 35.31 mm

Driven pulley = $0.41^2 \sqrt{225 \times 400 + 6}$

= 24.46 mm

Power $(T_1-T_2)V$

T_1-T_2 = $(22.5 \times 10)^3 / 14.60$

= 1534.78

T_1/T_2 = $e^{\mu\theta}$ = $e^{0.32 \times 2.5}$

T_1 = $2.11T_2$

$T_2 1.117$ = 1534.78

T_2 = 134.04

T_1 = 2908.79

Max Tension T = 8n σ t

T= $T_1 + T_C$

T = T_1

2908.79 = 86 x 2.3 x 5

b = 252.9 mm

b = 253mm

Selecting high speed belt load rating of belt at 180^o and 10m/s

Load rating at 180^o d 10 /m/sc = 0.023kw/mm/pl

d. Load rating at 157.5^o arc of contact V = 18.849 m/s

$$= 0.023 \times \frac{18.649}{10} \times \frac{157.5}{180}$$

Load Rating = 0.0379 kw/mm/ply

e. No. of plies 7.52

The minimum pulley dia is 250 mm and velocity is 18.849 m/s

No. of plies = 5

Load rating = 0.0379 x 5

= 0.1895 kw/mm

g. Design Power

Design Power = Fatal Power x k_s / k_c

k_s = 1

k_c = 1.08

Design Power = 10 x 1 / 1.08 = 9.26 kw

Problem 3

Design a flat belt drive for a tan running at 360 rpm which is driven by 10kw, 1440 rpm belt drive is open type when the space available for centre distance 2m approximately diameter of driven pulley is 1000 mm.

Given

n = 1440 rpm

N = 360 rpm

P = 10 kw

c = 2 m

CD = 1000 mm

Solution

1. Calculation of Pulley dia

$$\frac{D}{d} = \frac{n}{N}$$

$$d = \frac{1000}{4} = 250\text{mm}$$

2. Calculation of belt speed

$$V = \frac{\pi dn}{60} = \frac{\pi \times 1000 \times 360}{60} = 18.849 \text{ m/s}$$

3. Arc of Contact

$$\text{Arc of Contact } Q = 180^o - \frac{D-d}{C} \times 60^o$$

Arc of Contact Q = 157.5^o

4. Selecting high speed belt load rating of belt at 180^o and 10 m/s

= 0.023 kw / mm / ply

5. Load rating at 157.5^o a& 18.849 M/s

$$= 0.023 \times \frac{18.849}{10} \times \frac{157.5}{180}$$

= 0.0379 kw/mm/ply

No. of plies = 5 (for d = 250 mm, V = 18.849)

Load Rating = 0.0379 x 5 = 0.1896 kw/mm

Design Power = Fatal Power x k_s / k_c

= 10 x 1.2 / 1.08 = 11.11

Width of belt = Design Power / Load rating

= 11.11 / 0.1896

Width of belt = 58.60 mm

Pulley width = belt width + 13

= 76 + 13 = 89 mm

Calculate open belt length

$$L = 2c + \frac{\pi}{2}(D+d) + \frac{(D-d)^2}{4c}$$

$$L = 2x2 + \frac{\pi}{2}(1+0.25) + \frac{(1-0.25)^2}{4\ x2}$$

L = 6.033m

Initial tension

Actual Length reduced = (6.033×10^3) 1 / 100)

= 60.33 mm

Actual Length = $6.033 \times 10^3 - 60.31$

= 5972.96 mm

Specification

Belt Speed = 18.849 M/s

Actual Length Belt = 5972.96 mm

Pulley width = 89 mm

Pulley Design

Selecting CI Pulley

Driver Pulley = 4 arms

Driven Pulley = 9 arms

C/s of arm is elliptical

Thickness of arm b = $2.94 \sqrt[3]{aD / 4n}$

Driver pulley = $2.94 \sqrt[3]{(89 \times 1000)/(4 \times 6)}$

= 45.506 mm

Thickness of arm b, near arm

= 2/3 x 45.506

= 30.33

Radius of C/s of arm r = ¾ b

r = (3 / 4) x 45

= 33.75 mm

Problem 4

Design a flat belt to transmit 12 kw 450 rpm for an engine to a shaft running at 1200 rpm the dia of engine pulley is 600 mm centre distance is 2 m given

P	=	12kw		
Engine Speed	=	450 rpm	=	N
Shaft Speed	=	1200 rpm	=	n
Engine pulley dia	=	600 mm	=	D
CD	=	2 m		

Calculate the speed ratio

$$i = \frac{n}{N} = \frac{1200}{450}\ 2.607$$

$$i = \frac{D}{d} = d = \frac{600}{2.667}$$

d = 225 mm

2. Calculation of belt speed

$$V = \frac{\pi dn}{60} = \frac{\pi x600x450x10^{-3}}{60} = 14.137 \text{ m/s}$$

3. Arc of Contact

$$\text{Arc of Contact } Q = 180^o - \frac{D-d}{C} \, x60^o$$

$$\text{Arc of Contact } Q = 180^o - \frac{600-225}{C} \quad x60^o$$

Arc of Contact Q = 108.75^o

4. Selecting high speed belt load rating of belt at 180^o and 10 m/s

= 0.023 kw / mm / ply 7.54(PSG Data Book)

5. Load rating at 108.75^o a& 14.137 M/s

$$= 0.023 \times \frac{14.137}{10} \times \frac{168.75}{180}$$

= 0.0304 kw/mm/ply

No. of plies = 5 (for d = 22.5 mm, V = 14.137 m/s)

Load Rating = 0.0304 x 5 = 0.1520 kw/mm

Design Power = Fatal Power x k_s / k_c

k_s = Service Load Correction factor

k_s = 1 (Assume Normal load)

k_c = 1.04

Design Power = 12 x 1 / 1.04 = 11.538 kw

Width of belt = Design Power / Load rating

= 11.538 / 0.1525

Width of belt = 75.66 mm 7.52 (PSG Data Book)

Pulley width = belt width + 13mm 7.54(PSG Data Book)

= 76 + 13 = 89 mm

Length of the Belt (Assume Open Belt) **7.53**(PSG Data Book)

$$L = 2c + \frac{\pi}{2}(D+d) + \frac{(D-d)^2}{4c}$$

$$L = 2 \times 2000 + \frac{\pi}{2}(600+225) + \frac{(1600-225)^2}{4 \times 2000}$$

$$L = 5.313 \times 10^3 mm$$

To give Initial tension to the belt the length is reduced by one percentage

Length reduced = (5313) x (1 / 100)

= 53.13 mm

Actual Length of the belt = 5313

= 5.2598 m

Specification

Width of the belt = 76 mm

No of plies = 5

Length of the Belt = 5.2598 m

Pulley width = 89 mm

Pulley Design

Selecting CI Pulley 7.56(PSG Data Book)

Driver Pulley = 6 arms

Driven Pulley = 4 arms

b. Cross section s of arm is elliptical

c. Thickness of arm b = $2.94 \sqrt[3]{aD / 4n}$

Driver pulley = $2.94 \sqrt[3]{(89 \times 600)/(4x6)}$

= 38.38 mm

b = $2.94 \sqrt[3]{aD / 4n}$

Driver pulley = $2.94 \sqrt{(89 \times 225)/(4 \times 6)}$

= 31.68 mm

Thickness of arm b, near arm

b_1 = 2/3 x 38.38 (for driver)

= 25.58 mm

b_2 = 2/3 x 31.68 (for driven)

= 21.12 mm

Radius of C/s of arm r = ¾ b

r = (3 / 4) x 38.38

= 28.785 mm (for driver)

r = (3 / 4) x 31.68

= 23.76 mm (for driven)

Minimum Length of bore

l = 2/3 x a

= (2 / 3) x 89

= 59.333 mm

(f) $(d_1 - d_2) / 2$ = $0.412 \sqrt[3]{aD} + 6$

= 15.515 (driver)

Driver pulley = $0.412 \sqrt[3]{(a \times d)} + 6$

= $0.412 \sqrt[3]{89 \times 225} + 6$

=17.188 mm (for driven)

Problem 5

A Stone crushing machine receives power from motor rated at 50 kw at 1800 rpm by means of a flat belt pulley dia are 200 mm and 700 mm distance between pulley is 4 m design the belt drive the direction or rotation of 2 pulley opposite to each other.

Given

P	=	50 kw
C.D.	=	4 m
D	=	700 mm
d	=	200 mm
n	=	1800 rpm

1. Calculate the speed ratio

$$i = \frac{D}{d} = \frac{700}{200} \; 3.5$$

2. Calculation of belt speed

$$V = \frac{\pi dn}{60} = \frac{\pi x200x1800x10^{-3}}{60} = 18.849 \text{ m/s}$$

3. Arc of Contact

$$\text{Arc of Contact } Q = 180^o - \frac{D-d}{C} x60^o$$

$$i = \frac{n}{N} = 3.5$$

7.54

$$N = \frac{1800}{} = 514.285 \text{ rpm}$$

$$\overline{\quad 3.5 \quad}$$

$$Q = 180^o - \frac{700-200}{4000} \times 60^o$$

Arc of Contact $Q = 172.5^o$

4. Selecting high speed belt load rating of belt at 180^o and 10 m/s

= 0.023 kw / mm / ply

5. Load rating at 172.5^o a& 18.849 M/s 7.53

$$= 0.023 \times \frac{18.849}{10} \times \frac{172.5}{180}$$

= 0.0415 kw/mm/ply

V-BELTS AND PULLEYS

v-belts are used with electric motors to drive blowers, compressors, appliances (like mixer, grinder, etc.0, machine tools (like lathe, drilling machine, etc), farm and industrial machinery, and so on. V-belts are endless and run in grooved pulleys.

V-belts are made in trapezoidal section. The power is transmitted by the wedging action between the belt and the V-groove in the pulley or sheave.

MATERIALS OF V-BELTS

V-belts are made of cotton fabric and cords moulded in rubber and covered with fabric and rubber.

ADVANTAGES

- Power transmitted is more due to wedging action in the grooved pulley.
- V-belt is more compact, quiet and shock absorbing.
- Higher velocity ratio(upto 10)can be obtained.

DISADVANTAGES

- It cannot be used with large centre distances.
- It cannot be used for large power.
- The efficiency of the V-belt is lower than hat of the flat belt.

TYPES OF V-BELTS

According to Bureau of Indian standards (IS :2494-1974), the V-belts are classified as A,B,C,D and Etype (based on the cross-section of V-belts).

SPECIFICATIONS OF V-BELTS

V-belts are designated by its type and nominal inside length. For example, a C2845 belts has a cross-section of type C and has a nominal inside length of 2845mm.

DESIGN OF V-BELT DRIVE

Design procedure:

1.**Selection of belt section:**

select the cross-section of a belt depending on the power to be transmitted.(Refer data book page no: 7.58).

2.**Selection of pulley diameters(d and D):**

Select small pulley diameter(d) from the data book . Then using the speed ratio, calculate the pulley diameter (D). These pulley pulley diameters should be rounded off to a standard diameter. (Refer data book page no: 7.58).

3.**Selection of centre distance (C) :**

Select the centre distance, if not given, from the data book. (Refer data book page no: 7.61).

4.**Determination of norminal pitch length** :

determine the length of the belt L by using the formula

$$L= 2C + (\pi / 2) (D+d) + (D+d)^2 / 4C$$

5. **Selection of various modification factors;**

In order to calculate the design power, the following modification factors have to determined.

- **Length correction factor (Fc);**

  For the selected belt cross section, choose length correction factor from the data book. referring data book page no 7.58,7.59,7.60.

- **Correction factor for arc of contact (Fd);**

  First determine the arc of contact of the smaller pulley.

  $$\text{Arc of contact} = 180° - (D-d)/ C \times 60°$$

  For calculated the arc of contact, select the correction factor from the data book. consulting the data book page no 7.68

- **Service factor (Fd);**

  Select the service factor from the data book page no 7.69.

6.Calculation of maximum power capacity;

Calculate the maximum power capacity (in kw) of a V – belt using the formulas given the data book page no 7.62.

7. **Determination of number of belts (n_b);**

$n_b = P \times Fa / k W \times Fc \times Fd$ (data book page no.7.70)

where

P = Drive power in Kw

Fa = Service factor for V-Belts

Kw = Rated power

Fc = Length correction factor

Fd = Correction factor for arc of contact.

8. calculation of actual centre distance;

$C_{actual} = A + \sqrt{A^2 - B}$ (data book page no 7.61)

$A = L/4 - \pi (D+d /8)$

$B = (D-d)^2 / 8$

L = Nominal pitch length of the belt.

PROBLEM – 1:

Desisgn a V- belt drive to the following specifications:

Power to be transmitted = 7.5 kW

Speed of driving wheel = 1440 rpm

Speed of driven wheel = 400 rpm

Diameter of driving wheel = 300 mm

Centre distance = 1000mm

Service = 16 hours/ day.

Given data:

P= 7.5 kW

N1 =1440 rpm

N2 = 400 rpm

d = 300 mm = 0.3 m

C = 1000mm = 1m.

To Find:

Design a V- belt drive.

Solution :

1. Selection of the belt section :

Consulting the data book page no 7.58 for power 7.5 kW, B section is selected.

2.. Selection of pulley diameters (d and D):

Speed ratio = D/ d = N1/ N2 = 1440/ 400 = 3.6.

Small pulley diameter, d = 300mm.

Refer data book, preferred smaller pulley diameter, d = 315mm

Larger pulley diameter, D = 3.6 d = 3.6 × 315 = 1134mm.

Refer data book, preferred larger pulley diameter, D = 1250 mm.

3. Selection of centre distance(c) :

Centre distance, C= 1000 mm.

4. Determination of nominal pitch length:

Nominal inside length, $L = 2C+(\pi/2)(D+d)+(D-d)^2/4C$

$= 2\times1000+(\pi/2)(1250+315)+(1250-315)^2/4\times1000$

$= 4676.85$ mm.

For this nominal inside length and Bsection, consulting the data book and then take the nominal pitch length is selected as 4615mm.

5.Selection of various modification factors:

- **Length correction factor (Fc):**

For B section, referring data book page no 7.58,7.59,7.60.

Length correction factor, Fc= 1.14.

- **Correction factor for arc of contact (Fd):**

Arc of contact = $180° - (D-d)/C \times 60°$

$= 180° - (1250-315/1000) \times 60°$

$= 123.9°$

For this arc of contact, consulting the data book page no 7.68, correction factor for arc of contact is selected as Fd = 0.83.

- **Service factor(Fd):**

Consulting the data book page no 7.69, for lightduty 16 hours continuous service, for driving machinesof typeII, service factor is selected as Fa = 1.3.

6. Calculation of maximum power capacity:

Consulting the data book page no 7.62 for B section, power capacity formula is given as

$$kW = (0.79\,S^{-0.09} - 50.8/d_e - 1.32\times10^{-4}S^2)\,S$$

$S = \pi dN1/60 = \pi\times0.315\times1440/60 = 23.75$ m/s.

$d_e = dp\times f_b = 315\times1.14 = 359.1$mm.

But from the data book page no 7.62 maximum value of d_e in the formula should be 175mm.

$kW = (0.79\times23.75^{-0.09} - 50.8/175 - 1.32\times10^{-4}23.75^2)\ 23.75$

$= 5.445$Kw.

7. Determination of number of belts (n_b):

$n_b = P\times Fa / kW\times F_C\times F_{d\pi}$

$= 7.5\times1.3/5.445\times1.14\times0.83$

$= 1.892 \approx 2$ belts.

8. Calculation of actual centre distance:

Actual centre distance is given by

$C_{actual} = A + \sqrt{A^2 - B}$

$A = L/4 - \pi\ (D + d/8)$

$A = (4615/4) - \pi\ (1250 + 315/8)$

$= 539.17$

$B = (D-d)^2/8$

$= (1250 - 315)^2/8$

$= 109278.$

$C_{actual} = 539.17 + \sqrt{539.17^2 - 109278}$

$= 965.11$ mm.

EXERCISE – 1

A centrifugal pump running at 340 r.p.m. is to be driven by a 100 Kw motor running at 1440 rpm .The drive is to work for atleast 20 hours every day.

The centre distance between the motor shaft and the pump shaft is 1200mm. suggest a suitable multiple V- belt drive for this application. Also calculate the actual belt tensions and stess induced.

DESIGN OF V- BELT DRIVES USING BASIC EQUATIONS.

PROBLEM- 2

A V- Belt having a lap of 180°has a cross section area of 2.5 cm^2 and groove angle as 45°. The density of a belt is 0.0015 kg/cm^3 and maximum stress is limited to 400×10^4 N/ m^2. If μ = 0.15, find the power that can be transmitted, if the wheel has a mean diameter of 300 mm and runs at 1000 rpm.

GIVEN DATA:

$\alpha = 180° = 180° \times \pi / 180° = \pi$ radians. $a = 2.5\ cm^2 = 2.5 \times 10^{-4}\ m^2$

$\rho = 0.0015\ kg/cm^3 = 0.0015 \times 10^6\ kg/m^3$: $\sigma = 400 \times 10^4 N/m^2$: $\mu = 0.15$;

d= 300mm= 0.3m : N= 1000 r. p. m.

TO FIND;

Power transmitted (p).

SOLUTION :

$$\nu = \pi d N / 60$$

$$= \pi \times 0.3 \times 1000 / 60$$

$$= 15.71 \text{ m/s.}$$

Tension ratio $T_1 / T_2 = e^{\mu\alpha \,.\, \mathrm{cosec}\beta} = e^{0.15 \times\pi\times \mathrm{cosec}22.5° m}$

$= 3.426$

$T_1 = 3.426\, T_2$

Mass per unit length of belt , m = Density × area × Length

$= 0.0015\times10^6 \times 2.5 \times 10^{-4} \times 1$

$= 0.375$ kg/m.

Centrifugal tension , $Tc = mv^2$

$Tc = 0.375\,(15.71)^2$

$= 92.65$N.

Maximum tension in the belt, $T = \sigma\times a$

$= 400\times10^4\times2.5\times 10^{-4}$

$= 1000$ N

we know that the tension in the tight side of the belt,

$T= T_1+ T_C$

$T_{1=} T- T_C$

$= 1000- 92.55$

$= 907.5$ N

$T_2 = T_1 /3.426$

$= 907.5/3.426$

$= 264.9$ N

Power transmitted, $P = (T_1 - T_2)v$

$= (907.5-264.9)\times 15.71$

$=$**10.1 Kw.**

Exercise- 2:

Two shafts whose centres are 1m apart are connected by a V- belt drive. The driving pulley is supplied with 100 kw and has an effective diameter of 300mm. It runs at 1000rpm. While the driven pulley runs at 375 rpm . the angle of groove on the pulleys is 40° . The permissible tension in 400mm^2 cross sectional area of belt is 2.1 Mpa. The density of the belt is 1100 kg / m^3. Taking μ= 0.28, estimate the number of belts required.

DESIGN OF V- GROOVED PULLEYS:

Design procedure :

1. Select the cross section of the belt depending on the power to be transmitted by consulting data book page no 7.58.
2. For the selected cross- section of the belt, consulting the data book page no 7.70.,select the various required dimensions of the V- grooved pulley.

PROBLEM- 3

Design a V- grooved pulley of a V- belt drive to transmit 14.7 kW to a compressor.

GIVEN DATA:

P= 14.7 kW

TO FIND:

Design a V- grooved pulley.

SOLUTION:

1. **Selection of cross section of belt:**

For the given power transmitted consulting the data book page no 7.58. the belt cross section C is selected.

2. Selection of various dimensions of V-grooved pulley:

For the cross section C, Consulting the data book page no 7.70 the various dimensions of V-grooved pulley are given as below.

Pitch width l_p = 19 mm

Minimum distance down to pitch line b= 5.7mm

Pulley pitch diameter dp = 200 mm

Groove angle $2\beta = 34°$

Minimum depth below pitch line h = 14.3mm

Centre to centre distance of grooves e = 25.5m

Edge of pulley to first groove centre f = 17mm

Member of sheave grooves, n = 14

Face width l = (n-1)e+ 2f

= (14-1) 25.5 + 2×17

= 365.5mm.

3. Material selection:

Since the cast iron is economical, stable and durable, we can choose cast iron as a material for V- grooved pulley.

DESIGN WIRE ROPES AND PULLEYS.

Wire ropes are used whenever large power is to be transmitted over long distances (upto 150 m).The wire ropes are extensively used in elevators, oil well drilling, mine hoists, cranes, hauling devices, conveyors, tramways, suspension bridges and other material handling equipments.

ADVANTAGES OF WIRE ROPES :

- Lighter weight and high strength to weight ratio.
- More reliable in operation.
- Silent operation even at high working speeds.
- Less danger for damage due to jerks.

MATERIALS OF WIRE ROPES:

- Wrought iron, caststeel, plow steel and alloy steel.

CLASSIFICATION OF WIRE ROPES:

1. Cross lay ropes:

   In these ropes, the strands are twisted into a rope in the opposite direction to that of the wires in the strands.

2. Parrallel lay ropes:

   In these ropes, the direction of twist of the wires in the strand is the same as that of the strands in the rope .

3. Composite laid ropes:

   In these ropes, the wires in two adjacent strands are twisted in the opposite direction.

SPECIFICATION OF WIRE ROPES:

For example, a 6 × 7 rope means a rope made from six strands with seven wires in each strand.

DESIGN PROCEDURE FOR A WIRE ROPE :

1.Selection of suitable wire rope:

First select the suitable type of wire rope for the given application

2.Calculation of design load :

Calculate the design load by assuming a larger factor of safety, say 15 (data book page no : 9.1) Design load = load to be lifted × Assumed factor of safety.

3.Selection of wire rope diameter (d):

Select the wire rope diameter (d) from the data book page no 9.5 & 9.6

4.Calculation of sheave diameter(D):

Consulting the data book page no 9.1, obtain the diameter of sheave. Always larger sheave diameter is preferred.

5.Selection of the area of useful cross section of the rope (A):

Consulting the data book page no 9.1 select the area of useful cross section of the rope .

6.Calculation of wire diameter(d_w):

Calculate the diameter of wire using the relation

$$d_w = d/ 1.5\sqrt{i}$$

where

i = number of wires in the rope

= number of strands × number of wires in each strand

7. Selection of weight of rope (Wr):

Obtain the rope weight (Wr) from the data book page

no 9.5 & 9.6.

8. Calculation of various loads :

i. Direct load, Wd = W+ Wr

ii. Bending load Wb= $\sigma_b \times A$

$$= (Er \times dw) / D \times A$$

iii. Acceleration load due to change in the speed of hoisting

$$Wa = (W+Wr / g) \times a$$

Where $a = v_1 - v_2 / t$

iv. Starting or stopping load :

a. When there is no slack in the rope :
Starting load, Wst = 2. Wd = 2(W+Wr)

b. When there is slack in the rope :
Starting load, Wst $= \sigma_{st} \times A$

$$= (W+Wr) (1+\sqrt{}1+ 2 . a_s . h. Er / \sigma_d .l .g).$$

9. Calculation of effective loads :

i. Effective load on the rope during normal working, $W_{en} = W_d+W_b$

ii. Effective load on the rope during accelerationof the load,

$$W_{ea} = W_d + W_b+W_a$$

iii. Effective load on the rope during starting, West = $W_b + W_{st}$

10. Calculation of working factor of safety (FS_w):

FS_w = Breaking load / Effective load.

Breaking load taken from the data book page no 9.5& 9.6 .

11. Check for safe design:

Compare the calculated working factor of safety(FS_w) with the recommended factor of sfety (n') . If the working factor of safety is greater than the recommended factor of safety . Then the design is safe. Suppose design is not safe means change the other rope.

12. Calculation of number of ropes:

Number of ropes = Recommended factor of safety / Working factor of safety .

PROBLEM – 4:

Design a wire rope for an elevator in a building 60 m height and for a total load of 20 KN. The speed of the elevator is 4 m/ sec and the full speed is reached in 10 seconds.

GIVEN DATA:

Height = 60 m : W= 20kN= 20×10^3 N : ν = 4 m / sec= 240 m/ min:

t = 10 sec.

TO FIND :

Design a wire rope

SOLUTION:

1. **selection of suitable wire rope:**

   Given that the wire rope is used for an elevator, for hoisting purpose. So lets use **6× 19** rope.

2. **Calculation of design load:**

   Assuming a larger factor of safety of 15, the design load is calculated.

Design load = load to be lifted × Assumed factor of safety

$= 20 \times 15 = 300$ kN.

3. Selection of wire rope diameter (d):

From data book page no 9.5&9.6, taking the design load as the breaking strength, the wire rope diameter is selected as 25 mm

d = 25mm for σ_u= 1600 to 1750 N/ mm^2 and breaking strength = 340 kN.

4. **Calculation of sheave diameter (D) :**

From data book page no 9.1 for 6× 19 rope and class 4

$$D_{min}/d = 27\times(1.08)^{5-1}$$

$$= 36.73 \text{ say } 40.$$

Sheave diameter, D = 40×d

= 40× 25

= 1000mm.

4. Selection of the area of useful cross section of the rope(A):

From the data book page no 9.1 for 6× 19 rope

$$A= 0.4\, d^2$$

$$= 0.4 \times (25)^2$$

$$= 250mm^2$$

5. **Calculation of wire diameter (d_w):**

wire diameter (d_w) = d / 1.5 √ i

i = number of strands × number of wires in each strand.

= 6× 19

= 114

$d_w = 25 / 1.5\sqrt{114}$

$= 1.56mm$

5. Selection of weight of rope (Wr):

From the data book page no 9.5&9.6

Approximate mass = 2.41 kg /m

Weight of rope / m = 2.41 × 9.81

= 23.6 N/ m

Weight of rope, Wr= 23.6 × 60

= 1416N

6. Calculation of various loads:

Direct load, $W_d = W + Wr$

$= 20000 + 1416$

$= 21416$ N.

Bending load , $W_b = \sigma_b \times A$

$= Er \times dw / D \times A$

$= 0.84 \times 10^5 \times 1.56 / 1000 * (250)$

$= 32760$ N (take $Er = 0.84 \times 10^5$ N / mm^2).

Acceleration load Wa = (W+Wr/ g)*a

$a = (v_2 - v_1)/ t_1$

= 4-0/ 10

= 0.4 m/s^2 .

Wa = (20000 +1416 / 9.81) 0.4

$= 873.23$ N

Starting load (Wst) $= 2. W_d = 2 (W+Wr)$

$= 2 (20000 +1416)$

$= 42832$ N.

9. **Calculation of effective loads on the rope :**

i. Effective load on the rope during normal working, $W_{en} = W_d+W_b$

$= 21416+ 32760$

$= 54176$ N

ii. . Effective load on the rope during accelerationof the load,

$W_{ea} = W_d + W_b+W_a$

$=21416+ 32760 + 873.23$

$= 55049.23$N

iii. Effective load on the rope during starting, West $= W_b + W_{st}$

$= 32760 + 42832$

$= 75592$ N

10. **Calculation of working factor of safety:**

FS_w = Breaking load / Effective load

$= 340000 / 55049.23 = 6.176$

11. **Check for safe design:**

From the data book page no 9.1 ,for hoists and class 4, the recommended factor of safety = 6.

Since the working factor of safety is greater than the recommended factor of safety, so design is safe.

DESIGN PROCEDURE OF ROLLER CHAIN

1. **Selection of the transmission ratio (i):**
   Select a preferred transmission ratio from data book, page no. 7.74

2. **Selection of number of teeth on the driver sprocket (z_1):**
   Select the number of teeth on the driver sprocket (z_1) by consulting data book, page no. 7.74

3. **Determination of number of teeth on the driven sprocket (z_2)** :
   Determine the number of teeth on the driven sprocket (z_2) by using the transmission ratio (i) and (z_1).

   $$\therefore \quad z_2 = i\, z_1$$

   Recommended value of z_2 : $z_{2\,max}$ = 100 to 120 … [from data book, page no. 7.74]

   Now check whether the calculated z_2 is less than the recommended $z_{2\,max}$. Because, when z_2 is large, the stretched chain may slip off the sprocket for a small pull.

4. **Selection of standard pitch (p):**
   Knowing (or assuming) the initial centre distance (a), determine the range of chain pitch by using the relation

   $$a = (30 - 50)\, p$$

   From the pitch range obtained, consulting from data book, page no. 7.74

5. **Selection of the chain:**
   Select the chain type and chain number, by using the selected standard pitch, from data book, page nos. 7.71, 7.72 and 7.73.

6. **Calculation of total load on the driving side of the chain (P_T):**
   Total load on the driving side (P_T) = Tangential force due to power transmission (P_t) + Centrifugal tension (P_c) due to speed of the chain + Tension due to chain sagging (P_s)

   $$P_T = P_t + P_c + P_s$$

   (i) To find tangential force (P_t) :

$$P_t = \frac{1020N}{v}$$

Where N = Transmitted power in kW, and

v = Chain velocity in $m/s = \frac{z_1 \times p \times N_1}{60 \times 1000}$ or $\frac{z_2 \times p \times N_2}{60 \times 1000}$

(ii) To find centrifugal tension (P_c):

$P_c = mv^2$

Where m = Mass of chain / metre, from data book page nos. 7.71, 7.72 and 7.73.

(iii) To find tension due to sagging (P_s):

$P_s = k .w.a$

Where k = Coefficient of sag taking into account the arrangement of chain drive,

from data book page nos. 7.78

w = Weight of chain / metre = m . g, and

a = Centre distance in metre.

7. **Calculation of service factor (k_s):**
The service factor is used to account for variations in the driving and driven sources for roller chains.

∴ Service factor, $k_s = k_1 . k_2 . k_3 . k_4 . k_5 . k_6$

Select the values of k_1, k_2, k_3, k_4, k_5, and k_6 from data book nos. 7.76 and 7.77

8. **Calculation of design load:**
Design load = Total load on the driving side of the chain x service factor or

Design load = P_T x k_s

9. **Calculation of working factor of safety (FS_w):**
Calculate the working factor of safety by using the relation

$$\text{Factor of safety} = \frac{\text{Breaking load Q obtained from data book page nos. 7.71, 7.72 and 7.73}}{\text{Design load}}$$

$$= \frac{Q}{P_T \times k_s}$$

10. Check for factor of safety :

Compare the working factor of safety with the recommended minimum value of factor of safety given in data book page no. 7.77

If the working factor of safety (FS_w) is greater than the recommended minimum value of factor of safety (n'), then the design is **safe and satisfactory.**

If the working factor of safety is not satisfactory, one more chain may be added (i.e., simplex to duplex or duplex to triplex) to the existing one or the chain pitch may be increased.

11. Check for the bearing stress in the roller:

- Calculate the bearing stress in the roller using the formula

$$\sigma = \frac{Tangential load}{Bearing area} = \frac{P_t \times k_s}{A}$$

Take the bearing area (A) value from data book page nos 7.71, 7.72 and 7.73

12. Calculation of actual length of chain (L):

- Calculate the number of links (l_p) using the formula

$$l_p = 2a_p + \left[\frac{z_1 + z_2}{2}\right] + \frac{\left(\frac{z_2 - z_1}{2\pi}\right)^2}{a_p} \quad \text{(from data book, page no. 7.75)}$$

$$a_p = \frac{a_0}{p} = \frac{Initial\ centre\ distance}{pitch}$$

- Correct the calculated number of link (l_p) into an even number.
- Now calculate the actual length (L) of chain using the formula
  $L = l_p \times p$ (from data book, page no. 7.75)

13. Calculation of exact centre distance:

Calculate the exact centre distance corrected to an even number of links (pitches) using the relation

Exact centre distance, $a = \frac{e + \sqrt{e^2 - 8M}}{4} \times p$

Where $e = l_p - \left(\frac{z_1 + z_2}{2}\right)$

And $M = \left(\frac{z_2 - z_1}{2\pi}\right)^2$ = constant [from data book, page no. 7.75]

$\therefore$ Exact centre distance = a – 0.01a = 0.99a

14. Calculation of pitch circle diameters (pcd) of sprockets:

Pcd of smaller sprocket, $d_1 = \frac{p}{\sin(180/z_1)}$

Pcd of larger sprocket, $d_2 = \frac{p}{\sin(180/z_2)}$

Smaller sprocket outside diameter, $d_{01} = d_1 + 0.8\ d_r$

And Larger sprocket outside diameter, $d_{02} = d_2 + 0.8\ d_r$

Where d_r = Diameter of roller taken from data book page nos. 7.71, 7.72 and 7.73.

PROBLEM 5

A truck equipped with a 9.5 kW engine uses a roller chain as the final drive to the rear axle. The driving sprocket runs at 900 r.p.m and the driven sprocket at 400 r.p.m. with a centre distance of approximately 600mm. Select the roller chain.

Given data: N = 9.5kW; N_1 = 900 r.p.m.; N_2 = 400 r.p.m.; a_0 = 600 r.p.m.

To find : Select (i.e., design) the roller chain.

☺ **Solution:**

1. **Determination of the transmission ratio (i):**
   Transmission ratio, i = N_1 / N_2 = 900 / 400 = 2.25

(Since the transmission ratio can be calculated from the given data, therefore we need not to consult data book, page no. 7.74)

2. **Selection of number of teeth on the driver sprocket (z_1):**
From data book, page no. 7.74 $z_1 = 27$ (for i = 2 to 3) is selected.

3. **Determination of number of teeth on the driven sprocket (z_2)**
$z_2 = i \times z_1 = 2.25 \times 27 = 60.75 = 61$

Recommended value, $z_{2max} = 100$ to 120

$\therefore$ $z_2 = \mathbf{61}$ is satisfactory.

4. **Selection of standard pitch (p):**
We know that centre distance, a = (30 – 50) p

$\therefore$ Maximum pitch, $p_{max} = \dfrac{a}{30} = \dfrac{600}{30} = 20\ mm$

and Minimum pitch, $p_{min} = \dfrac{a}{50} = \dfrac{600}{50} = 12\ mm$

any standard pitch between 12 mm and 20 mm can be chosen. But to get a quicker solution, it is always preferred to take the standard pitch closer to p_{max}. Refer data book page no. 7.74

$\therefore$ standard pitch, p = **15.875 mm** is chosen.

5. **Selection of the chain:**
Assume the chain to be duplex. Consulting data book page nos. 7.71, 7.72 and 7.73. the selected chain number is 10A-2 / DR50.

6. **Calculation of total load on the driving side of the chain (P_T):**
   (i) Tangential force (P_t) :

$$P_t = \frac{1020N}{v}$$

Where N = Transmitted power in kW = 9.5 kW

v = Chain velocity in m/s

$$= \frac{z_1 \times p \times N_1}{60 \times 1000} = \frac{27 \times 15.875 \times 900}{60 \times 1000} = 6.43 m/s$$

$$P_t = \frac{1020N}{v} = \frac{1020 \times 9.5}{6.43} = 1507N$$

(ii) Centrifugal tension (P_c) :

$P_c = mv^2$

From data book page nos. 7.71, 7.72 and 7.73.

$m = 1.78$ kg/m

$P_c = 1.78\,(6.43)^2 = 73.59$ N

(iii) Tension due to sagging (P_s) :

$P_s = k \,.\, w \,.\, a$

From data book page nos. 7.78

$k = 6$ (for horizontal)

$w = mg = 1.78 \times 9.81 = 17.46$N.

a = Initial centre distance = 0.6m

$P_s = 6 \times 17.46 \times 0.6 = 62.82$ N

(iv) Total load (P_T):

$P_T = P_t + P_c + P_s$

$= 1507 + 73.59 + 62.82 = 1643$ N

7. Calculate of service factor (k_s) :

We know that the service factor,

$$k_s = k_1 \,.\, k_2 \,.\, k_3 \,.\, k_4 \,.\, k_5 \,.\, k_6$$

From data book page no. 7.76 $k_1 = 1.25$ (for load with mild shocks)

From data book page no. 7.76 $k_2 = 1$ (for adjustable supports)

From data book page no. 7.76. $k_3 = 1$ ($\because$ we have used $a_p = (30 \text{ to } 50)\, p$)

From data book page no. 7.77 $k_4 = 1$ (for horizontal drive)

From data book page no. 7.77 $k_5 = 1$ (for drop lubrication)

From data book page no. 7.77 $k_6 = 1.25$ (for 16 hours / day running)

$\therefore$ $k_s = 1.25 \times 1 \times 1 \times 1 \times 1 \times 1.25 = 1.5625$

8. Calculation of design load:

Design load = $P_T \times k_s = 1643.4 \times 1.5625 = 2567.8$N

9. Calculation of working factor of safety (FS_w):

$$FS_w = \frac{Breaking\ load\ Q\ \ from\ Table\ 4.5}{Design\ load} = \frac{44400}{2567.8} = 17.29$$

10. Check for factor of safety :

From PSGDB 7.77, for smaller sprocket speed of 900 r.p.m. and pitch 15.875 mm, the required minimum factor of safety is 11. Therefore the working factor of safety is greater than the recommended minimum factor of safety. Thus ***the design is safe and satisfactory.***

11. Check for the bearing stress in the roller:

We know that $\sigma_{roller} = \dfrac{P_t \times k_s}{A}$;

Where A = 140 mm² from data book page nos. 7.71, 7.72 and 7.73.

$$= \frac{1507 \times 1.5625}{140} = 16.8 \text{ N/mm}^2$$

Consulting data book page no. 7.77, for smaller sprocket speed of 900 r.p.m. and pitch 15.875 mm, the allowable bearing stress is 22.4 N/mm². Therefore the induced stress is less than the allowed bearing stress. Thus ***the design is safe and satisfactory.***

12. Calculation of length of chain (L):

Number of link $l_p = 2a_p + \left(\dfrac{z_1 + z_2}{2}\right) + \dfrac{\left[(z_2 - z_1)/2\pi\right]^2}{a_p}$

Where $a_p = \dfrac{a_0}{p} = \dfrac{Centre\ distance}{pitch} = \dfrac{600}{15.875} = 37.795$

$\therefore \quad l_p = 2\,(37.795) + \left(\dfrac{27+61}{2}\right) + \dfrac{\left[(61-27)/2\pi\right]^2}{37.795} = 120.36$

$\approx$ 122 links (rounded off to an even number)

$\therefore$ Actual length of chain, L = l_p x p = 122 x 15.875 = **1936.75 mm**

13. Calculation of exact centre distance (a):

We know that $a = \dfrac{e + \sqrt{e^2 - 8M}}{4} \times p$

Where $e = l_p - \left(\dfrac{z_1 + z_2}{2}\right) = 122 - \left(\dfrac{27+61}{2}\right) = 78$

and $\quad M = \left(\frac{z_2 - z_1}{2\pi}\right)^2 = \left(\frac{61-27}{2\pi}\right)^2 = 29.28$

$\therefore \quad a = \frac{78+\sqrt{78^2 - 8\times 29.28}}{4}\times 15.875 = 6.1311\ mm$

Decrement in centre distance for an initial sag = 0.01a = 0.01 (613.11) = 6.1311 mm

$\therefore$ Exact centre distance = 613.11 – 6.1311 = **606.978 mm**

14. Calculation of sprocket diameters:
Smaller sprocket:

Ped of smaller sprocket, $d_1 = \frac{p}{\sin\ (180/27)} = \mathbf{1}36.74\ mm$

And Sprocket outside diameter, $d_{01} = d_1 + 0.8\ d_r$

Where $\quad d_r$ = Diameter of roller, from data book page nos. 7.71, 7.72 and 7.73. = 10.16 mm

$\therefore \quad d_{01}$ = 136.74 + 0.8 x 10.16 = **144.868 mm**

Larger sprocket:

Ped of larger sprocket, $d_2 = \frac{p}{\sin(180/z_2)} = \frac{15.875}{\sin(180/61)}$ = **308.38 mm**

And Sprocket outside diameter, $\quad d_{02} = d_2 + 0.8\ d_r$

= 308.38 + 0.8 x 10.16 = **316.51 mm**

PART – B

1. A flat belt drive is to design to drive a flour mill. The driving power requirements of the mill are 22.5 KW at 750 rpm with a speed reduction of 3.0. The distance between the shafts is 3m. Diameter of the mill pulley is 1.2 m. Design and makes a neat sketch of the drive. **(16)** **(M/J 2012)**

2. Design a chain drive to drive a centrifugal compressor from an electric motor 15 KW at 1000 rpm. The speed reduction ratio required is 2.5. The compressor to work for 16 hours a day. State solutions for common problems encountered in continuous operation of the drive. **(16) (M/J 2012)**

3. Design a V-belt drive to transmit 50 KW at 1440 rpm from an electric motor to a textile machine running 24 hours a day. The speed of the machine shaft is 480 rpm.

(16) (A/M 2008)

4. A crane is lifting a load of 18 KN through a wire rope and hook. The weight of the hook etc. is 10 KN. The load is to be lifted with an acceleration of $1 m/sec^2$. Calculate the diameter of the wire rope. The rope diameter may be taken as 30 times the diameter of the rope. Take a factor of safety of 6 on a young's modulus for the wire rope $0.8 \times 10^5 N/mm^2$. The ultimate stress may be taken as $1800 N/mm^2$. The cross-sectional area of the wire rope may be taken as 0.38 times the square of the wire rope diameter. **(16) (N/D 2007)**

5. a) A V-belt having a lap of 180˚ has a cross section area of $2.5 cm^2$ and groove angle as 45˚. The density of a belt is $0.0015 Kg/cm^3$ and maximum stress is limited to $400 \times 10^4 N/m^2$. If μ=0.15. Find the power that can be transmitted, if the wheel has a mean diameter of 300 mm and runs at 1000 rpm. **(08)**

   b) Power is transmitted between two shafts by a V-belt whose mass is 0.9 Kg/m length. The maximum permissible tension in the belt is limited to 2.2 KN. The angle of lap is 170˚ and the groove angle 45˚. If the coefficient of friction between the belt and pulleys is 0.17, find

   i. Velocity of the belt for maximum power and
   ii. Power transmitted at this velocity. **(08) (M/J 2011)**

6. a) Find the width of the belt necessary to transmit 7.5 KW to a pulley of 300mm diameter, if the pulley makes 1600 rpm and the coefficient of friction between the belt and the pulley is 0.22. Assume the angle of contact as 210˚ and the maximum tension in the belt is not exceeding 8 N/mm width. **(08)**

   b) A leather belt 125 mm wide and 6 mm thick, transmits power from a pulley with the angle of lap 150˚ and μ=0.3. If the mass of $1 m^3$ of leather is 1 Mg and the stress in the belt is not to exceed 2.75 Mpa. Find the maximum power that can be transmitted and the corresponding speed of the belt. **(08) (A/M 2011)**

7. Design a flat belt drive to transmit 110 KW for a system consisting of two pulleys of diameters 0.9m and 1.2m respectively, for a Centre distance of 3.6m, belt speed of 20m/s and coefficient of friction = 0.3. There is a slip of 1.2% at each pulley and 5% friction loss at each shaft with 20% over load. **(16) (N/D 2009)**

8. Design a chain drive to transmit 6 KW at 900 rpm of a sprocket pinion. Speed reduction is 2:5:1. Driving motor is mounted on an adjustable base. Assume that load is steady, drive is horizontal and service is 16 hours/day. **(16) (A/M 2010)**
9. Design a flat belt drive to transmit 6 KW at 900 rpm of the driver pulley. Speed reduction is to be 2:5:1. Assume that the service is 16 hours a day. **(16) (A/M 2010)**
10. A truck equipped with a 9.5 KW engine uses a roller chain as the final drive to the rear axle. The driving sprocket runs at 900 rpm and the driven sprocket at 400 rpm with a Centre distance of approximately 600 mm. select the roller chain. **(16) (A/M 2011)**

<u>Reference books:</u>

1. Machine design (volume –II), Design of Transmission Systems, S.Md.Jalaludeen
2. Machine design – R.S. Khurmi & J.K. Gupta
3. Design of transmission systems – T.J. Prabhu
4. Design of transmission systems – V. Jayakumar