MODULE 5

DESIGN OF FLAT AND V BELT DRIVES

Design of flat belt- materials for belts, slip of the belts, creep, centrifugal tension
Design of V-belt drives, Advantages and limitations of V-belt drive

MECHANICAL DRIVES

- MECHANICAL DRIVES
  - RIGID DRIVES
    - GEAR DRIVES
  - FLEXIBLE DRIVES
    - BELT DRIVES
    - ROPE DRIVES
    - CHAIN DRIVES

ADVANTAGES AND DISADVANTAGES OF FLEXIBLE DRIVE OVER RIGID DRIVES

ADVANTAGES

1. Flexible drive transmits power over a comparatively long distance due to intermediate link between driving and driven shafts.
2. Since the intermediate link is long and flexible, it absorbs shock loads and damps vibration.
3. Flexible drives provide considerable flexibility in the location of the driving and driven shafts. The tolerances on the centre distance are not critical as compared with gear drive.
4. Flexible drives are cheap as compared to gear drives. Their initial cost and maintenance costs are low.

DISADVANTAGES

1. They occupy more space.
2. The velocity ratio is relatively small.
3. In general, the velocity ratio is not constant which results in slip.

BELT DRIVES

- Flexible drive
- Belts are used to transmit power between two shafts by means of friction.
- In belt drives ,the rotary motion of the driving shaft is first converted in to translatory motion of the belt and then again converted into rotary motion of the driven shaft.
- Centre-centre distance can be varied .
- Belt drives has ability to absorb the shock and damp vibrations.
- Employed for transmitting power over large distance .

ADVANTAGES OF BELT DRIVE

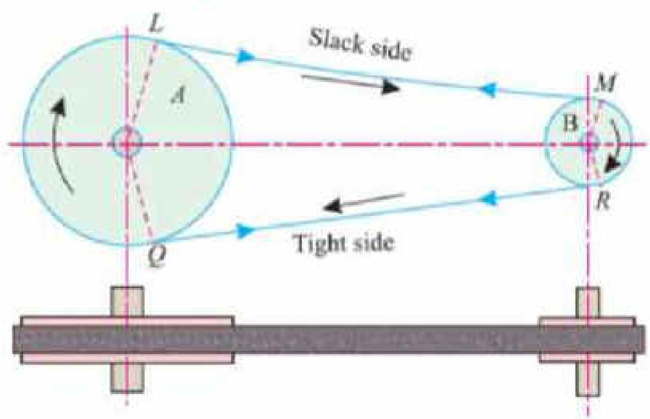
1. Belt drive can transmit power over considerable distance.
2. The operation of belt drive is smooth and silent.
3. They have the ability to absorb the shocks and damp vibration.
4. They are simple to design.
5. They have low initial cost.
6. They can transmit only a definite load, which if exceeded, will cause the belt to slip over the pulley, thus protecting the parts of the drive against overload.

DISADVANTAGES OF BELT DRIVE

1. Belt drives have large dimensions and occupy more space.
2. The velocity ratio is not constant due to belt slip.
3. They impose heavy loads on shafts and bearings.
4. There is considerable loss of power resulting in low efficiency.
5. Belt drives have comparatively shorter service life.

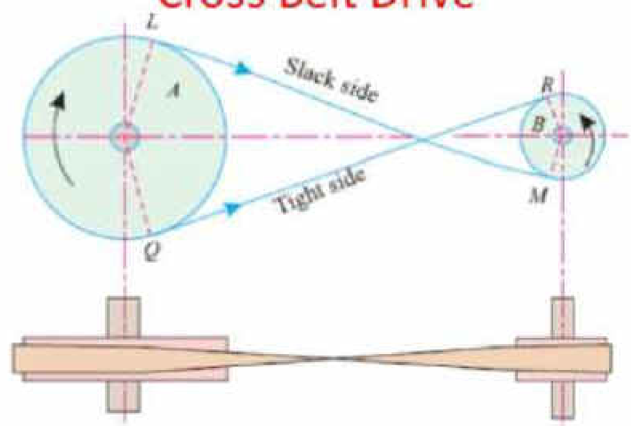
Types of Belt drives

Open Belt Drive



- two pulleys rotate in the same direction
- Length of the belt is smaller
- Angle of lap is different for driver and driven pulley

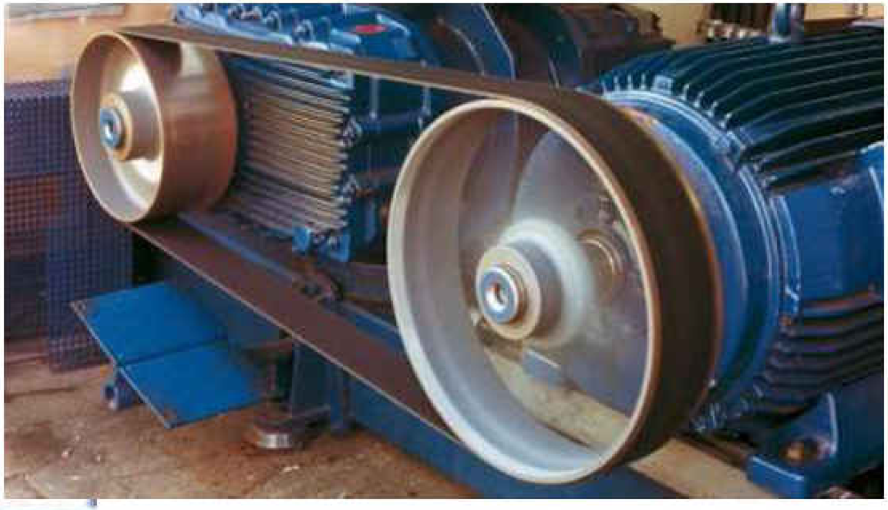
Cross Belt Drive



- pulleys rotate in the opposite directions
- Length of the belt is larger
- Angle of lap is same for driver and driven pulley

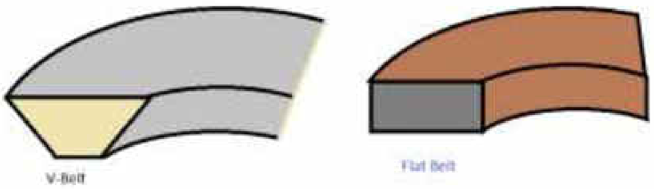
APPLICATIONS

- Electric Motors
- Machine Tools
- Automobiles
- Conveyors
- Alternators



COMPARISON OF FLAT BELT DRIVE AND V BELT DRIVE

FLAT BELT DRIVE	V BELT DRIVE
1. Narrow rectangular cross section	1. Trapezoidal cross section
2. Low velocity ratio(up to 4:1)	2. High velocity ratio (up to 7:1)
3. Adjustable velocity ratio possible using stepped pulley.	3. Fixed velocity ratio
4. The efficiency of flat belt drive is more than V belt drive.	4. Low efficiency
5. Design and construction of flat belt drive is simple and inexpensive and easy to maintain.	5. Design and construction of V belt drive is complex and costlier.
6. They have large dimensions and consume much higher space for operation.	6. V belt have short centre distance which results in compact construction



COMPARISON OF FLAT BELT DRIVE AND V BELT DRIVE

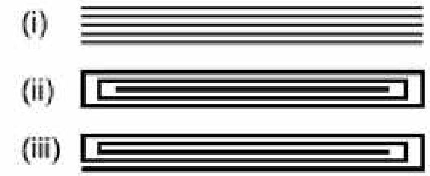
FLAT BELT DRIVE	V BELT DRIVE
7. Flat belt produce more noise than V belts.	7. V belts are endless which results in smooth and quiet operation even at high operating speeds.
8. Power transmitting capacity of flat belt drive is low.	8. The force of friction between the surfaces of the belt and V grooved pulley is high due to wedge action which results in increase in power transmitting capacity.
9. They can be used in dusty and abrasive atmosphere and requires no closed casing.	9. The drive is positive because slip is negligible due to wedge action.
10. In general, flat belt drives are horizontal and not vertical.	10. V belt drive can operate in any position even when the belt is vertical.
	11. Construction of V grooved pulleys is complicated and costlier compared with pulleys of flat belt drive.

BELT MATERIALS

1. Leather: advantage←high coefficient of friction and consequently high power transmitting capacity
2. Canvas
3. Rubber
4. Rubberised fabric←They are made from several layers of canvas or cotton –duck impregnated with rubber
5. Synthetic materials

BELT CONSTRUCTIONS

(a) Four-Ply Leather Belt



(b) Fabric Rubber Belt

Flat Belts

FABRIC RUBBER BELTS

1. The fabric transmits major portion of load.
2. The rubber protects the fabric against damage and increases the coefficient of friction.
3. The presence of rubber allows different plies of fabric to work together as one unit.

ADVANTAGES OF FABRIC RUBBER BELTS

1. They have high load carrying capacity
2. They have long service life.
3. They can operate at high operating speed up to 300m/s

DISADVANTAGES OF FABRIC RUBBER BELTS

1. They cannot operate on small diameter pulleys.
2. They are subjected to destruction in the presence of mineral oil, gasoline and alkalis.

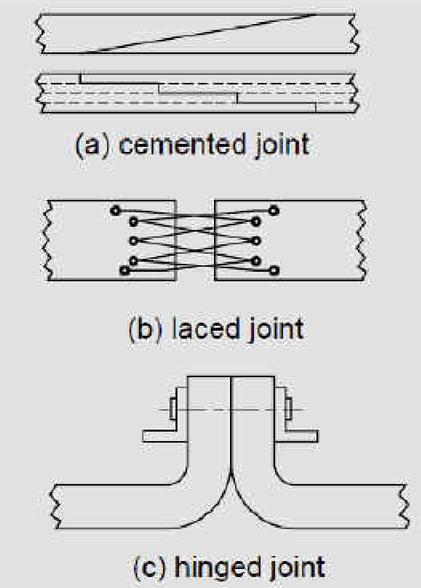
DESIRABLE PROPERTIES OF BELT MATERIALS

- The belt material should have high coefficient of friction with the pulleys.
- The belt material should have high tensile strength to withstand belt tension.
- The belt material should have high wear and fatigue resistance.
- It should be flexible.
- It should be reliable and durable.
- Material should be able to operate at very high temperature.

Flat belts are produced in the form of long bands and stored in the form of coils. The ends of these belts are joined by different methods.

FLAT BELT JOINING METHODS

- CEMENTING
- LACING
- USING METAL FASTENERS



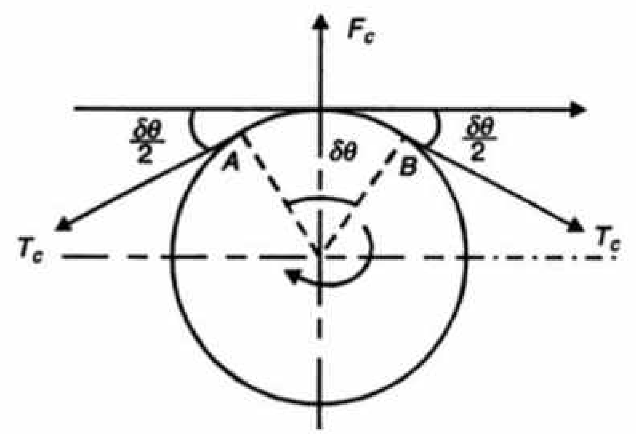
Flat Belt Joints

CENTRIFUGAL TENSION IN BELTS

When a belt operates at high speed ,there is a considerable centrifugal force (inertia force) acting on the belt .This force is developed due to centrifugal action of belt which tries to lift the belt from the pulley. On account of this inertia force, two tensions of equal magnitude are induced on the tight and slack sides of the belt.

Consider a small element of belt which is in equilibrium under the action of the following forces.

1. Centrifugal force F_c
2. Centrifugal tension T_c acting on tight and slack side in addition to normal tension on the tight and slack side.



Let

m = mass of the belt per unit length

r = radius of the pulley

v = peripheral velocity of the belt

and $\delta\theta$ = angle of contact of the element over the pulley

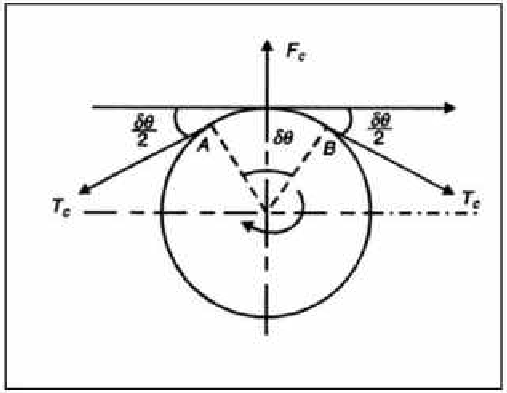
Centrifugal force on the element, F_c

F_c = mass of the element × acceleration = $mr\,\delta\theta \times \frac{v^2}{r}$

ie $F_c = mv^2\delta\theta \leftarrow (1)$

For the equilibrium of element AB, let us resolve the force in vertical direction.

$F_c = 2T_C \sin\frac{\delta\theta}{2} \rightarrow F_c = T_C\delta\theta$ (for small angle $\sin\frac{\delta\theta}{2} = \frac{\delta\theta}{2}$) $\leftarrow (2)$



From the above two equations (1) and (2)

$mv^2\delta\theta = T_c\,\delta\theta$

Therefore centrifugal tension, $T_c = mv^2$

Centrifugal tension on the belt is a function of the mass of the belt and peripheral velocity and it is independent of tensions on tight and slack side.

POWER TRANSMISSION CAPACITY

The power transmission capacity of the belt is given by the following relation:

$$\dot{P} = \frac{(T_1 - T_2)v}{1000} \text{ kW}$$

For the condition of maximum power transmission capacity, $T = 3mv^2 = 3T_c$

Therefore for max power to be transmitted, the maximum allowable belt tension should be equal to 3 times the centrifugal tension.

The threshold speed of the belt, $v_{max} = \sqrt{\frac{T}{3m}}$, where **T is the total tension on tight side** $= T_1 + T_C$

The ratio of tensions on tight and slack sides, when the effect of centrifugal tension is considered, $\frac{T_1 - T_C}{T_2 - T_C} = e^{\mu\theta}$

DESIGN PROCEDURE FOR FLAT BELT

STEP 1: Make preliminary decision regarding

a. Material used for belt –generally oak tanned /mineral tanned leather
   Design stress of belt-assume design stress 2.06 MN/m^2refer →DB PGNO 291,Eq 14.4
b. Material used for pulley –generally CI,because of damping property.
c. Type of joint required –generally cemented with η_j =100% or Refer table 14.5/page 307
d. Service condition ;service factor ,C_s =1.2 →general or refer table 14.8/page 310
e. Calculate design power ,P_d=P(KW)=Px$C_s(KW)$

STEP 2: diameter of motor pulley (driver)

d= $(525\text{-}630)\sqrt[3]{\frac{P(KW)}{\omega_{max}}} = (525\text{-}630)\sqrt[3]{\frac{P(KW)}{2\pi n_{max}}}$ where n_{max} =speed in rps (refer DB eqn 14.9(a)/page 292)

DESIGN PROCEDURE OF FLAT BELT DRIVE

STEP 3: diameter of driven pulley considering creep of the belt

$D=(1-\epsilon)di$ (DB Eqn 14.9(b)/page 292) ,where i←velocity ratio,where ϵ=0.01to 0.03 (coefficient of creep)

STEP 4: Standardise pulley diameters in steps 2 & 3 using Table 14.13(b)/page 313

Step 5: speed

$v=\frac{\pi D_1 N_1 (1-\epsilon)}{60}$,where D_1 ←diameter of driver ,N_1 ←rpm of driver

STEP 6: centre distance

$c \geq (1.5-2)(D+d)$ (refer DB 14.2(d)/page 290)

DESIGN PROCEDURE OF FLAT BELT DRIVE

STEP 7 : Coefficient of friction between pulley &belt using Barths formula

$\mu = 0.54 - \frac{0.712}{2.542+v}$ ←below eqn 14.3(d)/page290

Or using Table 14.2(b)/page 305

If material of belt different select μ from table 14.2(a)/page305

STEP 8: Determine length of belt (open/cross) refer eqn 14.2(b),14.2(c)/page 290

STEP 9: Angle of contact (open/cross) refer Eqn 14.1(a)or 14.1(b)/page 289

DESIGN PROCEDURE OF FLAT BELT DRIVE

Step 10: width of belt (b) ←find standard width from DB table 14.1/page 305

Power transmitted, P (KW)= $\frac{btv}{1000}\left[\sigma_d - \frac{wv^2}{10^6 g}\right]\left(\frac{e^{\mu\theta}-1}{e^{\mu\theta}}\right)\eta_j$ ← Eqn 14.5(a)/page 291

η_j = **efficiency** of joint ←table 14.5/page307

$\frac{D_{min}}{t}$ <50 ;D_{min} refers to smaller diameter

STEP 11: calculate tensions in the belt T_1, T_2 &T_o using

$P_d = P = \frac{(T_1-T_2)v}{1000}$ ←DB Eqn 14.5(a)/page 291

At high velocities; v>10m/sec, we should consider centrifugal tension, otherwise we can neglect it .

$\frac{T_1-T_c}{T_2-T_c}=e^{\mu\theta}$ ← DB Eqn14.3(c)/page 290

Relation between initial tension and power tensions; $\sqrt{T_1} + \sqrt{T_2}=2\sqrt{T_O}$,where T_O is initial tension in N.(refer Eqn 14.8/page 291)

DESIGN OF FLAT BELT DRIVE PROBLEM DISCUSSION

Q1.A horizontal drive is required to drive a compressor by means of electric motor. Select suitable flat drive from following details.

Power=6KW, slip=2.5%,Speed of motor pulley=1400rpm, service factor =1.2,working stress =2 MPa, joint efficiency =90%,Speed of compressor =500 rpm

STEP 1: Make preliminary decision regarding

a. Material used for belt –generally oak tanned /mineral tanned leather
   Given working stress of belt= 2 MPa (given)
b. Material used for pulley –generally CI, because of damping property.
c. Type of joint required –given η_j =100%
d. Service condition ;service factor ,C_s =1.2 (given)
e. Calculate design power ,P_d=P(KW)=Px$C_s(KW)$=7.2 KW

STEP 2: diameter of motor pulley (driver)

d= $(525\text{-}630)\sqrt[3]{\frac{P(KW)}{\omega_{max}}} = (525\text{-}630)\sqrt[3]{\frac{P(KW)}{2\pi n_{max}}}$ where n_{max} =speed in rps (refer DB eqn 14.9(a)/page 292)

$$d = 630\times \sqrt[3]{\frac{P(KW)}{2\pi n_{max}}} = 230.71 \text{ mm}$$