ME 245 : ENGINEERING MECHANICS AND THEORY OF MACHINES

LECTURE: POWER TRANSMISSION BY BELT, ROPE AND CHAIN DRIVES

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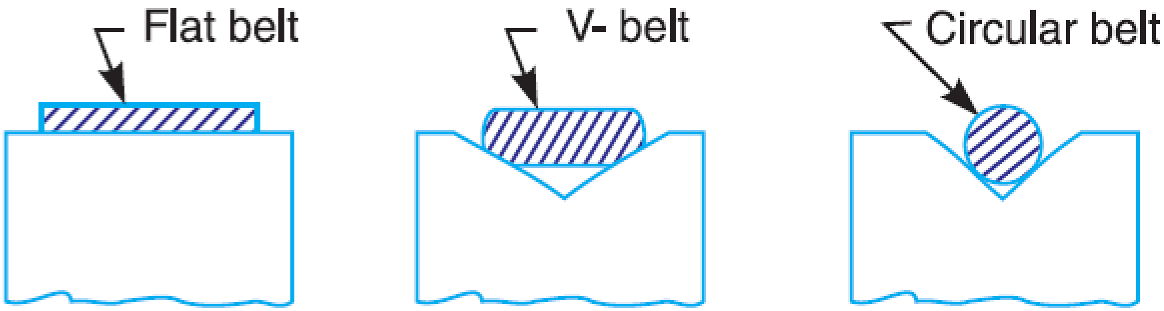
The belts or ropes are used to transmit power from one shaft to another by means of pulleys which rotate at the same speed or at different speeds.

The amount of power transmitted depends upon the following factors :

1. The velocity of the belt.
2. The tension under which the belt is placed on the pulleys.
3. The arc of contact between the belt and the smaller pulley.
4. The conditions under which the belt is used.

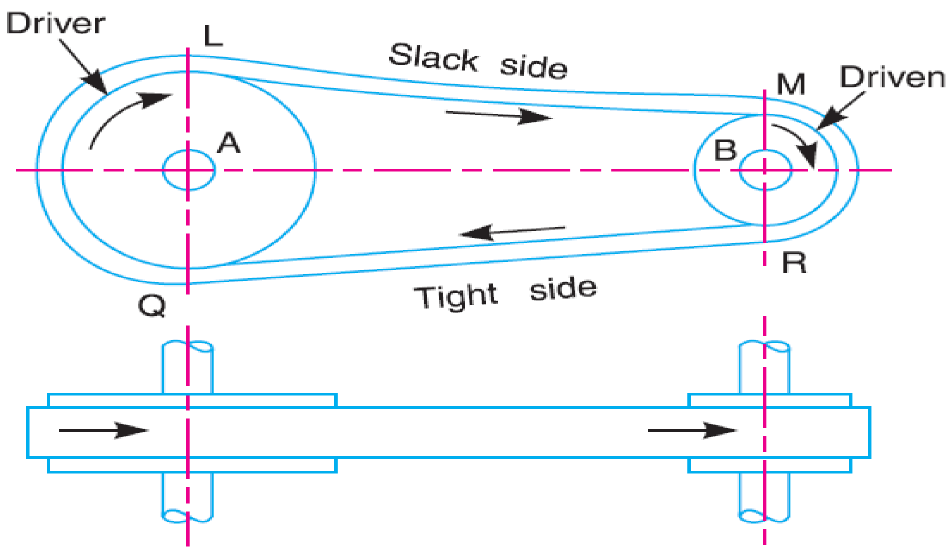
Types of Belts



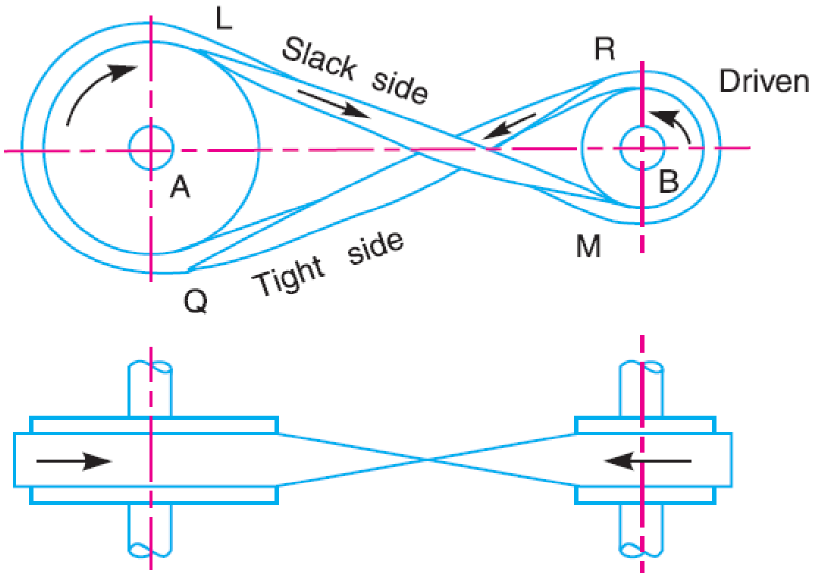
(*a*) Flat belt. (*b*) V-belt. (*c*) Circular belt.

TYPES OF FLAT BELT DRIVES

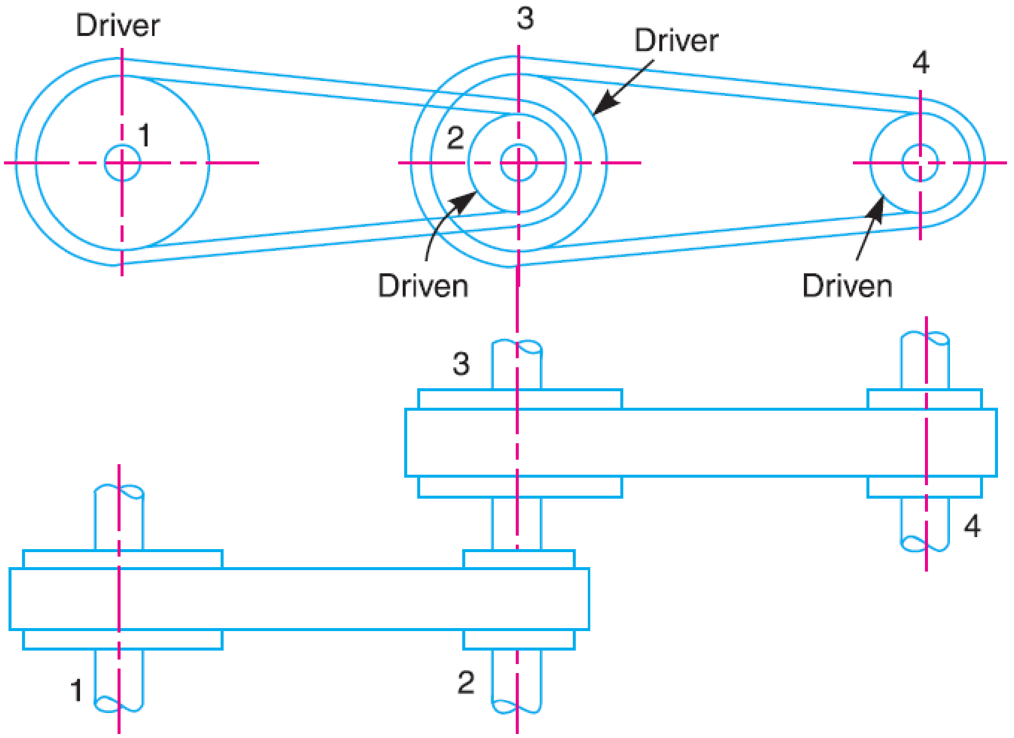
1. Open belt drive. The open belt drive, as shown in Fig., is used with shafts arranged parallel and rotating in the same direction. In this case, the driver *A pulls the belt from one side (i.e.*
lower side *RQ) and delivers it to the other side (i.e. upper side LM). Thus the tension in the lower side* belt will be more than that in the upper side belt. The lower side belt (because of more tension) is known as *tight side whereas the upper side belt (because of less tension) is known as slack side*



2. *Crossed or twist belt drive.* *The crossed or twist belt drive, as shown in Fig., is used* with shafts arranged parallel and rotating in the opposite directions.



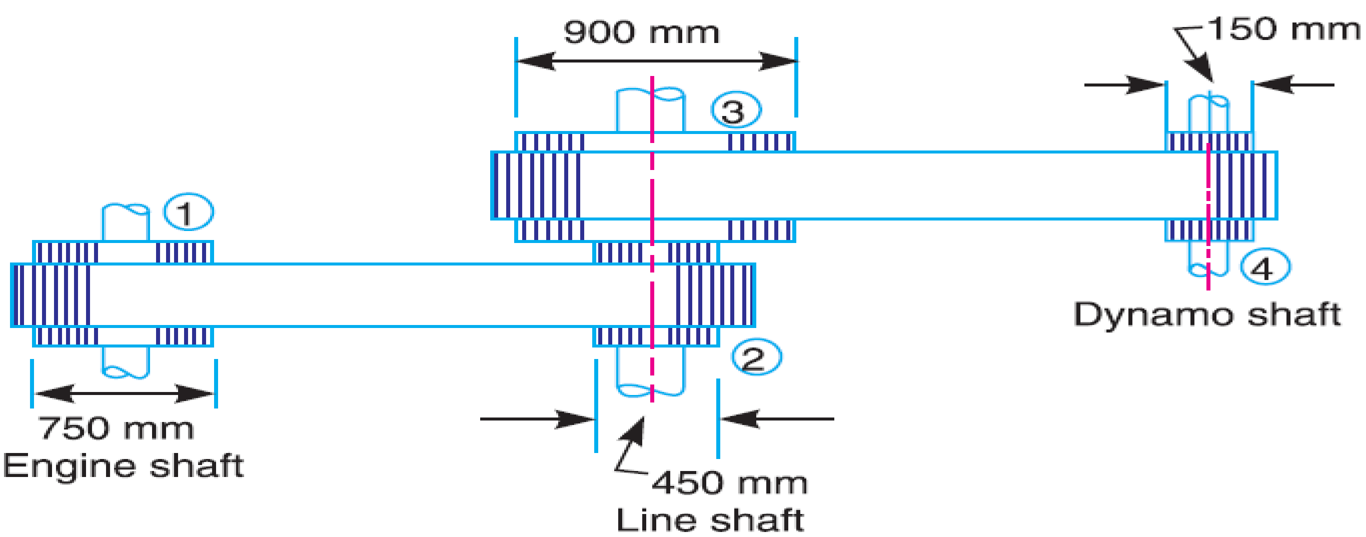
COMPOUND BELT DRIVE



SLIP OF BELT

The motion of belts and shafts assuming a firm frictional grip between the belts and the shafts. But sometimes, the frictional grip becomes insufficient. This may cause some forward motion of the driver without carrying the belt with it. This may also cause some forward motion of the belt without carrying the driven pulley with it. This is called ***slip of the belt and is generally expressed*** as a percentage.

An engine, running at 150 r.p.m., drives a line shaft by means of a belt. The engine pulley is 750 mm diameter and the pulley on the line shaft being 450 mm. A 900 mm diameter pulley on the line shaft drives a 150 mm diameter pulley keyed to a dynamo shaft. Find the speed of the dynamo shaft, when ***1. there is no slip, and 2. there is a slip of 2% at each drive.***



CREEP OF BELT

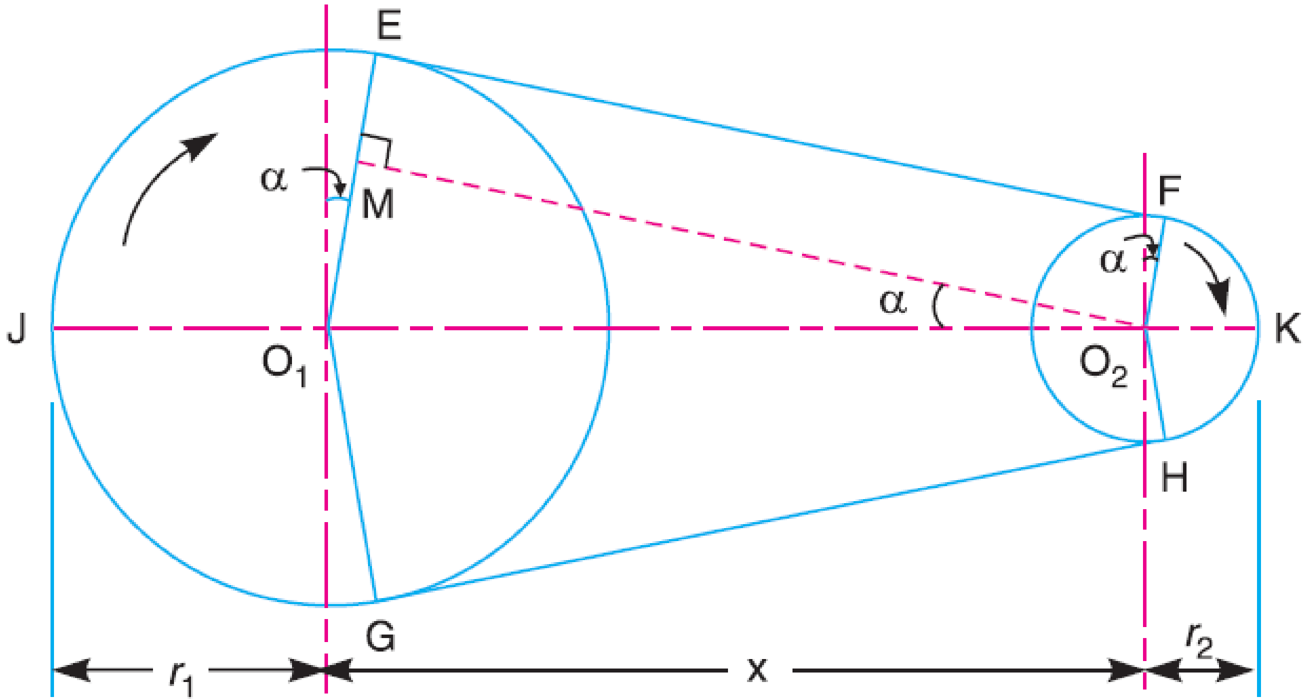
When the belt passes from the slack side to the tight side, a certain portion of the belt extends and it contracts again when the belt passes from the tight side to slack side. Due to these changes of length, there is a relative motion between the belt and the pulley surfaces. This relative motion is termed as ***creep. The total effect of creep is to reduce slightly the speed of the driven pulley or*** follower.

$$\frac{N_2}{N_1} = \frac{d_1}{d_2} \times \frac{E + \sqrt{\sigma_2}}{E + \sqrt{\sigma_1}}$$

where σ_1 and σ_2 = Stress in the belt on the tight and slack side respectively, and

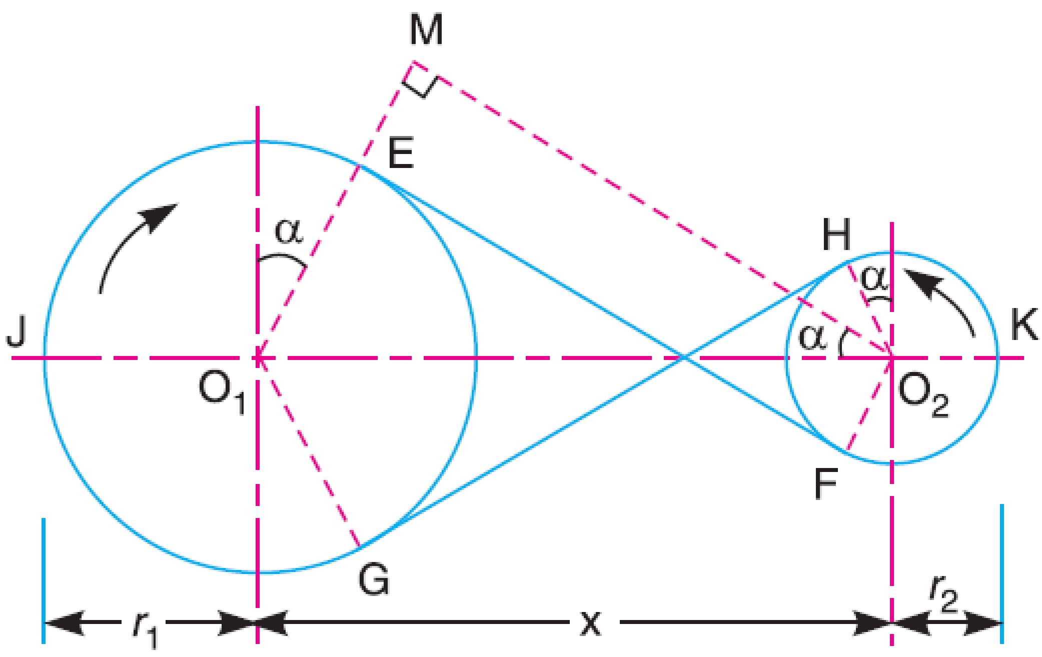
E = Young's modulus for the material of the belt.

LENGTH OF AN OPEN BELT DRIVE



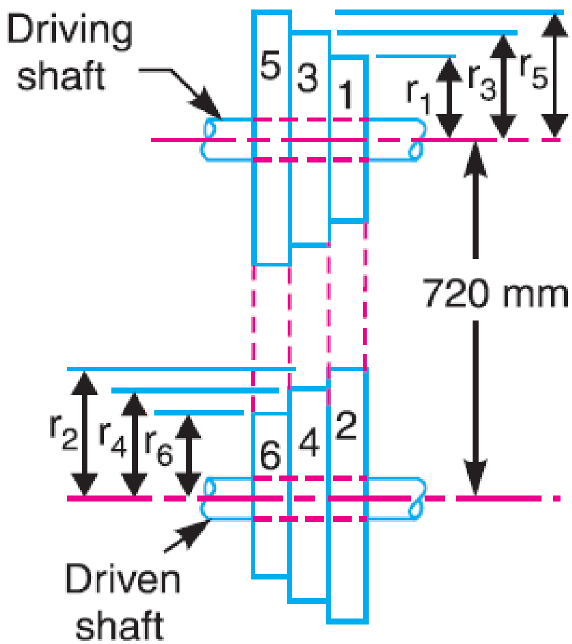
$$= \frac{\pi}{2}(d_1 + d_2) + 2x + \frac{(d_1 - d_2)^2}{4x}$$

LENGTH OF A CROSS BELT DRIVE

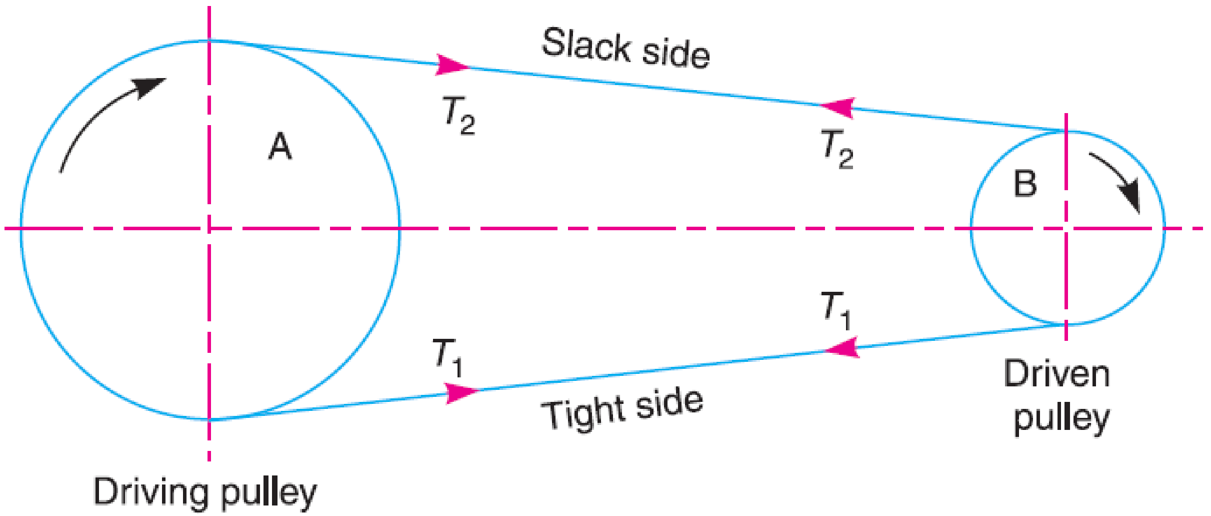


$$= \frac{\pi}{2}(d_1 + d_2) + 2x + \frac{(d_1 + d_2)^2}{4x}$$

A shaft which rotates at a constant speed of 160 r.p.m. is connected by belting to a parallel shaft 720 mm apart, which has to run at 60, 80 and 100 r.p.m. The smallest pulley on the driving shaft is 40 mm in radius. Determine the remaining radii of the two stepped pulleys for ***an open belt.*** *Neglect belt thickness and slip.*

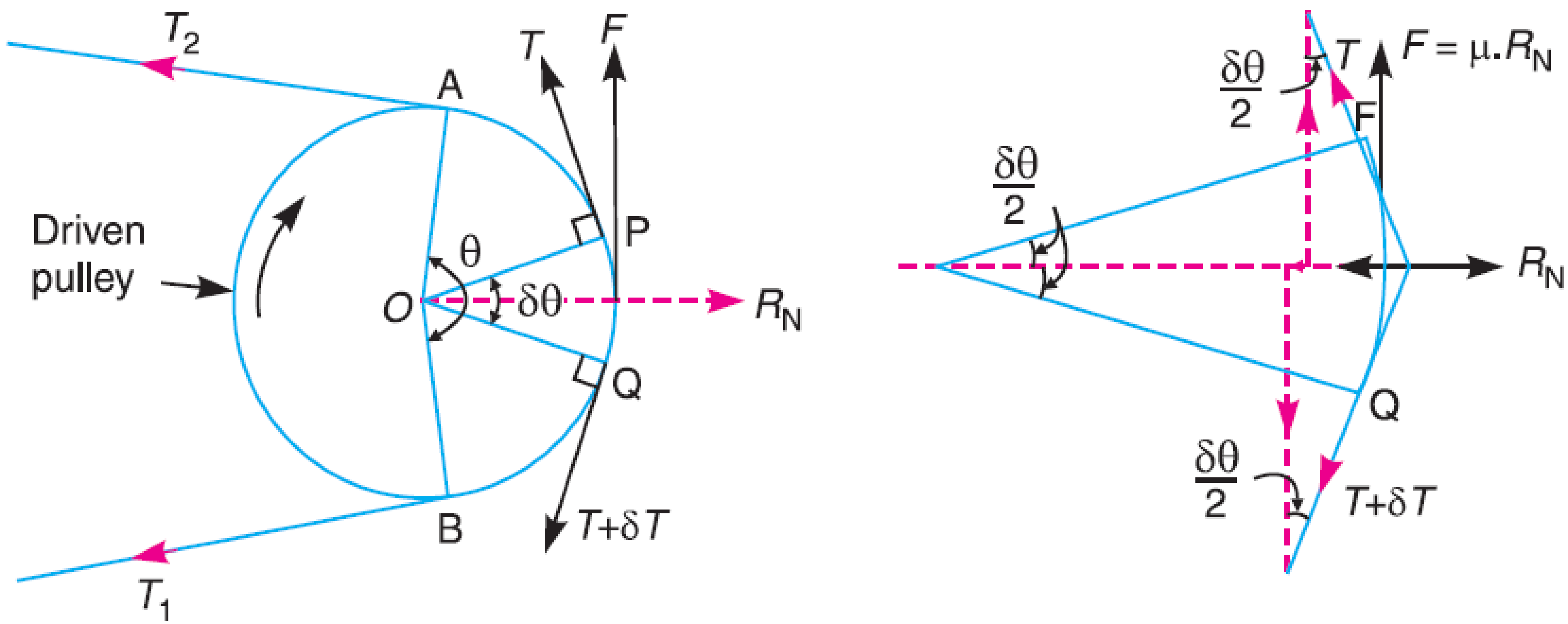


POWER TRANSMITTED BY A BELT



power transmitted, $P = (T_1 - T_2)\, v$

RATIO OF DRIVING TENSIONS FOR FLAT BELT DRIVE

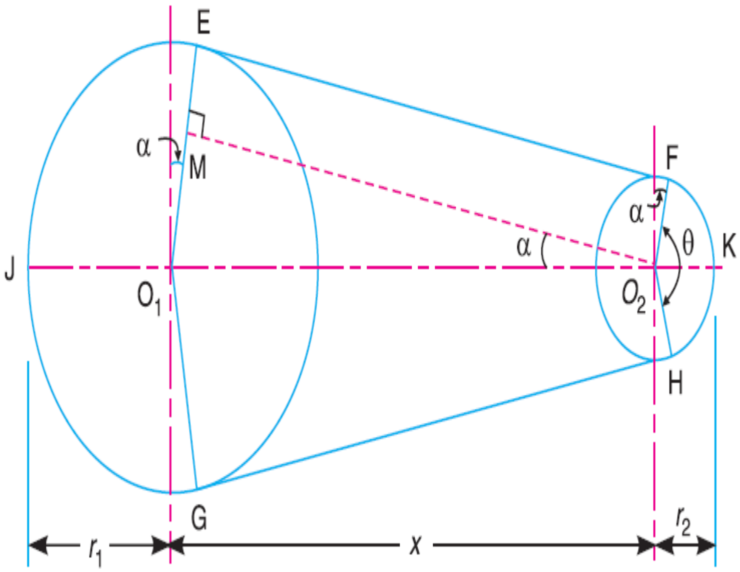


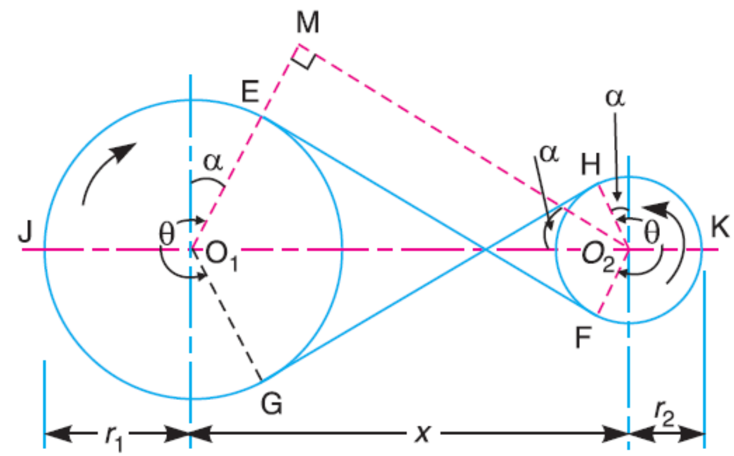
Let T_1 = Tension in the belt on the tight side,

T_2 = Tension in the belt on the slack side, and

θ = Angle of contact in radians (*i.e.* angle subtended by the arc AB, along which the belt touches the pulley at the centre).

DETERMINATION OF ANGLE OF CONTACT





$$\sin\alpha = \frac{O_1 M}{O_1 O_2} = \frac{O_1 E - ME}{O_1 O_2} = \frac{r_1 - r_2}{x}$$

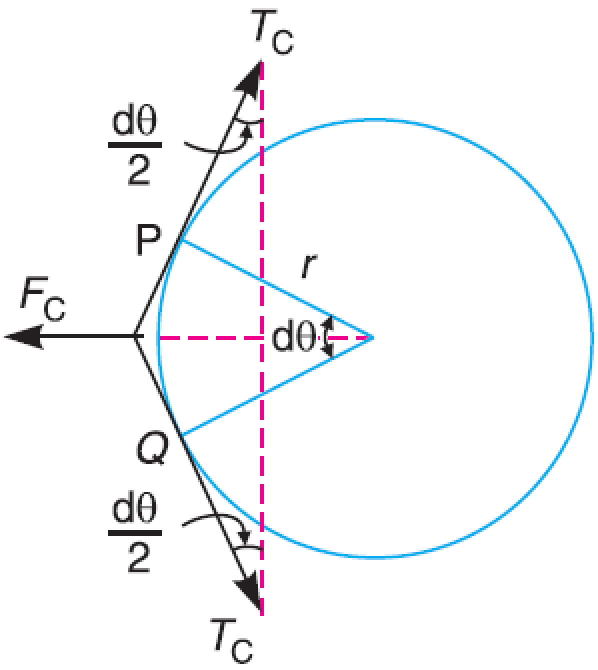
$$\sin\alpha = \frac{O_1 M}{O_1 O_2} = \frac{O_1 E + ME}{O_1 O_2} = \frac{r_1 + r_2}{x}$$

$\therefore$ Angle of contact or lap, $\theta = (180^\circ + 2\alpha)\dfrac{\pi}{180}$ rad

Two pulleys, one 450 mm diameter and the other 200 mm diameter are on parallel shafts 1.95 m apart and are connected by a crossed belt. Find the length of the belt required and the angle of contact between the belt and each pulley. What power can be transmitted by the belt when the larger pulley rotates at 200 rev/min, if the maximum permissible tension in the belt is 1 kN, and the coefficient of friction between the belt and pulley is 0.25 ?

CENTRIFUGAL TENSION

Since the belt continuously runs over the pulleys, therefore, some centrifugal force is caused, whose effect is to increase the tension on both, tight as well as the slack sides. The tension caused by centrifugal force is called ***centrifugal tension. At lower*** belt speeds (less than 10 m/s), the centrifugal tension is very small, but at higher belt speeds (more than 10 m/s), its effect is considerable and thus should be taken into account.



Let m = Mass of the belt per unit length in kg,

v = Linear velocity of the belt in m/s,

$$T_C = m \cdot v^2$$

$$2.3 \log\left(\frac{T_{t1} - T_C}{T_{t2} - T_C}\right) = \mu . \theta$$

$$T_{t1} = T_1 + T_C$$

T_{t1} = Maximum or total tension in the belt.

CONDITION FOR THE TRANSMISSION OF MAXIMUM POWER

$$P = (T_1 - T_2)\, v$$

T_1 = Tension in the tight side of the belt in newtons,

T_2 = Tension in the slack side of the belt in newtons, and

v = Velocity of the belt in m/s.

$$\frac{T_1}{T_2} = e^{\mu.\theta} \quad \text{or} \quad T_2 = \frac{T_1}{e^{\mu.\theta}}$$

When the power transmitted is maximum, 1/3rd of the maximum tension is absorbed as centrifugal tension.

Determine the width of a 9.75 mm thick leather belt required to transmit 15 kW from a motor running at 900 r.p.m. The diameter of the driving pulley of the motor is 300 mm. The driven pulley runs at 300 r.p.m. and the distance between the centre of two pulleys is 3 metres. The density of the leather is 1000 kg/m^3. The maximum allowable stress in the leather is 2.5 MPa. The coefficient of friction between the leather and pulley is 0.3. Assume open belt drive and neglect slip of the belt.

INITIAL TENSION IN THE BELT

When a belt is wound round the two pulleys (*i.e. driver and follower), its two ends are joined* together ; so that the belt may continuously move over the pulleys, since the motion of the belt from the driver and the follower is governed by a firm grip, due to friction between the belt and the pulleys. In order to increase this grip, the belt is tightened up. At this stage, even when the pulleys are stationary, the belt is subjected to some tension, called ***initial tension.***

the increase of tension in the tight side

$$= T_1 - T_0$$

decrease in tension in the slack side

$$= T_0 - T_2$$

$$\alpha (T_1 - T_0) = \alpha (T_0 - T_2)$$

$$T_0 = \frac{T_1 + T_2}{2} \quad = \frac{T_1 + T_2 + 2T_C}{2}$$

Considering centrifugal tension

T_0 = Initial tension in the belt,

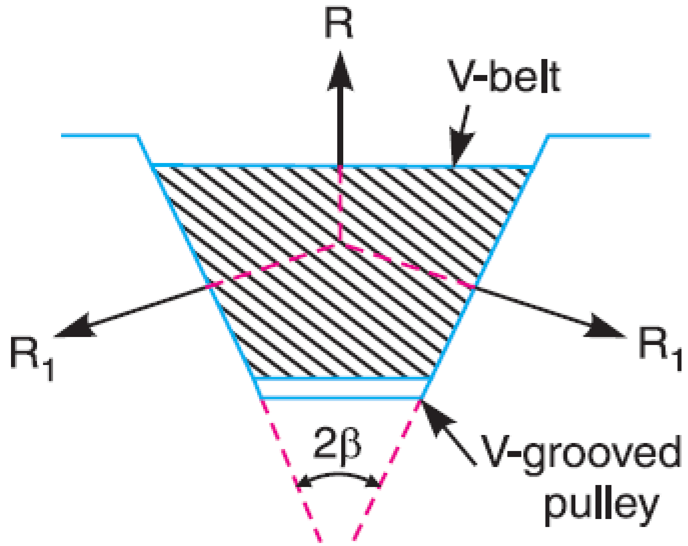
T_1 = Tension in the tight side of the belt,

T_2 = Tension in the slack side of the belt, and

α = Coefficient of increase of the belt length per unit force.

The following data refer to an open belt drive :
Diameter of larger pulley = 400 mm ; Diameter of smaller pulley = 250 mm ; Distance between two pulleys = 2 m ; Coefficient of friction between smaller pulley surface and belt = 0.4 ; Maximum tension when the belt is on the point of slipping = 1200 N.
Find the power transmitted at speed of 10 m/s. It is desired to increase the power. Which of the following two methods you will select ?
1. Increasing the initial tension in the belt by 10 per cent.
2. Increasing the coefficient of friction between the smaller pulley surface and belt by 10 per cent by the application of suitable dressing on the belt.
Find, also, the percentage increase in power possible in each case.

RATIO OF DRIVING TENSIONS FOR V-BELT



$$2.3 \log\left(\frac{T_1}{T_2}\right) = \mu . \theta \operatorname{cosec} \beta$$

A compressor, requiring 90 kW is to run at about 250 r.p.m. The drive is by V-belts from an electric motor running at 750 r.p.m. The diameter of the pulley on the compressor shaft must not be greater than 1 metre while the centre distance between the pulleys is limited to 1.75 metre. The belt speed should not exceed 1600 m/min. Determine the number of V-belts required to transmit the power if each belt has a crosssectional area of 375 mm^2, density 1000 kg/m^3 and an allowable tensile stress of 2.5 MPa. The groove angle of the pulley is 35°. The coefficient of friction between the belt and the pulley is 0.25.

Calculate also the length required of each belt.