Subject Name: **Theory of machines & mechanics**

Subject Code: **ME-3003**

Semester: **3rd**

Unit-VI

Belt Rope & Chain Drive : Types of Belts, Velocity ratio of a belt drive, Slip in belts, Length of open belt and crossed belt, Limiting ratio of belt-Tensions, Power transmitted by a belt, Centrifugal tension, Maximum tension in a belt, Condition for maximum power transmitted, Initial tension in a belt, Creep in belt, Applications of V-Belt, Rope and Chain drives.

Introduction

To transmit power from one shaft to another the belts or ropes are used 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 pulley.
4. The conditions under which the belt is used. It may be noted that
(a) The shafts should be properly in line to ensure uniform tension across the belt section.
(b) The arc of contact on the smaller pulley may be as large as possible for that the pulleys should not be too close together
(c) The pulleys should not be so far apart as to cause the belt to weigh heavily on the shafts, thus increasing the friction load on the bearings
(d) The belt to run out of the pulleys caused due to the long belt tends to swing from side to side, which in turn develops crooked spots in the belt.
(e) The tight side of the belt should be at the bottom so that whatever sag is present on the loose side will increase the arc of contact at the pulleys.
(f) The maximum distance between the shafts should not exceed 10 meters and the minimum should not be less than 3.5 times the diameter of the larger pulley in order to obtain good results with flat belts.

Selection of a Belt Drive

The selection of belt drives depends on the following important factors:

1. Speed of the driving and driven shafts,
2. Speed reduction ratio,
3. Power to be transmitted,
4. Centre distance between the shafts,
5. Positive drive requirements,
6. Shafts layout,
7. Space available, and
8. Service conditions.

Types of Belt Drives

The belt drives are classified into the following three groups:

1. Light drives: To transmit small powers (at belt speeds up to about 10 m/s) light drives are used, as in agricultural machines and small machine tools.
2. Medium drives. To transmit medium power (at belt speeds over 10 m/s but up to 22 m/s) medium drives are used, as in machine tools.
3. Heavy drives. To transmit large powers (at belt speeds above 22 m/s) heavy drives are used, as in compressors and generators.

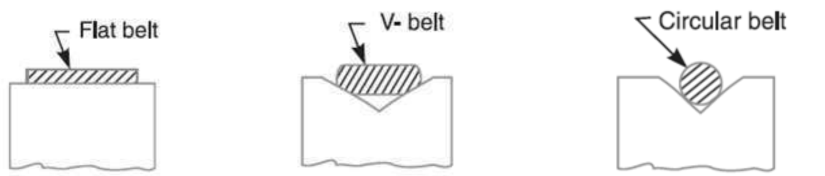
Types of Belts

There are many types of belts used these days, the following are important:

1. Flat belt. The flat belt, as shown in Fig. 6.1 (a), is mostly used in the factories and workshops, where a moderate amount of power is to be transmitted, from one pulley to another when the two pulleys are not more than 8 meters apart.

2. V-belt. The V-belt, as shown in Fig. 6.1 (b), is mostly used in the factories and workshops, where a moderate amount of power is to be transmitted, from one pulley to another, when the two pulleys are very near to each other.

3. Circular belt or rope. The rope or circular belt, as shown in Fig. 6.1 (c), is mostly used in the factories and workshops, where a great amount of power is to be transmitted, from one pulley to another, when the two pulleys are more than 8 meters apart.



(a) Flat Belt (b) V- Belt (c) Circular Belt

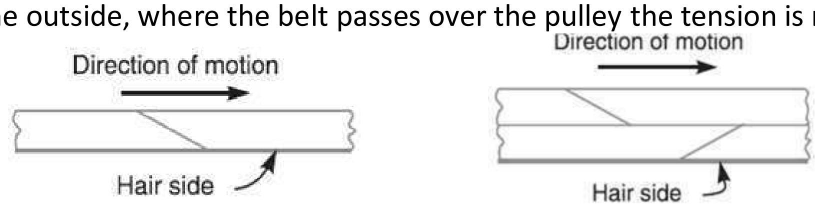
Fig. 6.1 Types of belts

For transmitting a huge amount of power a single belt may not be sufficient. Wide pulleys (for V-belts or circular belts) with a number of grooves are used to transmit a huge amount of power.

Material used for Belts

The material used for belts and ropes must be strong, flexible, and durable. It must have a high coefficient of friction. The belts, according to the material used, are classified as follows:

1. Leather belts. The most important material for the belt is leather. The best leather belts are made from 1.2 meters to 1.5 meters long strips cut from either side of the backbone of the top grade steer hides. In leather, the hair side is smoother and harder than the flesh side, but the flesh side is stronger. The fibres on the hair side are perpendicular to the surface, while those on the flesh side are interwoven and parallel to the surface. Therefore for these reasons, the hair side of a belt should be in contact with the pulley surface, as shown in Fig. 6.2. This gives a more intimate contact between the belt and the pulley and places the greatest tensile strength of the belt section on the outside, where the belt passes over the pulley the tension is maximum.



(a) Single Layer Belt (b) Double Layer Belt

Fig. 6.2 Leather belts

The leather may be either oak-tanned or mineral salt tanned e.g. chrome tanned. In order to increase the thickness of the belt, the strips are cemented together. The belts are specified according to the number of layers used e.g. single, double or triple ply and according to the thickness of hides used e.g. light, medium or heavy. These belts must be cleaned periodically and treated with a compound or dressing containing neat foot or other suitable oils so that the belt will remain soft and flexible.

2. Cotton or fabric belts. By folding canvass or cotton duck to three or more layers (depending on the thickness desired) and stitching together fabric belts are made. Cotton or fabric belts are woven also into a strip of the desired width and thickness. To make the belts waterproof and to prevent injury to the fibres, they are impregnated with some filler like linseed oil. These belts are cheaper and much more suitable in warm climates, in damp atmospheres and in exposed positions. Cotton belts are mostly used in farm machinery, belt conveyor etc as they require little attention.

3. Rubber belt. Rubber belts are made up of layers of fabric impregnated with rubber composition and have a thin layer of rubber on the faces. These belts are very flexible but are quickly destroyed if allowed to come into contact with heat, oil or grease. The principal advantages of these belts are that they may be easily made endless. These belts are found suitable for sawmills, paper mills where they are exposed to moisture.

4. Balata belts. Balata gum is used in these belts otherwise these belts are similar to rubber belts. Balata belts are acid proof as well as waterproof and it is not affected by animal oils or alkalis. These belts should not be used at temperatures above 40° C because at this temperature the balata begins to soften and becomes sticky. The balata belts are having 25 percent higher strength than the rubber belts.

Types of Flat Belt Drives

The power from one pulley to another may be transmitted by any of the following types of belt drives:

1. Open belt drive. The open belt drive, as shown in Fig. 6.3, 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 on 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 a **slack side**, as shown in Fig. 6.3.

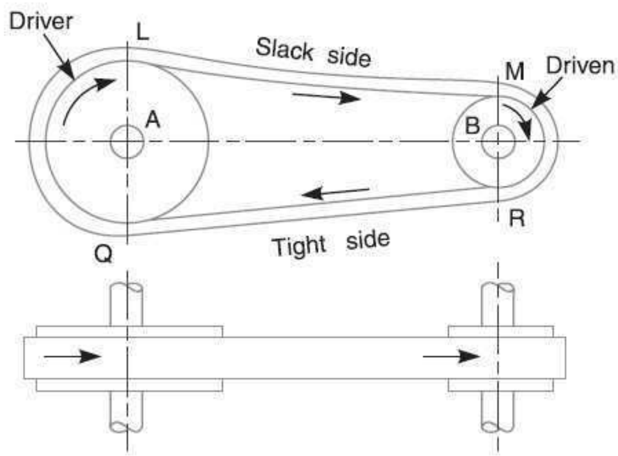


Fig. 6.3 Open belt drive

2. Crossed or twist belt drive. The crossed or twist belt drive, as shown in Fig. 6.4, is used with shafts arranged parallel and rotating in the opposite directions.

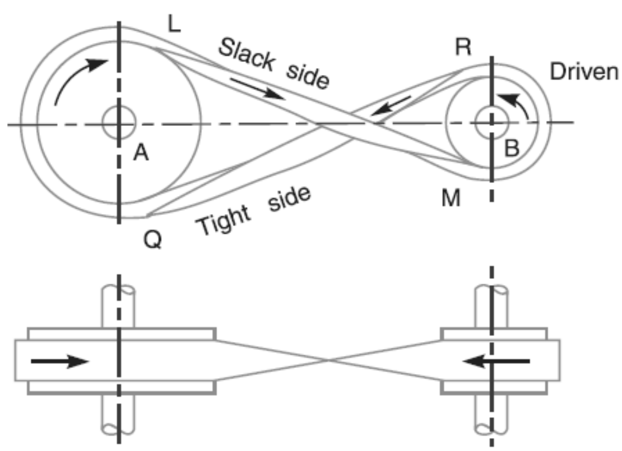
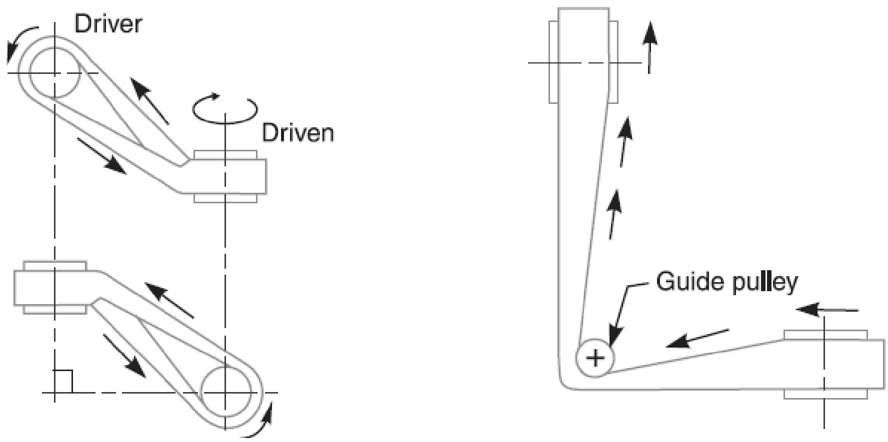


Fig. 6.4 Crossed or twist belt drive

In crossed belt drive the driver pulls the belt from RQ side and delivers it to the LM side. Thus the tension in the side RQ will be more than that in the side LM. The belt RQ (because of more tension) is known as a **tight side,** whereas the belt LM (because of less tension) is known as a **slack side**, as shown in Fig. 6.4.

Here let us consider that at a point where the belt crosses, it rubs against each other and there will be excessive wear and tear. In order to avoid this, the shafts should be placed at a maximum distance of 20 b, where b is the width of the belt and the speed of the belt should be less than 15 m/s.

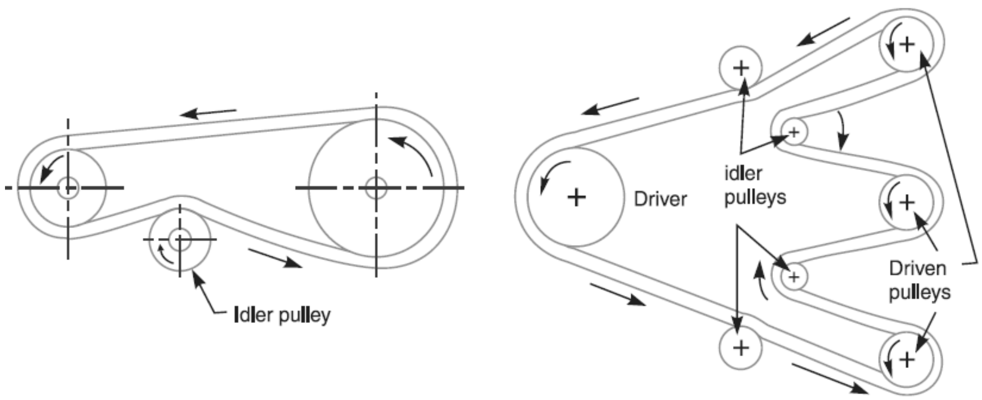
3. Quarter turn belt drive. The quarter turn belt drives also known as right angle belt drive, as shown in Fig. 6.5 (a), is used when the shafts are arranged at right angles and rotating in one definite direction. The width of the face of the pulley should be greater or equal to 1.4 b to prevent the belt from leaving the pulley, where b is the width of the belt.
When the pulleys are not arranged, as shown in Fig. 6.5 (a), or when the reversible motion is desired, then a **quarter turn belt drive with guide pulley**, as shown in Fig. 6.5 (b), may be used.



(a) Quarter turn belt drive (b) Quarter turn belt drive with guide pulley

Fig. 6.5 Quarter Turn Belt Drive

4. Belt drive with idler pulleys. A belt drives with an idler pulley, as shown in Fig. 6.6 (a), is used with shafts arranged parallel and when an open belt drive cannot be used due to the small angle of contact on the smaller pulley. To obtain high-velocity ratio and when the required belt tension cannot be obtained by other means belt drives with idler pulleys are used.



(a) Belt drive with single idler pulley (b) Belt drive with many idler pulleys

Fig. 6.6 Belt Drive with Idler Pulleys

When one has to transmit motion from one shaft to several numbers of shafts, all arranged in parallel, a belt drive with many idler pulleys, as shown in Fig. 6.6 (b), may be employed.

5. Compound belt drive. A compound belt drive, as shown in Fig. 6.7, is used when power is transmitted from one shaft to another through a number of pulleys.

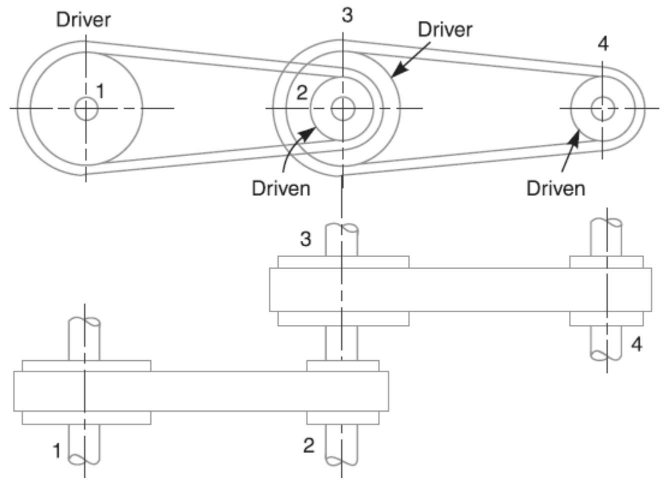


Fig. 6.7 Compound belt drive

6. Stepped or cone pulley drive. A stepped or cone pulley drive (Fig. 6.8) is used for changing the speed of the driven shaft while the main or driving shaft runs at constant speed. This is accomplished by shifting the belt from one part of the steps to the other.

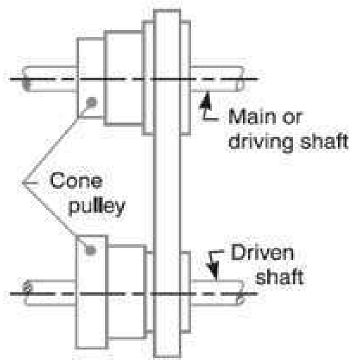


Fig. 6.8 Stepped or cone pulley drive

7. Fast and loose pulley drive. A fast and loose pulley drive, as shown in Fig. 6.9, is used when the driven or machine shaft is to be started or stopped whenever desired without interfering with the driving shaft. The fast pulley is keyed to the machine shaft and runs at the same speed as that of machine shaft. A loose pulley runs freely over the machine shaft and is incapable of transmitting any power. When the driven shaft is required to be stopped, the belt is pushed onto the loose pulley by means of a sliding bar having belt forks.

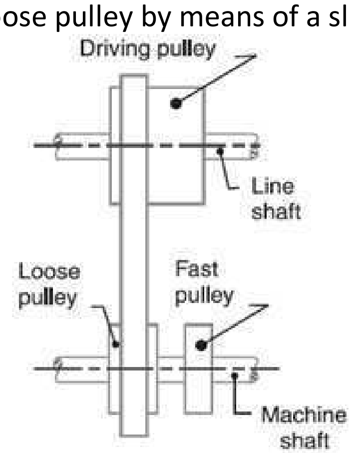


Fig. 6.9 Fast and loose pulley drive

Velocity Ratio of Belt Drive

The ratio between the velocities of the driver and the follower or driven is known as the velocity ratio of belt drives**.** It may be expressed, mathematically, as discussed below:

Let d1 = Diameter of the driver,

d2 = Diameter of the follower,

N1 = Speed of the driver in r.p.m., and

N2 = Speed of the follower in r.p.m.

∴ Length of the belt that passes per minute over the driver = $\pi\, d_1.N_1$

Similarly, length of the belt that passes over the follower, in one minute = $\pi\, d_2.\, N_2$

Since the length of belt that passes over the driver in one minute = the length of belt that passes over the follower in one minute, therefore

$\pi\, d_1.N_1 = \pi\, d_2.\, N_2$

∴ Velocity ratio,

$N_2 / N_1 = d_1 / d_2$

When the thickness of the belt (t) is considered, then velocity ratio,

$N_2 / N_1 = d_1 + t / d_2 + t$

Slip of Belt

We know that 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 movement of the belt without carrying the driven pulley with it. This is called **slip of the belt** and is generally expressed as a percentage.

The result of the belt slipping is to reduce the velocity ratio of the system. As we know that the most common phenomena are the slipping of the belt, thus the belt should never be used where a definite velocity ratio is of importance (as in the case of the hour, minute and second arms in a watch).

Let s1 % = Slip between the driver and the belt, and

s2 % = Slip between the belt and the follower.

∴ Velocity of the belt passing over the driver per second

$v = \pi.\, d_1.\, N_1 / 60 - \pi.\, d_1.\, N_1 / 60 \times s_1/100 = \pi.\, d_1.\, N_1 / 60\ (1 - s_1/100)$

and velocity of the belt passing over the follower per second,

$\pi\, d_2.\, N_2/60 = v - v \times s_2/100 = v\ (1 - s_2/100)$

Substituting the value of v from equation,

$\pi\, d_2.\, N_2/60 = \pi.\, d_1.\, N_1 / 60\ (1 - s_1/100)\ (1 - s_2/100)$

$N_2/N_1 = d_1/d_2\ (1 - s_1/100 - s_2/100)$

$N_2/N_1 = d_1/d_2\ [1 - (s_1 + s_2)/100] = = d_1/d_2\ (1 - s/100)$

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

$N_2/N_1 = d_1 + t/d_2 + t\ (1 - s/100)$

Length of Open Belt Drive

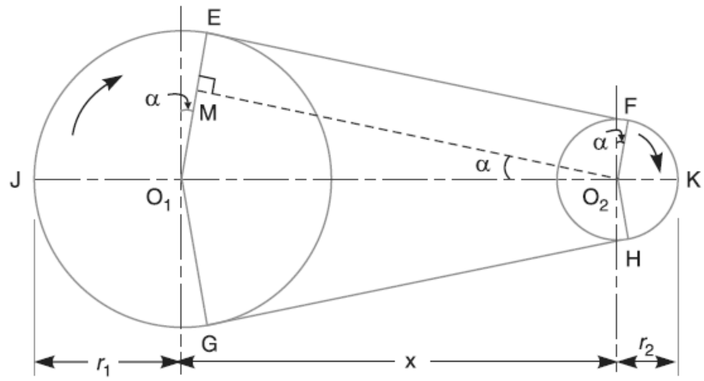


Fig. 6.10 Length of an open belt drive

In an open belt drive, both the pulleys rotate in the **same** direction as shown in Fig. 6.10.
Let r_1 and r_2 are the radii of the larger and smaller pulleys,
x = Distance between the centres of two pulleys (i.e. $O_1 O_2$), and
L = Total length of the belt.
Let the belt leaves the larger pulley at E and G and the smaller pulley at F and H as shown in Fig. 6.10. Through O_2, draw $O_2 M$ parallel to FE.
From the geometry of the fig. 6.10, we find that $O_2 M$ will be perpendicular to $O_1 E$.
Let the angle $MO_2 O_1$ will be equal to α radians
We know that the length of the belt,
L = Arc GJE + EF + Arc FKH + HG = 2 (Arc JE + EF + Arc FK) ... (i)
From the geometry of the figure, we find that
$\sin \alpha = O_1M/O_1O_2 = (O_1E - EM) / O_1O_2 = (r_1 - r_2)/x$
Since α is very small, therefore putting
$\sin \alpha = \alpha$ (in radians) = $r_1 - r_2 / x$ ... (ii)
∴ Arc JE = $r_1 (\pi/2 + \alpha)$ ... (iii)
Similarly Arc FK = $r_2 (\pi/2 - \alpha)$ ... (iv)
$EF = MO_2 = [(O_1O_2)^2 - (O_1M)^2]^{1/2} = [x^2 - (r_1 - r_2)^2]^{1/2}$
$EF = x [1 - \{(r_1 - r_2)/x\}^2]^{1/2}$
Expanding this equation by binomial theorem,
$EF = x [1 - ½ \{(r1 - r_2)/x\}^2 + \ldots\ldots] = x - (r_1 - r_2)^2/2x$ ... (v)
Substituting the values of arc JE from equation (ii), arc FK from equation (iii), and EF from equation (v), in equation (i), we get
$L = 2[r_1 (\pi/2 + \alpha) + x - (r_1 - r_2)^2/2x + r_2 (\pi/2 - \alpha)]$
On solving above expression we get,
$L = \pi (r_1 + r_2) + 2\alpha (r_1 - r_2) + 2x - (r_1 - r_2)^2/x$
Substituting the value of $\alpha = r_1 - r_2 / x$ from above said equation,
$L = \pi (r_1 + r_2) + 2(r_1 - r_2) (r_1 - r_2)/x + 2x - (r_1 - r_2)^2/x$
On solving above expression we get,
$L = \pi (r_1 + r_2) + 2x + (r_1 - r_2)^2/x$

Length of a Cross Belt Drive

In a cross belt drive, both the pulleys rotate in **opposite** directions as shown in Fig. 6.11.

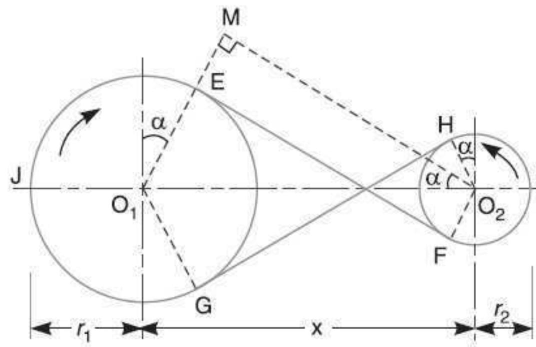


Fig. 6.11 Length of a cross belt drive

Let r_1 and r_2 are the radii of the larger and smaller pulleys,

x = Distance between the centres of two pulleys (i.e. $O_1 O_2$), and

L = Total length of the belt.

Let the belt leaves the larger pulley at E and G and the smaller pulley at F and H, as shown in Fig. 6.11. Through O_2, draw an O_2M parallel to FE.

From the geometry of the figure, we find that O_2M will be perpendicular to O_1E.

Let the angle $MO_2 O_1 = \alpha$ radians.

We know that the length of the belt,

$L = \text{Arc } GJE + EF + \text{Arc } FKH + HG = 2 (\text{Arc } JE + EF + \text{Arc } FK)$ ... (i)

From the geometry of the figure, we find that

$\sin \alpha = O_1M/O_1O_2 = (O_1E + EM) / O_1O_2 = (r_1 + r_2)/x$

$\sin \alpha = \alpha$ (in radians) $= r_1 + r_2 / x$ ... (ii)

$\therefore$ Arc $JE = r_1 (\pi/2 + \alpha)$ ... (iii)

Similarly Arc $FK = r_2 (\pi/2 + \alpha)$ ... (iv)

$EF = MO_2 = [(O_1O_2)^2 - (O_1M)^2]^{1/2} = [x^2 - (r_1 - r_2)^2]^{1/2}$

$EF = x [1 - \{(r_1 - r_2)/x\}^2]^{1/2}$

Expanding this equation by binomial theorem,

$EF = x [1 - ½ \{(r_1 + r_2)/x\}^2 + \ldots\ldots.] = x - (r_1 + r_2)^2/2x$ ... (v)

Substituting the values of arc JE from equation (iii), arc FK from equation (iv) and EF from equation (v) in equation (i), we get

$L = 2[r_1 (\pi/2 + \alpha) + x - (r_1 + r_2)^2/2x + r_2 (\pi/2 + \alpha)]$

On solving above expression we get,

$L = \pi (r_1 + r_2) + 2\alpha (r_1 + r_2) + 2x - (r_1 + r_2)^2/x$

Substituting the value of $\alpha = r_1 + r_2 / x$ from equation,

$L = \pi (r_1 + r_2) + 2(r_1 + r_2) (r_1 + r_2)/x + 2x - (r_1 + r_2)^2/x$

On solving above expression we get,

$L = \pi (r_1 + r_2) + 2x + (r_1 + r_2)^2/x$

It may be noted that the above expression is a function of $(r_1 + r_2)$. It is thus obvious that if the sum of the radii of the two pulleys is constant, the length of the belt required will also remain constant, provided the distance between centres of the pulleys remain unchanged.

Power Transmitted by a Belt

Fig. 6.12 shows the driving pulley (or driver) A and the driven pulley (or follower) B. We know that the driving pulley pulls the belt from one side and delivers the same to the other side. Thus it is obvious that the tension on the former side (i.e. tight side) will be greater than the latter side (i.e. slack side) as shown in Fig. 6.12.

Let T_1 and T_2 = Tensions in the tight and slack side of the belt respectively in Newton,

r_1 and r_2 are the radii of the driver and follower respectively, and
v = Velocity of the belt in m/s.

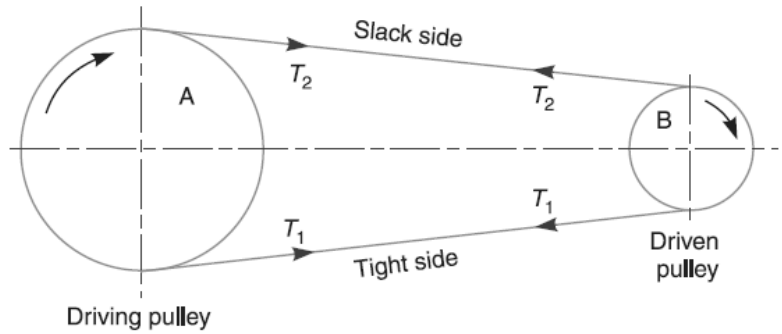


Fig. 6.12 Power transmitted by a belt

The effective turning (driving) force at the circumference of the follower is the difference between the two tensions (i.e. $T_1 – T_2$).
∴ Work done per second = $(T_1 – T_2)$ v N-m/s
And the power transmitted will be, P = $(T_1 – T_2)$ v W ... (∵ 1 N-m/s = 1 W)
Let us consider that the torque exerted on the driving pulley is $(T_1 – T_2) r_1$.
Similarly, the torque exerted on the driven pulley i.e. follower is $(T_1 – T_2) r_2$.

Ratio of Driving Tensions for Flat Belt Drive
Consider a driven pulley rotating in the clockwise direction as shown in Fig. 6.13.
Let T_1 will be the Tension in the belt on the tight side and T_2 will be the Tension in the belt on the slack side,

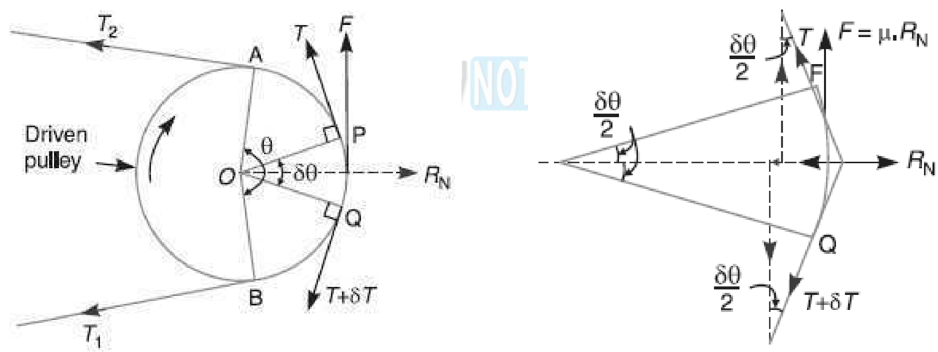


Fig. 6.13 Ratio of driving tensions for flat belt

θ = Angle of contact in radians
Now consider a small portion of the belt PQ, subtending an angle δθ at the centre of the pulley as shown in Fig. 6.13. Under the following forces the belt PQ is in equilibrium:
1. Tension T in the belt at P,
2. Tension (T + δ T) in the belt at Q,
3. Normal reaction RN, and
4. Frictional force, F = μ × RN, where μ is the coefficient of friction between the belt and pulley.
Resolving all the forces horizontally and equating the same,
$R_N = (T + \delta T) \sin \delta\theta/2 + T \sin \delta\theta/2$ ... (i)
As we know that the angle δθ is too small, therefore putting sin δθ / 2 = δθ / 2 in equation (i),
$R_N = = (T + \delta T) \delta\theta/2 + T \delta\theta/2 = T \delta\theta/2 + \delta T \delta\theta/2 + T \delta\theta/2 = T \delta\theta/2$ ... (ii)
... (Neglecting δT δθ/2)

Now resolving the forces vertically, we have
$\mu \times R_N = (T + \delta T) \cos \delta\theta/2 - T \cos \delta\theta/2$ ... (iii)
As we know that the angle δθ is too small, therefore putting cos δθ / 2 = 1 in equation (iii),

$\mu \times R_N = T + \delta T - T$ or $RN = \delta T/\mu$ ... (iv)

Equating the values of RN from equations (ii) and (iv),

$T\, \delta\theta/2 = \delta T/\mu$ or $\delta T/T = \mu.\, \delta\theta$

Integrating both sides between the limits T2 and T1 and from 0 to θ respectively,

$_{T2}\int^{T1} \delta T/T = \mu.\, _{\theta}\int^{\theta} \delta\theta$ or $\log_e (T_1/T_2) = \mu.\, \theta$ or $T_1/T_2 = e^{\mu\theta}$ ...(v)

Equation (v) can be expressed in terms of corresponding logarithm to the base 10, i.e.

$2.3 \log (T_1/T_2) = \mu.\, \theta$

The above expression gives the relation between the tensions of tight side and slack side, in terms of coefficient of friction and the angle of contact.

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. Centrifugal tension is the tension caused by centrifugal force. 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.

Consider a small portion PQ of the belt subtending an angle dθ the centre of the pulley as shown in Fig. 6.13.

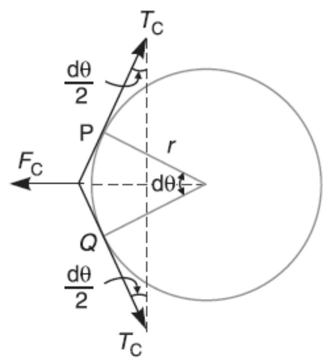


Fig. 6.14 Centrifugal Tension

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

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

r = Radius of the pulley over which the belt runs in meters, and

TC = Centrifugal tension acting tangentially at P and Q in Newton.

We know that length of the belt PQ = r. dθ

And the mass of the belt PQ = m. r. dθ

∴ Centrifugal force acting on the belt PQ,

$F_C = (m.\, r.\, d\theta)\, v^2/r = m.\, d\theta.\, v^2$

The centrifugal tension TC acting tangentially at P and Q keeps the belt in equilibrium.

Now resolving the forces (i.e. centrifugal force and centrifugal tension) horizontally and equating the same, we have

$T_C \sin (d\theta/2) + T_C \sin (d\theta/2) = F_C = m.\, d\theta.\, v^2$

Since the angle dθ is very small, therefore, putting sin (dθ/2) = dθ / 2 in the above expression,

$2T_C \sin (d\theta/2) = m.\, d\theta.\, v^2$ Or $TC = m.\, v^2$

Maximum Tension in the Belt

A little consideration will show that the maximum tension in the belt (T) is equal to the total tension on the tight side of the belt (T_{t1}).

Let σ will be the maximum safe stress in N/mm^2,

b will be the width of the belt in mm, and

t will be the thickness of the belt in mm.

We know that maximum tension in the belt,

T = Maximum stress × cross-sectional area of belt = σ. b. t
When centrifugal tension is neglected, then
T (or T_{t1}) = T_1, i.e. Tension on the tight side of the belt
And when centrifugal tension is considered, then
T (or T_{t1}) = $T_1 + T_C$

Condition for the Transmission of Maximum Power

The power transmitted by a belt,
$P = (T_1 - T_2)\ v$ ... (i)
Where T_1 = Tension on the tight side of the belt in Newton,
T_2 = Tension on the slack side of the belt in Newton, and
v = Velocity of the belt in m/s.
The ratio of driving tensions is
$T_1 / T_2 = e^{\mu\theta}$ or $T_2 = T_1 / e^{\mu\theta}$ ... (ii)
Substituting the value of T_2 in equation (i),
$P = [T_1 - (T_1/e^{\pi\theta})]\ v = T_1\ [1 - (1/e^{\pi\theta})]\ v = T_1.\ v.\ C$ ... (iii)
Where $C = 1 - 1 / e^{\mu\theta}$
We know that $T_1 = T - T_C$
Where T = Maximum tension to which the belt can be subjected in Newton, and
T_C = Centrifugal tension in Newton.
Substituting the value of T_1 in equation (iii),
$P = (T - T_C)\ v.\ C$
$= (T - m.v^2)\ v.\ C = (T.\ v - m\ v^3)\ C$ ... (Substituting $TC = m.\ v^2$)
For maximum power, differentiate the above expression with respect to v and equate to zero, i.e.
$dP / dv = 0$ or $d/dv\ (T.\ v - m\ v^3)\ C = 0$
$\therefore T - 3\ m\ .\ v^2 = 0$
Or $T - 3\ T_C = 0$ or $T = 3\ T_C$ ... (iv)
It shows that when the power transmitted is maximum, 1⁄3rd of the maximum tension is absorbed as centrifugal tension.

Initial Tension in the Belt

When a belt is wound around 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 the 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**.
When the driver pulls the belt from one side (increasing tension in the belt on this side) and delivers it to the other side (decreasing the tension in the belt on that side). The increased tension on one side of the belt is called tension on the tight side and the decreased tension on the other side of the belt is called tension on the slack side.
Let T_0 = Initial tension in the belt,
T_1 = Tension on the tight side of the belt,
T_2 = Tension on the slack side of the belt, and
α = Coefficient of increase of the belt length per unit force.
A little consideration will show that the increase of tension on the tight side = $T_1 - T_0$
and increase in the length of the belt on the tight side = $\alpha\ (T_1 - T_0)$ ... (i)
Similarly, the decrease in tension of the slack side = $T_0 - T_2$
and decrease in the length of the belt on the slack side = $\alpha\ (T_0 - T_2)$ ... (ii)
Now let us assume that the belt is made up of perfectly elastic material such that the length of the belt remains constant, when it is at rest or in motion, therefore increase in length on the tight side is equal to

decrease in the length on the slack side. Thus, equating equations (i) and (ii),

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

$T_0 = (T_1 + T_2) / 2$ ... (Neglecting centrifugal tension)

$T_0 = (T_1 + T_2 + 2T_C) / 2$ ... (Considering centrifugal tension)

Creep of Belt

A certain portion of the belt extends when the belt passes from the slack side to the tight side 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 a **creep.** The speed of the driven pulley or follower is slightly reduced due to the total effect of creep. Considering creep, the velocity ratio is given by

$N_2/N_1 = d_1/d_2 \text{ X } [E + (\sigma_2)^{1/2}] / [E + (\sigma_1)^{1/2}$

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

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

Advantages and Disadvantages of V-belt Drive over Flat Belt Drive

Following are the advantages and disadvantages of the V-belt drive over a flat belt drive.

Advantages

1. The V-belt drive gives compactness due to the small distance between the centres of pulleys.
2. The slip between the belt and the pulley groove is negligible thus the drive is positive.
3. Since the V-belts are made endless and there is no joint trouble, therefore the drive is smooth.
4. It provides longer life, 3 to 5 years.
5. These are easy to install and remove.
6. The operations of the belt and pulley are quiet.
7. The belts have the ability to cushion the shock when machines are started.
8. The high-velocity ratio (maximum 10) may be obtained.
9. The wedging action of the belt in the groove gives a high value of limiting ratio of tensions. Therefore the power transmitted by V-belts is more than flat belts for the same coefficient of friction, arc of contact and allowable tension in the belts.
10. The V-belt may be operated in either direction with a tight side of the belt at the top or bottom. The centre line may be horizontal, vertical or inclined.

Disadvantages

1. The V-belt drive cannot be used with large centre distances.
2. The V-belts are not so durable as flat belts.
3. The construction of V-grooved pulleys for V-belts is more complicated than flat belt pulleys.
4. Since the V-belts are subjected to a certain amount of creep, therefore these are not suitable for constant speed application such as synchronous machines, and timing devices.
5. The belt life is greatly influenced by temperature changes, improper belt tension and mismatching of belt lengths.
6. The centrifugal tension prevents the use of V-belts at speeds below 5 m/s and above 50m/s.

Advantages of Rope Drives

The fibre rope drives have the following advantages:

1. They offer smooth, steady and quiet service.
2. They are not much affected by outdoor conditions.
3. The shafts may be out of strict alignment.
4. The power may be taken off in any direction and in fractional parts of the whole amount.
5. They give high mechanical efficiency.

Advantages and Disadvantages of Chain Drives over Belt or Rope Drive

Following are the advantages and disadvantages of chain drive over belt or rope drive:

Advantages

1. As no slip takes place during chain drive, hence perfect velocity ratio is obtained.
2. As the chains are made of metal, thus they occupy less space in width than a belt or rope drive.
3. The chain drives may be used when the distance between the shafts is less.
4. The chain drive gives high transmission efficiency (up to 98 percent).
5. The chain drive gives fewer loads on the shafts.
6. The chain drive has the ability to transmit motion to several shafts by one chain only.

Disadvantages

1. The production cost of chains is relatively high.
2. The chain drive needs accurate mounting and careful maintenance.
3. The velocity fluctuations are offered by chain drives especially when unduly stretched.

