BELT, ROPE AND CHANIN DRIVES

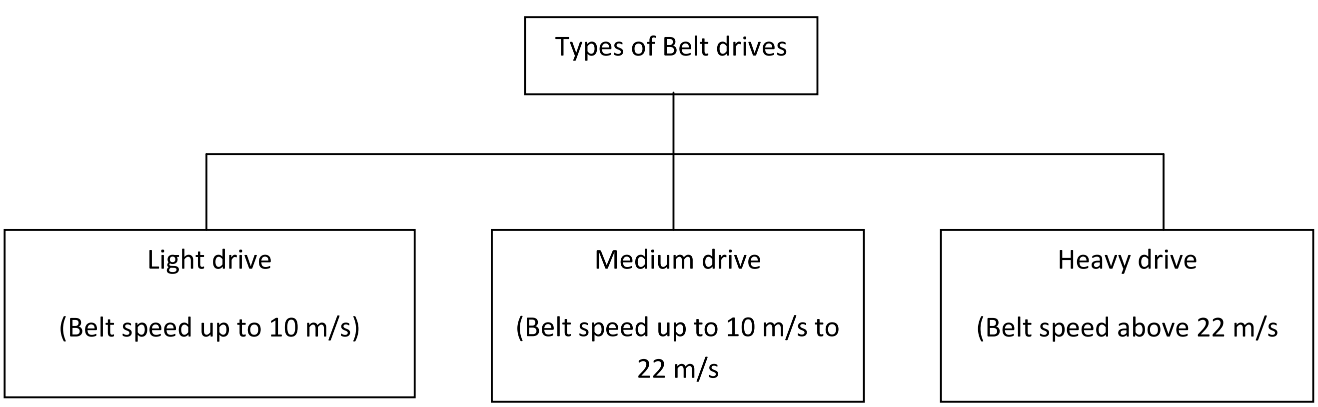
The belt or ropes are used to transmit power from one shaft by means of pulley which rotates at same speed or different speed. The amount of power transmission depends upon the following factors:

1. Velocity of belts.
2. The tension under which the belt is placed on the pulley.
3. The arc of contact between the belt and the smaller pilley.
4. The conditions under which the belt is used it may be noted:
    a. The shafts should be properly in line to insure uniform tension across the belt tension.
    b. The pulley should not be too close together in order that the arc of contact on the smaller pulley may be as large as possible.
    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 bearing.
    d. A long belt tends to swing from side to side causing the belt to run out of the pulleys, which in turn develops crooked spot 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 on the pulley.

Selection of Belt Drive:

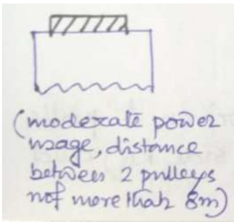
Followings are the various important factors upon which the selection of a belt drive depends:

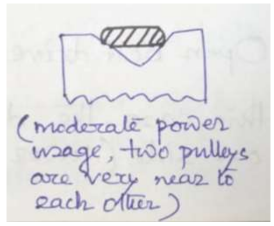
a) Speed of the driving and driven shafts.
b) Speed reduction ratio.
c) Power to be transmitted.
d) Centre distance between the shafts.
e) Positive drive requirements.
f) Shafts layout.
g) Space available.
h) Service conditions

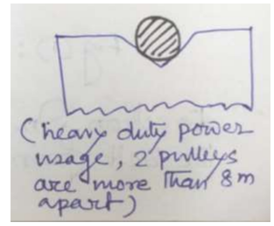


Types of Belts

- Flat Belt
- V-Belt
- Circular Belt







Materials used for Belts:

a. Leather belts
b. Cotton or fabric belts
c. Rubber belts
d. Balata belts (Similar to rubber bets, only balata gum is used in place of rubber. It generally works at a temperature below 40^{O} for optimum use.)

Types of flat belt drives:

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

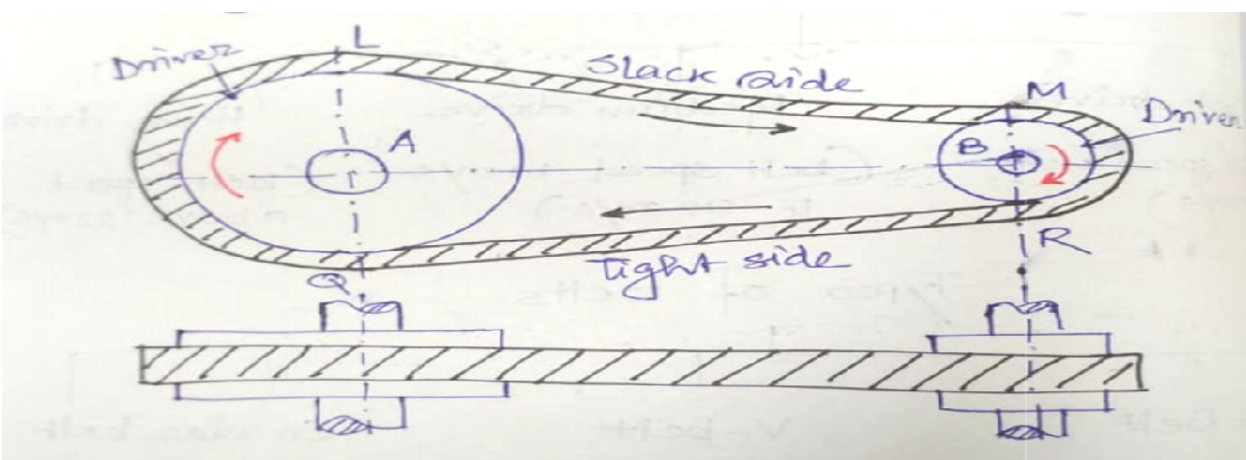
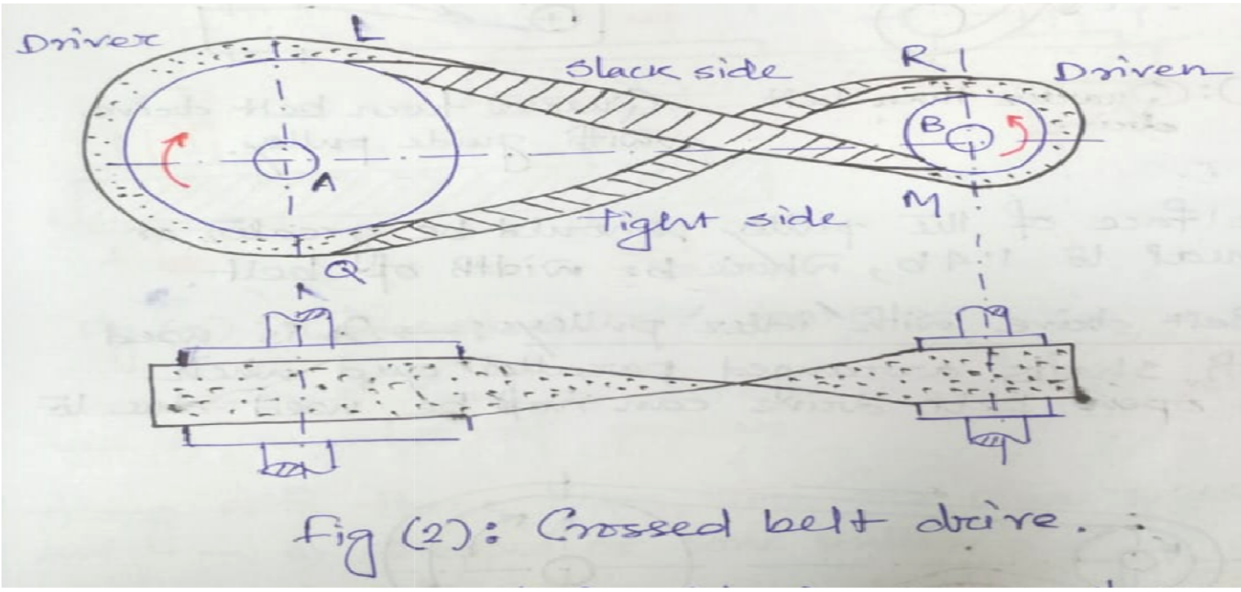


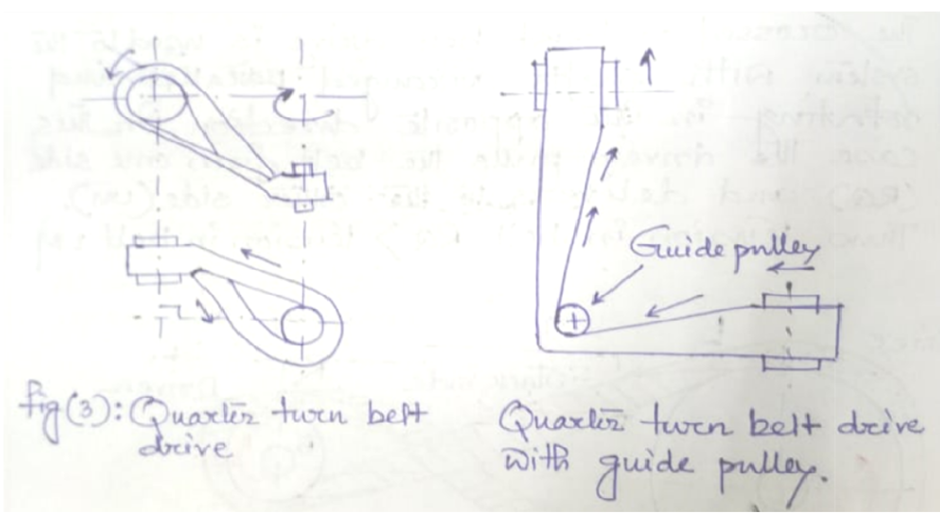
Fig (1): Open belt drive

2. **<u>Crossed or twisted belt drive:</u>** The crossed or twisted belt drive is used to the system, with shafts arranged parallel and rotating in the opposite direction. In this case the driver pulls the belt from one side (RQ) and delivers to the other side (LM). Thus tension in belt RQ > tension in belt LM.



The belt RQ → tight side & LM → Slack side. To avoid the rubbing at the crossing point, the shafts should be placed at a distance of (20 X b), where b = width of belt and speed of belt should be less than 15m/s.

3. **<u>Quarter turn belt drive:</u>** It is also known as right angle belt drive, it is used with shafts arranged at right angle and rotating in one definite direction. In order to prevent the belt from leaving the pulley, the width of the face of the pulley should be greater or equal to 1.4b, where b = width of belt.



4. **Belt drive with idler pulley:** It is used with shafts arranged parallel and when an open belt drive cannot be used due to small angle of contact on the small pulley. This type of drive is provided to obtain high velocity ratio and when the required belt tension cannot be obtained by other means.

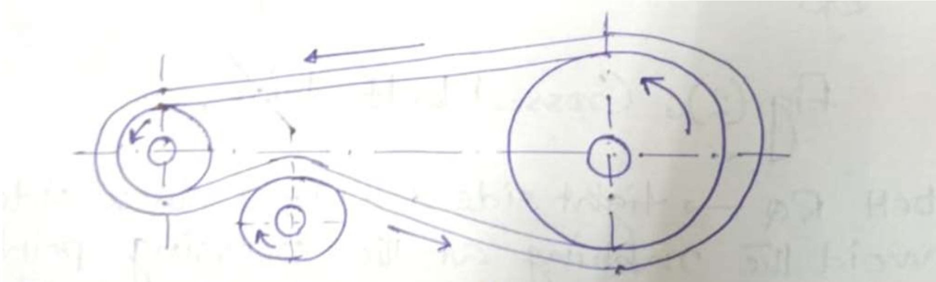


Fig (4): Belt drive with single idler pulley

5. **Compound belt drive:** A compound belt drive as shown in fig. is used when power is transmitted from one shaft to another shaft via a number of pulleys.

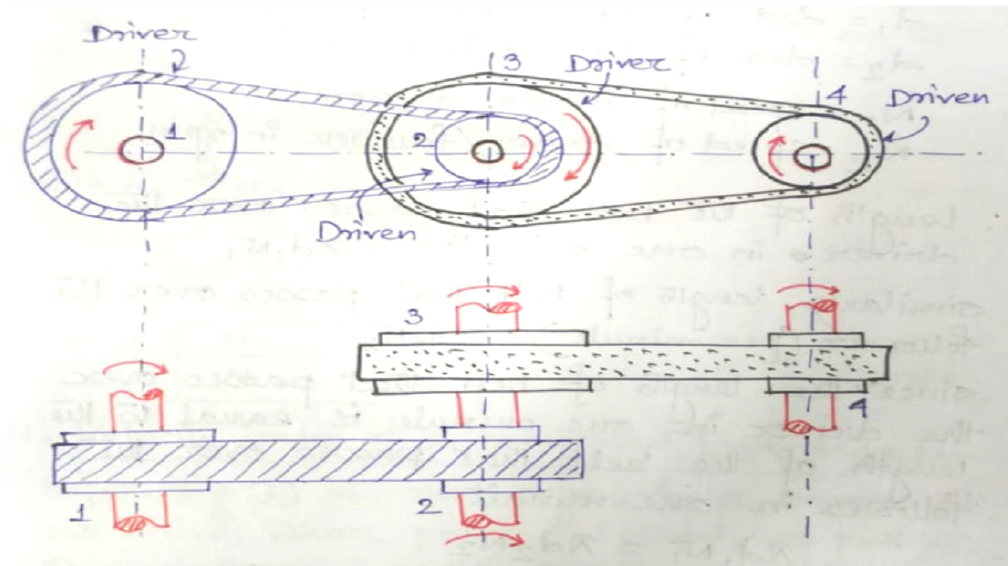


Fig (5): Compound belt drive

Along with these types, there are other types available:

a. Stepped or cone pulley
b. Fast & loose pulley type. Etc.

Velocity ratio of belt drive: It is the ratio between the velocities of the driver and the follower or driven. Let go through the mathematical expression

Let, taking reference of Fig. (1)
d_1 = dia. of the driver pulley
d_2 = dia. Of the driven pulley
N_1 = Speed of the driver in rpm
N_2 = Speed of the driven / followr in rpm

∴Length of the belt, that passes over the driver in one minutes = $\pi d_1 N_1$
Similarly, length of the belt that passes over the follower (per minute) = $\pi d_2 N_2$
Since the length of the belt that passes over the driver in one minute is equal to the length of the belt that passes over the follower in one minute.

$$\therefore \pi d_1 N_1 = \pi d_2 N_2$$

$$\therefore \text{Velocity ratio} \Rightarrow N_2/N_1 = d_1/d_2$$

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

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

Note: The velocity ratio of a belt drive may also be obtained as below:
As per our knowledge, the peripheral velocity of the belt on driving pulley

$$V_1 = \pi d_1 N_1 / 60 \text{ m/s}$$

And peripheral velocity of the belt on the follower pulley

$$V_2 = \pi d_2 N_2 / 60 \text{ m/s}$$

When there is no slip,

$$V_1 = V_2$$

$$\therefore \pi d_1 N_1 / 60 = V_2 = \pi d_2 N_2 / 60$$

$$\Rightarrow N_2/N_1 = d_1/d_2$$

Velocity ratio of a compound belt drive: Refer fig. (6) in next page, for a compound belt drive, where pulley 1 is driving pulley 2. Since pulley 2 & pulley 3 are keyed to the same shaft, therefore pulley 1 also drives pulley 3, which in turn drivers pulley 4 and so on.

Let d_1 = dia of pulley 1
N_1 = speed of pulley in rpm
d_2, d_3, d_4….. & N_1, N_2, N_3, N_4 = corresponding values of pulleys 2,3,4…..

We know that, velocity ratio of pulleys 1 & 2

$$N_2/N_1 = d_1/d_2 \quad \text{-----(i)}$$

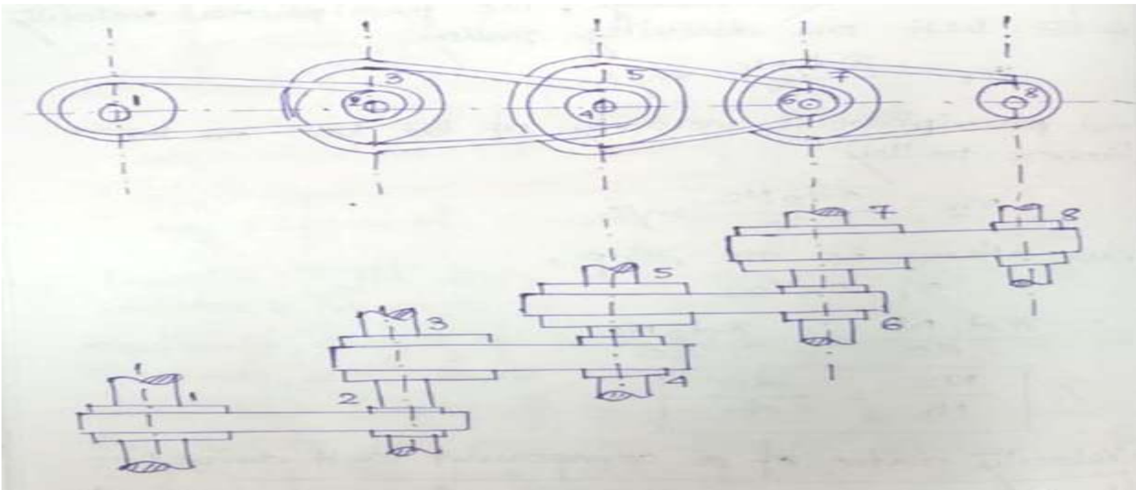


Fig (6): Compound belt drive velocity ratio.

Similarly, velocity ratio of pulleys 3 & 4

$$N_4/N_3 = d_3/d_4 \quad \text{-----(ii)}$$

Multiplying (i) & (ii)

$$N_2/N_1 \text{ X } N_4/N_3 = d_1/d_2 \text{ X } d_3/d_4$$

$$\Rightarrow N_4/N_1 = d_1 X d_3 \;/\; d_2/d_4$$

[As $N_2 = N_3$, being keyed to same shaft]

Now if there are 8 pulleys as per fig. 6

$$N_8/N_1 = d_1 X d_3 \text{ X } d_4 \text{ X } d_5 \text{ X } d_7 \;/\; d_2/d_4 \text{ x } d_6 \text{ x } d_8$$

Or Speed of the last driven = Product of dia. of drivers
Speed of the first driven = product of dia. of drivens

Slip of Belt: As per the previous discussion, while motion of belts & shafts assuming a firm frictional grip between the belts 7 the shafts. But in original cases, sometimes, the frictional grip becomes insufficient. This may cause some forward motion of the driver without carrying the belt along 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 it is generally expressed as a percentage.

The result of the belt slipping is to reduce the velocity ratio of the system. As the slipping of the belt is a common phenomenon, thus the belt should never be used where a definite velocity ratio is of importance.

Let, $S_1\%$ = Slip between the driver & belt

$S_2\%$ = Slip between the belt & follower

∴ velocity of the belt passing over the driver / second.

$$V = \pi d_1N_1/60 - \pi d_1N_1/60 \times S_1/100 = \pi d_1N_1/60 \ (1-S_1/100) \quad \text{----(i)}$$

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

$$\pi d_2N_2/60 = v - v.S_2/100 = v.(1-S_2/100)$$

$$\Rightarrow \pi d_2N_2/\not{60} = \pi d_1N_1/\not{60} \ (1-S_1/100)(1-S_2/100) \text{ [Putting value of v from eqn (i)]}$$

$$\Rightarrow N_2/N_1 = d_1/d_2 \ (1-S_1/100 - S_2/100) \text{ [Neglecting } S_1 \times S_2 / 100 \times 100]$$

$$\Rightarrow d_1/d_2 \ (1-S_1+S_2/100)$$

$$\Rightarrow d_1/d_2 \ (1-S/100) \text{ [Where } S=S_1+S_2 \text{ is the total percentage of slip]}$$

$$\therefore N_2/N_1 = d_1/d_2 \ (1-S/100)$$

If the thickness of belt (t) is considered

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

<u>Creep of Belt</u>: 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 & 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, considering creep, the velocity ratio is given by,

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

Where σ_1 & σ_2 = stress in the belt on the tight side & slack side

E = Young's modulus for the material

Length of a Open Belt drive: consider an open belt drive, both the pulleys rotates in the same direction as shown in fig.

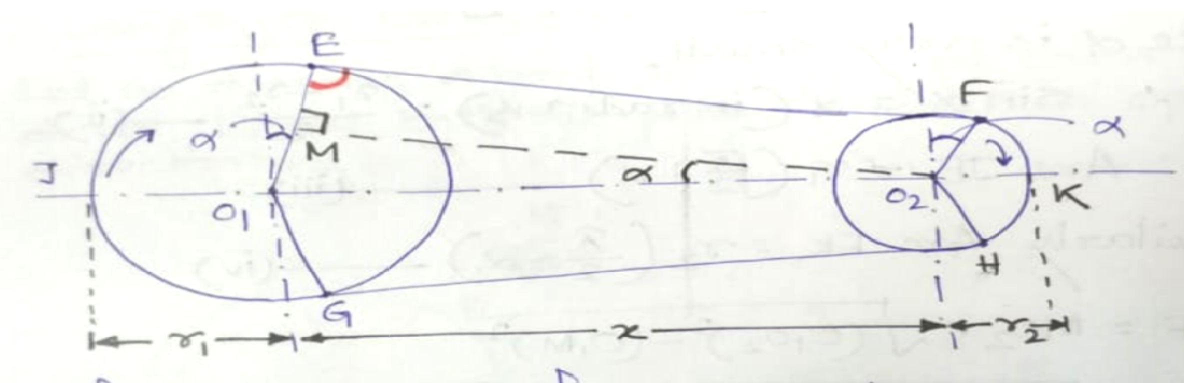


fig (7): Length of an open belt drive

Let, r_1 & r_2 = radius of larger & smaller pulley.

x = distance between the centre of two pulleys (O_1O_2)

L = total length of the belt

Let the belt leaves the larger pulley at E & G and the smaller pulley at F & H as shown in fig.

Let us draw a line O_2M parallel to FE from geometry of fig., we can conclude O_2Mwill be perpendicular to O_1E.

Let the angle MO_2O_1 = α radians

We know that the length of the belt

$$L = \text{Arc. GJE} + EF + \text{Arc. FKH} + HG$$

$$= 2(\text{Arc. JE} + EF + \text{Arc.FK}) \quad \text{---(i)}$$

From geometry of fig.

$$\sin\alpha = O_1M / O_1O2 = O_1E\text{-}EM / O_1O2 = r_1\text{-}r_2 / x$$

Since α is very small,

$$\therefore \sin\alpha = \alpha \text{ (in radius)} = r_1\text{-}r_2 / x$$

$$\therefore \text{Arc. JE} = r_1 \left(\frac{\pi}{2}+\alpha\right) \quad \text{-----(iii)}$$

Similarly Arc. FK = $r_2 \left(\frac{\pi}{2}+\alpha\right)$ -----(iv)

$$EF = MO = \sqrt{(O_1O2)^2 - (O_1M)^2}$$

$$= \sqrt{x_2\text{-}(r_1\text{-}r_2)^2} = x\sqrt{1\text{-}(r_1\text{-}r_2 / x)^2}$$

$= x - (r_1\text{-}r_2)^2 / 2x$ ----(v)substituting the value of arc. JE from eqn[n] (iii), arc. FK from eqn[n] (iv), in eqn[n] (i) we get,

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

$$= 2[r_1 \times \frac{\pi}{2} + r_1.\alpha + x - (r_1\text{-}r_2)^2 / 2x + r_2 \times \frac{\pi}{2} - r_2.\alpha]$$

$$= 2[\frac{\pi}{2}(r_1\text{-}r_2) + \alpha (r_1\text{-}r_2) + x - (r_1\text{-}r_2)^2 / 2x]$$

$$= \pi (r_1\text{-}r_2) + 2\alpha(r_1\text{-}r_2) + 2x - (r_1\text{-}r_2)^2 / x$$

Substituting the value of $\alpha = r_1\text{-}r_2 / x$ from eqn.(ii)

$$1 = \pi (r_1\text{-}r_2) + 2 \times (r_1\text{-}r_2)\, x(r_1\text{-}r_2) + 2x\text{-} (r_1\text{-}r_2)^2 / x$$

$$= \pi (r_1\text{-}r_2) + 2(r_1\text{-}r_2)^2 / x + 2x - (r_1\text{-}r_2)^2 / x$$

$$= \pi (r_1\text{-}r_2) + 2x + (r_1\text{-}r_2)^2 / x$$

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

<u>Length of cross belt drive:</u> Let us discuss about the length of cross belt drive, where both the pulleys rotate in opposite direction.

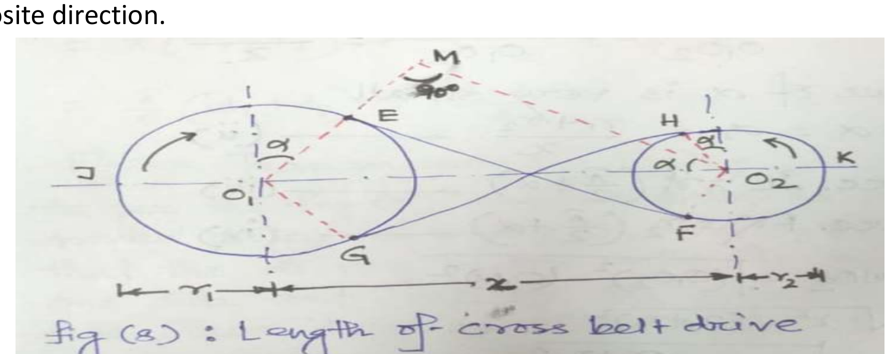


fig (8) : Length of cross belt drive

Let r_1 = radius of driver

R_2 = radius of the driven pulley

x = distance between centers of two pulleys (O1O2)

L= total length of belt

Let the belt leaves the larger pulley at E and G and the smaller pulley at F & H as shown in fig. (8)

Now drawing O_2M parallel to EF through O_2. As per the fig., we find O_2M will be perpendicular to O_1E.

Let, $LMO_2O_1 = \alpha$ radians

Length of the belt

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

From geometry of the fig. (8)

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

As value of α is very small

$$\therefore \sin\alpha = \alpha = (r_1+r_2) / x \quad \text{------(ii)}$$

$$\text{Now arc. JE} = r_1(\frac{\pi}{2} + \alpha) \quad \text{-----(iii)}$$

$$\text{And arc. FK} = r_2(\frac{\pi}{2} + \alpha) \quad \text{-----(iii)}$$

$$\therefore EF = MO_2 = \sqrt{(O_1O_2)^2 - (O_1M)^2}$$
$$= \sqrt{x^2 - (r_1 + r_2)^2}$$
$$= x\sqrt{1 - (r_1+r_2 / x)^2}$$

Expanding the eqn^n through binomial theorem,

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

Putting the values of JE, FK,EF from eqn^n (iii), (iv), (v) in eqn^n (i) we get,

$$1 = 2[r_1(\frac{\pi}{2} + \alpha) + x - (r_1+r_2)^2 / 2x + r_2(\frac{\pi}{2} + \alpha)]$$
$$= 2[\frac{\pi}{2}(r_1+r_2) + \alpha(r_1+r_2) + x - (r_1+r_2)^2 / 2x]$$
$$= \pi(r_1+r_2) + 2\alpha(r_1+r_2) + 2x - (r_1+r_2)^2 / x$$

Now putting the value of α from eqn^n(ii)

$$L = \pi(r_1+r_2) + 2. (r_1+r_2 / x) / X (r_1+r_2) + 2x - (r_1+r_2)^2 / x$$
$$= \pi(r_1+r_2) + 2. (r_1+r_2)^2 / x - (r_1+r_2)^2 / x + 2x$$
$$= \pi(r_1+r_2) + (r_1+r_2)^2 / x + 2x \quad \text{------(vi)}$$
$$= \frac{\pi}{2}(d_1+d_2) + (d_1+d_2)^2 / 4x + 2x \quad \text{----(vii)}$$

<u>Power transmission by belt:</u> As per the fig. (9), driving pulley is pulley A & driven pulley is pulley B. We already 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 in the tight side will be greater than that of the slack side.

Let, T_1 = Tension of the tight side in N

T_2 = Tension of the slack side in N

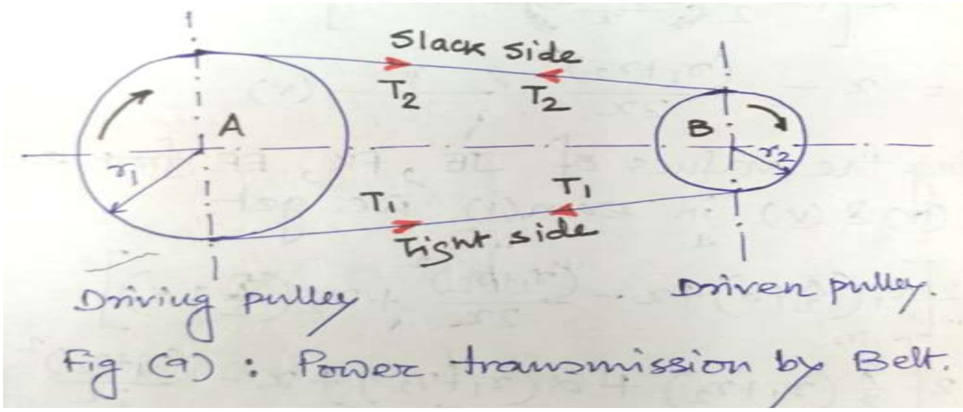


Fig (9) : Power transmission by Belt.

r_1 = Radius of the driver pulley

r_2 = Radius of the driven pulley

V = Velocity of belt m/s

The effective turning or driving force at circumference of follower is the difference between two tensions.

$$T_e = (T_1 - T_2)\ N$$

∴ work done per second

$$= T_e \times v\ \text{N-m/s}$$

$$= (T_1 - T_2) \times v\ \text{N-m/s}$$

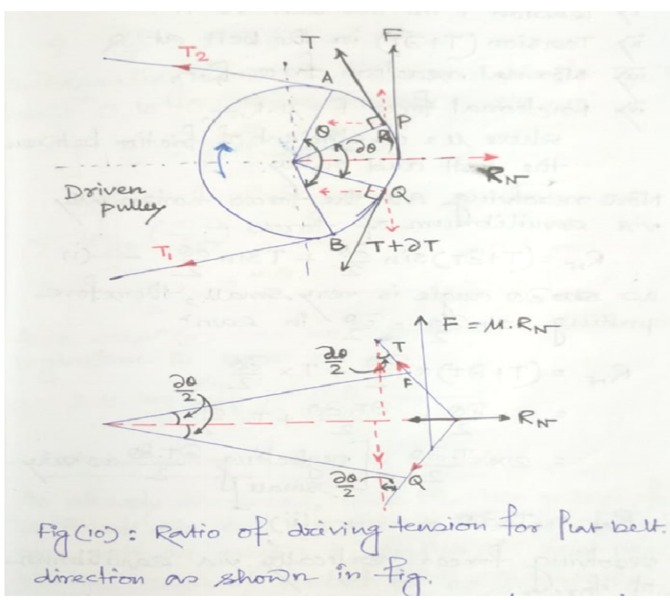
∴ Power transmitted $P = (T_1 - T_2) \times v$ Watt

Also torque exerted of driving pulley

$$T_{driver} = (T_1 - T_2) \times r_1$$

Similarly $T_{driver} = (T_1 - T_2) \times r_2$

<u>Ratio of driving tension for Flat belt drive:</u> Consider a driven pulley rotating in clockwise.



Fig(10): Ratio of driving tension for Flat belt.
direction as shown in Fig.

Let, T1 = Tension in the belt on tight side

T2 = Tension in belt on slack side

$\boldsymbol{\theta}$ = Angle of control (lap) in radians

Now let us consider a small portion of belt PQ, subtending as angle $\partial\boldsymbol{\theta}$ at the center of pulley as shown in fig.

The belt PQ is in equilibrium under the following factors forces:

- Tension T in the belt at R
- Tension (T + ∂T) in the belt at Q
- Normal reaction force R_N
- Frictional force F = μ R_N

Where μ = co-efficient of friction between the belt and pulley.

Now resolving all the forces horizontally via equilibrium of forces:

$$R_N = (T + \partial T) \text{ sign } \frac{\partial\theta}{2} + T \text{ sign} \frac{\partial\theta}{2} \quad \text{------(i)}$$

As $\partial\theta$ angle is very small, therefore putting sign $\frac{\partial\theta}{2} = \frac{\partial\theta}{2}$ in eqn^n

$$R_N = (T + \partial T) \text{ X } \frac{\partial\theta}{2} + T \text{ X } \frac{\partial\theta}{2}$$

$$= T \text{ X } \frac{\partial\theta}{2} + \frac{\partial T.\partial\theta}{2} + T \text{ X } \frac{\partial\theta}{2}$$

$$= 2 \text{ X } T \text{ X } \frac{\partial\theta}{2} \text{ [neglecting } \frac{\partial\theta}{2} \text{ as very small]}$$

$$\therefore R_N = T\partial\theta \quad \text{----(ii)}$$

Resolving forces vertically via equilibrium of forces,

$$F = (T + T\partial)\cos\frac{\partial\theta}{2} - T \cos \frac{\partial\theta}{2} \quad \text{------(iii)}$$

As $\partial\theta$ is very small, therefore cos $\frac{\partial\theta}{2}$ = 1

$$\therefore F = (T + \partial T) - T$$

$$\Rightarrow \mu.R_N = \partial T \quad \Rightarrow R_N = \frac{\partial T}{\mu} \quad \text{----(iv)}$$

From eqn_n (iii) &)(iv) we get,

$$T.\partial\theta = \frac{\partial T}{M}$$

$$\Rightarrow \frac{\partial T}{T} = \mu\partial\theta$$

Integrating both side between limits T_2, T_1 and O to $\boldsymbol{\theta}$ respectively

$$\int_{T2}^{T1} \frac{\partial T}{T} = \mu\int_{O}^{\theta} \partial\theta$$

$$\Rightarrow \log_e \frac{T1}{T2} = \mu\boldsymbol{\theta}$$

$$\Rightarrow \frac{T1}{T2} = e^{\mu\boldsymbol{\theta}} \quad \text{----(v)}$$

Also eqn^n (v) can be expressed in terms of logarithm to base 10

$$2.3 \log \left(\frac{T1}{T2}\right) = \mu\boldsymbol{\theta} \quad \text{------ (vi)}$$

Determination of angle of contact: As already discussed, when the two pulleys of different dia are connected by means of an open belt as shown in fig. (11/a). then the angle of contact or lap (***θ***) at the smaller pulley must be taken into consideration

Let, $r1$ = Radius of bigger pulley

$r2$ = Radius of smaller pulley

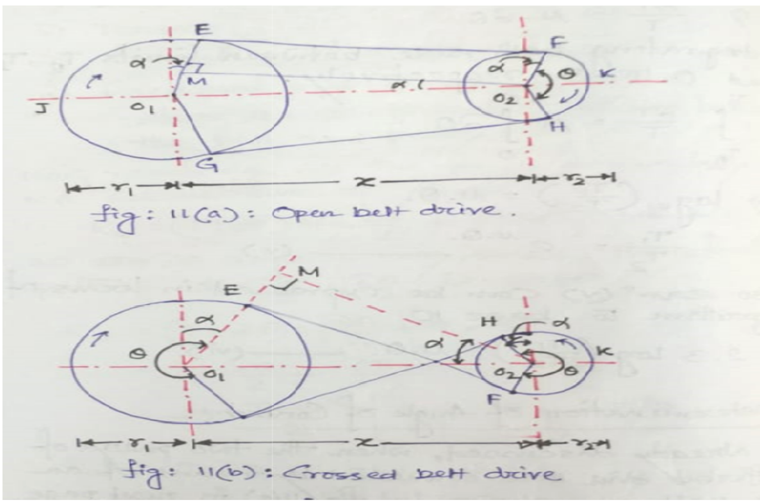
x = Distance of two centers (O_1O_2)

from fig 11(a) we can say

$\sin\boldsymbol{\alpha} = O_1M / O_2M = O_1E - EM / O_1O_2 = r_1 - r_2 / x$

∴ Angle of contact or lap

$$\boldsymbol{\theta} = (180^{O} - 2\boldsymbol{\alpha}).\frac{\pi}{180} \text{ rad.}$$



Similarly as per fig 11(b) when we consider crossed belt

$\sin\boldsymbol{\alpha} = O_1M / O_1O_2 = O_1E - EM / O_1O_2 = r_1 - r_2 / x$

∴ Angle of contact or lap

$$\boldsymbol{\theta} = (180^{O} - 2\boldsymbol{\alpha}).\frac{\pi}{180} \text{ rad.}$$

<u>Maximum tension in Belt</u>: A little consideration show that the max. Tension in belt (T_{max}) is equal to the total tension in the tight side of the belt (T_1)

Let, σ = Max. safe stress N/mm^2

B = width of belt in mm

T = thickness of belt in mm

∴ Max. tension in the belt

T_{max} = max. stress X cross sectional area of the belt

$= \sigma.b.t$

When we neglect centrifugal tension

The $T_{max} = T_1$(tension of tight side)

When we consider centrifugal tension

$T_{max} = T_1 + T_c$

<u>Condition for transmission of maximum power:</u> From previous discussion we know, that the power transmitted by belt

$P = (T_1 - T_2) X v$ -----(i)

Where, T1 = tension at the tight side in N

T2 = tension at the slack side in N

v = velocity of belt in m/s

Also as per previous discussion we know, ratio of driving tension = $\frac{T1}{T2} = e^{\mu\theta}$

$= T_2 = T_1 X 1 / e^{\mu\theta}$ ----(ii)

Putting value of T^2 in eqn^n (i), we get,

$P = T_1 (1- 1/ e^{\mu\theta}) X v = T_1 X C X v$ [where $C=1-1/ e^{\mu\theta}$] ------(iii)

We also know

$T_1 = T_{max} - T_c$

Where T_{max} = maximum tension of belt

T_c = centrifugal tension

Putting the value of T1 in eqn^n (iii)

$P = (T_{max} - T_c) X C X v$

$\Rightarrow P = (T_{max} - mv^2 / r) X C X v$ [as $T_c = mv^2 / r$)

$\Rightarrow P = (T_{max} v - mv^3 / r) X C$ ----(iv)

Now for maximum power we need to differentiate the eqn ( ) w.r.t v & equate to zero

$\frac{dp}{dv} = \frac{d}{dv} (T_{max}.v - mv^3) X C = 0$

$\Rightarrow \frac{dp}{dv} (T_{max}.v - mv^3) X C = 0$

$\Rightarrow T_{max}.v - 3mv^2 = 0$

$\Rightarrow T_{max}.v - 3T_c = 0$

$\Rightarrow T_{max}. = 3T_c$ -----(v)

It shows that when the power transmitted is maximum, 1/3rd of power (max.) is absorbed as centrifugal tension.

V-belt drive: As V-belt drive is most commonly used in factories & workshops where a great amount of power is to be transmitted from one pulley to other when the two pulleys are very near to each other.

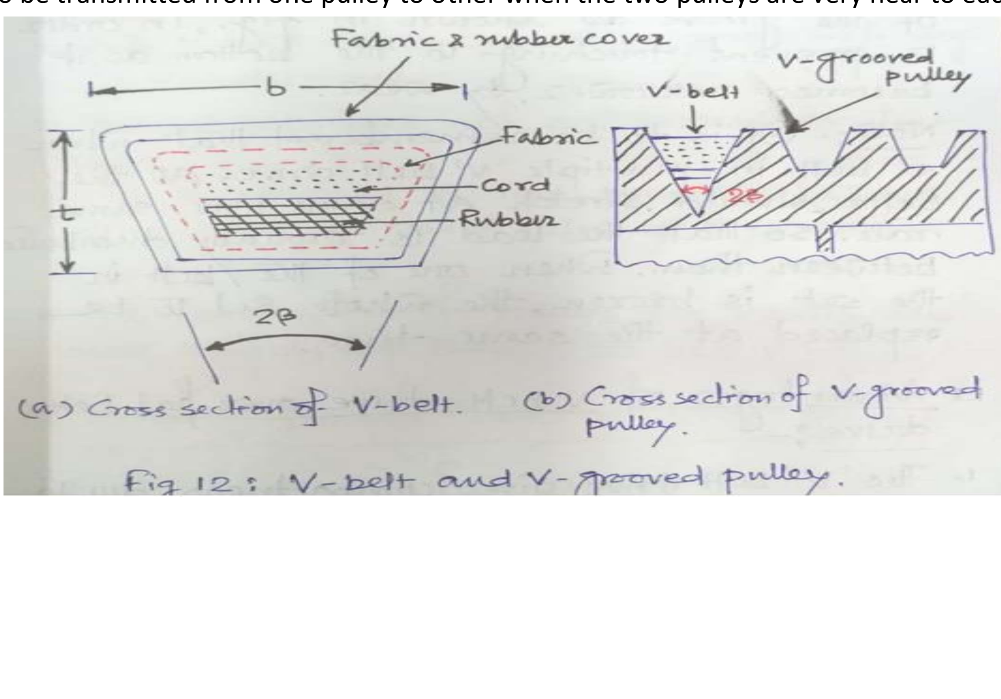


Fig 12: V-belt and V-grooved pulley.

The V-belt are made of fabric and cords moulded in rubber and covered in fabric & rubber as shown in fig. These belts are moulded to a trapezoidal shape & are made endless. These are particularly suitable for short drives, i.e when the shafts are at a short distance apart. The included angle for the V-belt is usually $30^{O} – 40^{O}$. In case of that belt drive, the belt runs over the pulleys whereas in case of "V" belt drive, the rim of the pulley is grooved in which the V belt runs. The effect of the groove is to increase the frictional grip of the "V" belt on the pulley and thus to reduce the tendency of shipping. The power is transmitted by the wedging action between the belt and the "V" groove in the pulley.

A clearance must be provided at the bottom of the grove as shown in fig., In order to prevent touching touching as it becomes narrower by wear.

Note: It is to be remembered that when a belt in multiple "V" belt drive, all the belts should stretch at same time and same rate. So that the load is equally distributed between them. When one of the belt in the set is broken, the whole set to be replaced at the same time.

Advantages of V-belt drive over flat belt drive:

- The "V" belt drive gives compactness due to small distance between center of pulleys.
- The drive is positive, because the slip between the belt and the pulley groove is negligible
- Since V-belt are made endless and there is no joint trouble, therefore the drive is smooth.
- It provides longer life, 3 to 5 years.
- The high velocity ratio (maximum 10) may be obtained.
- The V-belt may be operated in either dir^{n} with tight side of the belt at the top or bottom. The center line may be horizontal, vertical or inclined.

Disadvantages:

- The V-belt drive cannot be used with larger center distance.
- The V-belts are not so durable as flat belts.
- The centrifugal tension prevents the use of V belts at speed below 5 m/s and above 50 m/s.
- The construction of pulleys for V belts are more complicated than flat belt pulleys.

Ratio of driving tensions for V-belt:

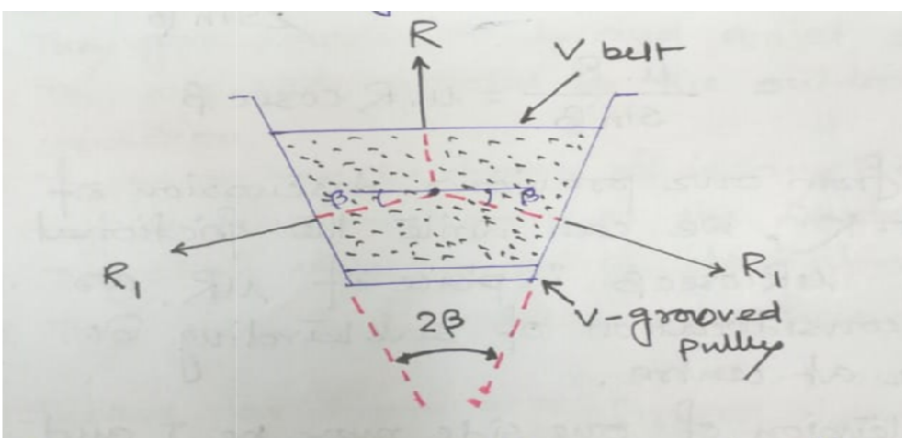


Fig (13): V belt with grooved pulley

As per the fig, we can understand the construction of V-belt with grooved pulley.

Let R_1 = Normal reaction force between the belt and side of the groove.

R = Total reaction in the plane of the groove.

2β = angle of groove

μ = co-efficient of friction between the belt & side of groove.

Resolving the forces vertically as oer the equilibrium of forces, to the groove,

$$R = R_1 \sin\beta + R_1 \sin\beta$$

$$\Rightarrow R_1 = \frac{R}{2 sin\beta}$$

∴ The frictional force for both the surface of groove = F + F

$$= 2F = 2.\mu.R_1 = \cancel{2}.\mu.\frac{R}{\cancel{2} sin\beta}$$

$$= \frac{\mu.R}{sin\beta} = \mu.R.\text{ Cosec }\beta$$

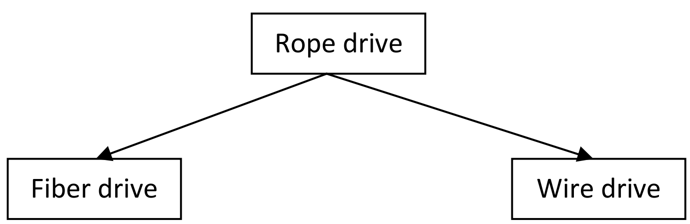
Now from our previous discussion of point K. We can write the frictional force μ.R. Cosec β in place of μR as per consideration of subtending $\partial\boldsymbol{\theta}$ angle to center.

The tension of one side may be T and other side would be $T+\partial T$.

∴ Relation between T_1 & T_2 for V-belt drive

$$2.3 \log (T_1 / T_2) = \mu.\boldsymbol{\theta}.\text{cosec}.\beta$$

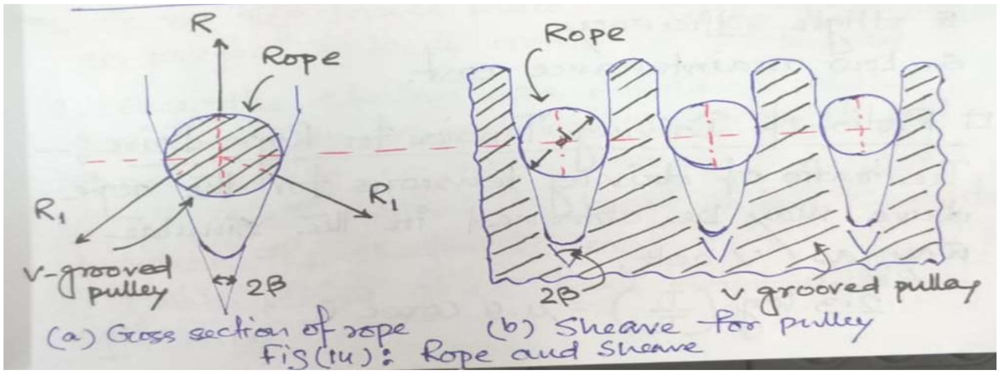
Rope drive: the rope drive widely used where a large amount of power is to be transmitted from one pulley to another, over a considerable distance. One of the main advantages of rope drives is that a number of separate drives may be taken from one driver pulley.



<u>Advantages of fiber rope drives:</u>

- They give smooth, steady and quite service.
- They are little effected by the outdoor condition.
- The power may be taken off in any direction and in fractional parts of the whole amount.
- The shaft may be out of strict alignment.
- They give high mechanical efficiency.

Sheave for fiber ropes:



The fiber ropes are usually circular is cross section as shown in fig. The sheave for fiber ropes shown in fig. 14(b). the groove angle of the pulley for rope drives is usually 45^O. The groves in the pulleys are made narrow at the bottom and the rope is pinched between the edges of the V-groove on the pulley.

Wire ropes: When a large amount of power is to be transmitted over long distance from one pulley to another (that is if two pulleys are 150m apart) then wire ropes are used. The wire ropes are widely used in elevators, mine hoist, cranes, hauling devices etc.

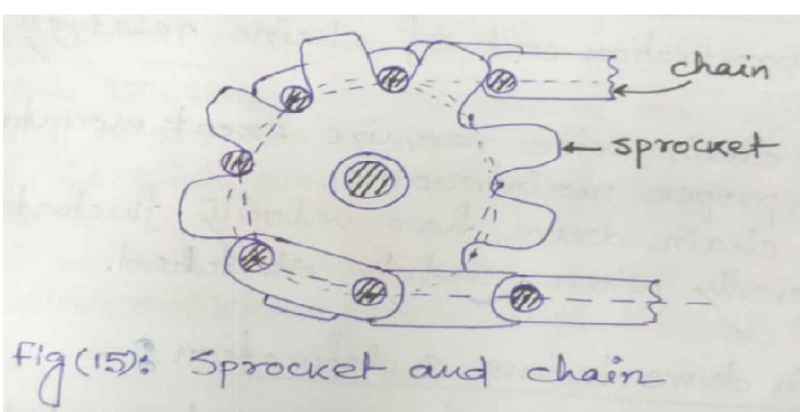
Advantages:

- Lighter in weight
- These offer silent operation
- Can withstand shock load
- More efficiency
- Low maintenance cost

Ratio of driving tension for rope drive: The ratio of driving tension for the rope drive may be obtained in the similar way as v belt.

$$2.3 \log (T_1/T_2) = \mu.\text{cosec } \beta$$

Chain drive: In case of belt & rope drive, slip may occur to arrive. To avoid slipping, steel chains are used.



The toothed wheels are known as sprocket wheels or simply sprocket. The chain are mostly used to transmit motion and power from one shaft to another, when the distance between the centers of the shafts is short such as bicycles, motor cycle etc.

Advantages of chain drive over belt & rope drive:

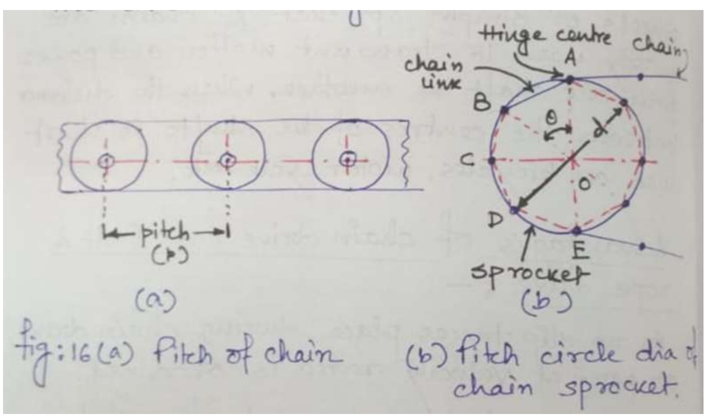
- As on slip takes place during chain drive, so perfect velocity ratio is obtained
- Since the chains are made of metal, therefore they occurs less space in width than a belt or rope drive
- The chain drive is used when the distance between the shafts is less
- Chain drive gives high transmission efficiency.
- The chain drive gives less load on shaft

Disadvantages of chain drive over belts & rope drive:

- The production cost of chains relatively high
- The chain drive require exact mounting and proper maintenance
- The chain drive have velocity fluctuation especially when unduly stretched

Chain drive terms & definition:

- Pitch of Chain: It is the distance between two consecutive hinge centers of two adjacent links as shown in the fig.16(a)



- Pitch circle diameter: It is the diameter of a circle on which the hinge centers of the chain lie, when the chain is wrapped around a sprocket as shown in fig. 16(b)

The points A,B,C,D,E etc. are the hinge centers of the chain and the circle drawn through these centers is called pitch circle and its dia. is known as pitch circle dia.

Relation between pitch and pitch circle dia: Since the links of the chain are rigid, therefore pitch of the chain does not lie on the arc of the pitch circle. The pitch length becomes a chord.

Let us consider one pitch length AB of the chain subtending an angle θ at the centre.

Let, d = dia of pitch circle

T = Number of teeth on the sprocket from fig. 16(a) we get, Pitch of chain P = AB

$= 2.AO.\sin\frac{\theta}{2}$

$= 2.\frac{d}{2}.\ \sin\frac{\theta}{2}$

$= d \times \sin\frac{\theta}{2}$

We know $\boldsymbol{\theta} = 360^{O} / T$

$\therefore P = d \times \sin 360^{O} / 2T$

$= d \times \sin 180^{O} / T$ => $\boxed{d = P.\mathrm{Cosec}\ 180^{O} / T}$

Relation between chain speed and angular velocity of sprocket:

$v = w \times d \times \mathrm{cosec}\ (\frac{\theta}{2})$

v = Linear Velocity

w = Angular velocity

Classification of chains

- **Hoisting & Hauling (crane) chains**
  - Chain with Oval links
  - Chain with square links
- **Conveyor chains**
  - Detachable or hook type chain
  - Close joint type
- **Power transmitting (driving) chain**
  - Block Chain
  - Bush roller Chain
  - Inverted tooth Chain

Length of Chain: An open chain drive system, connecting two sprockets shown fig.

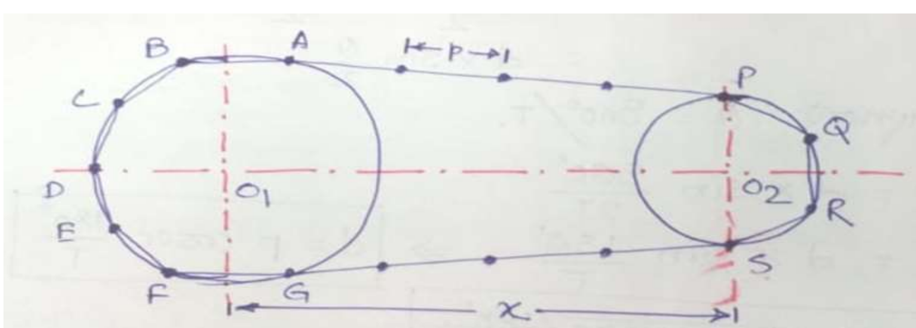


Fig 1F: Length of chain

We already know length of belt for open belt drive connecting two pulley

$$L = \pi (r_1 + r_2) + 2x + (r_1 - r_2)^2 / x \qquad \text{------(i)}$$

If we refer this eqn^n for determining the length of chain, then the results will be higher than the required length. This is due to the fact that the pitch line A,B,C,D,E,F,G and P,Q,R,S of the sprocket are the parts of a polygon and not a circle.

Let, T_1 = No. of teeth on larger sprocket

T_2 = No. of teeth on smaller sprocket

P = Pitch of chain

As per previous discussion

$$D = P.\text{Cosec}\ (180^O) / T$$

$$\Rightarrow r = P/2.\ \text{Cosec}\ (180^O)/ T$$

For larger sprocket -> $r_1 = (p/2)\ X\ \text{cosec}\ (180^O/T_1)$

For smaller sprocket -> $r_2 = (p/2)\ X\ \text{cosec}\ (180^O/T_2)$

Now since the term $\pi(r_1 + r_2)$ is equal to the half the sum of the circumference of the pitch circle,

∴ the length of the chain corresponding to

$$\pi(r_1 + r_2) = P/2(T_1 + T_2)$$

∴ putting values of r_1, r_2 $\pi(r_1 + r_2)$ in eqn^n (i)

$$L = (P/2\ (T_1 + T_2) + 2x + [P/2.\text{cosec}.\ 180^O/T_1 - \text{cosec}.180^O/T_2]^2 / x$$

$$= P[T1+T_2/2 + 2m + (\text{cosec}.180^O/T_1 - \text{cosec}.180^O/T_2)^2 / 4m] \quad [\text{consider } x = mp]$$

$$L = P.k$$

Where k = multiplying factor

$$= T_1 + T_2 / 2 + 2m + [\text{Cosec}\ (180^O/T_1) - \text{cosec}\ (180^O/T_2)]^2 / 4m$$

The value of "k' may not be a complete integer. But it should be rounded off.