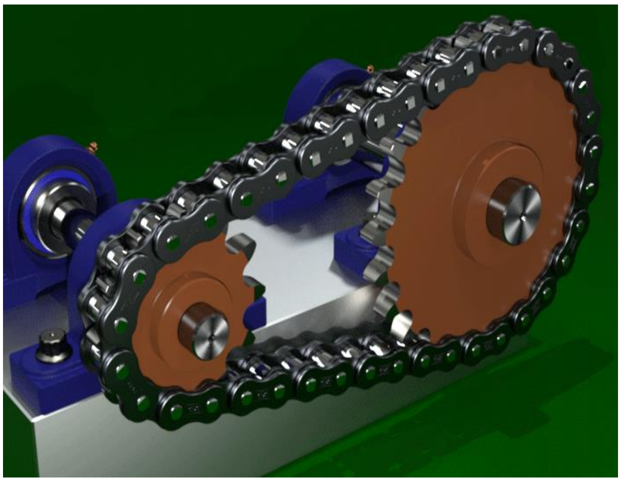
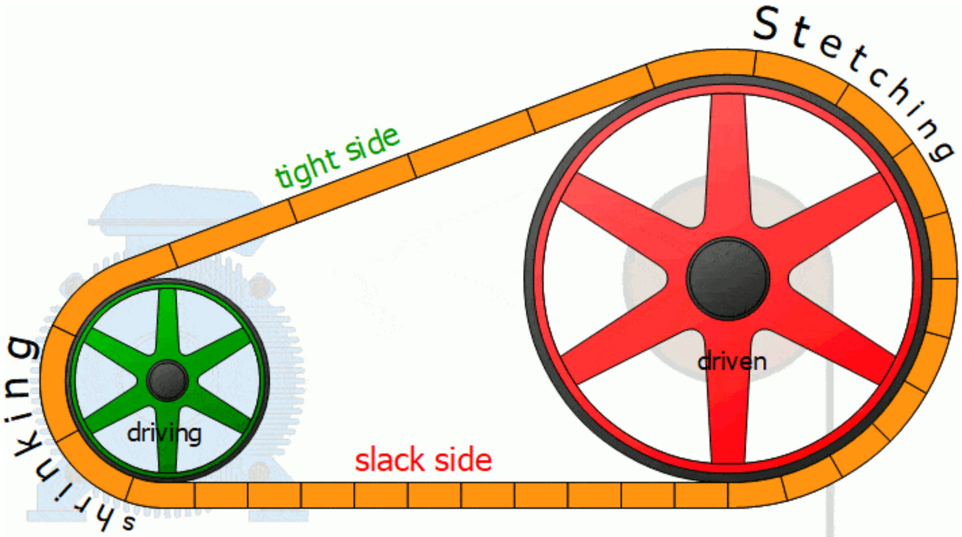
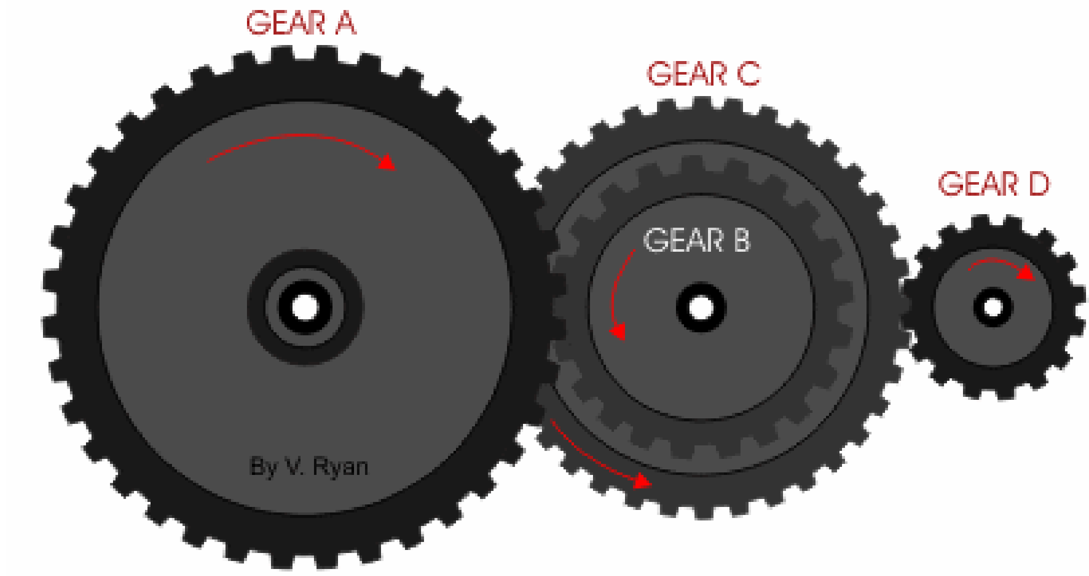
Some of power transmission elements







1. Flat Belt Drives

The belts 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.
5. The material of the belt used.

Selection of the Belt Drive:

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. Shaft layout.
7. Space available.

8. Service conditions.

It may be noted that

(a) The shafts should be properly in line to insure uniform tension across the belt section.

(b) The pulleys 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 bearings.

(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 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) To obtain good results with flat belts, the maximum distance between the shafts should not exceed 10m and the minimum should not be less than 3.5 times the diameter of the larger pulley

Advantages of belt drive

- They are simple. They are economical.
- Parallel shafts are not required.
- Overload and jam protection are provided.
- Noise and vibration are damped out. Machinery life is prolonged because load fluctuations are cushioned (shock-absorbed).
- They are lubrication-free. They require only low maintenance.
- They are highly efficient (90–98%, usually 95%). Some misalignment is tolerable.
- They are very economical when shafts are separated by large distances.

Disadvantages of belt drive

- The angular-velocity ratio is not necessarily constant or equal to the ratio of pulley diameters, because of belt slip and stretch.
- Heat buildup occurs. Speed is limited to usually 7000 feet per minute (35 meters per second).
- Power transmission is limited to 370 kilowatts (500 horsepower).
- Operating temperatures are usually restricted to −31 to 185°F (−35 to 85°C).
- Some adjustment of center distance or use of an idler pulley is necessary for wear and stretch compensation.
- A means of disassembly must be provided to install endless belts.

Types of Belts

1. ***Flat belt.***

is mostly used where a moderate amount of power is to be transmitted, from one pulley to another when the two pulleys are not more than 8 m apart.

2. ***V- belt.***

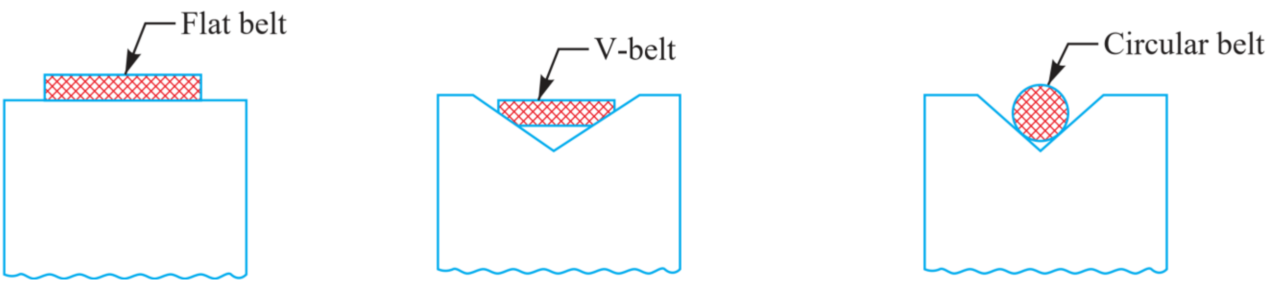
is mostly used where a great amount of power is to be transmitted, from one pulley to another, when the two pulleys are very near to each other.

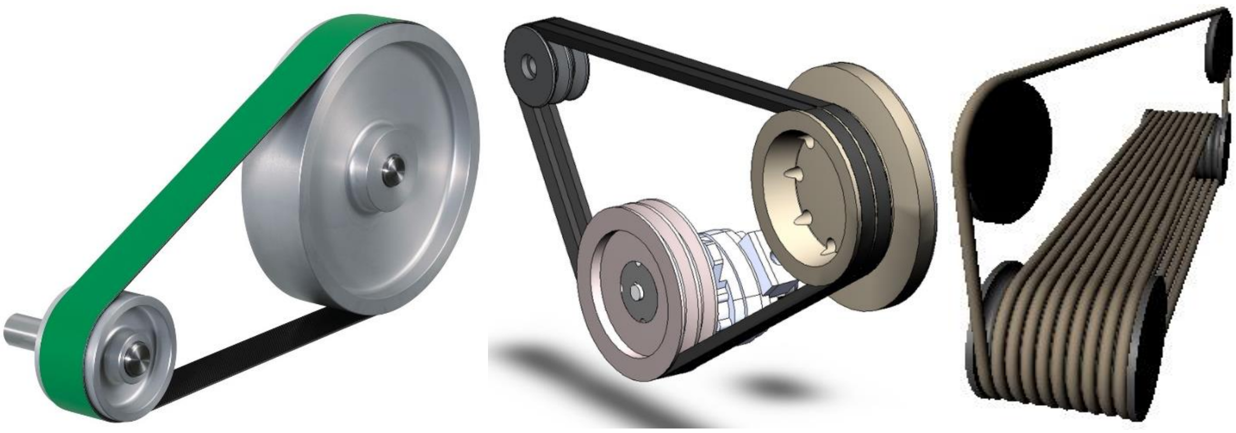
3. ***Circular belt or rope.***

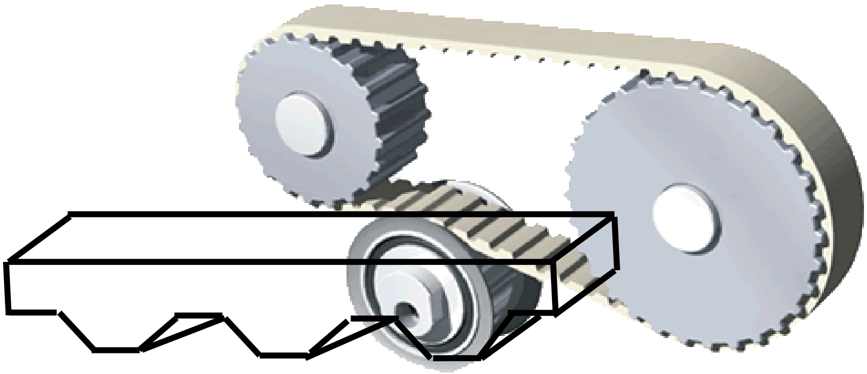
is mostly used where a great amount of power is to be transmitted, from one pulley to another, when the two pulleys are more than 8 m apart.

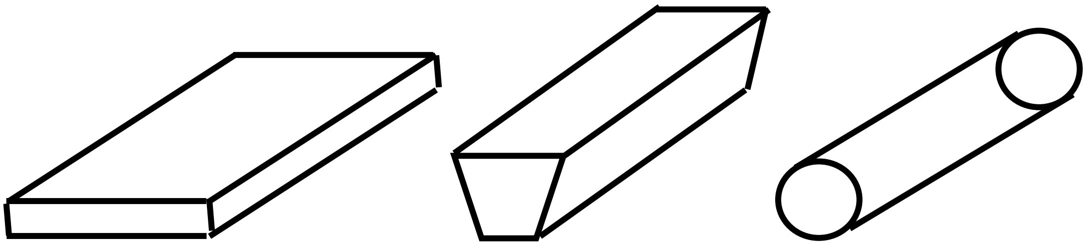
4. **Timing Belt**

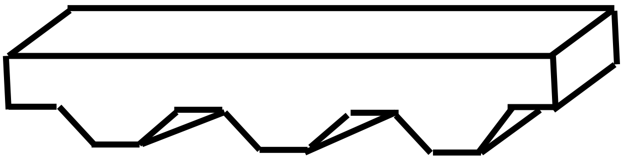
They are toothed belts which transmit power by means of teeth rather than friction. Hence there is no slip occurring in these types of belts. They need toothed wheels. e.g. CNC m/c, Automobiles



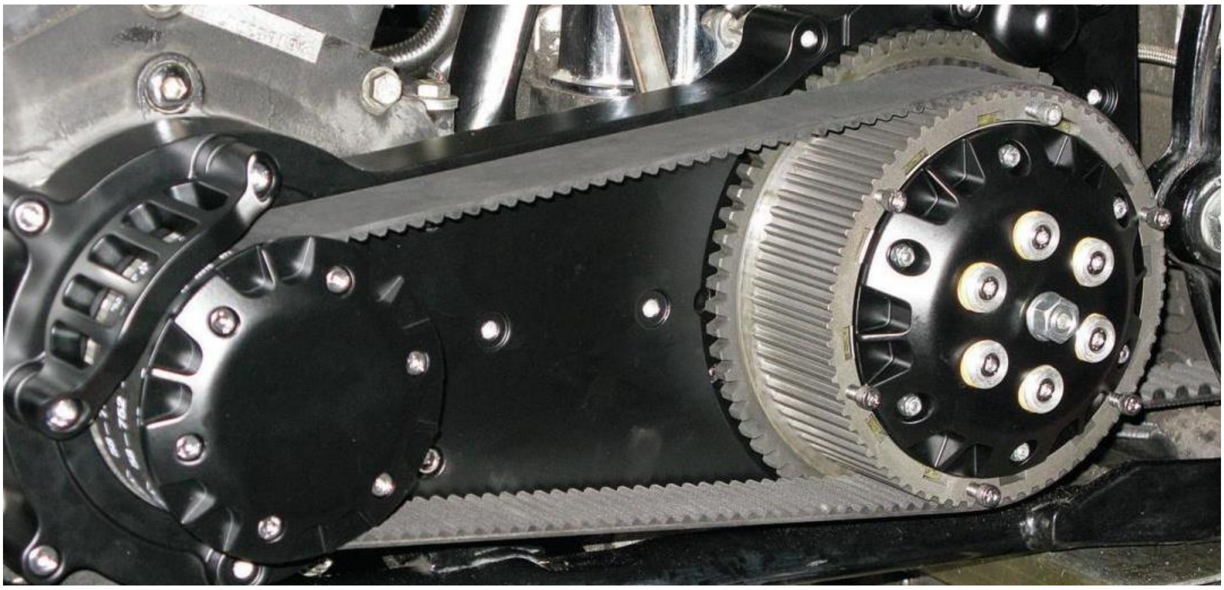








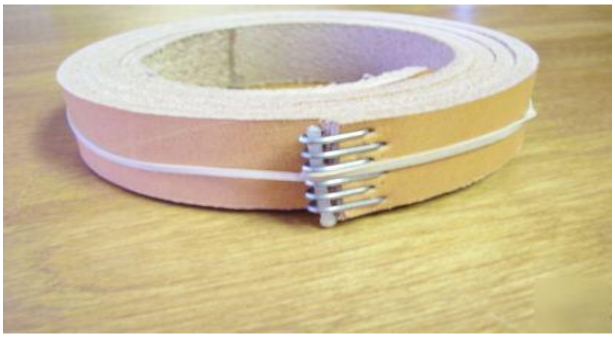

MOLI® SUPER BELT



Types of Belts [According to Materials]

1. **Leather Belt**:
   - Leather belts are made from 1.2 m to 1.5 m long strip cut from either side of the back bone of the top grade steer hide.
   - The leather may be oak- tanned and Chrome tanned. Leather belts are used in steam & oil condition.
   - No. of layers: Single, Double, Triple ply belts.

2. **Rubber Belt**
   - made from layers of fabric impregnated with rubber composition.
   - They cannot withstand in hot, oily, and greasy conditions.
   - They are very flexible and can be made endless.
   - They are used in sawmills, paper mills etc.

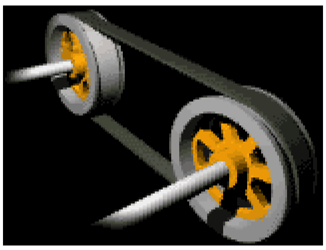


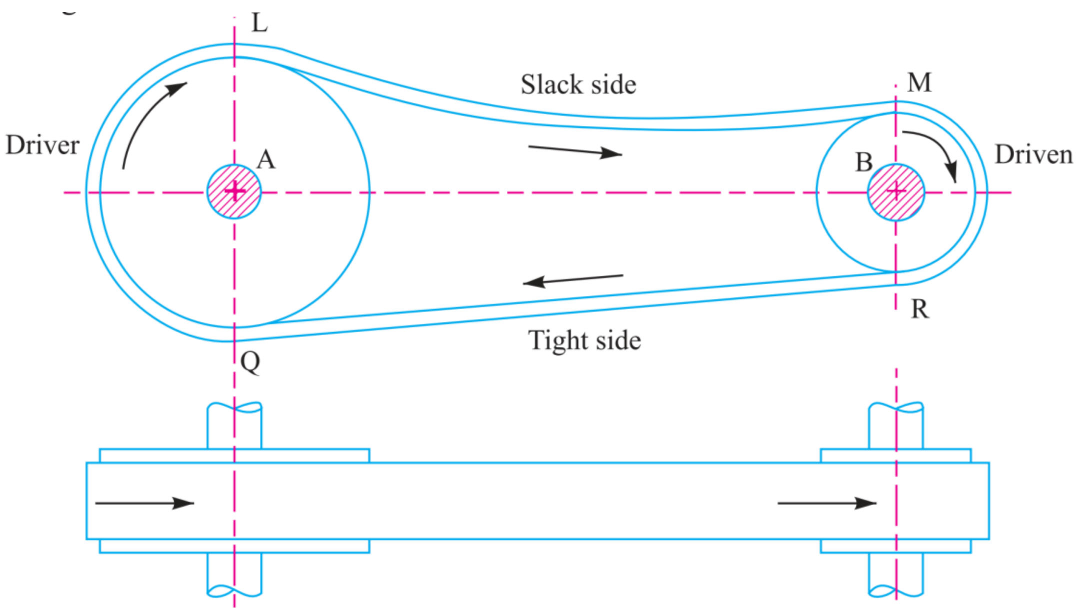
3. **Cotton or fabric belt :**

- These belts are made from folding canvas or cotton duck.
- They are impregnated with linseed oil to make water proof.
- They are suitable in warm climates, in damp atmosphere.
- They are used in form machinery, belt conveyor etc. i.e. Flooring mills

Types of Flat Belt Drives

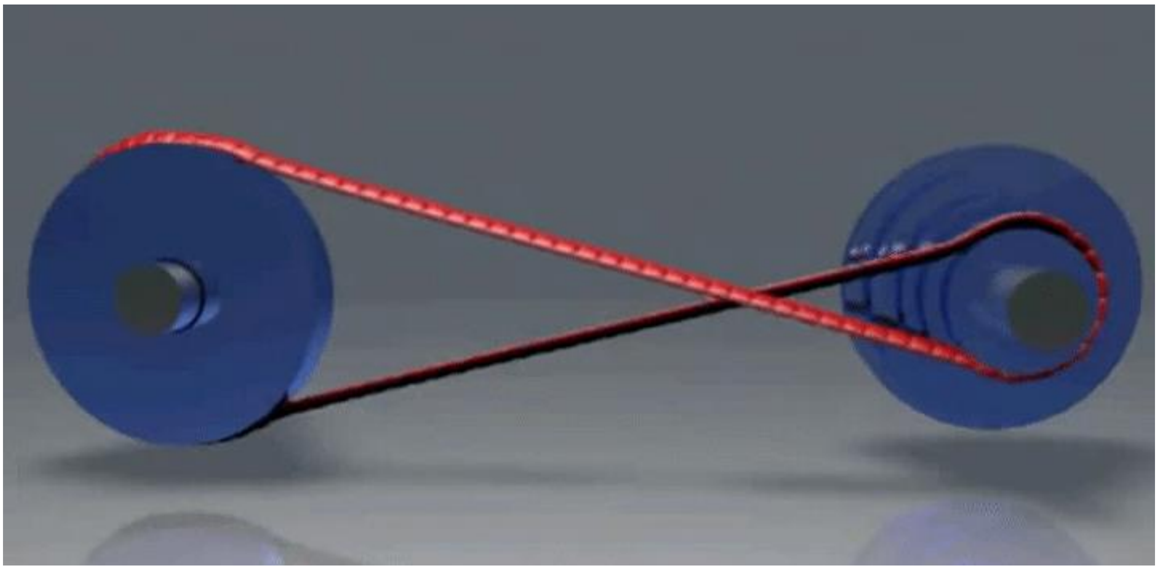
1. ***Open belt drive.***
   - is used with shafts arranged parallel and rotating in the same direction.
   - the driver *A* pulls the belt from one side (*i.e*. lower side *RQ*) and delivers it to the other side (*i.e*. upper side *LM*).
   - tension in the lower side belt will be more than that in 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***

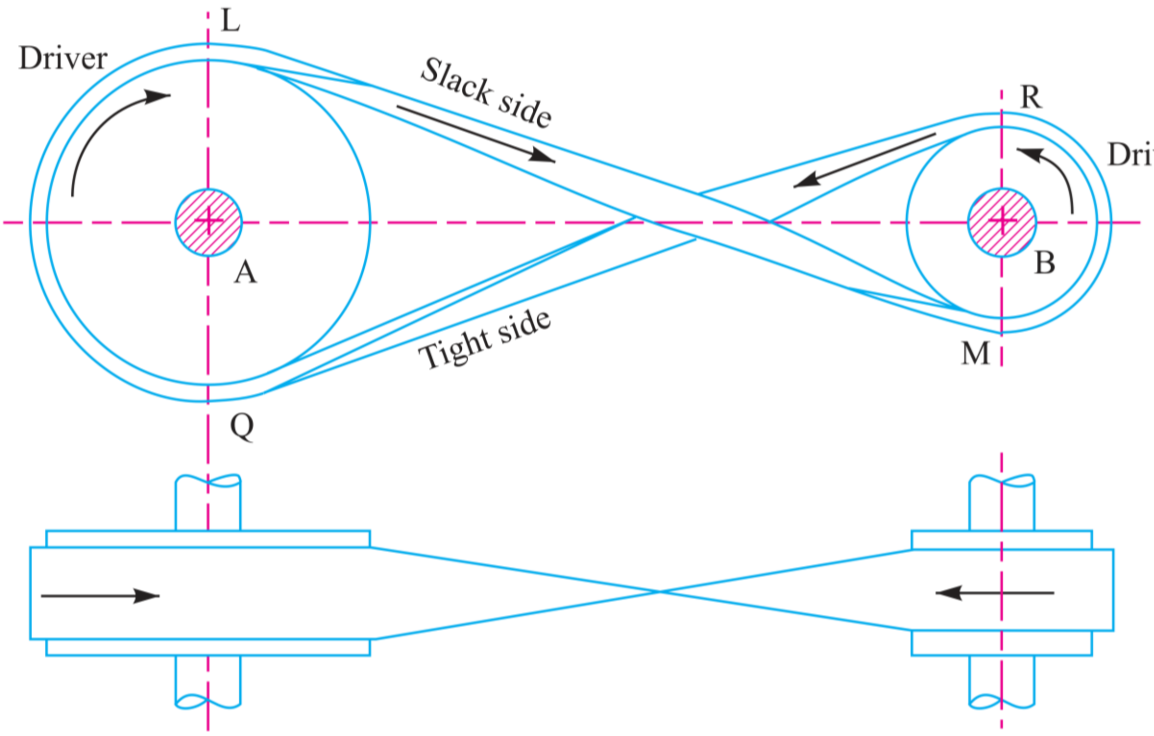




2. ***Crossed or twist belt drive.***

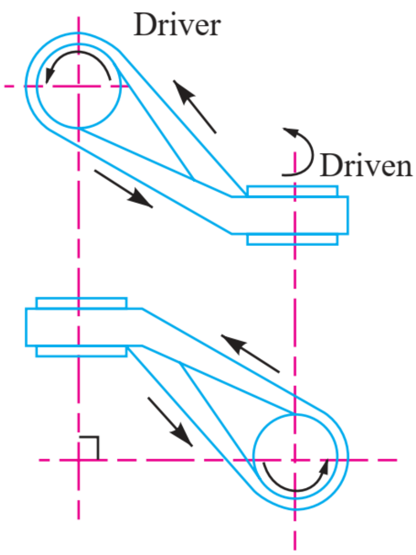
- is used with shafts arranged parallel and rotating in the opposite directions.
- In this case, the driver pulls the belt from one side (*i.e. RQ*) and delivers it to the other side (*i.e. LM*). Thus, the tension in the belt *RQ* will be more than that in the belt *LM*.
- The belt *RQ* (because of more tension) is known as ***tight side***, whereas the belt *LM* (because of less tension) is known as ***slack side***.
- A little consideration will show 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 belt, and the speed of the belt should be less than 15 m/s.



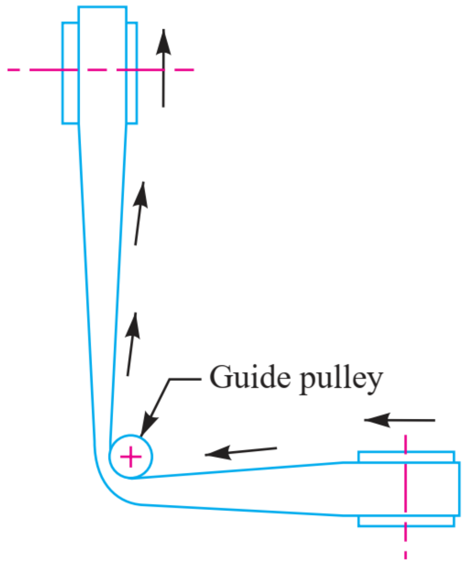


3. ***Quarter turn belt drive.***

- is used with shafts arranged at right angles and rotating in one definite direction.
- To prevent the belt from leaving the pulley, the width of the face of the pulley should be greater or equal to 1.4 *b*, where *b* is width of belt
- In case the of when the reversible motion is desired, then a ***quarter turn belt drive with a guide pulley***, may be used



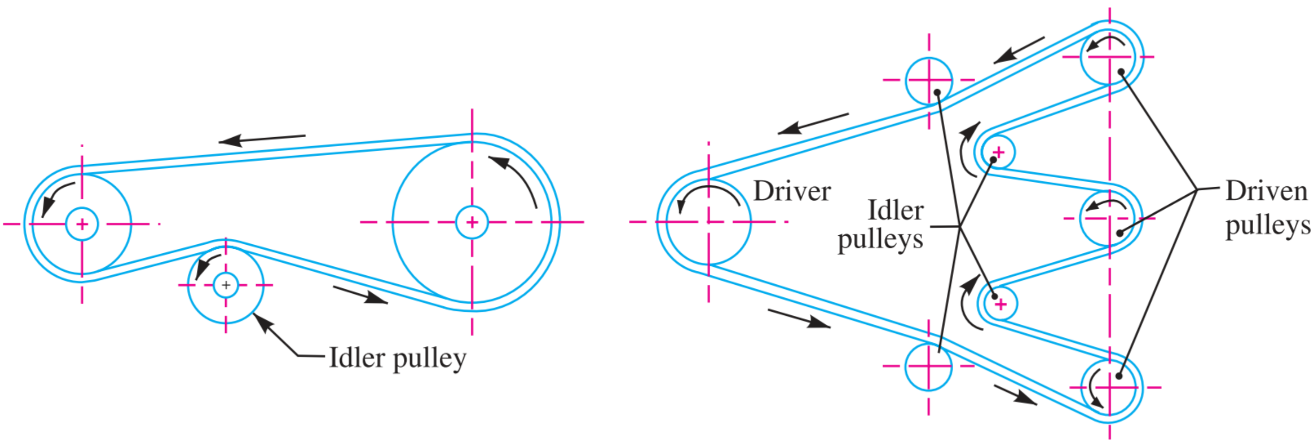
(*a*) Quarter turn belt drive.

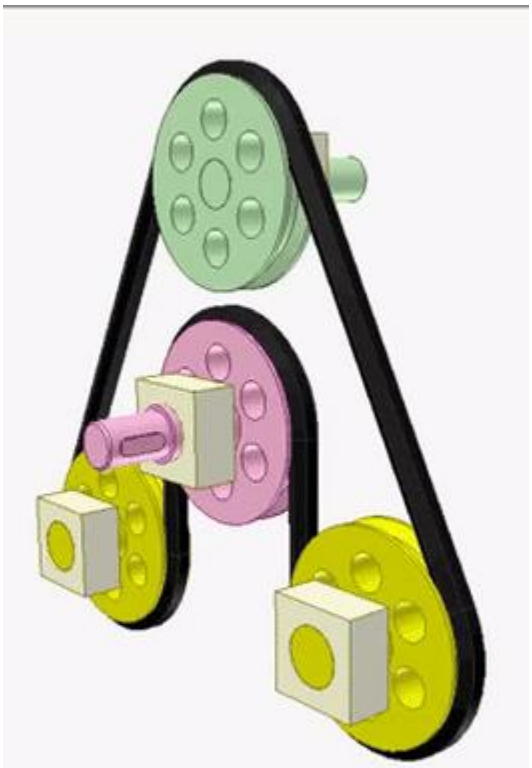


(*b*) Quarter turn belt drive with guide pulley.

4. *Belt drive with idler pulleys.*

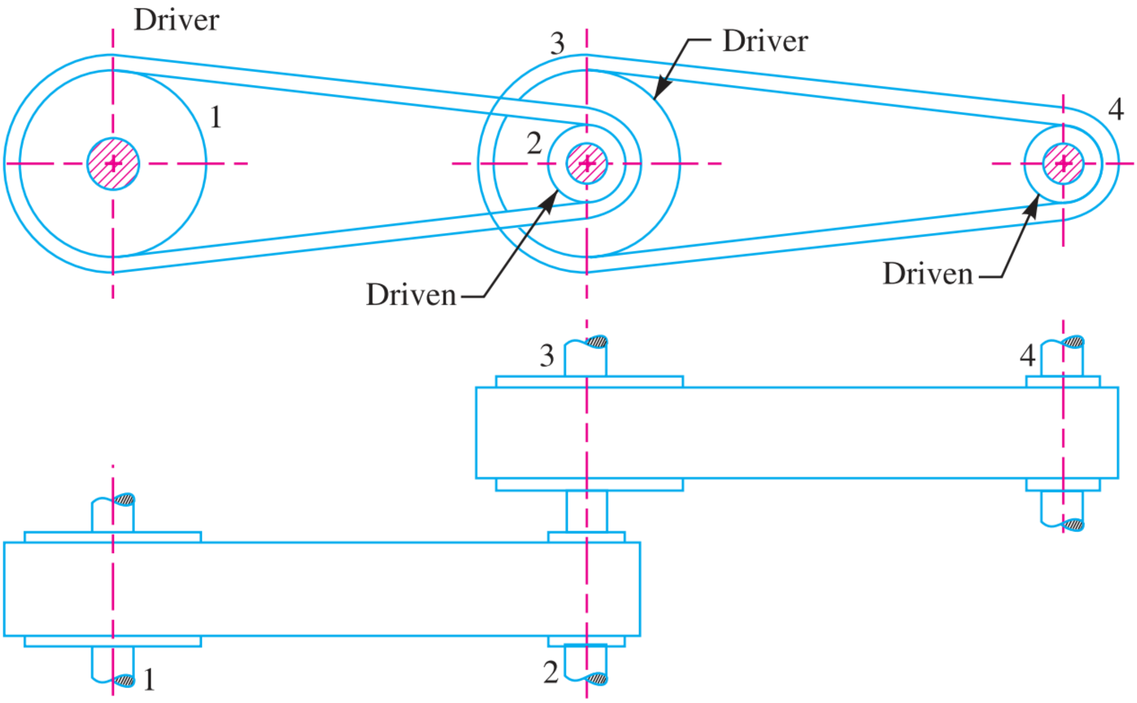
- is used with shafts arranged parallel and when an open belt drive cannot be used due to small angle of contact on the smaller pulley.
- This type of drive is provided to obtain high velocity ratio and when the required belt tension cannot be obtained by other means.
- When it is desired to transmit motion from one shaft to several shafts, all arranged in parallel, a belt drive with many idler pulleys, may be employed.



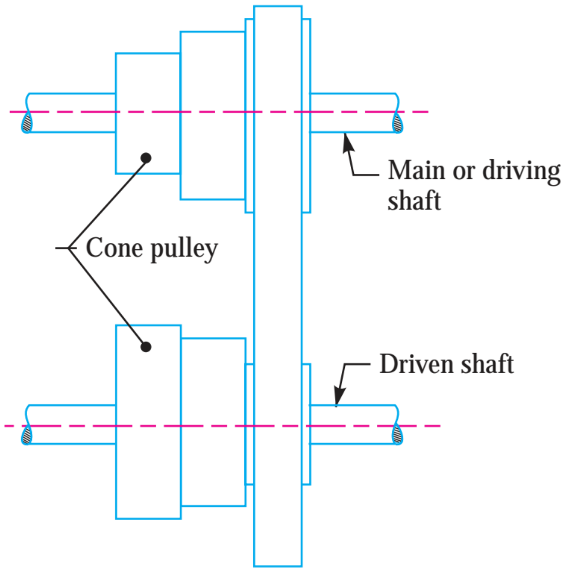


5. *Compound belt drive.*

which is used when power is transmitted from one shaft to another through a number of pulleys

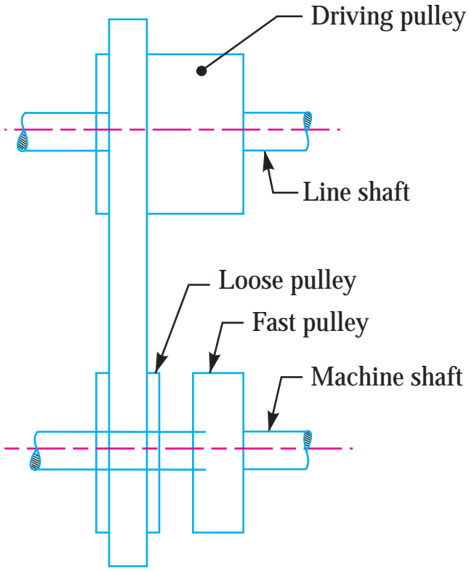


6. ***Stepped or cone pulley drive.***
   - which is used for changing the speed of the driven shaft while the main or driving shaft runs at constant speed. This is accomplished by shifting the belt from one part of the steps to the other



7. ***Fast and loose pulley drive.***
   - is used when the driven shaft is to be started or stopped whenever desired without interfering with the driving shaft. A pulley which is keyed to the machine shaft is called fast pulley 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 on to the loose pulley by means of sliding bar having belt forks

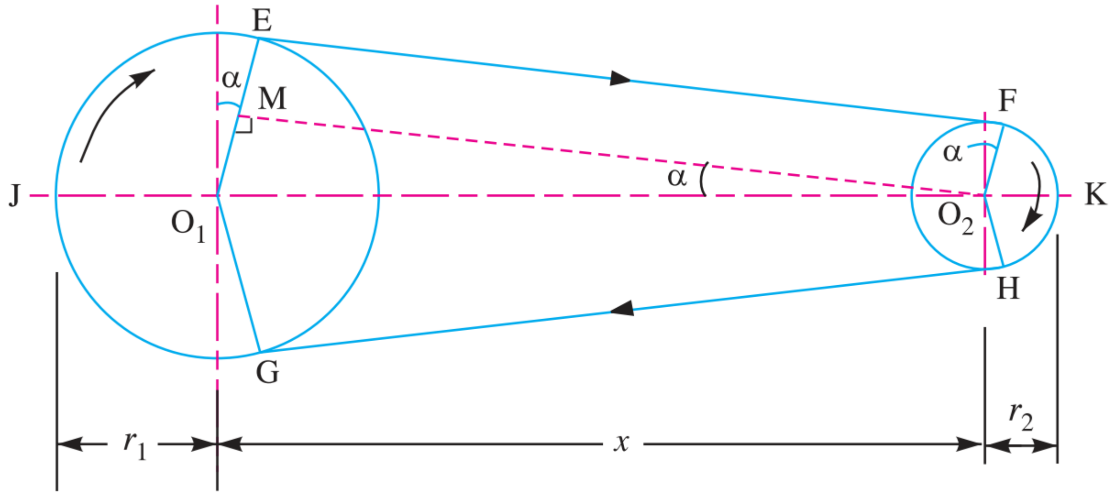


Terminology

- Length of the belt
- Velocity ratio
- Slip
- Tight side and slack side
- Length of the belt
- Angle of contact
- Ratio between the belt tensions
- Power transmitted

Length of an Open Belt Drive

We have discussed that in an open belt drive, both the pulleys rotate in the same direction.



Let

- r_1 and r_2 = Radii of the larger and smaller pulleys,
- x = Distance between the centres of two pulleys (i.e., O_1O_2), and
- L = Total length of the belt

$$L = \pi(r_1 + r_2) + 2x + \frac{(r_1 - r_2)^2}{x} \quad \text{... in terms of pulley radii}$$

$$L = \frac{\pi}{2}(d_1 + d_2) + 2x + \frac{(d_1 - d_2)^2}{4x} \quad \text{... in terms of pulley diameters}$$

The contact angle

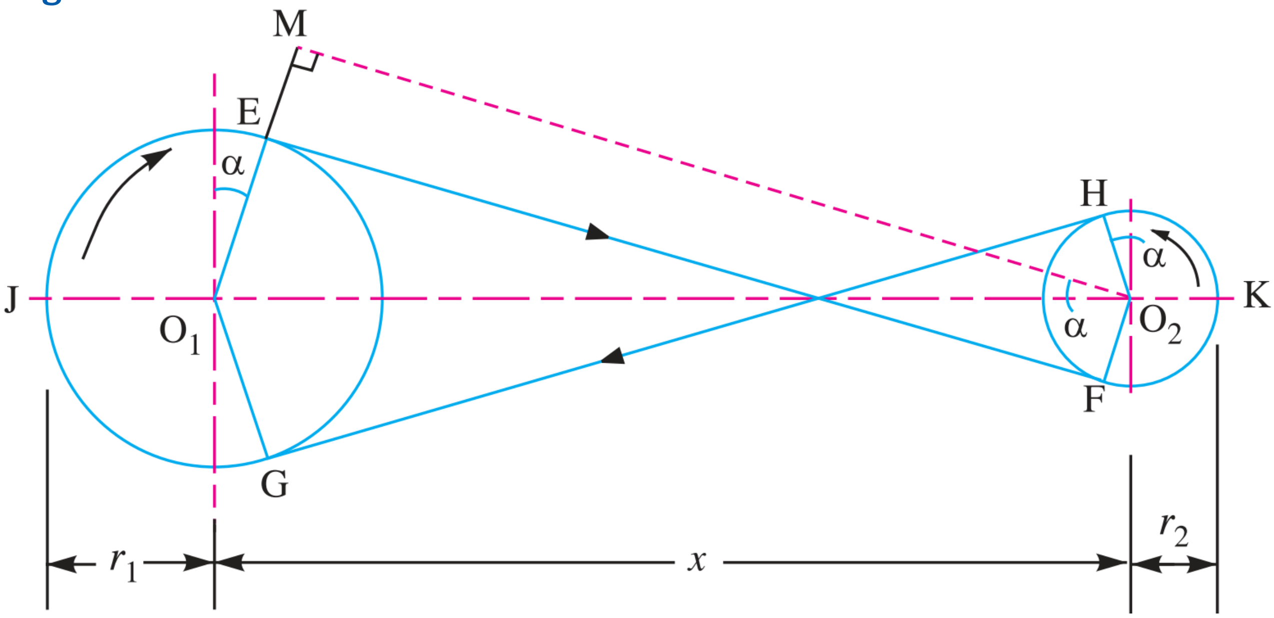
$$\theta = (180° - 2\alpha) \times \frac{\pi}{180} \ rad$$

where

$$\sin\alpha = \frac{r_1 - r_2}{x}$$

- While determining the angle of contact, it must be remembered that it is the angle of contact at the smaller pulley, if both the pulleys are of the same material.
- When the pulleys are made of different material (i.e. when the coefficient of friction of the pulleys or the angle of contact are different), then the design will refer to the pulley for which μ.θ is small.

Length of a Cross Belt Drive



We have discussed that in a cross belt drive, both the pulleys rotate in the opposite
directions.
Let

- r_1 and r_2 = Radii of the larger and smaller pulleys,
- x = Distance between the centres of two pulleys (i.e. O_1O_2), and
- L = Total length of the belt

$$\boldsymbol{L = \pi(r_1 + r_2) + 2x + \frac{(r_1 + r_2)^2}{x}} \quad \textit{... in terms of pulley radii}$$

$$\boldsymbol{L = \frac{\pi}{2}(d_1 + d_2) + 2x + \frac{(d_1 + d_2)^2}{4x}} \quad \textit{... in terms of pulley diameters}$$

The contact angle

$$\theta = (180° + 2\alpha) \times \frac{\pi}{180} \ rad$$

where

$$\sin\alpha = \frac{r_1 + r_2}{x}$$

Velocity Ratio

- d_1 = Diameter of the driver,
- d_2= Diameter of the follower,
- N_1= Speed of the driver in r.p.m.,
- N_2= Speed of the follower in r.p.m.,

∴ Length of the belt that passes over the driver, in one minute

$$= \pi d_1 N_1$$

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 is equal to the length of belt that passes over the follower in one minute, therefore

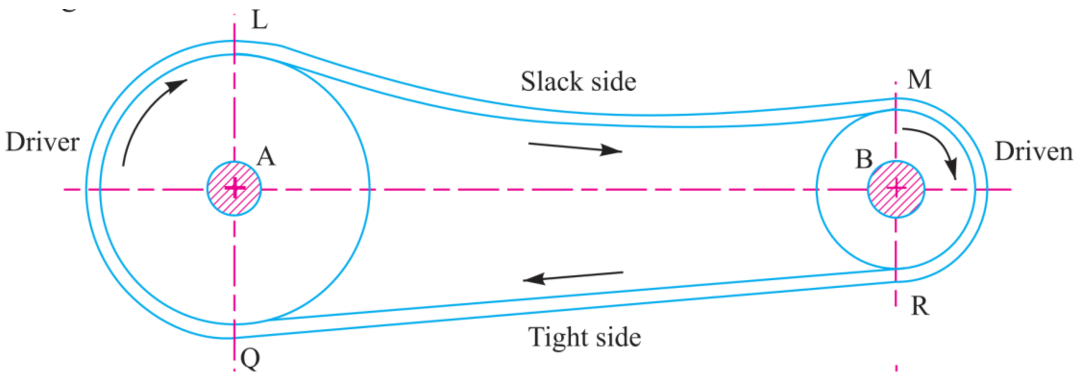
$$\therefore \qquad \pi d_1 N_1 = \pi d_2 N_2$$

velocity ratio,

$$\frac{N_2}{N_1} = \frac{d_1}{d_2}$$

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

$$\frac{N_2}{N_1} = \frac{d_1 + t}{d_2 + t}$$



Notes :

1. The velocity ratio of a belt drive may also be obtained as discussed below:

We know that the peripheral velocity of the belt on the driving pulley,

$$v_1 = \frac{\pi d_1 N_1}{60} \qquad \frac{m}{s}$$

and peripheral velocity of the belt on the driven pulley,

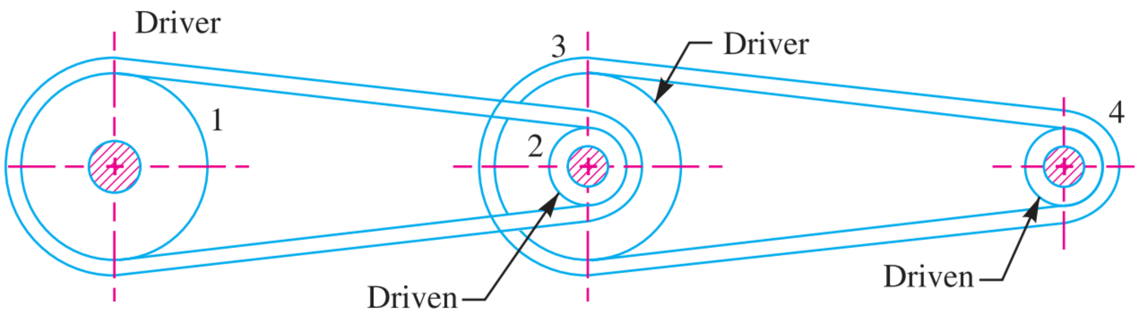
$$v_2 = \frac{\pi \boldsymbol{d_2 N_2}}{60} \qquad \frac{m}{s}$$

When there is no slip, then $v_1 = v_2$.

$$\frac{\pi \boldsymbol{d_1 N_1}}{60} = \frac{\pi \boldsymbol{d_2 N_2}}{60}$$

$$\frac{\boldsymbol{N_2}}{\boldsymbol{N_1}} = \frac{\boldsymbol{d_1}}{\boldsymbol{d_2}}$$

2. In case of a compound belt drive as shown in Fig., the velocity ratio is given by



$$\frac{\boldsymbol{N_4}}{\boldsymbol{N_1}} = \frac{\boldsymbol{d_1} \times \boldsymbol{d_3}}{\boldsymbol{d_2} \times \boldsymbol{d_4}}$$

Or $$\frac{\textit{speed of last driven}}{\textit{Speed of first driver}} = \frac{\textit{Product of diameters of drivers}}{\textit{Product of diameters of drivens}}$$

Slip of the Belt

In the previous articles we have discussed the motion of belts and pulleys assuming a firm frictional grip between the belts and the pulleys. But sometimes, the frictional grip becomes insufficient. This may cause some forward motion of the driver without carrying the belt 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.*

Let *s_1 % = Slip between the driver and the belt*

s_2 % = Slip between the belt and follower

∴ Velocity of the belt passing over the driver per second,

$$v = \frac{\pi \boldsymbol{d_1 N_1}}{60} - \frac{\pi \boldsymbol{d_1 N_1}}{60} \times \frac{s_1}{100} = \frac{\pi \boldsymbol{d_1 N_1}}{60}\left(1 - \frac{s_1}{100}\right)$$

and velocity of the belt passing over the follower per second

$$\frac{\pi d_2 N_2}{60} = v - v \times \frac{s_2}{100} \quad = v\left(1 - \frac{s_2}{100}\right)$$

Substituting the value of v from equation, we have

$$\frac{\pi d_2 N_2}{60} = \frac{\pi d_1 N_1}{60}\left(1 - \frac{s_1}{100}\right)\left(1 - \frac{s_2}{100}\right)$$

$$\frac{N_2}{N_1} = \frac{d_1}{d_2}\left(1 - \frac{s_1}{100} - \frac{s_2}{100}\right) \qquad Neglecting \ \frac{s_1 \times s_2}{100 \times 100}$$

$$= \frac{d_1}{d_2}\left(1 - \left(\frac{s_1 + s_2}{100}\right)\right)$$

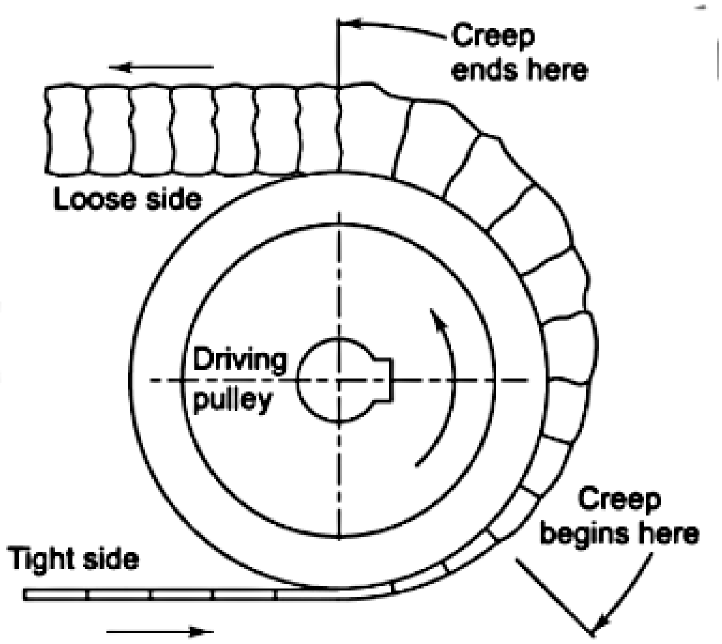
$$\therefore \frac{N_2}{N_1} = \frac{d_1}{d_2}\left(1 - \frac{s}{100}\right)$$ where $s = s_1 + s_2$ total percent of slip

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

$$\therefore \frac{N_2}{N_1} = \frac{d_1 + t}{d_2 + t}\left(1 - \frac{s}{100}\right)$$

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 the 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.*



Considering creep, the velocity ratio is given by

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

Where :

- σ_1 and σ_2 = Stress in the belt on the tight and slack side respectively,
- *E = Young's modulus for the material of the belt.*

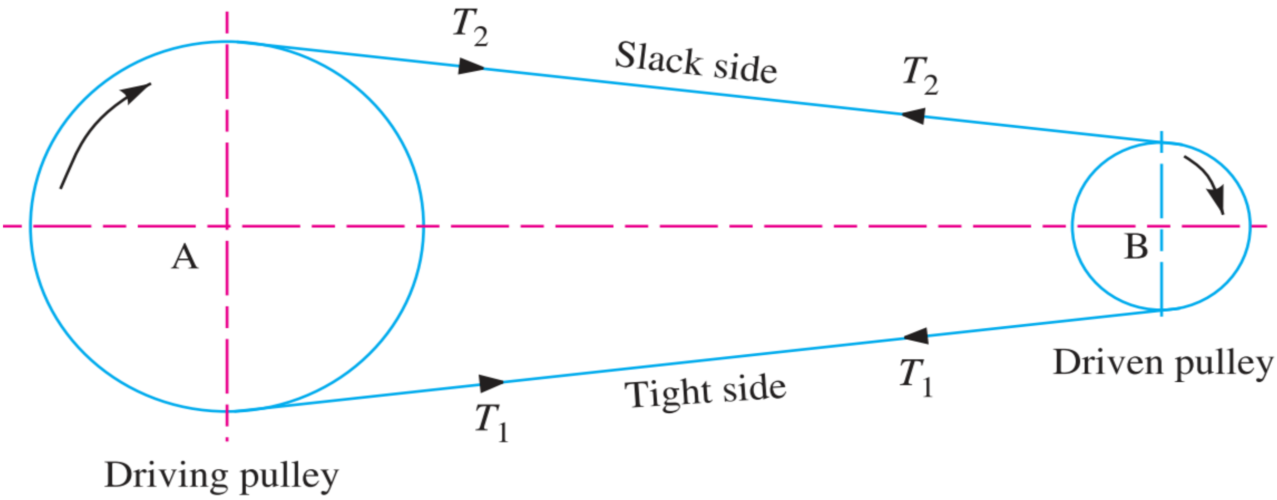
Note: Since the effect of creep is very small, therefore it is generally neglected.

Power Transmitted by a Belt

- This figure shows the driving pulley (or driver) *A* and the driven pulley (or follower) *B*.
- The driving pulley pulls the belt from one side and delivers it to the other side.
- The tension on the former side (*i.e.*, tight side) will be greater than the latter side (*i.e.*, slack side)

Let

- T_1 and T_2 = Tensions in the tight side and slack side of the belt (N)
- r_1 and r_2 = Radii of the driving and driven pulleys (m),
- ν = Velocity of the belt in m/s.



The effective turning (driving) force at the circumference of the driven pulley or follower is te difference between the two tensions (*i.e.* $T_1 - T_2$)

∴ Work done per second = $(T_1 - T_2)\ \boldsymbol{v}$ $\quad Nm/s$

So, the Power Transmitted

$$P = (T_1 - T_2)\, v \quad W \qquad , \qquad 1\,\frac{Nm}{s} = 1W$$

- The torque exerted on the driving pulley is $(T_1 - T_2)\ r_1$.
- the torque exerted on the driven pulley is $(T_1 - T_2)\ r_2$.

Ratio of Driving Tensions for Flat Belt Drive

Consider a driven pulley rotating in the clockwise direction.
Let

- T_1 = Tension in the belt on the tight side,
  T_2 = Tension in the belt on the slack side,
- θ = Angle of contact in radians.
- μ is the coefficient of friction between the belt and pulley

$$\frac{T_1}{T_2} = e^{\mu\theta}$$

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 the 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,
- at higher belt speeds (more than 10 m/s), its effect should be considered.

Let

- m = Mass of belt per unit length in kg,
- v = Linear velocity of belt in m/s,
- r = Radius of pulley over which the belt runs in meters, and
- T_C = Centrifugal tension acting tangentially at P and Q in newtons.

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

Where

$$m = Area \times length \times density = b \times t \times L \times \rho$$

Notes :

1. When centrifugal tension is considered,

The total tension in the tight side,

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

and total tension in the slack side,

$$\boldsymbol{T_{t2} = T_2 + T_C}$$

2. Power transmitted

$$P = (T_{t1} - T_{t2})v \qquad W$$

$$\therefore P = (T_1 + T_C) - (T_2 + T_C) = \boldsymbol{(T_1 - T_2)\, v} \qquad \textbf{same as above}$$

Thus, we see that the centrifugal tension has no effect on the power transmitted.

3. The ratio of driving tensions may also be written as

$$\boldsymbol{\frac{T_1}{T_2} = \frac{T_{t1} - T_C}{T_{t2} - T_C} = e^{\mu\theta}}$$

Maximum Tension in the Belt

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

- σ = Maximum safe stress,
- b = Width of the belt, and
- t = Thickness of the belt.

We know that the maximum tension in the belt,

$$\boldsymbol{T = Maximum\ stress \times Cross - sectional\ area\ of\ belt}$$

$$\boldsymbol{T = \sigma . b . t}$$

When centrifugal tension is neglected, then

$\boldsymbol{T\ (or\ T_{t1}) = T_1}$, i. e. Tension in the tight side of the belt.

When centrifugal tension is considered, then

$$\boldsymbol{T\ (or\ T_{t1}) = T_1 + T_C}$$

Condition for the Transmission of Maximum Power

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

T = Maximum tension in belt (N),

$\boldsymbol{T_C}$ = Centrifugal tension in newtons

$$T = 3\,\boldsymbol{T_C}$$