JAIPUR ENGINEERING COLLEGE AND RESEARCH CENTER

Year & Sem. – I Year & I SEM

Subject –Basic Mechanical Engineering (1FY3-07)

Unit– 4

Presented by – Jitendra Kumar Gupta (Assistant Professor)

VISION AND MISSION OF INSTITUTE

VISION OF INSTITUTE

To became a renowned centre of outcome based learning and work towards academic professional ,cultur al and social enrichment of the lives of individuals and communities .

MISSION OF INSTITUTE

Focus on evaluation of learning ,outcomes and motivate students to research aptitude by project based learning.

- Identify based on informed perception of Indian ,regional and global needs ,the area of focus and prov ide platform to gain knowledge and solutions.
-
- Offer opportunities for interaction between academic and industry .
- Develop human potential to its fullest extent so that intellectually capable and imaginatively gifted lea ders may emerge.

VISION AND MISSION OF DEPARTMENT

Vision

The Mechanical Engineering Department strives to be recognized globally for excellent technical knowledge and to produce quality human resource, who can manage the advance technologies and contribute to society through entrepreneurship and leadership.

Mission

1) To impart highest quality technical knowledge to the learners to make them globally competitive mechanical engineers.
2) To provide the learners ethical guidelines along with excellent academic environment for a long productive career.
3) To promote industry-institute linkage.

Course Outcomes of BME

- To describe the importance of mechanical engineering in any industry and to apply the various concepts in thermal based industry.
- To understand the various machines and power transmission related to it and also the effect of parameters on a job.
- To relate the industrial issues with the environment and to consider key concepts in in engineeri ng materials.
- To come across new practices and researches going in mechanical engineering line CAD, CAM etc.

Contents of UNIT-4

- Introduction.
- Types of Belts.
- Rope Drives.
- Gears.

Introduction

- Rotating elements which possess mechanical energy has to be utilized at required place by transmitting.
  - From prime mover to machine
  - From one shaft to another

Transmission system and Types

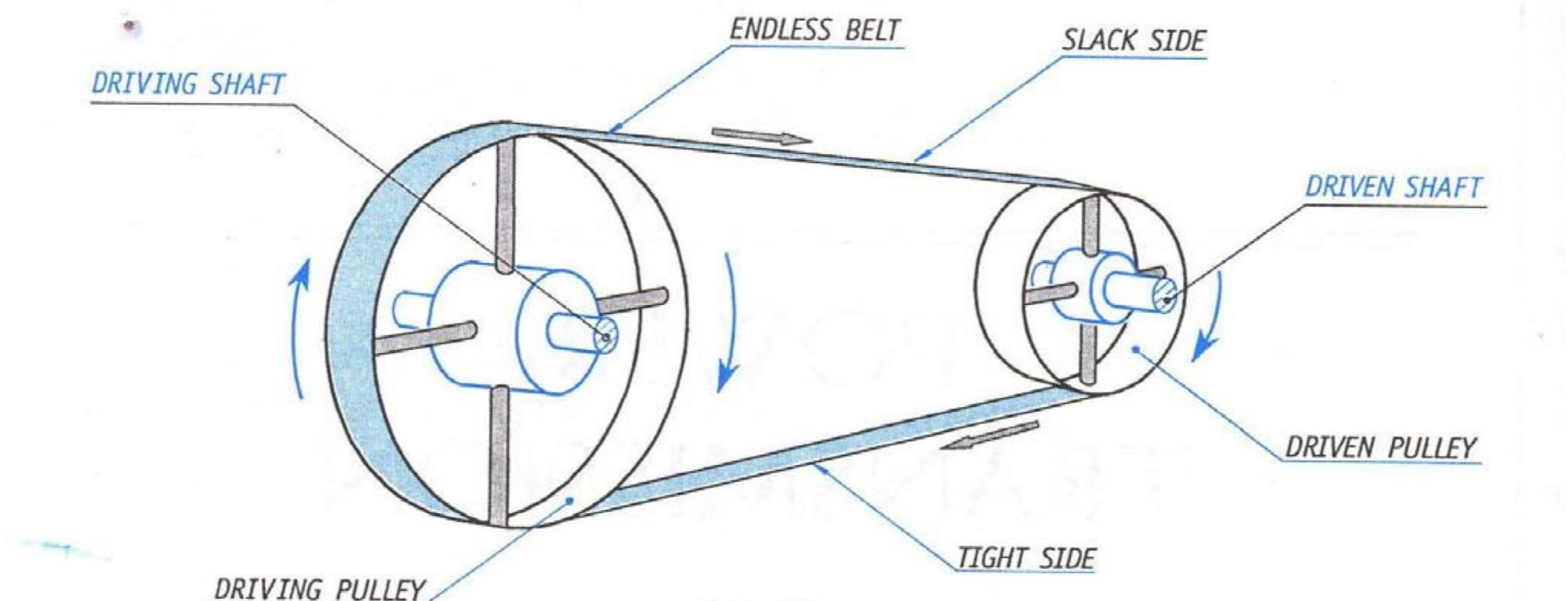
- The system that is used to transmit power from one mechanical element to another mechanical element
- Types
  - Belt drives
  - Rope drives
  - Chain drives
  - Gear drives

Factors to select transmission system

- Distance between driver and driven pulley shaft.
- Operational speed.
- Power to be transmitted

Belt drives

- Power is to be transmitted between the parallel shaft.
- Consists of two pulleys over which a endless belt is passed encircling the both.
- Rotary motion is transmitted from driving pulley to driven pulley.



Belt Drive

Terminology of a belt drive

- Driver : in a transmission system the one which drives or supplies power to other mechanical element.
- Driven : in a transmission system the one which follows the driver or receives power from driver.
- Tight side : the portion of the belt in maximum tension. Denoted by T_1 Newton.
- Slack side : the portion of the belt in minimum tension. Denoted by T_2 Newton
- Arc / angle of contact : it is the portion of the belt which is in contact with pulley surface. Denoted by

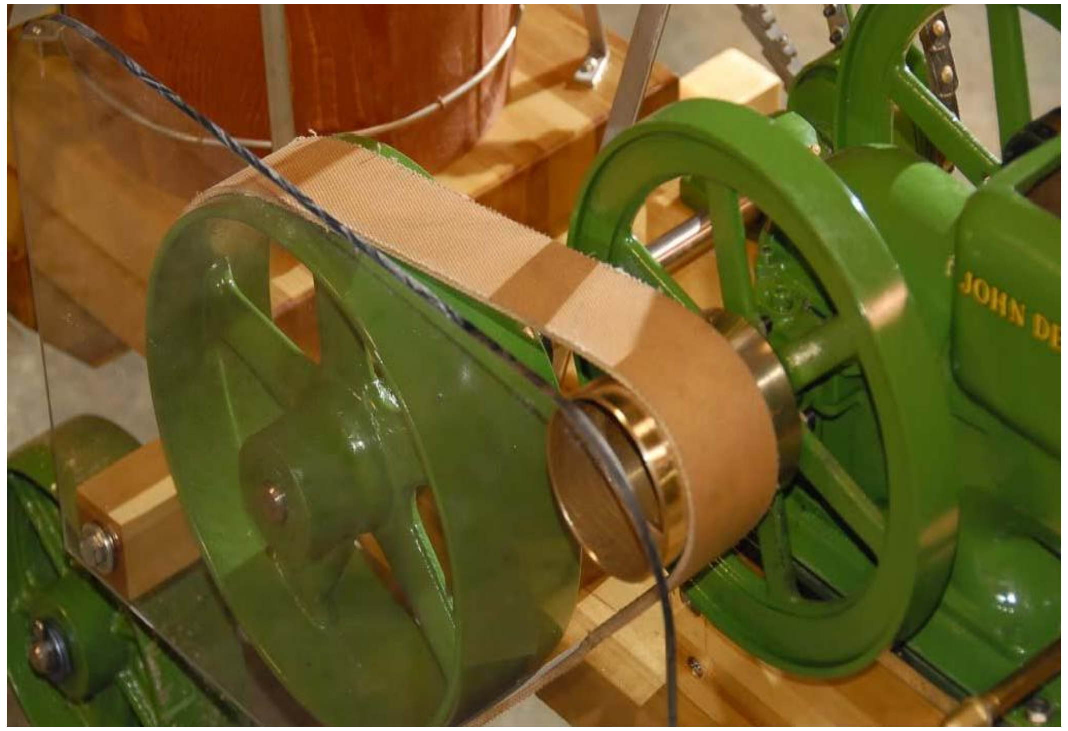
Belt material

- Rubber
- Leather
- Canvas
- Cotton
- Steel

Power transmission systems

- In factories, the power or rotary motion, from one shaft to another at a considerable distance is, usually, transmitted by means of belts, ropes and gears.

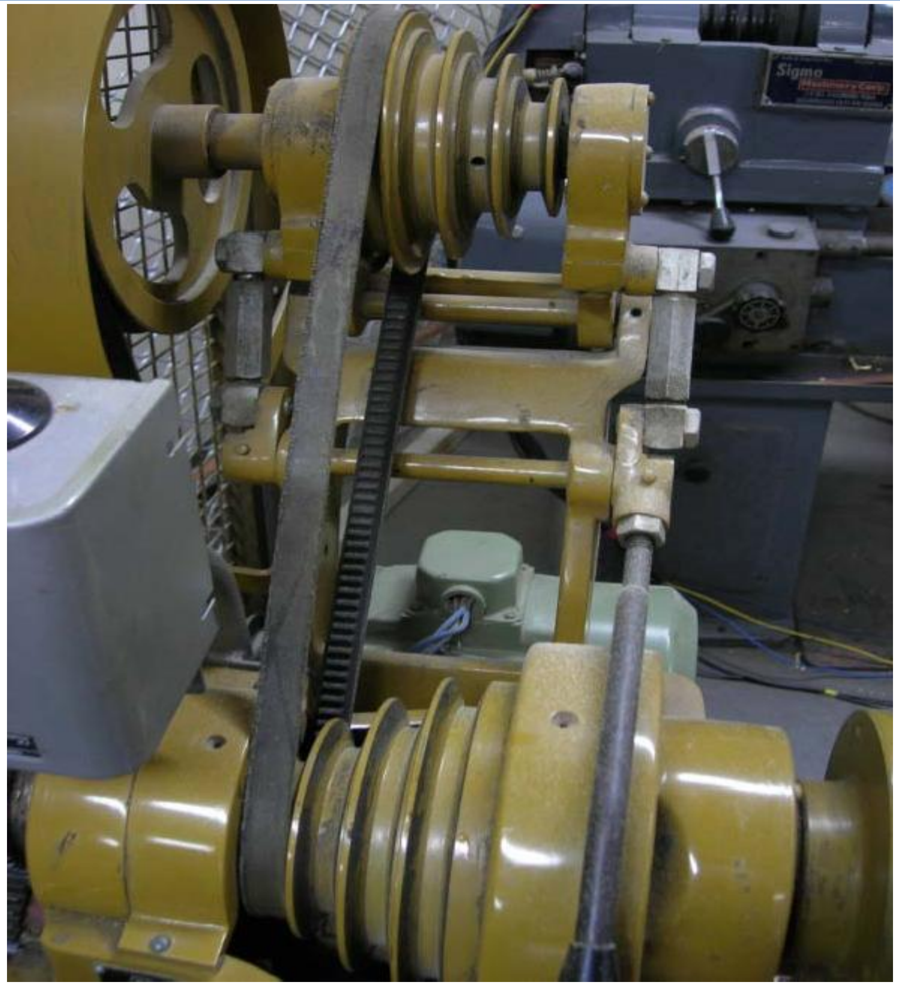
Belt Drives



Belt Drives

Drilling machine with speed cone pulleys

A open belt drive in a jig-saw machine

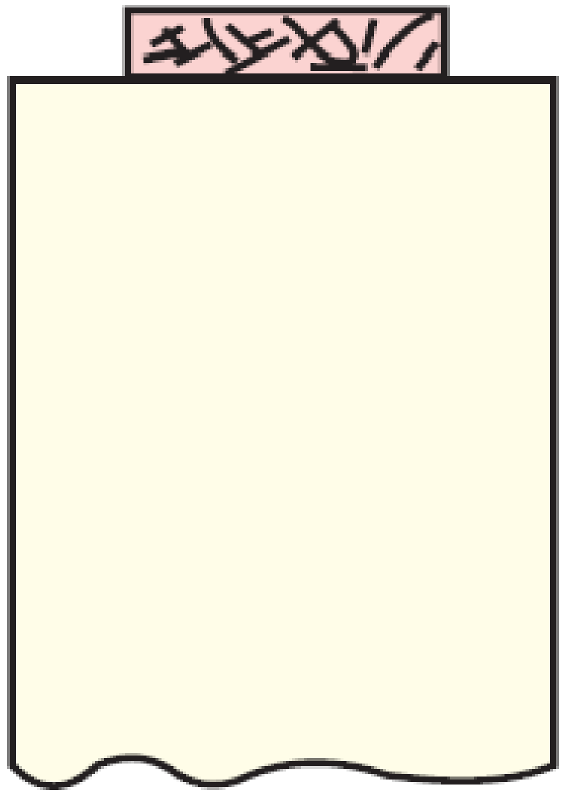


Lathe machine with speed cones and timing belt

Selection of a Belt Drive

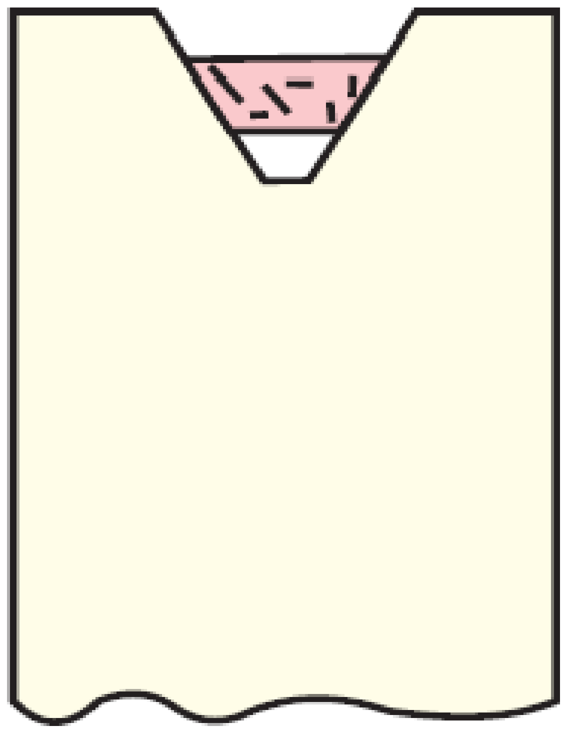
- Following are the various important factors upon which the selection of a belt depends:
- 1. Speed of the driving and driven shafts,
- 2. Speed reduction ratio,
- 3. Power to be transmitted,
- 4. Centre distance between the shafts,
- 5. Positive drive requirements,
- 6. Shafts layout,
- 7. Available space,
- 8. Service conditions.

Types of Belts



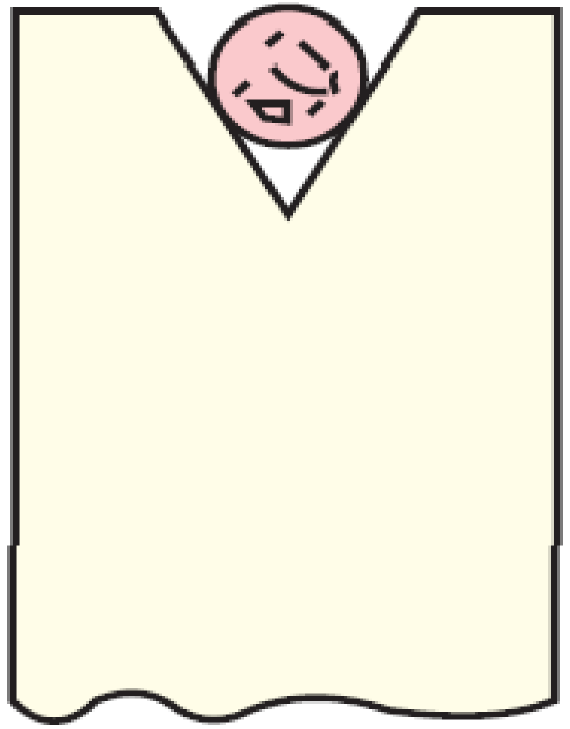
(a) Flat Belt

Moderate amount of power two pulleys are not more than10 m apart.



(b) V-Belt

Great amount of power two pulleys are very nearer to each other.



(c) Circular

Great amount of power two pulleys not more than 5 m apart.

Types of Belt Drives

Belts are classified in many types according to usage,position,shape like flat, v-belt, round ropes etc., but Belt drives are different from the belts, these are described as combination of pulleys according to their position and also their carrying or transmitting power from one pulley to another pulley.

The belt drives can be classified base on speed into the following three groups :

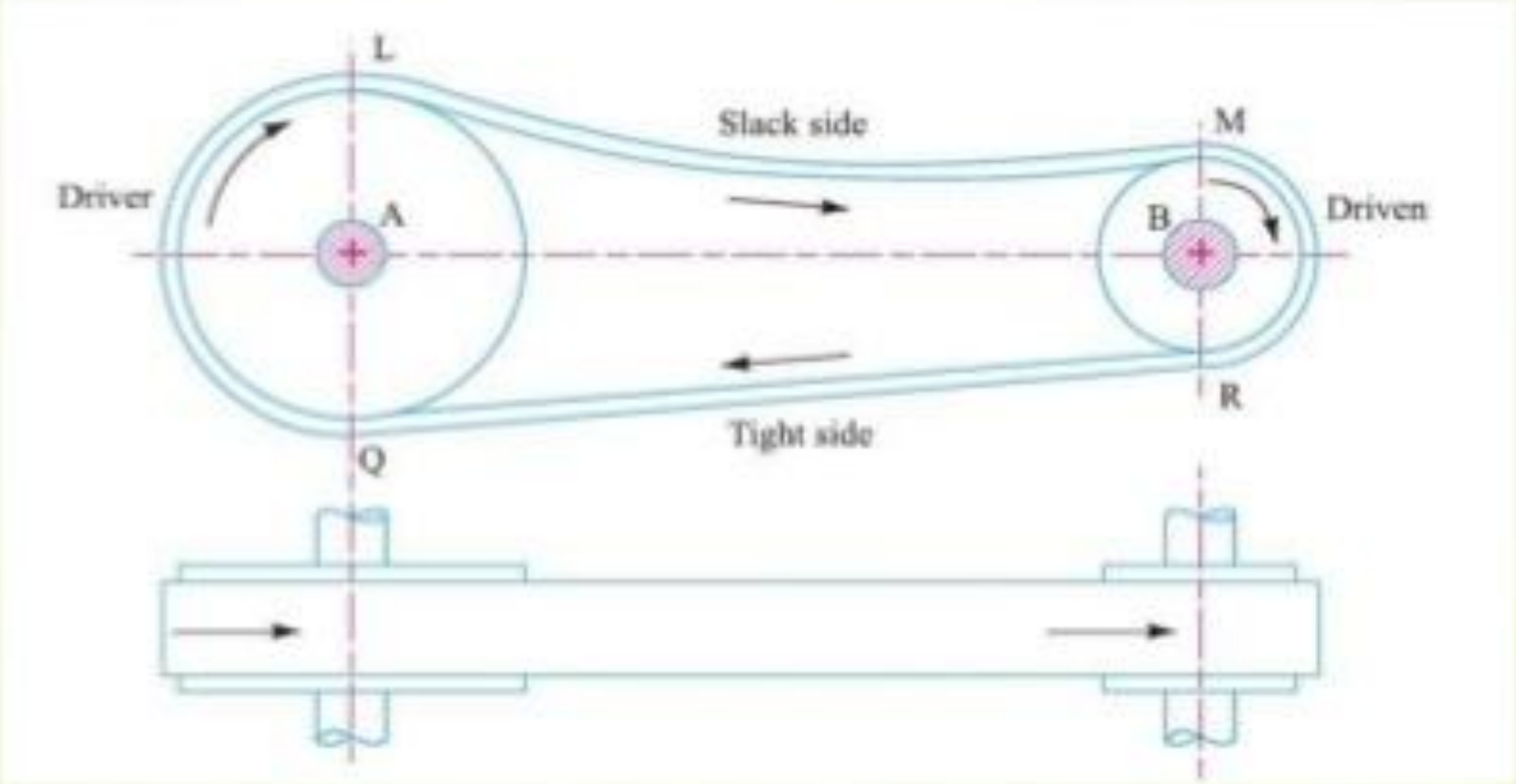
1. Light drives: These are used to transmit small powers at belt speeds upto about 10 m/s, as in agricultural machines and small machine tools.

2. Medium drives: These are used to transmit medium power at belt speeds over 10 m/s but up to 22 m/s, as in machine tools.

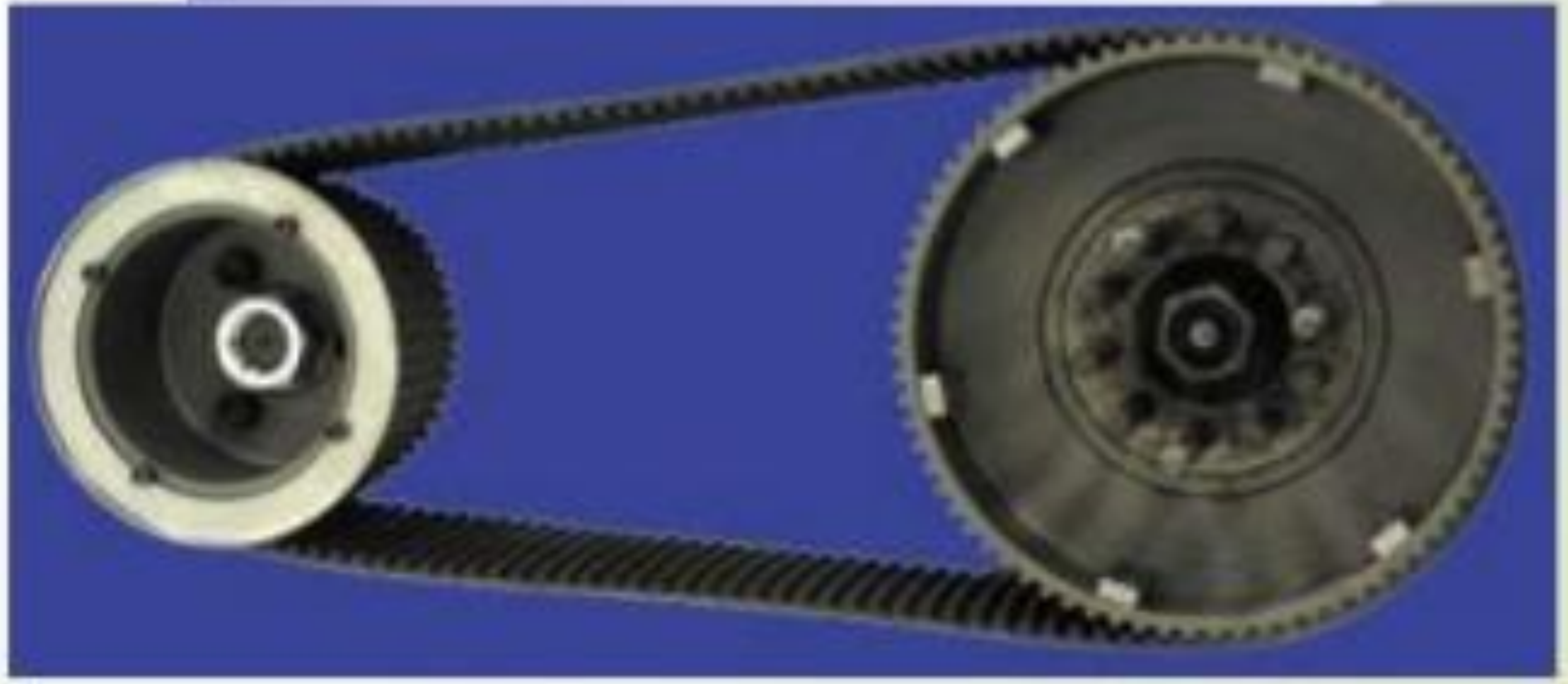
3. Heavy drives: These are used to transmit large powers at belt speeds above 22 m/s, as in compressors and generators.

1.Open belt drives

- An open belt drive is used to rotate the driven pulley in the same of driving pulley. In the motion of belt drive, power transmission results make one side of pulley more tightened compared to the other side.

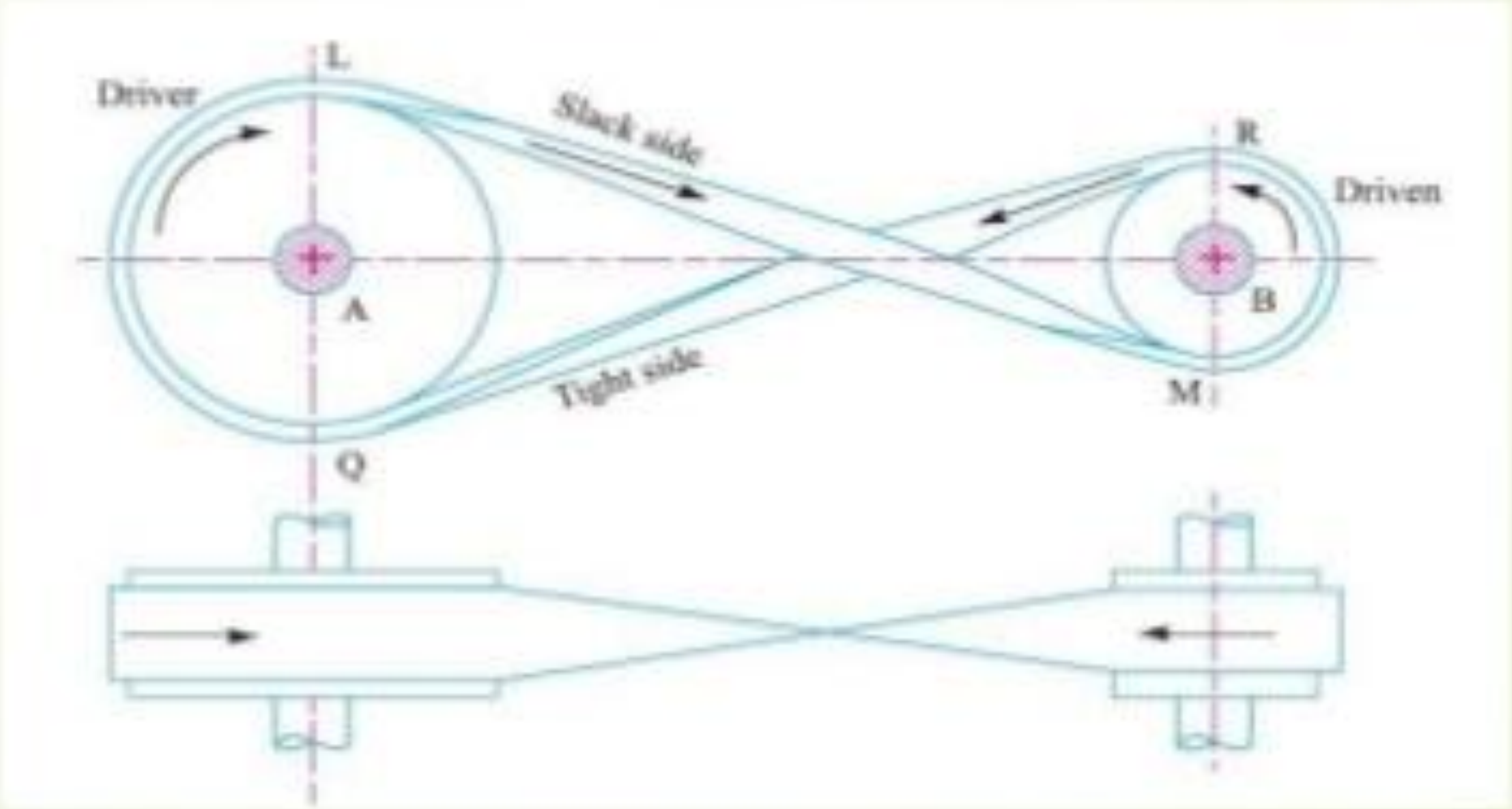


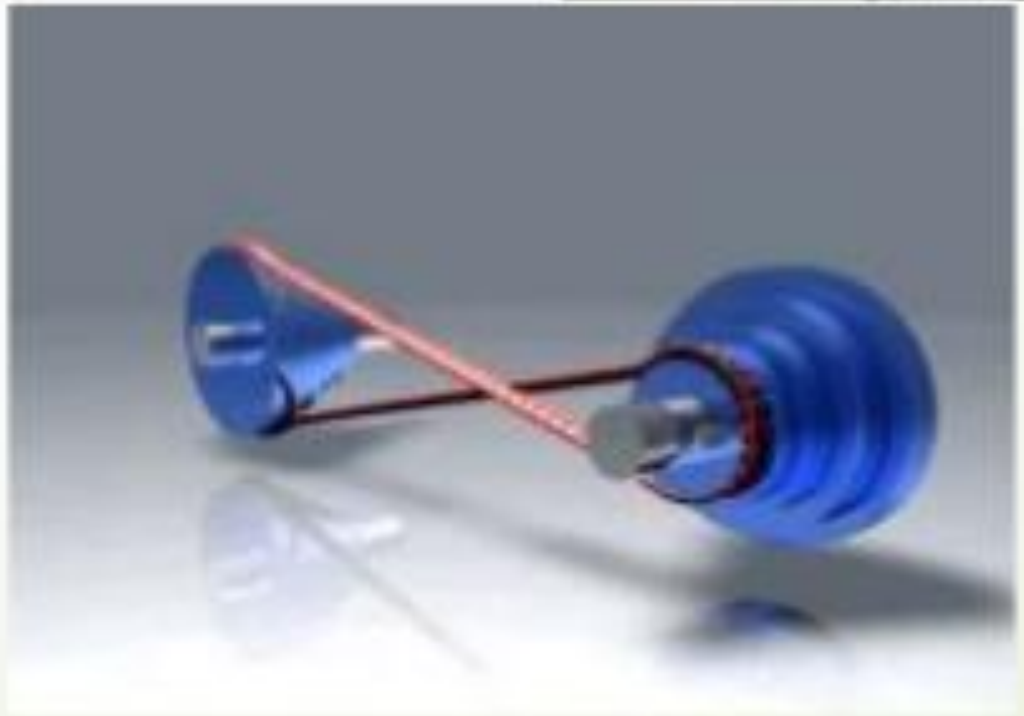
- Example of Industry



2.Crossed belt drives

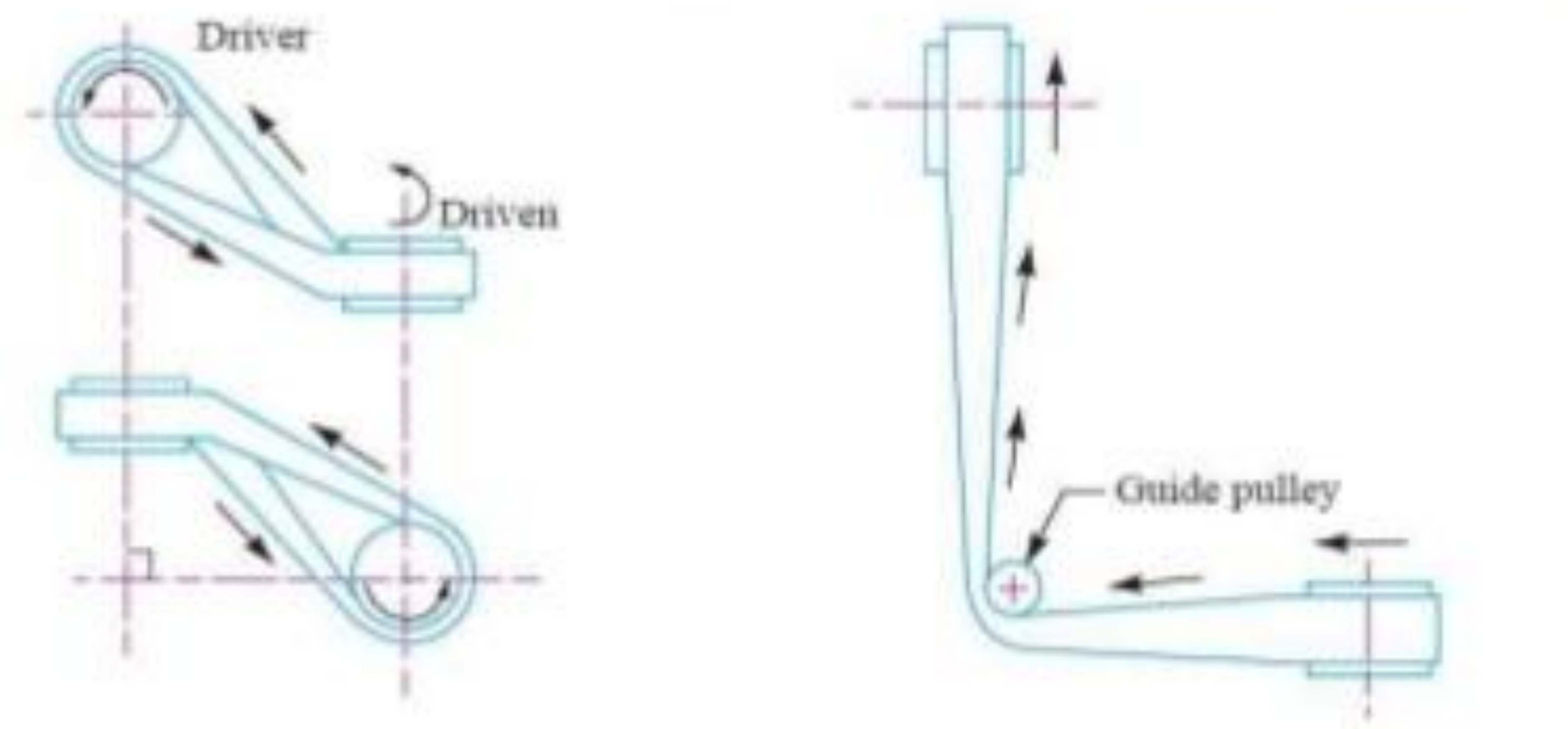
- A crossed belt drive is used to rotate driven pulley in the opposite direction of driving pulley. Higher the value of wrap enables more power can be transmitted than an open belt drive. However, bending and wear the belt are important concerns.





3. Quarter Turn Belt Drive

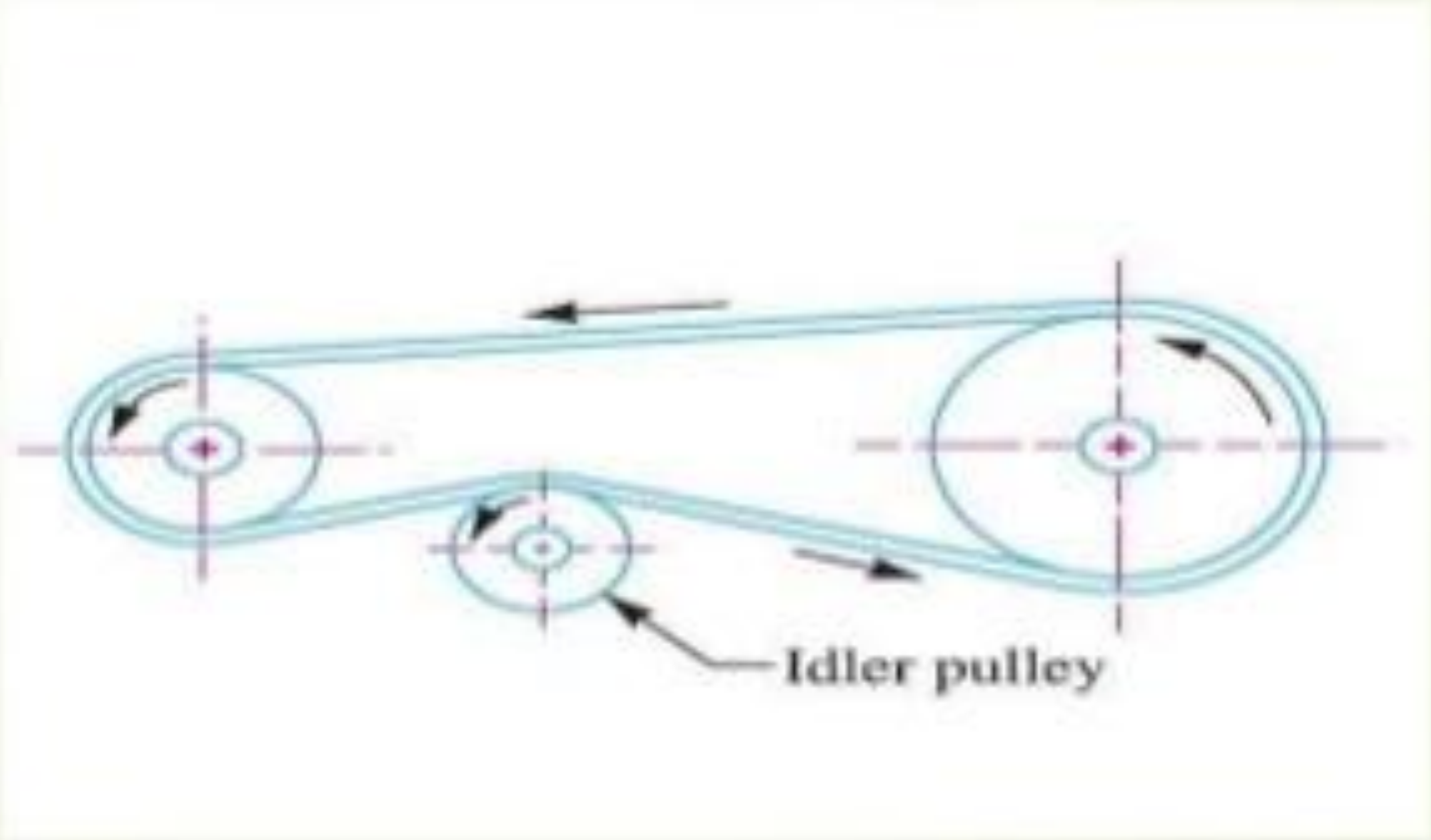
- The quarter turn belt drive (also known as right angle belt drive) as shown in is used with shafts arranged at right angles and rotating in one definite direction.



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

4. Belt drive with idler pulleys

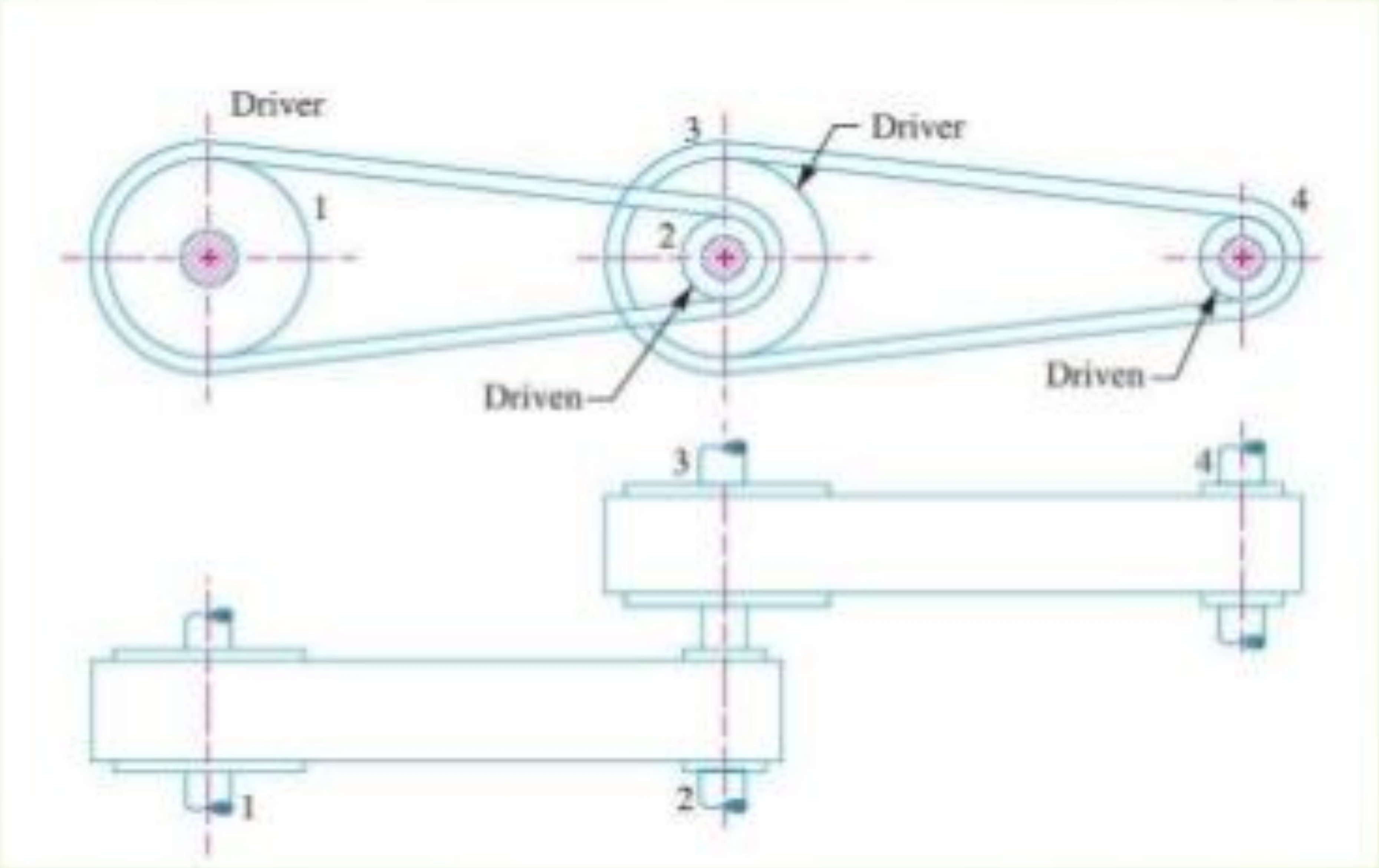
- Belt drive with an idler pulley (also known as jockey pulley drive) as shown in is used with shafts arranged parallel and when an open belt drive can not be due to small angle of contact on the smaller pulley. This type of drive is provided obtain high velocity ratio and when the required belt tension can not be by other means.



- Examples of Industry

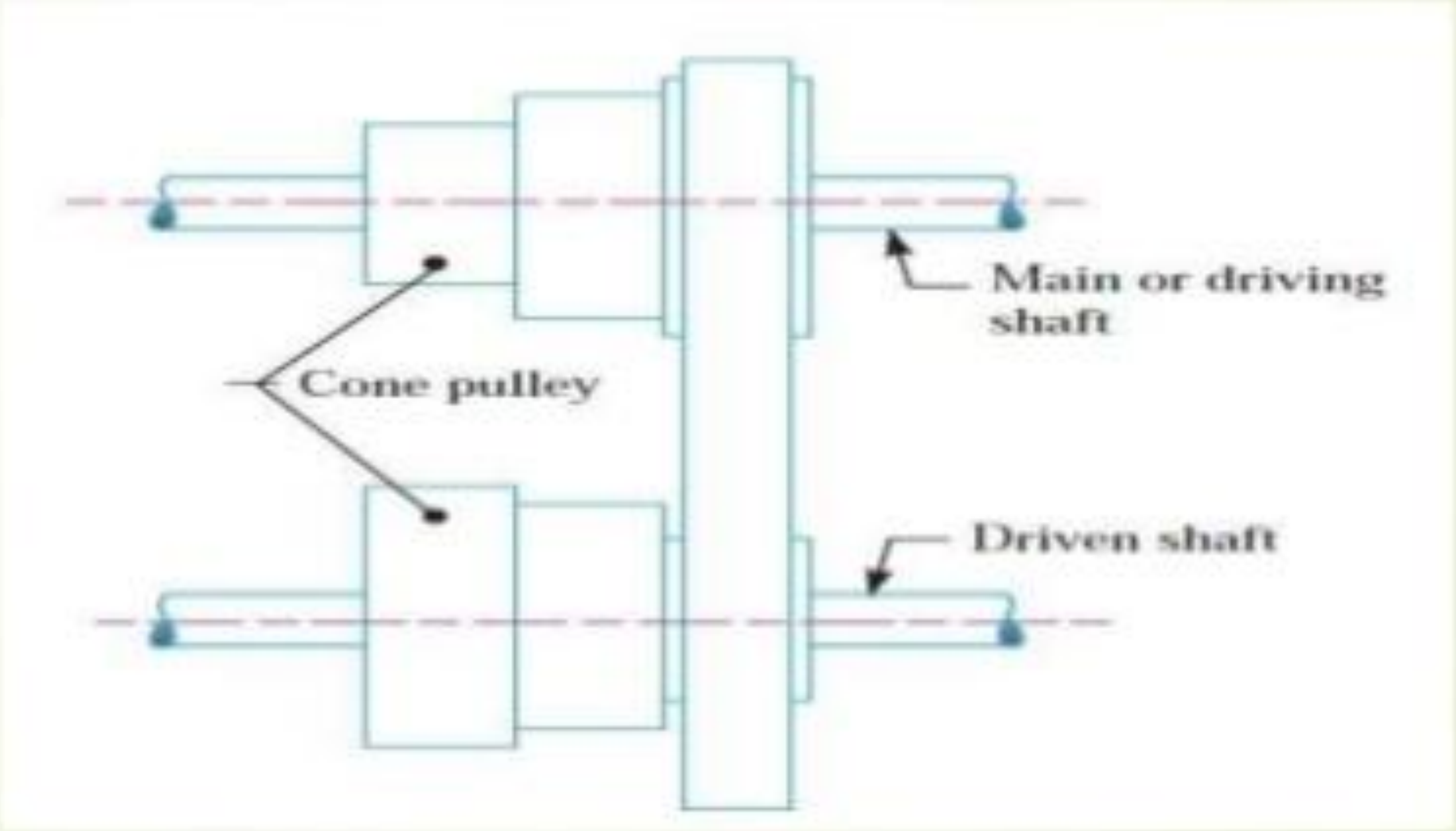
5. Compound belt drive

- A compound belt drive as shown in figure, is used when power is transmitted one shaft to another through a number of pulleys.



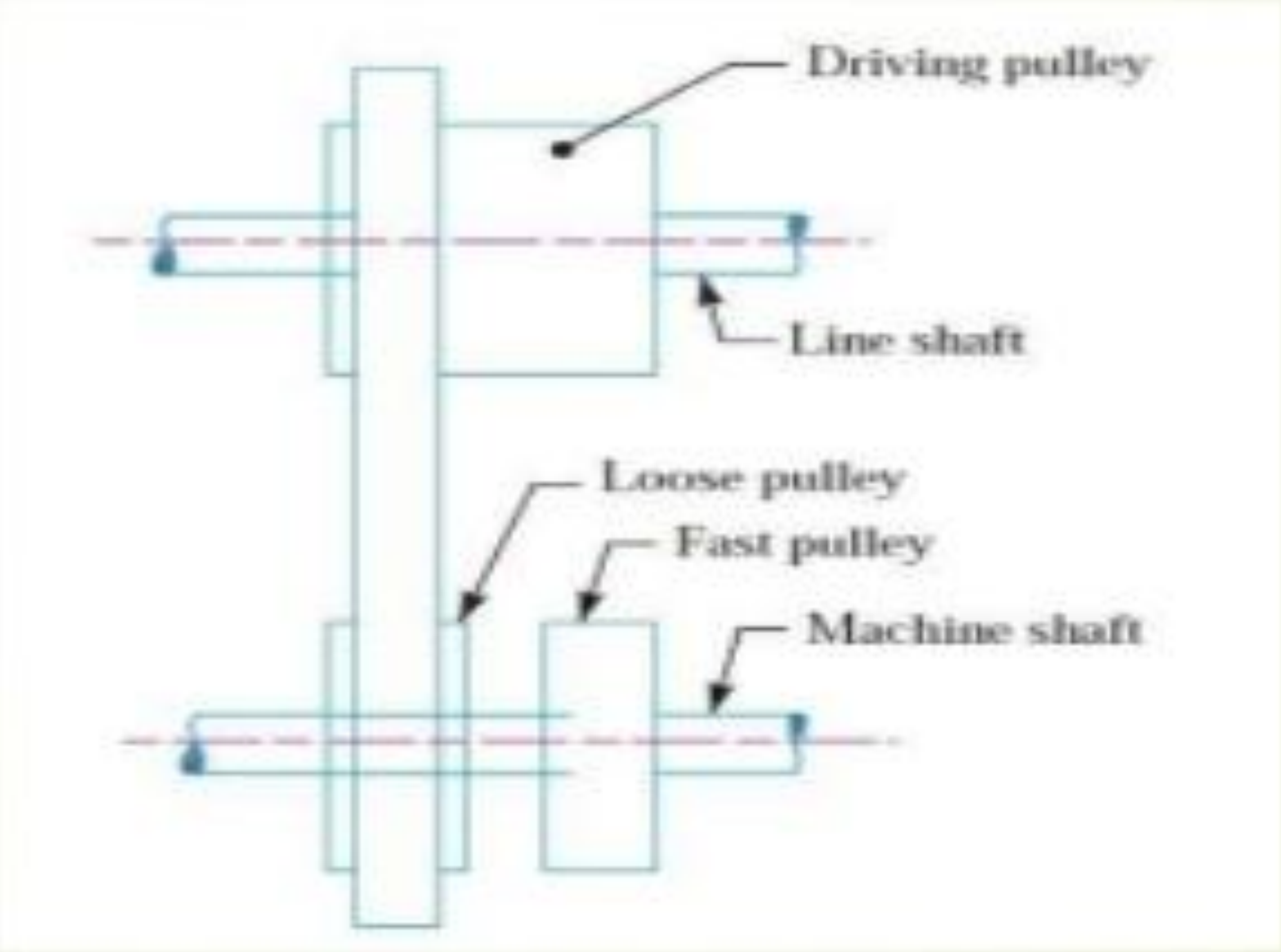
6. Stepped or cone pulley drive

- A stepped or cone pulley drive, as shown in figure, is used for changing the 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.



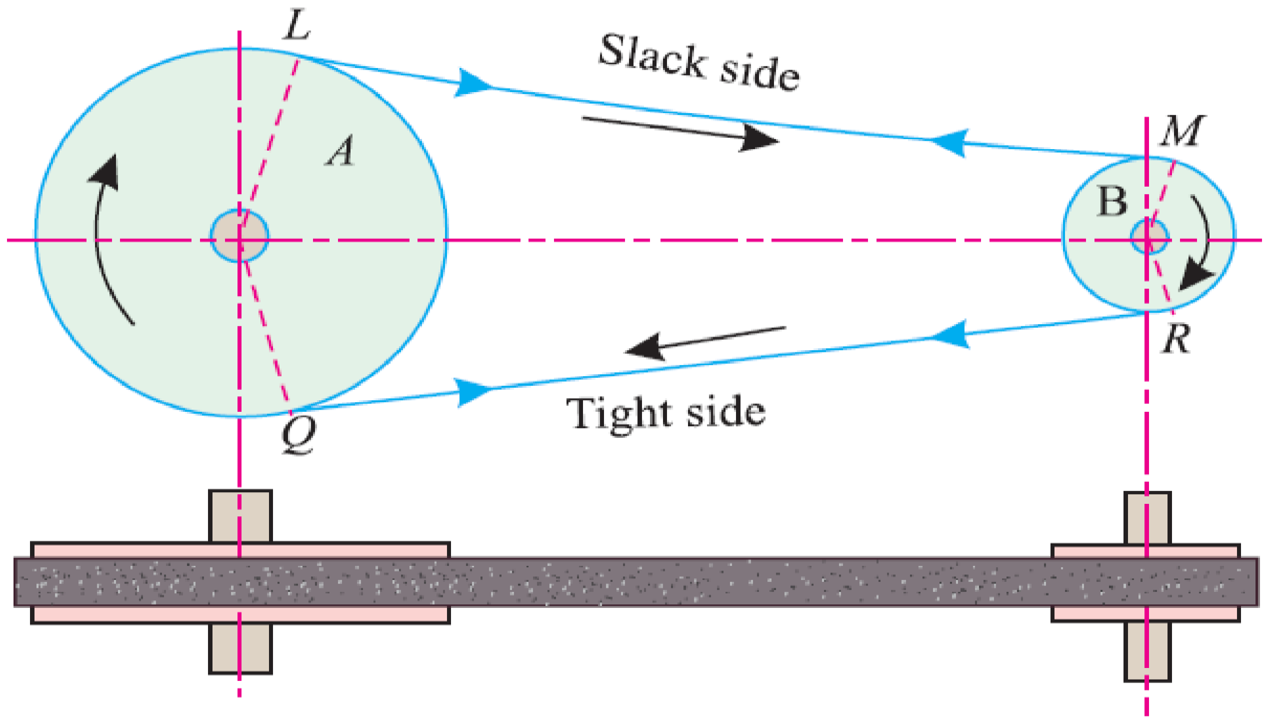
7. Fast and loose pulley drive

- Fast and loose pulley drive, as shown in figure, is used when the driven or shaft is to be started or stopped whenever desired without interfering with the driving shaft.



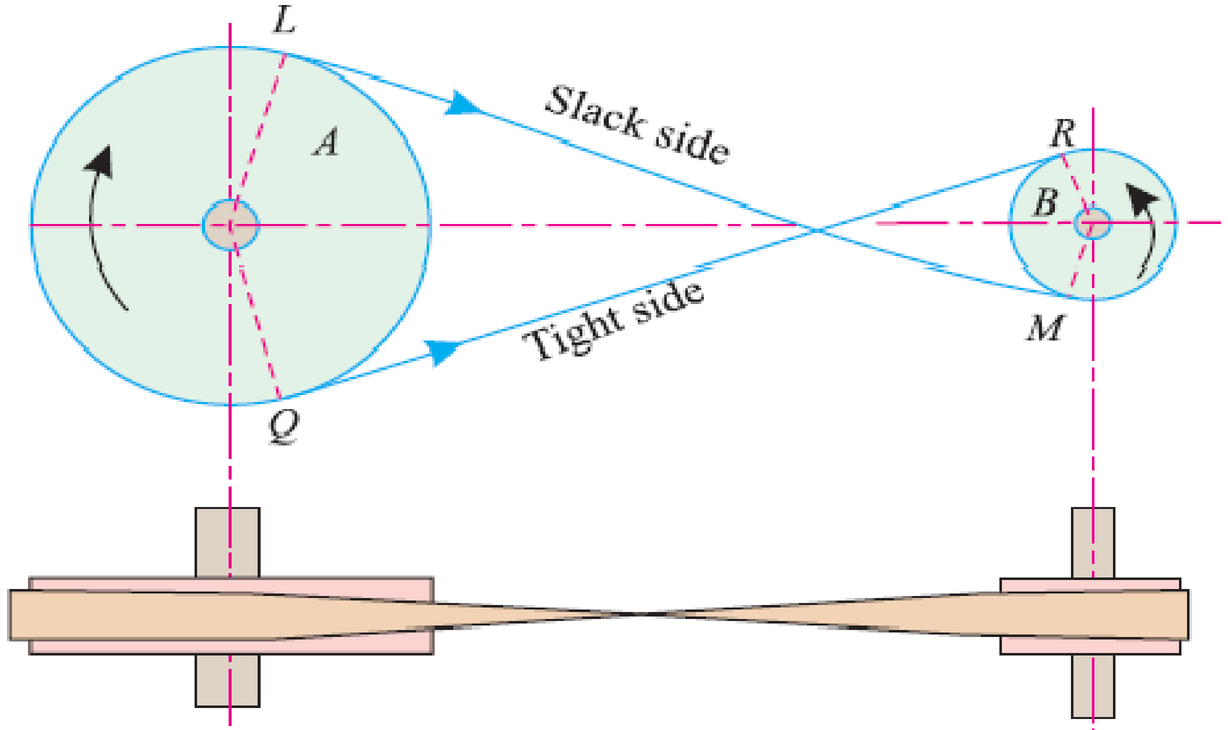
Difference b/n OpenBelt & Cross belt Drive

Open Belt Drive



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

Cross Belt Drive



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

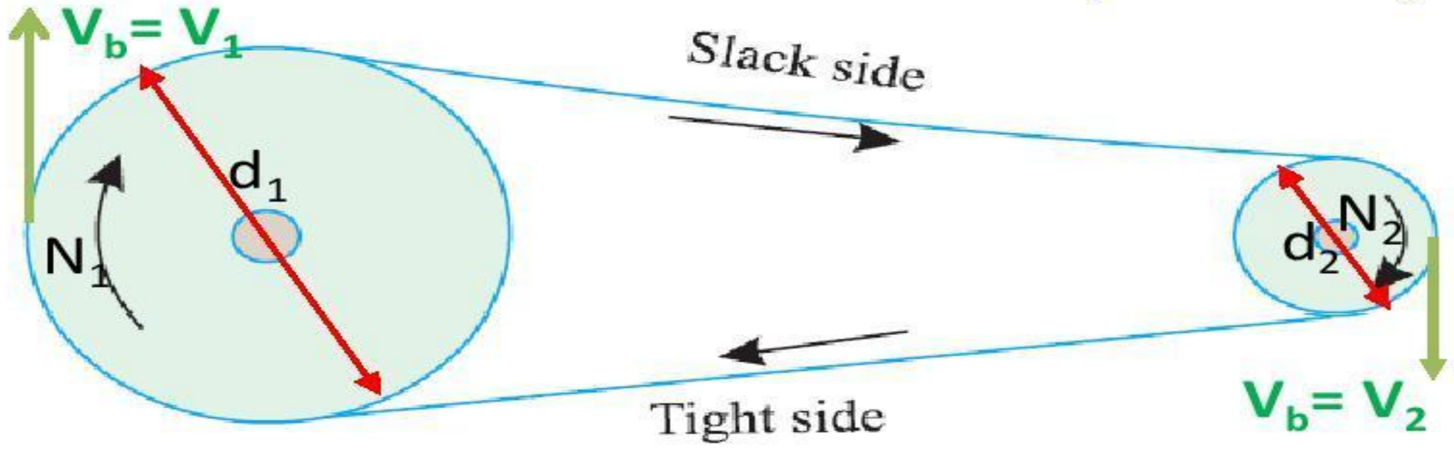
Velocity Ratio(VR)

It is the ratio between the velocities of the driver and the driven (follower)

Let d_1, d_2 -Diameters, m

N_1, N_2 - Speeds, rpm

V_1, V_2, V_b -Velocities, m/min



For no slip

$$\left\{ \begin{array}{c} Length\ of\ the\ belt \\ passing\ over\ driver\ pulley \\ in\ one\ minute \end{array} \right\} = \left\{ \begin{array}{c} length\ covered \\ by\ a\ point\ on\ driver\ pulley \\ in\ one\ minute \end{array} \right\}$$

$$V_b = \pi d_1 N_1$$

$$\left\{ \begin{array}{c} Length\ of\ the\ belt \\ passing\ over\ driven\ pulley \\ in\ one\ minute \end{array} \right\} = \left\{ \begin{array}{c} length\ covered \\ by\ a\ point\ on\ driven\ pulley \\ in\ one\ minute \end{array} \right\}$$

$$V_b = \pi d_2 N_2$$

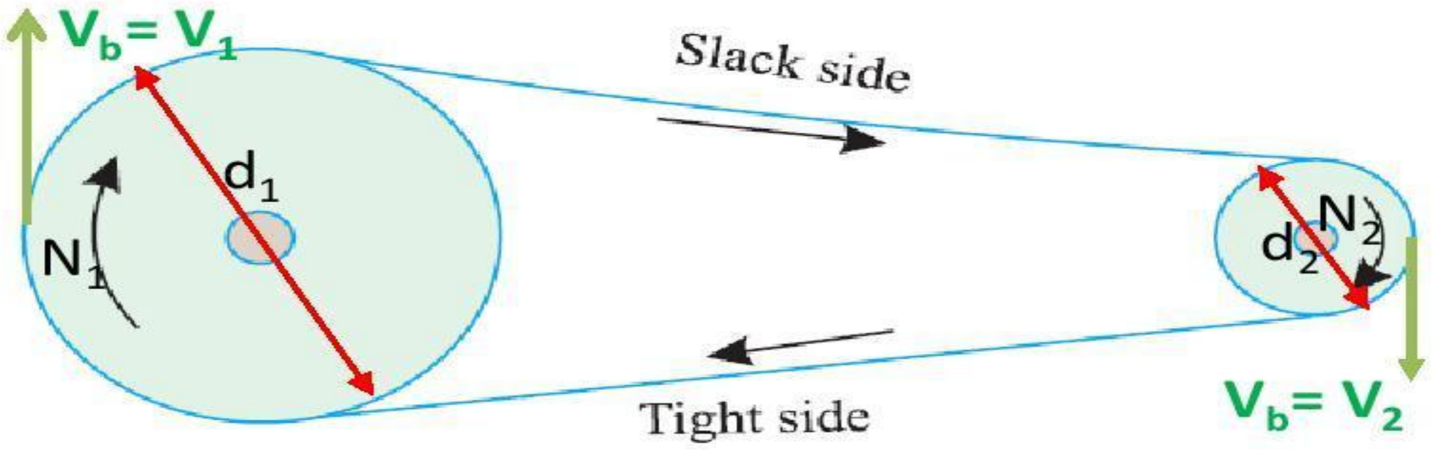
Velocity Ratio(Contd..,)

$$\begin{Bmatrix} Length\ of\ the\ belt \\ passing\ over\ driver\ pulley \\ in\ one\ minute \end{Bmatrix} = \begin{Bmatrix} Length\ of\ the\ belt \\ passing\ over\ driven\ pulley \\ in\ one\ minute \end{Bmatrix}$$

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

$$Velocity\ Ratio, VR = \frac{Speed\ of\ Driven}{Speed\ of\ Driver} = \frac{N_2}{N_1} = \frac{d_1}{d_2}$$

$$\therefore N \propto \frac{1}{d}$$



From the equation it is obvious that in simple belt drive if diameter of the pulley decrease Speed will increases and vice versa.

If thickness(t) of the belt is considered

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

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Prob: RS Khurmi/Example 33.1/page 672

- It is required to drive a shaft at 720 revolutions per minute, by means of a belt from a parallel shaft, having a pulley A 300 mm diameter on it and running at 240 revolutions per minute. What sized pulley is required on the shaft B ?

Given: Speed of the driver, N_2 = 620 rpm.;
Diameter of pulley, d_1 = 300 mm and
speed of the pulley, N1 = 240 rpm.

Find Diameter of the follower, d_2

Solution:
Velocity Ratio, VR= $\frac{N_2}{N_1} = \frac{d_1}{d_2} = \frac{720}{240} = 2.58$

$$\Rightarrow d_2 = \frac{d_1}{VR} = \frac{300}{3}$$

$$d_2 = 100\ mm$$

Case (2):
N_2 = 1440 rpm.;
d_1 = 300 mm and
N_1 =240 rpm.

$$\frac{N_2}{N_1} = \frac{d_1}{d_2} = \frac{1440}{240} = 6$$

$$\Rightarrow d_2 = \frac{d_1}{VR} = \frac{300}{6}$$

$$d_2 = 50\, mm$$

Limitations of simple belt drive

- Higher Velocity ratios ratios, lessen the arc of contact, causing slippage and loss of power.
- For maximum power transfer on the belts and pulleys, the pulle y ratio should be 3 to 1 or less
- To avoid excessive single-step ratios or undersize pulleys .
  - The central distance can be increased
  - Compound drive /two-step drive /counter-shaft) can be used to

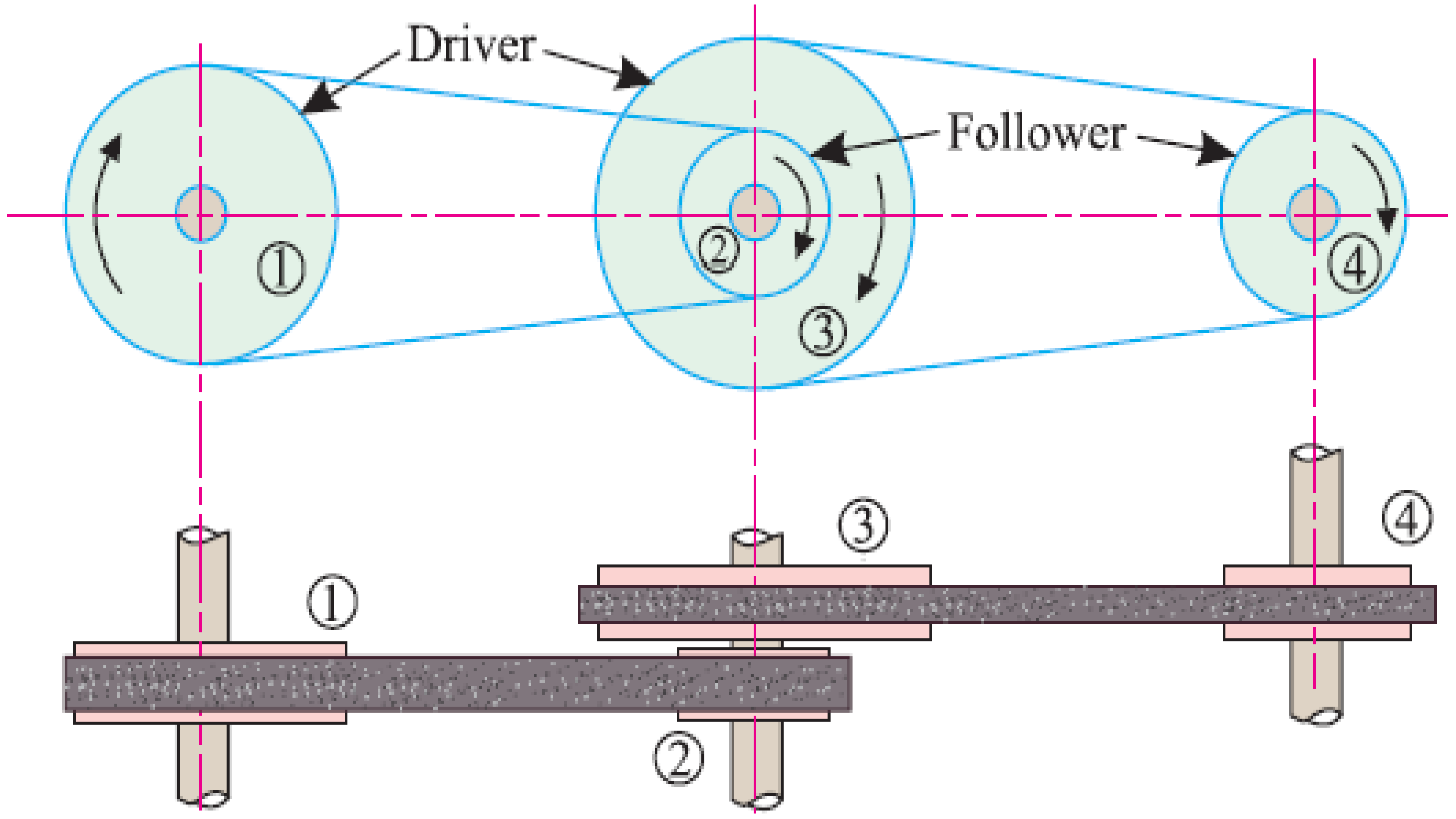
Compound belt drive

- power is transmitted, from one shaft to another, through a number of pulleys

- Consists of more number of simple belt drives

- Pulleys 2 and 3 are keyed to the same that to the same shat

- Pulley 1 and 2 forms one belt drive and Pulley 3 and 4 another



Compound belt drive

Let d_1, d_2, d_3, d_4, and N_1, N_2, N_3, N_4= diameters and speeds for pulleys 1, 2, 3 and 4.
We know that velocity ratio of pulleys 1 and 2,

$$VR_1 = \frac{N_2}{N_1} = \frac{d_1}{d_2} \quad \text{----------------} \quad (1)$$

Similarly, velocity ratio of pulleys 3 and 4,

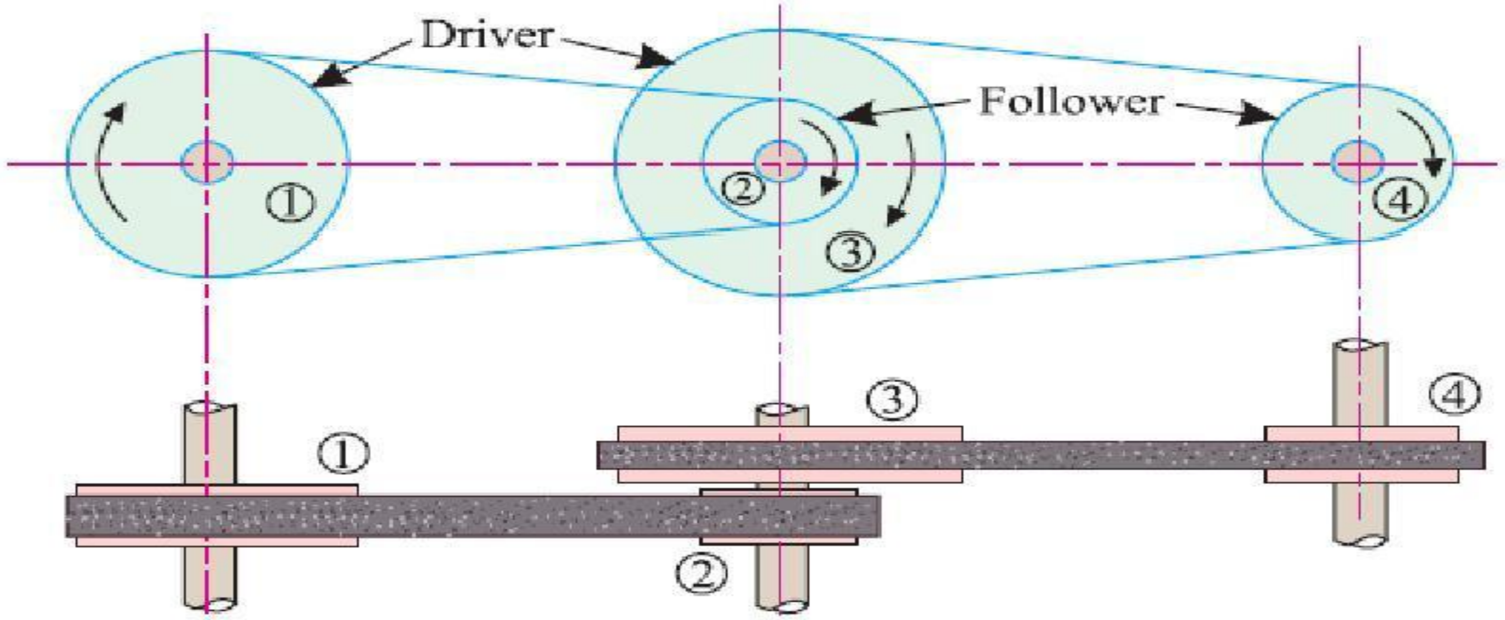
$$VR_2 = \frac{N_4}{N_3} = \frac{d_3}{d_4} \quad \text{----------------} \quad (2)$$

Multiplying the above equations

$$VR_1 \times VR_2 = \frac{N_2 \times N_4}{N_1 \times N_3} = \frac{d_1 \times d_3}{d_2 \times d_4} \quad \text{----------------} \quad (3)$$

Since $N_2=N_3$, therefore velocity ratio of compound belt drive

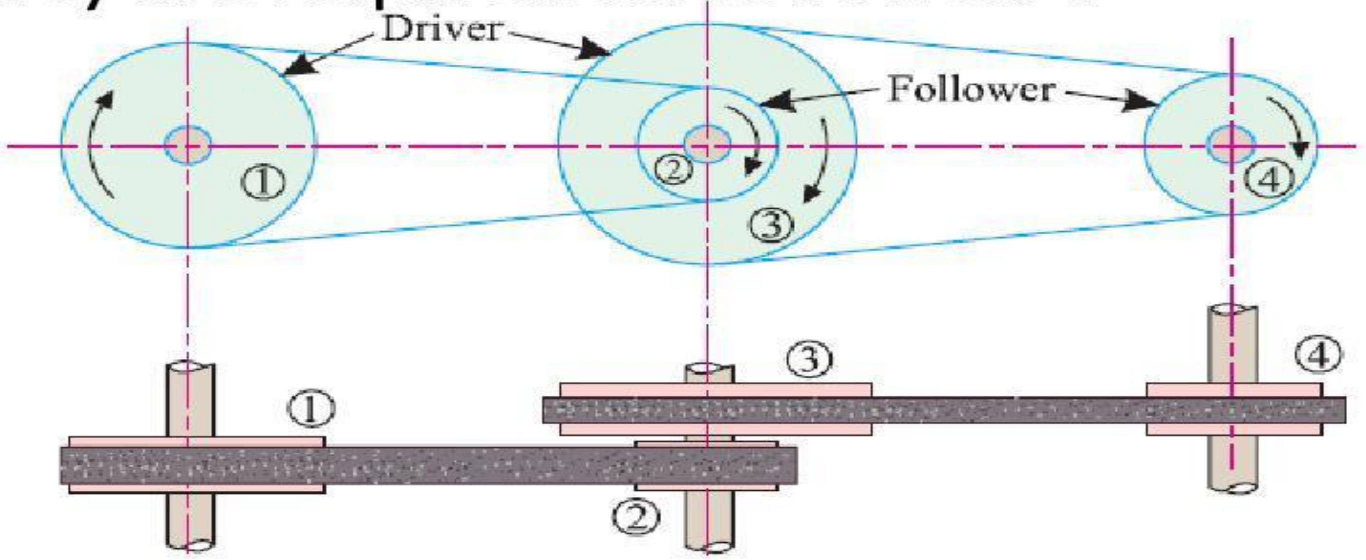
$$VR = VR_1 \times VR_2 = \frac{N_4}{N_1} = \frac{d_1 \times d_3}{d_2 \times d_4} \quad \text{----------------} \quad (4)$$



$$VR = \frac{Speed\ of\ last\ follower}{Speed\ of\ first\ driver} = \frac{product\ of\ diameters\ of\ drivers}{product\ of\ diameters\ of\ followers}$$

Problem:

It is required to drive a shaft at 1440 revolutions per minute, by means of compound belt from a parallel shaft, having drivers 300 mm diameter and first driver is running at 240 revolutions per minute. What sized pulley are required for followers ?



Given:

Speed of the driver, N_4 = 620 rpm.;

Diameter of pulleys, $d_1 = d_3$ =300 mm and speed of the pulley, N1 = 240 rpm.

Find Diameter of the follower, d_2 and d_4

Solution:

Velocity Ratio compound drive,

$$VR = VR_1 \times VR_2 = \frac{N_4}{N_1} = \frac{d_1 \times d_3}{d_2 \times d_4} = \frac{1440}{240} = 6$$

$$VR = 6 \begin{cases} VR_1 & \times & VR_2 \\ 2 & \times & 3 & \leftarrow Case\,1 \\ 3 & \times & 2 & \leftarrow Case\,2 \end{cases}$$

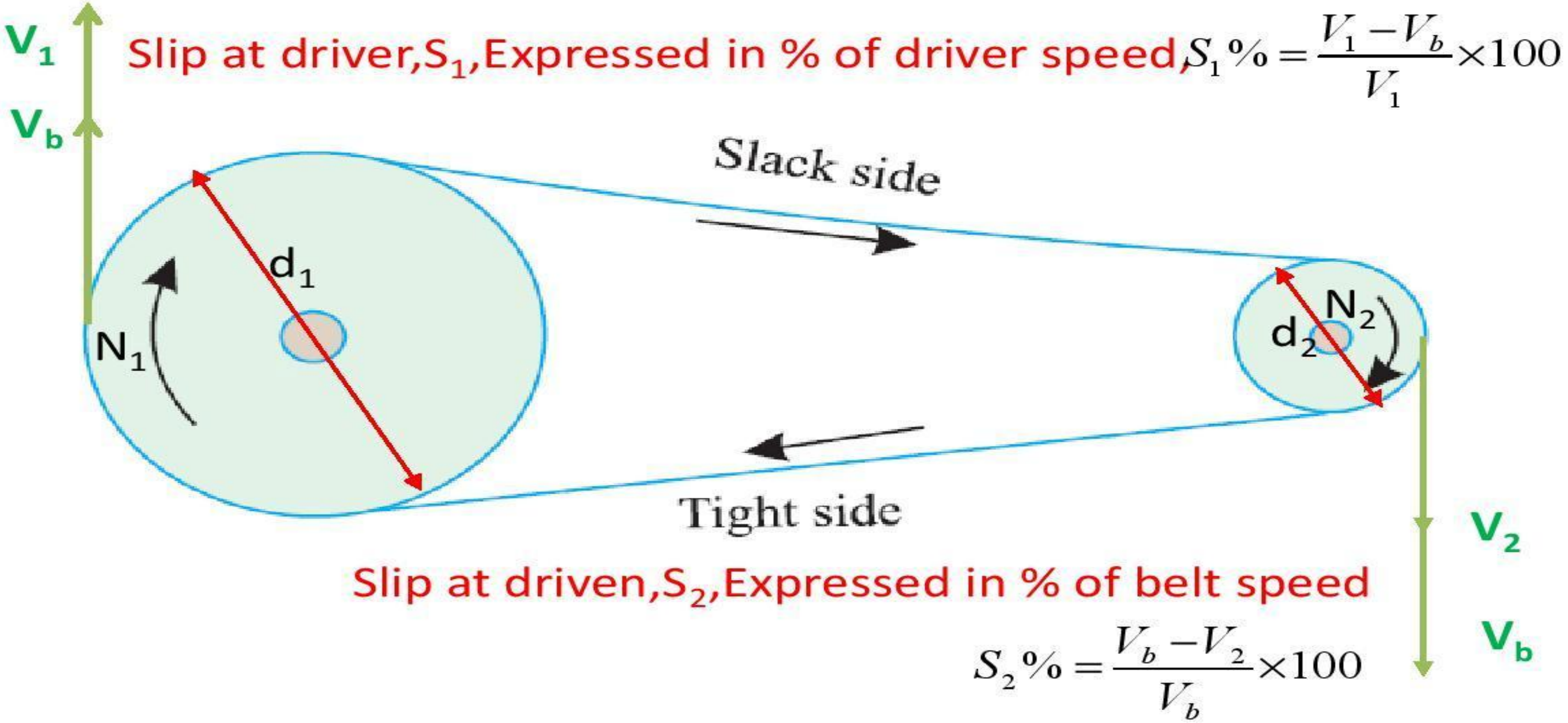
For Case 1

$$d_2 = \frac{d_1}{VR_1} = \frac{300}{2} = 150\,mm$$

$$d_4 = \frac{d_3}{VR_2} = \frac{300}{3} = 100\,mm$$

Slip

- If there is no firm frictional grip between the belts and the shafts. This may cause forward motion of the driver pulley without carrying the belt with it or 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 and denoted by S.



Slip

$$S_1 = \frac{V_1 - V_b}{V_1} \times 100$$

$$V_b = V_1 \left(1 - \frac{S_1}{100}\right) \text{ ---------------- (1)}$$

$$S_2\% = \frac{V_b - V_2}{V_b} \times 100$$

$$V_2 = V_b \left(1 - \frac{S_2}{100}\right) \text{ ---------------- (2)}$$

Substituting the value V_b in eq (2)

$$V_2 = V_1 \left(1 - \frac{S_1}{100}\right)\left(1 - \frac{S_2}{100}\right)$$

$$\pi d_2 N_2 = \pi d_1 N_1 \left(1 - \frac{S_1}{100} - \frac{S_2}{100} + \frac{S_1 \times S_2}{10000}\right)$$

Neglecting $\frac{S_1 \times S_2}{10000}$

$$\frac{N_2}{N_1} = \frac{d_1}{d_2}\left(1 - \frac{S_1 + S_2}{100}\right)$$

Assuming $S_1+S_2=S$

$$\boxed{\frac{N_2}{N_1} = \frac{d_1}{d_2}\left(1 - \frac{S}{100}\right)}$$

If thickness(t) of the belt is considered

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

Length of an Open Belt Drive

From geometry $O_1M = O_1E - ME = r_1 - r_2$

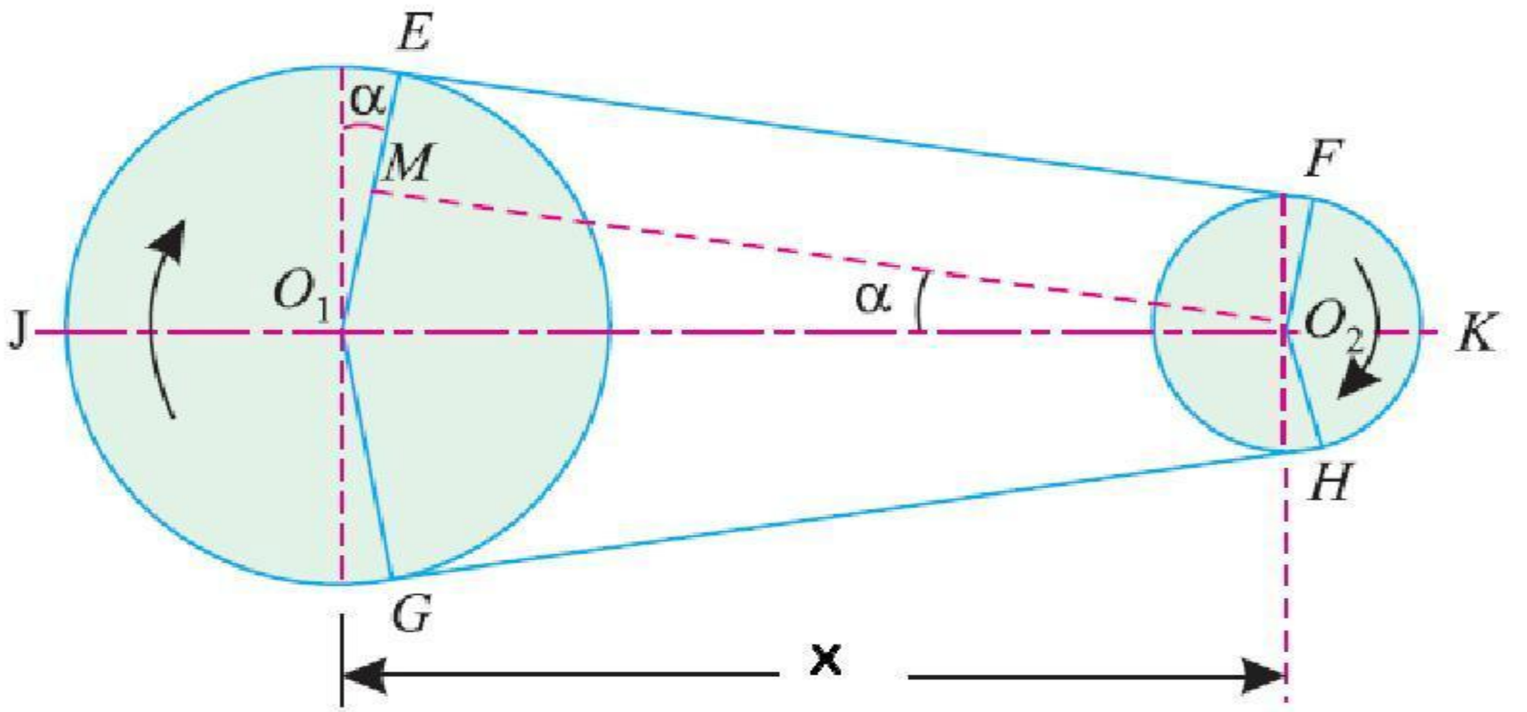
From right angled triangle O_1MO_2

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

For small values of α,

$\sin\alpha = \alpha$

$$\alpha = \frac{r_1 - r_2}{x} \quad \text{----------------- (1)}$$



Arc length JE= $r_1\left(\frac{\pi}{2} + \alpha\right)$ ----------------- (2)

$(\because l = r\theta)$

Arc length FK= $r_2\left(\frac{\pi}{2} - \alpha\right)$ ----------------- (3)

Length of an Open Belt Drive

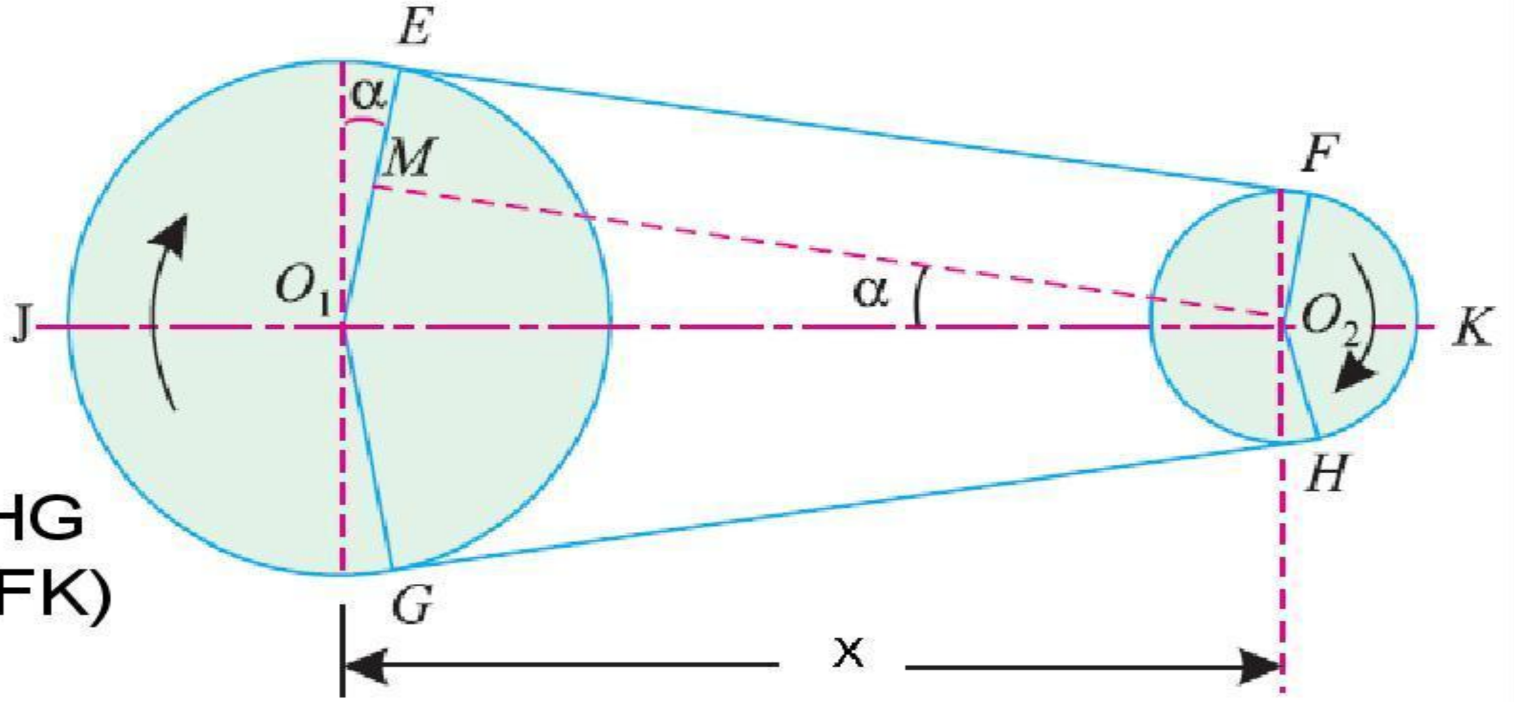
$$MO_2 = EF = \sqrt{x^2 - (r_1 - r_2)^2}$$ (pythagoras theorem)

$$= x\sqrt{1 - \left(\frac{r_1 - r_2}{x}\right)^2}$$

$$= x\left(1 - \frac{1}{2}\left(\frac{r_1 - r_2}{x}\right)^2 + \frac{1}{8}\left(\frac{r_1 - r_2}{x}\right)^4 - \cdots\cdots\right)$$ (Binomial expansion)

$$= x\left(1 - \frac{1}{2}\left(\frac{r_1 - r_2}{x}\right)^2\right)$$ (neglecting higher order terms)

$$MO_2 = EF = x - \frac{1}{2}\frac{(r_1 - r_2)^2}{x}$$ ---------------- (4)



Length of the belt = Length of arc GJE + EF + Length of arc FKH + HG

L=2 (Length of arc JE + EF + Length of arc FK)

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Length of an Open Belt Drive

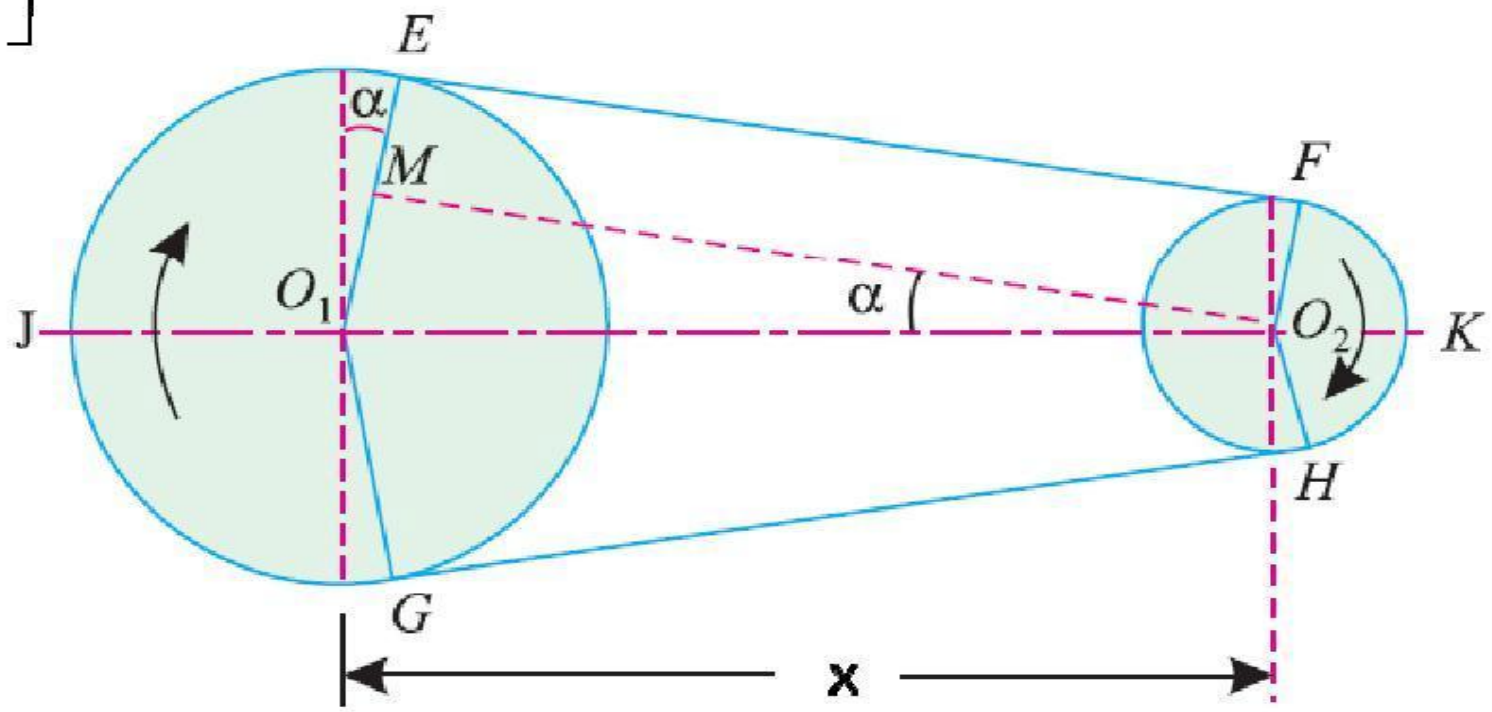
Substituting the values of length of arc JE from equation (2), length of arc FK from equation (3) and EF from equation (4) in this equation,

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

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

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

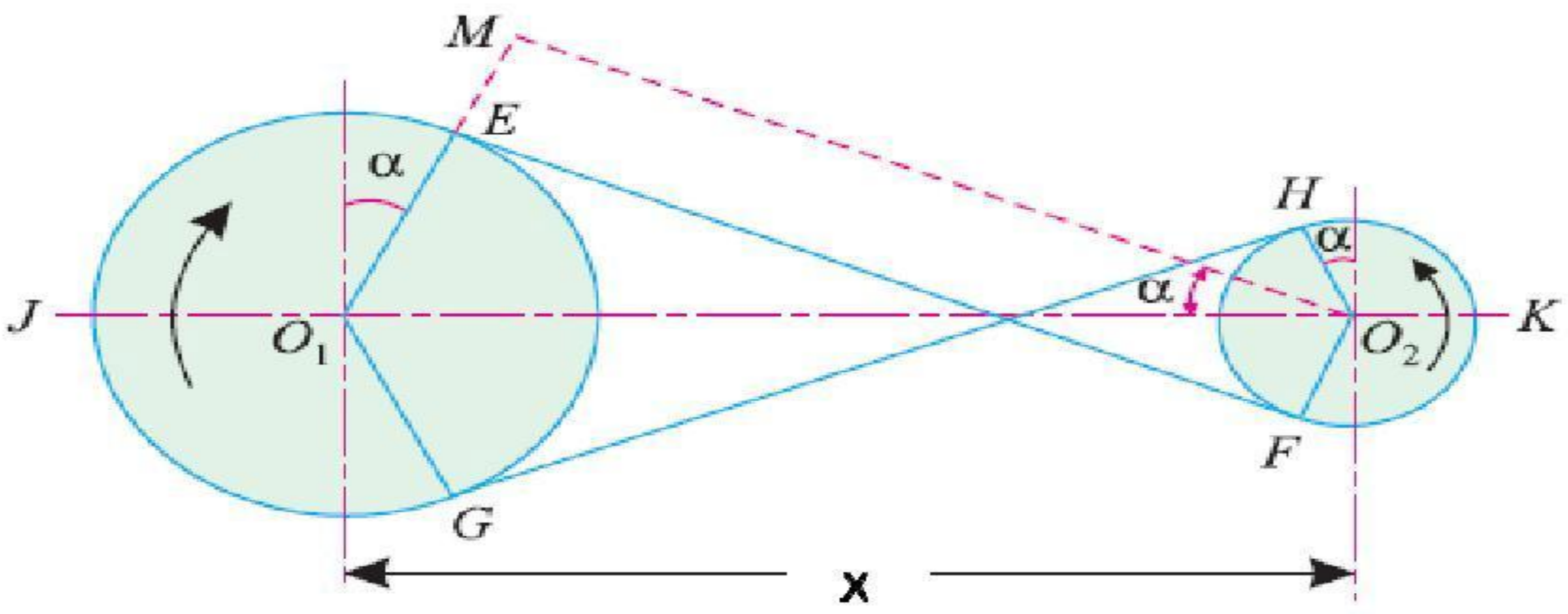
$$L = \pi(r_1+r_2) + 2x + \frac{(r_1+r_2)^2}{x}$$



Length of an Cross Belt Drive

From geometry $O_1M= O_1E- ME= r_1+r_2$

From right angled triangle O_1MO_2



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

For small values of α, sinα=α

$$\alpha = \frac{r_1 - r_2}{x}$$ ---------------- (1)

Arc length JE= $r_1\left(\frac{\pi}{2}+\alpha\right)$---------------- (2)

$(\because l=r\theta)$

Arc length FK= $r_2\left(\frac{\pi}{2}+\alpha\right)$---------------- (3)

Length of an Cross Belt Drive

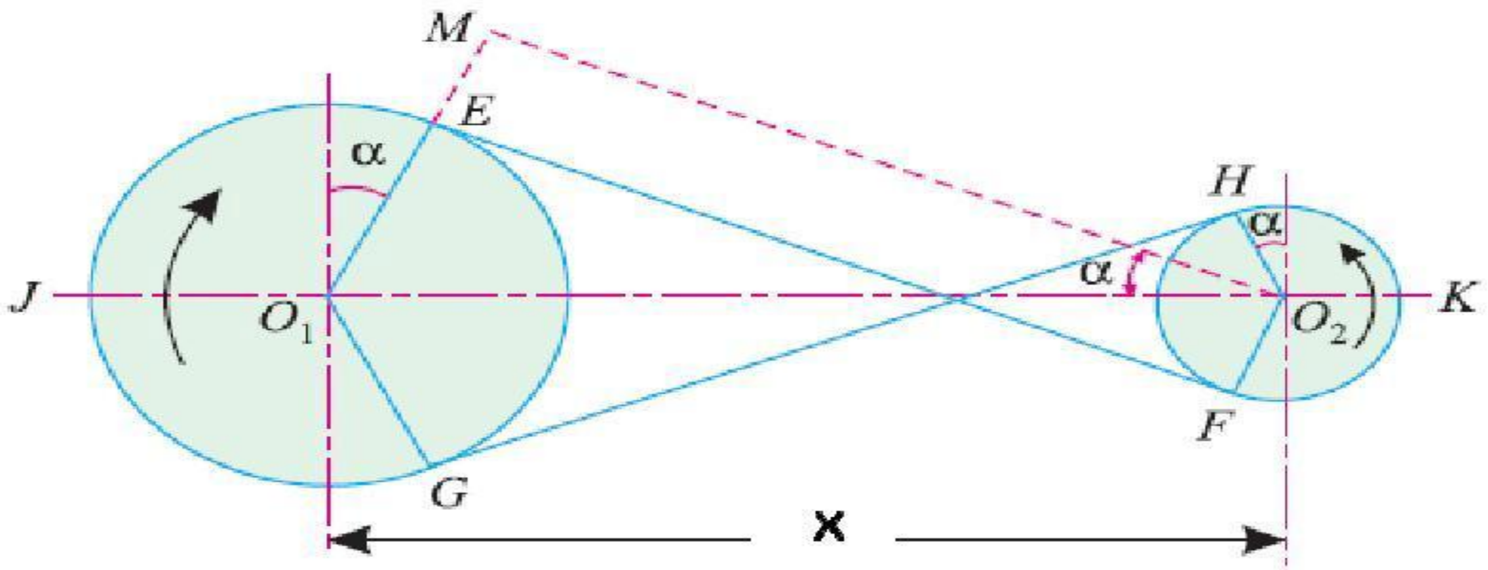
$$MO_2 = EF = \sqrt{x^2 - (r_1 + r_2)^2}$$ (pythagoras theorem)

$$= x\sqrt{1 - \left(\frac{r_1 + r_2}{x}\right)^2}$$

$$= x\left(1 - \frac{1}{2}\left(\frac{r_1 + r_2}{x}\right)^2 + \frac{1}{8}\left(\frac{r_1 + r_2}{x}\right)^4 - \cdots\cdots\right)$$ (Binomial expansion)

$$= x\left(1 - \frac{1}{2}\left(\frac{r_1 + r_2}{x}\right)^2\right)$$ (neglecting higher order terms)

$$MO_2 = EF = x - \frac{1}{2}\frac{(r_1 + r_2)^2}{x} \quad \text{----------------- (4)}$$



Length of the belt =Length of arc GJE + EF
+ Length of arc FKH + HG

L=2 (Length of arc JE + EF + Length of arc FK)

Length of an Cross Belt Drive

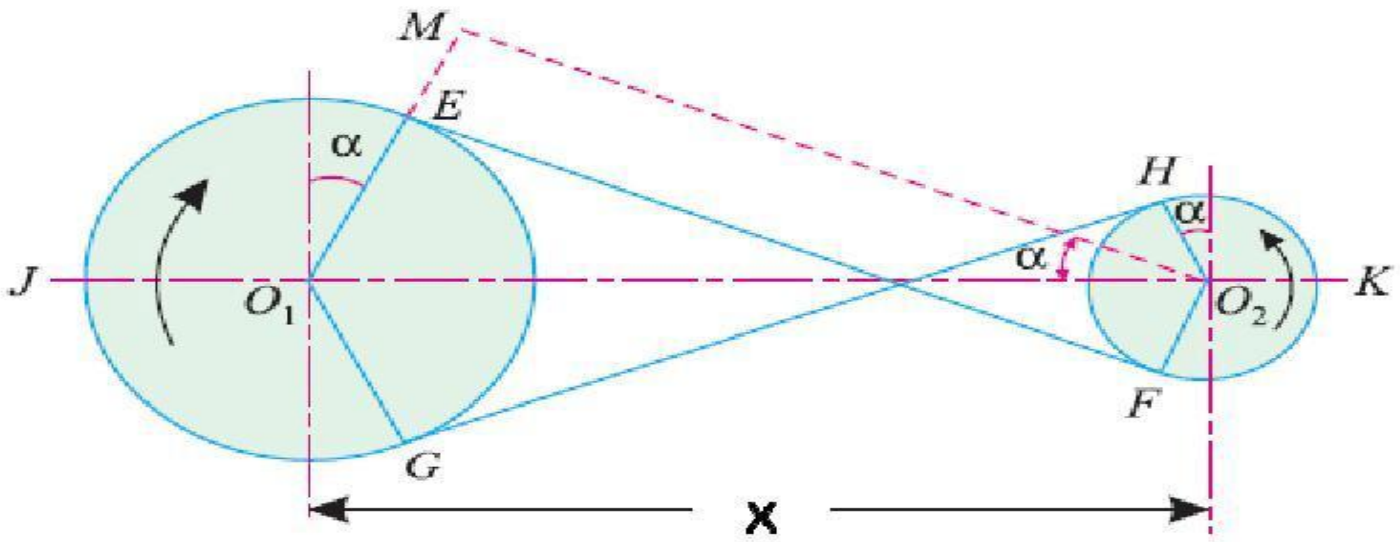
Substituting the values of length of arc JE from equation (2), length of arc FK from equation (3) and EF from equation (4) in this equation,

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

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

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

$$L = \pi(r_1+r_2) + 2x + \frac{(r_1+r_2)^2}{x}$$



Prob:RS Khurmi/Example 33.4/679

Find the length of belt necessary to drive a pulley of 500 mm diameter running parallel at a distance of 12 meters from the driving pulley of diameter 1600 mm.

Given:
Diameter of the driven pulley (d_2) = 500 mm = 0·5 m or radius (r_2) = 0·25 m;
Diameter of the driving pulley (d_1) = 1600 mm = 1·6 m or radius (r_1) = 0·8 m.
Distance between the centres of the two pulleys (x) = 12 m

Find length of the belt for 1. open belt drive 2. Cross belt drive

Solution:

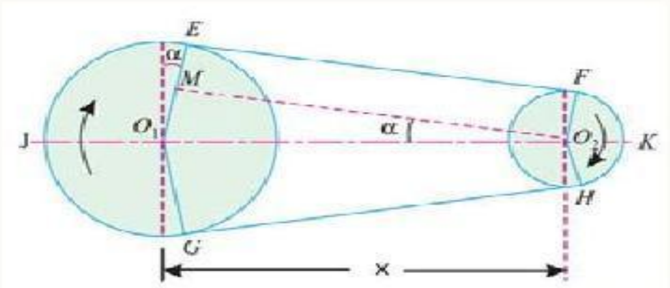
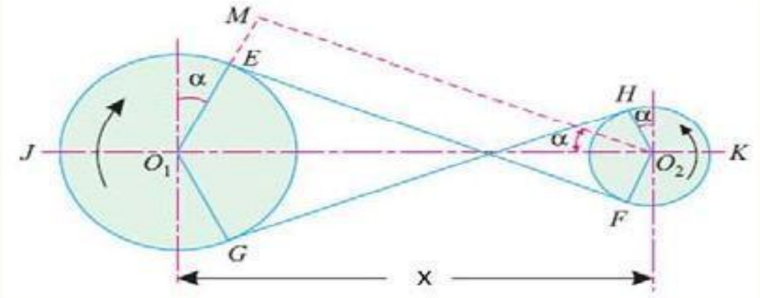
1. Open Belt drive

$$L = \pi(r_1 + r_2) + 2x + \frac{(r_1 - r_2)^2}{x} = \pi(0.8 + 0.25) + 2\times 12 + \frac{(0.8 - 0.25)^2}{x} = 27.32\,m$$

2. Cross Belt drive

$$L = \pi(r_1 + r_2) + 2x + \frac{(r_1 + r_2)^2}{x} = \pi(0.8 + 0.25) + 2\times 12 + \frac{(0.8 + 0.25)^2}{x} = 27.39\,m$$

Open belt drive Vs Close belt drive

Item	Open Belt Drive	Closed Belt Drive
Arrangement		
Rotation of pulleys	same direction	opposite direction
useful alignment of shafts	horizontal or inclined	horizontal or inclined or vertical
rubbing	no rubbing point, the life of the belt is more	rubbing point, the life of the belt reduces.
Length of the belt (same centre distance, pulley diameters.)	less length	Require more length
Angle of contact (big and small pullys)	different	Same

Power transmitted by a belt

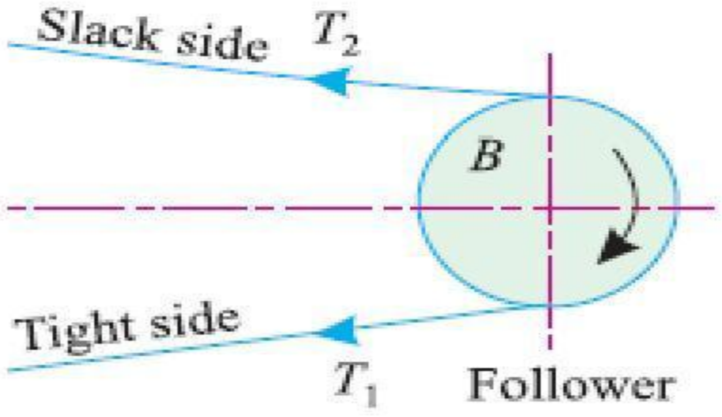
- the effective turning (i.e. driving) force at the circumference of the follower is

  $F = T_1 - T_2$.

- Work done per second

  = Force × Distance = $T_1 - T_2 \times v$

  Power = $(T_1 - T_2)v$ J/s



$$P = T_1\left(1 - \frac{T_2}{T_1}\right)v = T_1\left(1 - \frac{1}{T_1/T_2}\right)v$$

$$P = T_1\left(1 - \frac{1}{e^{\mu\theta}}\right)v$$

Notes:

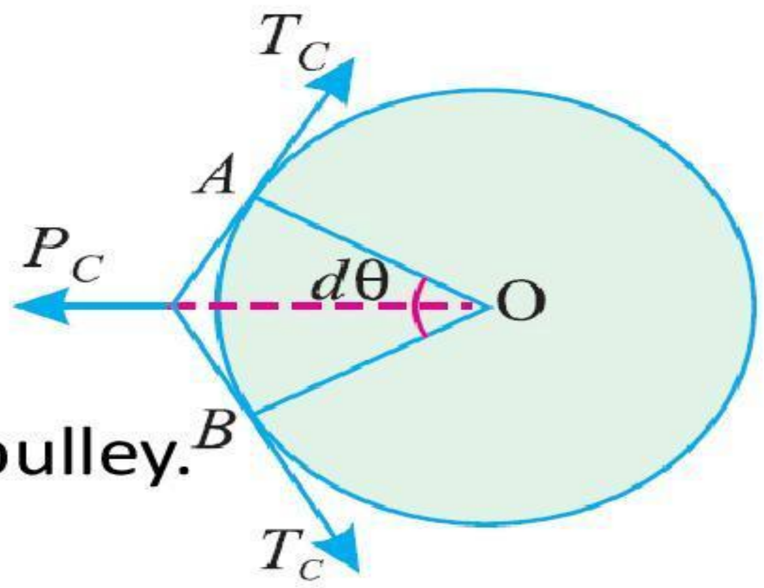
1. The torque exerted on the driving pulley $=(T_1 - T_2)\, r_1$
2. Similarly, the torque exerted on the follower $= (T_1 - T_2)\, r_2$

   where r_1 and r_2 are in metres.

Centrifugal tension

- The belt continuously runs over both the pulleys. It carries some centrifugal force in the belt, at both the pulleys,
- whose effect is to increase the tension on both, tight as well as the slack sides.
- The tension caused by the centrifugal force is called centrifugal tension.
- At lower speeds, the centrifugal tension is very small and may be neglected.
- But at higher speeds, its effect is considerable, and thus should be taken into account.

Centrifugal tension



m = Mass of the belt per unit length,

v = Linear velocity of the belt,

r = Radius of the pulley over which the belt runs,

T_C = Centrifugal tension acting tangentially at P and Q and

dθ = Angle subtended by the belt AB at the centre of the pulley.

Length of belt AB = r $d\theta$

total mass of the belt M = mr $d\theta$

We know that centrifugal force of the belt AB, $P_C = \frac{Mv^2}{r} = \frac{mrd\theta v^2}{r}$

$$P_C = md\theta v^2$$

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

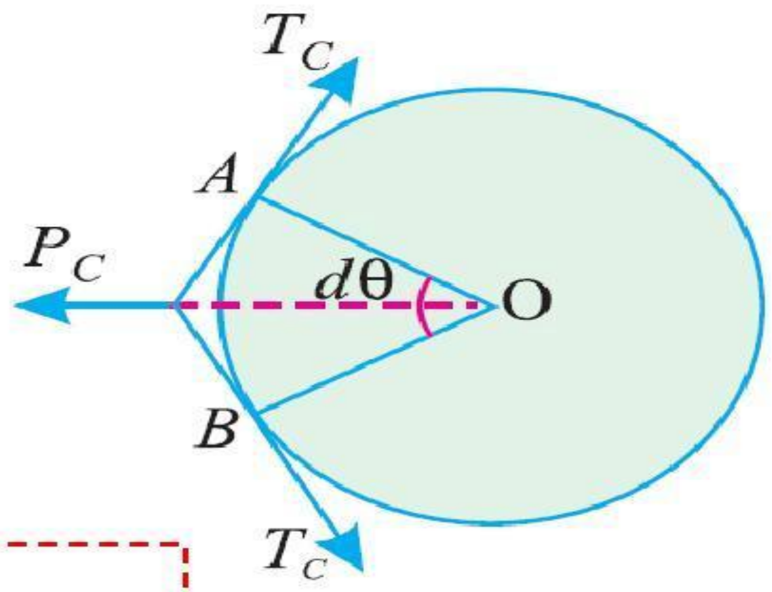
$$2T_C \sin\frac{d\theta}{2} = md\theta v^2$$

Centrifugal tension

For small values of $\frac{d\theta}{2}, \sin\frac{d\theta}{2} = \frac{d\theta}{2}$

$$2T_C \sin\frac{d\theta}{2} = md\theta v^2$$

$$\boxed{T_C = mv^2}$$



Notes:

1. When the centrifugal tension is taken into account, the total tension in the tight side = $T_1 + T_C$ and total tension in the slack side = $T_2 + T_C$

2. The centrifugal tension on the belt has no effect on the power transmitted by it. The reason for the same is that while calculating the power transmitted, we have to use the values :
= Total tension in tight side – Total tension in the slack side
$= (T_1 + T_C) – (T_2 + T_C) = (T_1 – T_2)$.

Maximum tension in the belt

- Let σ = Maximum safe stress in the belt, N/mm^2

  b = Width of the belt in mm, and

  t = Thickness of the belt in mm.

- We know that maximum tension in the belt,

  T = Maximum stress × Cross-sectional area of belt

  $= \sigma bt$

- When centrifugal tension is neglected, then maximum tension, $T = T_1$ and
- when centrifugal tension is considered, then maximum tension, $T = T_1 + T_C$

Condition for transmission of maximum power

- that the power transmitted by a belt,

$$P = T_1\left(1 - \frac{1}{e^{\mu\theta}}\right)v$$

$$P = T_1 C v \left(\text{assuming } C = \left(1 - \frac{1}{e^{\mu\theta}}\right)\right)$$

But $T_1 = T - T_c$ and $T_c = mv^2$

$\therefore P = (Tv - mv^3)C$

Differentiating w.r.t v and equating to zero

$$\frac{dP}{dv} = \frac{d}{dv}\left(Tv - mv^3\right)$$

$$0 = T - 3mv^2$$

$$T = 3mv^2$$

$$T = 3T_c$$

It shows that when the power transmitted is maximum 1/3 rd of the maximum tension is absorbed as centrifugal tension

Belt speed for maximum power

for maximum power transmission, $T = 3mv^2$

Speed of the belt for maximum transmission of power

$$v = \sqrt{\frac{T}{3m}}$$

Note: Maximum tension in the belt is equal to sum of tensions in tight side (T_1) and centrifugal tension (T_C).

Initial tension in the belt

- the motion of the belt (from the driver) and the follower (from the belt) is governed by a firm grip due to friction between the belt and the pulleys, therefore the belt is tightened up, in order to keep a proper grip of the belt over the pulleys. Initially, even when the pulleys are stationary the belt is subject to some tension, called initial tension.

Let 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*

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

Initial tension in the belt

that increase of tension in the tight side = $T_1 - T_0$

increase in the length of the belt on the tight side

$= n\,(T_1 - T_0)$

Similarly, decrease in tension in the slack side = $T_0 - T_2$

decrease in the length of the belt on the slack side

$= n\,(T_0 - T_2)$

For constant length of the belt, when it is at rest or in motion,

The increase in length on the tight side = equal to decrease in the length on the slack side

Therefore, equating

$n\,(T_1 - T_0) = n\,(T_0 - T_2)$

$\therefore\ T=(T_1+T_2)/2$

Note: If centrifugal tension is taken into consideration, then

$T=(T_1+T_2)/2+T_c$

Rope Drives

- The rope drives are widely used where a large amount of power is to be transmitted, from one pulley to another, over a considerable distance.

- It may be noted that the use of flat belts is limited for the transmission of moderate power from one pulley to another when the two pulleys are not more than 8 metres apart.

- If large amounts of power are to be transmitted, by the flat belt, then it would result in excessive belt cross-section.

- The ropes drives use the following two types of ropes :

1. Fibre ropes
2. Wire ropes.

1. Fibre ropes

- The ropes for transmitting power are usually made from fibrous materials such as hemp, manila and cotton.

Hemp rope

Manila rope

- Since the hemp and manila fibres are rough, therefore the ropes made from these fibres are not very flexible and possesses poor mechanical properties.
- When the hemp and manila ropes are bent over the sheave, there is some sliding of the fibres, causing the rope to wear and chafe internally.
- In order to minimize this defect, the rope fibres are lubricated with a tar, tallow or graphite.
- The fibre ropes are suitable only for hand operated hoisting machinery and as tie ropes for lifting tackle, hooks etc.

Advantages of Fibre Rope Drives

The fibre rope drives have the following advantages:

1. They give smooth, steady and quiet service.
2. They are little affected by out door 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.

Wire Ropes:

- When a large amount of power is to be transmitted over long distances from one pulley to another (i.e. when the pulleys are up to 150 metres apart), then wire ropes are used.
- The wire ropes are widely used in elevators, mine hoists, cranes, conveyors, hauling devices and suspension bridges.
- The wire ropes run on grooved pulleys but they rest on the bottom of the *grooves and are not wedged between the sides of the grooves.
- The wire ropes are made from cold drawn wires in order to have increase in strength and durability.
- It may be noted that the strength of the wire rope increases as its size decreases. The various materials used for wire ropes in order of increasing strength are wrought iron, cast steel, extra strong cast steel, plough steel and alloy steel.
- For certain purposes, the wire ropes may also be made of copper, bronze, aluminum alloys and stainless steels.

Wire rope is made with two types of winding:

Advantages of the rope drives

- Significant power transmission.
- It can be used for long distance.
- Ropes are strong and flexible.
- Provides smooth and quiet operation.
- It can run any direction.
- Low-cost and economic.
- Precise alignment of the shaft not required.

Disadvantages of the rope drive

- Internal failure of the rope has no sign on external, so it if often get unnoticed.
- Corrosion of wire rope.

GEAR.....

- Power transmission is the movement of energy from its place of generation to a location where it is applied to performing useful work

- A gear is a component within a transmission device that transmits rotational force to another gear or device

TYPES OF GEARS

1. According to the position of axes of the shafts.

a. Parallel

1.Spur Gear

2.Helical Gear

3.Rack and Pinion

b. Intersecting

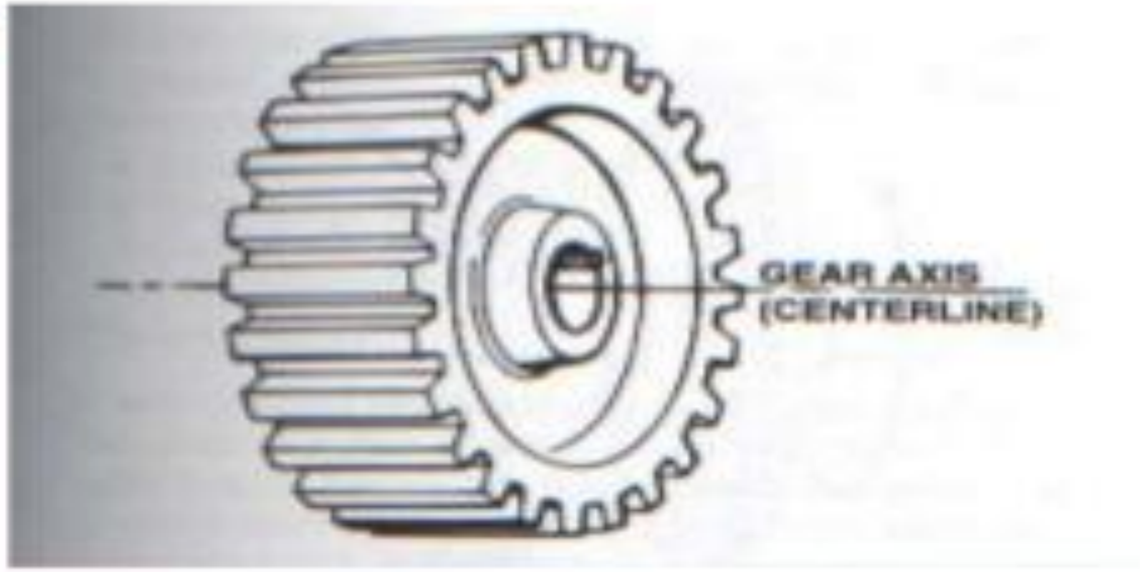
Bevel Gear

c. Non-intersecting and Non-parallel

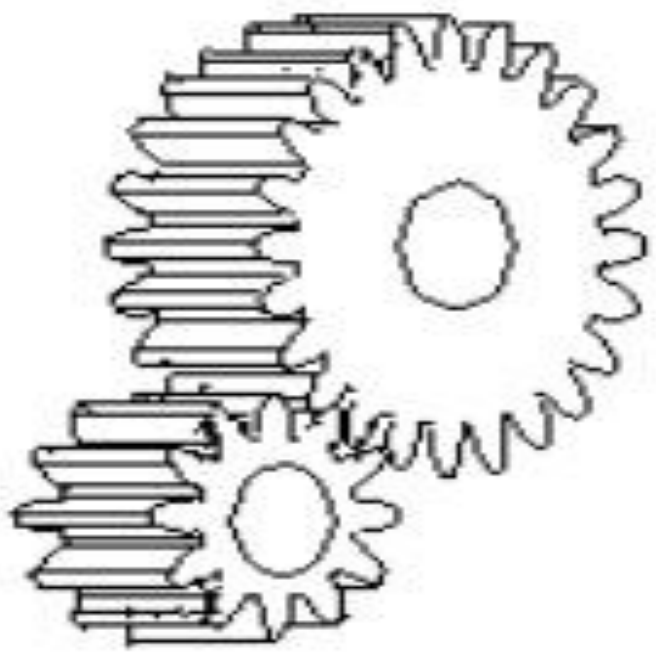
worm and worm gears

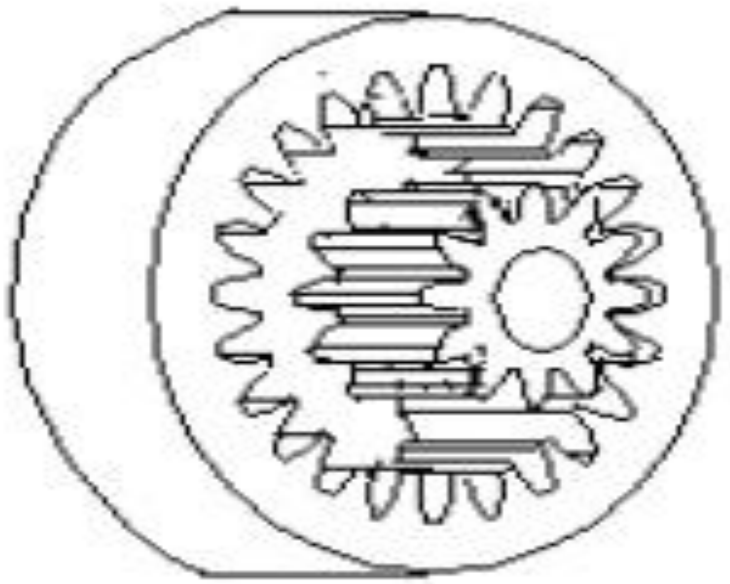
SPUR GEAR

- Teeth is parallel to axis of rotation
- Transmit power from one shaft to another parallel shaft
- Used in Electric screwdriver, oscillating sprinkler, windup alarm clock, washing machine and clothes dryer



External and Internal spur Gear...





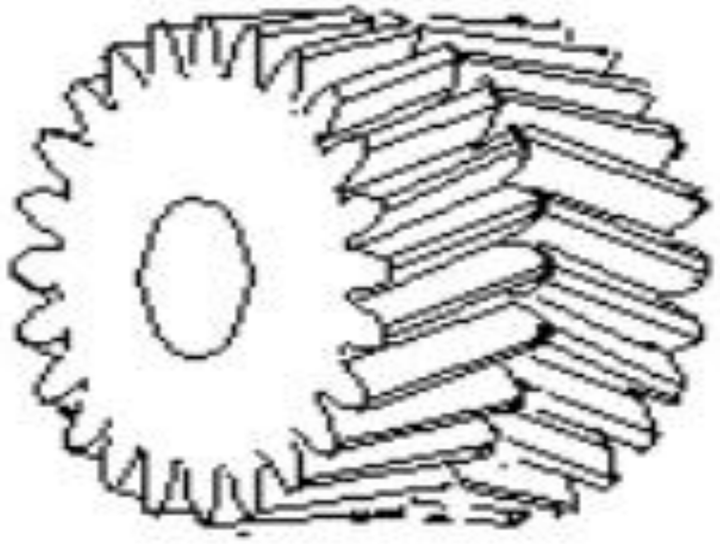
Helical Gear

- The teeth on helical gears are cut at an angle to the face of the gear
- This gradual engagement makes helical gears operate much more smoothly and quietly than spur gears
- One interesting thing about helical gears is that if the angles of the gear teeth are correct, they can be mounted on perpendicular shafts, adjusting the rotation angle by 90 degrees

Helical Gear…

Herringbone gears

- To avoid axial thrust, two helical gears of opposite hand can be mounted side by side, to cancel resulting thrust forces



- Herringbone gears are mostly used on heavy machinery.

Rack and pinion

- **Rack and pinion gears** are used to convert rotation (From the pinion) into linear motion (of the rack)

- A perfect example of this is the steering system on many cars

Bevel gears

- **Bevel gears** are useful when the direction of a shaft's rotation needs to be changed
- They are usually mounted on shafts that are 90 degrees apart, but can be designed to work at other angles as well
- The teeth on bevel gears can be **straight**, **spiral** or **hypoid**
- locomotives, marine applications, automobiles, printing presses, cooling towers, power plants, steel plants, railway track inspection machines, etc.

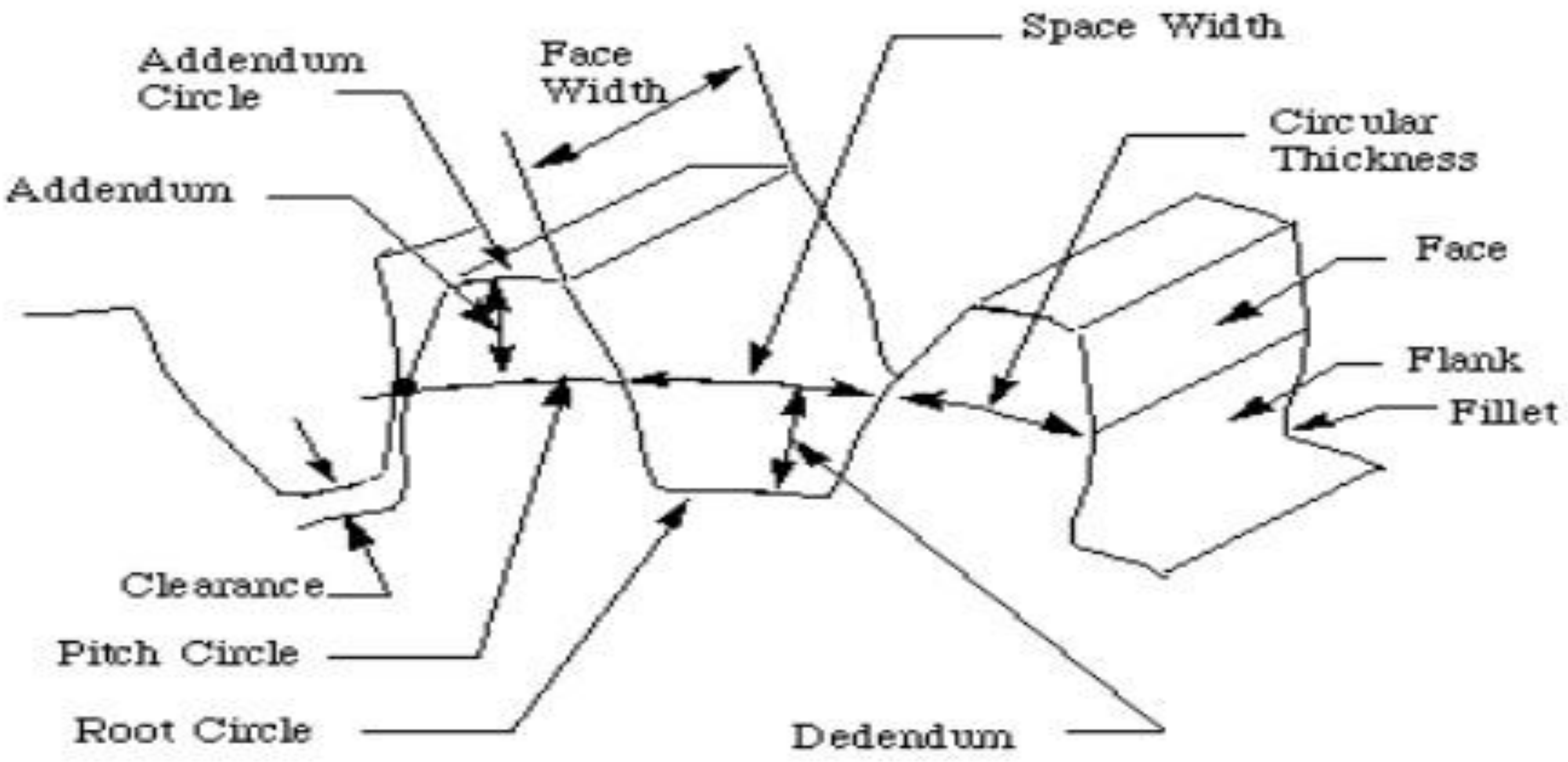
Straight and Spiral Bevel Gears

WORM AND WORM GEAR

- **Worm gears** are used when large gear reductions are needed. It is common for worm gears to have reductions of 20:1, and even up to 300:1 or greater
- Many worm gears have an interesting property that no other gear set has: the worm can easily turn the gear, but the gear cannot turn the worm
- Worm gears are used widely in material handling and transportation machinery, machine tools, automobiles etc

WORM AND WORM GEAR

NOMENCLATURE OF SPUR GEARS



NOMENCLATURE….

- **Pitch surface**: The surface of the imaginary rolling cylinder (cone, etc.) that the toothed gear may be considered to replace.
- **Pitch circle**: A right section of the pitch surface.
- **Addendum circle**: A circle bounding the ends of the teeth, in a right section of the gear.
- **Root (or dedendum) circle**: The circle bounding the spaces between the teeth, in a right section of the gear.
- **Addendum**: The radial distance between the pitch circle and the addendum circle.
- **Dedendum**: The radial distance between the pitch circle and the root circle.
- **Clearance**: The difference between the dedendum of one gear and the addendum of the mating gear.

NOMENCLATURE....

- **Face of a tooth**: That part of the tooth surface lying outside the pitch surface.
- **Flank of a tooth**: The part of the tooth surface lying inside the pitch surface.
- **Circular thickness** (also called the **tooth thickness**): The thickness of the tooth measured on the pitch circle. It is the length of an arc and not the length of a straight line.
- **Tooth space**: pitch diameter The distance between adjacent teeth measured on the pitch circle.
- **Backlash**: The difference between the circle thickness of one gear and the tooth space of the mating gear.
- **Circular pitch** (Pc) : The width of a tooth and a space, measured on the pitch circle.

$$P_c = \frac{\pi D}{N}$$

NOMENCLATURE....

- **Diametral pitch** (Pd): The number of teeth of a gear unit pitch diameter. The diametral pitch is, by definition, the number of teeth divided by the pitch diameter. That is,

$$P_d = \frac{N}{D}$$

Where
Pd = diametral pitch
N = number of teeth
D = pitch diameter

- **Module** (m): Pitch diameter divided by number of teeth. The pitch diameter is usually specified in inches or millimeters; in the former case the module is the inverse of diametral pitch.

$$m = D/N$$

VELOCITY RATIO OF GEAR DRIVE

d = Diameter of the wheel

N = Speed of the wheel

ω = Angular speed

$$\text{velocity ratio (n)} = \frac{\omega_2}{\omega_1} = \frac{N_2}{N_1} = \frac{d_1}{d_2}$$

GEAR TRAINS

- A gear train is two or more gear working together by meshing their teeth and turning each other in a system to generate power and speed
- It reduces speed and increases torque
- Electric motors are used with the gear systems to reduce the speed and increase the torque

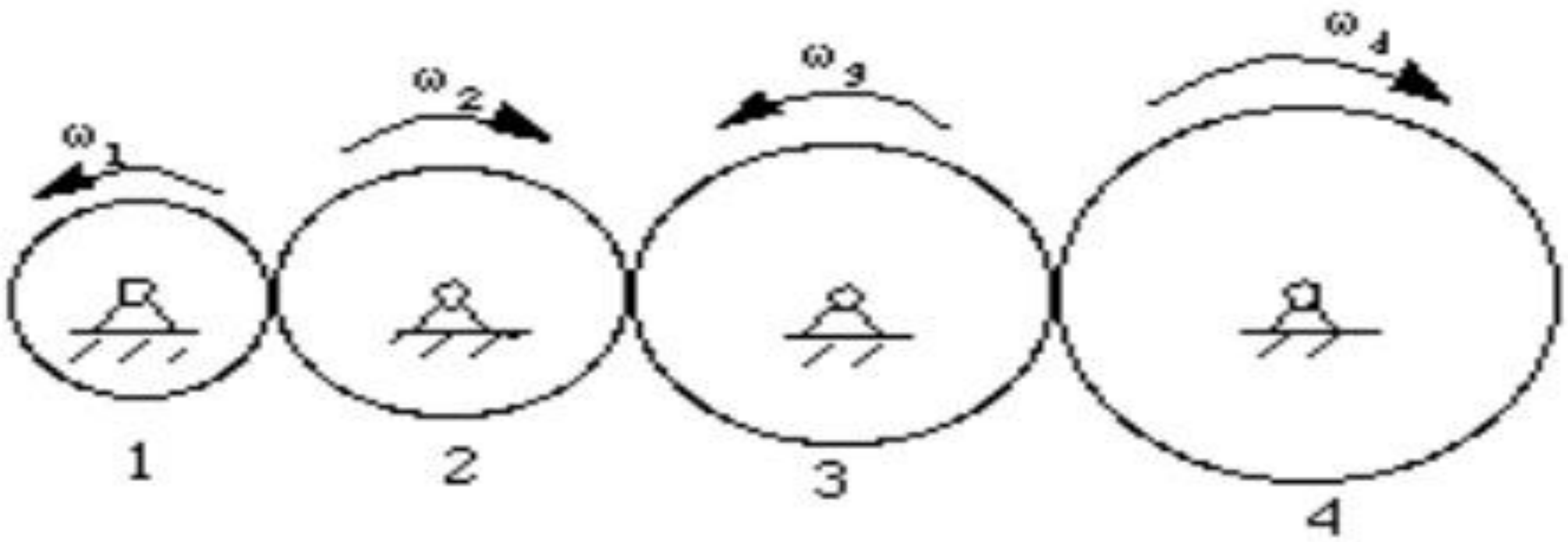
Types of Gear Trains

- Simple gear train
- Compound gear train
- Planetary gear train

Simple Gear Train

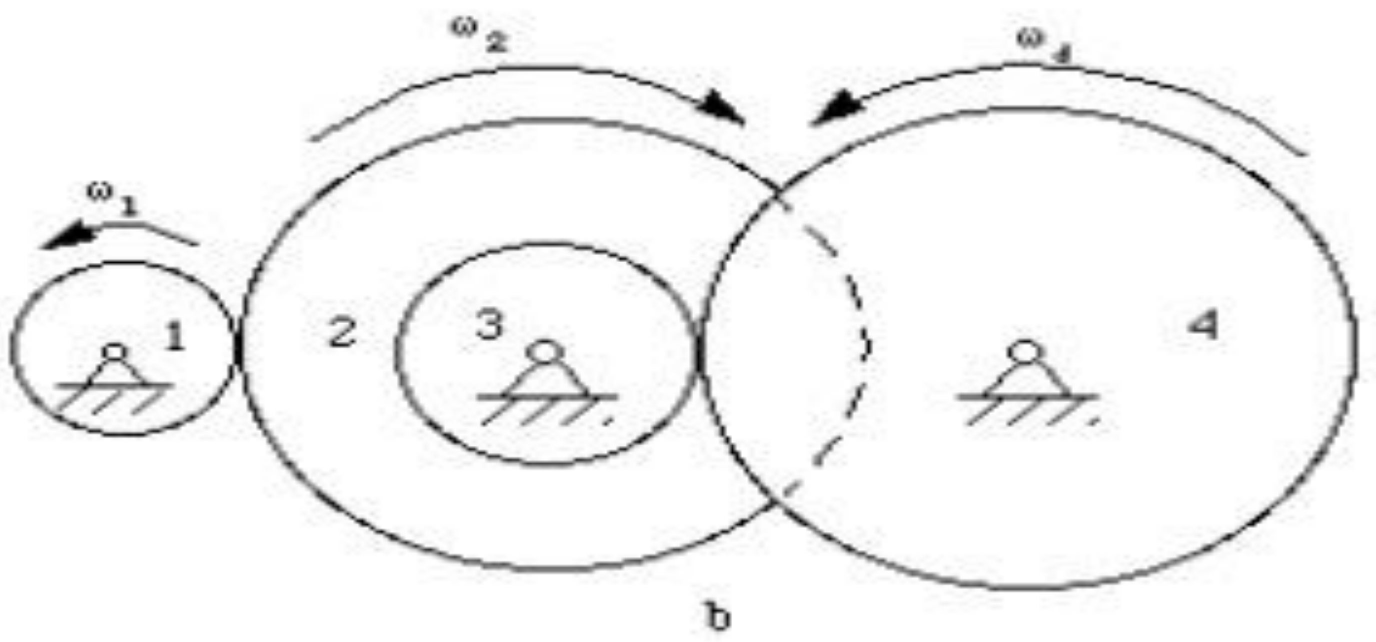
- The most common of the gear train is the gear pair connecting parallel shafts. The teeth of this type can be spur, helical or herringbone.
- Only one gear may rotate about a single axis

Simple Gear Train



Compound Gear Train

- For large velocities, compound arrangement is preferred
- Two or more gears may rotate about a single axis



Planetary Gear Train (Epicyclic Gear Train)

Planetary Gear Train…

- In this train, the blue gear has six times the diameter of the yellow gear
- The size of the red gear is not important because it is just there to reverse the direction of rotation
- In this gear system, the yellow gear (the sun) engages all three red gears (the planets) simultaneously
- All three are attached to a plate (the planet carrier), and they engage the inside of the blue gear (the ring) instead of the outside.

Planetary Gear Train...

- Because there are three red gears instead of one, this gear train is extremely rugged.
- planetary gear sets is that they can produce different gear ratios depending on which gear you use as the input, which gear you use as the output, and which one you hold still.

Planetary Gear Train…

- They have higher gear ratios.
- They are popular for automatic transmissions in automobiles.
- They are also used in bicycles for controlling power of pedaling automatically or manually.
- They are also used for power train between internal combustion engine and an electric motor

References

1. R.S. Khurmi & J.K . gupta,2005, “a text book of machine design”, first multicolor edition, eurasia publishing house (pvt.) Ltd.
2. K.L. Narayana, P. Kannaiah & K. Venkat reddy,2006,”machine drawing”, 3rd edition, new age international (p) limited, publishers
3. wikipedia.org

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