MODULE – 3

Gear Drives: Types – Spur helical, bevel, worm and rack and pinion, velocity ratio, simple and compound gear trains, Applications, numerical problems.

Belt Drives: Open and crossed belt drive, Types of belt (Flat and V-Belt), length of the belt and tension ratio (No derivations), Applications, numerical problems on velocity ratio and length of the belt.

Introduction to Mechanical Power Transmission

- Mechanical power transmission is the transfer of energy from where it's generated to a place where it is used to perform work using simple machines, linkages and mechanical power transmission elements.

GEAR DRIVES

- Gear drives find a very prominent place in mechanical power transmission.
- Gear drives are preferred when considerable power has to be transmitted over a short centre distance positively with a **constant velocity ratio.**

TYPES OF GEARS

- There are various types of gears to suit various applications.
- They differ in the shape of the gear wheel like cylindrical or conical or elliptical, the orientation of their axes and the angle at which the teeth mesh,

Gear drives transmit power between the shafts when their axes are:

- 1) Parallel or 2) Intersecting or 3) Neither parallel nor intersecting.

The different types of Gears used in these cases are:

1. **Spur Gears** - For parallel axes shafts
2. **Helical Gears** - For both parallel and Non-parallel and Non-intersecting Axes shafts
3. **Bevel Gears** - For Intersecting Axes shafts
4. **Worm Gears** - For Non-Parallel and Non-co-planar Axes shafts.
5. **Rack and Pinion -** For converting Rotary motion into linear motion

The detailed explanation is given below

1. SPUR GEARS

- When the axes of the driving and driven shafts are parallel and co-planar as shown in Fig.1. and the teeth of the gear wheels are parallel to the axes, the gears are called Spur Gears.

Fig. 1. Spur Gear

- Teeth of the spur gears are cut on the circumference of the cylindrical discs.
- The contact between the mating gears will be along a line, hence spur gears can transmit higher power.
- Because of the instantaneous line contact when the teeth mesh, noise will be very high.
- They are widely used in machine tools, automobile gear boxes and in all general cases of power transmission where gear drives are preferred.

2. HELICAL GEAR

- Helical gears are similar to the spur gears except that the teeth are cut in the form of the helix around the gears as shown in Fig. 2.

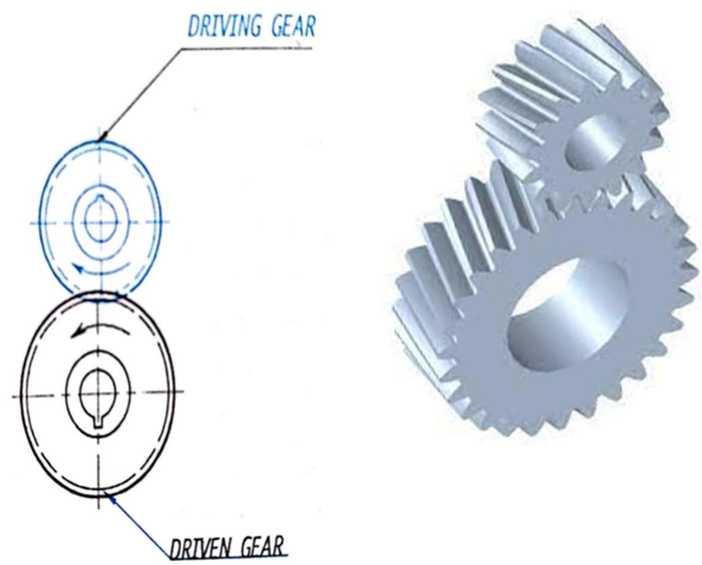


Fig.2. Helical Gear

- Helical gears are used for transmitting power between two parallel shafts and also between non-parallel, non-intersecting shafts.
- The curvilinear tooth contact is progressive, i.e., it extends diagonally across the meshing teeth starting first at one end of a pair of engaging teeth, then, a little further along and so on, progressively to the end of the particular tooth.
- Helical gears are preferred to spur gears when smooth and quite running at higher speeds are necessary.
- The main disadvantages of the helical gears are that it produces and thrusts on the driving and driven shafts.
- Generally, they are used in automobile power transmission.

3. BEVEL GEAR

- When the axes of the two shafts are inclined to one another, and interest when produced, bevel gears shown in Fig. 3.

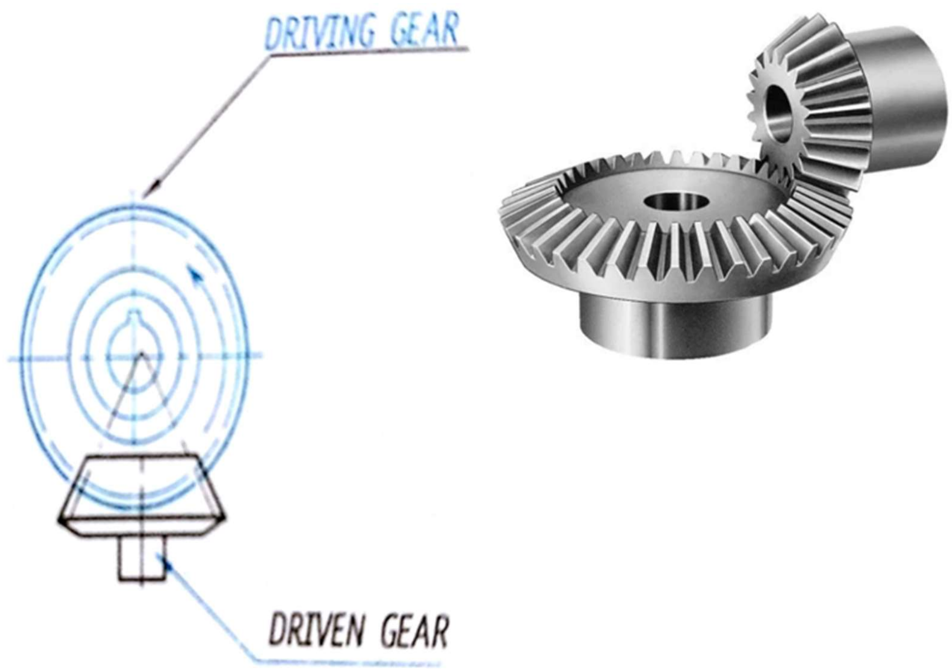


Fig. 3. Bevel Gear

- Teeth of the bevel gears are cut on the conical surfaces.
- The most common examples of power transmission by bevel gears are those in which the axes of two shafts are at right angles to each other.
- When two bevel gears have their axes at right angles and are of equal sizes, they are called milter gears.

4. WORM GEAR

- Worm gears are used to transmit power between the driving and driven shafts having their axes at right angles and non-coplanar as shown in fig. 4.
- A worm drive consists of a worm (essentially a screw) which may have one or more number of helical threads of trapezoidal shape cut on it and a worm wheel ---a gear wheel with the tooth profile consisting of a small segment of a helix which engages with the worm.
- Worm gears are suitable for transmission of power when a high velocity ratio as high as 60:1 is required.
- They are generally employed in machine tools, like lathe, milling, drilling machines etc. to get large speed reduction.
- Another important characteristic of the worm and worm wheel drive is that it offers itself locking facility between the driven and the driving units when the direction of the drive is reversed.

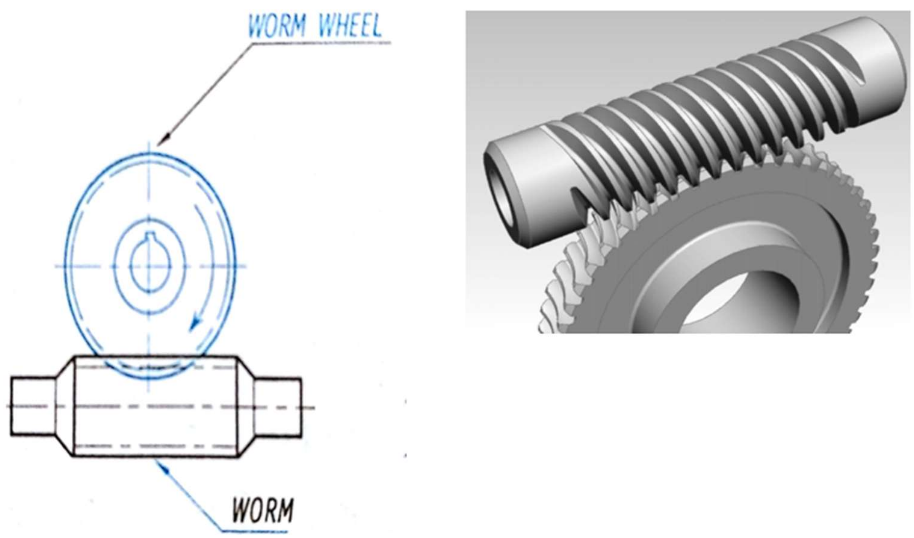


Fig.4. Worm gear

5. RACK AND PINION

- When a rotary motion is to be converted into a linear motion, rack and pinion arrangement is used.
- Rack is a rectangular bar with a series of straight teeth cut on it as shown in fig. 5.
- Theoretically rack is considered to be a spur gear of infinite diameter.
- Rack and pinion arrangement finds their application in machine tools, such as, lathe, drilling, planning machines, and on some steep rail tracks.
- Where the teeth of the locomotive wheel mesh with a rack embedded in the ground, offering the locomotive improved traction.

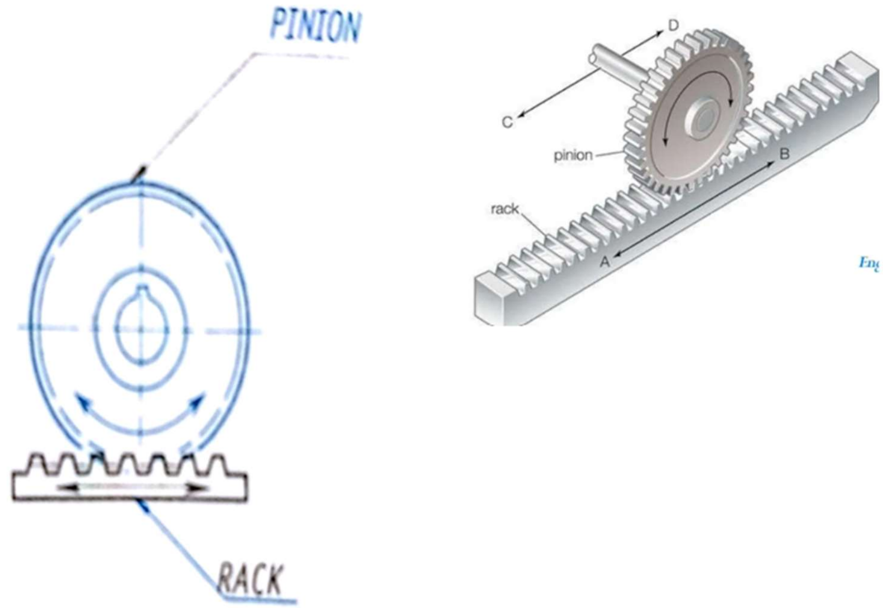
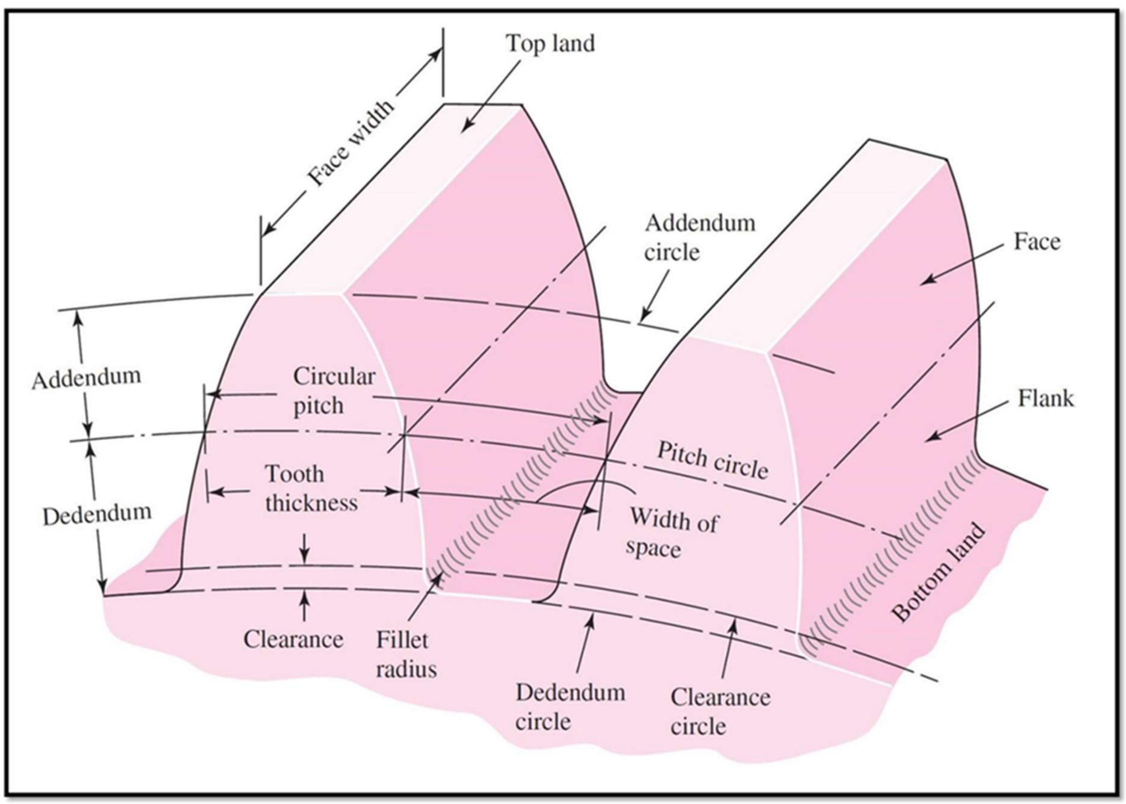


Fig.5. Rack And Pinion

TERMINOLOGY RELATED TO SPUR GEAR



Pitch circle diameter: It is the diameter of the pitch circle, or it is defined as the mean diameter of the gear wheel.

Module (m): It is the ratio of the pitch circle diameter of a gear in 'millimeter' to the number of teeth.

$$m = \frac{d}{T}$$

Where, d= pitch circle diameter of the gear wheel,

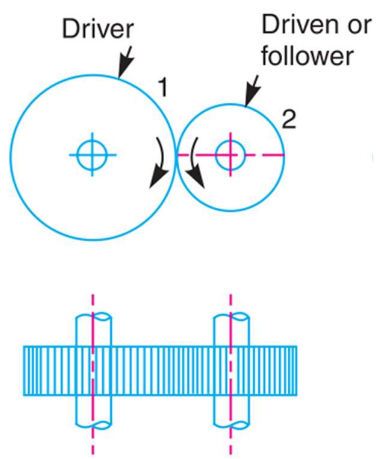
T = number of teeth on gear wheel

Pitch (P_c): It is the distance from a point on the tooth to the corresponding point on the next tooth.

$$P_c = \frac{\pi \times d}{T}$$

VELOCITY RATIO OF GEAR DRIVES

- The velocity ratio of a gear drive is defined as the ratio of the **speed of the driving (driver) gear** to the **speed of the driven gear**



Expression for velocity ratio of a gear drive

- d_1 = pitch circle diameter of the driving gear in mm
- d_2 = pitch circle diameter of the driven gear in mm
- T_1 = number of teeth on the driving gear
- T_2 = number of teeth on the driven gear
- N_1 =speed of the driving gear in rpm
- N_2 = speed of the driven gear in rpm

- Since there is **no slip between the pitch** cylinders of the two gear wheels, The linear speed of the two pitch cylinders must be equal.

$$\begin{bmatrix} \text{Linear speed of the pitch} \\ \text{cylinder representing the Driving gear} \end{bmatrix} = \begin{bmatrix} \text{Linear speed of the pitch} \\ \text{cylinder representing driven gear} \end{bmatrix}$$

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

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

- The circular pitch for both the meshing gears remains same.

$$p_c = \frac{\pi d_1}{T_1} = \frac{\pi d_2}{T_2}$$

i.e., $$\frac{d_2}{d_1} = \frac{T_2}{T_1} ---------- (2)$$

- From equations (1) and (2)
- $Velocity\ ratio\ of\ a\ gear\ Drive = \frac{N_1}{N_2} = \frac{d_2}{d_1} = \frac{T_2}{T_1}$

GEAR TRAINS

- When two or more gears are used to transmit power from one shaft to another, the arrangement is called a gear train.

OR

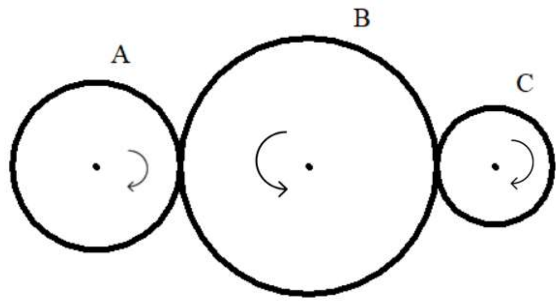
- A Gear train is a combination of Gears which is used when we have to obtain large velocity reduction (or vice versa) in a limited space
- Gear trains are used in almost all machines which are dealing with the mechanical power. Some of the places where gear trains are used are engines, lathes, clocks, gear box and Differential of automobiles etc.
- The nature of gear train i.e., number of gears used depends upon the desired velocity ratio and the relative position of the axis of the shafts.

<u>Depending on the arrangement the gear trains are classified as</u>

- 1) Simple gear train
- 2) Compound gear train

SIMPLE GEAR TRAIN

- In a simple gear train a *series of gear wheels are mounted on different shafts* between the *driving and driven shafts* and **each shaft carries only one gear.**
- A → Driving gear
- B → Intermediate gear
- C → Driven gear



N_A = Speed in RPM of gear A

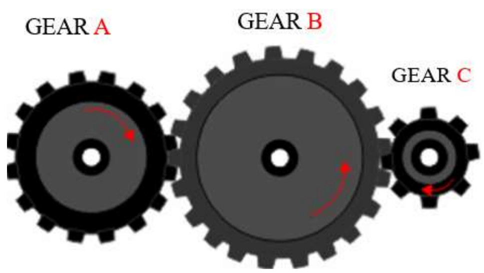
N_B = Speed in RPM of gear B

N_C = Speed in RPM of gear C

T_A = Number of teeth of gear A

T_B = Number of teeth of gear B

T_C = Number of teeth of gear C



i) Gear A drives gear B

$$\frac{N_A}{N_B} = \frac{T_B}{T_A} \text{ -------(1)}$$

ii) Gear B drives gear C

$$\frac{N_B}{N_C} = \frac{T_C}{T_B} \text{ -------(2)}$$

Velocity ratio between the driving and driven gears is given by,
Equating equation (1) and (2) on both sides, LHS=RHS

- Velocity Ratio = $\frac{N_A}{N_B} \times \frac{N_B}{N_C} = \frac{T_B}{T_A} \times \frac{T_C}{T_B}$
- **Velocity ratio** = $\frac{N_A}{N_C} = \frac{T_C}{T_A}$
  - Train Value = $\frac{1}{Velocity\ ratio}$
  - **Train Value** = $\frac{N_C}{N_A} = \frac{T_A}{T_C}$

$$\text{Velocity ratio} = \frac{\text{Speed of driver}}{\text{Speed of driven}} = \frac{\text{No. of teeth on driven}}{\text{No. of teeth on driver}}$$

$$\text{Train value} = \frac{\text{Speed of driven}}{\text{Speed of driver}} = \frac{\text{No. of teeth on driver}}{\text{No. of teeth on driven}}$$

COMPOUND GEAR TRAIN

- "A compound gear train is one in which, **when there are more than one gear on a shaft, it is called a compound gear train."**
- A compound gear train, the intermediate shaft carries two gears, which are keyed to it.
- When the Velocity Ratio is very high a simple gear train become practically impossible.

Gear B →Compound gear

Gear C →Compound gear

Gear A → Driver gear

Gear D→ Driven gear

N_A = speed in RPM of gear A

N_B = speed in RPM of gear B

N_C = speed in RPM of gear C

N_D = speed in RPM of gear D

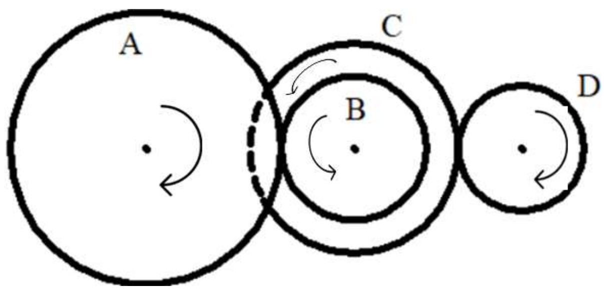
$\mathbf{N_B = N_C}$ (Since compound gear train)

T_A = Number of teeth of gear A

T_B = Number of teeth of gear B

T_C = Number of teeth of gear C

T_D = Number of teeth of gear D



i) Gear A drives gear B

$$\frac{N_A}{N_B} = \frac{T_B}{T_A} \text{-------(1)}$$

ii) Compound gear B and C

$\mathbf{N_B = N_C}$,(Since compound gear train – Gear B and C keyed to single shaft) $\mathbf{T_B \neq T_C}$

iii) Gear C drives gear D

$$\frac{N_C}{N_D} = \frac{T_D}{T_C} \text{-------(2)}$$

Velocity ratio between the driving and driven gears is given by,
Equating equation (1) and (2) on both sides , LHS=RHS

- Velocity Ratio = $\frac{N_A}{N_B} \times \frac{N_C}{N_D} = \frac{T_B}{T_A} \times \frac{T_D}{T_C}$ $(N_B = N_C)$
- **Velocity ratio** = $\frac{N_A}{N_D} = \frac{T_B}{T_A} \times \frac{T_D}{T_C}$
- Train Value = $\frac{1}{Velocity\ ratio}$
- **Train Value** = $\frac{N_D}{N_A} = \frac{T_A}{T_B} \times \frac{T_C}{T_D}$

$$\textbf{Velocity ratio} = \frac{\text{Speed of the first driver}}{\text{Speed of the last driven or follower}}$$

$$\textbf{Velocity ratio} = \frac{\text{Product of the number of teeth on the drivens}}{\text{Product of the number of teeth on the drivers}}$$

$$\text{Train value} = \frac{\text{Speed of the last driven or follower}}{\text{Speed of the first driver}}$$

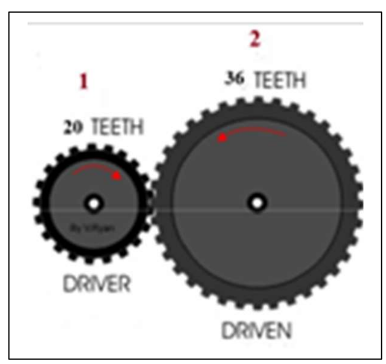
$$\textbf{Train value} = \frac{\text{Product of the number of teeth on the drivers}}{\text{Product of the number of teeth on the drivens}}$$

PROBLEM 1: A gear wheel of 20 teeth drives another gear wheel having 36 teeth running 200 RPM. Find the speed of Driving wheel and Velocity Ratio

Given data:

- $Driving\ Gear\ Wheel$: $T_1 = 20 teeth,\ N_1 = ?$
- $Driven\ Gear\ Wheel$: $T_2 = 36 teeth,\ N_2 = 200\ rpm$

To find: $Speed\ of\ Driving\ Wheel\ N_1 = ?$, Velocity Ratio $\frac{N_1}{N_2} = ?$



Solution:

To find $Speed\ of\ Driving\ Wheel\ N_1 = ?$

- $Velocity\ ratio\ of\ simple\ gear\ train = \frac{N_1}{N_2} = \frac{T_2}{T_1}$
- $Velocity\ ratio\ of\ a\ gear\ Drive = \frac{N_1}{200} = \frac{36}{20}$

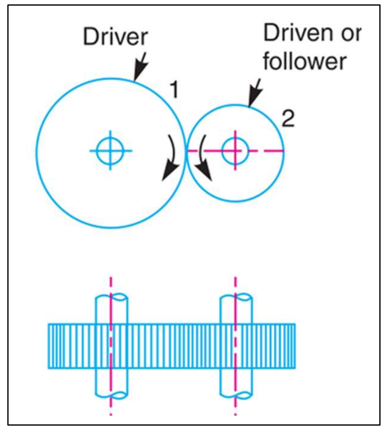
$$Speed\ of\ Driving\ Wheel\ \boldsymbol{N_1 = 360\ rpm}$$

- $Velocity\ ratio\ = \frac{N_1}{N_2} = \frac{360}{200}$
- $\boldsymbol{Velocity\ ratio\ = \frac{1.8}{1}}$

PROBLEM 2: Two gear wheels having 80 teeth and 30 teeth mesh with each other. If the smaller gear wheel runs at 480 rpm, find the speed of the larger wheel.

Given data:

- $Larger\ Gear\ Wheel\ T_1 = 80\ teeth,\ \ Speed\ N_1 = ?$
- $Smaller\ Gear\ Wheel\ T_2 = 30\ teeth,\ N_2 = 480\ rpm$



To find: $Speed\ of\ Larger\ Wheel\ N_1 = ?$

Solution:

- Velocity ratio of simple gear train
- $Velocity\ ratio\ of\ simple\ gear\ train = \frac{N_1}{N_2} = \frac{T_2}{T_1}$
- $Velocity\ ratio\ of\ a\ gear\ Drive = \frac{N_1}{480} = \frac{30}{80}$

$Speed\ of\ (larger\ Wheel)\ Driving\ Wheel\ \boldsymbol{N_1 = 180\ rpm}$

PROBLEM 3: A simple Gear train consists of 3 gears. The number of teeth on the driving gear is 60, on the roller gear is 40 and on the driven gear is 80. If the driving gear rotates at 1200 rpm, find speed of driven gear and also the velocity ratio. Sketch the arrangement of gear drive.

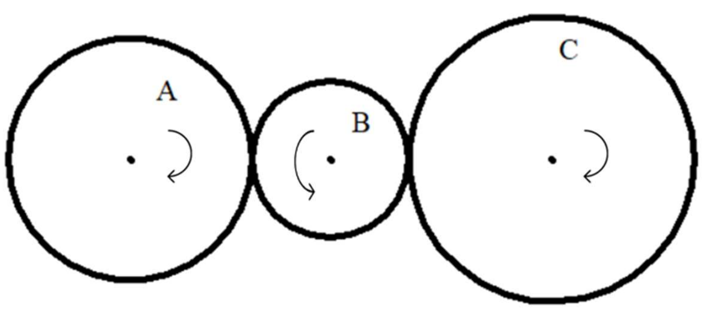
Given data: Simple Gear train consists of 3 gears

- $Driving\ Gear\ Wheel:\ \ T_A = 60 teeth,$
- $Roller\ gear\ \ or\ \ Intermediate\ gear\ : T_B = 40\ teeth, N_B = \ ?\ ;$
- $Driven\ Gear\ Wheel\ OR$ Last follower: $T_C = 80 teeth,\ N_C = \ ?,$
- **When** driving gear rotates $N_A = 1200\ rpm,$

To find: $Speed\ of\ driven\ gear\ \ N_C = \ ?$, Velocity ratio $= \frac{\boldsymbol{N_A}}{\boldsymbol{N_C}} = ?$

Sketch the arrangement of gear drive

Solution:



i) **Gear A drives gear B**

- $\frac{N_A}{N_B} = \frac{T_B}{T_A}$
- $\frac{1200}{N_B} = \frac{40}{60}$

$Speed\ of\ Intermediate\ gear\ B,\ \boldsymbol{N_B = 1800\ rpm}$

ii) Gear B drives gear C

- $\frac{N_B}{N_C} = \frac{T_C}{T_B}$
- $\frac{1800}{N_C} = \frac{80}{40}$

$Speed\ of\ Driven\ gear\ C,\ \boldsymbol{N_C = 900\ rpm}$

Velocity ratio between the driving and driven gears is given by,

Velocity ratio = $\frac{N_A}{N_C} = \frac{T_C}{T_A}$

Velocity ratio = $\frac{N_A}{N_C} = \frac{1200}{900}$

Velocity ratio = $\frac{N_A}{N_C} = \frac{4}{3}$

PROBLEM 4: A simple Gear train is made up of Gear **A, B C** and **D** having 20, 40, 60 and 70 teeth respectively, if **A** is main driver rotating at 500 RPM clockwise. calculate following,

1) Speed of Intermediate gear
2) Speed and Direction of Last follower
3) Train Value

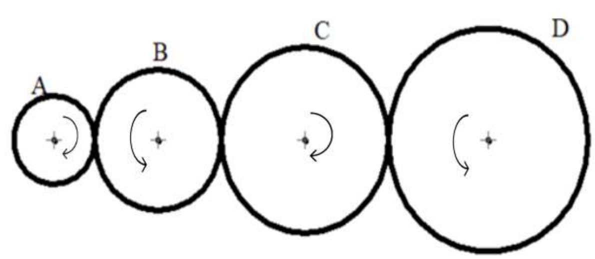
Given data:

- $Driving\ Gear\ Wheel$: $T_A = 20 teeth,\ N_A = 500\ rpm$
- $Intermediate\ gear$: $T_B = 40\ teeth, N_B = ?;\ T_C = 60 teeth, N_C = ?,$
- $Driven\ Gear\ Wheel\ OR$ Last follower: $T_D = 70\ teeth\ N_D = ?$

Solution:

1)To find $Speed\ of\ Intermediate\ gear$ $T_B = 40\ teeth, N_B = ?;\ T_C = 60 teeth, N_C = ?,$

i) **Gear A drives gear B**



$$\frac{N_A}{N_B} = \frac{T_B}{T_A}$$

$$\frac{500}{N_B} = \frac{40}{20}$$

$$\boldsymbol{N_B = 250\ rpm}$$

$Speed\ of\ Intermediate\ gear\ B$

ii) Gear B drives gear C

$$\frac{N_B}{N_C} = \frac{T_C}{T_B}$$

$$\frac{250}{N_C} = \frac{60}{40}$$

$$\boldsymbol{N_C = 166.7\ rpm}$$

Speed of Intermediate gear C

2) Speed and Direction of Last follower

iii) Gear C drives gear D

$$\frac{N_C}{N_D} = \frac{T_D}{T_C}$$

$$\frac{166.7}{N_D} = \frac{70}{60}$$

$$\boldsymbol{N_D = 142.86\ rpm,}$$

Speed of Driven Gear Wheel OR Last follower D, $\boldsymbol{N_D = 142.86\ rpm}$, ***Anticlockwise direction***

3) Train Value

Velocity ratio = $\frac{N_A}{N_D}$

Velocity ratio = $\frac{500}{142.86} = \frac{3.5}{1}$

Train Value = $\frac{1}{Velocity\ ratio}$

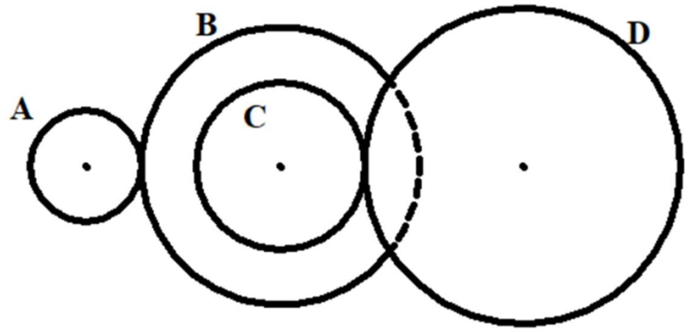
Train Value = $\frac{1}{3.5}$ **= 0.285**

NUMERICALS ON COMPOUND GEAR

PROBLEM 5: In a compound gear train of wheels, A, B, C and D have 15,30,20,40 teeth respectively. The wheel B and C are keyed to the same shaft. If the wheel A runs at 400 rpm, find the speed of wheel D. Sketch the arrangement if B meshes with A and C meshes with D.

Given data: Compound Gear train consists of 4 gears

- $T_A = 15, T_B = 30, T_C = 20, T_D = 40\ teeth$
- B and C are keyed to the same shaft ($N_B = N_C$) Compound gear
- **If** the wheel **A** runs, $N_A = 400\ rpm$
- **To find** *Speed of wheel* ***D*** $N_D = ?$
- **Sketch the arrangement**, if **B** meshes with **A** and **C** meshes with **D**.



Solution:

To find *Speed of wheel* $\boldsymbol{D}$ $N_D = ?$

i) **Gear A drives gear B**

$$\frac{N_A}{N_B} = \frac{T_B}{T_A}$$

$$\frac{400}{N_B} = \frac{30}{15}$$

$Speed\ of\ Wheel\ \boldsymbol{B},\ \boldsymbol{N_B = 200\ rpm}$

ii) B and C are keyed to the same shaft ($\mathbf{N_B} = \mathbf{N_C} = \mathbf{200}\ \boldsymbol{rpm}$) Compound gear,

iii) **Gear C drives gear D**

$$\frac{N_C}{N_D} = \frac{T_D}{T_C}$$

$$\frac{200}{N_D} = \frac{40}{20}$$

$Speed\ of\ Wheel\ D,\ \boldsymbol{N_D = 100\ rpm}$

PROBLEM 6: A compound gear train consists of 4 gears, P, Q, R, S having 20, 40, 60 and 80 teeth respectively. The gear P is keyed to the driving shaft, gear S to driven shaft. Q and R are compound gears. Q meeting with P and R meshes with S. If P rotates with 150 rpm, what is the speed of gear **S**? Show the gear arrangements.

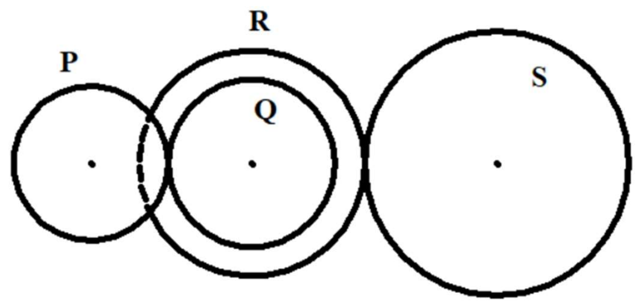
Given data: Compound Gear train consists of 4 gears

- $T_P = 20,\ T_Q = 40,\ T_R = 60,\ T_S = 80\ teeth$
  - The gear P is driving shaft, gear S to driven shaft.
  - Q and R are Compound gear, ($\mathbf{N_Q} = \mathbf{N_R}$)
  - Q meeting with P and R meshes with S
  - **If** the gear **P rotates**, $N_P = 150\ rpm$

To find *Speed of gear* $\boldsymbol{S}$, $N_S = ?$

Solution:

- **To find** *Speed of gear* ***S***, $N_S = ?$



(i) **Gear P drives gear Q**

$$\frac{N_P}{N_Q} = \frac{T_Q}{T_P}$$

$$\frac{150}{N_Q} = \frac{40}{20}$$

$Speed\ of\ gear\ Q,\ \boldsymbol{N_Q = 75\ rpm}$

(ii) Q and R are Compound gear

($\mathbf{N_Q = N_R = 75\ rpm}$)

(iii) Gear R drives gear S

$$\frac{N_R}{N_S} = \frac{T_S}{T_R}$$

$$\frac{75}{N_S} = \frac{80}{20}$$

$Speed\ of\ Wheel$ **S**, $\boldsymbol{N_S = 18.75\ rpm}$

PROBLEM 7: A gear wheel has 50 teeth of module 5mm. find pitch circle diameter and circular pitch.

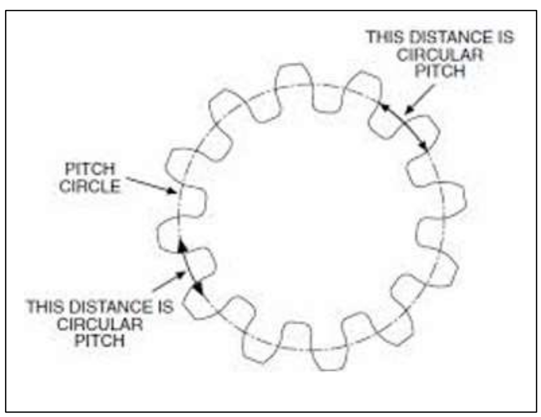
Given data:

- $Gear\ Wheel\ \ has\ a\ teeth$: $T = 50\ teeth,$
- Module **m** = 5 mm, $\boldsymbol{m = \frac{d}{T}}$ **;**
- where d= pitch circle diameter, T= number of teeth

To find

1) Pitch circle diameter **d=? ;** $\boldsymbol{m = \frac{d}{T}}$

2) Circular Pitch $\mathbf{P_c}$ = ?; $\mathbf{P_c} = \boldsymbol{\frac{\pi d}{T}}$



Solution

1) Pitch circle diameter, $m = \frac{d}{T}$

- $5 = \frac{d}{50}$
- **Pitch circle diameter $d = 250$ mm**

2) Circular Pitch $P_c = \frac{\pi d}{T}$

$P_c = \frac{(\pi \times 250)}{50}$

$P_c = 15.7$ **mm**

Advantages of Gear Drive

- They are non-Slip drive
- Convenient for small centre
- Transmit power when axes are non-parallel
- Velocity ratio constant throughout
- Convenient for low medium and high-power transmission
- It can be used even for low speeds
- Efficiency is High
- Can be cast in Metal and Non Metal

Disadvantages of Gear Drive

- Not suitable for very large center distance
- Always require some kind of Lubrication
- Noise and vibration is high
- Not Economical
- Increases weight when gear rains are used

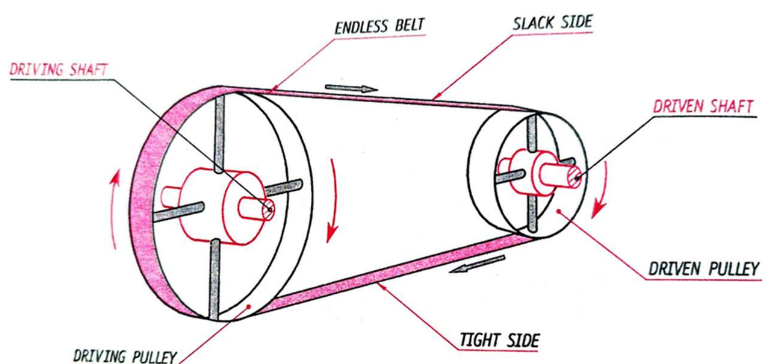
Applications of Gear Drive

Gear drives have diverse applications across industries, including:

1) **Automotive**: Transmission systems for cars.
2) **Industrial Machinery**: Power transmission in manufacturing.
3) **Aerospace**: Landing gear and engine components.
4) **Power Generation**: Wind turbines and hydroelectric plants.
5) **Mining Equipment**: Crushers, conveyors, and hoists.
6) **Robotics**: Precision control of joint movements.
7) **Defense Systems**: Military vehicles and weapon systems.
8) **Consumer Electronics**: Cameras, printers, and household appliances.

BELT DRIVES

- Belt drives are used to transmit power from one shaft to another by means of a thin inextensible belt running over two pulleys.
- Belt drives are one of the common methods generally employed whenever power or rotary motion is to be transmitted between two parallel shafts.
- The arrangement consists of two pulleys mounted on two different shafts.
- One shaft called the **driving shaft receives power** from the mains and transmits it to another shaft called **driven shaft.**
- The pulley mounted on the driving shaft is called **driving pulley** or driver while the other pulley mounted on a shaft to which power has to be transmitted is called the **driven.**
- The belt passing over the two pulleys is kept in tension so as to avoid slip over the pulleys.
- This helps in transmitting power effectively from one shaft to another.



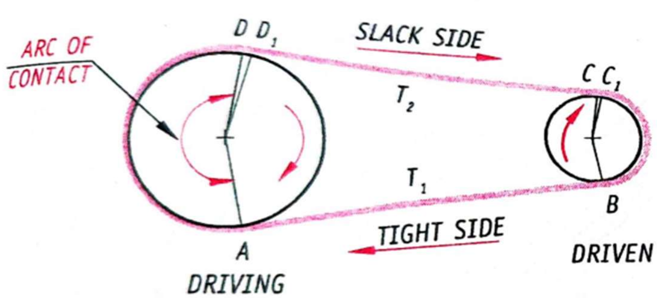
Belt Drive

Types of belt drives are:

1) Open belt drive
2) Cross belt drive

OPEN BELT DRIVE

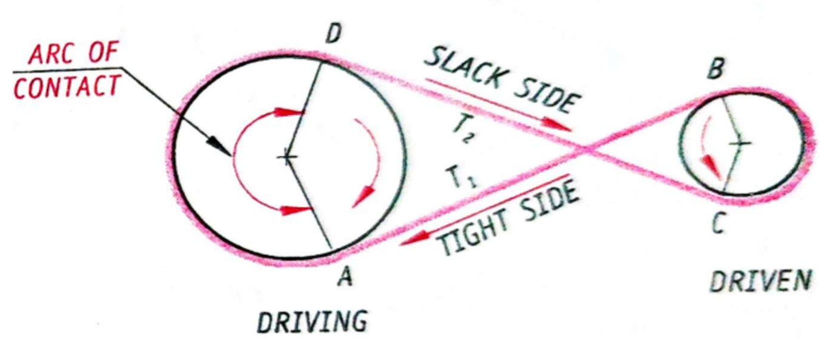
- This type of belt drive shown in fig. is employed when the two parallel shafts have to rotate in the same direction.
- When the shafts are placed far apart, the lower side of the belt should be the tight side and the upper side must be the slack side.
- This is because, when the upper side becomes the slack side, it will sag due to its own weight and thus increases the arc of contact which in turn increases the capacity of the drive.



Open Belt

CROSS BELT DRIVE

- This type of belt drive shown in fig. is employed when two parallel shafts have to rotate in the opposite direction.
- At the junction where the belt crosses, it rubs against itself and wears off.
- To avoid excessive wear the shaft must be placed at a maximum distance from each other and operated at very low speeds



Cross Belt

VELOCITY RATIO OF BELT DRIVE

Expression for velocity ratio of a Belt drive

- Velocity ratio of a belt drive is defined as the ratio of the speed of the driving pulley to the speed of the driven pulley.
- Let $\mathbf{d_1}$ and $\mathbf{d_2}$ be the diameter of driving and the driven pulley respectively and
- Let $\mathbf{N_1}$ and $\mathbf{N_2}$ be speed of driving and the driven pulley in RPM respectively

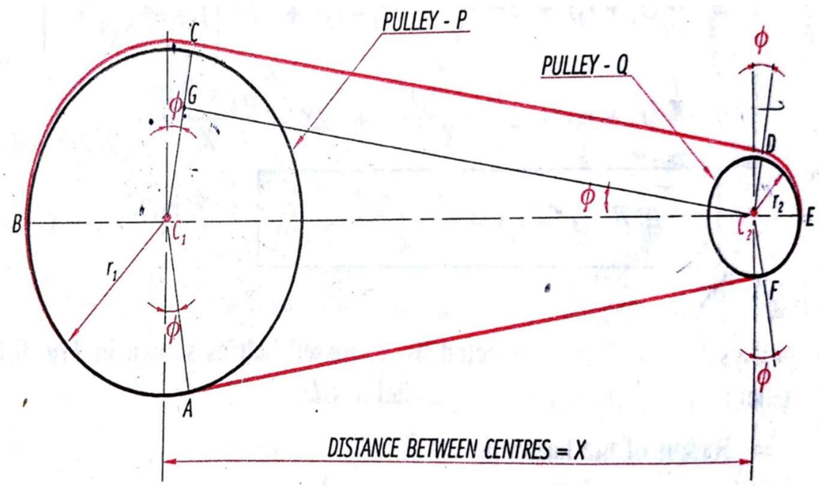
[Linear Speed of Belt] = [Circumferential speed of the driving pulley] = [Circumferential speed of the driven pulley]

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

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

OPEN BELT SYSTEM.

- Let the two pulleys P and Q be connected by an open belt as shown in Fig. from the centre C_2, of the smaller pulley draw a line C_2G parallel to CD.
- Let, $\mathbf{r_1}$ = radius of the large pulley- ***P***
- $\mathbf{r_2}$ = Radius of the smaller pulley – **Q**
- **X** = Distance between the centers of the pulleys



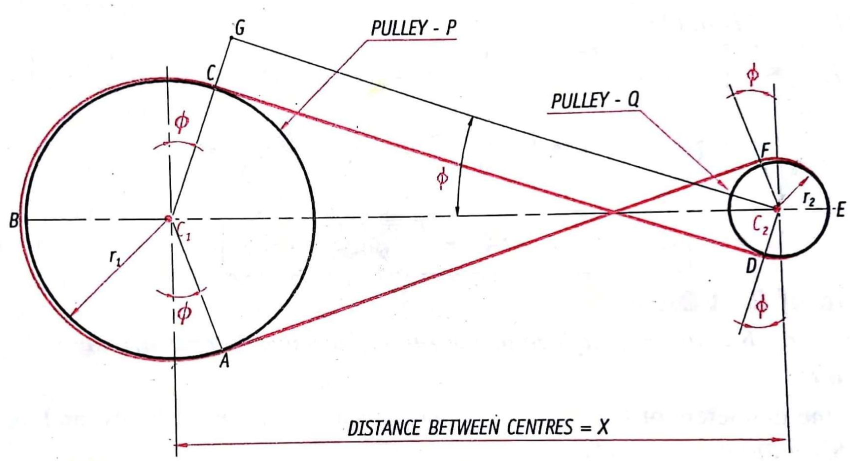
Lenth of Belt – Open Belt Drive

The length of the Open belt drive is given by,

$$L = \Pi(r_1 + r_2) + \frac{(r_1 - r_2)^2}{X} + 2X$$

CROSSED BELT SYSTEMS

- Let the two pulleys P and Q are connected by a crossed belt as shown in Fig. from the centre $\mathbf{C_2}$ of the smaller pulley, draw a line $\mathbf{C_2G}$ parallel to **CD**.
- Let, r_1 = radius of the larger pulley - **P**
- r_2 = Radius of the smaller pulley - **Q**
- X = Distance between the centres of the two pulley



Lenth of Belt – Crossed Belt Drive

The length of Crossed belt drive is given by.

$$L = \Pi(r_1 + r_2) + \left[\frac{(r_1 + r_2)^2}{X}\right] + 2X$$

Expression for θ = Angle of contact.

The angle of lap is always considered for smaller pulley

$$\boldsymbol{\theta = 180 - 2\emptyset}$$

Where, θ *in Radians*

Example, $\theta = \theta^{\circ} \times \frac{\pi}{180}\ radians$

For Open belt drive, $\emptyset$ *Calcuted*	*For Crossed belt drive,* $\emptyset$ *Calcuted*
From the triangle GC_1C_2 $Sin\phi = \frac{r_1 - r_2}{X}$	From the triangle GC_1C_2, $Sin\phi = \frac{r_1 + r_2}{X}$

Expression for Tensions in Tight side (T_1) and Slack side (T_2) of a Belt drive

Tensions in Tight side (T_1) and Slack side (T_2) of a Belt drive is given by

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

- Where, μ = Coefficient of friction,
- θ = Angle of contact. $\theta = \theta^{\circ} \times \frac{\pi}{180}\ radians$
- T_1 = Tension in Tight side (Newton)
- T_2 = Tension in Slack side (Newton)

PROBLEM 1: It is required to transmit a power between 2 parallel shafts by means of belt drive arrangement. The speeds of driving and driven shafts are 150 rpm and 250 rpm respectively. Distance between parallel shafts is 2.7m. Driven pully diameter is 60cm. Determine the length of the belt for cross drive arrangement.

Given data:

Driving Pully System (Shaft 1)

- $N_1 = 150$ rpm
- $d_1 = ?$ Velocity Ratio of Belt drive $\frac{N_1}{N_2} = \frac{d_2}{d_1}$

Driven Pully System (Shaft 2)

- $N_2 = 250$ rpm
- $d_2 = 60$ cm i.e, $d_2 = 0.6$ m

Distance between parallel shafts is **X = 2.7m**

To find:

(i) Length of the belt for CROSS DRIVE arrangement L =?

SOLUTION:

To find Radius of driving pulley r_1

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

$$\frac{150}{250} = \frac{0.6}{d_1}$$

$$\boldsymbol{d_1 = 1\text{m}}$$

$$\boldsymbol{r_1 = 0.5\text{m}}$$

$$\boldsymbol{r_2 = \frac{d_2}{2} = \frac{0.6}{2} = 0.3\text{m}}$$

(ii) Length of the belt CROSS DRIVE

$$L = \pi(r_1 + r_2) + \left[\frac{(r_1 + r_2)^2}{X}\right] + 2X$$

$$L = \pi(0.5 + 0.3) + \left[\frac{(0.5 + 0.3)^2}{2.7}\right] + 2(2.7)$$

$$\boldsymbol{L} = 8.15 \text{ m}$$

PROBLEM 2: Power is to be transmitted from a shaft to another by means of a belt drive. The diameter of the larger pulley is 600 mm and that of the smaller pulley is 300 mm. The distance between the centres of the two pulleys is 3 meter. If the axes of the two shafts are in the same plane and parallel to each other, find the length of the belt required for: (i) open belt drive and (ii) crossed belt drive.

Given data:

- Radius of Larger pulley $r_1 = \frac{600}{2} = 300mm$
- Radius of Smaller pulley $r_2 = \frac{300}{2} = 150mm$

Distance between the axes of the Driving and driven shafts } $X = 3\text{ m} = 3000\text{ mm}$

To find:

Length of belt in the open System

$$L = \Pi(r_1 + r_2) + \frac{(r_1 - r_2)^2}{X} + 2X$$

Length of belt in the crossed system:

$$L = \Pi(r_1 + r_2) + \left[\frac{(r_1 + r_2)^2}{X}\right] + 2X$$

Solution:

Length of belt in the open belt drive System:

$$L = \Pi(r_1 + r_2) + \frac{(r_1 - r_2)^2}{X} + 2X$$

$$L = \Pi(300 + 150) + \frac{(300 - 150)^2}{3000} + 2 x 3000$$

$L = 7421.2$ mm

Length of belt in the crossed belt drive system:

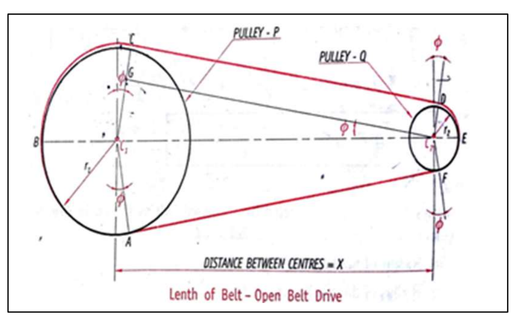
$$L = \Pi(r_1 + r_2) + \left[\frac{(r_1 + r_2)^2}{X}\right] + 2X$$

$$L = \Pi(300 + 150) + \left[\frac{(300 + 150)^2}{3000}\right] + 2 x 3000$$

$L = 7481.2$ mm

PROBLEM 3: An engine is driving a generator by means of a belt. The pulley on the driving shaft has a diameter of 55 cm and runs at 276 rpm. If the radius of the pulley on the generator is 15 cm, find its speed in rpm.

Given data:



- Engine : Driving System
- $d_1 = 55$ cm
- $N_1 = 276$ rpm
- Generator: Driven system
- $d_2 = 2r_2$
- $d_2 = 2 \times 15 = 30$ cm

To find: *Speed of* Generator: Driven system N_2 = ? in rpm

Solution:

Velocity Ratio of Belt drive

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

$$\frac{276}{N_2} = \frac{30}{55}$$

$$N_2 = \mathbf{506\ rpm}$$

PROBLEM 4: A motor running at 1750 rpm drivers a line shaft at 800 rpm. If the diameter of the pulley on the motor shaft is 160 mm. find diameter that of the pulley on the line shaft.

Given data:

- <u>Motor : Driving System</u>
- d_1 = 160 mm
- N_1 = 1750 rpm
- <u>Line shaft : Driven system</u>
- N_2 = 800 rpm
- d_2 = ?

To find: *find diameter that of the pulley on the line shaft*: Driven system d_2 = ?

Solution:

Velocity Ratio of Belt drive

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

$$\frac{1750}{800} = \frac{d_2}{160}$$

$$d_2 = \mathbf{350\ mm}$$

PROBLEM 5: A shaft running at 100 rpm is to drive a parallel shaft at 150 rpm. The pulley on the driving shaft is 35 cm in diameter. Find the diameter of the driven pulley. Calculate the linear velocity of the belt and also the velocity ratio

Given data:

- <u>Driving Shaft : Driving System</u>
- N_1 = 100 rpm
- d_1 = 35 cm
- <u>Driven pulley: Driven system</u>
- N_2 =150 rpm
- d_2 = ?

To find: a) Find the diameter of the driven pulley : Driven system d_2 = ?

b) Linear velocity of the belt = $\pi d_1 N_1$= ? ;

c) Velocity ratio = $\frac{N_1}{N_2}$ = ?

<u>**Solution:**</u>

a) Find the diameter of the driven pulley : Driven system d_2 = ?

Velocity Ratio of Belt drive

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

$$\frac{100}{150} = \frac{d_2}{35}$$

$$d_2 = \mathbf{23.33\ cm}$$

Solution:

b) Linear velocity of the belt, $v = \pi d_1 N_1$

Linear velocity of the belt $v = \pi * (35cm) * 100$ *(1meter =100cm)*

Linear velocity of the belt $v = \pi * (35/100) * 100$ *(1meter =100cm)*

Linear velocity of the belt =109.95 m/min

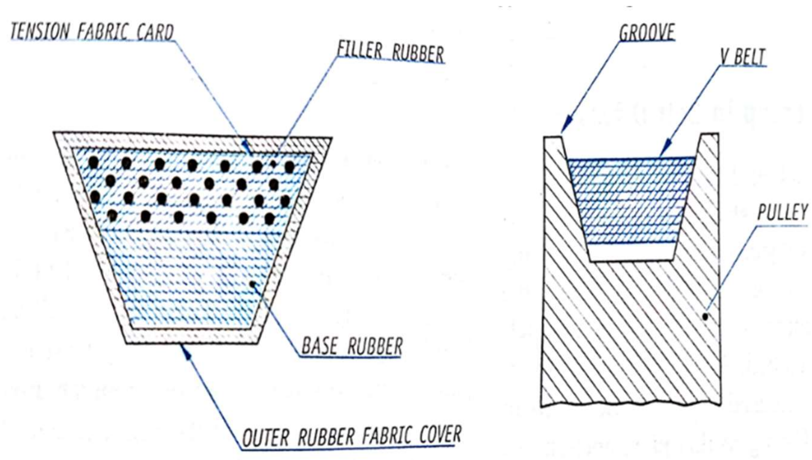
c) Velocity ratio = $\frac{N_1}{N_2}$

Velocity ratio = $\frac{100}{150}$

Velocity ratio = $\frac{\mathbf{N_1}}{\mathbf{N_2}} = \frac{\mathbf{2}}{\mathbf{3}}$

V-BELT

- These appear trapezoidal in cross section. These are *moulded as endless loops from rubber, reinforced with fibrous material.*
- These belts run in the V-grooved pulleys or sheaves.
- Multiple V-belts are used when the power transmitted is too great for a single belt.
- Power from 0.5 to 150 kW can be transmitted using V-belts
- It is used for general engineering applications, from domestic appliances to heavy duty rolling machines.



Section of V-Belt V-Belt in Groove

Advantages of V-Belt

1. It can transmit higher power
2. It can be used for smaller centre distances
3. It can permit large speed ratios
4. There is no slipping of the belt from the pulley
5. In an emergency it is possible to continue the drive temporarily even if one of the belts snaps.
6. It is possible to operate with the shaft axes in any position
7. Several machines can be driven from a single driving shaft

Disadvantages of V-Belt

1. The pulley construction is more complex in a V-belt drive when compared to flat belt drive
2. Durability of V-belts is less compared to flat belts
3. Not suitable for large center distances
4. It is a costlier system than flat belt drive.

Applications of Belt Drives

1. A belt drive is used to transfer power.
2. The belt drive is used in the Mill industry.
3. The belt drive is used in Conveyor.
4. The treadmill is another great example of a belt driven mechanism.
5. The drive belt used to transfer power from the engine’s flywheel.
6. In washing machines to transfer power from the motor shaft to the drum shaft
7. The belt drive is used in Lathe Machine, Milling Machines, Drilling machine, etc.
8. The belt drive is used in Alternators in automobiles

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2. Elements of Workshop Technology (Vol. 1 and 2), Hazra Choudhry and Nirzar Roy, Media Promoters and Publishers Pvt. Ltd., 2010.

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3. Robotics, Appu Kuttan KK K. International Pvt Ltd, volume 1