Power Transmission

The power is transmitted from electric motor shaft to machine by means of belt, rope, chain and gears.

Power transmission has following objective:

1) To transmit the power from motor shaft to driven shaft.

2) To change the speed.

3) To transmit the power from one source to different shafts.

~~Be~~ Belt drives

The Belts are used to transmit power from one shaft to another by means of pulley. the belts or ropes are wrapped around two pulleys and the ends are then connected to form an endless connecter.

Classification of belts:

a) **According to drives:**

1) Light drives belt: these belts are used to transmit small power at belt speed up to 10 m/s. It is mainly used in agricultural machines.

2) Medium drives belt:- these are used to drives at belt speed between 10 m/s to 22 m/s. It is mainly used in machine tools.

3) Heavy drives belt: these are used to drive heavy power at belt speed more than 22 m/s. It is mainly used in compressor and generators.

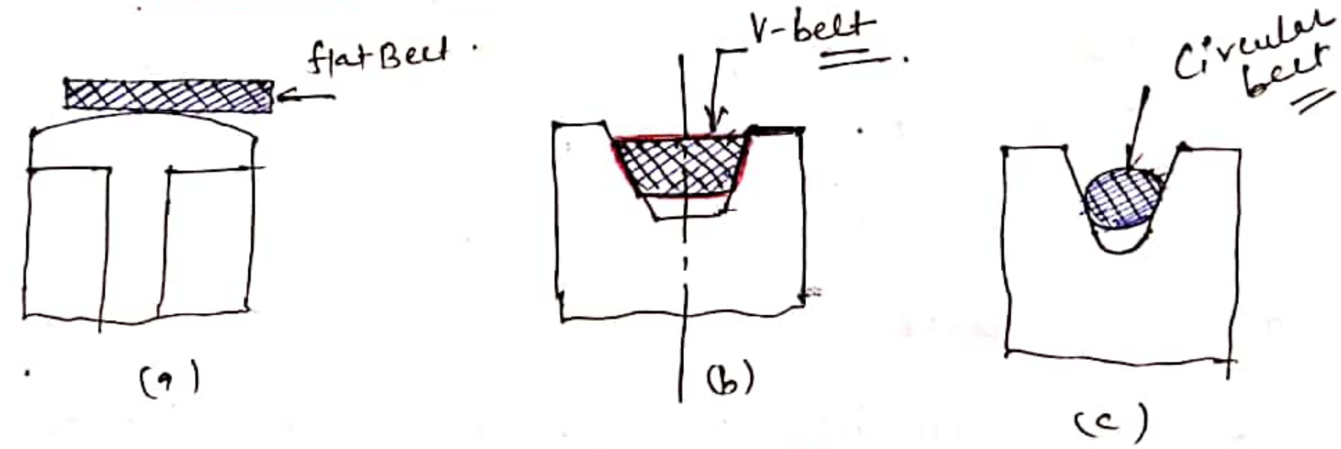
b) **According to shape**

1) Flat belt type: In this shape of belt is flat. It is used for moderate amount of power is to be transmitted. It is used where distance between two pulleys is not more than 8 meters.

2) V type belt: In this shape of belt is V shape. It is used where moderate amount of power is to be transmitted. It is used where two pulleys are very near.

3) Circular type belt: In this shape of belt is circular same as rope. It is used where large amount of power is to be

transmitted. It is used where distance between pulleys are more than 8 meters.



(C) According to Material used.

1) **Leather Belt:** Leather is most important material for belts. for heavy duty belts, two or three ply of leather are cemented and pressed one above the other. Such belts are called double or triple ply belts.

2) **Rubber belt:** these belts are very flexible and suitable where it is exposed to moisture. Rubber belts are made of Layers of fabric with rubber composition.

3) Balata Belts: these belts are acid and water proof and it is not affected by alkalies. these belts are made up from plies of stiched canvas filled with balata gum. maximum limit of temp. is 40°C. the strength of the balata belt is 25%. higher than rubber belt.

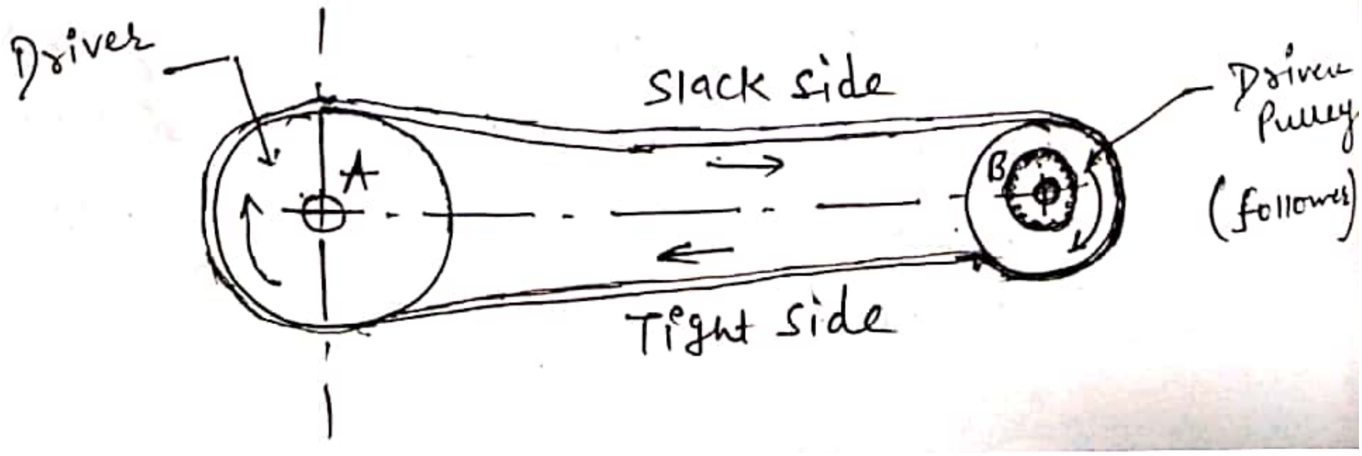
4) Cotton or fabric belt: most of the fabric belts are made by folding canvas or cotton duck to three or more layers and stiched. these belts are cheaper and suiteble in hot climate, in damp atmosphere.

Types of flat belt drives

a) Open Belt drive:

- An open belt drive is used when the driven pulley is to be rotated in the same direction as the driving pulley.

→ open belt drives are used to connect two parallel shafts having a centre distance up to 15m, depending on the belt width and other conditions.



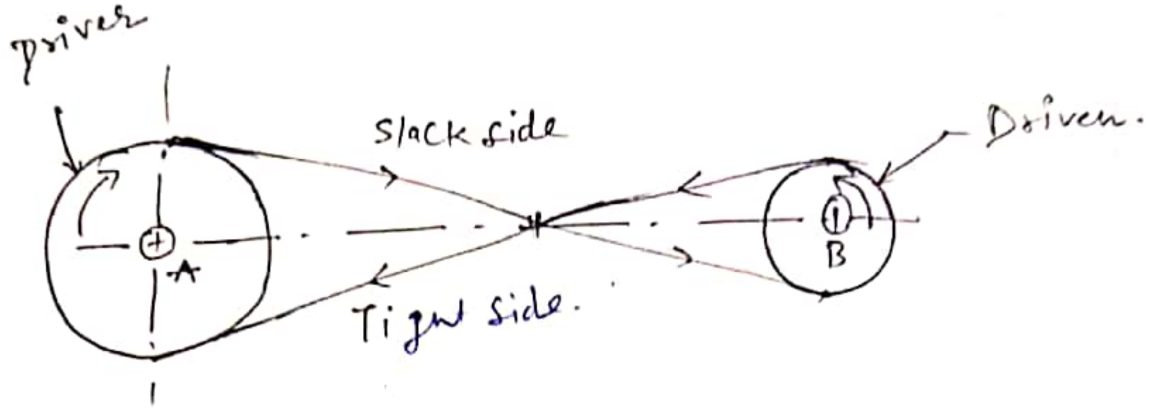
→ In this case, shafts are arranged parallel and driver A pulls the belt from one side (Lower side) and delivers it to the other side (upper side). Thus the tension is more in the Lower side of the belt than that in upper side.

→ the Lower side of the belt is known as tight side and the upper side belt is known as slack side.

Note: In case the tight side is at the upper side, the Sag will be greater at the Lower side, reducing the angle of wrap and slip could occur earlier. this affects the power to be transmitted.

(b) Crossed Belt drive

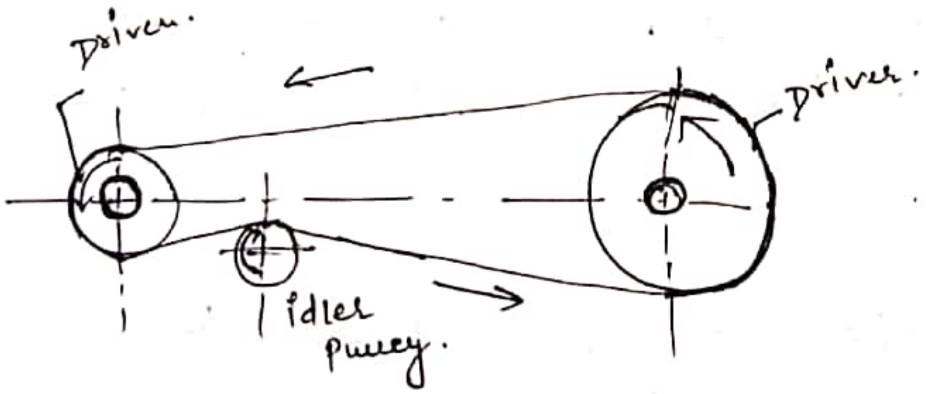
A Cross belt drive is used when the driven pulley (B) is to be rotated in the opposite direction of the driving pulley (A).



A crossed belt drive can transmit more power than an open belt drive as the angle of wrap more.

- the main ~~Advantage~~ disadvantages of crossed belt drive ~~___~~ : is that It ~~___~~ bends in two different planes, the belt wears out more at the point where the two ends of the belt meet.
- For small centre distance, the belt is not fully utilized.

(C) Belt drive with ~~___~~ idler pulleys:



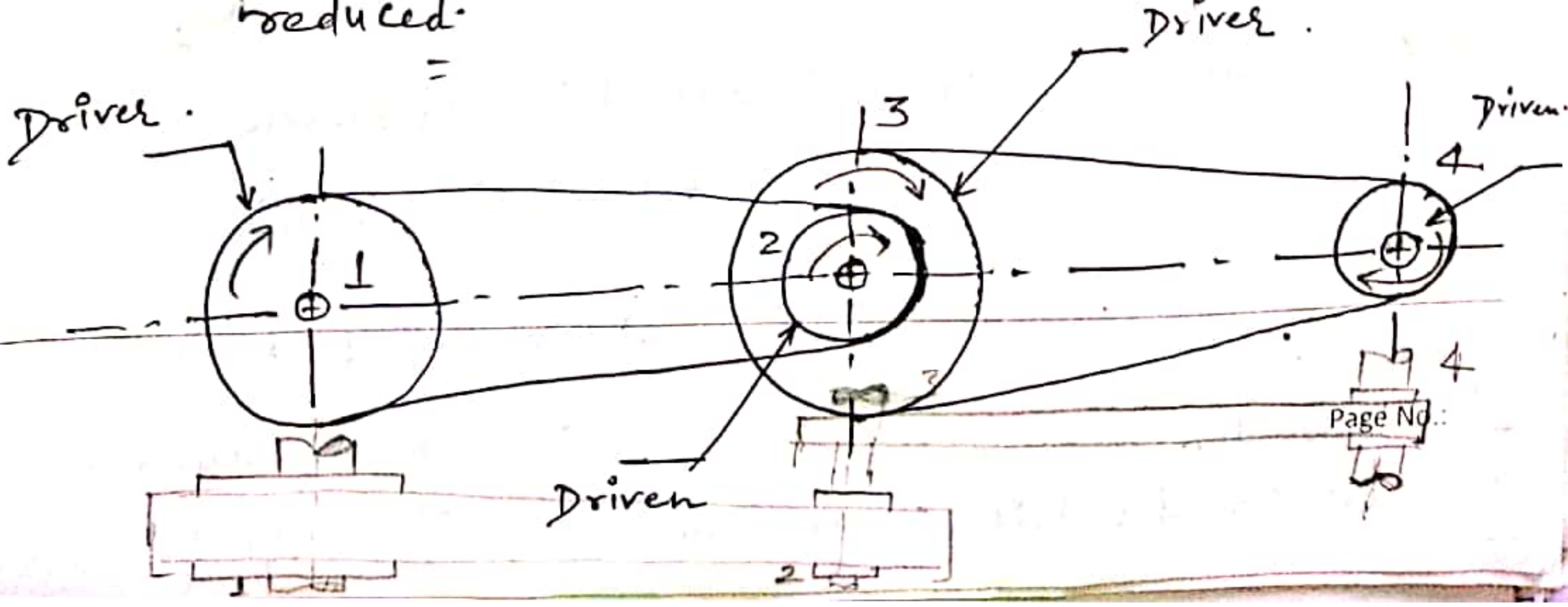
The purpose of providing idler pulley is to:

i) Increase tension in belt.
ii) Increase the angle of contact.

- The idler pulley is free to rotate on its axis. It presses the belt, on its driven side, resulting in the increase of angle of contact of the belt. the idler pulley also increase the life of belt by reducing the slippage.

Compound Belt drives.

- A compound belt drive is used when power is transmitted through one shaft to another shaft by using number of intermediate pulleys.
- when it is required to have Large ~~[illegible]~~ velocity ratios, ordinarily the size of the driver pulley will be quite big. However, by using an intermediate pulley the size can be reduced.



Velocity Ratio

It is the ratio of the speed of driven pulley (follower) and speed of the driving pulley (driver).

Let N_1 and N_2 = Rotational speeds of driver and driven pulleys in rpm respectively.

D_1 and D_2 : Diameters of driver and driven pulleys respectively.

Method 1 ω_1 and ω_2 = angular velocity of driver and follower.

Now:

Length of the belt that passes over the driver pulley in one minute: $\pi D_1 N_1$

Length of the belt that passes over the driven pulley in one minute: $= \pi D_2 N_2$.

The length of the belt passes over the driver and driven in one minute is equal, so that

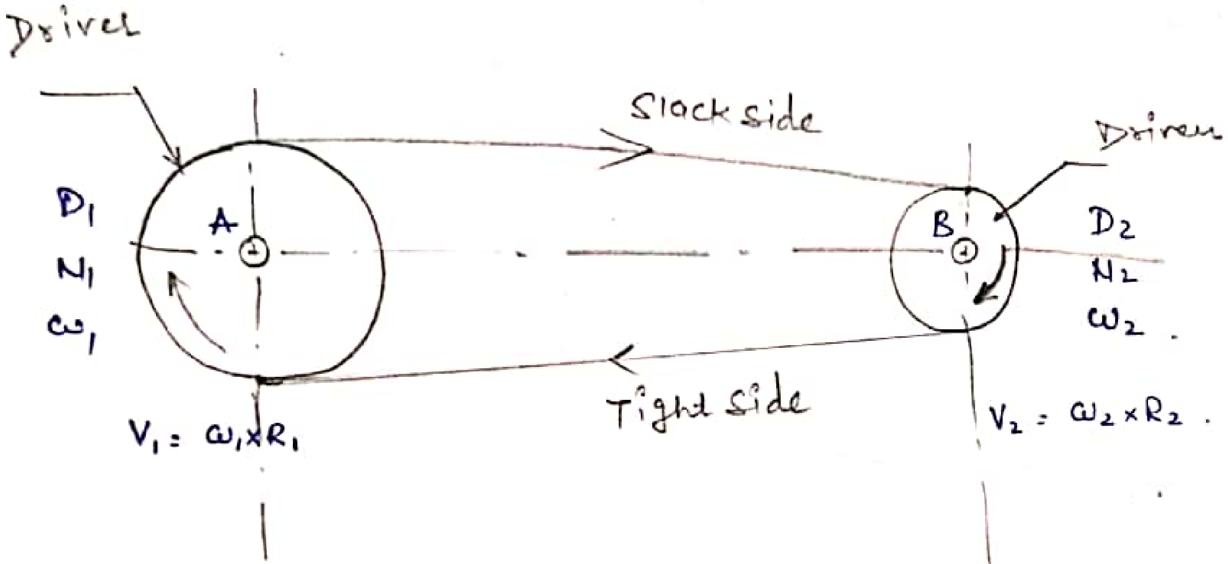
$$\pi D_1 N_1 = \pi D_2 N_2.$$

$$\text{Velocity Ratio} = \frac{N_2}{N_1} = \frac{D_1}{D_2}$$

or Velocity Ratio = $\dfrac{\text{rotational speed of driven}}{\text{rotational speed of driver}}$ = $\dfrac{\text{Diameter of driver}}{\text{Diameter of driven}}$.

When the thickness of belt is considered, then velocity ratio $= \dfrac{N_2}{N_1} = \dfrac{D_1 + t}{D_2 + t}$

$n = \frac{1}{T}$.



Assuming thickness of the belt to be negligible, and no slip between the belt and pulley,

→ the peripheral speed of the pulleys must be the same.

velocity of the belt $(V) = \omega_1 R_1 = \omega_2 R_2$.

$$= \frac{\omega_2}{\omega_1} = \frac{R_1}{R_2} = \frac{D_1}{D_2}$$

$$= \frac{2\pi N_2}{2\pi N_1} = \frac{D_1}{D_2}$$

$N_2 \propto \frac{1}{D_2}$

$$= \boxed{\frac{N_2}{N_1} = \frac{D_1}{D_2}}$$

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Speed of a pulley is inversely proportional to its diameter:

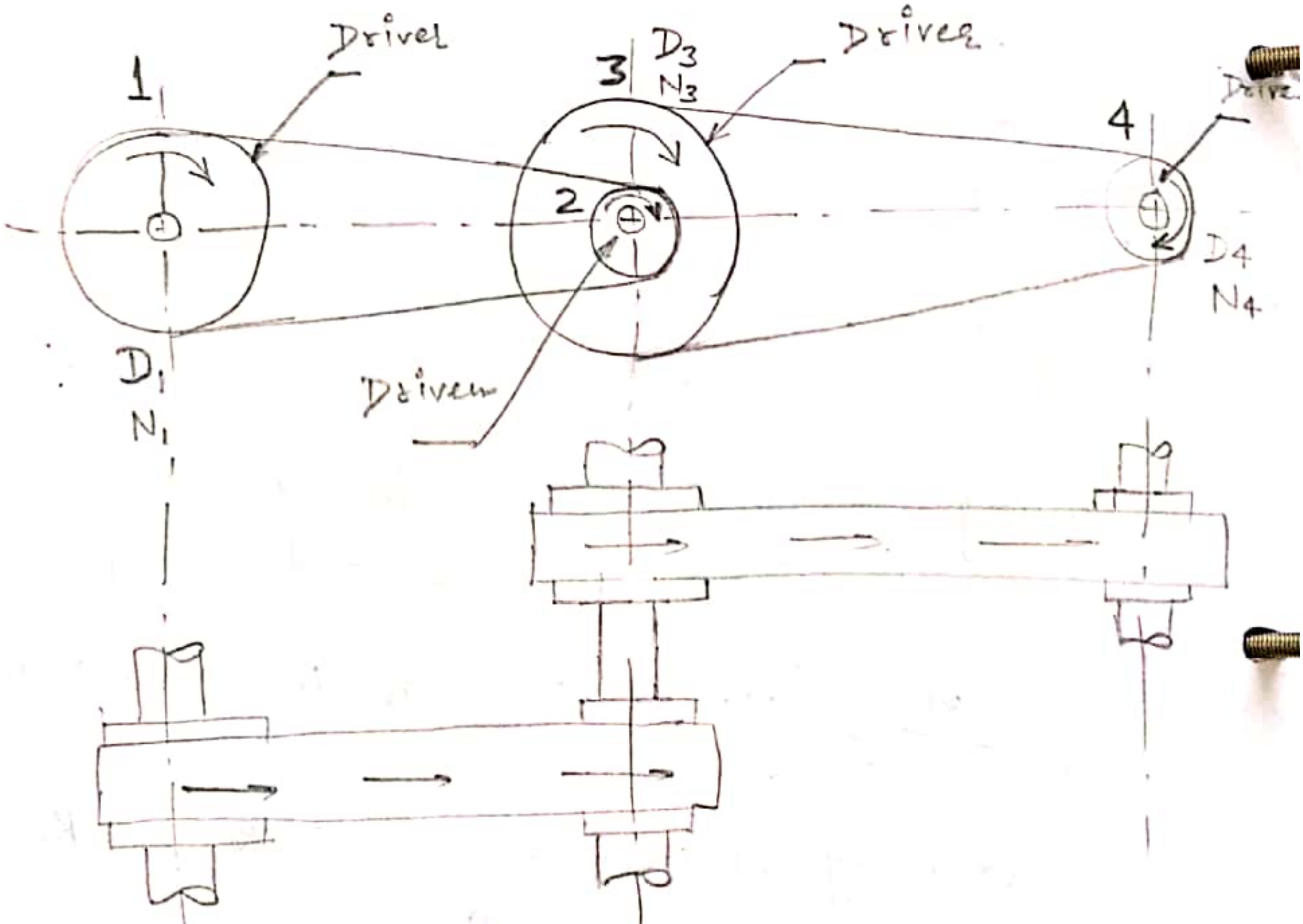
when the thickness of belt is considered, then.

$$\text{Velocity Ratio} = \frac{N_2}{N_1} = \frac{D_1+t}{D_2+t}.$$

~~Velocity of comp~~

Velocity ratio of compound belt drive:

In compound belt, the power is transmitted from one shaft to another, through number of pulleys.



Let 1 ~~be~~ is driver pulley and 2 is driven pulley, because 2 and 3 are keyed on same shaft, therefore. the pulley 1 also drives the pulley 3 and pulley 3 drives the pulley 4.

D_1, D_2, D_3 and D_4 = diameters of Pulleys 1, 2, 3 and 4 respectively.

N_1, N_2, N_3 and N_4 = Rotational speed of pulleys 1, 2, 3 and 4 respectively. in rpm.

Velocity ratio of pulley 1 and 2:

$$(V.R)_{1-2} = \frac{N_2}{N_1} = \frac{D_1}{D_2} \quad \text{--- (1)}$$

Velocity Ratio of pulley 3 and 4.

$$[V.R]_{3-4} = \frac{N_4}{N_3} = \frac{D_3}{D_4} \quad \text{--- (2)}$$

[$N_3 = N_2$, being keyed on same shaft]

Multiplying eqn (1) and (2),

$$\Rightarrow \frac{N_2}{N_1} \times \frac{N_4}{N_3} = \frac{D_1}{D_2} \times \frac{D_3}{D_4}$$

$$\therefore \frac{N_4}{N_1} = \frac{D_1 \times D_3}{D_2 \times D_4}$$

If n no. of pulley are used:

$$V.R = \frac{N_n}{N_1} = \frac{D_1 \times D_3 \times D_5 \times \cdots D_{n-1}}{D_2 \times D_4 \times D_6 \times \cdots D_n}$$

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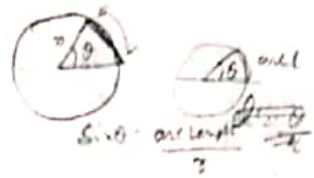
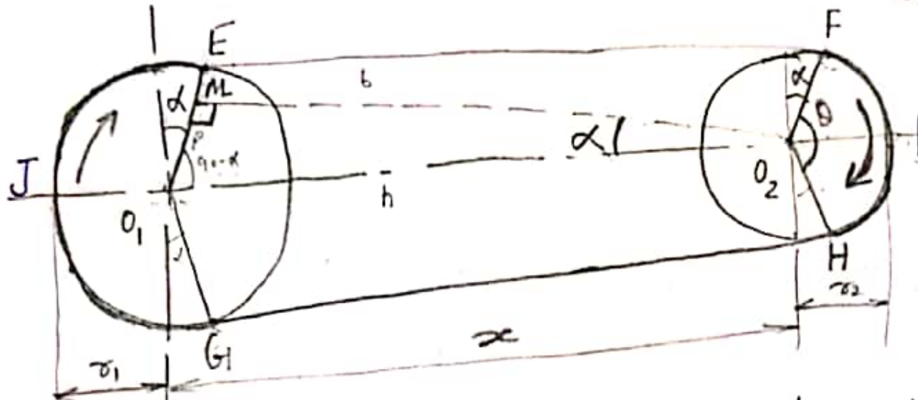


Length of open belt

angle of contact - $(180-2\alpha)\times\frac{\pi}{180}$



Let r_1 and r_2 = Radii of Larger and smaller pulley.

x = distance between the centres of two pulleys (i.e O_1O_2)

L = total Length of belt.

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

draw O_2M parallel to FE. and ⊥r to O_1E

Let the angle $MO_2O_1 = \alpha$ radian.

the Length of the belt L = Arc GJE + EF + Arc FKH + HG

$$= 2(\text{Arc } JE + EF + \text{Arc } FK) \quad \text{—(1)}$$

From Geometry. Δ ~~O₂M~~ O_1O_2M.

$$\sin\alpha = \frac{O_1M}{O_1O_2} = \frac{O_1E - EM}{O_1O_2} = \frac{r_1 - r_2}{x}.$$

Since angle (α) is very small, $\sin\alpha \approx \alpha$. –

$$\sin\alpha \approx \alpha = \frac{r_1 - r_2}{x} \quad \text{—(2)}.$$

$$\text{Arc } JE = r_1(\pi/2 + \alpha) \quad \text{—(3)}$$

Similarly $\text{Arc } FK = r_2(\pi/2 - \alpha)$ —(4).

and $EF = MO_2 = \sqrt{(O_1O_2)^2 - (O_1M)^2}$

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

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

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

Binomial theorem

$(1-x)^{1/2}$

$= \left[1 - \frac{1}{2}x + \cdots\right]$

Now expanding by binomial theorem:

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

$$= x - \frac{1}{2} \cdot \frac{(r_1 - r_2)^2}{x} \cdots$$

Now.

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

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

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

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

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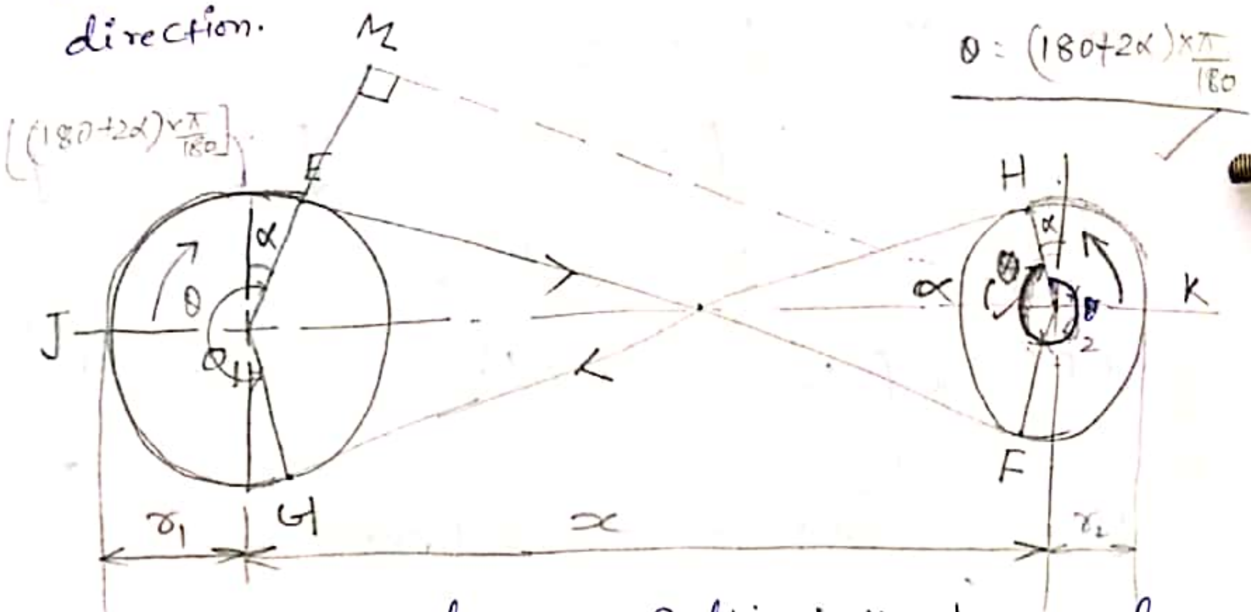
$$= \pi(r_1 + r_2) + 2\alpha(r_1 - r_2) + 2x - \frac{(r_1 - r_2)^2}{x}]$$

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

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

Length of cross Belt drive.

In Cross Belt drive, both the pulleys rotate in opposite direction.



Let r_1 and r_2 = Radii of the Larger and Smaller pulleys.

x = distance between the centers of two pulleys (i.e O_1O_2).

L = total length of the belt.

Let the belt leaves the Larger pulley at E and G and the smaller pulley at F and H as shown.

Through O_2 draw O_2M parallel to EF.

From the geometry, we find that $O_2M \perp$ to O_1E.

Let the angle $MO_2O_1 = \alpha$ radians.

Now. L = Arc GJE + EF + Arc FKH + HG)

= 2 (Arc JE + FE + Arc FK)

From geometry ΔO_1O_2M

$$\sin\alpha = \frac{O_1M}{O_1O_2} = \frac{O_1E + EM}{O_1O_2} = \frac{r_1+r_2}{x}.$$

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

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

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

$$EF = MO_2 = \sqrt{(O_1O_2)^2 - (O_1M)^2}$$

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

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

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

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

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

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

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

Substituting $\alpha = \left(\frac{r_1+r_2}{x}\right)$

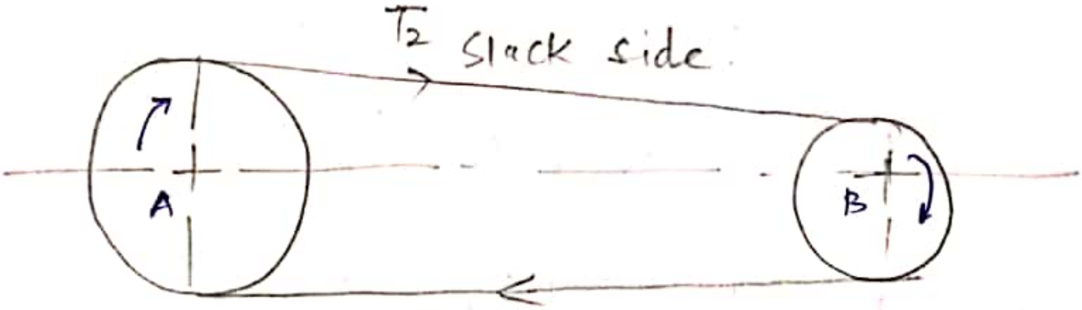
$$L = \pi(r_1+r_2) + 2 \times \frac{(r_1+r_2)}{x} \times (r_1+r_2) + 2x - \frac{(r_1+r_2)^2}{x}$$

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

$$= \pi(r_1+r_2) + 2x + \frac{(r_1+r_2)^2}{x}$$ [in terms of radius]

or $$L = \frac{\pi}{2}(d_1+d_2) + 2x + \frac{(d_1+d_2)^2}{4x}$$ [in terms of d].

Power transmitted by a belt



T_1 and T_2 : tension in tight side and slack side of belt respectively in newtons.

r_1 and r_2 : radii of the driving and driven pulley respectively in m.

V = Velocity of belt in m/s.

the driving pulley pulls the belt from one side and delivers it to other side.

the effective turning force (driving) at the circumference of the driven pulley or follower is the difference between the two tensions.

i.e $(T_1 - T_2)$.

$\therefore$ Power ~~transmitte~~ transmitted $= (T_1 - T_2) \times v$ Watt

Slip of Belt

- the relative motion between the belt and the pulley is known as slip. the difference between the linear speeds of the pulley and belt is the measurement of slip.

- In the belt drive, the motion of belts and shafts is considered ~~a~~ by a frictional grip. between the belt and the shafts. If the difference in tensions between tight ~~side~~ and slack sides of the belt is too large to be resisted by

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friction b/w belt and pulley, whole of the portion of the belt which is in contact with the pulley begins to slide.

— slip is expressed as a percentage.

— slip of belt reduces the velocity ratio of system.

Let S_1 = % slip b/w the driver pulley and the belt

S_2 = % slip b/w the driven pulley and the belt.

Total slip = $S_1 + S_2 - \frac{S_1 S_2}{100}$

$$\text{velocity Ratio} = \frac{N_2}{N_1} = \frac{D_1}{D_2}\left[1 - \frac{S_1}{100}\right]\left[1 - \frac{S_2}{100}\right]$$

$$\frac{N_2}{N_1} = \frac{D_1}{D_2}\left(1 - \frac{S}{100}\right)$$

Creep of Belt

the material of the belt is elastic. Therfore when the belt passes from the slack side to the tight side, a certain portion of belt extends and it contracts again when the belt passes from tight side to slack side. these uneven extension and contraction on the belt due to varying tension on it, cause a relative motion between belt and pulley surface which is known as creep in belts.

Velocity Ratio: $\frac{N_2}{N_1} = \frac{D_1}{D_2} \times \frac{E + \sqrt{\sigma_2}}{E + \sqrt{\sigma_1}}$

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

σ_1 and σ_2 = Stress in belt on tight and slack side respectively.

Comparison b/w ~~to~~ slip and creep in a belt drive.

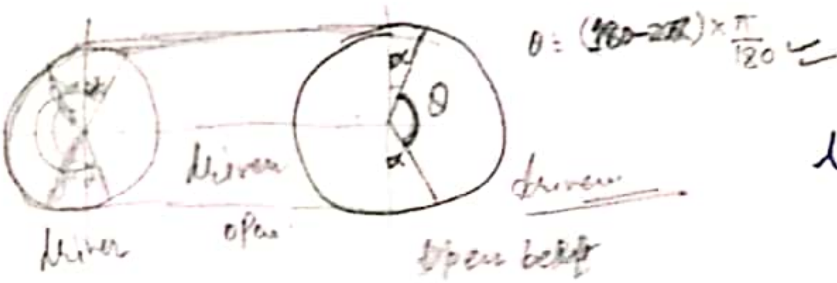
	Slip	Creep
1)	the relative motion b/w belt and pulley due to slide of belt from pulley is known as slip	the relative motion b/we belt and pulley surface due to varying tension in belt is known as creep.
2)	Slip depends on frictional grip between belt and pulley.	Creep depends upon elasticity of material and stresses on the belt.
3)	When slip considered, velocity ratio depends upon diameter of pulleys and slip of pulleys and belt.	When creep is considered, velocity ratio depends upon dia. of pulleys, elasticity of material and stress on the belt.

Important formula

1) Ratio of tension on tight side and slack sides of flat belt :-

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

T_1 = tension on tight side.
T_2 = tension of slack side.
θ = angle of contact b/w belt and pulley.
μ = coeff. of friction between the belt and pulley surface.



Intial tension

When a belt is fitted on two pulleys, an initial tension T_0 is given to the belt when the system is stationary.

When the belt is running and transmitting power, one side of the belt is ~~[illegible]~~ comes tight and tension increases from T_0 to T_1 and other side becomes slack and tension decreases from T_0 to T_2 :

Tension on tight side $T_1 = T_0 + \delta F$

tension on slack side :- $T_2 = T_0 - \delta F$.

~~[illegible]~~ Initial tension : $T_0 = \frac{T_1 + T_2}{2}$

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Centrifugal tension — due to Belt inertia. away from the centre around which body is moving:

When a belt is running force acts on the belt due to its own weight.

$\boxed{T_c = mv^2}$, where T_c = centrifugal tension on tight side and slack sides of short Length.

V = Velocity of the belt.

m = Mass per unit Length of the belt.

Derivation

Maximum power transmitted by a belt

Condition: $\boxed{T_c = \frac{T}{3}}$

For maximum power to be transmitted, centrifugal tension in the belt must be equal to one third of the maximum allowable belt tension and the belt should be on the point of slipping.

$P = (T_1 - T_2) \times V$ —— (1)

$= T_1 \left(1 - \frac{T_2}{T_1}\right) V$, we know that,

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

$P = T_1 \left(1 - \frac{1}{e^{\mu\theta}}\right) V = T_1 K V$ —— (2)

where $K = \left(1 - \frac{1}{e^{\mu\theta}}\right)$ = constant

Consider the effect of centrifugal tension in to account, maximum tension on tight side: (T) :-

$T = T_1 + T_c$.

or $T_1 = T - T_c$. —— (3)

Now eqn (2) and (3).

$P = T_1 K V = (T - T_c) K V$.

$= K T V - K V T_c$

$K T V - K V \times m v^2$

$= K T V - K m v^3$

for max. power transmission:

$\frac{dp}{dV} = 0$, $\therefore K T - K m (3 v^2)$

$= K T - 3 K m v^2 = 0$

$T - 3 m v^2 = 0$

$T = 3 m v^2$

$\therefore T = 3 T_c$.

$\therefore \boxed{T_c = T/3.}$

or $\boxed{T_1 = T - T_c = T - \frac{T}{3} = \frac{2}{3} T}$

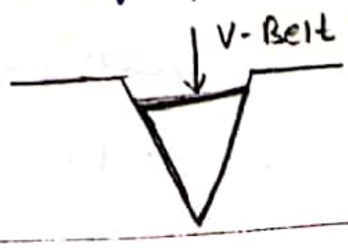
Similarly: $T_c = m V_{max}^2 = T/3$

$V_{max}^2 = T/3m$

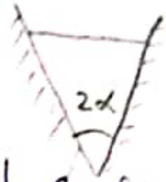
or $\boxed{V_{max} = \sqrt{T/3m}}$

V Belt drive.

- V- Belt is mostly used where a moderate amount of power is to be transmitted from one pulley to another pulley when the two pulleys are very near to each other.
- It is mostly used in Industries and workshops where a moderate amount of power is to be transmitted.



Ratio of tensions on V- Belt.



$$\frac{T_1}{T_2} = e^{\mu\theta/\sin\alpha}.$$

θ - angle of contact b/w belt and pulley.

→ the Ratio of $\frac{T_1}{T_2}$ is greater in case of V-Belt:-

Advantages and Dis-Advantages of V-belt drive over flat belt drive:

Advantages:

1) It provides Longer Life.
2) the high velocity ratio may be obtained.
3) the drive is positive because slip between belt and pulley is negligible.
4) It can be easily installed and removed.
5) power transmission is more in V belt drive for same coefficient of friction, arc of contact.

disadvantages

1) the V- belts are less durable as compared to flat belt.
2) the V- belt drive cannot be used with large centre distances.
3) the construction of pulley in V belt drive is more complicated.

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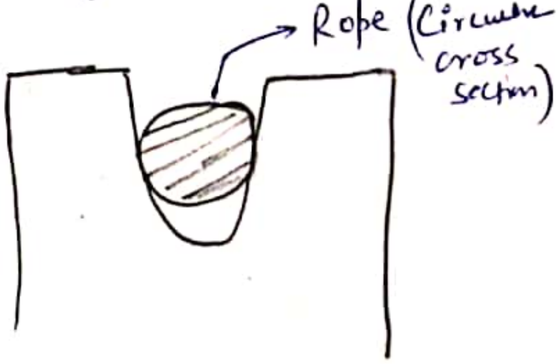
Rope drive

- Rope drives are used to transmit Large amount of power, from one pulley to another pulley
- For power transmission by ropes, grooved pulleys are used.
- Main Advantage of the rope drive is number of Seperate drives may be taken from one driving pulley and pulleys with several grooves can also be used to increase the capacity of power transmission
- Main application of rope drive are where Large amount of power is to be transmitted and preferred for long centre distance between the shafts.



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Classification of Rope drives:

1) Fibre rope drive. → It is used when the pulleys are about 60 metres apart. Fibre ropes are made from fibrous material such as hemp, cotton.

2) wire rope drive:

wire rope is used where Large amount of power is to be transmitted over Long distances from one pulley to another.

the ropes are widely used in elevators, mine hoists, Cranes, conveyor and suspension bridges.

Advantages of wire rope drives.

1) These are Lighter in weight.
2) These are more durable.
3) the cost is Low.
4) efficiency is high.
5) It does not fail suddenly.

* Differences b/w Rope drive and Belt drive:

	Rope drive	Belt drive.
1)	suitable for Long center distances between the Shafts (more than 15m)	Suitable for shorter center distances (not more than 15m)
2)	More power is transmitted	Moderate power is transmitted.
3)	frictional grip is more	frictional grip is Less.
4)	Slip is not possible	Slip is possible.

	V Belt	Flat Belt.
1)	suitable for shorter center distances between the shafts.	suitable for comparatively Longer center distances.
2)	Trapezoidal section	Rectangular section.
3)	Frictional grip is more	Frictional grip is Less.
4)	Power transmitted will be more.	Power transmitted is Less.
5)	velocity ratio is high	velocity Ratio is Low.

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Gear Drives

- Gear drives are used to transmit motion from one shaft to another. these are used when the distance between the driving shaft and driven shaft, is small.

- In order to avoid the slipping and to obtain constant velocity ratio or positive drive a number of teeth are provided on the periphery of the wheel.

- the wheels or discs with teeth are known as geal or gear wheels. A gear is a toothed wheel attached to a rotating shaft.

types of gears: (on the basis of parallel shaft)

1) Spur gear:

this is the simplest type of gear. It has teeth parallel to the axis of rotation and is used to transmit rotation from one shaft to another parallel shaft.

2) Helical gear

In helical gears, the teeth are curved or inclined to the axis of rotation. Two mating gears have same helix angle, but have teeth of ~~a~~ opposite h...

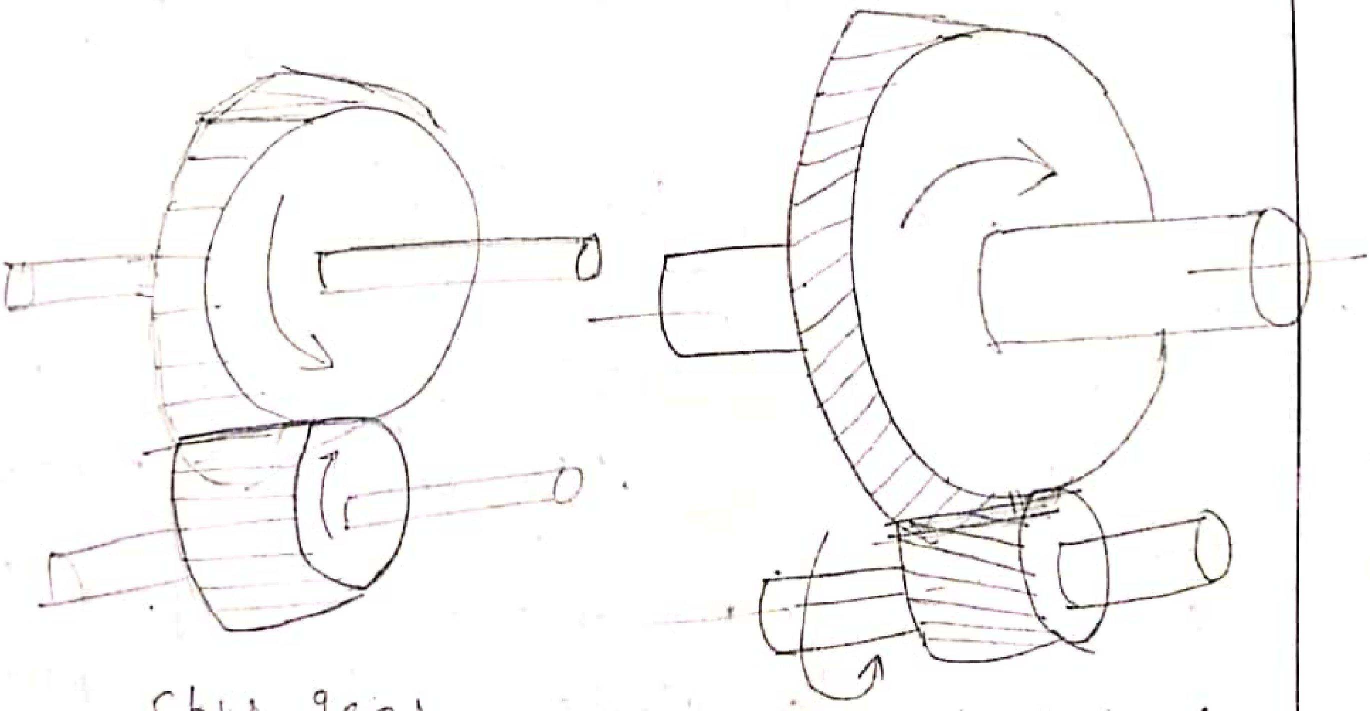
One Advantage of helical gears is its silent operation. the noise level is much less. Helical gears have the ability to transmit heavy loads at high speeds.

→ the main disadvantage of helical gear is that they are subjected to end thrust.

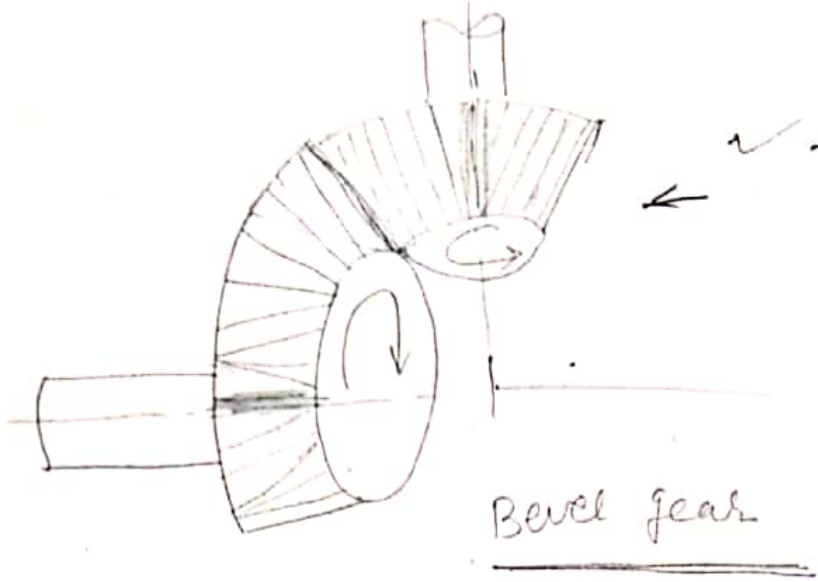
On the Basis of Intersecting Shafts.

i) Bevel gear:

these gears have their teeth formed on conical surfaces and are used to transmiting motion between two shafts at 90°, which run at low speeds.



Spur gear.   Helical gear.



teeth are straight, radial to the point of intersection of the shaft axis and vary in cross-section through out the length.

Gear trains.

A gear train is a combination of gears are used to transmit motion from one shaft to another shaft.

Gear trains are necessary for the following reasons

1) when a large velocity reduction is desired.
2) when the distance between shaft is not more.
3) when a particular velocity ratio is desired.

Classification of gear train

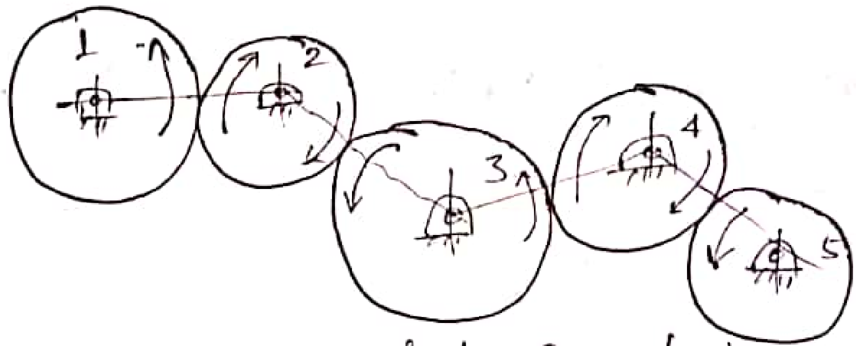
1) Simple gear train

A series of gears, (capable of receiving and transmitting) that receive and transmit motion from one gear to another is called a simple gear train. All the gear axes remain fixed relative to the frame and each gear is on a separate shaft.

in a simple gear train.

1) A pair of mated gears always move in opposite direction.

2) All odd number gear move in one direction and all even number gear in the opposite direction.



simple gear train

Speed Ratio of gear train

It is the ratio between the speed of driver and the speed of the follower.

$$\text{Speed Ratio} = \boxed{\frac{N_1}{N_5} = \frac{T_5}{T_1}}$$

~~Train value:~~

$$\text{Speed Ratio} = \frac{1}{\text{Train value}}$$

Train value: $\dfrac{\text{Speed of driven gear}}{\text{Speed of driver gear}} = \dfrac{\text{Number of teeth on driving gear}}{\text{Number of teeth on driven gear}}$

Let T = Number of Teeth on a gear.

N = Speed of a gear in rpm.

$$\boxed{\text{Train value} = \frac{N_5}{N_1} = \frac{T_1}{T_5}} = \frac{\text{No. of teeth on driving gear}}{\text{No. of teeth on driven gear}}$$

From fig:

$$\frac{N_2}{N_1} = \frac{T_1}{T_2}, \quad \frac{N_3}{N_2} = \frac{T_2}{T_3}, \quad \frac{N_4}{N_3} = \frac{T_3}{T_4}$$

and $\frac{N_5}{N_4} = \frac{T_4}{T_5}$.

Multiplying all the above:

$$\frac{N_2}{N_1} \times \frac{N_3}{\cancel{N_2}} \times \frac{N_4}{\cancel{N_3}} \times \frac{N_5}{\cancel{N_4}} = \frac{T_1}{\cancel{T_2}} \times \frac{\cancel{T_2}}{\cancel{T_3}} \times \frac{\cancel{T_3}}{\cancel{T_4}} \times \frac{T_4}{T_5}$$

$$= \frac{N_5}{N_1} = \frac{T_1}{T_5}$$

$\therefore$ Train value $= \frac{N_5}{N_1} = \frac{T_1}{T_5}$.

$$\text{Speed Ratio} = \frac{1}{\text{Train value}}$$

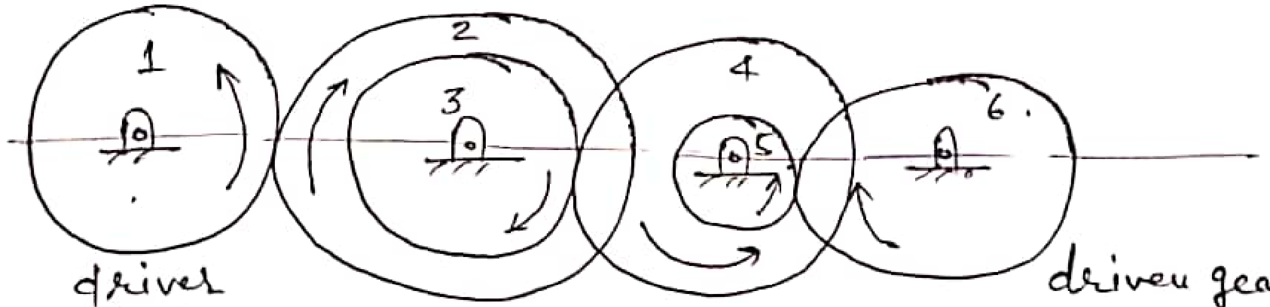
$$\boxed{\frac{N_1}{N_5} = \frac{T_5}{T_1}}$$

Thus the intermediate gears have no effect on the speed ratio. They are known as idlers pulley.

Compound gear train

- In compound gear train, each Intermediate gear shaft carries two gears, which are mounted together rigidly. Such gear are termed as compound gears.

- When a series of gears are connected in such a way that two or more gears rotate about an axis with the same angular velocity is known as compound gear train.



If gear 1 is driver gear, then:-

$$\frac{N_2}{N_1} = \frac{T_1}{T_2}, \quad \frac{N_4}{N_3} = \frac{T_3}{T_4}, \quad \frac{N_6}{N_5} = \frac{T_5}{T_6}$$

Multiplying all.:

$$\frac{\cancel{N_2}}{N_1} \times \frac{\cancel{N_4}}{\cancel{N_3}} \times \frac{N_6}{\cancel{N_5}} = \frac{T_1}{T_2} \times \frac{T_3}{T_4} \times \frac{T_5}{T_6} \qquad \left[\begin{array}{l} N_2 = N_3 \\ N_4 = N_5 \end{array}\right]$$

$$= \frac{N_6}{N_1} = \frac{T_1 \times T_3 \times T_5}{T_2 \times T_4 \times T_6}$$

~~Train~~

Train value := $\dfrac{\text{Product of number of teeth on driving gears.}}{\text{Product of number of teeth on driven gears.}}$

Advantages of compound gear trains over simple gear trains:

1) – A compound gear train provide a large velocity ratio in limited space.

2)

Q: A shaft runs at 100 rpm and drives another shaft at 150 rpm through belt drive. The diameter of driving pulley is 500 mm. Determine the diameter of the driven ~~shaft~~ pulley in the following cases:

1) Belt thickness is 5mm
2) A slip of 2% on each pulley:

Sol

$N_1 = 100\,rpm, \quad N_2 = 150\,rpm.$

$D_1 = 500\,mm \quad D_2 = ?$

1) Consider belt thickness is 5 mm.

$$\frac{N_2}{N_1} = \frac{D_1+t}{D_2+t} \quad \text{or} \quad \frac{150}{100} = \frac{500+5}{D_2+5}$$

$\Rightarrow \quad D_2 = 331.67\,mm$

2) A slip of 2% on each pulley:

$$\frac{N_2}{N_1} = \frac{D_1+t}{D_2+t}\left(\frac{100-S}{100}\right)$$

Where S = total slip $= S_1 + S_2 - \frac{S_1 S_2}{100}$

$$= 2+2 - \frac{4}{100} = 3.96\%$$

or $$\frac{150}{100} = \frac{500+5}{D_2+5}\left(\frac{100-3.96}{100}\right) = 318.33\,mm$$

Ans

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Q: Find the power transmitted by a belt running over a pulley of 60 cm diameter at 200 r.p.m. the coefficient of friction between the belt and pulley is 0.25, angle of lap 160° and maximum tension in belt is 2500N.

A $D = 60$ cm, $N = 200$ rpm, $\mu = 0.25$, $T_1 = 2500$N.

$\theta = 160° = \frac{160 \times \pi}{180} = 2.7925$ rad.

Power transmitted by belt: $(T_1 - T_2) \times V$.

$V = \frac{\pi D N}{60}$ m/s $= \frac{\pi \times 0.60 \times 200}{60}$

$= 6.283$ m/s.

$\frac{T_1}{T_2} = e^{\mu \theta} = e^{0.25 \times 2.7925} = e^{0.6981}$

$= 2.01$

$\frac{T_1}{T_2} = 2.01$

$T_2 = \frac{T_1}{2.01} = \frac{2500}{2.01} = 1243.78$N.

$P = (T_1 - T_2) \times V = (2500 - 1243.78) \times 6.283$

$= 7892.83$ W Ans

Q: An open belt drive connects two pulleys 120 cm and 50 cm diameter, on parallel shaft 4 m apart. the maximum tension in the belt is 1855.3 N. the coeff. of friction is 0.3. the driver pulley of 120 cm diameter runs at 200 rpm, calculate:

i) the power transmitted.

ii) torque exerted on driving shaft.

$D_1 = 120$ cm, $D_2 = 50$ cm

$x = 4$ m, $T_1 = 1855.3$ N

$\mu = 0.3$, $N_1 = 200$ rpm.

$(120 - 2\alpha) \times \frac{\pi}{180}$

$$V = \frac{\pi D_1 N_1}{60} = \frac{\pi \times 1.20 \times 200}{60} = 12.56 \text{ m/s}$$

Angle of Lap for open belt $\theta = (180 - 2\alpha) \frac{\pi}{180}$ rad.

where α = angle subtended by each common tangent.

$$\sin\alpha = \frac{r_1 - r_2}{x}, \quad r_1 = \frac{D_1}{2} = 0.60 \text{ m}$$

$$r_2 = \frac{D_2}{2} = 0.25 \text{ m}$$

$$\sin\alpha = \frac{0.60 - 0.25}{4} = 0.0875$$

$$\alpha = 5.02^\circ$$

$$\theta = (180 - 10.04) \times \frac{\pi}{180} \text{ radian}$$

$$\theta = 2.96 \text{ radian}$$

$$\frac{T_1}{T_2} = e^{\mu\theta} = e^{0.3 \times 2.96} = 2.434$$

$$T_2 = \frac{1855.3}{2.434} = 762.30 \text{ N}$$

$$P = (T_1 - T_2) \times V = (1855.3 - 762.3) \times 12.56$$

$$= 13728.08 \text{ W}$$

$$= 13.72 \text{ kW}$$

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$$T = (T_1 - T_2) \times \frac{D_1}{2} = (1855.3 - 762.3) \times 0.5/2 = 273.25 \text{ N-m}$$