* Power Transmission.

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Q①. Enlist the different modes of mechanical transmission

→ The different types of power (mechanical) transmission are as follows:

1) Mechanical Transmission: When the distance is small, measurable in a few meters or a fraction of a meter, then the power is transmitted by Mechanical transmission.

② Electric transmission: Electric drive refers to the use of electric motors to convert electrical energy into mechanical energy, to drive various types of production machinery, transportation vehicles and items that need to be moved.

③ Pneumatic transmission: The pneumatic transmission uses compressed gas as the working medium, and the fluid transmission of the power or information by the pressure of the gas.

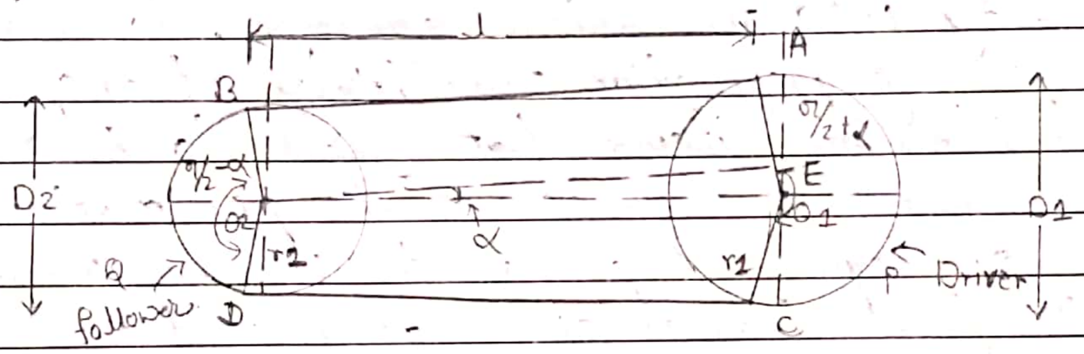
④ Hydraulic transmission: Hydraulic transmission is a transmission method that uses liquid as a working medium to transfer energy and control.

Q②. What are the different types of the belt drives? Derive the relation for length of the open belt and Cross belt over one another.

→ * There are many types of belt drive but we can be found seven types of belt drives and are as followed:

① Open Belt drives.
② Cross Belt drives
③ Right Angle Turn Drives
④ Drive with Idler pulley.
⑤ Drive over stepped pulley set
⑥ Individual and Group drive
⑦ flat and 'V' Belt drives.

★ Derive the expressions length of Open belt drives:



With open belt drive, if the driven is rotating clockwise, the follower also rotates in clockwise direction. length of belt required to connect a driven wheel of radius 'r_1' and follower wheel of radius 'r_2' placed at distance 'd' may be calculated as

Proof :- let O_2E be parallel to AB and $\angle O_1O_2E = \alpha$

$$\sin\alpha = \frac{O_1E}{O_1O_2E} = \frac{r_1 - r_2}{l}$$

∴ length of belt

$$L = 2(\text{arc } PA + AB + \text{arc } BQ)$$

$$= 2\left[r_1\left(\frac{\pi}{2}+\alpha\right) + EO_2 + r_2\left(\frac{\pi}{2}-\alpha\right)\right]$$

$$= \pi(r_1+r_2) + 2\alpha(r_1-r_2) + 2EO_2$$

Now,

$$EO_2 = \sqrt{l^2-(r_1-r_2)^2} = l\left[1-\left(\frac{r_1-r_2}{l}\right)^2\right]^{1/2}$$

Since, $\frac{r_1-r_2}{l}$ is a small quantity.

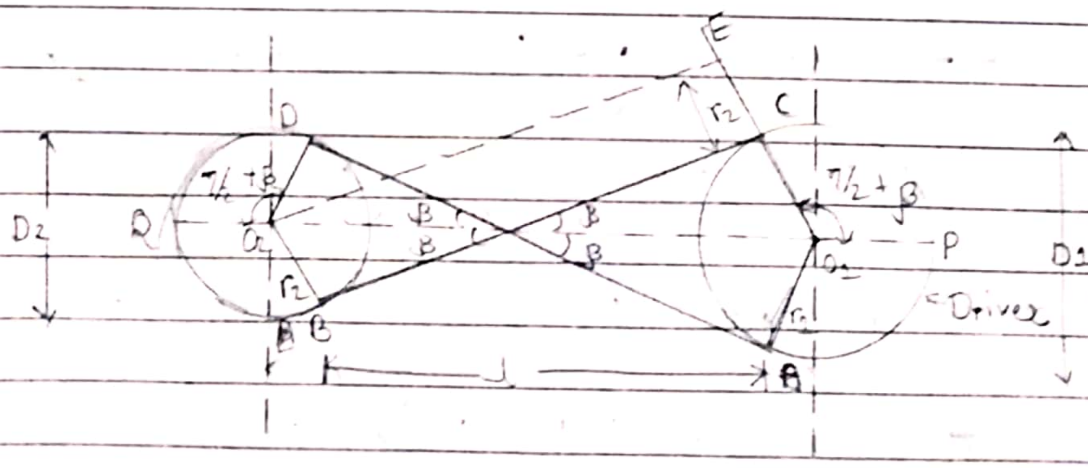
$$EO_2 = l\left[1-\frac{1}{2}\left(\frac{r_1-r_2}{l}\right)^2\right] = l - \frac{1}{2}\frac{(r_1-r_2)^2}{l}$$

α is small, $\sin\alpha = \alpha = \frac{r_1-r_2}{l}$

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

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

* length of Cross belt drives:



In cross belt drive, if driven is rotating clockwise follower rotates in anticlockwise direction. Driven wheel has radius 'r_1' and 'r_2' is follower radius.

Proof: let EO_2 be parallel to AB as shown above. Angle made by AB with O_1O_2 be β.

Then, $\angle PO_1A = \angle \phi O_2 B = \pi/2 + \beta$

and $\sin\beta = \dfrac{O_1E}{O_1O_2} = \dfrac{r_1+r_2}{l}$

Since, β is small, $\sin\beta = \beta = \dfrac{r_1+r_2}{l}$

$$AB = EO_2$$
$$= \left[l^2 - (r_1+r_2)^2\right]^{1/2}$$
$$= l\left[1 - \left(\frac{r_1+r_2}{l}\right)^2\right]^{1/2}$$

Since, $\dfrac{r_1+r_2}{l}$ is small,

$$AB = l\left[1 - \frac{1}{2}\left(\frac{r_1+r_2}{l}\right)^2\right].$$

$$l = 2\left[\text{arc } PA + AB + \text{arc } \phi B\right]$$
$$L = 2\left[r_1\left(\frac{\pi}{2}+\beta\right) + l\left\{l - \frac{1}{2}\left(\frac{r_1+r_2}{l}\right)^2\right\} + r_2\left(\frac{\pi}{2}+\beta\right)\right],$$
$$= \pi(r_1+r_2) + 2\beta(r_1+r_2) + 2l - \frac{(r_1+r_2)^2}{l}$$

Substituting $\dfrac{r_1+r_2}{l}$ for β

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

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

Q ③. What is slip and Creep of the belt? Derive the relation for velocity ratio in terms of slip for flat belt drives.

→ ① Slip of the belt : Slip is defined as insufficient fractional grip between pulley (driver/driven) and belt. Slip is the difference between the linear velocities of pulley (driver/driven) and belt.

② Creep of the belt : Uneven extensions and contractions of the belt when it passes from tight side to slack side. There is relative motion between belt and pulley surface, this phenomenon is called Creep of belt.

★ Velocity ratio : It is defined as the ratio of the speed of the driven wheel to the speed of the driving wheel.

proof : let, N_1 be the revolution per minute (rpm) made by driver and N_2 be the rpm of follower. Then angular velocity of driver is $\omega_1 = \frac{2\pi N_1}{60}$ and that of follower is $\omega_2 = \frac{2\pi N_2}{60}$.

If r_1 is the radius of driven and r_2 that of the follower, then the linear velocity of the belt.

$$v = r_1 \omega_1 = r_2 \omega_2$$ if there is no slip.

$$\frac{\omega_2}{\omega_1} = \frac{r_1}{r_2}$$

but, $$\frac{\omega_2}{\omega_1} = \frac{N_2}{N_1}$$

$\therefore$ Velocity ratio $= \frac{N_2}{N_1} = \frac{r_1}{r_2} = \frac{d_1}{d_2}$.

$\therefore$ Where d_1 is diameter of driver and d_2 is that of follower. If thickness of the belt is negligible, the linear velocity

$$v = (r_1 + t)\omega_1 = (r_2 + t)\omega_2$$

Where, t is the thickness of the belt.

Hence, $$\frac{N_2}{N_1} = \frac{\omega_2}{\omega_1} = \frac{r_1 + t/2}{r_2 + t/2} = \frac{2r_1 + t}{2r_2 + t}$$

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

Q④. Derive the relation for ratio of tensions in tight side (T_1) and slack side (T_2) for open belt and cross belt arrangement?

→ The belt segment subtends an angle $d\phi$ of the centre. Here, the length of the segment

$$dl = r\,d\phi \quad \text{—— (1)}$$

At the impending condition i.e. when the belt is in just in motion with respect to the pulley, the forces acting on the belt segment is subjected to a normal force acting from the pulley on the belt segment and due to the impending motion the frictional force will be acting in the direction as shown above.

$$f = \mu\, dN \quad \text{—— ②}$$ μ = co-efficient of friction

The centrifugal force due to the motion of the belt acting on the belt segment is denoted by CF and it is given by.

$$CF = [m(r\,d\phi \times v^2)]/r$$
$$= mv^2\, d\phi \quad \text{—— ③}$$

v = peripheral velocity of pulley.
m = mass of belt of unit length

$$m = b\,t\,\rho \quad \text{—— ④}$$

b = width, t = thickness, ρ = density of belt material

from the eqn of equilibrium in the tangential and normal direction $\Sigma F_t = 0$

$$T\cos\frac{d\phi}{2} - (T+dT)\cos\frac{d\phi}{2} + \mu\, dN = 0 \quad \text{—— ⑤}$$

$\Sigma F_n = 0$

$$mv^2\, d\phi + dN + T\sin\frac{d\phi}{2} - (T+dT)\sin\frac{d\phi}{2} = 0 \quad \text{—— ⑥}$$

On further simplication,

$$dN = \frac{dT}{\mu} \text{ ——— } (7)$$

Putting value of (7) in (6)

$$mv^2 d\phi + \frac{dT}{\mu} - T d\phi = 0.$$

or

$$\frac{dT}{T - mv^2} = \mu \, d\phi \text{ ——— } (8)$$

Considering entire angle of wrap

$$\int_{T_1}^{T_2} \frac{dT}{T - mv^2} = \int_0^{\alpha} \mu . d\phi$$

$$\left[\log (T - mv^2)\right]_{T_1}^{T_2} = \mu \left[\phi\right]_0^{\alpha}.$$

$$\log (T_2 - mv^2) - \log (T_1 - mv^2) = \mu\alpha.$$

$$\log \left(\frac{T_2 - mv^2}{T_1 - mv^2}\right) = \mu\alpha$$

Taking antilog on bothsides.

$$\frac{T_2 - mv^2}{T_1 - mv^2} = e^{\mu\alpha}.$$

$\therefore e = 2.73$

$\therefore \alpha =$ angle of contact.

here, α is in radian.

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Q⑤ What is centrifugal tension in the belt? Derive the relation for the same in terms of velocity of belt.

→ As the belt runs continuously, some centrifugal force is caused, that tends to increase the tension on both, tight as well as the slack sides. The tension caused by centrifugal force is called Centrifugal tension (TC).

proof: let, m = Mass of the belt per unit length in kg.
v = linear velocity of the belt in m/s.
r = Radius of the pulley over which the belt run. in meters.
Tc = Centrifugal tension acting tangentially at P and Q in ~~network~~ newtons.

We known that length of the belt PQ
$l = r \cdot d\phi$.
and mass of the belt PQ $= m \cdot r \cdot d\phi$.

∴ Centrifugal force acting on the belt PQ
$$F_C = (m \cdot r \cdot d\phi)\frac{v^2}{r} = m \cdot d\phi \cdot v^2$$

∴ Fc is split into tension. ~~$\Sigma Fc = 0$, $\Sigma Tc = 0$.~~

$$\therefore \; T_C \sin\left(\frac{d\phi}{2}\right) + T_C \sin\left(\frac{d\phi}{2}\right) = F_C = m \cdot d\phi \cdot v^2$$

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Since the angle $d\phi$ is very small, therefore putting $\sin(d\phi/2) = (d\phi/2)$ in eqn. (i) we have

$$2\,T_C \left(\frac{d\phi}{2}\right) = m \cdot d\phi \cdot v^2$$

$$T_C = m \cdot v^2.$$

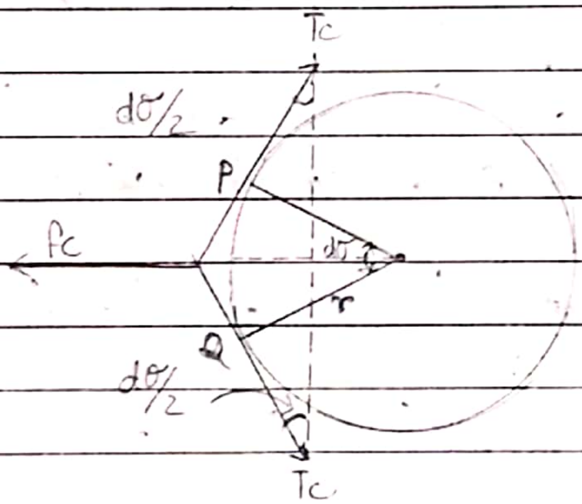


fig : velocity of belt

Q.6 Write a short note on gear drives giving their merits and demerits.

→★ Gear drives :

- A gear is a toothed wheel with the teeth cut on the periphery of a cylinder or a cone.
- Gears are ~~mounted~~ mounted on the shafts with key.
- There are two gears mounted, one on each of the driving and driven shaft.
- Therefore the teeth of the one gear is mesh with the teeth of the other gear.
- The rotation of gear with cause rotation of the other in the opposite direction.
- Gears can be classified by shaft positions as parallel, intersecting and non-paralle and non-intersecting of shaft gears.

★ Merits of Gear drives :

- Gear drives are positive drives.
- High transmission efficiency.
- High velocity possible, even up to 60:1.

- Velocity ratio will remain constant throughout
- Used for low, medium and high power transmission.

★ Demerits of Gear drives :-

- These Gear drives are Required lubrication.
- At very high speeds, produce noise and vibration
- Manufacturing of gears is costly.
- The large number of gear wheels in gear trains increased the weight of machine.
- Not suitable for shafts having large centre distance.

Q7. How the gears classified and What are the various terms used in spur gear terminology?

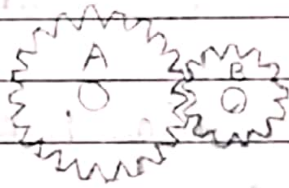
→ Gears: A component within a transmission device that transmits rotational force to another gear or device. It is classified according to the position of axes of the shafts.

a) Parallel ① Spur Gear
② Helical Gear
③ Rack and Pinion

b) Intersecting ① Bevel Gear

c) Non-Intersecting and Non-parallel ① Worm gear.

★ Spur gear Terminology:



diag: Spur gear

The following terms describe gears and gear teeth. The symbols in parentheses are standard gear nomenclature symbols used and taught at MR schools.

- Outside circle (OC): The circle formed by the tops of the gear teeth.
- Outside Diameter (OD): The diameter to which you will turn the blank or the overall diameter of the gears.
- Pitch Circle (PC): The contact point of mating gears, the basis of all tooth dimensions or an imaginary circle one addendum distance down the tooth.

- Pitch Diameter (PD): The diameter of the pitch circle. In parallel shaft gears, you can determine the pitch diameter directly from the center-to center distance and the number of teeth.

- Root Circle (RC): The circle formed by the bottoms of the gear teeth.

- Root Diameter (RD): The diameter through the center of the gear from one side of the root circle to the opposite side.

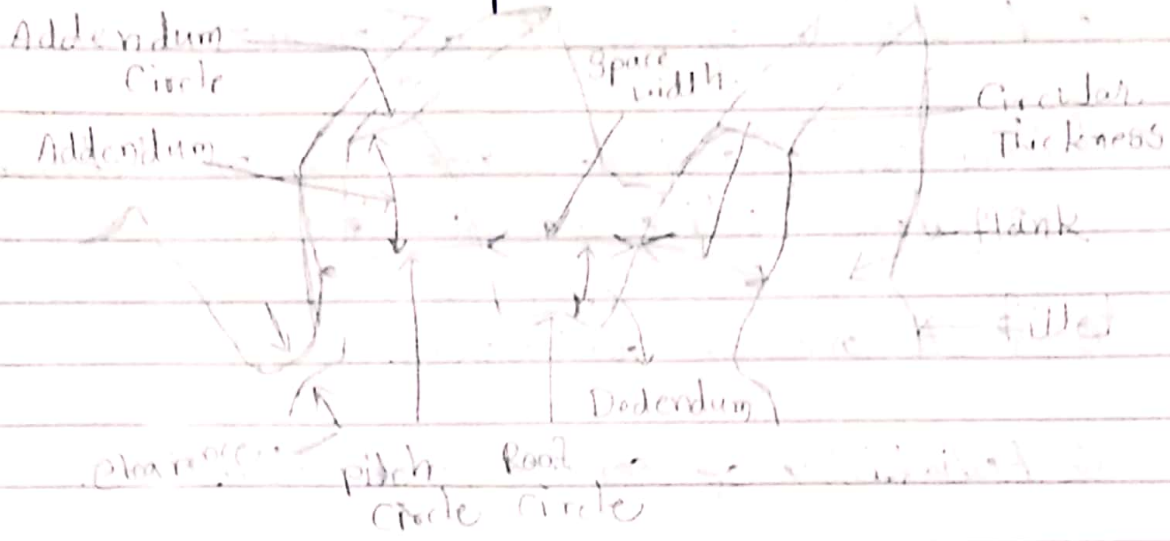
- Addendum (ADD): The height of the part of the tooth that extends outside the pitch circle.

- Circlar Pitch (CP): The distance from a point on one tooth to a corresponding point on the next tooth measured on the pitch circle.

- Circlar Thickness (CT): One-half of the circlar pitch, or the length of the arc between the two sides of a gear tooth on the pitch circle.

- Clearnce (CL): The space between the top of the tooth of one gear and the bottom of the tooth of its mating gear.

- Dedendum (DED): The depth of the tooth inside the pitch circle or the radial distance between the root circle and the pitch circle.



Diag: Spur gear terminology.

Q ⑧ What are rolling contact bearings? Discuss their advantages over sliding contact bearings.

⟹ Rolling contact bearing are also called antifriction bearings. This term refers to the wide variety of bearings that use spherical balls or some other type of roller between the stationary and the moving elements.

* The following are some advantages of rolling contact bearings over sliding contact bearings.

Advantages:

① low starting and runing friction except at very high speeds.

② Ability to withstand momentaly shock loads.

③. Accurancy of shaft alignment.

④ low cost of maintennance, as no lubrication is required while in service.

⑤ Small overall dimensions.

⑥ Reliability of service and cleanlines.

⑦ Easy to mount and erect.

Q⑨. Write short note on classification and differan types of antifriction bearings.

→ ★ An antifriction bearing is a bearing that contain moving elements to provide a low friction support surface for rotating or sliding surfaces. Antifriction bearing is also called a Rolling Contact bearings.

It is classified into following type:

① Ball Bearing and ② Roller bearing two types of antifrictional bearings.

① Ball Bearing : In ball bearing spherical balls are used as a rolling element.

The contact between the inner race and the ball or the outer race is a point contact. It is higher pair and light load use.

(2) Roller bearings: The roller bearings use the cylindrical roller, taper rollers or spherical rollers as the rolling elements. The contact between the two race is line contact. It is heavier load use.

And The rolling contact bearings depending upon the load to be carried are classified as:

(1) Radial bearings (2) Thrust bearing

Q (10). What are the advantages of lubrication?

⟹ (1) Keep friction And wear at bay: Lubrication does more than make surface slick and slippery.

(2) The protective layer formed by lubrication helps safeguard component surfaces against rust and corrosion.

(3) Lubricants absorb heat, drawing it away from surface. Depending on the applications, heat transfer into cooled.

④ Improve the life span, Efficiency and Reliability of machinary by minizing friction, wear, excessive heat, rust, corrosion, contamination and more, lubrication helps equipment do its job longer, more effectively.

⑤. Reduce the downtime and costs associated with maintenance and repair.

⑥ Selecting right lubricant with the precise properties that your particular application and operating conditions require could prove challenging.

Numerical

Q ⑪. Two pulleys, one 450 mm diameter and other 200 mm diameter, on parallel shafts 1.95 m apart are connected by a crossed belt. find the length of the belt required and the angle of contact between the belt and each pulley. What power can be transmitted by the belt, when the large pulley rotates at 200 rev/min., if the maximum permissible tension in the belt is 1000 N. and the co-efficient of friction between the belt and pulley is 0.25 ?

$\Longrightarrow$ Given;

$d_1 = 0.45\,m$, $d_2 = 0.2\,m$.

$r_1 = 0.225\,m$, $r_2 = 0.1\,m$.

$x = 1.95\ m$, $N_1 = 200\ rpm$, $T_1 = 1\ kN$,
$\mu = 0.25$.

① length of belt (L) $= \pi(r_1+r_2) + 2x + \frac{(r_1+r_2)^2}{x}$

$= 3.14 \times (0.225 + 0.1) + 2 \times 1.95 + \frac{(r_1+r_2)^2}{1.95}$

$= \boxed{4.975\ m}$

② Angle of contact : $\sin\alpha = \frac{r_1+r_2}{x} = \frac{0.225+0.1}{1.95}$

$\alpha = \sin^{-1}(0.1667)$

$\boxed{\alpha = 9.6^\circ}$

$\theta = 180^\circ + 2\alpha = 180^\circ + 2 \times 9.6 = 199.2^\circ$

$\theta = 199.2 \times \pi/180 = \boxed{3.477\ rad.}$

③ Power transmitted :
Let, T_2 = Tension in slack slide of the belt
we know that,

$2.3 \log\left(\frac{T_1}{T_2}\right) = \mu\theta$.

$\log\left(\frac{T_1}{T_2}\right) = \frac{0.25 \times 3.477}{2.3} = 0.378$

$T_2 = \frac{T_1}{2.387} = \underline{419\ N}$

Power trans. $= (T_1 - T_2)\,v = (1000 \times 419)\,4.714$
$= \boxed{2.74\ kW}$

Q (18). A flat belt is required to transmit 30 kW from a pulley of 1.5 m effective diameter running at 300 rpm. The angle of contact is spread over 11/24 of the circumference. The co-efficient of friction between the belt and pulley surface is 0.3. Determine, taking centrifugal tension into account, width of the belt required. It is given that the belt thickness is 9.5 mm, density of its material is 1100 kg/m³ and the related permissible working stress is 2.5 MPa.

→ Given, $d = 1.5$ m, $N = 300$ rpm, $\mu = 0.3$,

$P = 35$ kW, $\theta = \frac{11}{24} \times 360 = 2.88$ rad.

We know that,

$$v = \frac{\pi d N}{60} = \frac{\pi \times 1.5 \times 300}{60} = \boxed{23.55 \text{ m/s}}$$

$$\therefore \frac{T_1}{T_2} = e^{\mu\theta} = e^{0.3 \times 2.88} = \boxed{e^{0.864}} = \underline{\underline{2.372}}$$

Now, $P = v\,(T_1 = T_2)$

$$35 \times 10^3 = (T_1 - T_2) \times 23.55$$

$$T_1 - T_2 = 1486.2$$

$\therefore$ Max. tension in the belt $= \underline{\underline{2372\ N}}$

★