Dt - 17.12.2019

CH.1 SIMPLE MECHANISM

Machine:- It is a device which receives energy in some available form & utilises it to do some particular type of work.

TOM:- It is the branch of science which deals with relative motion of various parts of a machine with considering their forces or viceversa.

Kinematics:- It is the branch of science which deals with relative motions of the various parts of a machine.

Dynamics:- It deals with forces & their effects, while machine parts in motion.

Kinetics:- It deals with inertia of forces which arise from masses & motion of the machine parts.

Statics:- It deals with forces & their effects when the body at rest.

SIMPLE MECHANISM

Kinematic link / Element :-

→ If a part of a machine transmit motion to other part by a support is called kinematic link

→ The kinematic link should have following characteristics.

(i) The link must be a resistant or rigid body.

(ii) It should have relative motion.

Types of Links :-

(i) **Rigid link:-** This type of link have no deformation

(or) It is defined as a rigid membrane linked with a master node, to which slave nodes with a selected set of degree of freedom are attached

(ii) **Flexible link:-** A flexible link is a resistant kinematic link that undergoes partial deformation when transmitting motion.

(iii) **Fluid link:-** A fluid link which is transmitting motion through hydraulic & air Pneumatic.

Dt - 20.12.17

Structure

It is a rigid body which have no deformation but it can distribute load.

Difference between machine & structure

(i) Machine have relative motion but structure don't have.

(ii) Machine transfer energy into work but structure don't have.

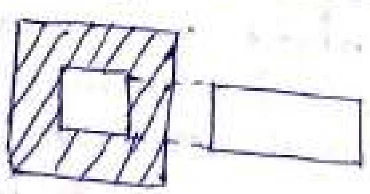
(iii) The link of a machine may transmit both power & motion but the member of a structure transmit force only.

Kinematic pair

The two links or element of a machine when in contact with each other they form a pair.

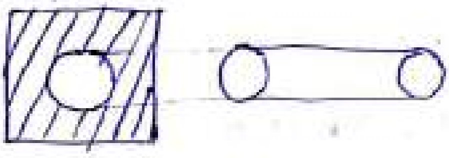
V.V.I
Types of constrained motion
lock

1. Completely constrained motion



→ If a square member will insert inside a square hole then it's only have one direction to move it's called completely constrained motion.

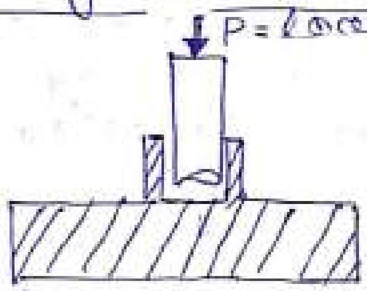
2. Incompletely constrained motion



→ If a cylindrical member will insert inside a cylindrical hole then it's only have two direction to move it's called incompletely constrained motion.

→ Two direction are (i) Rotational
(ii) Longitudinal.

3. successfully constrained motion



[Foot step bearing]

→ If we insert a shaft inside a bearing housing to rotate inside it & to obstruct the vertical motion we give a upward load so that shaft only have to rotate called successfully constrained motion.

Classification of kinematic pair

1. According to type of relative motion between the elements.

(a) sliding pair:-
If the pair is sliding to each other is called sliding pair.
Ex:- Piston cylinder arrangement.

(b) Turning pair:-
If the pair will turn to each other is called turning pair.
Ex:- Nut & bolt,

(4)

(c) Rolling pair

If the pair will roll to each other is called rolling pair.

Ex:- Rolling mill, Roller. etc.

(d) Screw pair

If the pair will revolve through the screw is called screw pair.

Ex:- Lead screw of a lathe machine
↳ thread Acme is 29°.

(e) Spherical pair

When the two elements of the pair are connected in such a way that one element turn about the other fixed element.

V.V.I Ex:- Ball & socket joint, Bike mirror, etc.

2. According to type of contact between the elements.

(a) Lower pair

If the two elements have surface or area contact is called lower pair.

Ex:- standing on a floor, Rolling pair, turning pair, screw pair, etc.

(b) Higher pair

If the two elements have point or line contact is called higher pair.

Ex:- Gear transmit power, Belt drive, Cam & follower, etc.

3. According to the type of closure.

(a) Self closure / self closed pair

When the two elements of a pair are connected together mechanically in such a way that only required kind of relative motion occurs.

Ex:- Lower pair.

(b) Force closed pair

When the two elements of the pair are not connect mechanically but are kept in contact by the action of external force the pair is said to be force closed pair.

Ex:- Cam & follower.

Kinematic ~~pai~~ chain

(i) When the kinematic pairs are coupled in such a way that the last link is joint to the first link to transmit definite motion i.e. completely or successfully constrained motion is called kinematic chain.

(ii) If each link is assumed to form a two pair when two adjacent link then we can express it by a equation.

$$\boxed{l = 2p - 4} \rightarrow \text{Relation betn link \& pair} \quad (1)$$

$l \rightarrow$ No. of link

$p \rightarrow$ No. of kinetic pair.

$$\boxed{J = \frac{3 \times l}{2} - 2} \rightarrow \text{Relation betn joint \& link} \quad (2)$$

$J \rightarrow$ No. of joint

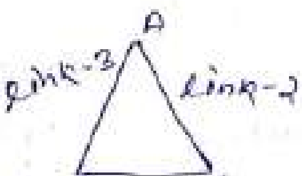
Both equation 1 & 2 are applicable for kinematic chain.

Case-1

$l = 3$

$p = 3$

$J = 3$



put all the value in eqn-1

$l = 2p - 4 \Rightarrow \boxed{3 > 2}$

$\boxed{L.H.S > R.H.S}$

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Now put all the value in eq^n-2

$$J = \frac{3}{2}l - 2$$

$$\Rightarrow 3 = \frac{3}{2} \times 3 - 2$$

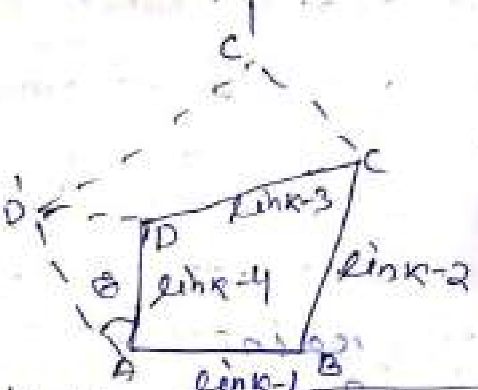
$$\Rightarrow 3 = 2.5$$

$$\Rightarrow \boxed{L.H.S > R.H.S}$$

Conclusion

If L.H.S > R.H.S, it's called locked chain.

Case-II



$l = 4$
$P = 4$
$J = 4$

Apply eq^n-(1) $\Rightarrow l = 2P - 4 \Rightarrow 4 = 4 \Rightarrow \boxed{L.H.S = R.H.S}$

" " (2) $\Rightarrow J = \frac{3}{2}l - 2 \Rightarrow 4 = 4 \Rightarrow \boxed{L.H.S = R.H.S}$

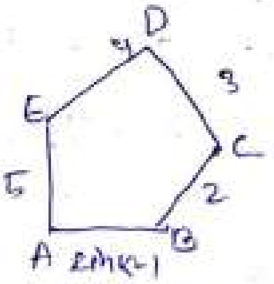
*It is also called completely constrained motion.

Conclusion

Here L.H.S = R.H.S, so that this kinematic chain have one degree of freedom.

Case-III

$l = 5$
$P = 5$
$J = 5$



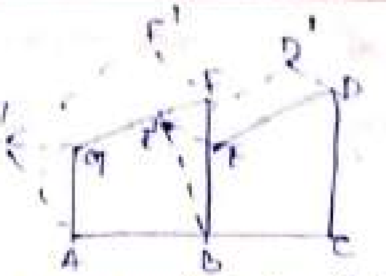
Apply eq^n-(1) $\Rightarrow l = 2P - 4 \Rightarrow 5 = 6 \Rightarrow \boxed{L.H.S < R.H.S}$

" " (2) $\Rightarrow J = \frac{3}{2}l - 2 \Rightarrow 5 = 5.5 \Rightarrow \boxed{L.H.S < R.H.S}$

Conclusion

Here L.H.S < R.H.S, so that this kinematic chain is called unconstrained chain.

$\boxed{\text{Case - II}}$



$l = 6$
$p = 5$
$J = 7$

Apply eqn-(1) => $l = 2p - 4 \Rightarrow 6 = 6 \Rightarrow \boxed{L.H.S = R.H.S}$

" " (2) => $J = \frac{3}{2} l - 2 \Rightarrow 7 = 7 \Rightarrow \boxed{L.H.S = R.H.S}$

Imp Degree of freedom $\boxed{(f/n) = 3(l-1) - 2J - h}$

h = higher pair (point contact)

$$\Rightarrow n = 3(l-1) - 2J - h$$
$$= 3(6-1) - 2\times 7 - 0$$
$$= 15 - 14 = 1$$

Conclusion

Here L.H.S = R.H.S, so that this is compound kinematic chain have one degree of freedom.

$\boxed{\text{Dt - 7.1.2020}}$

Mechanism

If one link of a kinematic chain is fixed we called it as mechanism.

Ex - 1. Quick return mechanism
2. slider crank mechanism.
3. cycle pedal.

Inversion of Mechanism

If more than one link is fixed on a machine we got different mechanism at different motion called Inversion of mechanism.

Types of kinematic chain

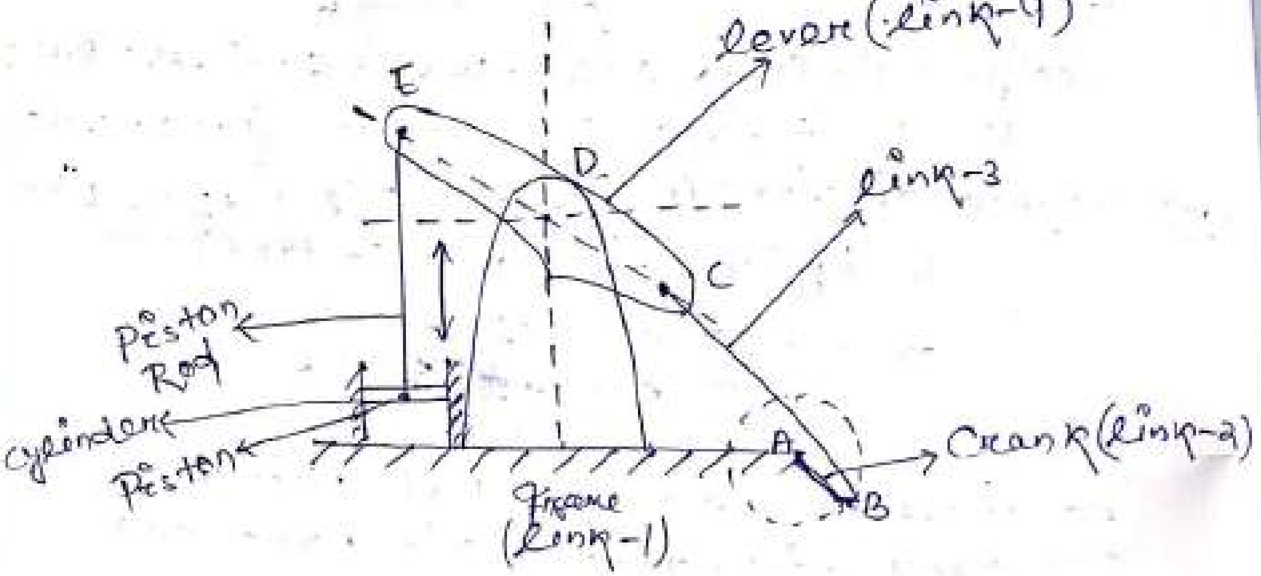
10 Marks

10 Mark

Imp 1. Single slider crank
Imp 2. Double " "
3. 4-bar chain mechanism.

(8) Inversion of 4-bar chain

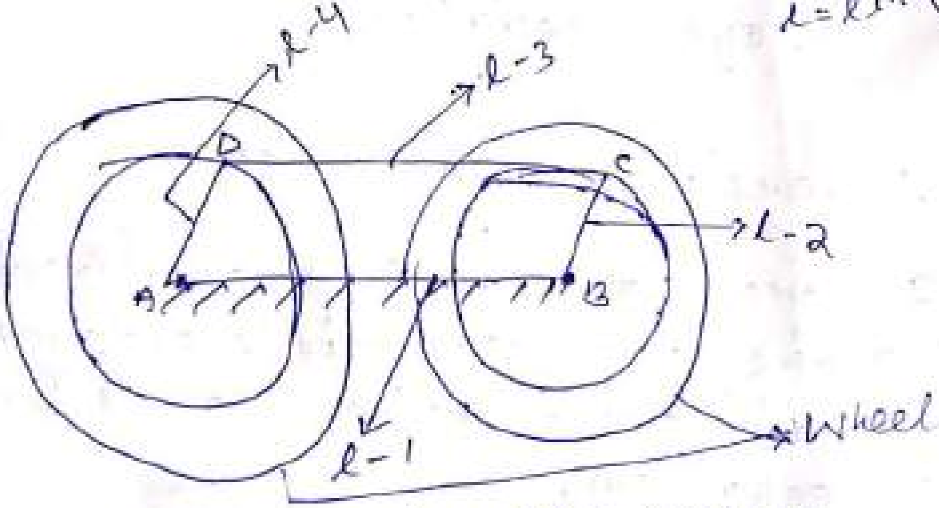
a. Beam engine (Crank & lever mechanism)



It consist of one crank & one lever which is used to reciprocate the piston while the rotation of crank.

b. Coupling rod of a heavy locomotive (Double crank mechanism)

l = link.

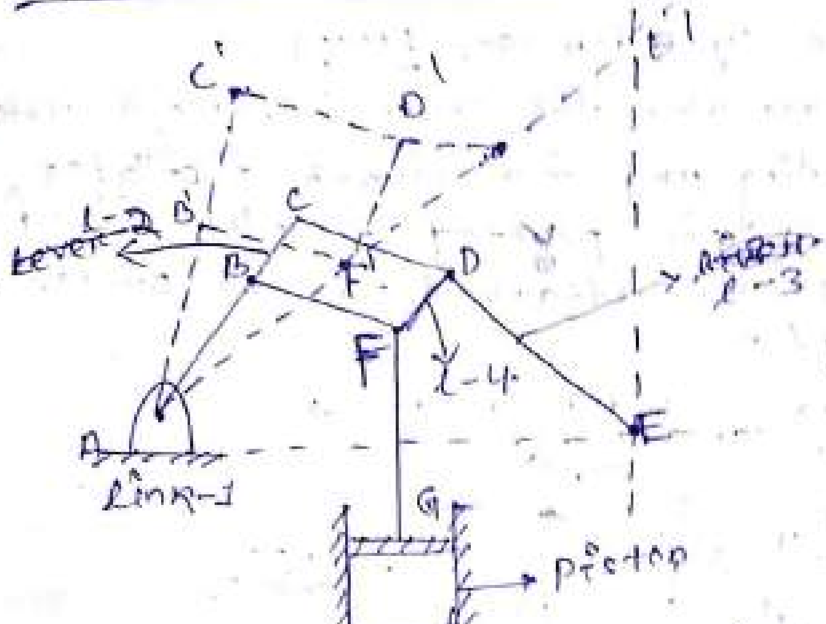


→ The l-2 & l-4 are the two crank.

→ Here AB fixed link which obey the law of inversion.

→ The link CD act as a coupling rod.

c. Watt's indicator mechanism (Double lever mechanism)

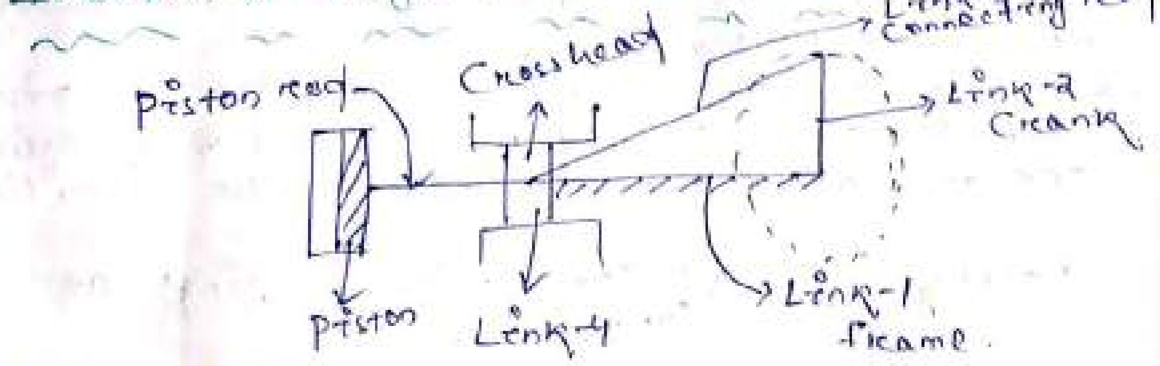


→ In this mechanism it consist of 2 lever which reciprocate the piston so that we can do some work. (i.e. BFD & CE link)

~~→ AC & CF are 2 lever.~~

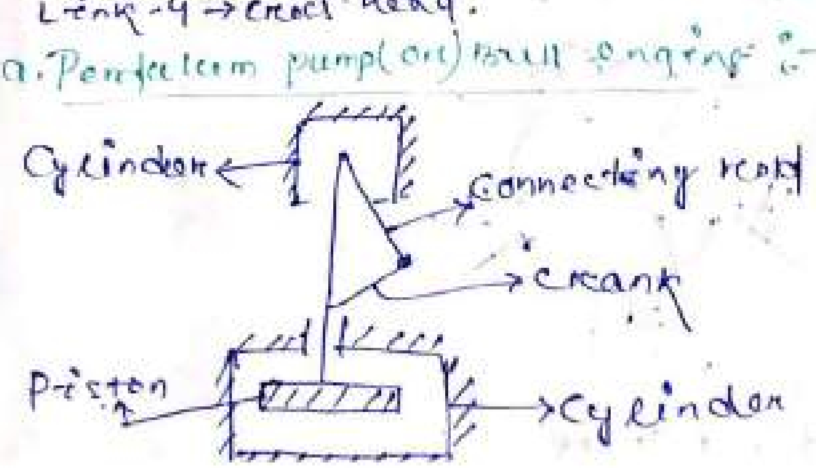
→ 4 Links are A, AC, CF & BFD links. |01-12/1.20|

Inversion of single slider crank chain



Link-1 → frame
Link-2 → crank
Link-3 → connecting rod
Link-4 → cross head.

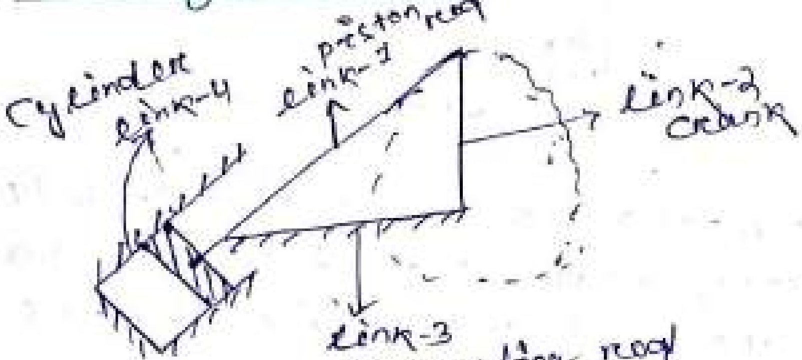
a. Pendulum pump (or) Bull engine :-



→ In this mechanism the inversion is obtain by fixing the cylinder (or) link-4.

→ In this case when the crank i.e. link-2 rotates the connecting rod i.e. link-3 oscillates between a pin pivoted to the fixed link-4. And the piston attached to the piston rod i.e. link-1.

(b) oscillating cylinder engine :-

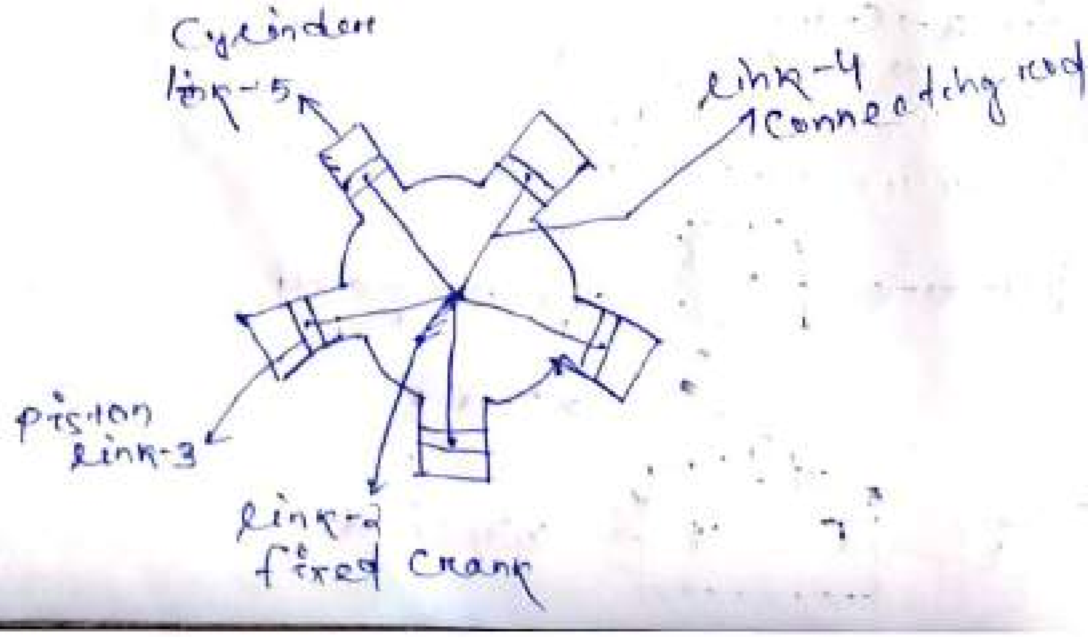


→ In this mechanism the inversion is obtain by fixing the cylinder (link-4) & connecting rod (link-3)

→ This mechanism is used to convert reciprocating motion into rotary motion.

→ In this case when the crank rotates, the piston attached to piston rod reciprocates & the cylinder oscillates about a pin pivoted to the fixed link.

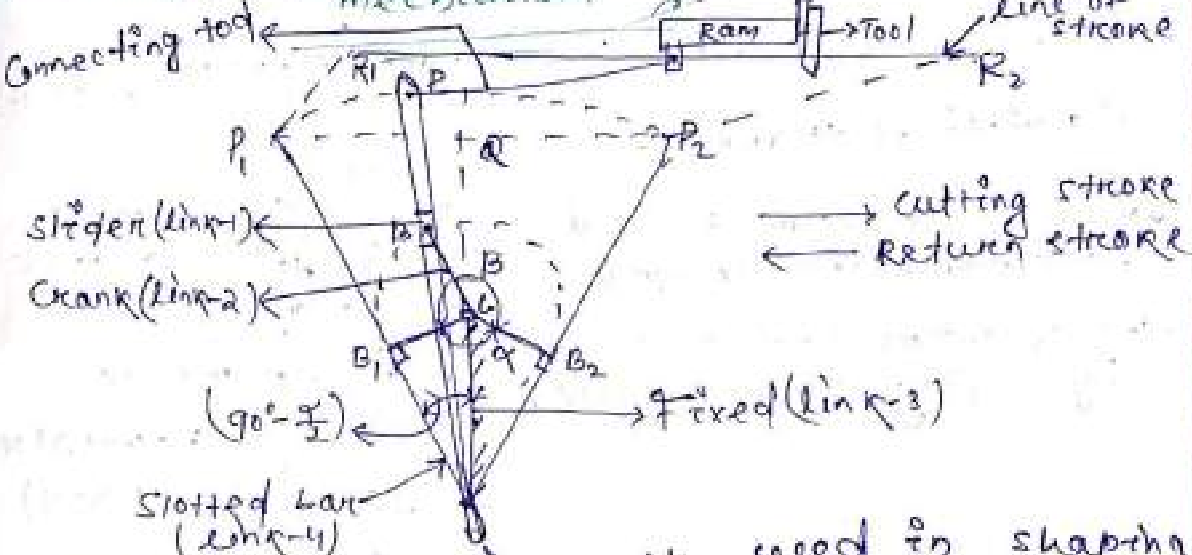
(c) Rotary Internal combustion engine (or) (Gnome engine)



→ In this mechanism the crank (link-2) is fixed.

→ In this mechanism, when the connecting rod rotates, the piston reciprocates inside the cylinders forming.

(d) Crank & slotted lever quick return mechanism

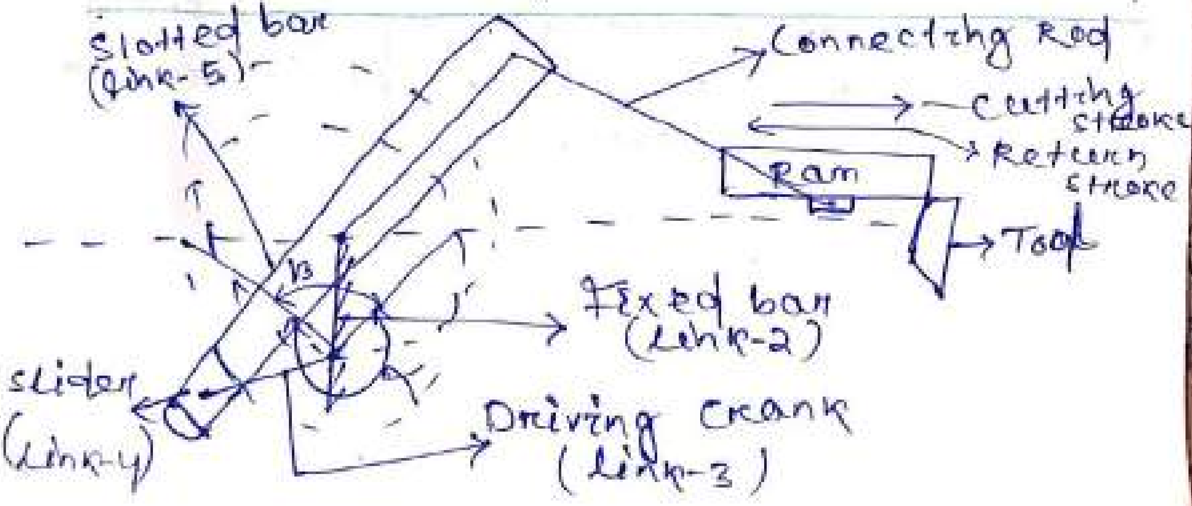


→ This mechanism is mostly used in shaping machine & also in rotary I.C. engine.

→ In crank & slotted lever quick return mechanism the tool in forward stroke cut the work piece & in backward stroke it is come back to its original position very quickly without machining.

$$\boxed{\frac{\text{The time of cutting stroke}}{\text{Time of return stroke}} = \frac{\beta}{\alpha} = \frac{\beta}{(360° - \beta)}}$$

(e) Whitworth quick return mechanism.



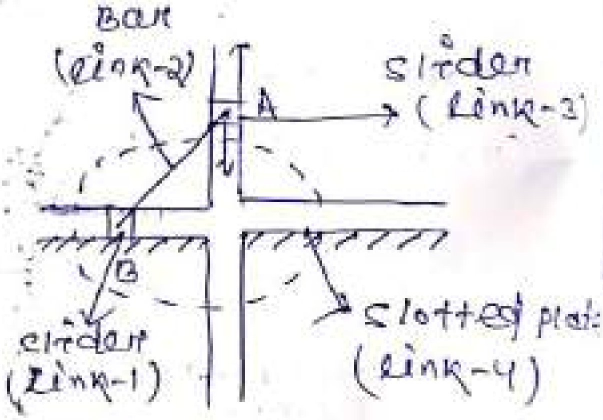
→ This machine is used in slotting & shaper machine.

$$\boxed{\frac{T.C.S}{T.R.S} = \frac{\alpha}{\beta} = \frac{\alpha}{(360-\alpha)}}$$

Inversion of double slider crank mechanism

Dt-20.1.2

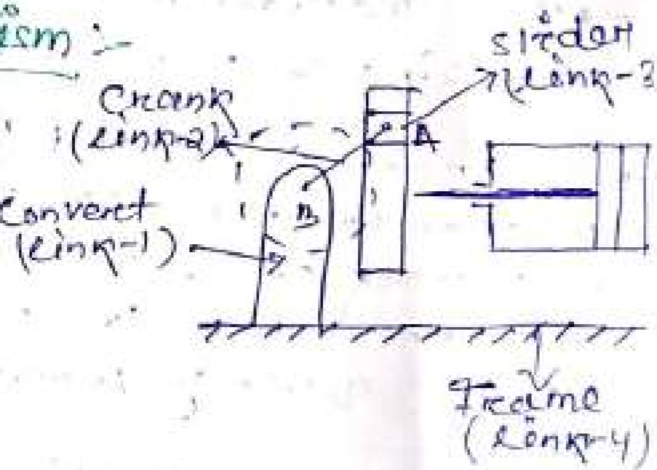
(a) Elliptical trammel.



→ It's a instrument used to draw elipse diagram.

→ This instrument obtained by fixing slotted plate.

(b) Scotch yoke Mechanism :-



→ This mechanism is used to rotating motion to reciprocating motion.

→ Either link-1 (or) link-3 must be fixed.

(c) Oldham coupling :-

→ This coupling is used where two shaft are parallel to each other.

→ If one shaft rotate at very high speed then the other coupler shaft is rotate at same speed also.

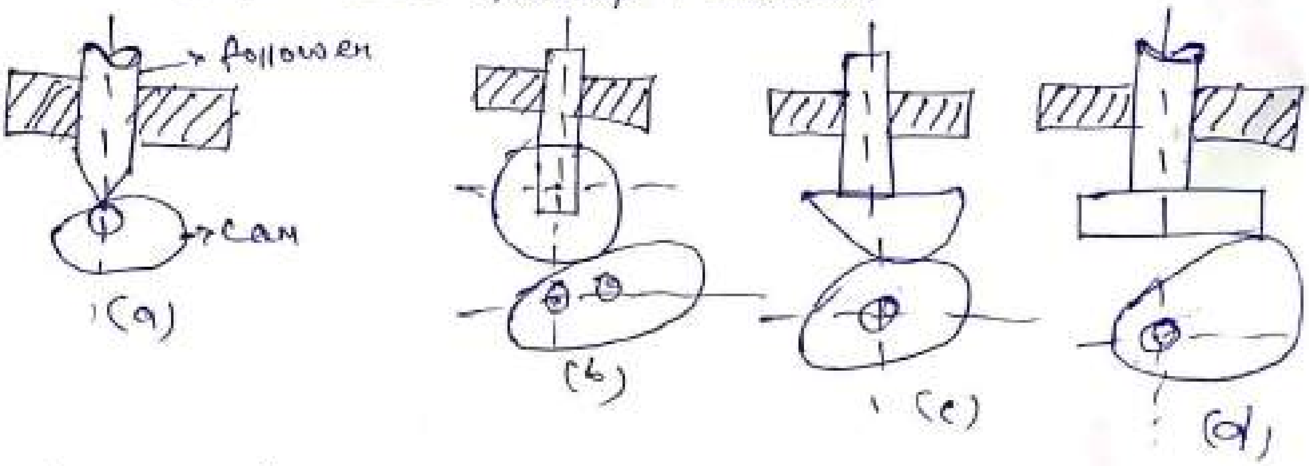
Dt-27.1.20

CAMS:-

→ A cam is a rotating machine element which gives reciprocating or oscillating motion to another element known as follower.

Classification of followers :-

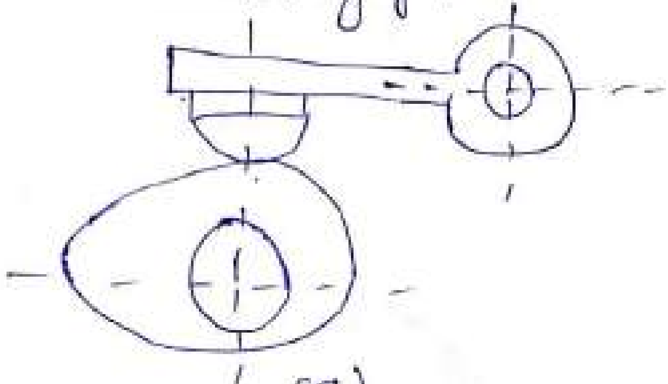
1. According to the surface in contact:-
   - (a) Knife edge follower. [Contacting end of follower is like knife edge.
   - (b) Roller follower. [Contacting end of follower is ro...
   - (c) flat faced or mushroom follower.
   - (d) spherical faced follower.



2. According to the motion of follower :-
   - (a) Reciprocating or translating follower
   - (b) Oscillating or Rotary

→ When cam rotates the follower will reciprocate accordingly

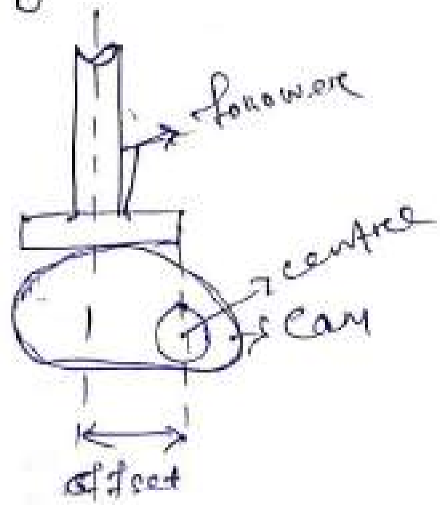
→ When cam rotates the follower will oscillate accordingly.



(a)

3. According to the path of motion of the follower
   (a) Radial follower
   In radial follower the motion is along an axis passing through the ~~axis~~ centre of cam.

   (b) Offset follower
   When the motion of the follower is passing away from the centre of the cam.



IMP

Terms used in radial cam :- Dt-24.1.20

1. Base circle :- Smallest circle that can drawn to cam profile.
2. Trace point :- Reference point on follower to generate pitch curve.
3. Pressure angle :- Angle between direction of follower motion & normal to pitch curve.
4. Pitch point :- Point on pitch curve having maximum pressure angle.
5. Pitch circle :- Circle drawn from the circle of cam through pitch point.
6. Pitch curve :- Curve generated by trace point at the follower moves relative to the cam.

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7. Prime circle :- smallest circle that can be drawn from the cam centre.

8. Lift or stroke :- Maximum lift of follower from down side.

PTLB

std.

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CH-2 FRICTION Dt-4.3.20

Friction :- It is a resistance force that one surface or object encounter when moving over another subject.

Ex:- Rolling, sliding, etc.

Types of friction :-

1. Static friction:-
It is the friction, experienced by a body, when at rest.

2. Dynamic friction :-
It is the friction experienced by a body, when in motion. The dynamic friction is also called kinetic friction & is less than the static friction. It is 3 types.

(a) Sliding friction :-
It is the friction experienced by a body, when it slides over a another body.

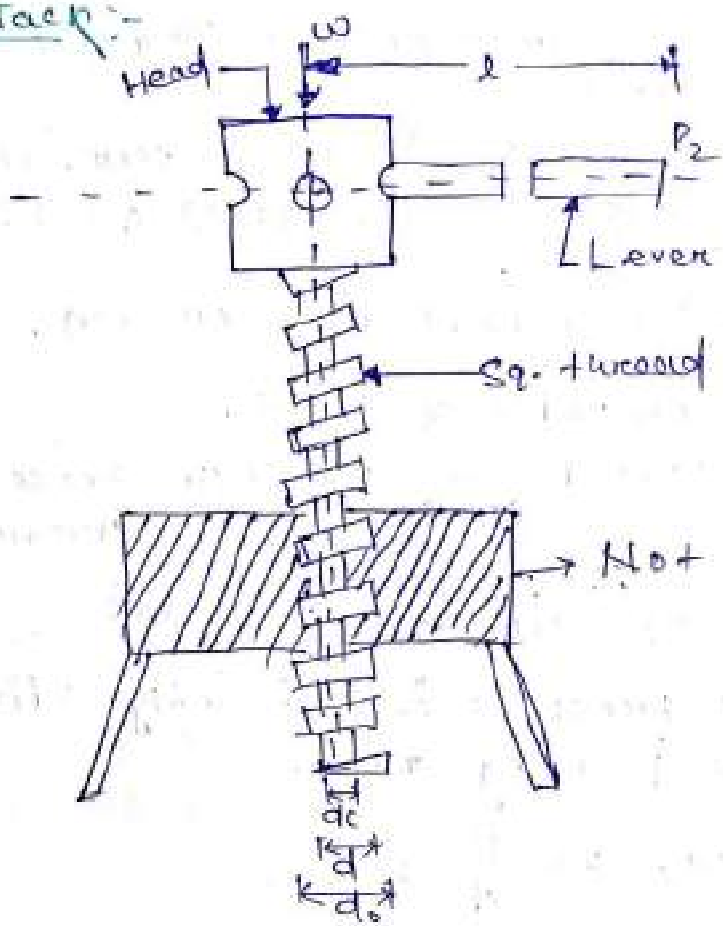
(b) Rolling friction :-
It is the friction experienced ~~by a body~~ between the surface which has balls or rollers interposed between them.

(c) Pivot friction :-
It is the friction experienced by a body due to the motion of rotation as in case of foot step bearings.

The friction may further be classified as:-

1. Friction between unlubricated surfaces,
2. Friction between lubricated surfaces.

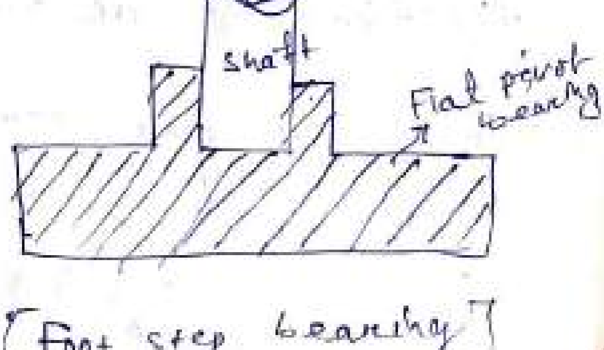
Screw Jack :-



- It's a mechanical device which lift the load by applying small effort. $\boxed{DT - Rs. 3.20}$
- It consist of square thread through which the load will lift very easily.
- since square thread will carry maximum load capacity compared to other threads, because it's perpendicular to the plane.

- **Torque transmission in flat pivot bearing (FVB)**

When vertical shaft rotates in FVB (Foot step bearing), here the sticking friction will along the surface of contact between the shaft & bearing.



[Foot step bearing]

Let, $W \rightarrow$ Load transmitted over the bearing surface.

$R \rightarrow$ Radius of bearing surface.

$P \rightarrow$ Intensity of pressure on the bearing surface.

$\mu \rightarrow$ Coefficient of friction.

We will consider 2 cases.

1. considering uniform pressure.
2. " " wear.

1. Considering uniform pressure.

When the pressure is uniformly distributed over the bearing area.

$$\text{then, } p = \frac{F}{A} = \frac{W}{\pi R^2}$$

Consider a ring of radius 'r' & thickness 'dr' of bearing area;

∴ Area of bearing surface $= 2\pi \times r \times dr$.

Load transmitted to the ring,

$$\delta W = p \times A = p \times 2\pi r\, dr \quad \text{——(1)}$$

Frictional resistance to sliding on the ring acting tangentially at radius 'r',

$$F_r = \mu \times R_N = \mu \times \delta W$$

$$\Rightarrow F_r = \mu \times p \times 2\pi r\, dr$$

$$\Rightarrow F_r = 2\pi \mu p r\, dr$$

Frictional torque on the ring, $T_r = F_r \times r$
$= 2\pi \mu p r^2 dr$ ——(2)

Total frictional torque.

$$T = \int_0^R T_r$$

$$= \int_0^R 2\pi \mu p r^2 dr$$

$$\Rightarrow T = 2\pi\mu p \int_0^R r^2 \, dr$$

$$= 2\pi\mu p \left[\frac{r^3}{3}\right]_0^R$$

$$= 2\pi\mu p \left[\frac{R^3}{3} - \frac{0^3}{3}\right]$$

$$= \frac{2}{3}\pi \times \mu \times \frac{W}{\pi R^2} \times \frac{R^3}{3}$$

$$\Rightarrow \boxed{T = \frac{2}{3}\mu W R}$$

When the shaft rotates at ω rad/sec, then the power lost in friction.

$$\boxed{P = T\omega = T \times \frac{2\pi N}{60}}$$

Dt - 17.3.20

2. Considering uniform wear

For uniform wear, $p \cdot r = C \Rightarrow p = \frac{C}{r}$

Load transmitted to the ring from eqn - ①,

$$\delta W = p \times 2\pi r \cdot dr$$

$$= \frac{C}{r} \times 2\pi r dr = 2\pi C dr$$

Total load transmitted to the ~~ring~~ bearing

$$W = \int_0^R 2\pi C \cdot dr = 2\pi C \int_0^R dr$$

$$= 2\pi C \times [r]_0^R$$

$$\Rightarrow W = 2\pi C R$$

$$\Rightarrow C = \frac{W}{2\pi R}$$

We know that frictional torque acting on the ring,

$$T_r = 2\pi\mu p r^2 dr$$

$$= 2\pi\mu \times \frac{C}{r} \times r^2 dr$$

$$= 2\pi\mu C r \, dr$$

$\therefore$ Total frictional torque on the bearing

$$T = \int_0^R 2\pi\mu C r \, dr$$

$$= 2\pi\mu C \int_0^R r \, dr$$

$$= 2\pi\mu C \left[\frac{r^2}{2}\right]_0^R$$

$$= 2\pi\mu C \times \frac{R^2}{2} = \pi\mu \times \frac{W}{2\pi R} \times R^2$$

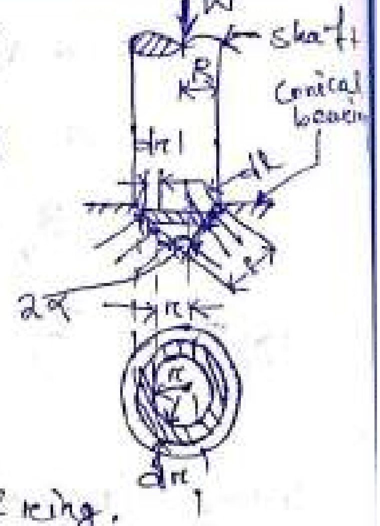
$$\Rightarrow \boxed{T = \frac{1}{2} \times \mu \cdot W \cdot R}$$

(50)

Dt - 13.3.21

* Torque transmission in conical pivot bearing

The conical pivot bearing supporting a shaft carrying a load W →



Let, P_n = Intensity of pressure normal to the cone.

α = semi angle of the cone

μ = Coefficient of friction between shaft & bearing

R = Radius of the shaft.

Consider a small ring of radius 'r' & thickness dr. Let dl is length of ring.

$dl = dr \operatorname{cosec}\alpha$

Area of the ring (A) $= 2\pi r \cdot dl$

$= 2\pi r\, dr \operatorname{cosec}\alpha$

1. Considering uniform pressure,

We know that δW_n = Press. × Area
(normal load)

$= P_n \times 2\pi r \cdot dr \operatorname{cosec}\alpha$

Vertical load δW = vertical component of δW_n

$= \delta W_n \cdot \sin\alpha$

$= P_n \times 2\pi r \cdot dr \operatorname{cosec}\alpha \cdot \sin\alpha$

$= P_n \times 2\pi r \cdot dr$

$W = \int_0^R P_n \times 2\pi r \cdot dr$

$= 2\pi P_n \left[\frac{r^2}{2}\right]_0^R = \cancel{2}\pi P_n \times \frac{R^2}{\cancel{2}} = \pi R^2 P_n$

$\Rightarrow P_n = W/\pi R^2$.

We know that, $F_r = \mu \delta W_n = \mu P_n \cdot 2\pi r \cdot dr \operatorname{cosec}\alpha$

$= 2\pi\mu \cdot P_n \operatorname{cosec}\alpha \cdot r \cdot dr$

Frictional torque acting on the ring

~~$F_r = \mu \delta W_n = 2\pi r \mu P_n dr \operatorname{cosec}\alpha$~~

~~$= 2\pi\mu P_n \operatorname{cosec}\alpha \cdot r \cdot dr$.~~

$T_r = F_r \times r = 2\pi\mu \cdot P_n \cdot \operatorname{cosec}\alpha \cdot r \cdot dr \times r$

$= 2\pi\mu \cdot P_n \operatorname{cosec}\alpha\, r^2 dr$

∴ Total frictional torque

$T = \int_0^R 2\pi\mu P_n \operatorname{cosec}\alpha\, r^2 dr$

$\therefore T = \frac{2}{3} \times \mu \cdot W \cdot R \cdot \operatorname{cosec}\alpha$

2. Considering uniform wear.

$$P_r \cdot r = C \Rightarrow P_r = \frac{C}{r}$$

$$\delta W = P_r \times 2\pi r \cdot dr = \frac{C}{r} \times 2\pi r \cdot dr = 2\pi C \cdot dr$$

$$W = \int_0^R 2\pi C \cdot dr = 2\pi C [r]_0^R = 2\pi C \cdot R$$

$$\Rightarrow C = \frac{W}{2\pi R}$$

Frictional torque acting on the ring

$$T_r = 2\pi\mu \cdot P_r \operatorname{cosec}\alpha\, r^2 \cdot dr = 2\pi\mu \times \frac{C}{r} \times \operatorname{cosec}\alpha\, r^2 dr$$

$$= 2\pi\mu C \operatorname{cosec}\alpha\, r \cdot dr.$$

∴ Total frictional torque acting on the ring bearing

$$T = \int_0^R 2\pi\mu C \operatorname{cosec}\alpha\, r \cdot dr.$$

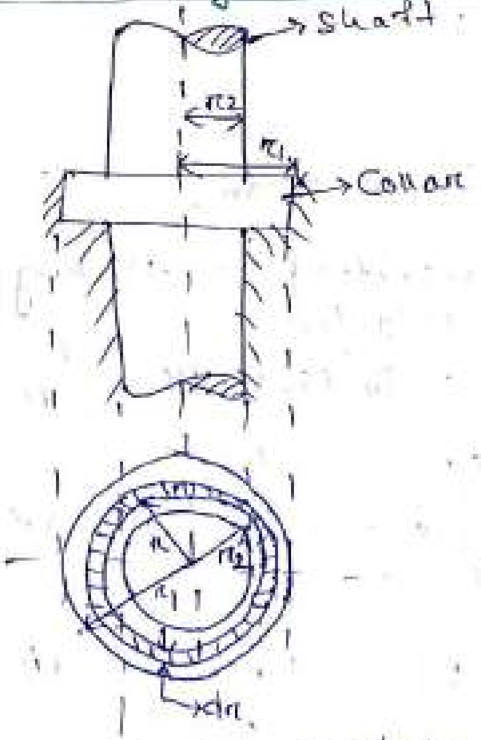
$$= \pi\mu C \cdot \operatorname{cosec}\alpha \cdot R^2.$$

or

$$T = \pi\mu \times \frac{W}{2\pi R} \times \operatorname{cosec}\alpha\, R^2 = \frac{1}{2} \times \mu W R \operatorname{cosec}\alpha$$

$$\Rightarrow \boxed{T = \frac{1}{2} \times \mu W \times l}$$

Flat collar bearing of single types



→ Collar bearing actually used to carry axial thrust of the rotating shaft. These type of bearing also called thrust bearing.

Consider a single flat collar bearing supporting a shaft as shown in figure.

Let r_1 & r_2 = External & Internal radius of the collar.

(52) Area of the bearing $(A) = \pi r^2$.

$$\Rightarrow A = \pi (r_1^2 - r_2^2)$$

1. Considering uniform pressure

$$P = \frac{W}{A} = \frac{W}{\pi (r_1^2 - r_2^2)}$$

frictional torque, $T_r = 2\pi \mu p r^2 dr$.

Total frictional torque.

$$\Rightarrow \int_{r_2}^{r_1} T_r = \int_{r_2}^{r_1} 2\pi \mu p r^2 dr$$

$$\Rightarrow T = 2\pi \mu p \int_{r_2}^{r_1} r^2 dr$$

$$= 2\pi \mu p \left[\frac{r^3}{3}\right]_{r_2}^{r_1}$$

$$=$$

2. Considering uniform wear.

The load transmitted on the ring by considering uniform wear will be

$$\delta W = P_r \times 2\pi r dr = \frac{C}{r} \times 2\pi r \, dr$$

Total load

$$\int_{r_2}^{r_1} \delta w = \int_{r_2}^{r_1} \frac{C}{\cancel{r}} \times 2\pi \cancel{r} dr.$$

$$\Rightarrow W = C 2\pi \int_{r_2}^{r_1} 1 \, dr$$

$$\Rightarrow W = 2\pi C [r]_{r_2}^{r_1}$$

$$\Rightarrow \boxed{W = 2\pi C (r_1 - r_2)}$$

$$\Rightarrow C = \frac{W}{2\pi (r_1 - r_2)}$$

$$\boxed{\begin{array}{l} P \times V = \text{wear } (C) \\ \Rightarrow P \times r = C \Rightarrow P = \frac{C}{r} \end{array}}$$

Frictional torque on the ring.

$$T_r = \mu \times \delta w \times r$$

$$= 2\pi \mu C r \, dr$$

Total torque

$$\int_{r_2}^{r_1} T_r = \int_{r_2}^{r_1} 2\pi \mu C r \, dr$$

$$\Rightarrow T = 2\pi \mu C \int_{r_2}^{r_1} r \, dr$$

$$= 2\pi \mu C \left[\frac{r^2}{2}\right]_{r_2}^{r_1}$$

$$= 2\pi \mu C \left(\frac{r_1^2}{2} - \frac{r_2^2}{2}\right)$$

$$= \cancel{2}\pi \mu C \frac{(r_1^2 - r_2^2)}{\cancel{2}}$$

$$\Rightarrow T = \mu \pi C (r_1^2 - r_2^2)$$

Friction clutch

Friction clutch is a mechanical element which engage & disengage with the gearbox & flywheel when we need necessary action of speed increase & decrease.

Types of clutch

1. single plate clutch
2. Multi " "
3. conical " "
4. centrifugal " "

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- The proper alignment of the bearing must be maintained & should be located as close to clutch as possible so that :

1. The contact surface should develop friction force that may pickup & hold the load with reasonably low pressure.
2. The heat due to friction should be rapidly dissipated.
3. Surface should be backward by material stiff enough to ensure & reasonably uniform distribution of pressure.

Imp

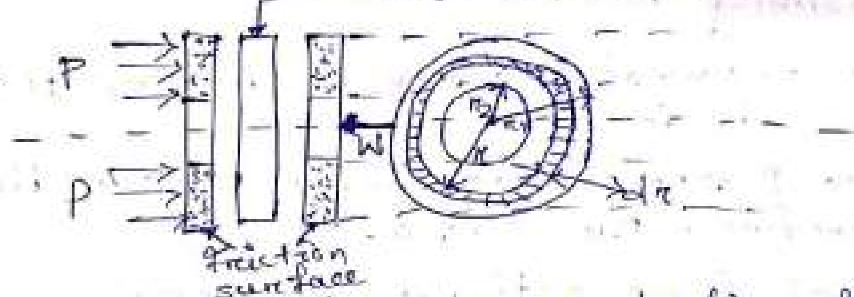
Single plate clutch (Disc).

- It consist of clutch plate whose both sides are faced with friction material (Ferrodo). It's mounted on a hub which is free to move axially along the splines of the driven shaft.

- The pressure plate is mounted inside the clutch body which is bolted to the flywheel. Both the pressure plate & flywheel rotate with the engine crank shaft or the driving shaft.
- When we apply clutch pedal which is immediately free from gear box & only rotate with flywheel, if we apply 1st gear which is now engage with clutch plate & ready to rotate similarly 2nd, 3rd & 4th gear also.

Torque transmitted by single plate clutch.

Let, T = Torque transmitted by clutch
P = Intensity of pressure with contact surface



r_1 & r_2 → External & internal radius of friction face

μ = coefficient of friction.

Consider elementary ring of radius 'r' & thickness 'dr'.

Area of contact surface $= 2\pi r\,dr$

Axial force on the ring $\Rightarrow \delta W$ = press. × Area.

$\Rightarrow \delta W = p \times 2\pi r\,dr$.

Frictional force on the ring acting tangentially

$F_r = \mu \times \delta W = \mu \times p \times 2\pi r\,dr$.

1. Considering uniform pressure.

$$P = \frac{W}{\pi(r_1^2 - r_2^2)}$$

$$T_r = 2\pi\mu p r^2 dr$$

Total ~~Total pressure~~ frictional torque $(T) = \int_{r_2}^{r_1} 2\pi\mu p r^2 dr$.

$$= 2\pi\mu p \int_{r_2}^{r_1} r^2 dr$$

$$= 2\pi\mu p \left[\frac{r^3}{3}\right]_{r_2}^{r_1}$$

$$= 2\pi\mu p \left[\frac{(r_1)^3 - (r_2)^3}{3}\right]$$

Now substitute the value of 'P'.

$$\Rightarrow T = 2\cancel{\pi}\mu \times \frac{W}{\cancel{\pi}\left[(r_1)^2 - (r_2)^2\right]} \times \frac{(r_1)^3 - (r_2)^3}{3}$$

$$\Rightarrow T = \frac{2}{3} \times \mu W \left[\frac{(r_1)^3 - (r_2)^3}{(r_1)^2 - (r_2)^2}\right]$$

$$\Rightarrow \boxed{T = \mu.W.R} \quad \left[\because R = \frac{2}{3}\left[\frac{(r_1)^3 - (r_2)^3}{(r_1)^2 - (r_2)^2}\right]\right]$$

Mean Radius of friction surface

2. Considering uniform wear

Let p = Normal intensity of pressure at a distance 'r' from axis of clutch.

Since 'p' varries inversely with the distance 'r', therefore, $p \cdot r = C \Rightarrow p = \frac{C}{r}$

∴ Normal force acting on the ring

$$\delta W = p \cdot 2\pi r \cdot dr$$

$$\Rightarrow \delta W = \frac{C}{r} \times 2\pi r \times dr = 2\pi C \cdot dr.$$

Total force acting on the frictional surface.

$$W = \int_{r_2}^{r_1} 2\pi C \cdot dr$$

$$\Rightarrow W = 2\pi C \int_{r_2}^{r_1} dr$$

$$\Rightarrow W = 2\pi C \, [r]_{r_2}^{r_1}$$

$$\Rightarrow W = 2\pi C (r_1 - r_2)$$

$$\Rightarrow C = \frac{W}{2\pi (r_1 - r_2)}$$

We know that frictional torque acting on the ring

$$T_r = 2\pi \mu \cdot p r^2 \cdot dr$$

$$= 2\pi \mu \times \frac{C}{r} \times r^2 dr$$

$$= 2\pi \mu C r \cdot dr$$

∴ Total frictional torque on the friction surface.

$$T = \int_{r_2}^{r_1} 2\pi \mu \cdot C \cdot r \, dr$$

$$= 2\pi \mu C \int_{r_2}^{r_1} r \cdot dr$$

$$= 2\pi \mu C \left[\frac{r^2}{2}\right]_{r_2}^{r_1} = \cancel{2}\pi \mu C \left[\frac{(r_1)^2 - (r_2)^2}{\cancel{2}}\right]$$

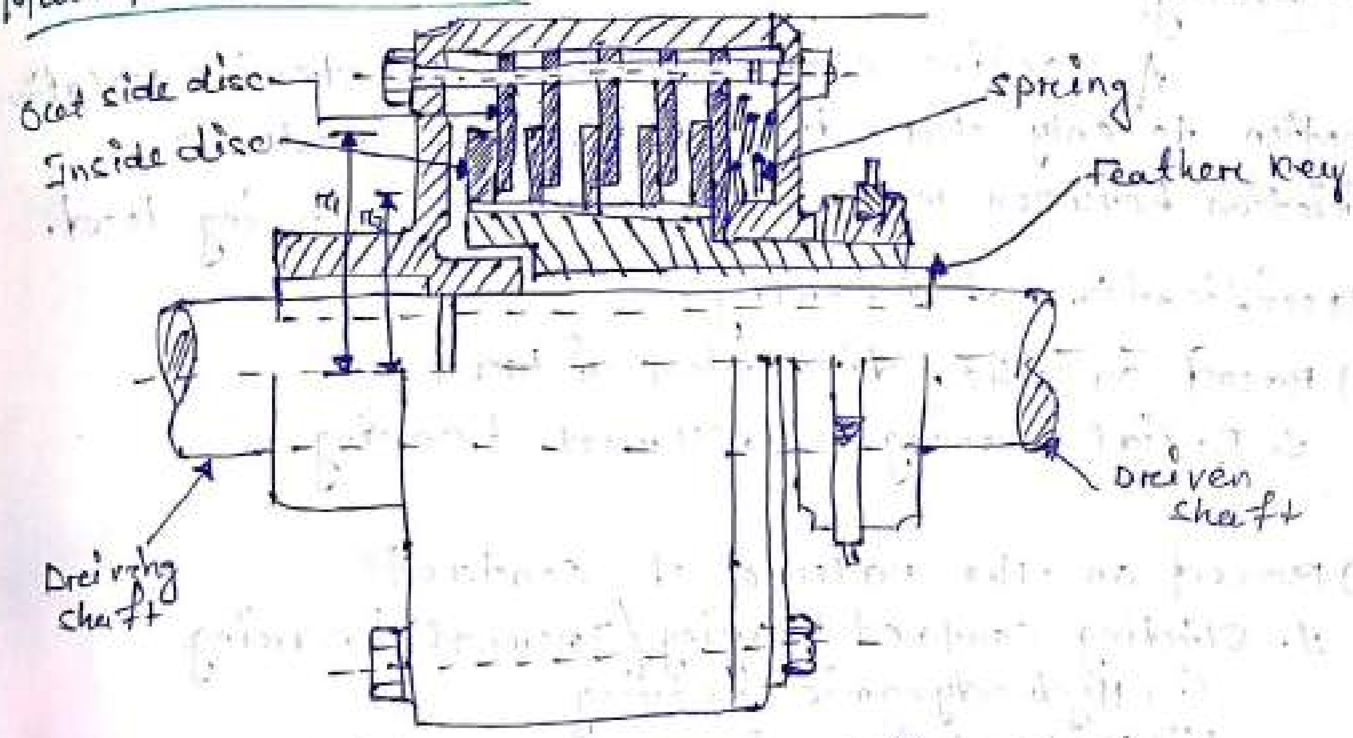
Now put the value of 'C'

$$\Rightarrow T = \cancel{\pi} \mu \times \frac{W}{2\cancel{\pi}(r_1 - r_2)} \times \left[(r_1)^2 - (r_2)^2\right]$$

$$\Rightarrow T = \frac{1}{2} \times \mu W (r_1 + r_2).$$

$$\Rightarrow T = \mu \cdot W \cdot R \quad \left[\because R = \frac{r_1 + r_2}{2}\right]$$

Multiple Disc Clutch



[Multiple Disc clutch]

- When large torque is to be ~~used~~ transmitted then the multiple disc clutch is used.
- The inside disc is usually of steel & the outside disc is bronze.
- The inside discs are fastened to the driven shaft & the outside discs is fastened to the driving shaft.
- This clutches are used in motor cars, machine tools etc.

Let n_1 & n_2 = No. of discs on the driving & driven shaft.

∴ No. of pairs of contact surfaces $(n) = n_1 + n_2 - 1$

& Total frictional torque acting on the friction surfaces or on the clutch,

$$\boxed{T = n \cdot \mu \cdot W \cdot R}$$

Bearing:-

A machine element that constrains relative motion to only the desired motion & reduces friction between moving parts while carrying load.

Classification of bearing

(a) Based on the direction of load
1. Radial bearing 2. Thrust bearing.

(b) Based on the nature of contact
1. Sliding contact bearing / Journal bearing
(i) Hydrodynamic bearing
(ii) Hydrostatic bearing.

2. Rolling contact bearing
(i) Ball bearing
(ii) Roller bearing

Hydrodynamic bearing:-

It's a lubricated journal bearing that uses fluid, liquid or gas lubricants to separate the moving surface completely without an external pressure supply.

Hydrostatic bearing:-

→ It's also called externally pressurized lubrication in which the pressurized lubricant poured into clearance of bearing & Journal hence it can support higher load even at stationary conditions with very low starting friction resulting very low tear & wear.

→ They are very expensive.

Rolling Contact bearing:-

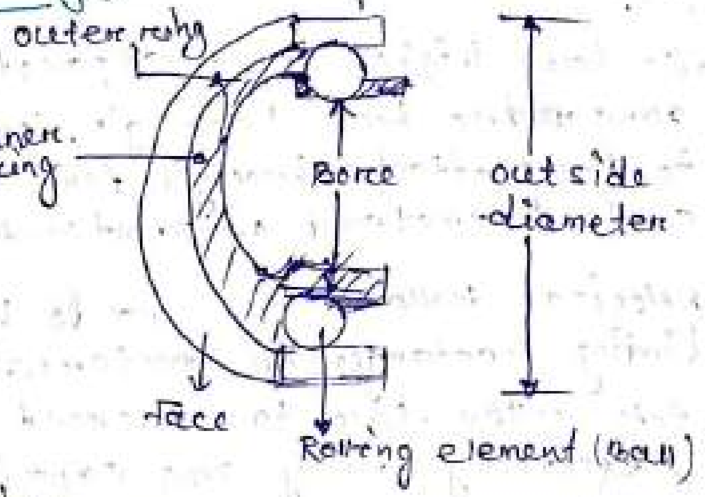
→ It's also called anti friction bearings.

→ The load, speed & operating viscosity of the lubricant affect the friction characteristics of rolling bearing.

→ These bearing provides μ between 0.001 & 0.002.

→ It's generally 2 types (a) Ball bearing
(b) Roller bearing.

Construction of bearing:-



→ Roller contact bearing with it's parts shown in figure.

→ Ball bearing is 3 types
1. Deep groove bearing
2. Filling notch bearing
3. Angular contact bearing.

→ Roller bearing is 4 types
1. Cylindrical bearing
2. Needle bearing
(3) Tapered "
4. Spherical "

Ball bearing

1. Deep groove bearing

→ It's a single row of deep groove ball bearing can combination of radial & thrust load.

→ Load capacity is limited by the no. of balls.

→ Primarily designed to support radial loads, the thrust capacity is about 70% of radial load capacity

2. Angular contact ball bearing

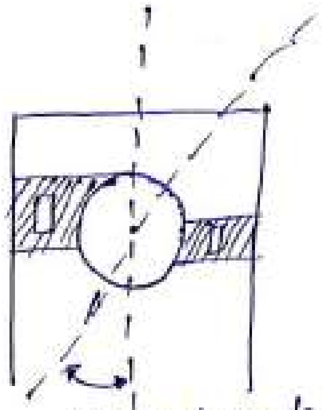
→ The centreline of contact between the ball & the race-way is at an angle to the plane perpendicular to the axis of rotation.

→ Used for high radial & thrust load application.

(68)

Roller bearing

→ It have higher load capacity compared to ball bearing's, load is transmitted through line contact instead of point contact.



Contact angle
(Angular Contact ball bearing)

→ Helical rollers are made by binding rectangular material into roller. Due to inherent flexibility they are capable of taking considerable misalignment.

→ A roller with length much larger than diameter is known as needle roller & are used where radial space is limited. Cases may be absent in needle roller bearing.

→ In needle roller bearing instead of roller we are attached needle shape rolling element only.

→ Needle roller bearing is used for less load capacity compared to roller bearing.

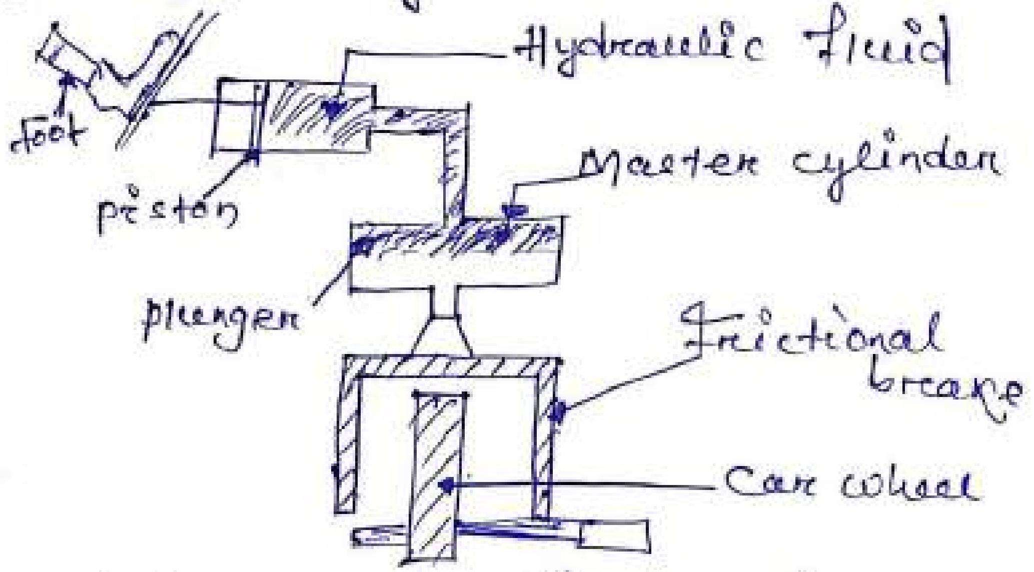
* Working of simple frictional brakes

→ To stop a moving vehicle or object we need to pressing with your foot to the brake but the foot would not generate enough force to apply all four brakes, thats why brakes are (a) Hydraulic (b) Pneumatics type.

→ In hydraulic brake we use fluid/liquid & in pneumatic brakes we use air as a pressing agent.

→ When you press on the brake pedal your foot moves a lever that forces a piston into a long, narrow cylinder ~~fluid~~ filled with hydraulic fluid.

→ As piston plunger into cylinder, the hydraulic fluid out through a long & narrow pipe at the end that push the frictional brake driven to stop the vehicle immidiately.



→ In this figure it's a hydraulic braking system, in case of pneumatic breaking system we used air instead of hydraulic fluid.

* Working of Absorption type of dynamometer :-

→ This type of dynamometers measures & absorb the power output of the engine to which they are coupled.

→ The power absorbed is usually dissipated as heat by some means.

→ In the absorption dynamometers, the entire energy or power produced by the engine is absorbed by the friction resistances of the brake & is transformed into heat, during the process of measurement.

CH-3 POWER TRANSMISSION

Types of drive

Belt drive :-

The amount of power transmitted depends upon following factors ;

1. Velocity of belt
2. Tension under which the belt & smaller pulley
3. Arc of contact between belt & " "
4. Condition under which belt is used.

* Selection of belt drive

1. Speed of driving & driven shaft.
2. Speed reduction ratio.
3. Power to be transmitted.
4. Centre distance between the shaft
5. Positive drive requirement.
6. Shaft law out.
7. Space available.
8. Service condition.

* Types of belt drive

1. Light belt drive :- Transmit small power, speed upto 10 m/s.
   Ex:- Agricultural machine.
2. Medium belt drive :- speed 10 m/s to 22 m/s.
   Ex:- machine tool.
3. Heavy belt drive :- > 22 m/s.
   Ex:- Heavy machining, Compressor & Generators

* Types of belt

1. Flat belt :-
   - → It is mostly used in factories & workshop.
   - → Where medium amount of power to be transmitted.

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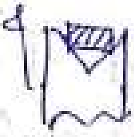
2. V-belt :-

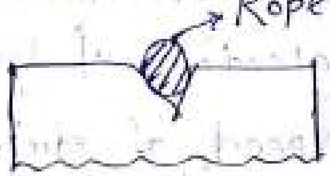
→ It is mostly used in factory & workshop where distance must be less.



3. Circular-belt / Rope belt :-

→ It is mostly used in factories & workshop only where great amount of power is transmitted.

→ In this type of belt distance between the shaft is more than 8 m.



→ If large amount of power is transmitted, than a single belt may not be sufficient.

→ In v-belts or circular belts no. of grooves are used then required amount of power is provide.

4. Balata

→ This belt is similar to rubber belt balata gum is used in the place of ~~bur~~ rubber.

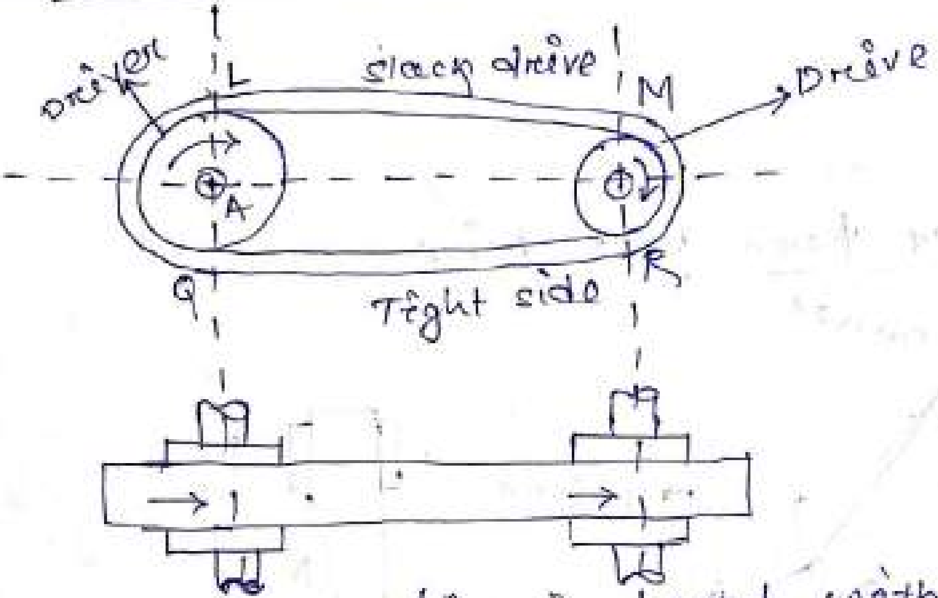
→ This belt are acid & water proof.

→ Balata belt shouldn't be used temp. above 40°. because at this temp. the balata begins to soften & become sticky.

→ It's strength is 25° higher than rubber belt.

Types of flat belt drive :-

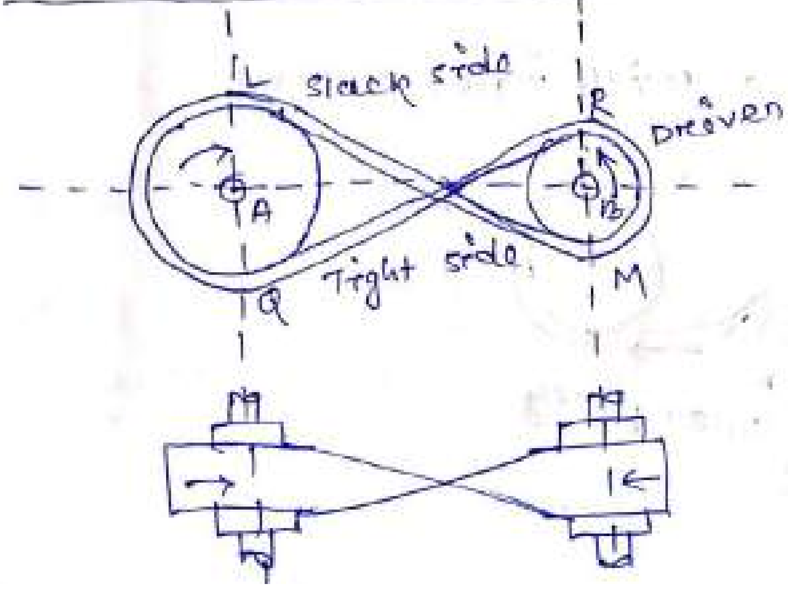
1. Open belt drive



→ The open belt drive is used with in shaft arrangement is parallel & rotating in the same direction.

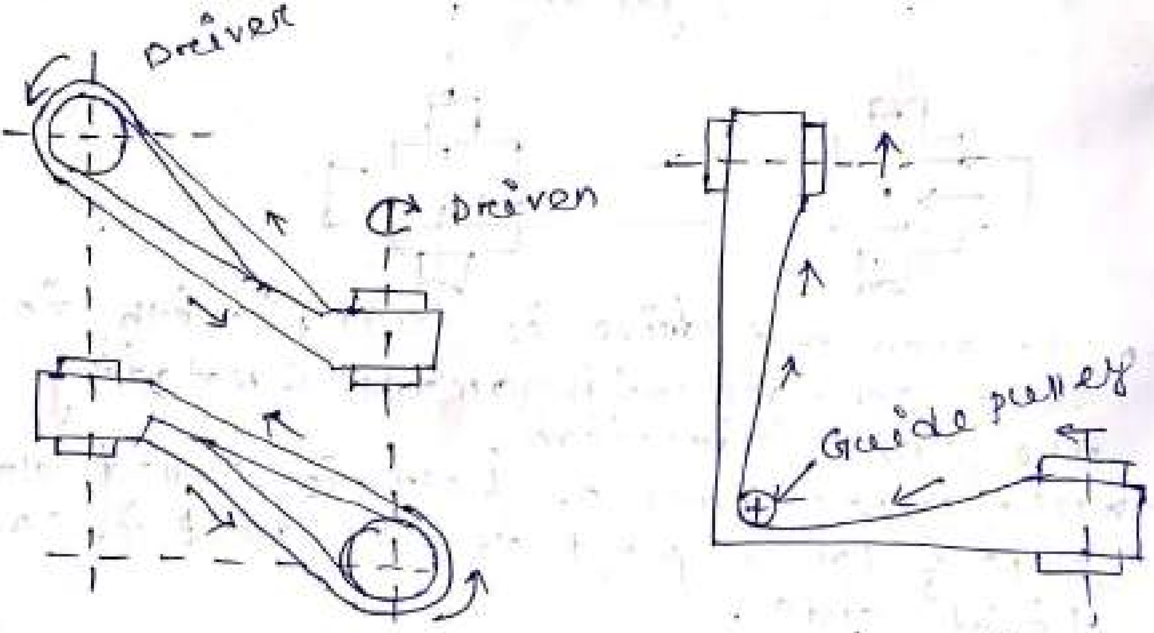
→ The upper part of belt is called slack side & lower part of the belt is called tight side.

2. Cross or twist belt drive :-



→ The cross or twist belt drive is used with shaft arranged in parallel & rotating in the opposite direction.

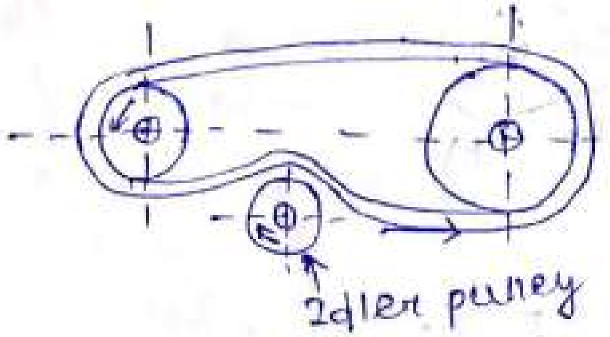
3. Quater turn belt drive

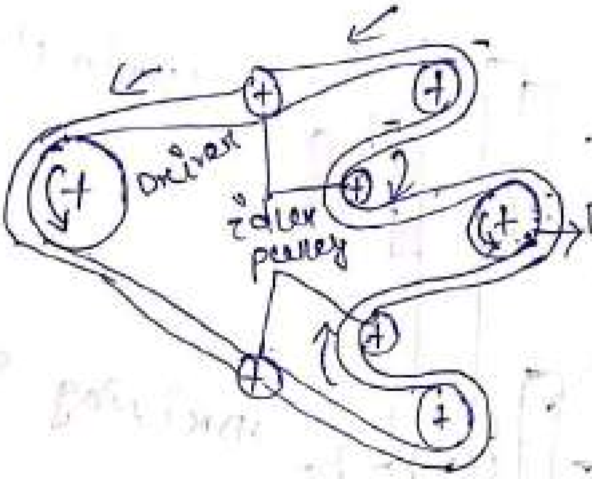


→ This belt drive is also called right angle belt drive.

→ This is used where the shaft arranged in right angles with each other & rotating in one definite direction.

4. Belt drive with idler pulleys

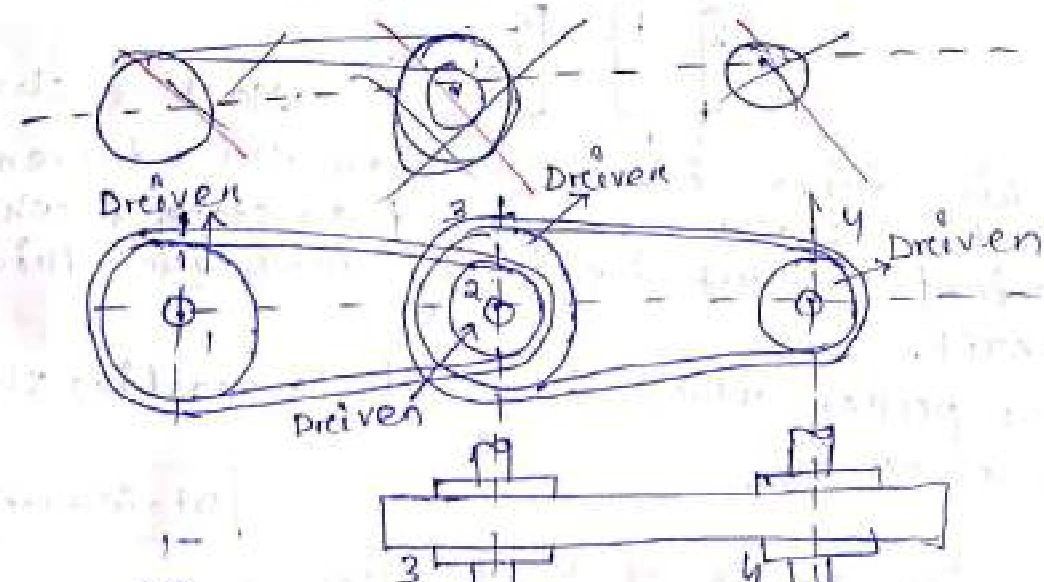




→ This belt belt drive with idler pulley is used with shaft arranged in parallel & when an open belt drive can't be used when small angle of contact on the smaller pulley.

→ This type of drive is provided to obtain higher velocity ratio & when the required belt tension can't be obtain.

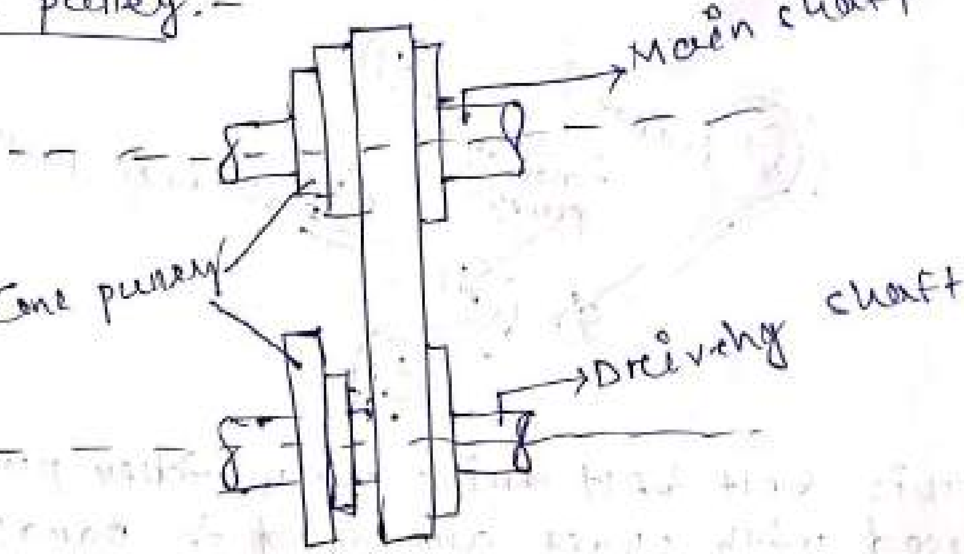
5. Compound belt drive:-



→ When power transmitted through more number of pulley is called compound belt drive.

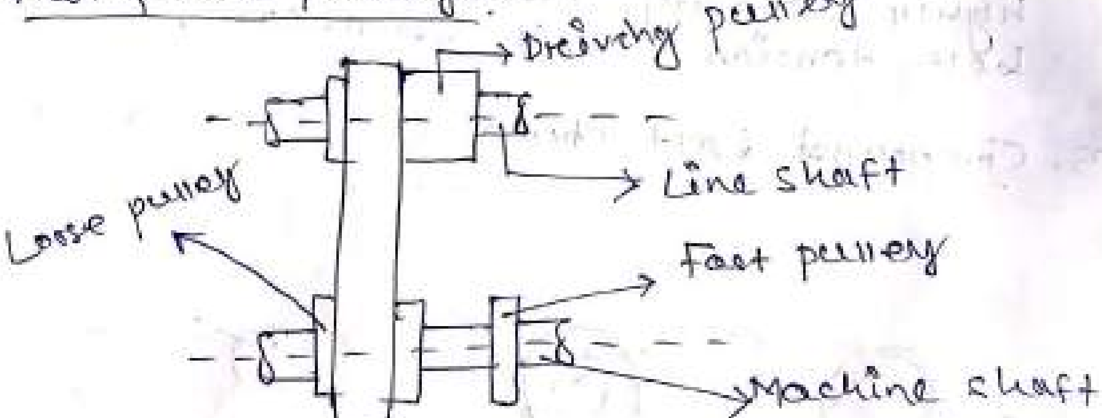
(27)

6. Cone pulley:-



→ This type of pulley is basically used to change the speed reduction ratio in automobiles.

7. Fast & loose pulley:-



→ This drive is used when the driven & machine shaft is started or stopped whenever desired without interfering with the driving shaft.

→ The pulley which is used to machine shaft fast pulley.

Dt- 27.1.20

Velocity ratio of belt drive

It's the ratio between driver & follower or driven.

Let d_1, d_2 = Diameter of driver & driven.
N_1, N_2 = speed of driver & driven.

Length of belt passes over driver in 1 minute $= \pi d_1 N_1$

similarly length of the belt passes over driven in 1 minute $= \pi d_2 N_2$

since the length of the belt passes over driver in 1 minute is equal to length of the belt passes over the driven $\pi d_1 N_1 = \pi d_2 N_2$

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

If thickness of the belt is consider then velocity ratio will be

$$\boxed{\frac{N_2}{N_1} = \frac{d_1 + t}{d_2 + t}} \quad \left[\because t = \text{thickness of the belt}\right]$$

VR of a compound belt drive

Let d_1 = Diameter of the pulley
N_1 = speed of the pulley in 1 rpm.
d_2, d_3, d_4 & N_2, N_3, N_4 = Corresponding values for pulleys 2, 3 & 4

We know that velocity ratio of pulley 1 & 2.

$$\frac{N_2}{N_1} = \frac{d_1}{d_2} \quad \text{—(i)}$$

similarly velocity ratio of pulley 3 & 4.

$$\frac{N_4}{N_3} = \frac{d_3}{d_4} \quad \text{—(ii)}$$

Multiplying eqn —(i) & (ii)

$$\frac{N_2}{N_1} \times \frac{N_4}{N_3} = \frac{d_1}{d_2} \times \frac{d_3}{d_4} \quad \left[\because N_2 = N_3 \text{ being keyed to the same shaft}\right]$$

A little consideration will show, that if there are six pulleys, then $\frac{N_6}{N_1} = \frac{d_1 \times d_3 \times d_5}{d_2 \times d_4 \times d_6}$

$$\frac{\text{speed of last driven}}{\text{speed of first driven}} = \frac{\text{Product of diameters of driver}}{\text{Products of diameters of driven}}$$

(24) Dt - 31.1.20

Slip of belt

If the frictional grip of the belt will decrease during some time of rotation around the pulley it creats less tension so that slip occurs.

Let, $s_1\%$ = slip between driver & the belt.
$s_2\%$ = slip between belt & the driven

velocity of the belt passing over the driver per sec = $v = \frac{\pi d_1 N_1}{60} - \frac{\pi d_1 N_1}{60} \times s_1\%$

$$\Rightarrow \boxed{v = \frac{\pi d_1 N_1}{60}(1 - s_1\%)} \quad \text{—— (i)}$$

$$\boxed{s_1\% = \frac{s_1}{100}}$$

Velocity of the belt passing over the driven are follows per second, ~~$v = \frac{\pi d_2 N_2}{60} - \left[\frac{\pi d_1 N_1}{60} - s_1\right]$~~

$$v_2 = v - [v \times s_2\%] \quad \text{—— (ii)}$$

$$\Rightarrow \frac{\pi d_2 N_2}{60} = \begin{bmatrix}\text{velocity of} \\ \text{driver} \\ \text{after slip}\end{bmatrix} - \begin{bmatrix}\text{velocity of} \\ \text{driver at to} \\ \times s_2\% \text{ slip}\end{bmatrix}$$

substituting the value of 'v' in eq^n —(ii)

$$\Rightarrow v_2 = \frac{\pi d_1 N_1}{60}(1 - s_1\%) - \left[\frac{\pi d_1 N_1}{60}(1 - s_1\%) \times s_2\%\right]$$

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

$$\Rightarrow \frac{N_2}{N_1} = \frac{d_1}{d_2}(1 - s_1\% - s_2\%)$$

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

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

If thickness of the belt is consider then we can write

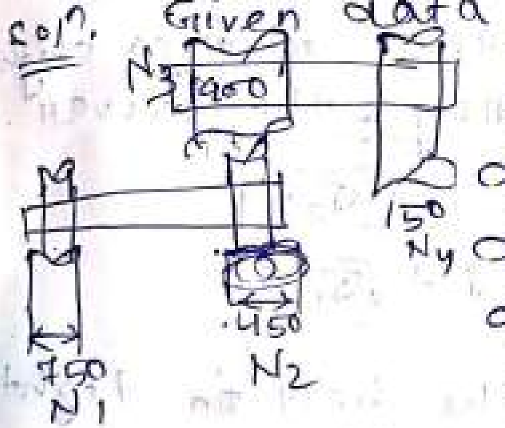
$$\Rightarrow \boxed{\frac{N_2}{N_1} = \frac{d_1 + t}{d_2 + t}\left(1 - \frac{s}{100}\right)}$$

Q. An engine running at 150 rpm drives a line shaft by using a belt the engine pulley is 750 mm diameter & the pulley on the shaft being 450mm, A 900mm diameter pulley on the line shaft drives a 150mm diameter pulley keep to a dynamo shaft. Find speed of a dynamo shaft.

(i) when their is no slip.

(ii) Their is a slip of 2% at each drive.

Soln. Given data



$N_1 = 150$ rpm

$d_1 = 750$ mm

$d_2 = 450$ mm

$d_3 = 900$ mm

$d_4 = 150$ mm

$N_4 = ?$ (speed of dynamo)

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

$$\text{(i)} \Rightarrow N_4 = \frac{d_1 \times d_3 \times N_1}{d_2 \times d_4} = \frac{750 \times 900 \times 150}{450 \times 150}$$

$$= 1500 \text{ rpm}$$

(ii) When their is a slip of 2% at each drive

$$\frac{N_4}{N_1} = \frac{d_1}{d_2} \times \frac{d_3}{d_4} (1 - S_1\%)(1 - S_2\%)$$

$$\Rightarrow N_4 = \frac{d_1 \times d_3 \times N_1}{d_2 \times d_4} \times (1 - S_1\%)(1 - S_2\%)$$

$$= 1500 \times (0.98 \times 0.98)$$

$$= 1440.6 \text{ rpm}$$

Creep of a belt

- When the belt passes from the slack side to the tight side a certain portion of the belt extend & contracts again when the belt passes from tight side to slack side, due to this changes of length their is a relative motion beth the belt & pulley surface. This relative motion is called creep.

- The total effect of creep reduce slightly the speed of driven pulley & the driver.

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

σ_1 & σ_2 = stress in the belt on tight side & slack side

E = Youngs Modulus.

Home work

Q. The power is transmitted from the pulley 1m diameter running at 200 rpm to a pulley 2.25m diameter by means of belt. Find the speed lost by the driven pulley as a result of creep. If the stress on tight & slack side is 1.4 mpa. & 0.5 mpa. the young's Modulus of the material is 100 mpa.

Soln Given data.

$d_1 = 1\ m$, $N_1 = 200\ rpm$, $d_2 = 2.25\ m$,

$\sigma_1 = 1.4\ mpa = 1.4 \times 10^6\ N/m^2$, $\sigma_2 = 0.5\ mpa = 0.5 \times 10^6\ N/m^2$

$E = 100\ mpa = 100 \times 10^6\ N/m^2$.

$N_2 = ?$

For without creep

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

$$\Rightarrow N_2 = \frac{d_1 N_1}{d_2} = \frac{1 \times 200}{2.25} = 88.8\ rpm$$

With creep we know that

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

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

$$= 88.8 \times \frac{(100\times10^6)+\sqrt{0.5\times10^6}}{(100\times10^6)+\sqrt{1.4\times10^6}}$$

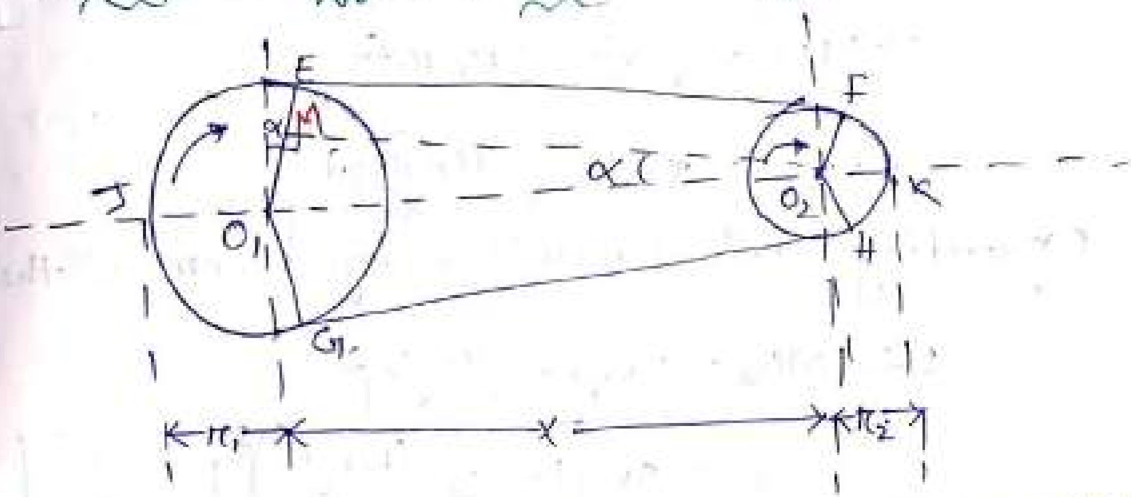
$$= 88.79 \text{ rpm}$$

So speed lost by driven pulley due to creep is $88.88 - 88.79 = 0.01$ rpm.

Imp for internal

Dt - 3.2.20

Length of an open belt drive



Let, r_1 & r_2 = Radius of larger & smaller pulley.
x = Distance between the centre of two pulley.
L = Length of the open belt drive.

Let the belt leaves the larger pulley at E & G & smaller pulley F & H.
Through O_2 draw O_2M which is parallel to FE.

Let $MO_2O_1 = \alpha$ radian
we know that length of open belt drive

$$L = \text{Arc } GJE + FE + \text{Arc } FKH + HG$$

$$* \Rightarrow L = 2(\text{Arc } JE + \text{Arc } FK + EF) \quad \text{— (A)}$$

(28)

From geometry of fig. we find that

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

since α value is very small ~~we neglecting~~ so, that we can put. $\sin\alpha = \alpha = \frac{r_1 - r_2}{x}$

$$\text{Arc JE value} = r_1\left(\frac{\pi}{2}+\alpha\right) = r_1\left(90^\circ+\alpha\right) \quad \text{—(i)}$$

$$\text{Arc FK} = r_2\left(\frac{\pi}{2}-\alpha\right) = r_2\left(90^\circ-\alpha\right) \quad \text{—(ii)}$$

$EF = MO_2$

According to train gear MO_1O_2

$$MO_2 = \sqrt{(O_1O_2)^2 - (O_1M)^2} \quad \left[\because h^2 = p^2 + b^2\right]$$

$$\Rightarrow MO_2 = \sqrt{x^2 - (r_1 - r_2)^2}$$

$$\Rightarrow MO_2 = x\sqrt{1 - \left(\frac{r_1 - r_2}{x}\right)^2}$$

Expanding this equation by binomial theor.

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

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

substituting all the value of eqn—(i), (ii) & (iii) in eqn—(A). we get.

$$\Rightarrow L = 2\left(\text{Arc JE} + \text{Arc FK} + EF\right)$$

$$= 2\left[r_1(90^\circ+\alpha) + r_2(90^\circ-\alpha) + x\left[1 - \frac{1}{2}\left(\frac{r_1-r_2}{x}\right)^2 + \cdots\right]\right]$$

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

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

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

Now substituting the value of α in this above eqn. we get

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

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

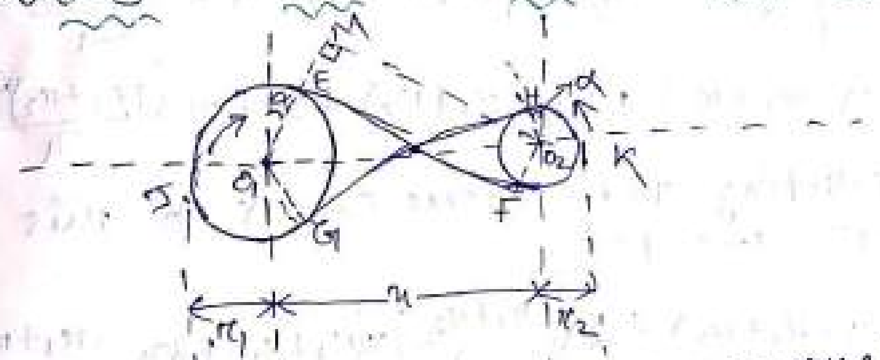
$$\Rightarrow \boxed{L = \pi(r_1+r_2) + 2x + \frac{(r_1-r_2)^2}{x}}$$ (In terms of pulley radii).

(or) $$\boxed{L = \frac{\pi}{2}(d_1+d_2) + 2x + \frac{(d_1-d_2)^2}{4x}}$$ (In terms of pulley dia.)

DT-5.2.20

IMP

Length of the cross belt drive



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

~~α~~ ~~Let~~ from geometry of fig. $\sin\alpha = \frac{O_1M}{O_1O_2}$

$$\Delta MO_1O_2 = \frac{O_1E + EM}{O_1O_2} = \frac{r_1+r_2}{x}$$

for $\sin\alpha$ value is very small, so that we can put $\sin\alpha = \alpha = \frac{r_1+r_2}{x}$

$$\text{Arc } JE = r_1\left(\frac{\pi}{2}+\alpha\right) \quad \text{—(ii)}$$

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

$EF = MO_2$

According to pythogoreas theorem. $\because h^2 = p^2 + b^2 \Rightarrow b = \sqrt{h^2 - p^2}$

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

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

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

Expanding the eqn-(iv) by binomial them.

$$EF = MO_2 = x\sqrt{1 - \left(\frac{r_1+r_2}{x}\right)^2}$$

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

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

Putting as the value of eqn (ii), (iii) & (v) in we get.

$$\Rightarrow L = 2\left(\text{Arc JE} + \text{EF} + \text{Arc FK}\right)$$

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

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

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

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

Now substituting the value of α in this above eqn. we get.

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

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

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

or

$$\boxed{L = \frac{\pi}{2}(d_1+d_2) + \frac{(d_1+d_2)^2}{4x} + 2x}$$

Power transmitted by belt :-

Let T_1 & T_2 are the tensions on in tight side & slack side respectively.

r_1 & r_2 are the radices of driver & driven pulley respectively.

v = velocity of the belt in m/s.

The effective turning force are the the circumference of the driven pulley is $(T_1 - T_2)$.

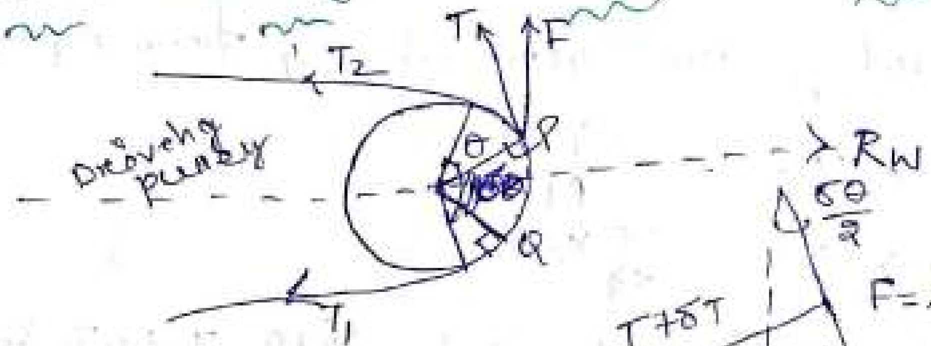
Workdone/sec $= \boxed{W = v \times (T_1 - T_2)}$ N×m.

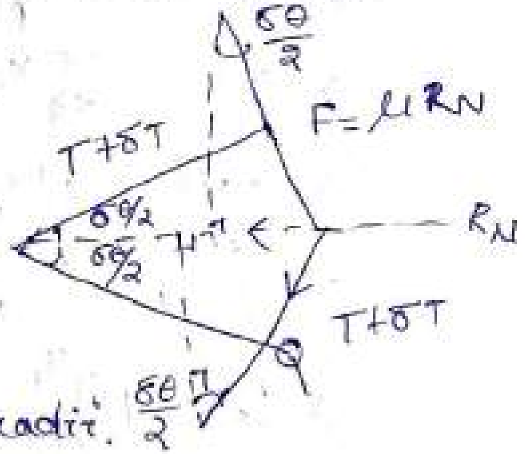
$$\boxed{P = \frac{W.D}{time} = v \times (T_1 - T_2)} \text{ watt}$$

V. V. I

Dt-7.2.20

Ratio of driving tension for flat belt drive





Let T_1 & T_2 = Tension for tight side & slack side.

θ = Angle of contact in radii.

1. Tension T in the belt at P
2. Tension $(T + \delta T)$ in the belt at Q
3. Normal Reaction (R_N)
4. $F = \mu R_N$ (frictional force)

$\sin\frac{\delta\theta}{2} = \frac{R_N}{T + \delta T}$

$\Rightarrow R_N = (T + \delta T) \times \sin\frac{\delta\theta}{2}$

Resolving all the forces horizontally

$$R_N = (T + \delta T)\sin\frac{\delta\theta}{2} + T\sin\frac{\delta\theta}{2} \quad \text{--- (1)}$$

since $\delta\theta$ is very small, therefore putting

$\sin\frac{\delta\theta}{2} = \frac{\delta\theta}{2}$ in eqn (1)

$$\Rightarrow R_N = (T + \delta T)\frac{\delta\theta}{2} + T \times \frac{\delta\theta}{2} = T \times \frac{\delta\theta}{2} + \delta T \times \frac{\delta\theta}{2} + T\frac{\delta\theta}{2}$$

$$\Rightarrow \boxed{R_N = T\delta\theta} \quad \text{--- (2)} \quad \left[\because \text{Neglecting the value } \frac{\delta T \times \delta\theta}{2}\right]$$

~~S R T~~

(2)

Now Resolving all the forces vertically

$$\mu R_N = (T+\delta T) \times \cos\frac{\delta\theta}{2} - T\cos\frac{\delta\theta}{2} \quad \text{--- (3)}$$

Since $\delta\theta$ is very small i.e. $\cos\frac{\delta\theta}{2} = 1$ in eqn (3)

$$\Rightarrow \mu R_N = (T+\delta T) - T = \delta T$$

$$\cancel{= T\frac{\delta\theta}{2} + \delta T\frac{\delta\theta}{2} - T\frac{\delta\theta}{2}}$$

$$\Rightarrow \boxed{R_N = \frac{\delta T}{\mu}} \quad \text{--- (4)} \quad \left[\cancel{\text{Neglecting } \delta T \times \frac{\delta\theta}{2}}\right.$$

Equating the value of R_N from eqn - 2 & 4

$$\Rightarrow T\delta\theta = \frac{\delta T}{\mu}$$

$$\Rightarrow \frac{\delta T}{T} = \delta\theta \times \mu$$

Intigrating the both side T_2 to T_1 & 0 to θ

$$\Rightarrow \int_{T_2}^{T_1} \frac{\delta T}{T} = \int_0^{\theta} \mu\, \delta\theta$$

$$\Rightarrow \left[\log_e T\right]_{T_2}^{T_1} = \mu\left[\theta\right]_0^{\theta}$$

$$\Rightarrow \log_e T_1 - \log_e T_2 = \mu(\theta - 0)$$

$$\Rightarrow \boxed{\log_e\left(\frac{T_1}{T_2}\right) = \mu\theta} \quad \text{V.V.I}$$

$$\Rightarrow \boxed{\frac{T_1}{T_2} = e^{\mu\theta}} \quad \text{V.V.I}$$

Q. Find the power transmitted by a belt running over a pulley of 600 mm dia. at 200 rpm. The co-efficient of friction betn the belt & pulley 0.25, the angle of lap is 160° & maximum tension in the belt is 2500N.

Soln Given data:-

$D = 600\text{ mm} = 0.6\text{ m}$

$N = 200\text{ rpm}$

$\mu = 0.25$

$\theta = 160° = 2.79\text{ radi.}$

$T_1 = T_{max} = 2500\text{ N}$

$$\boxed{v = \frac{\pi D N}{60}} = \frac{\pi \times 0.6 \times 200}{60} = 6.28 \text{ m/s}$$

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

$$\Rightarrow T_2 = \frac{T_1}{e^{\mu\theta}} = \frac{2500}{e^{0.25 \times 2.79}} = 1244.57 \text{ N}$$

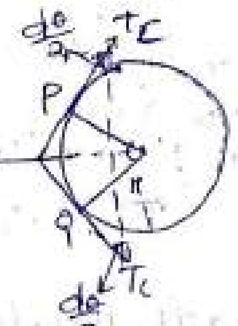
$$\therefore P = v \cdot (T_1 - T_2) = 6.28(2500 - 1244.57)$$
$$= 7884.1 \text{ W}$$
$$= 7.8 \text{ kW}.$$

Centrifugal tension

Force → centre — Centripetal; Force ← centre — centrifugal

→ Since the belt continuously run over the pulley therefore some centrifugal force is caused. Whose effect is to increase the tension on both the tight side & slack side. The tension caused by the centrifugal force is called centrifugal tension.

→ At lower belt speed i.e. less than 10 m/s the centrifugal forces is very small.



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 runs in meters, and

T_c = centrifugal tension acting tangentially at P & Q in newton (N).

We know that length of the belt PQ
$= r \cdot d\theta$
$= m \cdot r \cdot d\theta$.

and mass of belt PQ

$\therefore$ centrifugal force acting on the belt PQ

$$\boxed{F_C = (m \cdot r\, d\theta)\frac{v^2}{r} = m \cdot d\theta \cdot v^2}$$

(34)

DT-11.2.20

The centrifugal Tension T_c is acting tangential at P & Q keeps the belt equilibrium.

Equating the forces horizontally

$$T_c \sin\left(\frac{d\theta}{2}\right) + T_c \sin\left(\frac{d\theta}{2}\right) = F_C = m\, d\theta\, v^2$$

since $\sin\frac{d\theta}{2}$ is very small so we write

$\sin\frac{d\theta}{2} = \frac{d\theta}{2}$

$$\Rightarrow T_c \cdot \frac{d\theta}{2} + T_c \cdot \frac{d\theta}{2} = m\, d\theta\, v^2$$

$$\Rightarrow \frac{\cancel{2} \times T_c \cancel{d\theta}}{\cancel{2}} = m \cancel{d\theta} v^2$$

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

Maximum tension in the belt

Let σ = Maximum shear stress in N/mm^2

b = Width of the belt in mm.

t = Thickness of the belt in mm

Maximum tension (T) = Maximum stress × area of belt

$\Rightarrow \boxed{T = T_1 + T_C}$ (when centrifugal tension is given)

$\Rightarrow \boxed{T_{max} = T_1}$ (when their is no T_c)

$\Rightarrow \boxed{T_{max} = \sigma \times bt}$

Maximum power transmission condition

$\boxed{T = 3 \times T_C}$

V.V.I.
for Internal

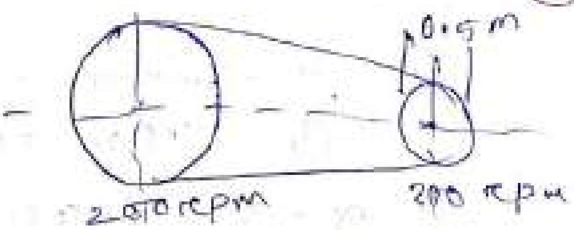
Q. The shaft rotating at 200 rpm drive another shaft at 300 rpm & transmit 6kw through a belt. The belt is 100 mm ~~length~~ wide & 10 mm thick distance between the shaft is 4m. smaller pulley is 0.5m in diameter. Calculate the stress in the belt. If in the belt

1. open belt drive
2. cross-belt drive

$\mu = 0.3$.

Scanned with CamScanner

Soln. Given data.



$P = 6 kW$
$= 6 \times 10^3 W$
$b = 150 mm$
$t = 10 mm$
$x(or) l = 4 m$
$N_1 = 200 rpm$
$N_2 = 300 r.p.m.$
$\mu = 0.3$
$d_2 = 0.5 m$

1. The stress in belt for open belt drive
we know that

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

$$\Rightarrow d_1 = \frac{d_2 N_2}{N_1} = \frac{0.5 \times 300}{200} = 0.75 m$$

Now velocity of the belt (v)

$$v = \frac{\pi d_2 N_2}{60} = \frac{\pi \times 0.5 \times 300}{60} = 7.853 m/s$$

we know for an open belt drive

$$\sin\alpha = \frac{r_1 - r_2}{x} = \frac{\frac{d_1}{2} - \frac{d_2}{2}}{x}$$

$$= \frac{d_1 - d_2}{2x} = \frac{0.75 - 0.5}{2 \times 4} = 0.031$$

$$\Rightarrow \alpha = \sin^{-1}(0.031) = 1.776^\circ$$

Angle of contact $(\theta) = 180^\circ - 2\alpha$
$= 180^\circ - (2 \times 1.776^\circ)$
$= 176.448^\circ$
$= 176.448 \times \frac{\pi}{180} = 3.079$ rad.

we know that

$$\frac{T_1}{T_2} = e^{\mu\theta} = e^{0.3 \times 3.079} = 2.51 \quad \text{—(i)}$$

Also we know that

$$P = (T_1 - T_2) v \Rightarrow 6 \times 10^3 = (T_1 - T_2)\, 7.853$$

$$\Rightarrow T_1 - T_2 = \frac{6 \times 10^3}{7.853} = 764.039 N \quad \text{—(ii)}$$

~~Now equating~~ from eq^n (i) & (ii)

$$2.51 T_2 - T_2 = 764.039 \Rightarrow 1.51 T_2 = 764.039$$

$$\Rightarrow T_2 = \frac{764.039}{1.51} = 505.986 N$$

$$\& T_1 = 764.039 + 505.986 = 1270.025 N$$

$$\Rightarrow T_{max} = \sigma \times bt$$

$$\therefore \sigma = \frac{T_{max}}{bt} = \frac{1270.025}{0.1 \times 0.01} = 1270025 N/m^2$$

$= 1.270 N/mm^2$
$= 1.270 MPa.$

(26) Initial tension in the belt

Let, T_0 = Initial tension in the belt
T_1 & T_2 = Tension in the belt on tight side & slack side
α = Coefficient of increase in belt lenth per force.

$$\boxed{T_0 = \frac{T_1 + T_2}{2}}$$ (Neglecting centrifugal tension)

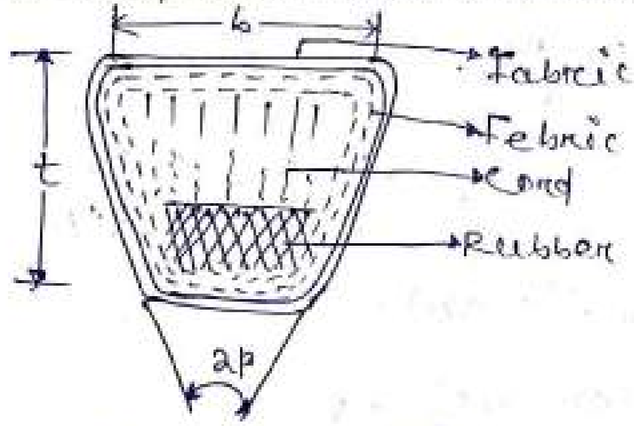
$$\Rightarrow \boxed{T_0 = \frac{T_1 + T_2 + 2T_c}{2}}$$ (Considering T_c)

* V belt

Dt-12.2.20

→ The v-belt are made of fabric and cords moulded in rubber and covered with fabric and rubber.

→ These belts are moulded to a trapezoidal shape and are made endless.



Cross-section of v-belt

Advantages.

(1) The v-belt drive gives compactness due to small distance between the centres of pulleys.

(2) The drive is positive, because the slip between the belt and the pulley groove is negligible.

(3) Since the v-belts are made endless and there is no joint trouble, therefore the drive is smooth

(4) It provides longer life, 3 to 5 years.

(5) It can be easily installed and removed.

(6) The operation of the belt & pulley is quite.

(7) The belts have ability to cushion the shock when machines are started.

(8) The high velocity ratio (maximum 10) may be obtained.

Limitation

(1) V-belt drive can't be used when centre distance between the pulley is very high.

(2) These are not so durable as flat belts.

(3) Construction of v-belt pulley is very complicated.

(4) The belt drive is greatly influenced with temp. change improper belt tension & mis-matching of belt length.

(5) Centrifugal tension prevent the use of v-belts as speed of below 5 m/sec & above 50 m/sec.

* Crowning of pulley

→ This is a process of locking the pulley with belt so that the belt will turn around in a track without slip.

* Chain drive

→ In order to avoid slipping we used chain drive where it consist of chain & sprocket, so that chain is locked inside the teeth of sprocket.

→ It gives positive drive & proper velocity ratio.

→ It is used in automobiles (cycle, bike, car etc).

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(page No 25 Question Ans)

② Stress in the belt for cross belt drive

For cross belt drive.

$$\sin\alpha = \frac{r_1+r_2}{x} = \frac{d_1+d_2}{2x}$$
$$= \frac{0.75+0.5}{2\times4} = 0.156$$

$$\Rightarrow \alpha = \sin^{-1}(0.156) = 8.97^\circ \approx 9^\circ.$$

→ Angle of contact $(\theta) = 180^\circ + 2\alpha$
$$= 180^\circ + (2\times9^\circ) = 198^\circ = 198\times\frac{\pi}{180} = 3.455$$

we know that $\frac{T_1}{T_2} = e^{\mu\theta} = e^{0.3\times3.455} = 2.81$ —— (iii)

From eqn (ii) & (iii)

$$2.81T_2 - T_2 = 764.039$$
$$\Rightarrow 1.81T_2 = 764.039$$
$$\Rightarrow T_2 = \frac{764.039}{1.81} = 422.120\ N$$
$$\&\ T_1 = 2.81\times422.120 = 1186.157\ N.$$

$$T_{max} = \sigma b t$$
$$\Rightarrow \sigma = \frac{T_{max}}{b\times t} = \frac{1186.157}{0.1\times0.01} = 1186157\ N/m^2$$
$$= 1.186\ N/mm^2$$
$$= 1.186\ mpa.$$

[Dt-14.2.20]

Advantage & disadvantage of chain drive over belt or rope drive :-

Advantage :-

→ As no slip takes place during chain drive, so perfect velocity ratio obtained.

→ Since the chains are made up metal, therefore they occupy less space in width than belt or ~~chain~~ rope drive.

→ The chain drive may used when distance between the shaft ~~is~~ less.

→ The chain drive gives high transmission efficiency (upto 98%)

→ The chain drive gives less load on the shaft.

Disadvantages :-

→ It's costlier than B.D.
→ It's very complex to make.
→ It needs more skill.
→ It require more maintenance than B.D.

* Gear drive :-

→ If more than one no. of gear are attached together to transmit power from driver gear to driven gear with perfect velocity ratio we called it as gear drive.

Types of gear :-

1. Spur gear - 90° (In hobbing & milling m/c gear are made)
2. Helical " - 45°
3. Bevel " - 60
4. Herring bone gear. (combining of 2 & 3 gear)
5. Worm gear.

Advantages of gear drive

→ It transmit exact velocity ratio.
→ It may be used to transmit large power.
→ It has high efficiency.
→ It has reliable service.

Disadvantages of gear drive

→ The manufacture of gear require special tool & equipment.
→ The error in cutting teeth may cause vibration & noise during operation.

Classification of tooth wheel :- 01-12-2020

(A) According to position of axis of shaft :

(i) parallel shaft :- (spur gear)
(ii) Intersecting shaft :- (Worm & worm gear)
(iii) Non-parallel non-intersecting shaft :- (skew gear)

(B) According to peripheral velocity of gear

(i) Low velocity :- upto 3 m/s

(ii) Medium " :- (3 - 15) m/s

(iii) High " :- >15 m/s

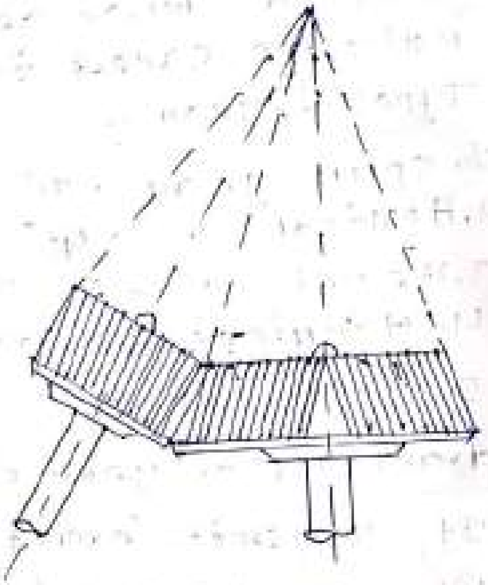
escape velocity
11.2 km/sec
to
14 km/s

(C) According to type of gear

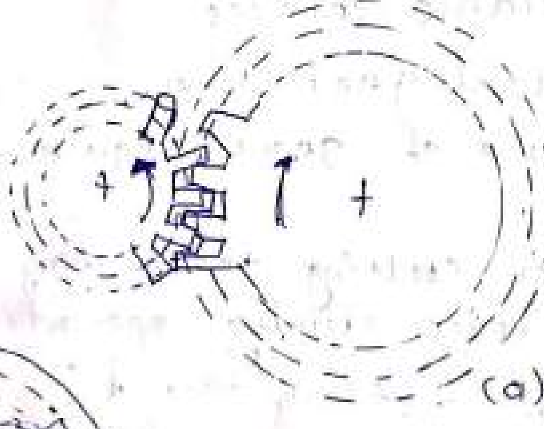
(i) External gear

(ii) Internal "

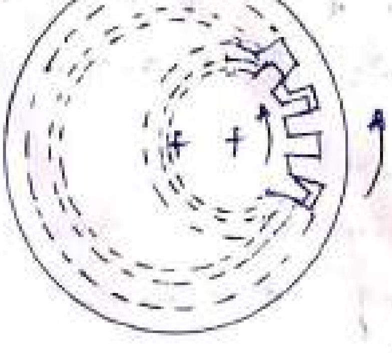
(iii) Rack & pinion "



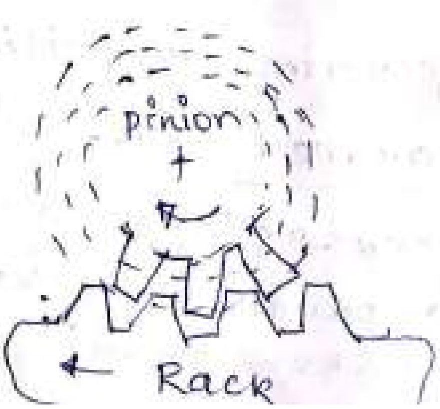
(a) single helical gear (b) Double helical gear (c) Bevel gear



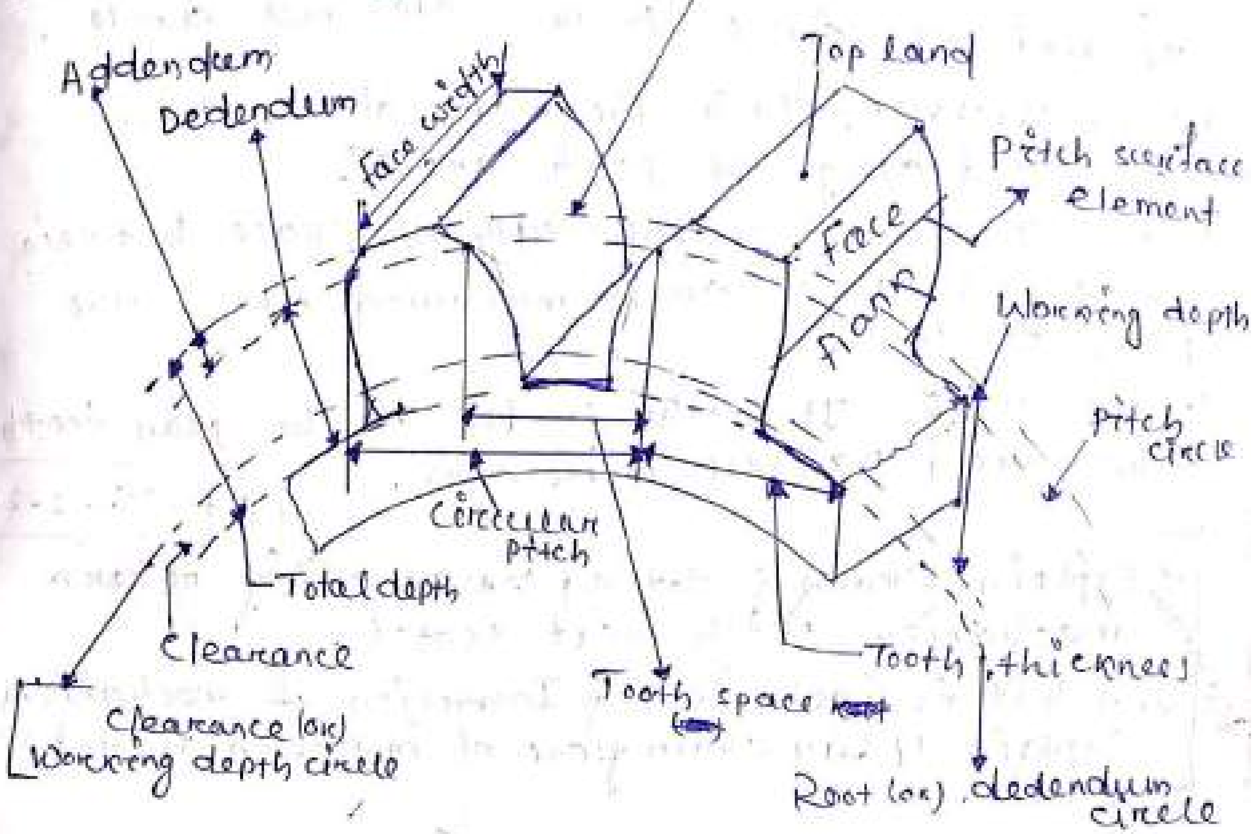
(a) External gearing



(b) Internal gearing



Gear Terminology:-



[Terms used in gears]

1. **Pitch circle:-** It is an imaginary circle which by pure rolling action, would give the same motion as the actual gear. ~~$P_c = \frac{\pi D}{T}$ (T = no of teeth) & (Pc = circular pitch)~~
2. **Pitch surface:-** It is the surface of the rolling discs which the meshing gears have replaced at the pitch circle.
3. **Addendum:-** It is the radial distance of a tooth from the pitch circle to the top of the tooth.
4. **Dedendum:-** It is the radial distance of a tooth from the pitch circle to the bottom of the tooth.
5. **Addendum circle:-** It is the circle drawn through the top of the teeth and is concentric with the pitch circle.
6. **Dedendum circle:-** It is the circle drawn through the bottom of the teeth. It is also called root circle.
7. **Clearance:-** It is the radial distance from the top of the tooth to the bottom of the tooth in a meshing gear.

→ A circle passing through the meshing gear is known as clearance circle.

8. Working depth :- It is the radial distance from the addendum circle to the clearance circle.

9. Tooth thickness :- It is the width of the tooth measured along the pitch circle.

10. Tooth space :- It is the width of space between the two adjacent teeth measured along the pitch circle.

11. Face width :- It is the width of the gear tooth measured parallel to its axis.

Dt - 26.2.21

Assignment

1. Explain crank & slotted lever quick return mechanism with neat sketch.
2. What is mechanism & Inversion of mechanism. Explain 4 bar chain & one of inversion of 4-bar chain.

12. Diametral pitch (P_d) :-

It is the ratio of no. of teeth to the pitch circle diameter. $\boxed{P_d = \frac{T}{D}} = \frac{\pi}{P_c}$

13. Circular teeth ; (P_c) :-

It is the distance measured on the circumference of the pitch circle from the point of one tooth to the corresponding on the next tooth.

$\boxed{P_c = \frac{\pi D}{T}}$ (T = no. of teeth)

14. Module (m) :-

It is the ratio of P_c diameter to the no. of teeth $\boxed{m = \frac{D}{T}}$

Gear Material :-

→ The material used for gear manufacturing depend upon strain service conditions like wear noise etc.

→ The gear may be manufactured from metal or non-metalic material depends upon our purpose of work.

→ phosporous bronze is widly used for worm gear in order to reduce wear.

→ Cast iron is widely used for manufacture of gear due to good wearing property, excelent machinability & complicated shape of casting method.

→ Non metalic gears are used to prevent the noise. [Ex:- Wood, rubber, etc.]

→ Steel is used for ~~[illegible]~~ to increase the high strain & tooth hardness.

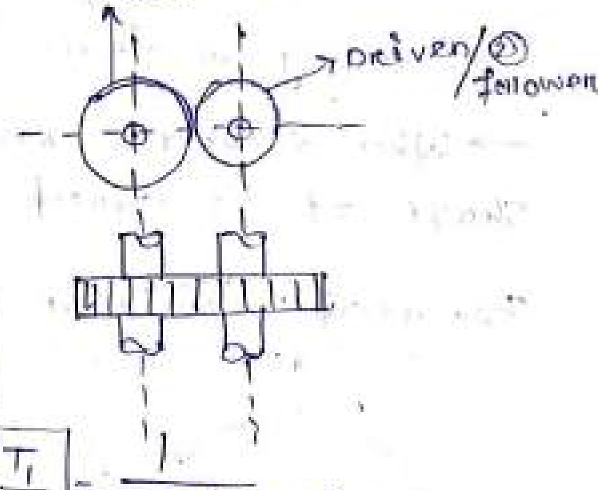
Dt - 28.2.20

Gear train :-

Some times two more than two gears are engaged to transmit power to give perfect velocity ratio is caled gear train.

Types of Gear Train

1. Simple gear train

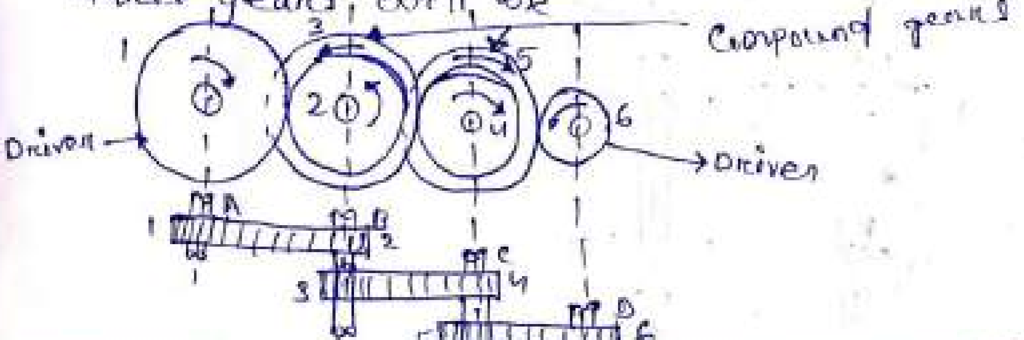


Let N_1 = Speed of gear 1
T_1 = Teeth of " "
N_2 & T_2 = speed & teeth of gear - 2.

Imp Speed ratio ⇒ $\boxed{\frac{N_1}{N_2} = \frac{T_2}{T_1}}$

Imp Train value ⇒ $\boxed{\frac{N_2}{N_1} = \frac{T_1}{T_2}} = \frac{1}{\text{speed ratio}}$

If we calculate the gear speed ratio for three gears, will be



For gear 1&2 , $\frac{N_1}{N_2} = \frac{T_2}{T_1}$ ——— (1)

For gear 2,&3 , $\frac{N_2}{N_3} = \frac{T_3}{T_2}$ ——— (2)

By multiplying eqn — (1) & (2) we get

$$\frac{N_1}{\cancel{N_2}} \times \frac{\cancel{N_2}}{N_3} = \frac{\cancel{T_2}}{T_1} \times \frac{T_3}{\cancel{T_2}}$$

$$\Rightarrow \boxed{\frac{N_1}{N_3} = \frac{T_3}{T_1}}$$

$$\text{Speed ratio} = \frac{\text{speed of driver}}{\text{speed of driven}} = \frac{\text{Teeth of driven}}{\text{Teeth of driver}}$$

Home work

Assignment

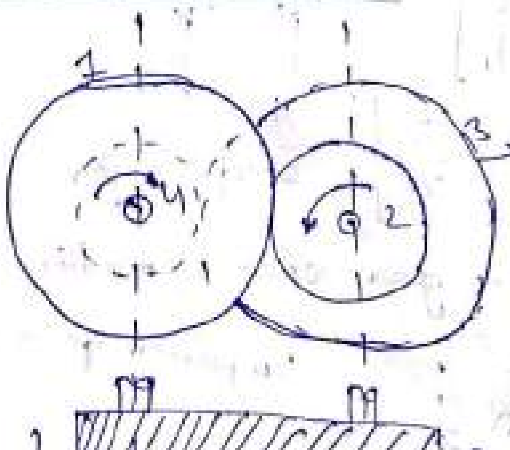
* For 8 No. of gear. Calculate speed ratio (compound gear).
* Working principle of simple gear train drive.

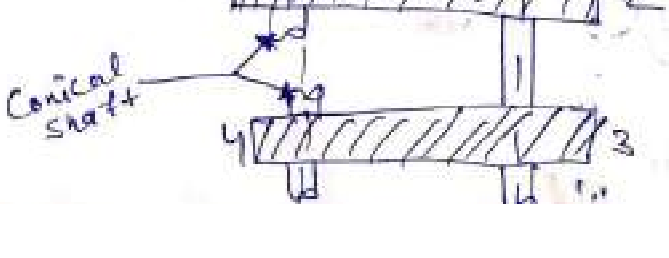
Compound gear train

→ When there are more than one gear on a shaft it is called compound gear train.

Reverted Gear Train

D+ - 3.3.20





→ When the axes of the first gear (i.e. first driver) & the last gear (i.e. driven or follower) are co-axial, then the gear train is known as reverted gear train.

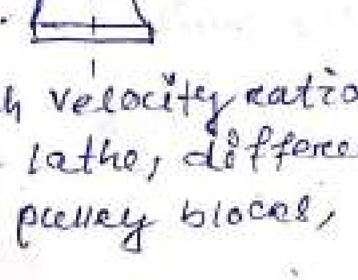
→ We see that gear 1 (i.e first driver) drives the gear 2 (i.e. first driven or follower) in the opposite direction. Since the gear 2 & 3 are mounted on the same shaft, therefore they form a compound gear & the gear 3 will rotate in the same direction as that of gear 2.

→ The gear 3 (which is now the second driver) drives the gear 4 (i.e. the last driven or follower) in the same direction as that of gear 1. Thus we see that in a reverted gear train the motion of the first gear & the last gear is like.

Epicyclic Gear Train :-

→ In an epicyclic gear train, the axes of the shafts, over which the gears are mounted, may move relative to a fixed axis. A simple epicyclic gear train as a gear A & the arm C have a common axis at O_1, about which they can rotate. The gear A & has its axis on the arm at O_2, about which the gear B can rotate.

If the arm is fixed, the gear train is simple & gear A can drive gear B or vice versa, but if gear A is fixed & the arm is rotate about the axis of 'A', then gear B is forced to rotate upon & around gear A, is called epicyclic gear train.



→ It is useful for transmitting high velocity ratios.

→ It is used in the back gear of lathe, differential gear of the automobiles, hoists, pulley blocks, wrist watches etc.

CH-4 GOVERNORS & FLYWHEEL

Function of Governor :-

It's a device which regulate the mean speed of an engine, when there are variations in the load i.e. if load of an engine increases it speed decreases therefore it's necessary to increase the supply of working fluid.

Classification of governors :-

- Governor
  - Centrifugal governors
    - Pendulum type
      - Watt governor
    - Loaded type
      - Dead Weight
        - Porter
        - Proell
          - Hartnell
          - Hartung
          - Wilson hartnell
          - Pickering
      - Spring Controlled
  - Inertia governor

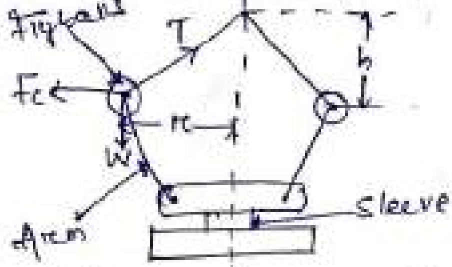
IMP

Working of Watt governor :-

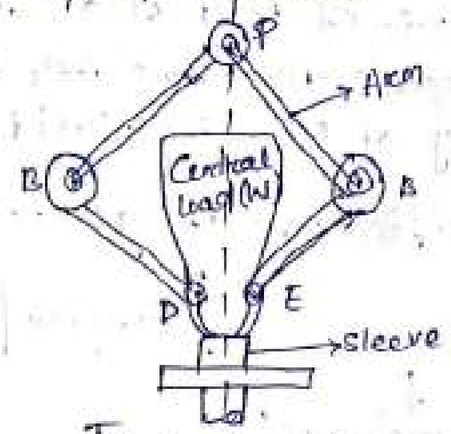
- Watt governor belongs to centrifugal governor & based on balancing of centrifugal force on the rotating balls by an equal & opposite radial force called controlling force.
- It consist of two balls of equal mass which attached to arm called as fly ball, the balls revolve with spindle which is driven by the engine bevel gears.

→ The upper end of the arms are pivoted to the spindle, so that the balls may raise up or fall down as they revolve about vertical axis.

→ The sleeve revolve with the spindle but can slide up & down. As the spindle speed increases the sleeve rise up & viceversa.



[Watt governor]



[Porter governor]

Porter governor :-

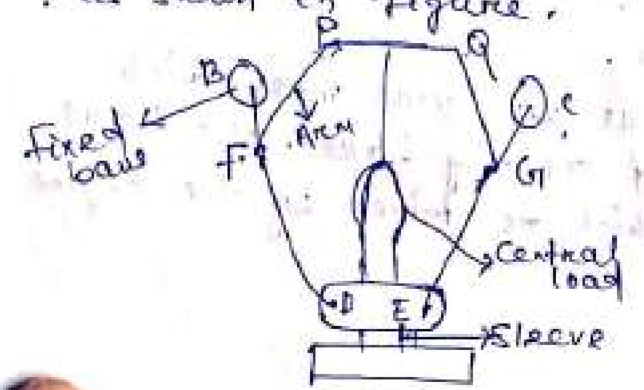
→ It's worked same as watt governor but it's slide modification of watt's governor, with central load attached to the sleeve.

→ The load moves up & down the central spindle. The additional downward force increases the speed of revolution required to enable the ball raise to any predetermined level.

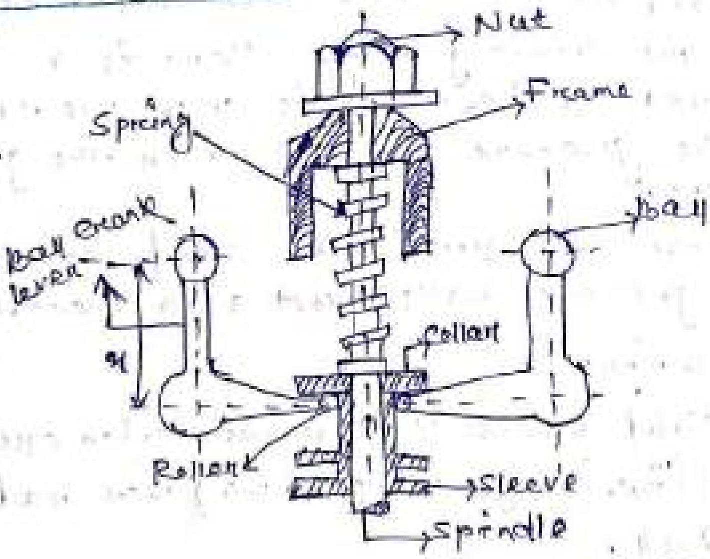
Proell governor :-

→ Same as watt, porter working principle but modification is it has fixed ball at B & C to the extension of the links DF & EG.

→ The arm FP & GQ are pivoted at P & Q respectively as shown in figure.



Hartnell governor :-



- It's a spring loaded governor. It consist of two ball crank lever pivoted at the points 'O', O to the frame.
- The frame attached to governor spindle & therefore rotates with it. Each lever carries a ball at the end of the vertical arm & a roller at the end of horizontal arm.
- A hellical spring in compression provides equal downward force on the two roller through a collar on the sleeve.
- The spring force may be adjusted by screwing a nut up or down on the sleeve.

* Sensitiveness of Governor :-

- Generally the greater lift of the sleeve corresponding to a given frictional change in speed, the greater is the sensitiveness of governor.
- It's the ratio of difference between the maximum & minimum equilibrium speed to the mean equilibrium speed.

Let, N_1 = Minimum equilibrium speed
N_2 = Maximum " "
N = Mean " "

$$N = \frac{N_1 + N_2}{2}$$

$$\boxed{\text{Sensitiveness of governor} = \frac{N_2 - N_1}{N} = \frac{2(N_2 - N_1)}{N_1 + N_2}}$$

or $\frac{2(\omega_2 - \omega_1)}{\omega_1 + \omega_2}$ (In terms of Angular speed)

* Stability of Governor :-

→ A governor said to be stable when for every speed within the working range there is a definite configuration i.e. there is only one radius of rotation of the governor balls at when the governor is in equilibrium.

→ For stable governor if equilibrium speed increases the radius of governor balls must also increase.

* Isochronous Governors :-

A governor said to be Isochronous when equilibrium speed is constant (i.e. range of speed = 0) for radii of rotation of ball.

* Hunting :-

→ It means if the speed of the engine fluctuates continuously above & below the mean speed.

→ Hunting is caused by a too sensitive governor which changes the fuel supply by a large amount when small change in the speed of rotation takes place.

Example :- When load on engine increases speed decreases if the governor is very sensitive the governor sleeve immediately falls to it's lowest position & this result opening of control valve wide which will supply excess fuel to engine.

* Function of fly wheel :-

It's a device used in machines serves as a reservoir, which stores energy during the period when the supply of energy is more than requirement & release during the period when the requirement of energy is more than supply.

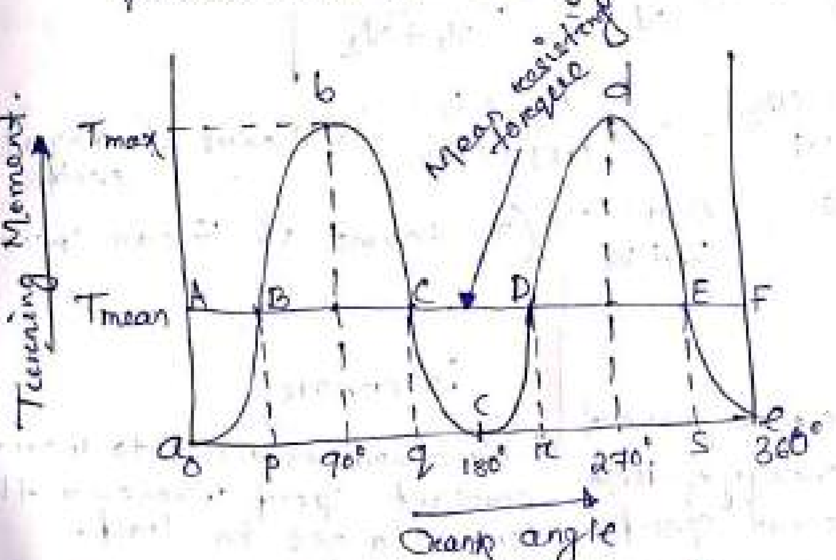
* Fluctuation of energy :-

→ The fluctuation of energy may be determined by turning moment diagram for one complete cycle of operation.

→ The difference between the maximum & minimum energy is called "maximum fluctuation of energy"

→ In diagram the variation of energy above & below the mean resisting torque line are called fluctuation of energy.

The areas BbC, CcD, DdE etc represents fluctuation of energy.



Coefficient of fluctuation of energy :- (C_E)

It's defined as the ratio of the maximum fluctuation of energy to workdone per cycle.

$$C_E = \frac{\text{Maximum fluctuation of energy}}{\text{Workdone per cycle.}}$$

* Workdone / cycle = $T_{mean} \times \theta$

[$\theta \Rightarrow$ Angle turned in radians in one revolution
$\theta = 2\pi$ (In case of steam engine & 2-stroke I.C engine)
$\theta = 4\pi$ (In case of 4-stroke I.C. engine)

* Mean torque (T_{mean}) $= \frac{P \times 60}{2\pi N} = P/\omega$

* Workdone / cycle $= \frac{P \times 60}{n}$

[n = No. of working strokes / minute
$n = N$ (for 2-stroke)
$n = \frac{N}{2}$ (for 4-stroke)

* ## Coefficient of fluctuation of speed :-

The difference between the maximum & minimum speeds during a cycle is called the maximum fluctuation of speed. The ratio of the maximum fluctuation of speed to the mean speed is called the coefficient of fluctuation of speed.

Let, N_1 & N_2 = Maximum & Minimum speeds in r.p.m during the cycle.

N = Mean speed in r.p.m $= \frac{N_1 + N_2}{2}$

∴ Coefficient of fluctuation of speed (C_s).

$$\boxed{C_s = \frac{N_1 - N_2}{N} = \frac{2(N_1 - N_2)}{N_1 + N_2}}$$

or $C_s = \frac{\omega_1 - \omega_2}{\omega} = \frac{2(\omega_1 - \omega_2)}{\omega_1 + \omega_2}$ (In terms of angular speed)

or $C_s = \frac{V_1 - V_2}{V} = \frac{2(V_1 - V_2)}{V_1 + V_2}$ (In terms of linear speed)

Flywheel	Governor
(i) Flywheel is used to prevent fluctuation of energy & doesn't maintain a constant speed.	(i) Governor is used to maintain constant speed whenever there are changes in load.
(ii) Generally flywheel is a heavy part of the machine.	(ii) Governor is a lighter in weight than flywheel.
(iii) It's a rotating component.	(iii) It's a non-rotating component.
(iv) Energy generated due to flywheel is directly proportional to the square of it's angular speed.	(iv) There is no such proportional or equation in a governor.
(v) While storing energy rotational speed increases & during supply speed decreases.	(v) Under all fluctuating load condition mean speed is regulated.
(vi) The moment of inertia of flywheel is very large.	(vi) Moment of inertia is very small.
(vii) It doesn't control fuel supply.	(vii) It controls fuel supply.

CH-5 BALANCING OF MACHINE

Balancing:-

It's the process of connecting or eliminating either partially or completely. The effects due to resultant Inertia force & couple acting on machine parts.

Static balancing:-

- It's statically balanced if the centre of mass lie on the axis of rotation.
- Statically balanced, the resultant of all the dynamic forces/centrifugal forces acting on the system during rotation must be zero.

Dynamic balancing:-

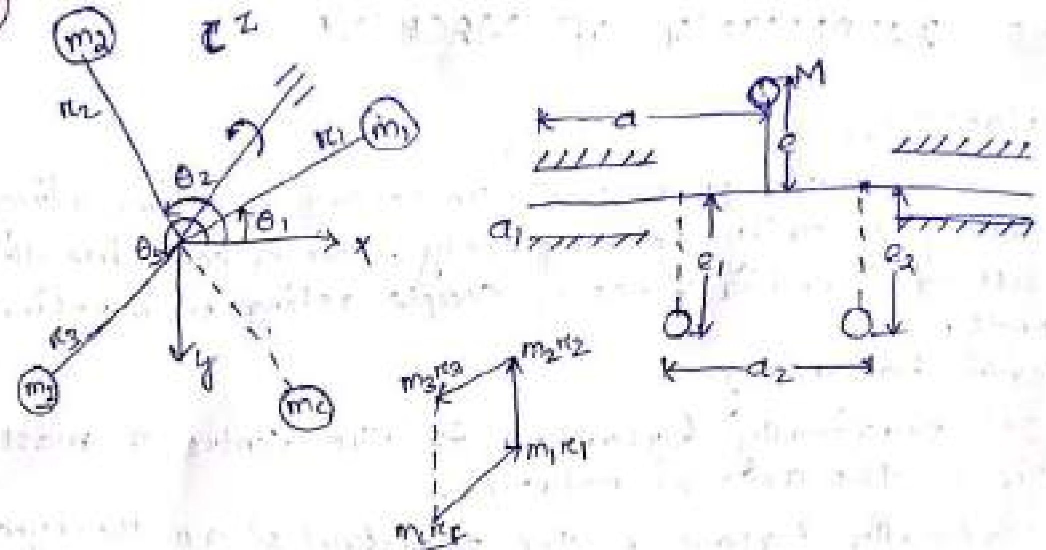
- The resultant of all dynamic forces acting on the system during rotation must be zero.
- Resultant couples due to all the dynamic forces acting on the system during rotation, about any plane must be zero

Balancing of rotating masses:-

- In any rotating system, having one or more rotating masses if the centre of mass of the system doesn't lie on the axis of rotation, the system is unbalanced.
- Unbalanced in rotating system mainly due to
  - (a) Errors & tolerance in manufacturing & assembly.
  - (b) Non-homogeneous material.
  - (c) Unsymmetrical shape of the rotors due to frictional requirement.
- If the centre of mass of rotating machine doesn't lie on the axis of rotation, the inertia force by

$$\boxed{F_I = m\omega^2 e}$$

m = Mass of m/c
ω = Angular speed of m/c
e = Eccentricity i.e. distance from the centre of mass to the axis of rotation.



→ If a shaft carries a no of unbalanced masses such that the centre of mass of the system is said to be statically balanced.

$$m_1r_1 + m_2r_2 + m_3r_3 + m_cr_c = 0$$

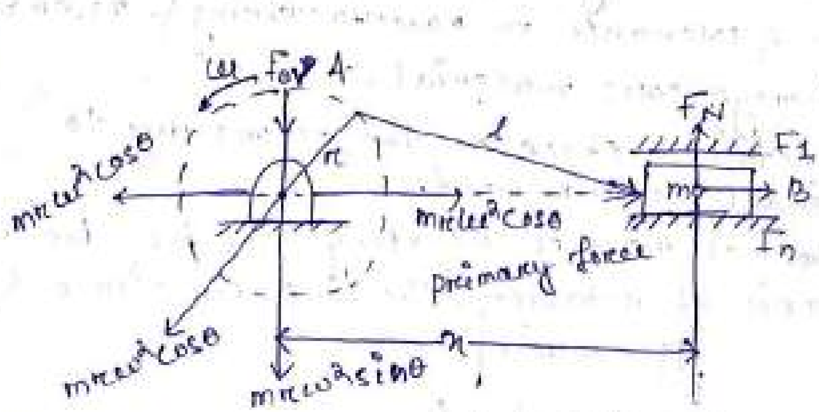
$$\Sigma mr + m_cr_c = 0$$

For horizontal calculation $\Rightarrow \Sigma mr\cos\theta + m_cr_c\cos\theta = 0$

For Vertical calculation $\Rightarrow \Sigma mr\sin\theta + m_cr_c\sin\theta = 0$

$$\boxed{\tan\theta_c = \frac{-\Sigma mr\sin\theta}{-\Sigma mr\cos\theta}}$$

* Principle of reciprocating parts :-



Force required to accelerate mass,

$$F = \underbrace{mr\omega^2\cos\theta}_{\text{primary acceleration force}} + \underbrace{mr\omega^2\frac{\cos 2\theta}{n}}_{\text{2ndary acceleration force}}$$

$n \rightarrow$ Ratio of length of COR to radius of crank

$n = \frac{l}{r}$

→ The force on the sides of the cylinder walls (F_N) & the vertical component F_{bv} are equal & opposite & thus form a shaking couple of magnitude $F_N \times x$ & $F_{bv} \times x$.

→ So from the diagram we can found that the effect of reciprocating parts is to produce a shaking force & shaking couple. Since the S.C & S.F vary in magnitude & direction during the engine cycle, therefore they cause very clear vibration.

→ Thus the main purpose of balancing reciprocating masses is to eliminate the shaking force & couple.

→ In most of the cases we can eliminate by reduce by the adding appropriate masses but in other words we can say the reciprocating mass are only partially balanced.

* Causes of unbalance :-

→ Bent or bowed between supporting bearing.
→ Unevenly distribution of solid or liquid inside rotor.
→ Loose parts on rotor.
→ Eccentrically manufactured diameter on the rotor.
→ Misalignment of the drive train to rotor axis.
→ Loose tolerance between assembled parts on rotor.
→ Void or cavities within the rotor.
→ Misalignment of bearing force shaft to bow.

* Effect of unbalancing :-

→ Creat breakdown inside m/c rotating member.
→ Creat noise or vibration.
→ Efficiency of m/c go down.
→ Life of m/c components also decreases.

(72)

Factors	Static balancing	Dynamic balancing
Nature	→ Work load is assigned at compile time.	→ Work load assigned at run time.
Overhead Involved	→ Little overhead.	→ Greater overhead due to process distribution.
Resource Utilization	→ Less	→ More
Predictability	→ Easy to predict.	→ Difficult to predict
Stability	→ More	→ Less
Complexity	→ Less	→ More

CH-6 VIBRATION OF MACHINE PARTS

Vibration :-

→ When a elastic bodies such as spring, beam & shaft are displaced from the equilibrium position by the application of external force & then released, they execute to & fro motion called as vibration.

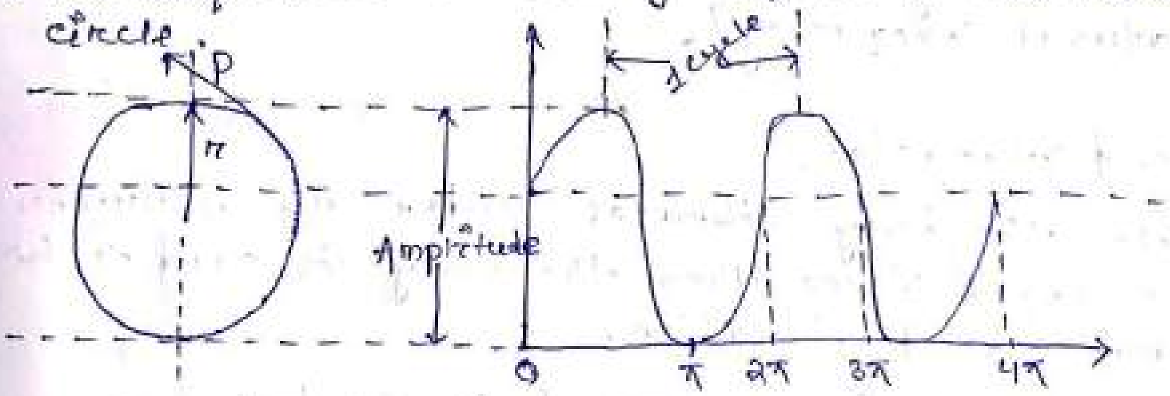
→ This is the reason that when a body is displaced the internal forces in the form of elastic or strain energy are present in the body when the energy release it come back to it's original position.

Terms used in vibration :-

1. Amplitude :-

→ It's the maximum displacement of a body from its mean position.

→ The amplitude is always equal to the radius of circle.



2. Period of vibration or Time period :-

→ It's time interval after which the motion is repeated itself, The periods of vibration is usually expressed in seconds.

3. Cycle :-

→ It's the motion completed during one time period.

4. Frequency

→ It's the no. of cycles described in one second.

* In S.I units → Hertz (Hz) = 1 cycle/second

* Classification of vibration :-

- Vibration
  - Free or Natural vibration
    - → Longitudinal vibration.
    - → Transverse vibration.
    - → Torsional vibration.
  - Forced vibration
  - Damped vibration

1. Free or Natural vibration :-

→ When no external force acts on the body, after giving it an initial displacement, then the body is said to be under free or Natural vibration.

→ The frequency related to free vibration called "Natural frequency".

2. Forced vibration :-

→ When the body vibrates under the influence of external force then the body is said to be under forced vibration.

→ The external force applied to the body is periodic disturbing force created by unbalance & the vibration have same frequency as applied force.

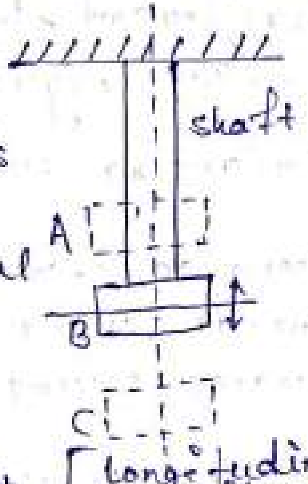
3. Damped Vibration :-

→ When there is a reduction in amplitude over every cycle of vibration, the motion is said to be damped vibration.

→ This is due to the fact that a certain amount of energy possessed by vibrating system is always dissipated in overcoming frictional resistance to the motion.

Longitudinal Vibration :-

→ To understand this consider a weightless spring or shaft whose one end is fixed & other end carrying heavy disc show in figure.

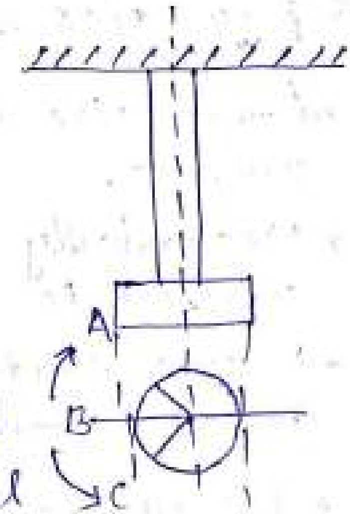


→ When the particles of this shaft or disc moves parallel to the axis of shaft shown in figure, then the vibration is called longitudinal vibration.

→ In this case the shaft is elongated & shortened alternately [longitudinal vibration] & thus the tensile & compressive stress are induced alternately in shaft.

→ In the given figure, 'B' is the mean position. A&C lie on the extreme position.

Torsional Vibration :-



→ When the particles of the shaft or disc move in a circle about the axis of shaft as shown in figure, then the vibration is called torsional vibration.

→ In this case the shaft is twisted & untwisted alternately & the torsional shear stresses are induced in the shaft.

→ If the limit of proportionality is not exceeded in the 3 types of vibration then the restoring force in longitudinal & transverse vibrations or the restoring couple in torsional which is exerted on the disc by the shaft is directly proportional to mean position or Displacement of disc from equilibrium.

* Causes of vibration :-

- It's due to alignment problem i.e. may be parallel misalignment, Angular misalignment & combined parallel-angular misalignment.
- Unbalancing which may be static or Coupled.
- Resonance :- formation means when rotation frequency coincide with resonance frequency of the machine resonance occurs resonace make major impact on m/c.
- Loose parts arrangement inside m/c.
- Bearing damage may be inner, outer, cage or rolling element.
- Damaged or worn out gears teeth.

* Remedies of vibration :-

- Limit the time spent by workers on a vibrating surface.
- Mechanically isolate the vibrating source or surface to reduce exposure.
- Ensure that equipment is well maintained to avoid excessive vibration.
- Install vibration damping seats.
- Always take step if machine create abnormal sound.