

SHORT QUESTIONS & LONG QUESTIONS ON THEORY OF MACHINES (Theory - 1)

4th Semester Mechanical Engineering
(As per SCTE&VT, Odisha Syllabus)

Prepared by :

ER. RAMESH CHANDRA PRADHAN

Lecturer in Mechanical Engineering Department



PNS SCHOOL OF ENGINEERING & TECHNOLOGY
Nishamani Vihar, Marshaghai, Kendrapara

CHAPTER - 1

CHAPTER – 1 (SIMPLE MECHANISM)

Q.KUTZBACH CRITERION FOR MOVABILITY OF MECHANISM HAVING PLANE MOTION?

Criterion is $n=3(L-1)-2J-H$, Where n=no of movability, L=no of links, j=no of joints, h=higher pair

Q. Define kinematic chain

Ans: When kinematic pairs are coupled in such a way that the last link is joined to the first link to transmit definite motion it is called kinematic chain.

Q. Define Kinematic pair.

Ans: When the relative motion between two pairs is in a definite direction then the pair is known as kinematic pair.

Q. Define lower pair

Ans:: When two elements of a pair have a surface contact when relative motion takes place and surface of one element slides over the surface of other the pair formed is known as lower pair. Sliding pairs, turning pairs and screw pairs form lower pairs.

Q. Differentiate between machine and mechanism

Ans: Mechanism, It is used for transmitting or transforming motion.

Machine: When mechanism is required to transmit power or do some particular type of work it then becomes a machine.

Q. Define link.

Ans: Each part of machine which moves relative to some other part is known as link.

Q. Explain sliding pair, turning pair, rolling pair and screw pair

Ans: **Sliding pair** : when two elements of a pair are connected in such a way that one can only slide relative to the other the pair is known as sliding pair. The piston and cylinder, crosshead and guides of a reciprocating steam engine, ram and its guides in shaper are examples of sliding pair.

Turning pair: When two elements of a pair are connected in such a way that one can turn about of a fixed axis of another link the pair is known as turning pair. Example crankshaft in a journal bearing cycle wheels turning about their axles.

Rolling pair: When two elements of a pair are connected in such a way that one rolls over another fixed link the pair is known as rolling pair. Example : Ball and roller bearing

Screw pair: When two elements of a pair are connected in such a way that one element can turn about other by screw threads the pair is known as screw pair. Example : lead screw of lathe, with nut bolt with a nut.

Q. Define kinematic link. Mention its types.

Ans: Kinematic link: Each part of a machine which moves relative to some other part is known as a kinematic link (or simply link) or element. A link may consist of several parts, which are rigidly fastened together so that they do not move relative to one another.

Types of Kinematic links:

- (i) **Rigid link** : A rigid link is one which does not undergo any deformation while transmitting motion, Strictly speaking, rigid links do not exist for example a connecting rod, crank etc. of a reciprocating steam engine is not appreciable, they can be considered as rigid links.
- (ii) **Flexible link** : A flexible link is one which is partly deformed in a manner not to affect the transmission of motion. For example, belts, rope, chains and wires.
- (iii) **Fluid link** : A fluid link is one which is formed by having a fluid in a receptacle and the motion is transmitted through the fluid by pressure or compression only, as in the case of hydraulic presses, jacks and brakes.

Q. What do you mean by lower pair and higher pair ? Give two examples from each.

Ans: **Lower pair:** when the two elements of a pair have a surface contact when relative motion takes place and the surface of one element slides over the surface of the other, the pair formed is known as lower pair. It will be seen that sliding pairs. Turning pairs and screw pairs from lower pairs. Example for lower pairs are:

- (i) **Shaft rotating in a bearing and**
- (ii) **Nut turning on a screw**

Higher Pair: When the two elements of a pair have a line or point contact when relative motion takes place and the motion between the two elements is partly turning and partly sliding, then the pair is known as higher pair. A pair of friction discs, toothed gearing, belt and rope drives, ball and roller bearings and cam and follower are the examples of higher pair.

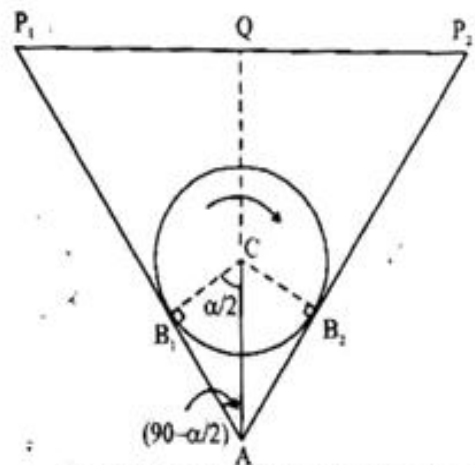
Q. In a crank and slotted lever mechanism (quick return), the distance between the fixed centres is 180 mm and the driving crank is 90 mm long. Determine the ratio of the time taken on the cutting and return strokes.

Ans: Data given,

Distance between the fixed centre's,

$AC = 180 \text{ mm}$

Length of driving crank, $CB_1 = 90 \text{ mm}$



The extreme positions of the crank are shown

$$\begin{aligned} \text{We know that, } \sin \angle CAB_1 &= \sin \left(90^\circ - \frac{\alpha}{2} \right) \\ &= \frac{CB_1}{AC} = \frac{90}{180} = 0.5 \end{aligned}$$

$$\angle CAB_1 = 90^\circ - \frac{\alpha}{2} = \sin^{-1} 0.5 = 30^\circ$$

$$\Rightarrow \frac{\alpha}{2} = 90^\circ - 30^\circ = 60^\circ$$

$$\Rightarrow \alpha = 2 \times 60 = 120^\circ$$

$$\text{we know that } \frac{\text{time of cutting stroke}}{\text{Time of return stroke}} = \frac{360^\circ - \alpha}{\alpha}$$

$$\frac{360^\circ - 120^\circ}{120} = \frac{240}{120} = 2$$

Q. What is inversion > Explain the inversion in Crank and connecting and mechanism ?

Ans: Inversion :-

The method of obtaining different mechanism by fixing different links is known as inversion.

The inversion is crank and connecting and slotted lever mechanism:-

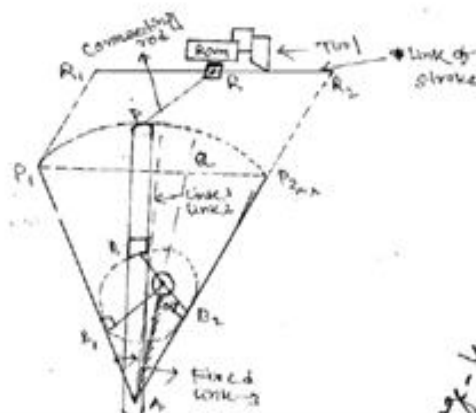
This mechanism is mostly used in slotter machine and rotary I.C. engine.

In this mechanism the link AC forming the turning pair which is fixed. The links correspond to the connecting rod of a reciprocating steam engine. The driving crank CB revolves with uniform angular speed, about the fixed center C.

A sliding block attached to the crank pin at B slider along the slotted bar AP to oscillate about the pivoted point A. A short link PR transmit the motion from AP to the ram which carries the tool and reciprocates along the line of stroke R_1, R_2 . The stroke of the ram is perpendicular to AC.

In the extreme position AP_1 and AP_2 are tangential to the circle and the cutting tool is at the end of the stroke the forward or cutting stroke occurs when the crank rotates from the position CB_1 and CB_2 in the clock wise direction. The return stroke occur when the crank rotates from the piston CB_2 to CB_1 in the clock wise direction. Therefore

$$\frac{\text{time of cutting stroke}}{\text{Time of return stroke}} = \frac{\beta}{\alpha} = \frac{\beta}{360^\circ - \beta} = \frac{360^\circ}{\alpha}$$



CHAPTER - 2

Chapter 2

Q. SELF LOCKING SCREWJACK: 2019

It means when the rotational force on the screw is removed, it will remain motionless where it was left and will not rotate backwards, regardless of how much load it is supporting.

Q. OVERHAULLING SCREW JACK

Over hauling of screws , if $\phi < \alpha$, then the torque required to lower the load will be negative. The load will start moving downward without the application of any torque, such a condition is known as over hauling of screws.

Q. Define angle of repose

Ans: It is the inclination of plane to horizontal such that the body placed begins to move down the plane.

Q. Define Co-efficient of friction

Ans: It is defined as the ratio of limiting friction to normal reaction Co-efficient of friction

$$M = \frac{F}{RN}$$

Q. Explain laws of friction

- i. The magnitude of force of friction is exactly equal to force which tends the body to move.
- ii. The force of friction acts in opposite direction to motion of body.
- iii. The ratio of limiting friction bears a constant ratio to normal reaction i.e.

$$\frac{F}{RN} = M$$

- iv. The force of friction is independent of area of contact.
- v. The force of friction depends upon roughness of surface.

Q. Define pitch, helix, depth of thread lead, slope of thread. 2013 (s)

Ans: Pitch : It is the distance from a point of screw to the corresponding point on the next thread measured parallel to axis of screw.

Helix: It is the curve traced by a particle while moving along screw thread.

Depth of thread: It is the distance between top and bottom surface of a thread

Lead: It is the distance a screw thread advances axially in one turn.

Slope of thread: It is the inclination of thread with horizontal.

Q. Define Clutch

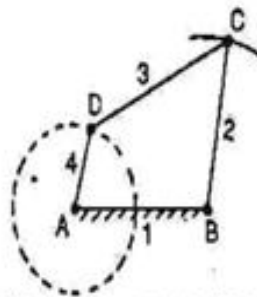
Ans: It is used to connect the driven shaft with the engine and brings the driven shaft up to proper speed.

Q. Classify clutch.

- i. Disc or plate clutch (single disc or multiple disc clutch)
- ii. Cone clutches
- iii. Centrifugal clutches.

Q. What is four bar chain? Explain any two inversion of four bar Chain.

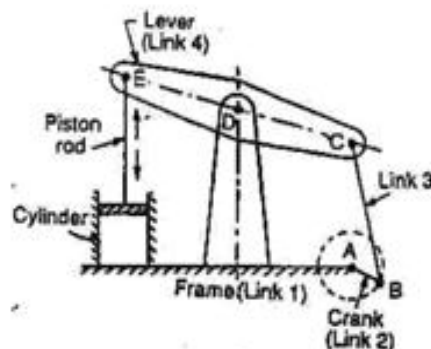
Ans: The simplest and the basic kinematic chain is a bar chain. It consists of four links, each of them forms a turning pair at A, B, C and D. the four links may be of different lengths.



In four bar chain, one of the links, in particular the shortest link will make a complete revolution relative to the other three links. The link BC (link 2) Which makes a partial rotation of oscillates and the link CD (link 3). Which connects the crank and lever. The fixed link AB (link 1) is known as frame of the mechanism.

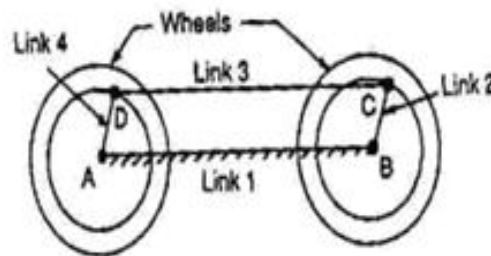
(A) CRANK AND LEVER MECHANISM (BEAM ENGINE)

- i. It consists of four links.
- ii. In this mechanism, Which the crank rotates about the fixed centre A, the lever oscillates about a fixed centre D.
- iii. the end E of the lever CDE is connected to a piston rod which reciprocates due to the rotation of the crank.



(B) DOUBLE CRANK MECHANISM (COUPLING ROD OF A LOCOMOTIVE)

- i. It consists of four links
- ii. In this mechanism the link AD and BC act as cranks and are connected to the respective wheels.
- iii. The link CD acts as a coupling rod and the link AB is fixed in order to maintain a constant centre to centre distance between them.
- iv. It is meant for transmitting rotary motion from one wheel to the other wheel.



Q. Function of dynamometer

Ans: The function of dynamometer is :

- i. It measures the frictional resistance.
- ii. It measures the output of the rotating shaft.

A shaft has a number of collars integral with H . The external diameter of the collars is 400 mm and the shaft diameter 250 mm, if the intensity of pressure is 0.35 N/mm² (uniform) and the coefficient of friction is 0.05, estimate.

- i. Power absorbed when the shaft runs at 105 r.p.m. carrying a load of 150 KN and
- ii. number of collars required.

Ans: Given $d_1 = 400$ mm or $r_1 = 200$ mm

$D_2 = 250$ mm or $r_2 = 125$ mm

$$P = 0.35 \text{ N/m}^2 \quad \mu = 0.05, \quad N = 105 \text{ r.p.m.}$$

$$W = \frac{2\pi N}{60} = \frac{2\pi \times 105}{60} = 11 \text{ rad/s}$$

$$W = 150 \text{ KN} = 150 \times 10^3 \text{ N}$$

- i. Power absorbed

Four uniform pressure, total frictional torque transmitted.

$$T = \frac{2}{3} \mu W \left[\frac{r_1^3 - r_2^3}{r_1^2 - r_2^2} \right] = \frac{2}{3} \times 0.05 \times 150 \times 10^3 \left[\frac{(200)^3 - (125)^3}{(200)^2 - (125)^2} \right]$$

$$= 5000 \times 248 = 1240 \times 10^3 \text{ N.mm}$$

$$\therefore \text{Power absorbed } P = T.W. = 1240 \times 11 = 13.64 \text{ KW}$$

- ii. Number of collars required

The intensity of uniform pressure $P_3 = 1.96/n$

$$0.35 = \frac{W}{n\pi(r_1^2 - r_2^2)} = \frac{150 \times 10^3}{n\pi(200^2 - 125^2)}$$

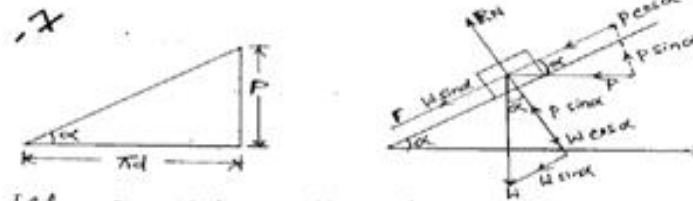
$$\therefore n = \frac{1.96}{0.35} = 5.6$$

Q. Explain single clutch plat

Ans: Single plate clutch

- i. It consists of a clutch plate whose both sides are faced with a friction material.
- ii. It is mounted on the hub which is free to move axially along the splines of the driven shaft.
- iii. the pressure plate is mounted inside the clutch body which is bolted to the flywheel. Both the pressure plate and the flywheel rotate with the engine crank shift or the driving shaft.
- iv. The pressure plate pushes the clutch plate towards the flywheel by a set of strong springs which are arranged radially inside the body.

Q. Drive an expression for torque required to lower the load by a screw Jack.



Let, P = pitch of the screw

d = Mean dia of screw

α = Helix angle

P = Effort applied

W = weight to be lifted

μ = Co-efficient of friction between the screw and load.

Resolving the forces horizontally

$$F = W \sin \alpha + P \cos \alpha$$

$$\Rightarrow \mu RN = W \sin \alpha + P \cos \alpha \dots\dots\dots (i)$$

Resolving the forces vertically

$$RN + P \sin \alpha = W \cos \alpha$$

$$\Rightarrow RN = W \cos \alpha - P \sin \alpha$$

Putting the value of RN in equation (i)

$$\mu (W \cos \alpha - P \sin \alpha) = W \sin \alpha + P \cos \alpha$$

$$\Rightarrow \mu W \cos \alpha - \mu P \sin \alpha = W \sin \alpha + P \cos \alpha$$

$$\Rightarrow \mu W \cos \alpha - W \sin \alpha = P \cos \alpha + \mu P \sin \alpha$$

$$\Rightarrow \tan \phi W \cos \alpha - W \sin \alpha = P \cos \alpha + \tan \phi P \sin \alpha$$

$$\Rightarrow W \left\{ \frac{\sin \phi}{\cos \phi} \cdot \cos \alpha - \sin \alpha \right\} = P \left\{ \cos \alpha + \frac{\sin \phi}{\cos \phi} \cdot \sin \alpha \right\}$$

$$\Rightarrow W \left\{ \frac{\sin \phi \cdot \cos \alpha - \cos \phi \cdot \sin \alpha}{\cos \phi} \right\} = P \left\{ \frac{\cos \alpha \cdot \cos \phi + \sin \alpha \cdot \sin \phi}{\cos \phi} \right\}$$

$$\Rightarrow P = W \left(\frac{\sin \phi \cdot \cos \alpha - \cos \phi \cdot \sin \alpha}{\cos \phi \cdot \cos \alpha + \sin \phi \cdot \sin \alpha} \right)$$

$$\Rightarrow P = W \frac{\sin(\phi - \alpha)}{\cos(\phi - \alpha)}$$

$$\Rightarrow P = W \tan(\phi - \alpha)$$

\therefore Torque required to lower the load by screw Jack

$$T = P \times \frac{d}{2}$$

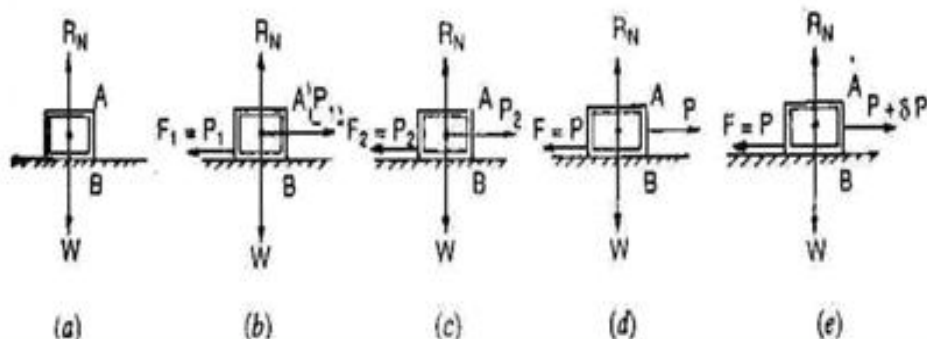
$$T = W \tan(\phi - \alpha) \times \frac{d}{2}$$

If $\alpha > \phi$, then

$$T = W \tan(\alpha - \phi) \times \frac{d}{2}$$

Q. Why frictional force in limiting and self adjusting in nature.

Ans: Consider that a body A of weight W is lying on a rough horizontal body B as shown. In the fig. (a). In this position, the body 'A' is in equilibrium under the action of its own weight W. Now If a small horizontal force P_1 is applied to the body A acting through its centre of gravity as shown in the fig. (b). It does not move because of the frictional force which prevents the motion. This shows that the applied force P_1 is exactly balanced by the force of friction F_1 acting in the opposite.



If we now increase the applied force to P_2 as shown in fig. (c). It is still found to be in equilibrium. This means that the force of friction has also increased to a value $F_2 = P_2$. Thus every time the effort is increased the force of friction also increases, so as to become exactly equal to the applied force. There is however, a limit beyond which the force of friction cannot increase as shown in fig (d). After this any increase in the applied effort not lead to any further increase in the force of friction as shown in fig. (e), thus the body 'A' begins to move in the direction of the applied force. This maximum value of frictional force. Which comes into play, when a body just begins to slide over the surface of the other body, is known as limiting force of friction or simply limiting friction. It may be noted that when the applied. Force is less than the limiting friction, The body remains at rest, and the friction into play is called static friction which may have any value between zero and limiting friction.

Q. Find the torque required to rotate vertical shaft resting on flat pivot bearing considering uniform were. (2013)

Ans : The rate of were depends upon the intensity of pressure (P) and the velocity of rubbing surfaces (V). It is assumed that the rate of wear is proportional to the product of intensity of pressure and the velocity of rubbing surfaces i.e. P.V. since the velocity of rubbing surfaces increases with the distance (i.e. radius r) from the axis of the bearing, therefore for uniform wear.

$P \cdot r = C$ (a constant) or $P = c/r$ and the load transmitted to the ring,

$\delta w = P \times 2\pi r \cdot dr$ from equation (I)

\therefore Total load transmitted to the bearing

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

$$\text{or } C = \frac{W}{2\pi R}$$

We know that frictional torque acting on the ring.

$$T_r = 2\pi\mu Pr^2 dr = 2\pi\mu \times \frac{c}{r} \times r^2 dr$$

$$= 2\pi\mu.c.rdr \text{ ----- } \left(\because P = \frac{c}{r} \right) \text{.....(ii)}$$

Total frictional torque on the bearing

$$T = \int_0^R 2\pi\mu.c.rdr = 2\pi\mu.c \left[\frac{r^2}{2} \right]_0^R$$

$$= 2\pi\mu.c \times \frac{R^2}{2} = \pi\mu.cR^2$$

$$= \pi\mu \times \frac{W}{2\pi R} \times R^2 = \frac{1}{2} \times \mu.wq.R \text{..... } \left(\because \frac{W}{2\pi R} \right)$$

Q. What is frictional force ? Write down the laws of dry friction.(2011)

Ans: It is observed that the surfaces of the bodies are never perfectly smooth. When even a very smooth surface is viewed under a microscope, It is found to have roughness and irregularities, which may not be detected by an ordinary touch. If a block of one substance is placed over the levee surface of the same or of different material, A certain degree of interlocking of the minutely projecting particles takes place. This does not involve any force, so long as the block does not move or tends to move but, when ever one block moves or tends to move tangentially with respect to the surface; on which is rest, the interlocking property of the projecting particles opposes the motion. This opposing force, which acts in the opposite direction of the movement of the upper block, is called the force of friction or simply friction

1. The force of friction is directly proportional to the normal load between the surface.
2. the force of friction is independent of the area of the contact surface.
3. The force of friction depends upon the material of which the contact surfaces are made.
4. The force of friction is independent of the velocity of sliding of one body relative to the other body.

Q. With a neat sketch explain the function of absorption type of dynamometer

Ans: Absorption Dynamometer : Absorption dynamometers consists of some form of brakes in which provision is made for measuring the frictional torque on the drum. The following are the important types of absorption dynamometer

- (i) Prony brake dynamometer
- (ii) Rope brake dynamometer

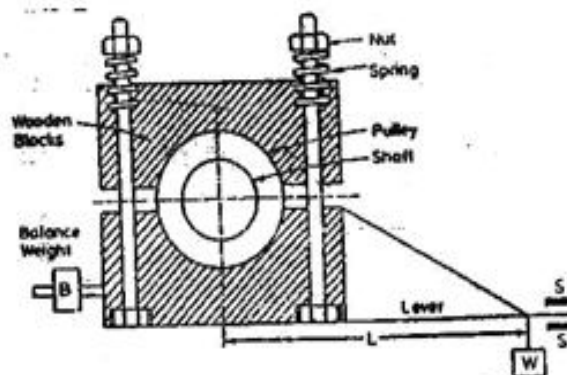


Fig. (a) : Prony Brake Dynamometer

For measuring the power of the engine, the long end of the lever is loaded with a known weight W . Now the nuts are tightened until the shaft runs at a constant speed and the lever is in horizontal position. Under these conditions, the moment due to weight W will balance the moment of the frictional resistance between the blocks and the pulley.

Let, W = weight at the end of the lever,

R = Radius of the pulley,

μ = Co-efficient of friction between pulley and blocks.

L = Horizontal distance of weight W from the centre of the pulley

N = Speed of the shaft in rpm.

Torque on the shaft, $T = W \times L$

\therefore Power of the engine = Torque \times Angular speed = $T \times \omega = T \times 2\pi N/60$

= $W \times L \times 2\pi N/60$ Watts ($\therefore T = W \times L$)

From the above equation, it is clear that the power of the engine is independent of : (i) radius of the pulley, R (ii) co-efficient of friction between pulley and wooden blocks and (iii) pressure exerted by tightening the nuts.

Q. Rope brake dynamometer : 2019

Figure-b shows the rope brake dynamometer which consists of one, two or more ropes wound round the rim of a pulley (or flywheel) fixed rigidly to the shaft of the engine whose power is required to be measured. The upper end of the ropes is attached to a spring balance (S) while the lower end carries the dead weight W. the ropes are spaced evenly across the width of the rim by means of three or four wooden blocks at different points round the rim (or around the circumference of the flywheel).

For measuring the power of an engine, the engine is made to run at a constant speed. Under this condition, the torque transmitted by the engine must be equal to the frictional torque due to the ropes.

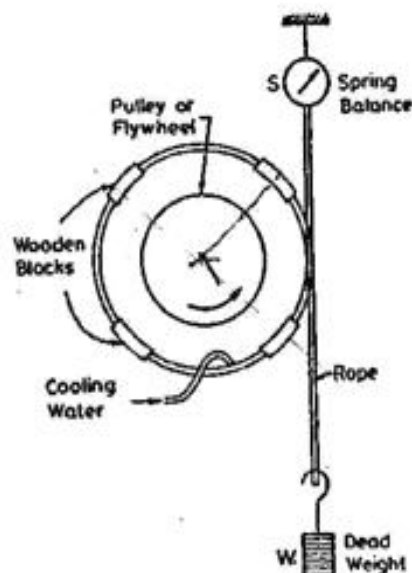


Fig. (b) : Rope Brake Dynamometer

Let N = Constant speed of the engine shaft

W = Dead weight

S = Spring balance reading

D = Diameter of flywheel (or diameter of the rim of pulley).

d = Diameter of rope.

Then net load on brake = $(W - S)$

∴ Frictional torque due to ropes

= (Net load on brake) × Distance of load line from the centre of shaft.

$$= (W - S) \times \left(\frac{D + d}{2} \right)$$

But torque transmitted engine at constant speed

= Frictional torque due to ropes

$$= (W - S) \times \left(\frac{D + d}{2} \right)$$

∴ Brake power of engine = Torque transmitted by engine × Angular speed of engine.

Q. Describe in brief about anti-friction bearing

Ans: Anti-friction bearings also known as a rolling contact bearings minimize friction by removing any possible sliding between bearing surfaces and replacing all contacts with rolling interfaces. They substitute balls or rollers for a hydro-dynamic or hydrostatic fluid film to carry loads with reduced friction. They utilize a separator to space the hardened rolling elements apart.

Anti friction bearings can be categorized to three different configurations

- Axial ball bearing
- Roller bearing
- Thrust bearing

They are more desirable than plain bearing due to their lower friction and reduced lubricant requirement. However the life of an anti-friction bearing is limited by the fatigue life of the material, they are made of an the type of lubricant being used. The types of anti-friction are grouped by the shape of the rolling element and they are ball bearing, cylindrical roller bearings, tapered roller bearings, and needle roller bearings.

Advantages :

- (i) Low starting friction torque.
- (ii) Ease of lubrication
- (iii) Capable of supporting both radial and thrust bearing.

- (iv) Readily replaceable.
- (v) Standardization and wide versatility with respect to mounting.

Disadvantages:

- (i) Greater diametral space required for comparable shaft diameter than journal bearing.
- (ii) Initial cost is usually higher.
- (iii) Noise in normal operation.
- (iv) Finite life due to eventually failure by fatigue.
- (v) Lesser capacity to withstand shock.
- (vi) Dirt, metal chips or any foreign material entering to the bearing can limit their life causing early failure.

Q. *What is the difference between a brake and a dynamometer ?*

Ans: A brake is a device used either to bring to rest a body which is in motion or to hold a body in a state of rest or of uniform motion against the action of external forces or couples. Actually the brake offers the frictional resistance to the moving body and this frictional resistance retards the motion and the body comes to rest. In this process, the kinetic energy of the body is absorbed by brakes.

Dynamometer: A dynamometer is device used to measure the frictional resistance or frictional torque. This frictional resistance is obtained by applying a brake. Hence dynamometer is also a brake in addition it has a device to measure the frictional resistance (or frictional torque.)

Q. *Write the function of bearing and classify them*

Ans:Function of bearing: A bearing is a machine element whose function is to support a moving element (known as journal/shaft) and to guide or confine its motion. While preventing motion in the direction of applied load. Since there is a relative motion between the bearing and the moving element, there will be a power of energy loss due to friction and if the rubbing surfaces are in direct contact, there will be rapid wear. In order to reduce frictional resistance and wear and in some cases to carry away the heat generated a layer of fluid known as lubricant may be may be provided. In many applications, the bearings are located between the shafts frame of a machine. They are also

located between the contact members and the frame or between contact members and linkage members.

Classification of Bearings:

Bearing may be classified in the following many ways

- (i) Depending upon the direction of load to be supported
 - (a) Radial Bearing : these are also known as journal bearings. In these bearing the main load is perpendicular to the axis of rotation of the moving element
 - (b) Thrust Bearing: In these bearings, the load acts along the axis of rotation.

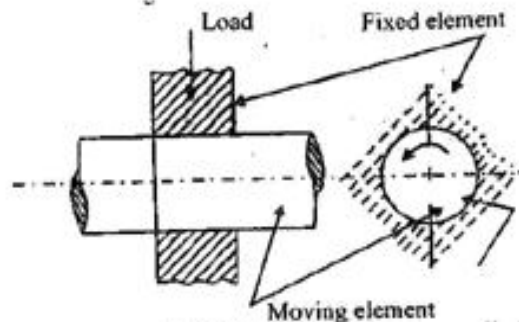


Fig. Thrust Bearing

- (ii) Depending upon the nature of contact between the working surface.
 - a) Sliding contact bearings or plain bearings: In these bearings, the sliding takes place along the surfaces contact between the moving element and the fixed element.

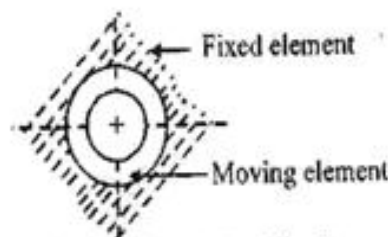


Fig. Sliding contact Bearing

Sliding contact bearings are also classified as :

- Full journal bearing.
- Partial journal bearing
- Fitted journal bearing

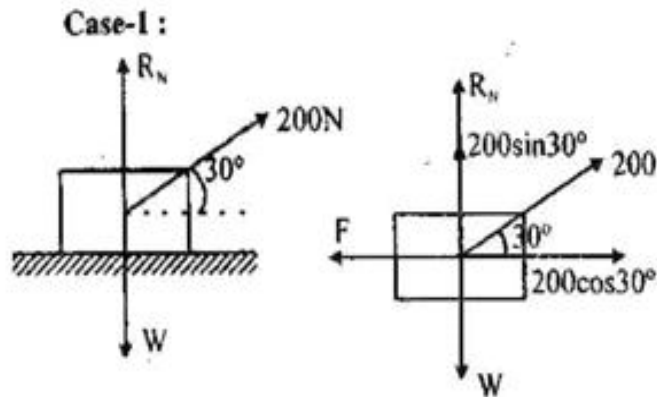
Again according to the thickness of layer of the lubricant between the bearing and the journal, may also be classified as follows :

→ Thick film bearings.

→ Thin film bearings

Q. A body resting on a rough horizontal plane required a pull of 200 N and inclined at 30° to the plane just to move it. It was found that a push of 240 N inclined at 30° to the plane just move the body. Determine the weight of the body and co-efficient of friction. 2013 (s)

Ans:



Resolving the forces horizontally,

$$\Sigma F_x = 0 \Rightarrow F = 200 \cos 30^\circ = 200 \times 0.866 = 173.2 \text{ N}$$

Resolving the forces vertically

$$\Sigma F_y = 0 \Rightarrow R_N + 200 \sin 30^\circ = W$$

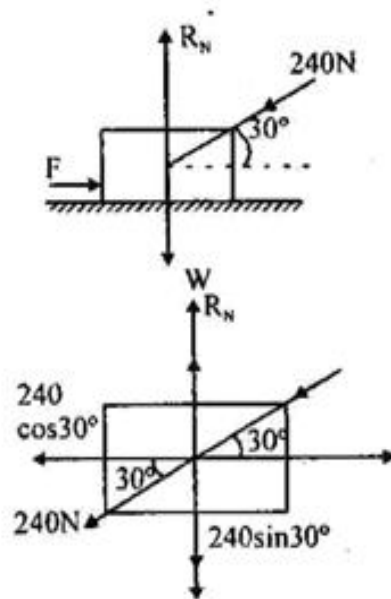
$$\Rightarrow R_N = W - 200 \sin 30^\circ = (W - 100) \text{ N}$$

But we know, $F = \mu R_N$

$$\text{Or } 173.2 = \mu (W - 100)$$

Case - II

Now let's consider a push of 240 N acting inclined at 30° to the plane



Resolving the forces horizontally,

$$\Sigma F_x = 0 \Rightarrow F = 240 \cos 30^\circ = 240 \times 0.866 = 207.84 \text{ N}$$

Now resolving the forces vertically,

$$\Sigma F_y = 0 \Rightarrow R_N = W + 240 \sin 30^\circ = (W + 120) \text{ N}$$

But we know, $F = \mu R_N$

$$\Rightarrow 207.84 = \mu (W + 120)$$

Solving equation (1) and (2) we have,

Co-efficient of friction, $\mu = 0.1574$

Weight of body, $W = 1200.4 \text{ N}$

- Q. A 200 mm diameter valve against which a steam pressure of 3 MN/m^2 is acting is closed by means of a square threaded screw of 70 mm in external diameter with 8 mm pitch if the co-efficient of friction is 0.2. Find the torque required to turn the handle. 2013 (s)**

Ans: Data given

Diameter of valve, $D = 200 \text{ mm} = 0.2 \text{ m}$

Steam pressure, $P_s = 3 \text{ MN/m}^2 = 3 \times 10^6 \text{ N/m}^2$

Outside diameter of square threaded screw,

$d_0 = 70 \text{ mm}$

Pitch, $p = 8 \text{ mm}$

Co-efficient of friction, $\mu = \tan \phi = 0.2$

We know that load on the valve,

$W = \text{pressure} \times \text{Area}$

$$p_s \times \frac{\pi}{4} D^2 = (3 \times 10^6) \times \left[\frac{\pi}{4} \times (0.2)^2 \right] = 94247.78 \text{ N}$$

Mean diameter of the screw

$$d = d_0 - \frac{P}{2} = 70 - \frac{8}{2} = 66 \text{ mm} = 0.066 \text{ m}$$

\therefore Slope of thread, $\tan \alpha = \frac{P}{\pi d}$

$$= \frac{8}{\pi \times 66} = 0.0385$$

We know that the force required to turn the handle,

$$\begin{aligned} P &= W \tan(\alpha + \phi) = W \left[\frac{\tan \alpha + \tan \phi}{1 - \tan \alpha \cdot \tan \phi} \right] \\ &= 94247.78 \left[\frac{0.0385 + 0.2}{1 - 0.0385 \times 0.2} \right] \\ &= 22652.52 \text{ N} \end{aligned}$$

Torque required to turn the handle.

$$\begin{aligned} T &= P \times \frac{d}{2} = 22652.52 \times \frac{0.066}{2} \\ &= 747.53 \text{ N-m} \end{aligned}$$

CHAPTER - 3

CHAPTER:3 (BELT, ROPE AND DRIVE)

Q. Define creep and slip

Ans: Creep : When belt passes from slack side to tight side a certain portion of belt extends and contracts again when passes from tight side to slack side. Due to these changes in length there is relative motion between belt and pulley known as creep.

Slip: When friction grip becomes insufficient the driver will move forward without carrying belt with it and the belt will move forward without carrying driven pulley with it. This is known as slip of belt and is expressed in percentage.

Q. Define velocity ratio of gear drive.

Ans: Velocity ratio: It is the ratio between velocities of driver and the follower or driven. Differentiate between total tension and centrifugal tension.

Total tension, $Tt_1 = T_1 + T_c$

Where Tt_1 = total tension in tight side

T_1 = Tension in tight side

T_c = centrifugal tension.

Q. What is open belt drive ?

Ans: Open belt drive is one in which shafts are arranged in parallel and rotate in same direction.

Q. What is crowning of Pulley ?

Ans: Crowning of pulley is done

- (i) To increase the grip between the belt and pulley
- (ii) To prevent the belt from slipping from the surface of pulley.

Q DEFINE MODULE OF GEAR? 2019

ANS:-"Module" is the unit of size that indicates how big or small a gear is. It is the ratio of the reference diameter of the gear divided by the number of teeth.

Q. Write is open belt drive

Ans: The open belt drive is used with shafts arranged parallel and rotating in the same direction. In this case, the driver A pulls the belt from one side (i.e., lower side RQ) and delivers it to the other side (i.e., upper side LM). Thus the tension in the lower side belt will be more than that in the upper side belt.

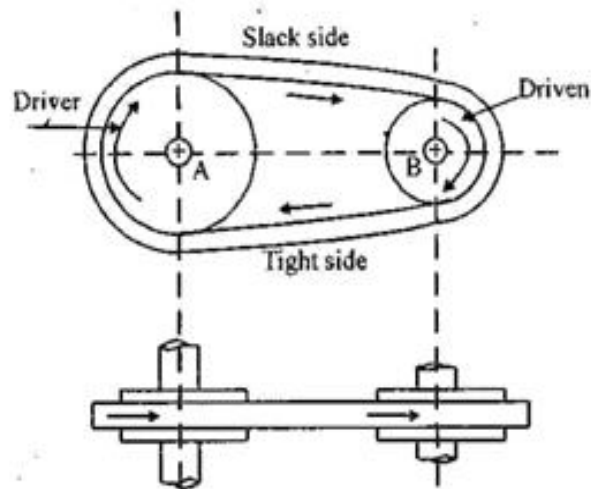


Fig. Open belt drive

The lower side belt (because of more tension) is known as tight side whereas the upper side belt (because of less tension) is known as slack side.

Q. Derive an expression for find out the length of a open belt drive.

Ans:

r_1, r_2 = Radius of larger and smaller pulley.

X = Distance between the centre of two pulley.

L = Total length of the belt.

$$L = \text{Arc AB} + \text{Arc BC} + \text{Arc CD} + \text{Arc DE} + \text{Arc EF} + \text{Arc FA} \\ = 2 (\text{AB} + \text{BC} + \text{CD})$$

From the geometry of fig. ΔGO_1O_2

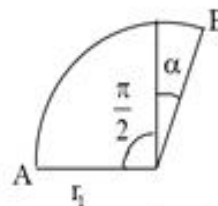
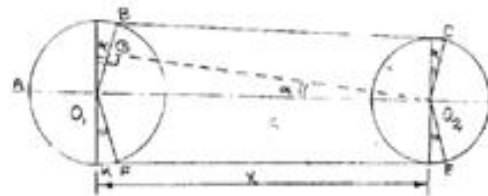
$$\sin \alpha = \frac{GO_1}{O_1O_2} = \frac{BO_1 - BG}{O_1O_2}$$

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

since α is very small $\sin \alpha = \alpha$

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

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



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

From ΔGO_1O_2

$$\begin{aligned} BC &= GO_2 \sqrt{(O_1O_2)^2 - (GO_1)^2} \\ &= \sqrt{(x)^2 - (r_1 - r_2)^2} \\ &= \sqrt{x^2 \left(1 - \left(\frac{r_1 - r_2}{x} \right)^2 \right)} \\ &= x \sqrt{1 - \left(\frac{r_1 - r_2}{x} \right)^2} \end{aligned}$$

Putting binomial theorem

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

$$L = 2(AB + BC + CD)$$

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

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

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

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

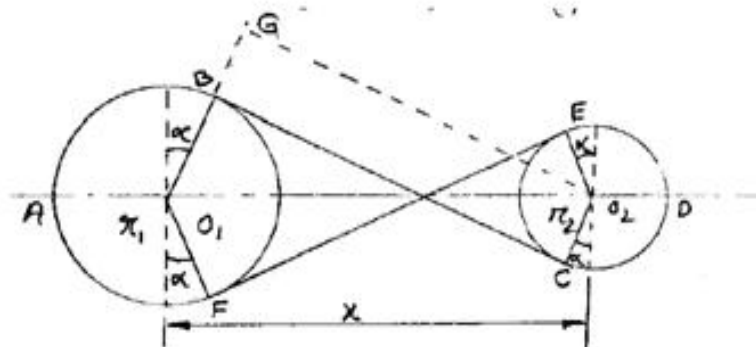
$$= \pi (r_1 + r_2) + 2 \frac{r_1 - r_2}{2x} (r_1 - r_2) + 2x - \frac{(r_1 - r_2)^2}{2x}$$

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

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

Q. Derive an expression for find out the length of cross Bell Drive. (2010

Ans:



r_1, r_2 = radius of smaller and larger pully

X = Distance between the center of two pully

L = Total length of the belt.

$L = \text{Arc AB} + \text{Arc BC} + \text{Arc CD} + \text{Arc DE} + \text{Arc EF} + \text{Arc FA}$

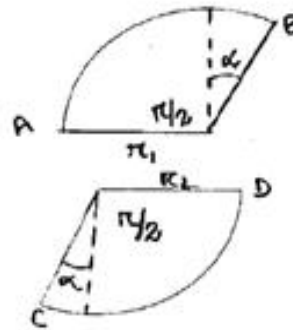
$= 2 (\text{Arc AB} + \text{BC} + \text{CD})$

$\text{Arc AB} = r_1 (\pi/2 + \alpha)$

$\text{Arc CD} = r_2 (\pi/2 + \alpha)$

Then

$$\begin{aligned} BC &= GO_2 \sqrt{(O_1O_2)^2 - (O_1G)^2} \\ &= \sqrt{(x)^2 - (r_1 - r_2)^2} \\ &= \sqrt{x^2 \left[1 - \left(\frac{r_1 + r_2}{x} \right)^2 \right]} \\ &= x \sqrt{1 - \left(\frac{r_1 + r_2}{x} \right)^2} \end{aligned}$$



Putting binomial theorem

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

$$\begin{aligned} \text{From } \triangle GO_1O_2 \quad \sin \alpha &= \frac{GO_1}{O_1O_2} \\ \sin \alpha &= \frac{r_1 + r_2}{x} \end{aligned}$$

Since α is very small $\sin \alpha = \alpha$

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

$L = 2(\text{AB} + \text{BC} + \text{CD})$

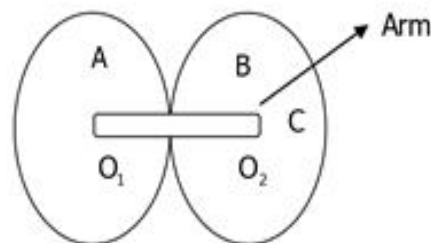
$$\begin{aligned} &= 2 \left[r_1 \left(\frac{\pi}{2} + \alpha \right) + x - \frac{(r_1 - r_2)^2}{2x} + r_2 \left(\frac{\pi}{2} + \alpha \right) \right] \\ &= 2 \left[r_1 \frac{\pi}{2} + r_1 \alpha + x - \frac{(r_1 - r_2)^2}{2x} + r_2 \frac{\pi}{2} + r_2 \alpha \right] \\ &= 2 \left[\frac{\pi}{2} (r_1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

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

Q. Short notes

Epicyclic gear train

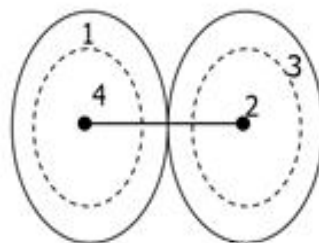
Ans:



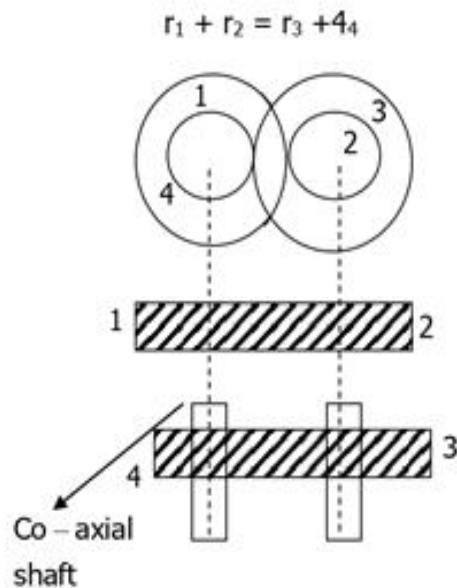
A simple Epicyclic gear train is shown in the figure. Where gear 'A' and the arm 'C' have a common axis at O_1 about which they can rotate. The gear 'B' meshes with gear 'A' and has its axis on the arm at O_2 . About which the gear 'B' can rotate. If the arm is fixed the arm gear train is simple and gear 'A' can drive gear 'B'. If gear 'A' is fixed the arm rotates about the axis of gear 'A'. Then the gear 'B' is forced to rotate upon and around gear 'A' such a motion is called epicyclic and the gear train is called epicyclic gear train.

Q. Reverted Gear train

Ans: When the axis of the gear and the last gear are co-axial then the gear train is known as Reverted gear train.



The gear 1 drives the gear 2 in the opposite direction since the gear 2 and 3 are mounted on the same shaft therefore they form a compound gear and the gear 3 will rotate in the same direction as that of gear 2, the gear 3 drives the gear 4 in the same direction as that of gear-1. So the motion of the first gear and the last gear is alike this called reverted gear train. Since the distance between the centre of the shaft of gear -1 and gear 2 as well gear 3 and gear 4 is same therefore.



Q. Explain slip of belt & creep of belt

2010 1(e)

Ans: Slip of Belt

Some times the frictional grip between the belt and the shaft become's in sufficient. So this may cause some forward motion between the driver and the belt or this may cause some forward motion between the belt and driven. This is called slip of Belt. It is generally expressed in percentage

$S_1 \%$ = Slip between the driver and belt

$S_2 \%$ = Slip between the belt and driven.

Velocity ratio due to slip :-

$$\frac{N_2}{N_1} = \frac{D_1}{D_2} \left(1 - \frac{S_1}{100}\right) \left(1 - \frac{S_2}{100}\right)$$

$$= \frac{D_1}{D_2} \left(1 - \frac{S_1 + S_2}{100}\right) \left(\text{Neglecting } \frac{S_1 \times S_2}{100 \times 100}\right)$$

$$\frac{N_2}{N_1} = \frac{D_1}{D_2} \left(1 - \frac{S}{100}\right) \quad \text{Where } S = S_1 + S_2$$

If the thickness of the belt is considered

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

Q. Creep of Belt :-

When the belt passes from the slack side to the tight side a certain portion the belt extend and when the belt passes from tight side to slack-side. Certain portion will contract due to this change of length. There is a relative motion between belt and pulley occur. This relative motion is called creep.

Velocity ratio due to Creep :

$$\frac{N_2}{N_1} = \frac{D_1}{D_2} \frac{E + \sqrt{\sigma_2}}{E + \sqrt{\sigma_1}}$$

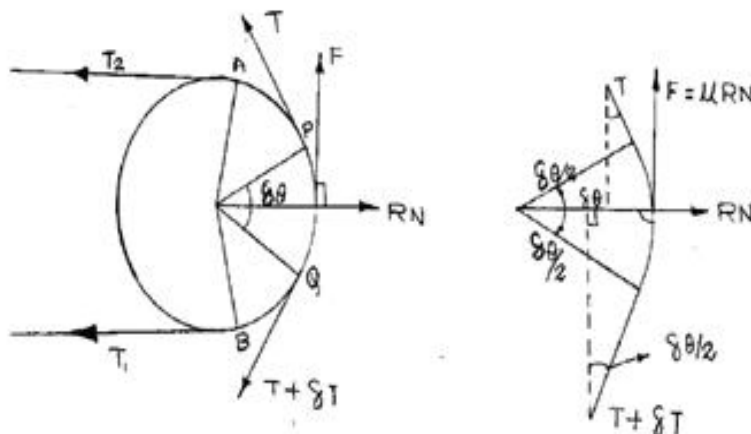
σ_1 = stress in the belt of tight side

σ_2 = stress in belt of slack side

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

Q. Prove that the ratio of Driving Tension $T_1/T_2 = e^{\mu\theta}$

Ans:



Consider a driven pulley rotating in the clockwise direction.

Let, T_1 = Tension in the belt on the tight side.

θ = Angle of contact in radian

T_2 = Tension in the belt on slack side.

Consider a small portion of the belt PQ creating an angle $\delta\theta$ at the centre of the pulley. The belt PQ is in equilibrium under the following forces.

- i. Tension T at P
- ii. Tension $T + \delta T$ at Q
- iii. Force of friction $F = \mu RN$
- iv. Normal reaction (RN)

Resolving forces horizontally

$$RN = T \sin \frac{\delta\theta}{2} + (T + \delta T) \sin \frac{\delta\theta}{2}$$

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

Since $\frac{\delta\theta}{2}$ is very small $\sin \frac{\delta\theta}{2} = \frac{\delta\theta}{2}$

$$RN = T \frac{\delta\theta}{2} + \frac{\delta\theta}{2} + \delta T \cdot \frac{\delta\theta}{2}$$

$$RN = 2T \frac{\delta\theta}{2}$$

$$RN = T\delta\theta \text{ ----- (1)}$$

Resolving the force vertically

$$F + T \cos \frac{\delta\theta}{2} = (T + \delta T) \cos \frac{\delta\theta}{2}$$

$$URN + T \cos \frac{\delta\theta}{2} = T \cos \frac{\delta\theta}{2} + \delta T \cos \frac{\delta\theta}{2}$$

$$\cos \frac{\delta\theta}{2} = 1$$

$$URN + \delta T$$

$$\Rightarrow RN = \frac{\delta\theta}{\mu} \text{ ----- (2)}$$

Equating Eqn. (1) and (2) and integrating T_1 to T_2 and 0 to θ we get

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

$$\text{LN} \left(\frac{T_1}{T_2} \right) = \mu \theta$$

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

Q. Two parallel shafts about 800 mm apart are connected by spur gear, one shaft is run at 400 rpm and other at 180 rpm. Design the gears if the circular pitch is 40 mm.(2013)

Ans:Data given

Distance between two parallel shaft,

$$X = 800 \text{ mm} = 0.8 \text{ m}$$

Speed of one shaft, $N_1 = 400 \text{ rpm}$

Speed of the other shaft, $N_2 = 180 \text{ rpm}$.

Circular pitch, $P_c = 40 \text{ mm} = 0.04 \text{ m}$

Let d_1 and d_2 are pitch circle diameter of the 1st and 2nd gear respectively.

We know that speed ratio $\frac{N_1}{N_2} = \frac{d_2}{d_1}$

$$\Rightarrow \frac{400}{180} = \frac{d_2}{d_1}$$

$$\Rightarrow \frac{d_2}{d_1} = 2.222$$

$$\Rightarrow d_2 = 2.222 d_1 \dots \dots \dots (1)$$

The centre distance between the shafts (x)

$$\Rightarrow 800 = \frac{1}{2}(d_1 + d_2)$$

$$\Rightarrow d_1 + d_2 = 1600 \dots \dots \dots (2)$$

For equations (1) and (2) we find that,

$d_1 = 496.5 \text{ mm}$ and $d_2 = 1103.4 \text{ mm}$

∴ Number of teeth on the first gear,

$$T_1 = \frac{\pi d_1}{P_c} = \frac{\pi \times 496.5}{40} = 38.99$$

Number of teeth on the second gear,

$$T_2 = \frac{\pi d_2}{P_c} = \frac{\pi \times 1103.4}{40} = 86.66$$

Since the number of teeth on both the gears are to be in complete numbers, therefore, let us make the number of teeth on the first gear as 39. Therefore for a speed ratio of 2.222, the number of teeth on the second gear should be

$$39 \times 2.222 = 86.66 \text{ say } 87$$

Now the exact pitch circle diameter of the first gear

$$d_1^1 = \frac{T_1 \times P_c}{\pi} = \frac{39 \times 40}{\pi} = 496.56 \text{ mm}$$

The exact pitch circle diameter of the second gear.

$$d_2^1 = \frac{T_2 \times P_c}{\pi} = \frac{87 \times 40}{\pi} = 1107.7 \text{ mm}$$

Exact distance between the two shafts,

$$x^1 = \frac{d_1^1 + d_2^1}{2} = \frac{496.56 + 1107.7}{2} = 802.213 \text{ mm}$$

Hence the number of teeth on the first and second gear must be 39 and 87 and their pitch circle diameters must be 496.56 mm and 1107.7 mm respectively. The exact distance between the two shafts must be 802.13 mm.

Q. Derive the velocity ratio of compound gear drive

Ans: When there are more than one gear on a shaft as shown is called a compound train of gear or compound gear drive.

In a compound train of gears, the 1 is the driving gear mounted on shaft A, gears 2 and 3 are compound gears which are mounted on shaft B. The gears 4 and 5 are also compound gears which are mounted on shaft C and the gear 6 is the driven gear mounted on shaft D.

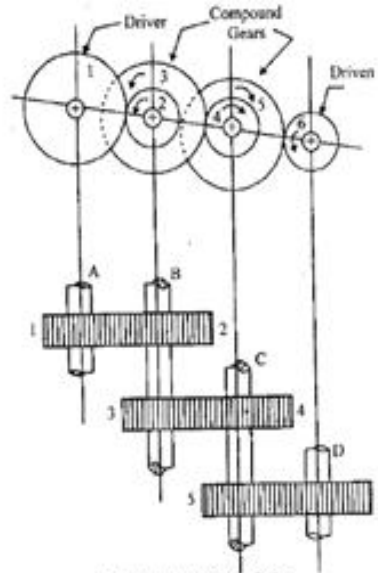


Fig. Compound Gear Drive

Let N_1 = sped of driving gear 1.

T_1 = Number of teeth on driving gear 1.

N_2, N_3, \dots, N_6 = Speed of respective gears in rpm and,

T_2, T_3, \dots, T_6 = Number of teeth on respective gears.

Since gear 1 is in mesh with gear 2, therefore its speed ratio is :

$$N_1/N_2 = T_2/T_1 \dots\dots\dots(1)$$

Similarly, the gears 3 and 4, speed ratio is

$$N_3/N_4 = T_4/T_3 \dots\dots\dots(2)$$

And for gears 5 and 6, speed ratio is

$$N_5/N_6 = T_6/T_5 \dots\dots\dots(3)$$

The speed ratio of compound gear train is obtained by multiplying the equation (1), (2) and (3)

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

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

i.e. speed = $\frac{\text{speed of the first driver}}{\text{Speed of the last driven or follower}}$
 = $\frac{\text{product of the number of teth on the drivens}}{\text{Product of the number of teeth on the drivers}}$
 Train value
 = $\frac{\text{Speed of the number of teeth on the drivers}}{\text{Sped of the number of teeth on the drivens}}$
 = $\frac{\text{Pr oduct of the number of teeth on the drivers}}{\text{Product of the number of teeth on the drivers}}$

The advantage of a compound train over a simple gear train is that a much larger speed reduction from the first shaft to the last shaft can be obtained with small gears. If a simple gear train is used to give a large speed reduction, the last gear has to be very large. Usually for a speed reduction in excess of 7 to 1, a simple train is not used and a compound train of worm gearing is employed.

Q. Two parallel shafts are to be connected by spur gearing. The approximate distance between the shafts is 600 mm. If one shaft runs at 120 rpm and the other at 360 rpm find the number of teeth on each wheel if the module is 8 mm. Also determine the exact distance apart of the shafts. 2015(s)

Ans: Data is given,

Distance between the two shafts,

$$X = 600 \text{ mm} = 0.6 \text{ m (Approx.)}$$

Speed of one shaft, $N_1 = 120 \text{ rpm}$.

Speed of other shaft, $N_2 = 360 \text{ rpm}$

Module, $m = 8 \text{ mm}$

Let $d_1 =$ pitch circle diameter of first gear

$D_2 =$ pitch circle diameter of the second gear.

We know the speed ratio,

$$\frac{N_1}{N_2} = \frac{d_2}{d_1} = \frac{120}{360} = \frac{1}{3}$$

$$\Rightarrow d_1 = 3d_2 \dots \dots \dots (1)$$

We have centre distances between the shafts

$$(x) = \frac{1}{2}(d_1 + d_2)$$

$$\Rightarrow 600 = \frac{1}{2}(d_1 + d_2)$$

$$\Rightarrow d_1 + d_2 = 1200 \dots \dots \dots (2)$$

From equation (1) and (2) we have,

$$\Rightarrow 3d_2 + d_2 = 1200$$

$\Rightarrow d_2 = 300$ mm and $d_1 = 3 \times 300 = 900$ mm. Let T_1 and $T_2 =$ Number of teeth on the 1st and 2nd gear respectively.

We have, module, $m = d/T$

$$m = \frac{d_1}{T_1} = \frac{900}{T_1}$$

$$\Rightarrow T_1 = \frac{900}{8} = 112.5$$

$$\text{Again, } m = \frac{d_2}{T_2} \Rightarrow \frac{d_2}{m} = \frac{300}{8} = 37.5$$

Since the number of teeth on both the gears are to be in complete numbers, therefore let's make the number of teeth on the 2nd gear as 38. Therefore for a speed ratio of 1/3, the number of teeth on the 1st gear should

$$\text{be } 38 \times 3 = 114 \left(\frac{d_2}{d_1} = \frac{T_2}{T_1} = \frac{1}{3} \right)$$

Now the exact pitch circle diameter of the first and second gear.

$$d_1' = m \times T_1 = 8 \times 114 = 912 \text{ mm.}$$

$$d_2' = m \times T_2 = 8 \times 38 = 304 \text{ mm.}$$

\therefore Exact distance between the two shafts.

$$x' = \frac{d_1' + d_2'}{2} = \frac{912 + 304}{2} = 608 \text{ mm}$$

Q. Find the power transmitted by a belt running over a pulley of 600 mm diameter at 200 rpm. The co-efficient of friction between the belt and the pulley is 0.25 angle of lap 160° and maximum tension in the belt is 2500 N.(2013)

Ans:Data given

Diameter of the pulley, $d = 600$ mm

Speed of pulley, $w = 200$ rpm

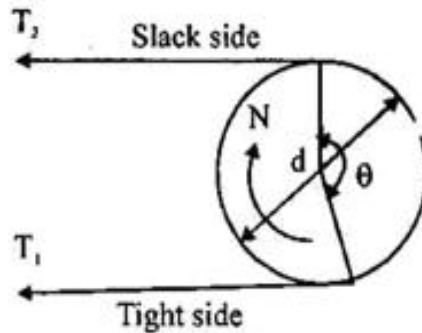
Co-efficient of friction , $\mu = 0.25$

Angle of lap , $\theta = 160^\circ = 160 \times \pi/180 = 2.793 \text{ rad}$

Tension in tight side or maximum tension,

$$T_1 = 2500 \text{ N.}$$

Let $T_2 =$ Tension in slack side.



We know velocity of the belt,

$$V = \frac{\pi d N}{60} = \frac{\pi \times 0.6 \times 200}{60} = 6.284 \text{ m/s}$$

Again we have the relation of tensions

$$2.3 \log_e \left(\frac{T_1}{T_2} \right) = \mu \theta = 0.25 \times 2.793 = 0.6982$$

$$\log_e \left(\frac{T_1}{T_2} \right) = \frac{0.6982}{2.3} = 0.3036$$

Taking antilog of 0.3036 we have

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

$$\Rightarrow T_2 = \frac{T_1}{2.01} = \frac{2500}{2.01} = 1244 \text{ N}$$

\therefore power transmitted by the belt,

$$P = (T_1 - T_2)V$$

$$= (2500 - 1244) \times 6.284$$

$$= 7890 \text{ W} = 7.89 \text{ KW.}$$

- Q. Two parallel shafts 6 metres apart are provided with 300 mm and 400 mm diameter pulleys and are connected by means of a cross belt. The direction of rotation of the follower pulley is to be reversed by**

changing over to an open belt drive. How much length of the belt has to be reduced ?(2015)

Ans: Data given

Diameter of pulley-1, $d_1 = 300 \text{ mm} = 0.3 \text{ m}$

Diameter of pulley-2, $d_2 = 400 \text{ mm} = 0.4 \text{ m}$

Distance between two pulleys, $x = 6 \text{ m}$

We know that distance between two pulleys of cross belt drive type is given by

$$L = \frac{\pi}{2}(d_1 + d_2) + 2x + \frac{(d_1 + d_2)^2}{4x}$$
$$= \frac{\pi}{2}(0.3 + 0.4) + (2 \times 6) + \frac{(0.3 + 0.4)^2}{4 \times 6} = 13.12 \text{ m}$$

Length of belt for open belt drive is

$$L = \frac{\pi}{2}(d_1 + d_2) + 2x + \frac{(d_1 - d_2)^2}{4x}$$
$$= \frac{\pi}{2}(0.3 + 0.4) + (2 \times 6) + \frac{(0.3 - 0.4)^2}{4 \times 6} = 13.01 \text{ m}$$

Length of belt has to be reduced from cross belt to open belt is $-dl = L_{\text{cross}} - L_{\text{open}}$
 $= 13.12 - 13.01 = 0.11 \text{ m} = 110 \text{ mm}.$

Q. Mention various types of gear drives and their advantage over belt drives.(2015)

Ans: Types of Gear Drives:

- i) According to the position of axes of the shafts.
 - Parallel gear drive (Ex. Spur gear)
 - Intersecting gear drive (Ex. Bevel gear)
 - Non-intersecting and non-parallel (Ex. Helical bevel gear, spiral gear etc.)
- ii) According to the peripheral velocity of the gears
 - Low velocity ($< 3 \text{ m/s}$)
 - Medium velocity (3 to 15 m/s)
 - High speed gears ($> 15 \text{ m/s}$)

- iii) According to the type of gearing.
 - External gearing.
 - Internal gearing.
 - Rack and pinion.
- iv) According to position of teeth on the gear surface.
 - According to position of teeth on the gear surface.
 - Straight
 - Inclined
 - Curved

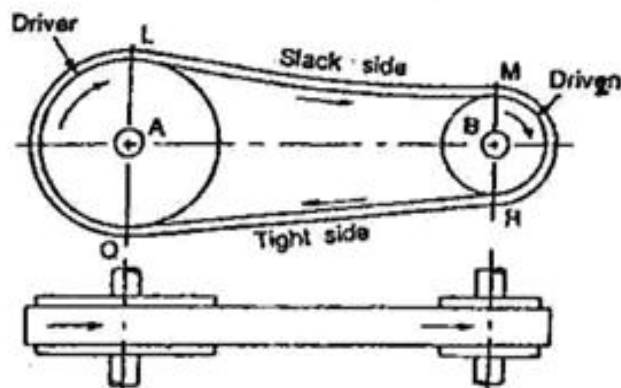
Advantages of Gear Drive over belt drive:

- i. It transmits exact velocity ratio.
- ii. It has high efficiency
- iii. It has reliable service
- iv. It has compact layout.
- v. It is used to transmit large power.

Q. Write various types of belt drive.(2013)

Ans:Types of Belt Drives : The power from one pulley to another may be transmitted by any of the following types of belt drives.

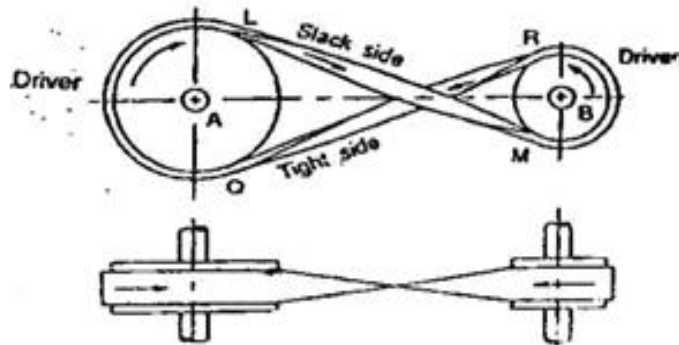
1. Open belt drive: The open belt drive is used with shafts arranged parallel and rotating in the same direction. In this case, the driver A pulls the belt from one side (i.e. lower side RQ) and delivers it to the other side (i.e. upper side LM). Thus the tension in the lower side belt will be more than that in the upper side belt. The lower side belt (because of more tension) is known as tight side whereas the upper side belt (because of less tension) is known as slack side, as shown in figure -a



2. Crossed or twist belt drive: The crosses or twist belt drive, as shown in figure b is used with shafts arranged parallel and rotating in the opposite directions.

In this case, the driver pulls the belt from one side (i.e., RQ) and delivers it to the other side (i.e., LM). Thus the tension in the belt RQ will be more than that in the belt LM. The belt RQ (because of more tension) is known as tight side, whereas the belt LM (because of less tension) is known as slack side, as shown in figure-b.

A little consideration will show that at a point where the belt crosses, it rubs against each other and there will be excessive wear and tear.



ig. (b) : Crossed or twist belt drive.

3. Compound belt drive : A compound belt drive is shown in figure-g is used when power is transmitted from one shaft to another through a number of pulleys.

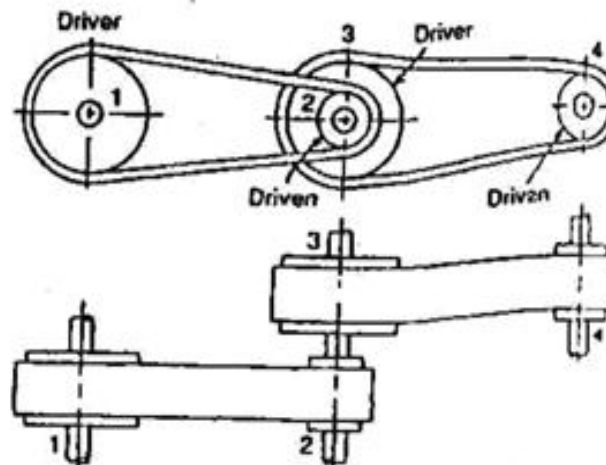


Fig. (g) : Compound belt drive

4. Speed or cone pulley drive: A stepped or cone pulley drive as shown in figure –h is used for hanging the speed of the driven shaft while the main or driving shaft runs at constant speed. This is accomplished by shifting the belt from one part of the steps to the other.

**Q. Drive an expression for maximum power transmission $T = 3T_c$
2010, 1(g),2016**

Ans: We know that the power transmitted by a belt

$$P = (T_1 - T_2) \times V \dots \dots \dots (1)$$

Let,,

T_1 = Tension in the tight side

T_2 = Tension in the slack side.

V = Velocity of the belt in m/sec.

We know that,

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

$$\Rightarrow T_2 = T_1/e^{\mu\theta}$$

Putting the value in equation(1)

$$P = (T_1 - T_1/e^{\mu\theta}) \times V$$

$$\Rightarrow T_1 (1 - 1/e^{\mu\theta}) \times V$$

$$P = T_1 \times C \times V$$

\therefore Where $C = 1 - 1/e^{\mu\theta}$

We know that, max. tension

$$T = T_1 + T_2$$

$$\Rightarrow T_1 = T - T_2$$

$$P = (T - T_2) CV$$

$$P = (T - T_2)V \times C$$

$$P = (T - mV^3) \times C$$

Condition for max. power differentially 'P' with respect to 'V' and equating with zero.

$$\begin{aligned}
\Rightarrow \frac{dp}{dv} &= 0 \\
\Rightarrow \frac{d(T_v - mv^3)c}{dv} &= 0 \\
\Rightarrow \frac{d(T_v)}{dv} - \frac{d(mv^3)}{dv} &= 0 \\
\Rightarrow T - 3mv^2 &= 0 \\
\Rightarrow T &= 3mv^2 \\
\Rightarrow T &= 3T_c \\
\text{Where } T_c &= mv^2
\end{aligned}$$

Q. Classification of kinematic pair. 2013, 1(c)2017s

Ans: According to the type of relative motion between the element it is further classified into various types.

- (a) Sliding pair.
- (b) Turning pair
- (c) Rolling pair
- (d) Screw pair
- (e) Spherical pair

- (a) Sliding pair:** When the two elements of a pair are connected in such a way that one, can slide related to other, the pair is known as sliding pair. Ex-Ram and its guides in shaper.
- (b) Turning pair:-**When the two element of a pair are connected in such a way that one can turn or revolve about a fixed axis of another link, the pair is known as turning pair. Ex. Cycle wheel turning over the axle.
- (c) Rolling pair:** When the two element of a pair are connected in such a way that one can rolls over the another fixed link. Ex. Ball and roller bearing.
- (d) Screw pair:-** When the two element of a pair are connected in such a way that one element can turn about the other by screw thread. Ex. Nut and bolt.
- (e) Spherical pair :-** When the two element of a pair are connected in such a way that one element turns about the other fixed element the pair is known as spherical pair. Ex- Ball and socket joint.

CHAPTER - 4

CHAPTER:4

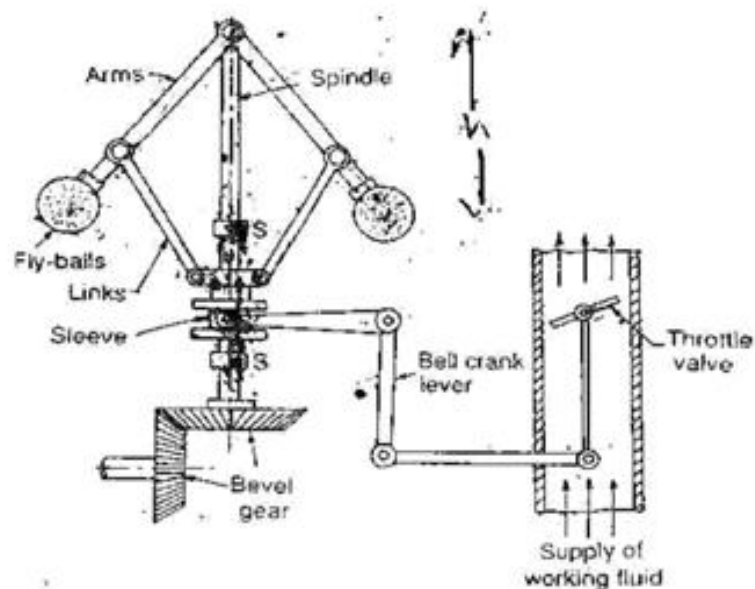
GOVERNOR AND FLY WHEEL

Q. Write the function of governor.

Ans: The function of governor is to regulate the mean speed of an engine when there are variations in load.

Q. Describe working of a simple watt governor:

Ans: The watt governor is a centrifugal type governor which consists of two fly balls two arms, links one sleeve and one spindle.



When speed of engine increases from mean speed the fly balls move outward due to increase in centrifugal force. Due to upward motion of sleeve the working fluid supply to engine is reduced by closing of throttle valve which is connected

when speed of engine decreases the fly balls move inward due to decrease in centrifugal force and sleeve moves down ward. Due to downward motion of sleeve the working fluid is supplied to engine by the opening of throttle valve connected at one end of bell crank lever

**Q. Explain with neat sketch the working of a hartnell governor, 2013(s)
(7c)**

Ans: It is a spring loaded governor which consists of one spring, two bell crank levers, one sleeve. Levers, one sleeve, two rollers, adjusting nut when speed of engine increases from mean speed the fly balls move outward due to increase in centrifugal force and sleeve moves upward. Due to upward motion of sleeve. The supply of working fluid is reduced by means of bell crank lever connected to groove of sleeve.

When speed of governor decreases the fly balls move inward due to decrease in centrifugal force and sleeve moves down ward . Due to downward motion of sleeve working fluid is supplied to the engine by means of another ball crank lever.

Q. Write the function of fly wheel.

Ans:The function of fly wheel is to store excess energy when supply is more than requirement and releases it during the period when requirement is more than supply.

Q. Give a comparison between governor and fly wheel?

Ans:Comparison between Governor and fly wheel: The comparisons are

Governor :

- (i) Its function is to regulate the supply of driving fluid producing energy, according to the load requirements so that at different loads almost a constant speed is maintained.
- (ii) It is provide on prime movers such as engines and turbines.
- (iii) It takes care of fluctuation of speed due to variation of load over long range of working of engines and turbines.
- (iv) It works intermittently, i.e., only when there is change in the load.
- (v) But for governor, there would have been unnecessarily more consumption of driving fluid. Thus it economizes its consumption.

Fly-wheel

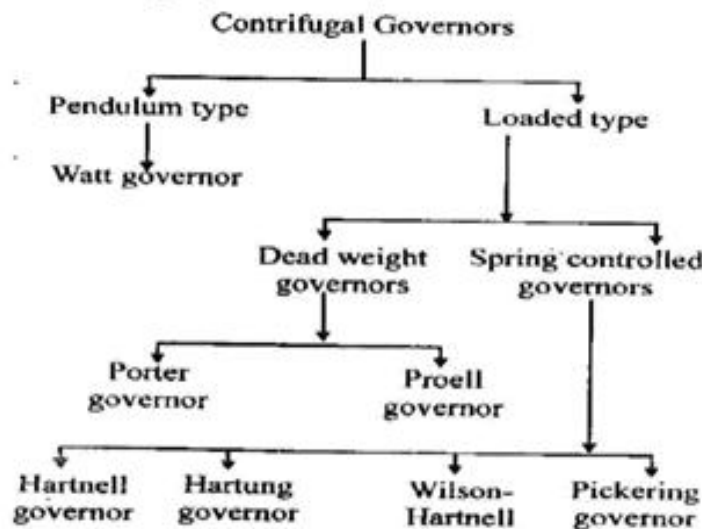
- (i) Its function is to store available mechanical energy when it is in excess of the load requirement and to part with the same when the available energy is less than that required by the load.
- (ii) It is provided on engine and fabricating machines viz, rolling mills, punching machines, shear machines, presses, etc.
- (iii) In engines it takes care of fluctuations of speed during thermodynamic cycle.
- (iv) It works continuously from cycle to cycle.
- (v) In fabrication machines it is very economical to use it as its use reduces capital investment on prime movers and their running expenses.

Q. Write down the classification of governor.

Ans: Classification of Governor: The governors may, broadly be classified as:

- (i) Centrifugal governors.
- (ii) Inertia governors.

The centrifugal governors may further be classified as follows:



Q. Explain the working of a porter governor.

Ans:

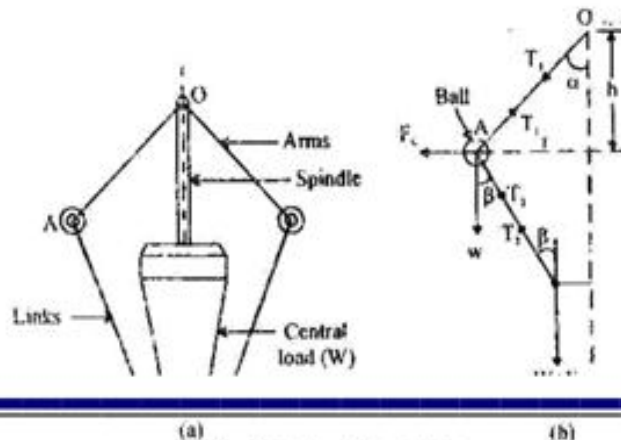


Fig. Porter Governor

Figure shows the diagram of a porter governor . In case of porter governor, a central heavy load is attached to the sleeve. The central load and sleeve move up and down the spindle.

Let M = Mass of central load.

W = Weight of central load = $M \times g$

w = Weight of each ball = $m \times g$

m = Mass of each ball

h = Height of governor

r = Radius of rotation.

F_c = Centrifugal force on the ball = $m \times \omega^2 \times r$

ω = Angular speed of ball = $2\pi N/60$ rad/s.

N = Speed of ball in r.p.m.

T_1 = Tension in upper link.

T_2 = Tension in lower link

α = Angle of inclination of the upper arm to the vertical.

β = Angle of inclination of the lower link to the vertical.

F_f = Force of friction between sleeve and spindle.

The force of the friction always acts in a direction opposite to that of the motion. When sleeve moves up, the force of the friction acts in the downward direction. Then the total force acting on the sleeve in the downward direction will be $(W + F_f)$. Similarly when the sleeve will be $(W - F_f)$. In general the total force acting on the sleeve will be $(W \pm F_f)$ depending upon whether the sleeve move upwards or downwards.

The relation between the height of governor and angular speed of ball.

Q. A vertical double acting steam engine develop 75 kW at 250 r.p.m. The maximum fluctuation of energy is 30 % of the workdone per stroke. The maximum and minimum speeds are not to vary more than

1 % on either side of the mean speed. Find the mass of the flywheel required if the radius of gyration is 0.6 m.(2015)

Ans:Data given,

Power developed by the engine, $P = 75 \text{ KW} = 75 \times 10^3 \text{ W}$

Angular speed,

$$\omega = \frac{2\pi N}{60} = \frac{2\pi \times 250}{60} = 26.2 \text{ rad/sec.}$$

Speed, $N = 250 \text{ r.p.m.}$

Radius of gyration , $K = 0.6 \text{ m}$

Maximum fluctuation of energy,

$$\Delta E = 30 \% \text{ of workdone/cycle} = 0.3 W.$$

Since the fluctuation of speed is 1 % of the measured speed therefore total fluctuation of speed.

$$\omega_1 - \omega_2 = 2 \% W = 0.02\omega.$$

\therefore Co-efficient of fluctuation of speed,

$$C_s = \frac{\omega_1 - \omega_2}{\omega} = 0.02$$

Let $m =$ Mass of flywheel.

We know that workdone per cycle,

$$W = \frac{P \times 60}{N} = \frac{75 \times 10^3 \times 60}{250} = 18 \times 10^3 \text{ N-m}$$

Maximum fluctuation of energy/stroke,

$$\Delta E = 0.3 \times \frac{W}{2} = \frac{0.3 \times 18 \times 10^3}{2} = 2.7 \times 10^3 \text{ N-m}$$

(Since it is a double acting steam engine. But we have maximum fluctuation of energy)

$$\Delta E = mK^2 \omega^2 \times Ls$$

$$\Rightarrow 2.7 \times 10^3 = m \times (0.6)^2 \times (26.2)^2 \times 0.2$$

$$\Rightarrow m = 547 \text{ kg.}$$

Q. Four masses A, B, C and D revolve at equal radii and are equally spaced along a shaft. The mass B is 7 kg and the radii of C and D make angles of 90° and 240° respectively with the radius of B. Find

the magnitude of the masses A, C and D and the angular position of A so that the system may be completely balanced.(2015)

Ans:As it is a balanced system, so the value of 'r' and 'l' are constant.

Assume, 1 kg = 1 cm

$$3m_D = 14 \Rightarrow m_D = 14/3 = 4.67 \text{ kg}$$

$$2m_C = 12.5 \Rightarrow m_C = 6.25 \text{ kg.}$$

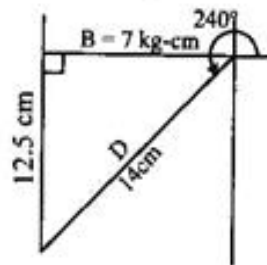


Fig.1 : Couple polygon (not to scale)

In 1st figure A takes R.F. that's why couple is zero

For B : m.r.l = 7.r.l

For C : m.f.l = m_Cr × 2l

For D : m.f.l = m_D.r.l

But r.l is constant

Assume radius = 400 mm and length = 200 mm.

Plane	Mass(m)	Radius (r)	Cent. force (m.r)	Distance	couple(m.r.l.)
A	m _a	0.4 m	M _a × 0.4	0.2	M _a × 0.8
B(R.F)	7 kg	0.4m	2.8	0	0
F	6kg	0.4m	2.4	0.2	4.8
D	4.67kg	0.4m	1.87	0.4	0.748

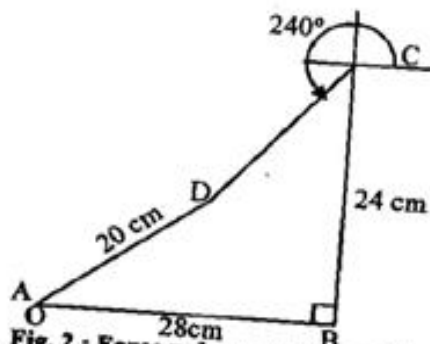


Fig. 2 : Force polygon (not to scale)

$$M_a \times 0.4 = 2$$

$$\Rightarrow M_a = \frac{2}{0.4} = 5 \text{ kg}$$

CHAPTER - 5

CHAPTER:5

Q DEFINE STATIC BALANCING

Static balancing definition refers to the ability of a stationary object to its **balance**. The occurs when a parts centre of gravity is on the axis of rotation.

Q. Differentiate between static and dynamic balancing?

Ans: Whenever a certain mass is attached to a rotating shaft, it exerts some centrifugal force whose effect is to bend the shaft and to produce vibration init. In order to prevent the effect of centrifugal force another mass is attached to the opposite side of shaft at such a point so as to balance the effect of centrifugal force of first mass.

This is done in such a way that the centrifugal force of both the masses are made to be equal and opposite. The process of providing the second mass to counter the effect of centrifugal force of first mass is called of centrifugal force of first mass is called balancing of rotating masses. Static balancing. The net dynamic force acting on shaft should be zero. It means the center of mass of system must lie on axis of rotation. This is condition for static balancing.

For dynamic balancing it should satisfy the condition of static balancing and also net couple due to dynamic forces acting on shaft is equal to zero. In other words the algebraic sum of moments about any point on the plane must be zero.

Q. Why is balancing required for rotating and reciprocating parts ?

Ans: When some members are connected to a reciprocating or rotating member during working, due to imbalance mass distribution they produce vibration noise which may lead to major breakdown. To avoid all these problems balancing is required.

Q EXPLAIN CO EFFICIENT OF FLUCTUATION OF SPEED AND ENERGY?2019

Answer:

(i) Coefficient of fluctuation of speed: Coefficient of fluctuation of speed is defined as the ratio of the maximum fluctuation of speed to the mean speed. It is denoted by C_s .

Mathematically,

$$C_s = (N_1 - N_2) / N$$

Where, N_1 = maximum speed in rpm;

N_2 = minimum speed in rpm; N = mean speed in rpm

(ii) Coefficient of fluctuation of energy: Coefficient of fluctuation of energy may be defined as the ratio of the maximum fluctuation of energy to the work done per cycle. It is denoted by C_e .

Mathematically,

C_e = Maximum fluctuation of energy/ Work done per cycle.

CHAPTER - 6

CHAPTER:6

Q. State causes and remedies of vibration?

Ans: Causes of vibration

Lack of balancing : In machines there may be a number of rotating and reciprocating parts having motion in different planes causing dynamic forces. If all dynamic forces are not completely balanced it may give rise to unbalanced it may give rise to unbalanced couple which may create vibration in machines.

Loose Fitting: If machine parts are not properly fitted i.e. nuts, bolts, screws and foundation bolts are not properly tightened this may create vibrations in machines.

Incorrect alignment: In a machine there may be one or more places where motion or power transmission may take place. If there is no proper alignment between machine and its foundation, vibrations will be set up in machine.

Vibration wave: If the heavy machines such as pneumatic hammer etc are installed nearby they produce sound waves due to their working impact while impinging on adjoining machine will cause vibration.

Lack of isolation : If vibration produced in a machine are not isolated by not. Providing isolating material between machine and foundation and between foundation block and soil and by not, providing side air gaps, the vibrations are transmitted to adjoining machines.

Lack of compact soil: If soil of machine foundation is wet loose and hence not compact settlement of foundation may be produced causing misalignment of machine resulting in development of vibrations.

Remedies:

Although it is impossible to eliminate the vibrations, yet these can be reduced by adopting various remedies, some of the remedies are listed below:

- (i) Partial balancing of reciprocating masses.
- (ii) Balancing of unbalanced rotating masses.
- (iii) Using helical gears instead of spur gears.
- (iv) Proper tightening and locking of fastenings and periodically ensuring it again.
- (v) Correcting the mis-alignment of rotating components and checking it from time to time
- (vi) Timely replacement of work-out moving parts, slides and bearings with excessive clearance.
- (vii) Isolating vibrations from other machines and sources by providing vibration insulation pads in the machine foundations.
- (viii) Making machine foundations on compact ground and making them sufficiently strong, so that they do not yield or settle under the load of the machine.

Q. Define time period and amplitude with respect to vibration.

Time period :

It is the time interval after which the motion is repeated itself, It is expressed in seconds.

Amplitude:

The maximum displacement of particle from mean position is known as amplitude.

Q. Define in short free vibration, forced vibration and damped vibration.

Ans: Free vibration:

When no external forces act on the body after giving it an initial displacement, then the body is said to be under free vibration.

Forced vibration :

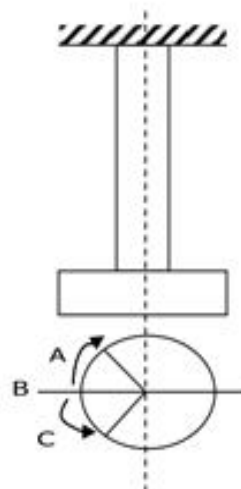
When the body vibrates under the influence of external forces then the body is said to be under forced vibration.

Damped vibration: When there is reduction in amplitude over every cycles of vibration the motion is said to be damped vibration. In this case a certain amount of energy is dissipated in overcoming frictional resistance to motion.

Q. With neat sketch explain torsional vibration and longitudinal vibration.

Ans: Torsional vibration.

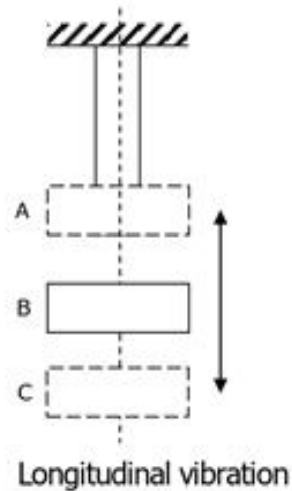
When particles of shaft or disc move in a circle about the axis of shaft then the vibration is known as torsional vibration. In this case the shaft is twisted and untwisted alternately and torsional shear stress is induced in the shaft.



Torsional vibration

Longitudinal vibration:

When particles of shaft or disc moves parallel to the axis of shaft then the vibrations are known as longitudinal vibration. In this case the shaft is elongated and shortened alternately and the tensile and compressive stresses are induced in the shaft.



Q. Explain classify the various types of vibration:

Ans: Types of vibration:

- i) Natural vibration.
- ii) Forced vibration
- iii) Damped vibration

NATURAL VIBRATION

When no external force act on the body after giving it an initial displacement then the body is said to be free vibration or natural vibration. It is three types

- i) Longitudinal vibration
- ii) Transversed
- iii) Torsional vibration

LONGITUDINAL VIBRATION

When the particles of the shaft moves parallel to the axis of th shaft then the vibration is known as longitudinal vibration.

TRANSVERSED VIBRATION:

When the particles of the shaft moves perpendicular to the axis of the shaft, then the vibration is known as transverse vibration.

TORSIONAL VIBRATION:

When the particles of the shaft moves in a circle about the axis of the shaft then the vibration is known as torsional vibration.

FORCED VIBRATION:-

When the body vibrate under the influence of external force. Then the body is said to be forced vibration.

DAMPED VIBRATION:-

When there is reduction amplitude for every cycle of operation then the motion is said to be damped vibration.