THEORY OF MACHINES

Lesson-01
(Mechanism)

THEORY OF MACHINES :- The theory of machine may be define as that branch of engineering science which deals with the study of relative motion between the various parts of machine.

SUBDIVISION OF THEORY OF MACHINE :-

1. Kinematics:- It is the branch of theory of machine which deals with the relative motion between the various machine parts.
2. Dynamics:- It is the branch of theory of machine which deals with the forces and their effects while acting on the machine parts in motion.
3. Kinetics:- It is the branch of theory of machine which deals with the inertial forces which arise from the combined effect of the mass and motion of the machine parts.
4. Statics:- It is the branch of theory of machine which deals with the forces and their effects while the machine parts are at rest.

SIMPLE MECHANISM

KINETIC LINK:- Each part of a machine which moves relative to some other parts is known as a kinematic link or element. A link may consists of several parts, which are rigidly fastened together. So that they do not move relative to another.

STRUCTURE:- It is an assemblage of a number of resistant bodies having no relative motion between them and meant for carrying loads having straining action.

KINEMATIC PAIR :- The two links or elements of a machine when in contact with each other are said to form a pair.If the relative motion between them is completely or successfully constrained, the pair is known as kinematic pair.

KINEMATIC CHAIN :- A kinematic chain is a combination of kinematic pairs, joined in such a way that each link forms a part of two pairs and the relative motion between the links or elements completely constrained.

MECHANISM:- When one of the link of a kinematic chain is fixed, the chain is fixed, the chain is known as mechanism.
A mechanism with four links is known as simple mechanism and the mechanism with more than four links is known as compound mechanism.

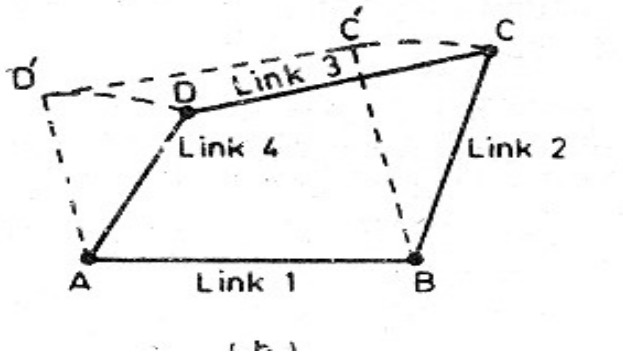
INVERSION:- Some time one of the link in a kinematic chain is fixed. In such a case, we may obtain as many mechanism as the links of the kinematic chain. This method of obtaining different mechanism by fixing in turn different links in a kinematic chain is known as inversion

TYPES OF KINEMATIC CHAIN :-

1. Four Bar Chain Or Quadric cycle chain.
2. Single slider crank chain.
3. Double slider crank chain.

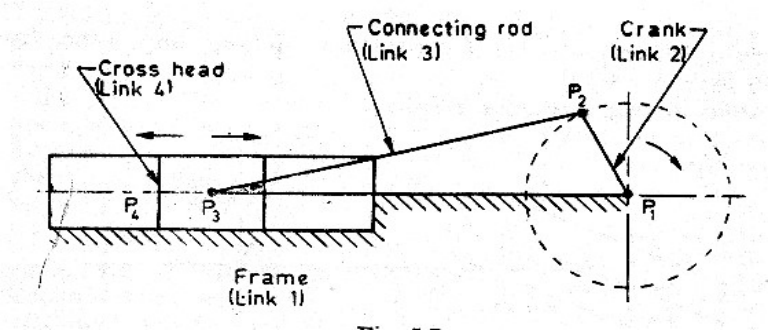
1. FOUR BAR CHAIN OR QUADRIC CHAIN:-

Kinematic chain is a combination of kinematic pairs .A kinematic chain is known as four bar chain or Quadric cycle chain as shown in figure. In a four bar chain each of the four pair is a turning pair. The four links or element may be of different lengths. A little consideration will show that,if a definite displacements given to the link AB, keeping the link AB fixed, the resulting displacement of the remaining two links BC and CD are also perfectly definite. Thus we see that in a four bar chain the relative motion is completely constrained. The practical application of a four bar chain are found in bam engine (crank and lever mechanism)



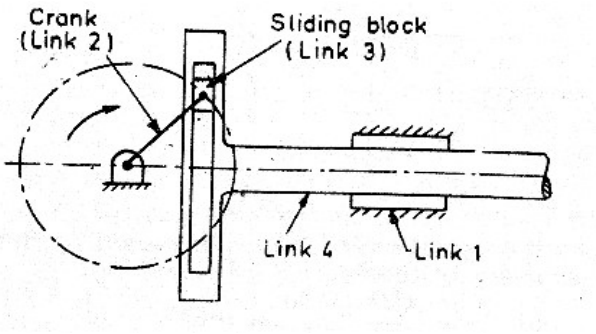
2. SINGLE SLIDER CRANK CHAIN:-

A single slider crank chain consists of one sliding pair and three turning pair. It is usually found in reciprocating steam engine mechanism. This type of mechanism converts rotary motion into reciprocating motion and vice-versa. In a single slider crank chain as shown in figure P_1, P_2, P_3 are turning pairs and P_4 is a sliding pair. The link -1 corresponds to the frame of engine, which is fixed to the link-2 corresponds to the cranklink-3 corresponds to the connecting rod & the link-4
Corresponds to the cross head. As the crank rotates the cross head reciprocates in the guides.



3. DOUBLE SLIDER CRANK CHAIN:-

A kinetic chain consisting of two turning pairs and two sliding pairs is known as double slider crank chain, which is shown in figure, we see that link-3 and link-4 form one sliding pair and link-4 and link-1 form second sliding pairs. The link-2 and link-1 form one turning pair & link-2
And link-3 form secondary turning pair.



Mechanisms and Machines
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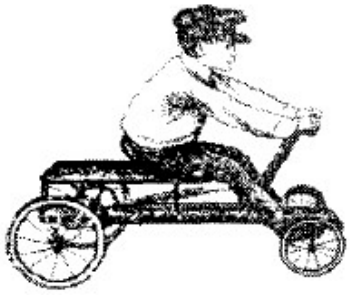
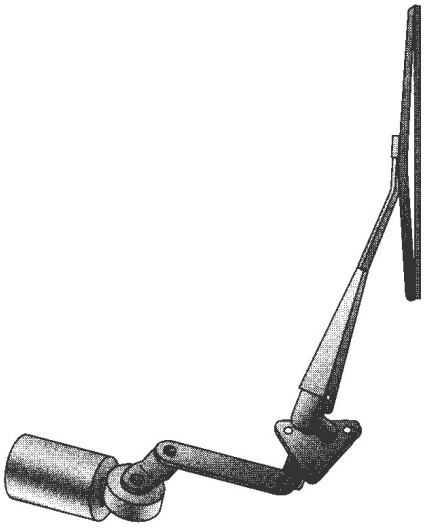


A mechanism

A machine

Rear-window



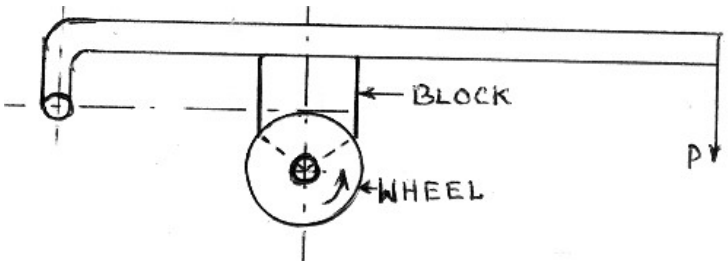
Lesson-02

(Brake & Dynamometers)

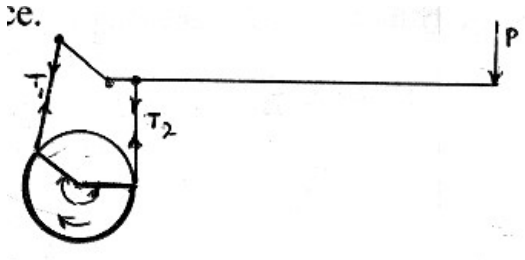
BRAKE:-A brake is a device by means of which artificial frictional resistance is applied to a moving body in order to retard or stop the motion of a body.

TYPES OF BRAKES:-

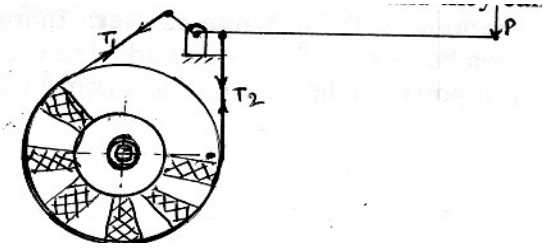
1. SIMPLE BLOCK OR SHOE BRAKE: - A simple block of brake consists of a block which is pressed against the rim of the revolving wheel. The block is made of a softer material than the rim of the wheel. The friction between block and wheel causes a tangential braking force to act on the wheel which outwards the rotation of the wheel. This type of brake are used on Railway train, tram etc.



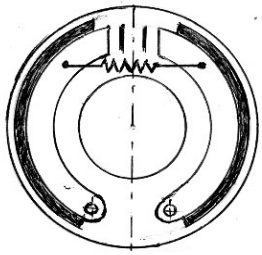
2. BAND BRAKE: - A band brake consists of a flexible band of lather, one or more ropes or steel lined with friction material which embraces a part of the circumference of the drum. The ends of band are joined to a lever pivoted on affixed pin. When a force is applied to the lever, the lever turns about the pin and tightens the band on the drum and hence brakes are applied. The friction and the drum provide the braking force.



3. BAND AND BLOCK BRAKE: - The band brake may be lined with blocks of wood or other materials. The friction between the blocks and the drum provides braking action .The advantage of providing wooden blocks is to give a higher co-efficient of friction and they can be easily replaced after being worn out.



4. INTERNAL EXPANDING BRAKE: - An internal expanding brake consists of two shoes. The outer surface of the shoes are lined with some frictional material to increase the co-efficient of friction and to prevent wearing away of the metal. Each shoe is provided at one end above a fixed fulcrum and made to contact a cam at the other end. When the cam rotates the shoes are pushed out ward against the rim of the drum. The friction between the shoes and the drum produces the braking torque and hence reduces the speed of the drum. This type of brake is commonly used in motor cars.



DYNAMOMETER:-

A dynamometer is a brake but in addition it has a device to measure the frictional resistance. Knowing the frictional resistance we may obtain the torque transmission and hence the horse power of the engine.

Types of Dynamometer:-

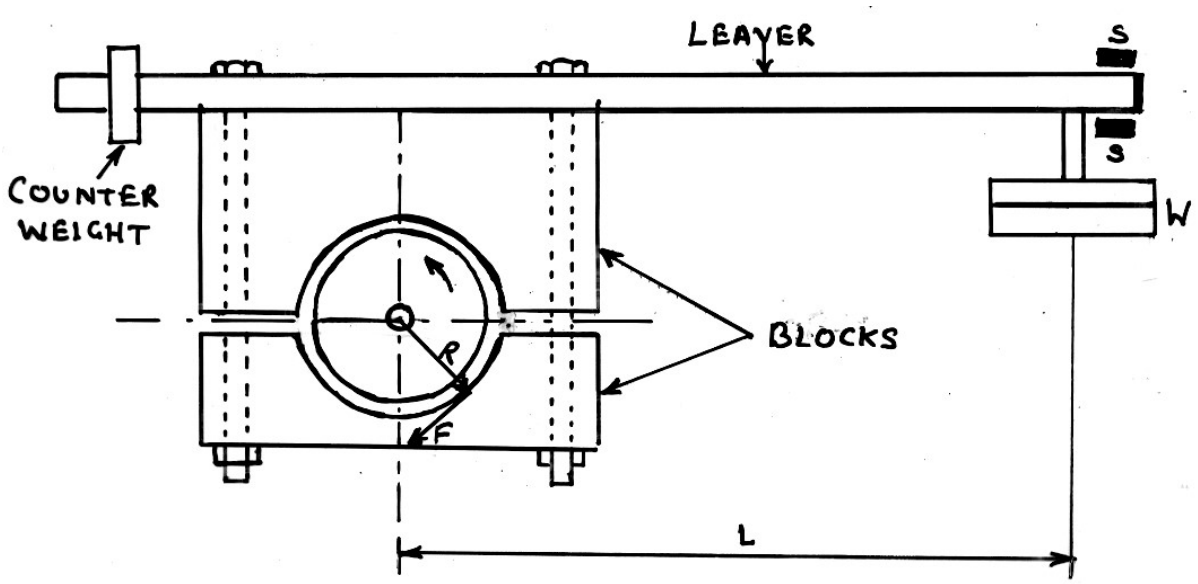
1. Absorption Type Dynamometer: - In the absorption type dynamometer the energy produced by the engine is absorbed by frictional resistance of the brake and is transformed into it.

Classification of Absorption Type Dynamometer:-

(i) Prony Brake Dynamometer
(ii) Rope Brake Dynamometer

(i) Prony Brake Dynamometer:-

It consists of two wooden block clamped together with a pulley between them. The pulley is fixed to a shaft of the engine or motor. The blocks are clamped by means of two bolts with nut. One of the blocks has a lever attached to it and carries a weight 'W' at its outer end. A counter weight is placed at the outer end of the lever which balances the brake, when unloaded.



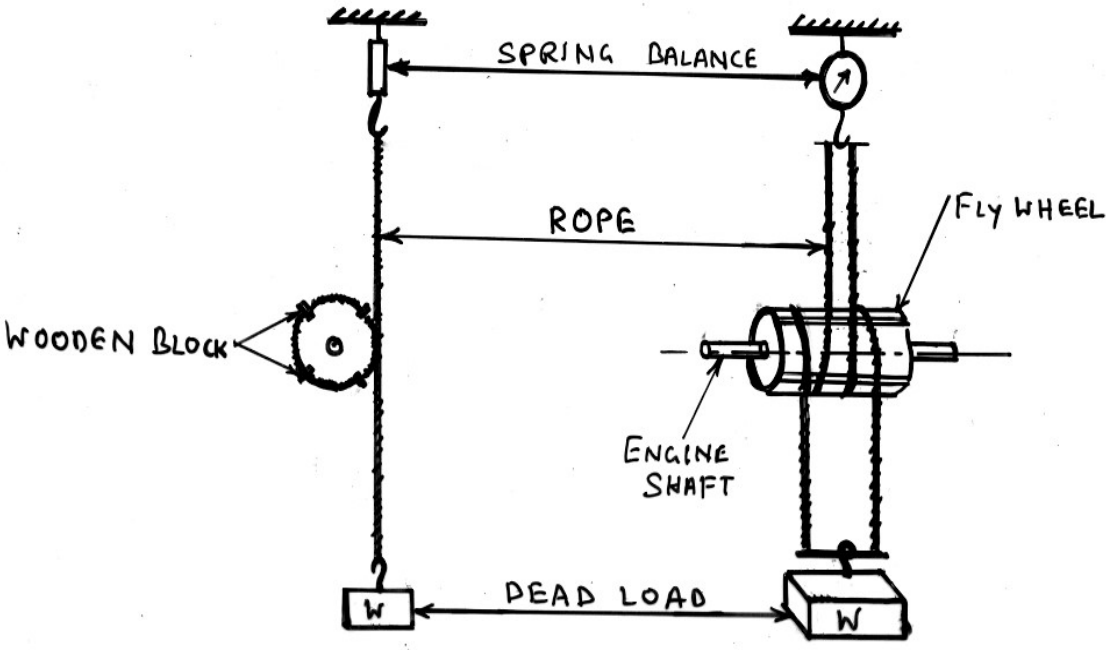
Let, W=weight at the outer end of the lever in kg.
L= Horizontal distance of the weight 'W' from the centre of the pulley in meter.
F= Frictional resistance between the blocks and pulley in kg.
R= Radius of the pulley in meter
N= Speed of the shaft in rpm.

$$\text{B.H.P.} = \frac{\text{Work done per minute}}{4500} \text{ H.P.}$$

$$\text{B.H.P.} = \frac{W \, L \times 2 \pi N}{4500} \text{ H.P.}$$

(ii) Rope Brake Dynamometer:-

It is the most common type of brake used for measurement of B.H.P of an engine. It contains two or three ropes wound on a fly wheel of an engine. The ropes are prevented from slipping off the wheel by means of wooden block. A dead weight is applied to one end of the ropes and a spring balance is attached to other end.



Let, W= Dead load in kg.
S= Spring balance reading in kg.
D= Diameter of the wheel in meter
d= Diameter of the rope in meter
N= Speed of the wheel in rpm.

So that; Net load on the wheel = (W-S) kg.
Work done per revolution = (W-S) π (D+d)
Work done per minute = (W-S) π (D+d) N

$$\text{B.H.P.} = \frac{\text{Work done per minute}}{4500} \text{ H.P.}$$

$$\text{B.H.P.} = \frac{(W-S)\,\pi\,(D+d)\,N}{4500} \text{ H.P.}$$

2. Transmission Type Dynamometer: - In transmission dynamometer the energy is not wasted in friction but is used for doing work. The energy is transmitted through the dynamometer from source of power to the machines and hence the power developed may be measured.

The following types of transmission dynamometers are important from the subject's point of view:

1. Epicyclical-train dynamometer
2. Belt transmission dynamometer
3. Torsion dynamometer

Lesson-03

(Belt, Rope and Chain drive)

BELT:-In factories the power or rotary motion from one shaft to another is usually transmitted by means of v-belts or ropes, running over pulleys.

TYPE OF BELT: -
(i) Flat belt
(ii) V- belt
(iii) Circular belt or Rope

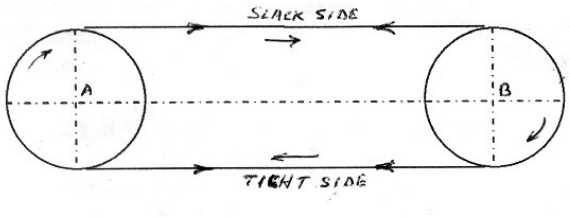
(i) Flat belt:-
The flat belt is mostly used in the factories and workshops where a moderate amount of power is to be transmitted form one pulley to another, when the two pulleys are not more than 10 meter apart.

(ii) V- belt:-
The V-belt is mostly used in the factories and workshops where a great amount of power is to be transmitted form one pulley to another, when the two pulleys are very near to each other.

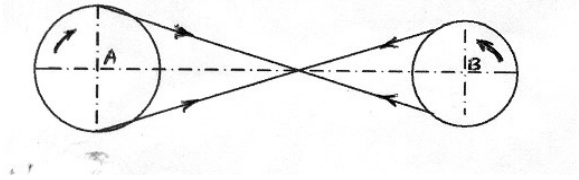
(iii) Rope:-
The rope is mostly used in the factories and workshops where a moderate amount of power is to be transmitted form one pulley to another, when the two pulleys are more than 5 meter apart.

MATERIALS USED FOR BELT:-
The materials used for belts and ropes must be strong, flexible and durable. It must have a high co-efficient of friction. The belts according to the material used are classified as:-
(i) Leather belt,
(ii) Cotton belt,
(iii) Rubber belt

TYPES OF FLAT BELT DRIVE:-
1. OPEN BELT DRIVE: - The open belt drive is used with the shafts arranged parallel and rotating in the same direction. In this case the driver 'A' pulls the belt from one side and delivers it to the other side. Thus the tension in the lower side belt is known as tight side and the upper side belt is known as slack side.

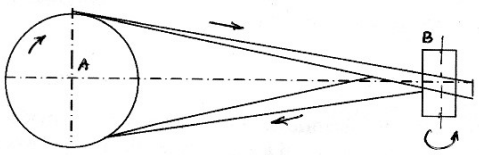


2. CROSS BELT DRIVE OR TWIST BELT DRIVE:-
The crossed or twist belt drive is used with shafts arranged parallel and rotating in the opposite direction. In this case driver pulls the belt from one side and delivers to the other sides.



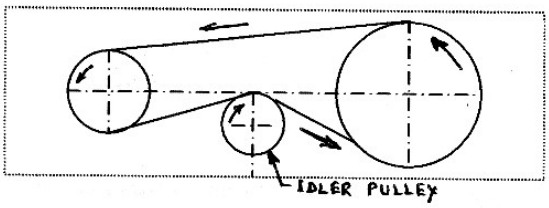
3. QUARTER TURN BELT DRIVE:-

The quarter turns belt drive also known as right angle belt drive is used with shaft arranged at right angles and rotating in one definite direction.



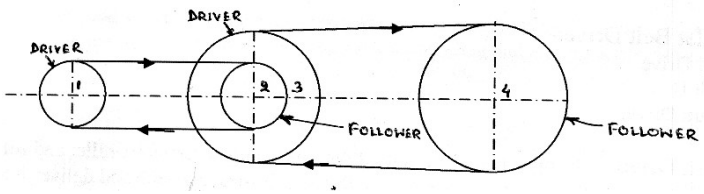
4. BELT DRIVE WITH IDLER PULLEY:-

The belt drive with an idler pulley is used with shaft arranged parallel and when an open belt drive can not be used due to small angle of contact on the smaller pulley.



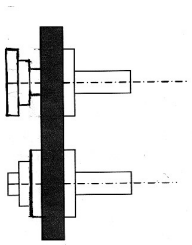
5. COMPOUND BELT DRIVE:-

A compound belt drive is used when power is transmitted from one shaft to another, through a number of pulleys.



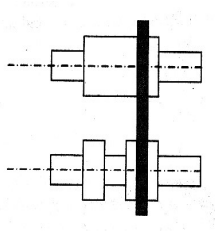
6. STEPPED OR CONE PULLEY DRIVE:-

A stepped or cone pulley drive is used for changing the speed of the driver. Shafts run at constant speed. This is accomplished by shifting the belt from one part of the stepped to the other.



7. FAST AND LOOSE PULLEY DRIVE

A fast and loose pulley drive is used when the driver or machine shaft I to be started or stopped when ever desired without interfering with the driving shaft. A pulley which is keyed to the machine shaft is called fast pulley and runs at the same speed as that of machine shaft. A loose pulley rounds freely over the machine shaft and it is capable of transmitting any power. When the driven shaft is required to be stopped, the belt is pushed out to the loose by means of sliding bar having belt lock.

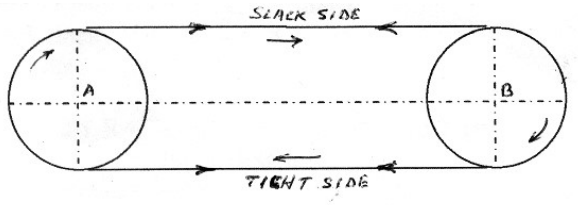


SLEEP OF BELT: - Sometimes the frictional grip between the belts and the shafts become insufficient. This causes some forward motion of the driven without carrying the belt with it. This is called slip of the belt.

CREEP OF BELT:- When the belt passes from slack side to the tight side , a certain portion of the belt extends when the belt passes from the tight side to slack side. Due to its change of length there is a relative motion between the belt and the pulley surface. The relative motion is termed as creep.

POWER TRANSMITTED BY A BELT:-

In the figure 'A' is the driver and 'B' is the follower. The driving pulley pulls the belt from one side and delivers the same to other side. It is obvious that the tension on former side will be greater than the later side (slack side).



Let T_1 & T_2 = Tension in the tight and slack side of the belt in kg.

V = Velocity of the belt in meters /second.

The effective turning (driving) force at the circumference of the follower is the difference between the two tension (T_1 - T_2)

Therefore,

$$\text{Power} = \frac{(T1 - T_2) \times V}{75} \quad \text{H.P.}$$

VELOCITY RATIO OF BELT DRIVE:-

It is the ratio between the velocity of the driver and follower or driven, it may be expressed as

$$\text{Velocity Ratio} = \frac{N_1}{N_2} = \frac{d_1}{d_2}$$

where , d1 = diameter of the driver,

d2 = diameter of the driven,

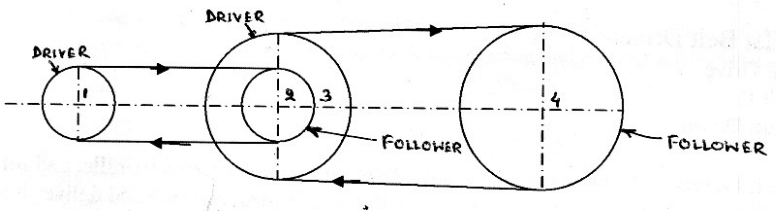
N_1 = speed of the driver in r.p.m.

N_2 = speed of the driven in r.p.m.

When the thickness of the belt (t) is considered, then

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

VELOCITY RATIO OF COMPOUND BELT DRIVE:-



Let, d1 = diameter of the driver (pulley)
N1 = speed of the driver (pulley) in r.p.m.
d2, d3, d4, N2, N3, N4 = corresponding values of pulley 2, 3 & 4

$$\frac{N4}{N1} = \frac{d1}{d2} \times \frac{d3}{d4}$$

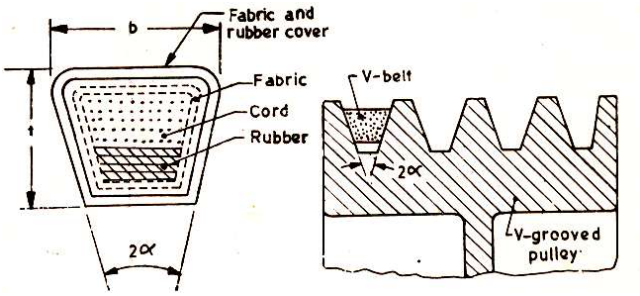
Hence, velocity ratio of compound belt drive=

$$\frac{\text{Speed of last follower}}{\text{Speed of first driver}} = \frac{\text{Product of diameter of driver}}{\text{Product of diameter of follower .}}$$

'V'- BELT DRIVE:-

Sometimes the power from one shaft to another is transmitted by means of v-belt drive instead of flat belt drive. The v-belt is 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 of endless. These are particularly suitable for short drives. In case of flat belt drive the belt runs over the pulleys, whereas in case of v-belt the rim of the pulley is grooved in which the v-belt runs.

The effect of the groove is to increase the frictional grip of the belt on the pulley and thus to reduce the tendency of slipping.



ROPE DRIVE:-

The ropes for transmitting power are usually made of manila, hemp and cotton. They are usually circular in cross-section. The rope drive is particularly suitable when the distance between the shafts is large. It may be noted that frictional grip in case of rope drives is more than that in v-drive. One of the main advantages of rope drives is that a number of separated drives may be taken from the one driving pulley.

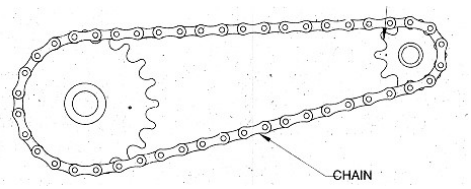
USES OF STEEL WIRE ROPES :-

In case the power is to be transmitted over long distance as in mining, hoisting and hauling etc. Steel wire ropes are extensively used. The wire ropes run on grooved pulleys but they rest on the bottom of the grooves and are not wedged between he sides of the grooves. Wire rope has the following advantages over cotton ropes.

i. These are lighter in weight,
ii. These offer silent operation.
iii. These can withstand
iv. These are more reliable.
v. They do not fail suddenly.

CHAIN DRIVE :-

We have seen belt and rope drive, that slipping may occur. In order to avoid slipping steel chains are used. These chains are used in combination with chain wheels or sprocket wheels. The projection on the wheel fit into cavities in the chain or vice versa. The wheel and chain are thus constrained to move together without slipping and ensures perfect velocity ratio. Chain is used for transmission of power in bicycle motor vehicles, agricultural machinery, and road rollers.



ADVANTAGE AND DISADVANTAGE OF V-BELT DRIVE OVER FLAT BELT DRIVE:-

Advantage:-

i. The v-belt drive gives compactness due to the small distance between centres of pulleys.
ii. The drive is positive because the slip between the belt and the pulley groove is negligible.
iii. The operation of the belt and pulley is quiet.
iv. The belts have the ability to cushion the shock when machines are started.
v. The high velocity ratio may be obtained.
vi. The power transmitted by v-belts is more than flat belts for the same co-efficient of friction.
vii. The v-belt may be operated in either direction, with tight side of the belt at the top or bottom.

Disadvantage:-

i. The v- belt drive cannot be used with large centre distance.
ii. The v-belts are not as durable as flat belts.
iii. The construction of pulley for v-belts is more complicated than pulleys of flat belts.

ADVANTAGE & DISADVANTAGES OF CHAIN DRIVE OVER BELT OR ROPE DRIVE:-

Advantages:-

i. As no slip takes place during chain drive, hence perfect velocity ratio is obtained.
ii. A chain drive takes up less space than a belt or rope drive.
iii. The chain drive may be used when the distance between the shafts is less.
iv. The chain drive gives high transmission efficiency.

Disadvantages:-

i. The production cost of chain is relatively high.
ii. The chain requires more careful maintenance.

(Gear)

INTRODUCTION:-

Gears are used to transmit motion from one shaft to another or between a shaft and slide. This is accomplished by successively engaging teeth.

Purpose Of Gear :-

- To change the velocity ratio.
- To change the direction of rotation.
- To get a positive drive

TOOTH GEARING:-

Precision machines in which a definite velocity ratio is is of importance, the only positive drive by means of gears or toothed wheels. A gear drive is also provided when the distance between the driver and the follower is very small.

Classification Of toothed Wheel Gear

1. According to the position of axes of the shaft:-
   a. Parallel, b. Intersecting, c. Non-intersecting spiral gear.

2. According to the peripheral velocity of the gears.-
   a. Low velocity:: -- Having velocity less than 3 m /sec.
   b. Medium velocity: -- Velocity between 3 to 15 m/sec.
   c. High speed gear: -- Velocity more than 15 m/sec.

3. According to the type of gearing:--
   a. External gearing, b. internal gearing, c. Rack and pinion.

4. According to the position of teeth on the gear surface:--
   The teeth on the gear surface may be straight, inclined or curved

TECHNICAL TERMS OF TOOTH GEAR:-

1. Pitch Circle: - It is an imaginary circle which by pure rolling action would give the same motion as the actual gear.

2. Pitch Circle Diameter: - It is the diameter of the pitch circle. The size of the gear is usually specified by the pitch circle diameter.

3. Pitch Point: - It is a common point of contact between two pitch circles.

4. Pitch Surface: - It is the surface of the rolling discs which the meshing gears have replaced at the pitch circle.

5. Addendum: - It is the radial distance of a tooth from the pitch circle to the top of the tooth.

6. Dedendum: - It is the radial distance of a tooth from the pitch circle to the top of the tooth.

7. Addendum Circle: - It is the circle drawn through the top of the teeth and is concentric with the pitch circle.

8. Dedendum Circle: - It is the circle drawn through the bottom of the teeth.

9. Circular Pitch:- It is the distance measured on the circumference of the pitch circle from a point of one tooth to the corresponding point yo the next tooth. It is usually denoted by P_c.

Mathematically, Circular Pitch $P_c = \frac{\pi d}{T}$

10. Diametral Pitch: - It is the ratio of number of teeth to the pitch circle diameter in millimetres. It is denoted by P_d, Mathematically.,

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

Where, d = Diameter of the pitch circle.

T= No. of teeth on the wheel.

11. Module: - It is the pitch circle diameter in millimetres to the number of teeth. It is usually denoted by 'm'. Mathematically,

$$\text{module }, m = \frac{d}{T}$$

12. 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 top of the meshing gear is known as clearance circle.

13. Total Depth:- It is the radial distance between the addendum and the dedendum of a gear. It is equal to the sum of the addendum and dedendum.

14. Working Depth: - It is the radial distance from the addendum circle to the clearance circle. It is equal to the sum of the addendum of the two meshing gear.

15. Tooth Thickness: - It is the width of the tooth measured along the pitch circle.

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

17. Face of The Tooth: - It is the surface of the tooth above the pitch surface.

18. Top Land: - It is the surface of the top of the tooth.

19. Flank of Tooth: - It is the surface of the tooth below the pitch.

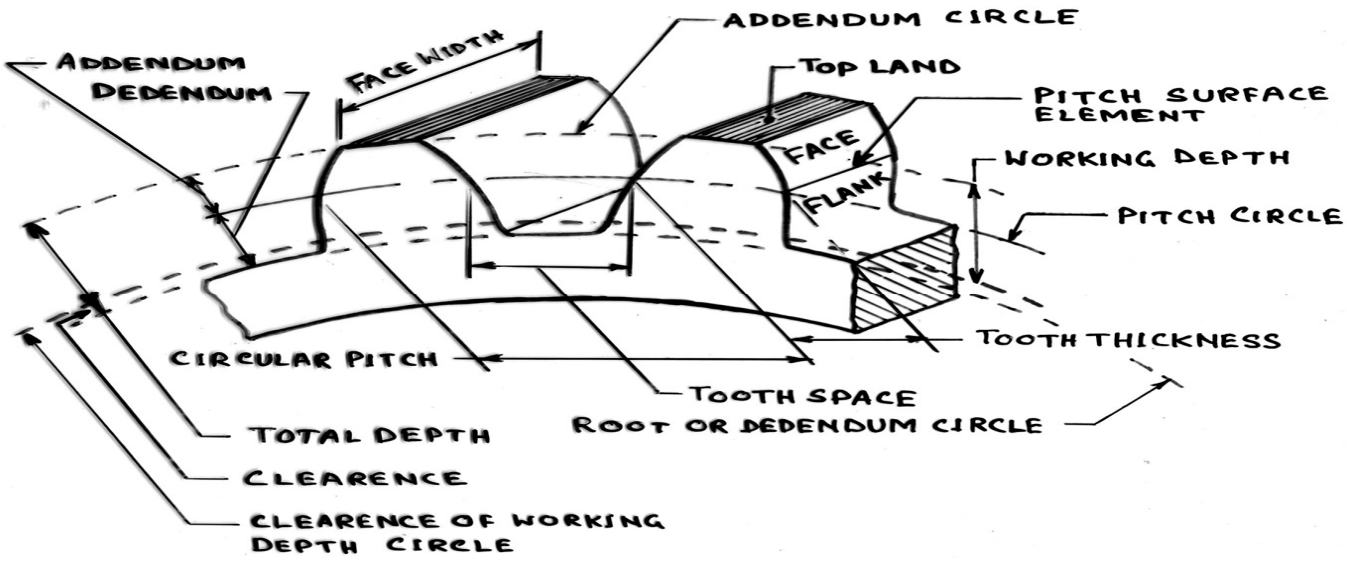
20. Face Width: - It is the width of the gear tooth measured parallel to its axis.

21. Profile: - It is the curved formed by the face and flank of the tooth.

22. Fillet Radius: - It is the radius that connects the root circle to the profile of the tooth.

23. Path Of Contact: - It is the path traced by the point of contact of two teeth from the beginning to the end of engagement

Gear Profile



TYPES OF GEAR:-

1. Spur Gear: - In this type of gear, the teeth are cut parallel to the axis of rotation. The spur gear is used to transmit power between two parallel shafts.

2. Helical Gear: - In a helical gear the teeth are cut at an angle to the axis of rotation, it may be used to transmit power between two parallel shaft. Helical gears run more silently than a spur gear

3. Bevel Gear: - The bevel gear is used to transmit motion between shafts at various angles to each other. The teeth profile may be straight or spiral. The bevel gears transmit motion, when the shaft is at right angles to each other.

4. Mitre Gear: - If two bevel gear are symmetrical to each other and transmit motion at right angles, such gears are called mitre gear.

5. Warm Shaft or Warm Gear: - The warm shaft has spiral teeth cut on the shaft and warm wheel is a special form of gear teeth cut to mesh with the warm shaft; They are widely used for speed reduction.

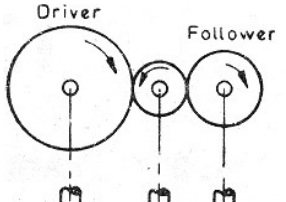
6. Rack and Pinion: - The rack and pinion changes rotary motion into linear motion and vice versa .This type of gear is used in drilling machine.

7. Hypoid Gear: - The hypoid gears are used in automatic differential gear boxes. The teeth action between each gear is a combination of rolling and sliding action along a straight line.

GEAR TRAIN

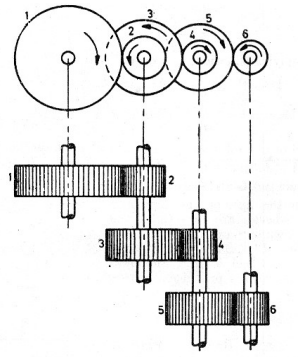
Sometime two or more gears are made to mesh with each other to transmit power from one shaft to another. Such a combination is called gear train.

<u>Types Of Gear Train:-</u>

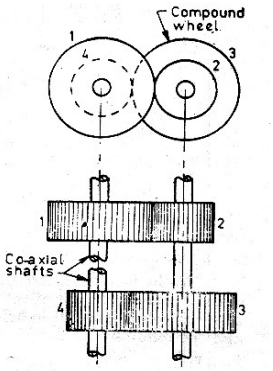


1. Simple Gear Train: - When the distance between the two wheels is greater , the motion from one wheel to another may be transmitted by providing the large sized wheels or by providing one or more intermediate size, This is known as simple gear.

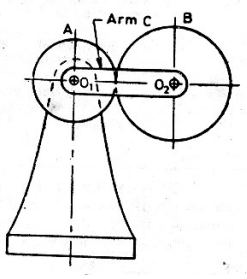
2. Compound Gear Train:- When ever the distance between the follower has to be bridged over by intermediate wheels and at the same time a great velocity ratio is required than the advantage of intermediate wheel is transmitted by providing compound wheels on intermediate shaft.



3. Reverted Gear Train :- When the axes of the first and last wheel are co- axial , the train is known as reverted gear train. Since the motion of the first and last wheel is like, therefore a compound wheel is provided.



4.Epicyclic Gear Train :- In an epicyclic gear train , the axes of the shaft over which the gears are mounted may move relative to a fixed axes.



VELOCITY RATIO OF GEAR DRIVE:-

It is the ratio between the velocity of the driver and follower or driven, it may be expressed as

$$\text{Velocity Ratio} = -\frac{\omega_2}{\omega_1} = \frac{N_2}{N_1} = \frac{d_1}{d_2}$$

where, d = diameter of the wheel,
N = speed of the wheel
ω = angular speed

GEAR MATERIAL:-

The material used for the manufacture of gears depends upon the strength and service conditions like wear, noise etc. The gears may be manufactured from metallic materials. The metallic gears without teeth are commercially obtainable in cast iron, steel and bronze. The non metallic materials like wood, compressed paper and synthetic resins like nylon are used for gears, especially for reducing noise.

Lessson-05

(Clutch)

CLUTCH:

A clutch is a mechanical device that provides for the transmission of power (and therefore usually motion) from one component (the driving member) to another (the driven member) when engaged, but can be disengaged.

Clutches are used whenever the transmission of power or motion must be controlled either in amount or over time (e.g., electric screwdrivers limit how much torque is transmitted through use of a clutch; clutches control whether automobiles transmit engine power to the wheels).

Clutch is used to engage or disengage the engine to the transmission or gear box.

Types of Clutch:-

Some types of clutches used in vehicles are given below:

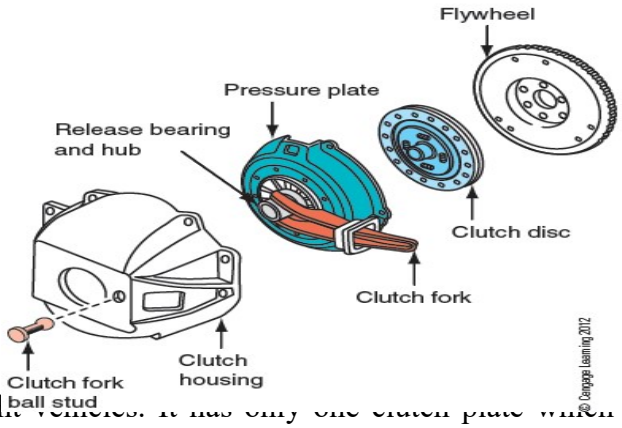
(a) Friction Clutch
- (i) Single plate clutch,
- (ii) Multi-plate clutch, or
- (iii) Cone clutch

Multi-plate clutch can be either wet or dry. A wet clutch is operated in an oil bath whereas a dry clutch does not use oil.

(b) Centrifugal clutch.
(c) Semi-centrifugal clutch.
(d) Hydraulic clutch.
(e) Positive clutch.
(f) Vacuum clutch.
(g) Electromagnetic clutch.

Parts of Clutch:

- Flywheel
- Pressure plate
- Friction disc
- Clutch disc
- Release mechanism



Friction Clutch (Single plate Type):

A single plate is commonly used in cars and light vehicles. It has only one clutch plate which is mounted on the splines of the clutch shaft. A flywheel is mounted on the crankshaft of the engine. A pressure plate is connected to the flywheel through the bolts and clutch springs. It is free to slide on the clutch shaft with the movement of clutch pedal. When clutch is in engaged position, the clutch plate remains gripped between flywheel and pressure plate. Friction linings are provided on both the

sides of clutch plate. On one side clutch plate is in touch with flywheel and on other side with pressure plate. Due to friction on both sides, the clutch plate revolves with engine flywheel.

Therefore, clutch transmits engine power to clutch shaft. Clutch shaft is connected to transmission (or gear box) of automobile. Thus, clutch transmits power from engine to transmission system which intern rotates wheels of engine.

When the clutch plate is to be disengaged, the clutch pedal is pressed. Because of this pressure plate moves back and clutch plate is disengaged from flywheel. Thus, clutch shaft stops rotating even if engine flywheel is rotating. In this position, power does not reach the wheels and vehicle also stops running.

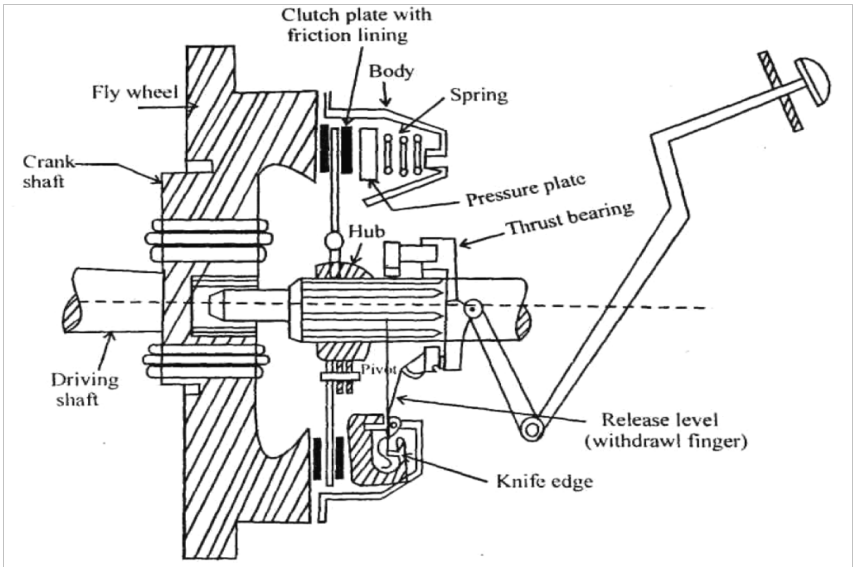


Fig. Single Plate Clutch

Friction Clutch (Multi plate Type):

A multiple plate clutch is a type of clutch system where multiple driven and drive plates are used in order to make up for torque loss due to slippage. This slippage is usually caused by a fluid that the plates are immersed in for cooling, cleaning and lubrication. This type of clutch system is commonly referred to as a wet clutch system. The type of arrangement is what is found in the automatic transmission in your car. This clutch system allows gears to be shifted up and/or down, without interrupting the power flow through the transmission, by lifting the accelerator.

Multi-plate clutch consists of more than one clutch plates contrary to single plate clutch which consists of only one plate. Friction surfaces are made in case of multi-plate clutch. Due to increased number of friction surfaces, a multi-plate clutch can transmit large torque. Therefore, it is used in racing cars and heavy motor vehicles witch have high engine power. The clutch plates are alternatively fitted with engine shaft and the shaft of gear box. He plates are firmly held by the force of coil springs and they assembled in a drum.

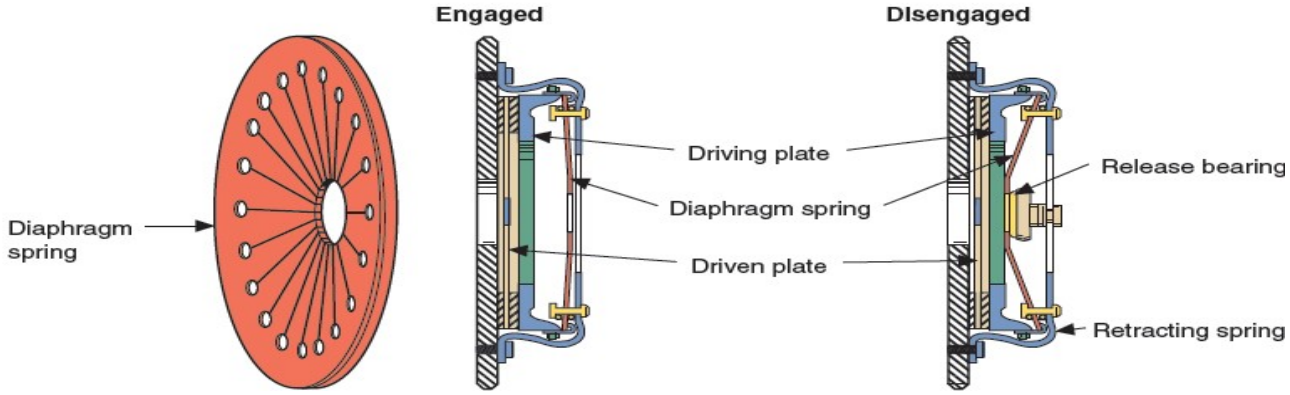
One plate slides in the grooves on the flywheel and the next plate slides on spines provided on pressure plate. Thus, each alternate plate slides in grooves on the flywheel and the other on splines of pressure plate. If we take two consecutive plates, then one has inner and other has outer splines.

When the clutch pedal is pressed, the pressure plate moves back against the force of coil spring, hen the clutch plates are disengaged and engine flywheel and gear box are decoupled. However, when clutch

pedal is not pressed the clutch remain in engaged position and the power can be transmitted from engine flywheel to the gear box.

Centrifugal type clutch:
In this type of clutch, the clutch pedal in the engaged position, the clutch disc facing are clamped between the friction surface on the engine fly wheel and the face of the clutch pressure plate by the pressure of the clutch springs. When the clutch is disengaged, the clutch disc will come to rest if the transmission is in neutral or the car is standing still. If the car is in gear and moving, the clutch disc will be rotating, being driven through the transmission by the rear wheels.

Diaphragm type clutch: The operating principle of a diaphragm –type clutch differs from that of the centrifugal type only in the method by which the pressure plate is held against the clutch disc. Instead of helical clutch springs, a disk-shaped diaphragm is used to supply the pressure to hold the clutch disc against the fly wheel facing. The diaphragm is positioned between the cover and the pressures plate so that the diaphragm spring is nearly flat when the clutch is engaged.



Troubles in Clutch:-

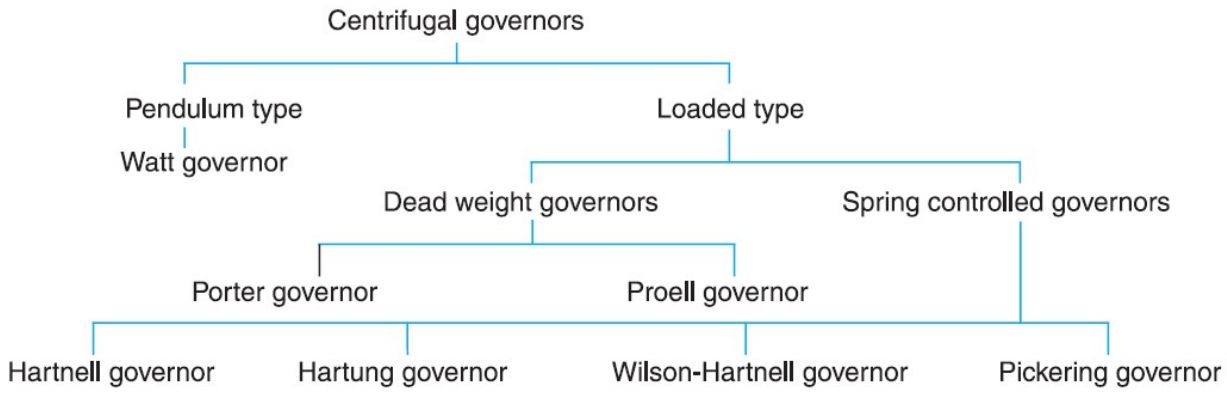
a. Clutch Chatter
b. Clutch Slipping
c. Difficult gear shifting
d. Clutch noisy.

Lessson-06
(Governor)

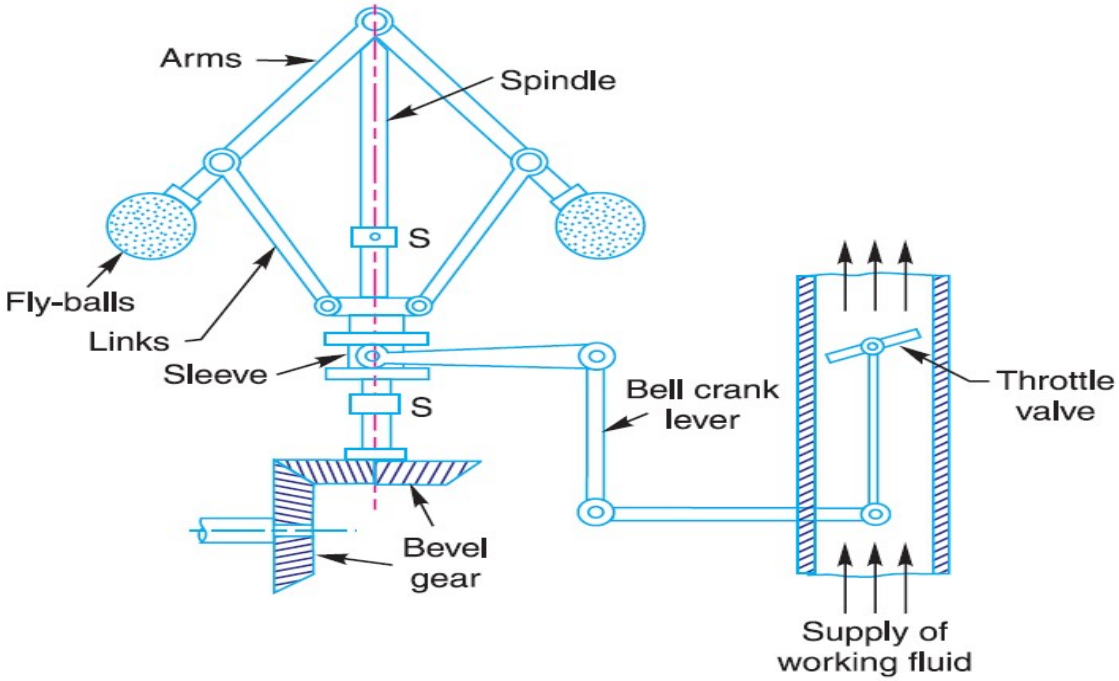
Governor: - The function of a governor is to regulate the machine speed of an engine when there is variation of load. The governor automatically controls the supply of working fluid to the engine with the varying load condition and keeps the mean speed within certain limit.

Types of Governor:-
The governor may broadly be classified into two categories:-
i. Centrifugal Governor.
ii. Inertia Governor

The centrifugal governor may further be classified as follows:



<u>Centrifugal Governor</u>:-



The centrifugal governor is based on the balancing of centrifugal force on the rotating balls by an equal opposite radial force, known as the controlling force.

It consists of two balls of equal weight which are attached to the arms as shown in the figure. These balls are known as governor balls or fly balls. The balls revolve with a spindle which is driven by the engine through bevel gears. The upper ends of the arms are pivoted to the spindle, so that the balls may rise up or fall down as they revolved about the vertical axis. The arms are connected by the links to a sleeve which is keyed to the spindle. This sleeve resolves with the spindle but can slide up and down. The balls and the sleeve rise when the speed increases and fall when the speed decreases. The sleeve is connected by a bell crank lever to a throttle valve. The supply of the working fluid decreases, when the sleeve rises and increases when it falls.

When the load on the engine increases the engine and the governor speed decreases. The result is the decrease of centrifugal force on the ball. Hence the balls and the sleeve move downward. This increase the supply of working fluid. And thus the engine speed increases. In this case the extra power output is provided to balance the increased load.When the load on the engine decreases the engine and the governor speed increases, these results in the increase of centrifugal force on the balls.

Thus the balls open out and the sleeve raises upwards. This reduces the supply of working fluid and hence the speed is decreased. In this case the power output is reduced.

Terms Used In Governor:-

i. Height of the Governor: - It is the vertical distance from the centre of the ball to a point where the axis of the arms intersects on the spindle axis.

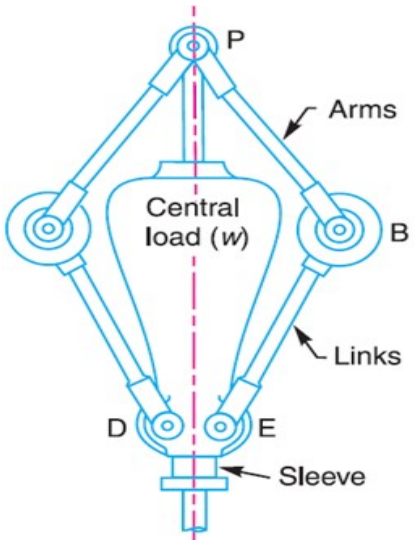
ii. Equilibrium Speed: - It is the speed at which the governor balls, arms etc. are in complete equilibrium and the sleeve does not tends to move upward or downward.

iii. Maximum and Minimum Equilibrium Speed: - The speed at the maximum radius of rotation of the balls without tending to move either way are known as maximum and minimum equilibrium speed.

iv. Mean Equilibrium Speed: - It s the speed at the mean position of the balls or the sleeve**.**

v. Sleeve Lift: - It is the vertical distance with the sleeve travels due to change in equilibrium speed.

<u>Porter Governor:</u>



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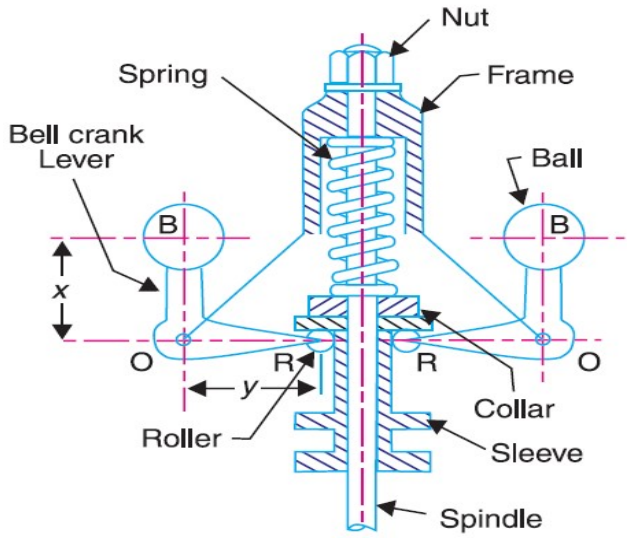
- In Porter governor central load is attached to the sleeve as shown in Fig .

- *The load moves up and down the central spindle. This additional* downward force increases the speed of revolution required to enable the balls to rise to any predetermined level.
- Consider the forces acting on one-half of the governor as shown in Fig.

Hartnell Governor

- A Hartwell governor is a spring loaded governor as shown in Fig. It consists of two bell crank levers pivoted at the points *O,O to the frame.*
- *The frame is attached to the governor spindle* and therefore rotates with it.



Sensitiveness Of Governor :- Considering two governors 'A' and 'B' running at the same speed, when this speed increases or decreases by a certain amount the lift of the sleeve of governor 'A' is greater than the lift of the sleeve of governor 'B' . It is then said that the governor 'A' is more sensitive than the governor 'B'.

In general the greater the lift of the sleeve corresponding to a given fractional change the speed, the greater is the sensitiveness the governor.

The sensitiveness is defined as the ratio of the difference between the maximum and minimum equilibrium speeds to the mean equilibrium speed.

Let N_1 = Minimum equilibrium speed,

N_2 = Maximum equilibrium speed, and

N = Mean equilibrium speed $= \frac{N_1 + N_2}{2}$

$\therefore$ Sensitiveness of the governor

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

$$= \frac{2(\omega_2 - \omega_1)}{\omega_1 + \omega_2}$$

Stability of Governor: - A governor is said to be stable when for every speed within the working range, there is only one radius of rotation of the governor balls at which the governor is in equilibrium.

Hunting of Governor: - A governor is said to be hunt if the speed of the engine fluctuates continuously above and below the mean speed. This is caused by a too sensitive governor which changes the fuel supply by a large amount when a small change in the speed of rotation takes place.

Effort and Power of a Governor

The effort of a governor is the mean force exerted at the sleeve for a given exerted at the sleeve for a given percentage change of speed (or lift of the sleeve). It may be noted that when the governor is running steadily, there is no force at the sleeve. But when the speed changes, there is a resistance at the sleeve which opposes its motion. It is assumed that this resistance which is equal to the effort varies uniformly from a maximum value to zero while the governor moves into its new position of equilibrium.
The power of a governor is the work done at the sleeve for a given percentage change of speed.
It is the product of the mean value of the effort and the distance through which the sleeve moves.

Mathematically,

Power = Mean Effort X lift of sleeve

Lessson-07
(FLYWHEEL & TURNING MOMENT DIAGRAMS)

A flywheel used in machines serves as a reservoir which stores energy during the period when the supply of energy is less than the requirement, and releases it during the period when the requirement of energy is more than the supply.

A little consideration will show that when the flywheel absorbs energy, its speed increases and when it releases energy, the speed decreases. Hence a flywheel does not maintain a constant speed; it simply reduces the fluctuation of speed.

In other words, a flywheel controls the speed variations caused by the fluctuation of the engine turning moment during each cycle of operation.

Coefficient of fluctuation of Speed:-

The difference between the maximum and 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 and N_2 = Maximum and minimum speeds in r.p.m. during the cycle, and

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

∴ Coefficient of fluctuation of speed,

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

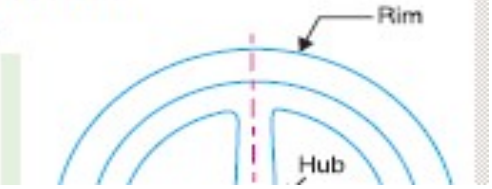
$$= \frac{\omega_1 - \omega_2}{\omega} = \frac{2(\omega_1 - \omega_2)}{\omega_1 + \omega_2} \quad \text{...(In terms of angular speeds)}$$

$$= \frac{v_1 - v_2}{v} = \frac{2(v_1 - v_2)}{v_1 + v_2} \quad \text{...(In terms of linear speeds)}$$

The coefficient of fluctuation of speed is a limiting factor in the design of flywheel. It varies depending upon the nature of service to which the flywheel is employed.

Note. The reciprocal of the coefficient of fluctuation of speed is known as *coefficient of steadiness* and is denoted by m.

$$\therefore \quad m = \frac{1}{C_s} = \frac{N}{N_1 - N_2}$$

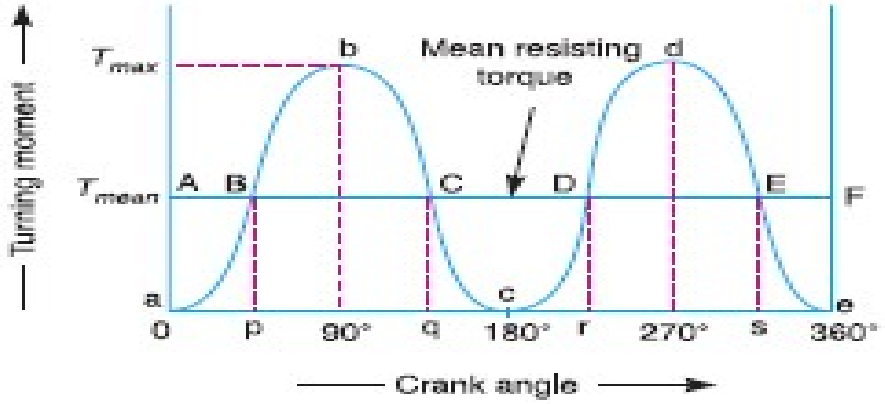


Turning Moment Diagram:

The turning moment diagram also known as crank effort diagram It is the graphical representation of the turning moment or crank effort for various positions of crank.
It is plotted on Cartesian coordinates ,in which the turning moment is taken as the ordinate and crank .

Turning Moment Diagram for A Single Cylinder Double Acting Steam Engine:

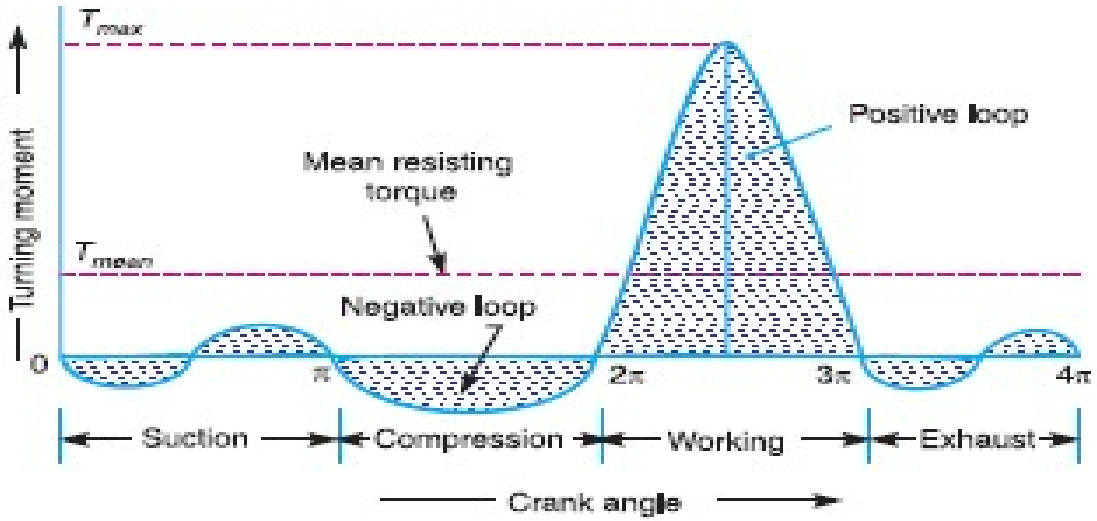
The vertical ordinate represents the turning moment and the horizontal ordinate represents the crank angle.



We see, that the turning moment (T) is zero, when the crank angle (θ) is zero. It is maximum when the crank angle is 90° and it is again zero when crank angle is 180°.This is shown by the curve *abc* in Fig. and it represents the turning moment diagram for outstroke.
The curve instroke *cde* is the turning moment diagram for the work done is the product of the turning moment and the angle turned; therefore the area of the turning moment diagram represents the work done per revolution. The height of the ordinate *a A* represents the mean height of the turning moment diagram. Since it is assumed that the work done by the turning moment per revolution is equal to the work done against the mean resisting torque, therefore the area of the rectangle *aAFe* is proportional to the work done against for flywheel.

Notes: 1. When the turning moment is positive, the crankshaft accelerates and the work is done steam.
2. When the turning moment is negative, the crankshaft retards and the work is done on the steam.
3. Then accelerating torque on the rotating parts of the engine = $T - T\ mean$

Turning Moment Diagram for A Four Stroke Cycle Internal Combustion Engine:



We
crank has turned through two revolutions, *i.e.* 720° (or 4 π radians). Since the pressure inside the engine

cylinder is less than the atmospheric pressure during the suction stroke, therefore a negative loop is formed as shown in Fig.

During the compression stroke, the work is done on the gases, therefore a higher negative loop is obtained.

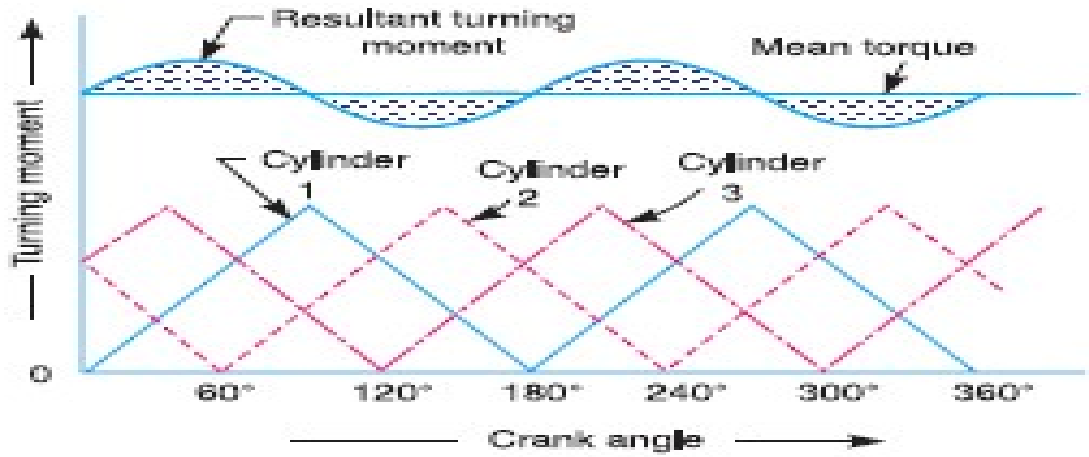
- During the expansion or working stroke, the fuel burns and the gases expand; therefore a large positive loop is obtained. In this stroke, the work is done by the gases
- During exhaust stroke, the work is done on the gases; therefore a negative loop is formed. It may be noted that the effect of the inertia forces on the piston is taken into account

Turning Moment Diagram for A Multi Cylinder Engine:

Diagram for a compound steam engine having three cylinders, and the resultant turning moment diagram is shown in Fig.

It may be noted that the first cylinder is the high pressure cylinder, second cylinder is the intermediate cylinder and the third cylinder is the low pressure cylinder.

The cranks, in case of three cylinders, are usually placed at 120° to each other.



Lessson-08

(BALANCING OF MASSES)

Balancing is the technique of correcting or eliminating unwanted inertia forces or moments in rotating or reciprocating masses and is achieved by changing the location of the mass centers.

The objectives of balancing an engine are to ensure:

1. That the centre of gravity of the system remains stationery during a complete revolution of the crank shaft and
2. That the couples involved in acceleration of the different moving parts balance each other.

Unbalance:- The condition which exists in a rotor when vibratory force or motion is imparted to its bearings as a result of centrifugal forces is called unbalance or the uneven distribution of mass about a rotor's rotating centerline.

Need for Balancing:-

Rotating a rotor which has unbalance causes the following problems.

- The whole machine vibrates.
- Noise occurs due to vibration of the whole machine.
- Abrasion of bearings may shorten the life of the machine.

Benefits of balancing:-

- Increase quality of operation.

- Minimize vibration.
- Minimize audible and signal noises.
- Minimize structural fatigue stresses.
- Minimize operator annoyance and fatigue.
- Increase bearing life.
- Minimize power loss.

Types of balancing:

a) **Static Balancing:**

i) Static balancing is a balance of forces due to action of gravity.

ii) A body is said to be in static balance when its centre of gravity is in the axis of rotation.

b) **Dynamic balancing:**

i) Dynamic balance is a balance due to the action of inertia forces.

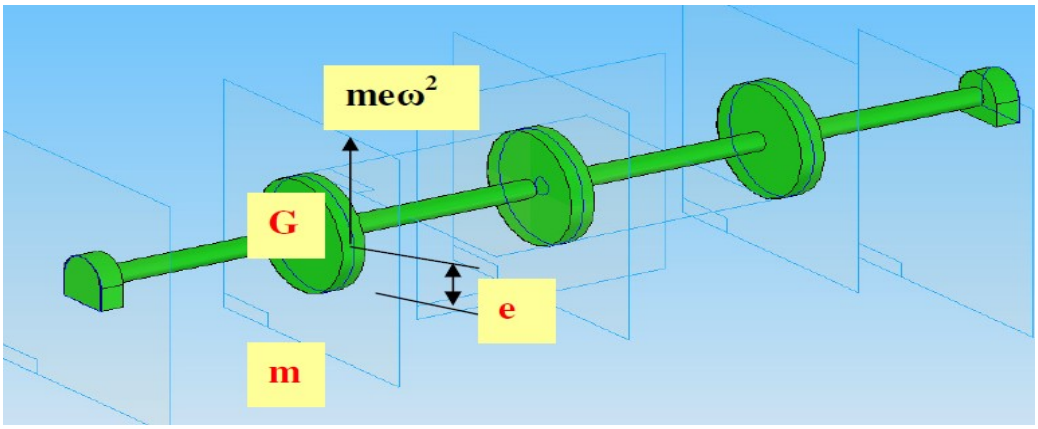
ii) A body is said to be in dynamic balance when the resultant moments or couples, which involved in the acceleration of different moving parts is equal to zero.

iii) The conditions of dynamic balance are met, the conditions of static balance are also met.

BALANCING OF ROTATING MASSES

When a mass moves along a circular path, it experiences a centripetal acceleration and a force is required to produce it. An equal and opposite force called centrifugal force acts radically outwards and is a disturbing force on the axis of rotation. The magnitude of this remains constant but the direction changes with the rotation of the mass.

In a revolving rotor, the centrifugal force remains balanced as long as the centre of the mass of rotor lies on the axis of rotation of the shaft. When this does not happen, there is an eccentricity and an unbalance force is produced. This type of unbalance is common in steam turbine rotors, engine crankshafts, rotors of compressors, centrifugal pumps etc.

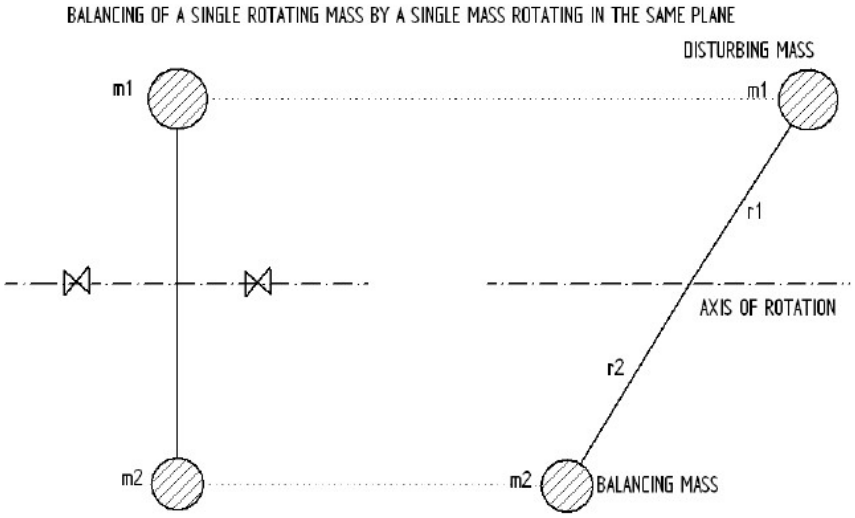


The unbalance forces exerted on machine members are time varying, impart vibratory motion and noise, there are human discomfort, performance of the machine deteriorate and detrimental effect on the structural integrity of the machine foundation.

Balancing involves redistributing the mass which may be carried out by addition or removal of mass from various machine members. Balancing of rotating masses can be of:

1. Balancing of a single rotating mass by a single mass rotating in the same plane.
2. Balancing of a single rotating mass by two masses rotating in different planes.
3. Balancing of several masses rotating in the same plane.
4. Balancing of several masses rotating in different planes.

BALANCING OF A SINGLE ROTATING MASS BY A SINGLE MASS ROTATING IN THE SAME PLANE



Consider a disturbing mass m1 which is attached to a shaft rotating at rad/s.
r = radius of rotation of the mass m

The centrifugal force exerted by mass m1 on the shaft is given by,
F = m r c 1 1

This force acts radially outwards and produces bending moment on the shaft. In order to counteract the effect of this force Fc1, a balancing mass m2 may be attached in the same plane of rotation of the disturbing mass m1 such that the centrifugal forces due to the two masses are equal and opposite.

BALANCING OF A SINGLE ROTATING MASS BY TWO MASSES ROTATING

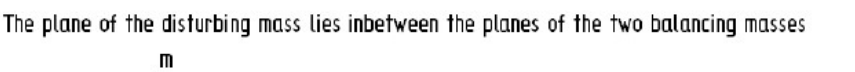
There are two possibilities while attaching two balancing masses:
1. The plane of the disturbing mass may be in between the planes of the two balancing masses.
2. The plane of the disturbing mass may be on the left or right side of two planes containing the balancing masses.

In order to balance a single rotating mass by two masses rotating in different planes which are parallel to the plane of rotation of the disturbing mass

i) The net dynamic force acting on the shaft must be equal to zero, i.e. the centre of the masses of the system must lie on the axis of rotation and this is the condition for static balancing
ii) The net couple due to the dynamic forces acting on the shaft must be equal to zero, i.e. the algebraic sum of the moments about any point in the plane must be zero.

The conditions i) and ii) together give dynamic balancing.

THE PLANE OF THE DISTURBING MASS LIES IN BETWEEN THE PLANES OF THE TWO BALANCING MASSES.



Consider the disturbing mass m lying in a plane A which is to be balanced by two rotating masses m_1 and m_2 lying in two different planes M and N which are parallel to the plane A as shown.

Let r, r_1 and r_2 be the radii of rotation of the masses in planes A, M and N respectively.
Let L_1, L_2 and L be the distance between A and M, A and N, and M and N respectively.
Now,
The centrifugal force exerted by the mass m in plane A will be,

$$F_c = m\ \omega^2 r \quad \text{----------(1)}$$

Similarly,
The centrifugal force exerted by the mass m_1 in plane M will be,

$$F_{c1} = m_1 \omega^2 r_1 \quad \text{----------(2)}$$

And the centrifugal force exerted by the mass m_2 in plane N will be,

$$F_{c2} = m_2 \omega^2 r_2 \quad \text{----------(3)}$$

For the condition of static balancing,

$$F_c = F_{c1} + F_{c2}$$
$$\text{or} \quad m\omega^2 r = m_1 \omega^2 r_1 + m_2 \omega^2 r_2$$
$$\text{i.e.} \quad m r = m_1 r_1 + m_2 r_2 \quad \text{----------(4)}$$

Now, to determine the magnitude of balancing force in the plane 'M' or the dynamic force at the bearing 'O' of a shaft, take moments about ' P ' which is the point of intersection of the plane N and the axis of rotation.

Therefore,

$$F_{c1} \times L = F_c \times L_2$$
$$\text{or} \quad m_1 \omega^2 r_1 \times L = m\omega^2 r \times L_2$$

Similarly, in order to find the balancing force in plane 'N' or the dynamic force at the bearing 'P' of a shaft, take moments about ' O ' which is the point of intersection of the plane M and the axis of rotation.

Therefore,

$$F_{c2} \times L = F_c \times L_1$$

$$\text{or} \quad m_2 \omega^2 r_2 \times L = m\omega^2 r \times L_1$$

Therefore,

$$m_2 r_2 L = mrL_1 \quad \text{or} \quad m_2 r_2 = mr\frac{L_1}{L} \text{ ---------(6)}$$

For dynamic balancing equations (5) or (6) must be satisfied along with equation (4).

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