Experiment No: 1

CAM ANALYSIS APPARATUS

Aim:

To study the profile of given can using cam analysis system and to draw the displacement diagram for the follower and the cam profile. Also to study the jump-speed characteristics of the cam & follower mechanism.

Apparatus required: Cam analysis system and dial gauge

Introduction:

A cam may be defined as a rotating or a reciprocating element of a mechanism which imparts a rotating, reciprocating or oscillating motion to another element termed as follower

Cam mechanism and its uses:

In most of the cases the cam is connected to a frame, forming a turning pair and the follower is connected to the frame to form a sliding pair. The cam and the follower form a three- link mechanism of the higher pair type.

The three links of the mechanism are:-

(a) The cam, which is the driving link and has a curved or a straight contact surface

(b)The follower, which is the driven link and it, gets motion by contact with the surface of the cam.

(c)The frame, which is used to support the cam and guide the follower. The cam mechanism is used in clocks, printing machines, automatic screw cutting machines, internal combustion engines for operating valves, shoe-making machinery etc.

Experimental procedure:

1. Fix the required cam & follower assembly on the apparatus.

2. Fix the dial gauge at top of follower shaft to get the follower displacement.

3. To find out the angular displacement, rotate the cam manually.

4. Note the angular displacement of cam and vertical displacement of the follower with the help of protractor & dial gauge respectively.

4. Draw the n –θ(follower displacement Vs rotation of cam) curve.

5. Now remove the dial gauge from the follower shaft.

6. Switch on the main power supply.

7. Slowly increase the rpm of the motor with the help of dimmer stat provided at the control panel & check the jump of the follower with the help of stroboscope

8. If jump of the follower is not appears then again adjust the speed of the motor. At certain speed jump of the follower will occur. When jump occurs the follower makes a good thumping sound on cam surface. This speed is the jump speed.

Tabulation:

1. **Cam profile**

Sl. No.	Cam Angle	Follower displacement mm
1	0	
2	30	
3	60	
4	90	
5	120	
6	150	
7	180	
8	210	
9	240	
10	270	
11	300	
12	330	
13	360	

2. Jump-speed.

Sl.No.	Load on the Follower Kg	Jump-speed N (RPM)
1	0	
2	0.5	
3	1	
4	1.5	

Precautions:

1. Always lubricate the cam before starting the apparatus
2. Tighten all the nuts properly before starting the apparatus.
3. Do not increase the speed of the motor at once

Result:

Experiment No: 2

WHIRLING OF SHAFTS

Aim:

To determine the critical speed of whirling shaft.

Apparatus : Whirling of shaft and Tachometer.

Procedure:

1. Fix the given shaft for suitable end condition. (Free-Free or Fixed Free).
2. Slowly increase the speed of rotation and find the minimum speed where the amplitude is maximum for the first mode.
3. Note down the speed.
4. Again slowly increase the speed of rotation and find the minimum speed where the amplitude is maximum for the second mode.
5. Note down the speed.
6. Repeat the procedure for various sizes of the shafts and for various end conditions.

Observations:

S.No	Dia. Of Shaft	**Condition**	**Critical Spped (Rpm)**

Result:

Experiment No: 3

MOTORIZED GYROSCOPE

Aim: To analyse the motion of a motorized gyroscope when the couple is applied along its spin axis.

Apparatus: Motorised gyroscope, weights, and voltage regulator.

Theory:

The angular velocity is a vector quantity and change in its magnitude can be caused by acceleration. To create this angular acceleration a torque or couple is required. To keep this angular velocity constant in magnitude due to the angular acceleration caused by the couple the spinning mass of the gyroscope undergoes a change called the angle of precession. This cause the gyroscopic couple to incline to a certain degree so that it can retain its angular velocity. This angle of precession for different torques and couple can be analysed by this experiment.

Specifications:

Moment of inertia of disc (I) =.063 Kg-m^2

Distance of point of application of load from center of disc(L) =

Maximum speed of motor (N) =

Procedure:

1. Set the rotating disc of the gyroscope in motion.
2. Increase the speed of motor from 500 rpm to 2500 rpm gradually in steps.
3. Put weights in pan from 500gm to 2500 gm for creating couple at defined speed in steps.
4. Observe the axis of spin will precess to a certain degree to retain the angular velocity.
5. Measure the angle of precession for the respective speed and weight.
6. Take the readings for the change in angle of precession in constant period say 15°.

Observations:

S. No.	Speed ω rad/sec	Weight in pan W kg	$\delta\theta$ in deg	δt in sec	$\omega p = \delta\theta / \delta t$	Torque kg-m (theoretical) W*L	Gyroscopic couple I * ω * ωp
1							
2							
3							

Calculations:

1. Angular Speed of the disc (ω) =(2*π*N)/60
2. Theoretical torque = W * L kg-m
   Where, L is distance of point of application of load from the center of disc is 0.22 m
   W is weight in pan in kg

2. Gyroscopic couple = I* ω * ω_p kg-m

   Where, I is moment of inertia of disc = kg-m^2

ω is angular velocity of disc in rad/sec

ωp is velocity of precession rad/sec

Precautions:

1. Increase the speed of the motor gradually in the range given.
2. Do not add large weight on the weight pan.
3. Always maintain safe distance from the apparatus

Result:

Experiment No: 4

SPRING MASS SYSTEM

Aim:

Determine the Natural frequency of vibration of spring mass system theoretically and actually.

Description

One end of open coil spring is fixed to the screw, which is firmly fixed to the upper bracket of vertical frame.

The spring is properly gripped by means of lock nut to the screw.

Lower end of the spring is attached to the platform carrying the weights.

Procedure:

1. Fix one end of the helical spring to the screw provided to the horizontal bracket.
2. Determine free length of the spring.
3. Put some weight on the platform and note down the deflection.
4. Stretch the spring through some distance and release.
5. Count the time required (in sec.) for some, say 10, 20 oscillations.
6. Determine the actual period.
7. Repeat the procedure for different weights.

Calculations

Observed Data:

Mass suspended m = ___________ kg

Weight suspended W = mg

= ___________ N

Free length of spring, h1 = _________ cm

Deflected length h2 = _________ cm

Deflection δ = h1 – h2

= __________ cm

= _____________ m

Number of oscillations n = _____________

Time for n oscillations t = ______________ sec.

Observations:

Sl. No.	Mass	Weight 'W'	Deflection				Stiffness of Spring	No. of Oscillations	Time for 'n' oscillations	Periodic Time 'Tp'	Natural Frequency fn (Experimental)	Natural Frequency fn (Theoretical)
	m'	W = mg	Free length h1	Deflected length h2	Deflection h1 - h2		S =	n	t	Tp = t / n	fn = 1/ Tp	fn =1/2π(√g/δ)Hz
	kg	N	mm	mm	mm	m	N/m		sec	sec	Hz	Hz
1												
2												
3												
4												
5												
6												

Sample Calculations:

1. To Find Stiffness of the spring (S)

Stiffness of the spring S $= W / \delta$

= __________ N/m

2. To find Periodic Time of oscillations (T_p)

Periodic Time T_p $= t/n$ seconds

= __________ seconds

3. To Find Natural Frequency – Experimentally $(f_n)_{ex.}$

Natural Frequency f_n $= 1/T_p$ Hz

= _______ Hz.

4. To Find Natural Frequency – Theoretically $(f_n)_{Th}$

Natural Frequency f_n $= \mathbf{1/2\pi(\sqrt{g/\delta})}$ Hz

= _______ Hz

Result:

Thus the longitudinal vibrations of a helical spring were studied and the Natural frequency was determined both theoretically and experimentally.

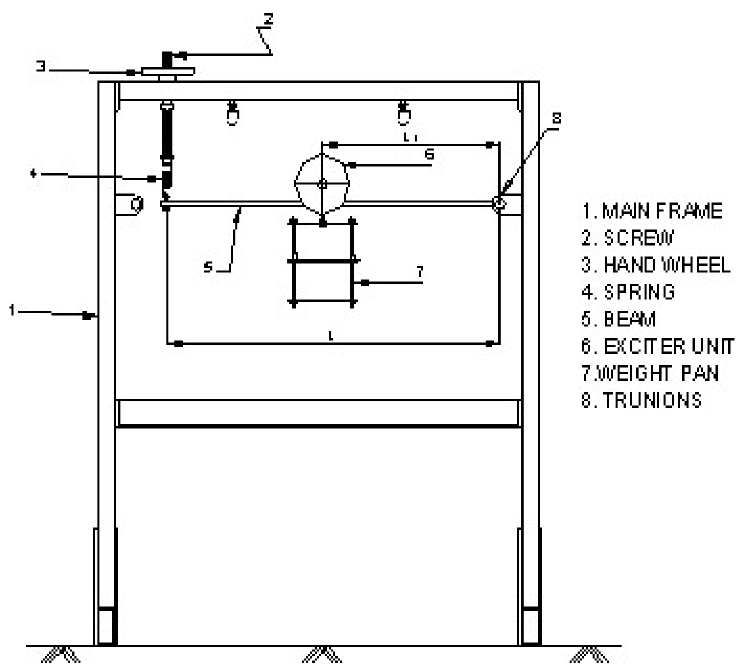
Experiment No: 5

FREE TRANSVERSE SYSTEM

Aim: To find the natural frequency of free transverse vibration system

Description:

The equipment is designed to study free damped and undamped vibration. It consists of M.S. rectangular beam supported at one end by a trunion pivoted in ball bearing. The bearing housing is fixed to the side member of the frame. The other end of beam is supported by the lower end of helical spring; upper end of the spring is attached to screw, which engages with screwed hand wheel. The screw can be adjusted vertically in any convenient position and can be clamped with the help of lock nut. The exciter unit can be mounted at any position along the beam. Additional known weights may be added to the weight platform under side exciter.



Free transverse vibration system

Experimental procedure:

1. Support one end of beam in the slot of trunion and clamp it by means of screw.
2. Attached the other end of the beam to lower end of spring.
3. Adjust the screw to which the spring is attached with the help of hand wheel such that beam is horizontal in position.
4. Clamp the assembly at any convenient position.
5. Measure the distance L1 of the assembly from pivot. Allow system to vibrate freely.
6. Measure the time for any 10 oscillations and periodic time and natural frequency of vibration.
7. Repeat the experiment by varying L1 and also putting different weights on platform.

Observation & Calculation:

Sr. No	*W (kg)*	*w (kg)*	*L_l (m)*	*L (m)*	*n*	*t (sec)*

Theoretical Calculations:

$m=(W+w)/g$

$T_{theo}=2\pi\sqrt{m/k}$

$f_{theo} = 1/ T_{theo}$

Practical Calculations:

$T_{act}=t/n$

$F_{act} = 1/ T_{act}$

e

Sr. No	*$T_{act.}$ (sec)*	*$T_{theo.}$ (sec)*	*$f_{act.}$ (sec^{-1})*	*$f_{theo.}$ (sec^{-1})*

Result:

Experiment No: 6

COMPOUND PENDULUM

Aim: To determine the radius of gyration 'k' and Moment of inertia of a given compound pendulum.

Apparatus Used: Compound pendulum test rig, Stop Watch.

Description:

The compound pendulum consists of a steel bar.
The bar is supported by knife edge.
Two pendulums of different lengths are provided with the setup.

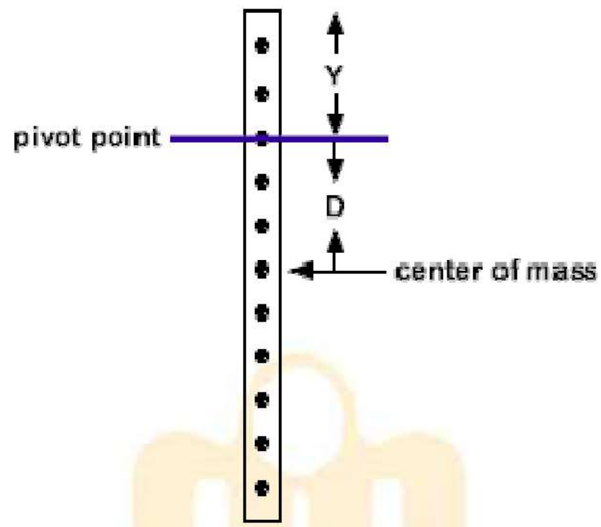


Figure: Compound pendulum

Procedure:

1. Support the rod on knife edge.
2. Note the length of suspended pendulum and determine og.
3. Allow the bar to oscillate and determine t by knowing the time for 10 oscillations.
4. . Repeat the experiment with different length of suspension.
5. Complete the observation table given bellow.

Formulae:

1. Time period actual

$T_{actual} = t/n$ sec

2. Actual radius of gyration, k_{act}

$T_{actual} = 2\pi \sqrt{\ } \{k_{act2} + (og)\ 2\ /g*(og)\}$

3. Theoretical radius of gyration, $K_{theo} = l/2\sqrt{3}$

4. Moment of Inertia (I)=m K^2

Observation & calculation table:

S.No.	L cm.	Og	No. Of Osc. N	Time for Osc.	T_{act}	K_{act}	K_{theo}	I
1								
2								
3								
4								

Nomenclature:

K_{act} = **radius** of gyration about cg in cm.
K_{theo} = radius of gyration about cg in cm.
L = length of suspended pendulum.
N = no. Of oscillations.
Og = distance of Centre of gravity of the rod from support.
T_{theo} = theoretical periodic time in sec.
T_{act} = actual time period.
T = time required for 10 oscillations.
I= moment Of Inertia.

Sample Calculation:

Result:

Experiment No: 7

BI-FILAR SUSPENSION.

Aim: To determine the radius of gyration “K” and Moment Of Inertia of given bar using bi-filar suspension.

Apparatus Used: bi-filar suspension rod and Stop Watch.

Description: A uniform rectangular section bar is suspended from the pendulum support frame by two parallel cords. Top ends of the cords pass through the two small chucks fitted at the top. Other ends are secured in the bi-filler bar. It is possible to adjust the length of the cord by loosening the chucks.

The suspension may be used to determine the radius of gyration of any body. In this case, the body under investigation is bolted to the centre. Radius of gyration of the combined bar and body is then determined.

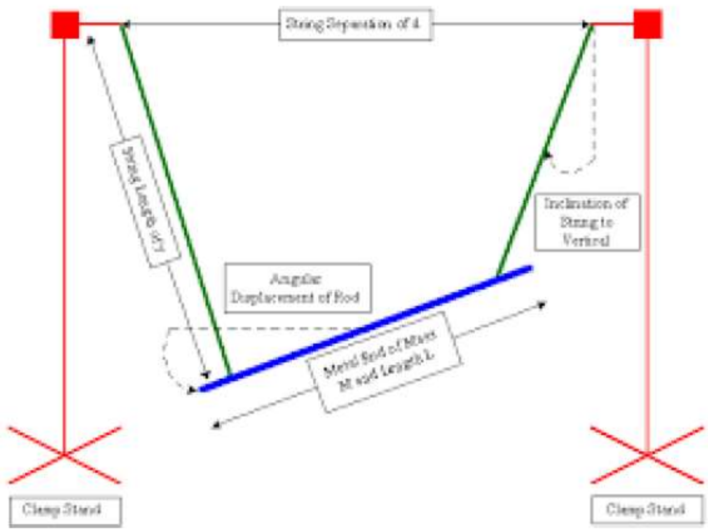


Figure: Radius of gyration of bar using bifiller suspension

Experimental procedures:

1. Suspend the bar from chuck, and adjust the length of the cord ‘l’ conveniently. Note that the suspension length of each cord must be same.
2. Allow the bar to oscillate the vertical axis passing through the center and measure periodic time t by knowing the time for say 10 oscillations.
3. Repeat the experiment by mounting the weights at equal distance from center.
4. Complete the observation table below.

Formulae:

1. Actual time period Tact = t/n sec
2. Actual radius of gyration, k act from equation Tact = $2\pi * k_{act}/a * \sqrt{l/g}$
3. Theoretical radius of gyration $K_{theo} = l/2\sqrt{3}$
4. Moment of Inertia (I) = $m K^2$

Observation & calculation table:

S . No.	Mass of the bar (kg)	Mass Added (kg)	Total Mass (kg)	Length of String (mm)	No. Of Oscill ation (n)	Time Taken For n Oscillations	Time Period (T_p)	Natural Frequen cy	Radiu s of Gyrat ion	Moment of Inertia (I)
1.										
2.										
3.										
4										
5										
6										
7										
8										
9										

Nomenclature:
2a = distance between the two string, g = acceleration due to gravity
K_{act}= actual radius of gyration of bi- filler suspension
K_{theo}= theoretical radius of gyration of bi-filler suspension
L = length of suspended string
N = nos. Of oscillation, n = number of oscillations

Sample Calculations:

Result:

Experiment No: 8

STATIC BALANCING APPARATUS

Aim: - 1. To observe the effect of vibration in a rotating system.

2. To balance the masses statically & dynamically of a single rotating mass system.

Theory:-

When a certain mass is attached to a rotating shaft, It exterts some centrifugal force, whose effect is to bend the shaft & to produce vibration in it. In order prevent the effect of centrifugal force; another mass is attached to the opposite side of the shaft, at such position so as to balance the effect of centrifugal force of the first mass. This is done is such a way that, the centrifugal force of both the masses are made to be equal & opposite. The process providing the balancing mass, in order to inter act the effect of centrifugal force of the first mass is called balancing of rotating mass. During balancing the net dynamic force acting on the shaft is equal to zero. This requires that the line of action of three centrifugal forces must be same. In other words the centre of the masses of the system must lie on the axis of rotation. This is the condition for static balancing. This can be observed by giving a small torque to the shaft by hand. For dynamic balancing the algebric sum of the moments about any point in the plane must be zero. For this condition we have to arrange the plane of disturbing mass between the planes of two balancing masses.& the plane of disturbing mass may lie on the or right of the two planes containing the balancing masses.

Consider any number of masses of magnitude m1, m2, m3, m4 at a distance r1, r2, r3, r4 from the axis of rotation shaft, let θ1, θ2, θ3, θ4 be the angle of the masses with horizontal line (axis of shaft) & they are rotating with a constant velocity of ω rad/see. The magnitude & position of the balancing mass may be find out analytically or graphically by plotting the forced diagram.

1. **Analytical method:**
First of all find out the centrifugal force (i.e. the product of mass & It's radius of rotation) exterted by each mass on the rotating shaft.

2. Find out the sum of centrifugal forces horizontally & vertically.
Sum of horizontal components of the centrifugal force.

$$\sum H = m_1 r_1 \cos\theta_1 + m_2 r_2 \cos\theta_2 + \cdots\cdots\cdots m_n r_n \cos\theta_n$$

Sum of vertical components of centrifugal force

$$\sum H = m_1 r_1 \sin\theta_1 + m_2 r_2 \sin\theta_2 + \cdots\cdots\cdots m_n r_n \sin\theta_n$$

3. Magnitude of resultant centrifugal force

$$F_c = \sqrt{(\sum H)^2 + (\sum V)^2}$$

4. Balancing angle

$$\theta = \tan^{-1}\frac{\sum V}{\sum H}$$

5. The balancing force is then equal to the resultant force. But in opposite direction. Now find out the magnitude of balancing mass

$F_C = m.r$

m = Balancing mass

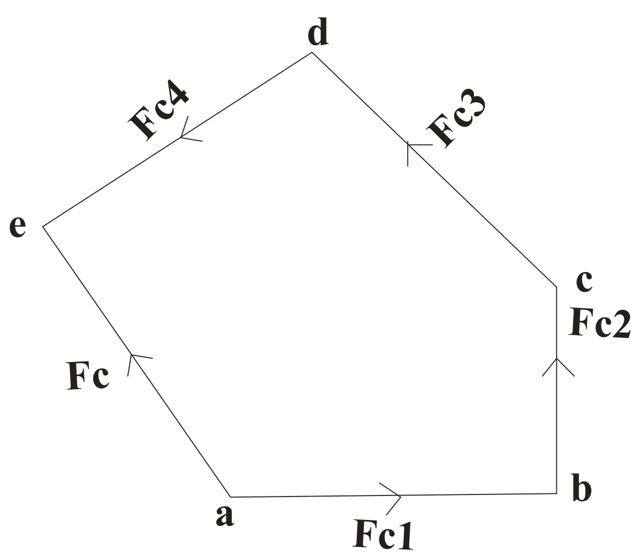
r= radius of rotation

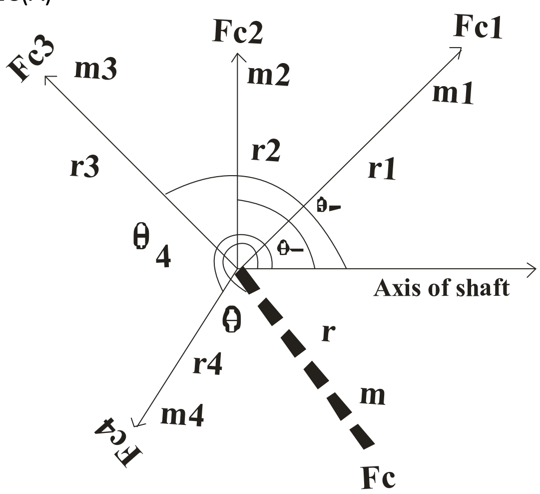
Graphical method

1. Draw the space diagram with the position of several masses.
2. Then find out the centrifugal force exterts by each mass on the rotating shaft.
3. Now draw the vector diagram with the help of centrifugal force.
4. Now as per polygon law of force closing side will represent the resultant force in magnitude & direction.
5. Find out the magnitude of balancing mass (m) at a given radius r such that

   mw^2r = resultant centrifugal force

   mr = resultant of m_1r_1, m_2r_2-----m_nr_n





Description:

This equipment is designed for carry out the experiment for balancing a rotation mass system. The apparatus consists of a stainless steel shaft fixed in a rectangular frame. A set of four blocks with a clamping arrangement provided. For static balancing each block is individually clamped on shaft & its balancing can check by giving a manually rotation. For dynamic balancing a moment polygon is a drawn using relative weight, angular & axial position of blocks. The blocks are clamped on shaft is rotated by a motor to check dynamic balance of the system.

Procedure:

1. First draw the space diagram by using the mass & radius of masses.
2. Now find out the centrifugal force exterted by each mass on the rotating shaft.
3. Now draw the vector diagram with the help of obtained centrifugal force, to a suitable scale & find out resultant force by closing the polygon.
4. Then arrange the masses on shaft with the help of spirit level provided with the equipment
5. Switch on the motor & slowly increase the speed of motor with the help of variac & observe the balancing of mass on shaft by seeing the vibration of equipment.

Observation:-

m_1 = ----gm, Θ_1=

m_2 = ---- gm Θ_2=

m_3 = ---- gm Θ_3=

m_4 = ------gm Θ_4=

Result:

Experiment No: 9

DYNAMIC BALANCING APPARATUS

Aim: - 1. To observe the effect of vibration in a rotating system.

2. To balance the masses statically & dynamically of a single rotating mass system.

Theory:-

When a certain mass is attached to a rotating shaft, It exterts some centrifugal force, whose effect is to bend the shaft & to produce vibration in it. In order prevent the effect of centrifugal force; another mass is attached to the opposite side of the shaft, at such position so as to balance the effect of centrifugal force of the first mass. This is done is such a way that, the centrifugal force of both the masses are made to be equal & opposite. The process providing the balancing mass, in order to inter act the effect of centrifugal force of the first mass is called balancing of rotating mass. During balancing the net dynamic force acting on the shaft is equal to zero. This requires that the line of action of three centrifugal forces must be same. In other words the centre of the masses of the system must lie on the axis of rotation. This is the condition for static balancing. This can be observed by giving a small torque to the shaft by hand. For dynamic balancing the algebric sum of the moments about any point in the plane must be zero. For this condition we have to arrange the plane of disturbing mass between the planes of two balancing masses.& the plane of disturbing mass may lie on the or right of the two planes containing the balancing masses.

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3. Analytical method:
First of all find out the centrifugal force (i.e. the product of mass & It's radius of rotation) exterted by each mass on the rotating shaft.

4. Find out the sum of centrifugal forces horizontally & vertically.
Sum of horizontal components of the centrifugal force.

$$\sum H = m_1 r_1 \cos\theta_1 + m_2 r_2 \cos\theta_2 + \cdots\cdots\cdots m_n r_n \cos\theta_n$$

Sum of vertical components of centrifugal force

$$\sum H = m_1 r_1 \sin\theta_1 + m_2 r_2 \sin\theta_2 + \cdots\cdots\cdots m_n r_n \sin\theta_n$$

3. Magnitude of resultant centrifugal force

$$F_c = \sqrt{(\sum H)^2 + (\sum V)^2}$$

4. Balancing angle

$$\theta = \tan^{-1} \frac{\sum V}{\sum H}$$

5. The balancing force is then equal to the resultant force. But in opposite direction. Now find out the magnitude of balancing mass

$F_C = m.r$

m = Balancing mass

r= radius of rotation

Graphical method

6. Draw the space diagram with the position of several masses.
7. Then find out the centrifugal force exterts by each mass on the rotating shaft.
8. Now draw the vector diagram with the help of centrifugal force.
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10. Find out the magnitude of balancing mass (m) at a given radius r such that

mw^2r = resultant centrifugal force

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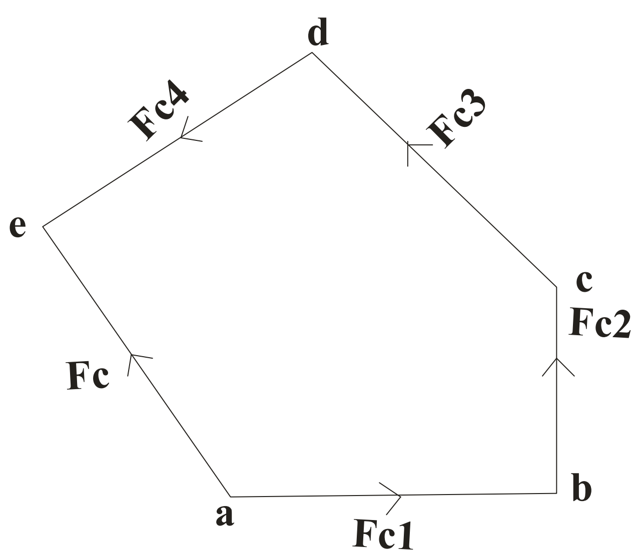

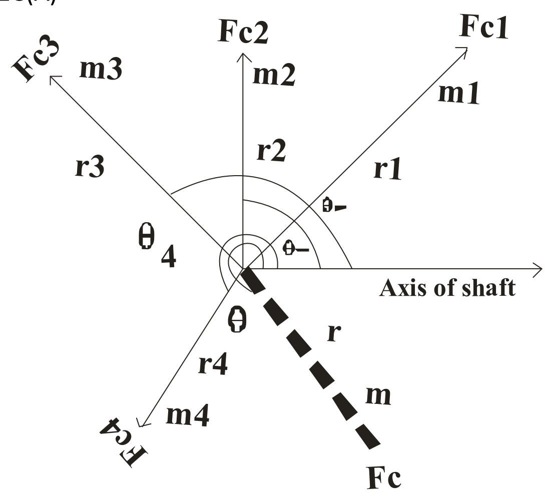

Description:

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Procedure:

1. First draw the space diagram by using the mass & radius of masses.
2. Now find out the centrifugal force exterted by each mass on the rotating shaft.
3. Now draw the vector diagram with the help of obtained centrifugal force, to a suitable scale & find out resultant force by closing the polygon.
4. Then arrange the masses on shaft with the help of spirit level provided with the equipment
5. Switch on the motor & slowly increase the speed of motor with the help of variac & observe the balancing of mass on shaft by seeing the vibration of equipment.

Observation:-

m_1 = ----gm, Θ_1=

m_2 = ---- gm Θ_2=

m_3 = ---- gm Θ_3=

m_4 = ------gm Θ_4=

Result:

Experiment No: 10

EPI CYCLIC GEAR TRAIN APPARATUS

Aim: To calculate the torque on a Planet Carrier and torque on internal gear using epicyclicgear train and holding torque apparatus.

Requirement: Epicyclic Gear Train Apparatus.

Introduction:

Any combination of gear wheels by means of which motion is transmitted from one shaft to another shaft is called a gear train. In case of epicyclic gear trains the axes of the shafts on which the gears are mounted may move relatively to a fixed axis.
The gear trains are useful for transmitting high velocity ratio with gears of moderate size in a comparatively lesser space. The epicyclic gear trains are used in the back gear of lathe, differential gears of automobiles, wristwatches.

Epicyclic gear train:

A simple gear train (shown in fig) is a train in which a 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 gear train is simple and gear A can drive gear B or vice versa, but if gear A is fixed and arm is rotated about the axis of gear A (i.e. O_1), then the gear B is forced to rotate upon and around gear A. Such a motion is called epicyclic and the gear trains arrangement in such a manner that one or more of their members move upon and around another member are known as epicyclic gear trains. The epicyclic gear trains may be simple or compound.

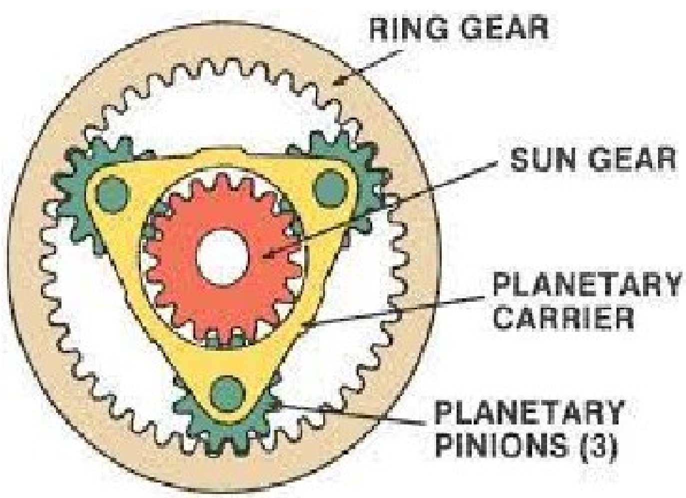


Figure: Epicyclic gear train

Velocity ratio of epicyclic gear-train:

The following two methods may be used for finding out the velocity ratio of an epicyclic gear train.

1. Tabular Method
2. Algebraic Method

A compound epicyclic gear train (internal type) consists of two co-axial S_1 and S_2 sun gear (A), an arm (H), three planetary gears (B,C,and E) and an annular gear (D) as shown in Fig.. Wheel A has 10 external teeth, B,C and E have 12 external teeth. The annular gear has 35 internal teeth. The sun gear A is fixed on the input shaft S_1. Three planetary compound gear (B,C,E) are mesh with sun gear A and annular gear D. The planetary gears are free to revolve on the pins of arm H.

Step No.	**Condition of Elements**	Revolution of Elements			
		Arm H	**Gear A**	**Compound gear B, C, E**	**Gear D**
1	Arm fixed gear A rotates through + 1 revolution (i.e. 1 rev. in anticlockwise)	0	+1	$-\frac{T_A}{T_B}$	$-\frac{T_A}{T_B}\times -\frac{T_B}{T_D}=\frac{T_A}{T_D}$
2	Arm fixed –gear A rotates through + X revolution	0	+X	$-X\frac{T_A}{T_B}$	$-X\frac{T_A}{T_D}$
3	Add + Y revolution to all elements	+Y	+Y	+Y	+Y
4	Total Motion	+Y	X + Y	$Y-X\frac{T_A}{T_B}$	$Y-X\frac{T_A}{T_D}$

Speed of Gear :-

If we know that the speed of arm is 271 R.P.M.

Therefore, y = 271 R.P.M.

And the gear D is fixed due to holding

Therefore, $Y - X\frac{T_A}{T_D} = 0$

$$271 - X\frac{10}{35} = 0$$

$$X = \frac{271 \times 35}{10}$$

$$= 948.5 \text{ R.P.M.}$$

Speed of A $= X + Y$

$= 948.5 + 271$

$= 1219.5$ R.P.M.

1219.5 R.P.M. in the direction of arm

Speed Ratio = Speed of Driver / Speed of Driven

= Speed of Sun gear A / Speed of Arm H

= 1219.5 / 271

= 4.5

Let d_A, and d_B and d be the pitch circle diameter of sun gear A, planet gear B and internally toothed gear D respectively. Assuming the pitch of all the gears to be same therefore from the fig. Geometry

$d_A + 2 d_B = d$

The numbers of teeth are proportional to their pitch circle diameters, therefore

$T_A + 2 T_{\mathbf{B}} = T_D$

$2T_{\mathbf{B}} + 10 = 35$

$2 T_{\mathbf{B}} = 35 – 10 = 25$

$T_{\mathbf{B}} = 25/2 = 12.5 = 12$

The numbers of teeth of planetary gears B, C, E are

$T_B = T_C = T_E = 12$

Torque in epicyclic gear train (internal type):-

If the parts of an epicyclic gear train are all moving at uniform speeds, so that no angular acceleration are involved, the algebraic sum of all external torque applied to the train must be zero or there are at least external torques for the train, and in many cases there are only three. There are:-

T_i The input torque on the driving member, Arm.

T_o The resisting, or load, torque on the driven member.

T_{he} The holding, or braking torque on the fixed member.

If there is no acceleration,

$T_i + T_o + T_h = 0$ ---------------(1)

Further, if there are no internal friction losses at the bearing and at the contact surfaces of the wheel teeth, the net energy dissipated by the train must be zero, or

$T_i\omega_i + T_o\omega_o + T_h\omega_h = 0$ ---------------(2)

Where, ω_I, ωo and ω_h are the angular velocities of the three members to which the external torques are applied. But for the

Fixed member, $\omega_h = 0$, so that

$T_i\omega_i + T_o\omega_o = 0$ --------------(3)

From the resisting or load, torque

$T_o = \frac{-T_i\omega_I}{\omega_o}$ -------------(4)

and from equation (1)

$Th = -(T_i + T_o)$

$= T_i (\omega_i/\omega_o - 1)$ --------(5)

These equations may be used to find the values of T_o and Th when the input torque T_i applied to the driving members is known. In addition, for complex trains they may be used to find the tooth loads or torques on all the intermediate members through which power is transmitted.

Procedure:

1. Check the experiment set-up.
2. Give supply to Motor from control panel.
3. Adjust the RPM of Input shaft to some fix value.
4. Apply holding torque just to hold the drum. This must be done carefully.
5. Take the readings of loads of the holding drum & output drum as well as take readings input & output RPM.
6. Take the next reading to apply load on output drum. By applying load on output drum, holding start to rotate.
7. Repeat the same procedure for next reading.

Formulae:

1. Gear ratio = $\frac{\text{Speed of driver shaft}}{\text{Speed of driven shaft}}$
2. Input Torque, T_i = $\frac{V \times I \times \eta \times 4500}{746 \times 2\pi N}$ kg m
3. Holding Torque, T_h = $(T_1 - T_2) \times R_1$ kgm
4. Output Torque, T_o = $(T_3 - T_4) \times R_2$ kg m

*** Take Efficiency (η) of motor = 80% = 0.80**

Observation & calculation data:

1. Number of teeth of SUN gear = 10 Teeth
2. Number of teeth of PLANET gear = 12 Teeth
3. Number of teeth of ANNULAR gear (Internal gear) = 35 Teeth
4. Diameter of holding drum = 186 mm = 0.186 m
5. Radius of holding drum, R_1 = 93 mm = 0.093 m
6. Diameter of output brake drum = 186 mm = 0.186 m
7. Radius of output brake drum, R_2 = 93 mm = 0.093 m

Experiment No: 11

KINEMATICS LINKS, PAIRS, CHAINS & MECHANISMS

Aim: - To study various types of kinematics links, pairs, chains & Mechanisms.

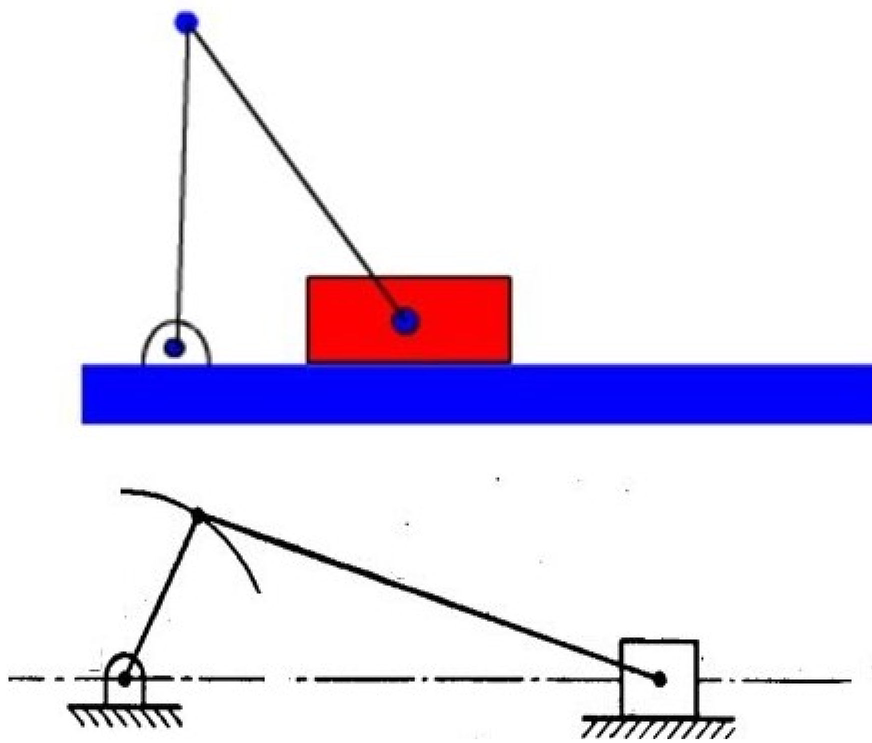
Apparatus used: - Kinematics links, pairs, chains & Mechanisms.

Theory: -

1. Definitions of kinematics links, pairs, chains & Mechanisms.
2. Classifications of kinematics links, pairs, chains & Mechanisms.
3. Diagrams of kinematics links, pairs, chains & Mechanisms
4 Advantages & Disadvantages of kinematics links, Pairs, chains & Mechanisms.
5. Applications of kinematics link, Pairs, chains & Mechanism
6. Examples of kinematics link, Pairs, chains & Mechanisms.

Kinematic link: -

A mechanism is made of a number of resistant bodies out of which Some may have motions relative to the others. A resistant body or a group of resistant bodies with rigid connections preventing their relative movement is known as a link. A link also Known as kinematic link or element.

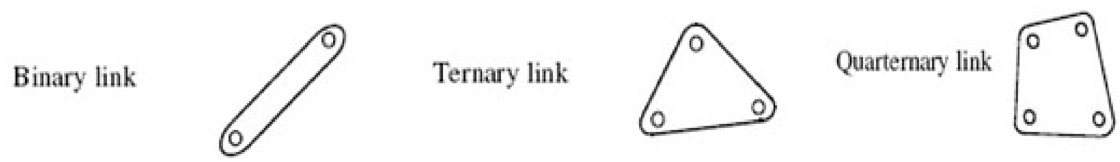


Kinematic Link

Examples: - A slider-crank mechanism consists of four links: frame and guides, crank connecting rod and slider, the crank link may have crankshaft and flywheel also, forming one link having no relative motion of these.

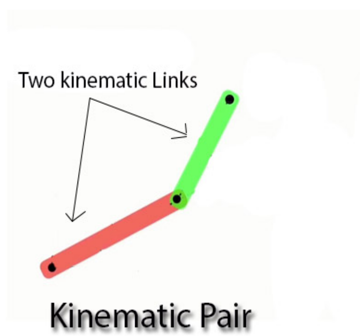
Classifications of links:-

1. Binary link
2. Ternary link
3. Quaternary link



Kinematic pair: -

A kinematic pair or simply a pair is a joint of two links having relative motion between them.



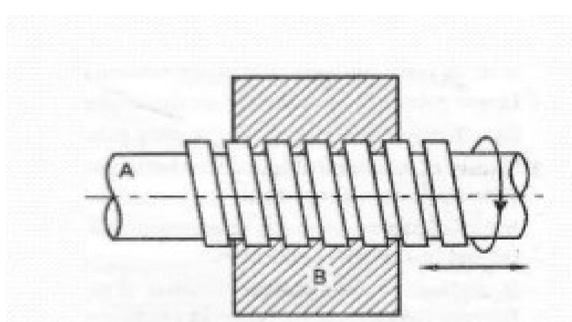
Classifications of pairs:

1-Kinematics pairs according to nature of contact:-

(i) Lower pair -links having surface or area contact

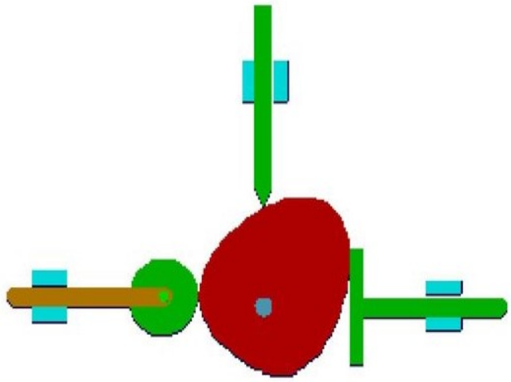
Examples-

Nut turning on a screw, shaft rotating in a bearing, universal joint etc.



Lower Pair

(ii) Higher pair -Point or line contact between the links.



Examples:- when rolling on a surface, cam and follower pair, tooth gears, ball and roller bearings etc.

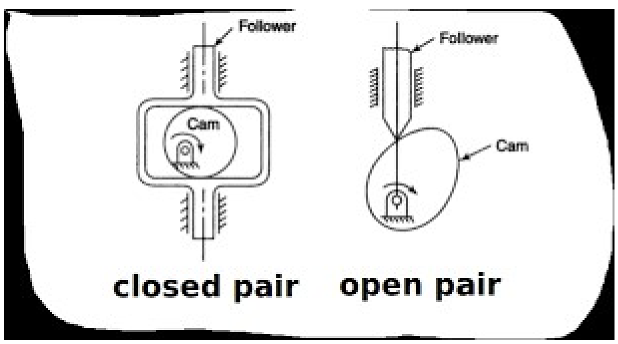
2- Kinematics pairs according to nature of Mechanical Constraint:-

(a) **Closed pair** - when the elements of a pair are held together mechanically

Examples: - all the lower pairs and some of the higher pair

(b) **Unclosed pair or Open Pair** -when two links of a pair are in contact either due to force of gravity or some spring action.

Example: - cam and follower pair.



3-Kinematics pairs according to nature of relative motion:-

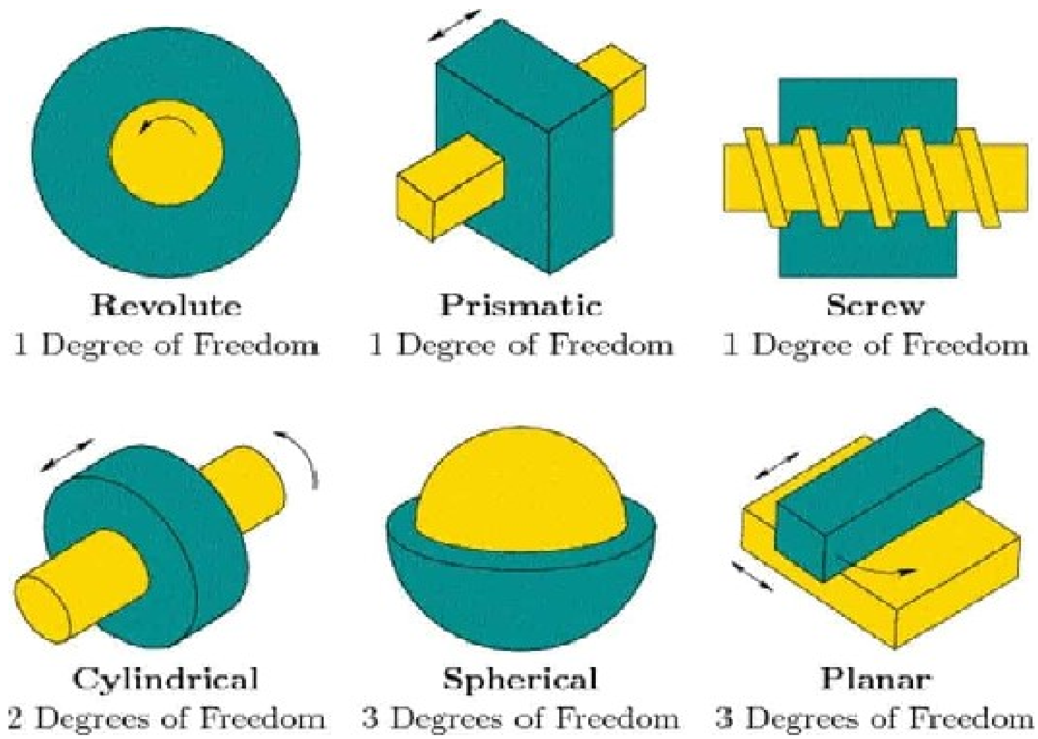
(i) Sliding pair

(ii) Turning pair

(iii) Rolling Pair

(iv) Screw pair (Helical pair)

(v) Spherical pair

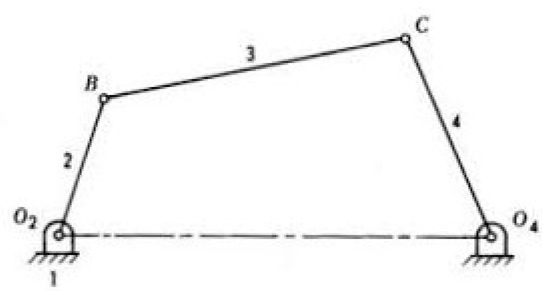


Kinematic chain: -

A kinematic chain is an assembly of links in which the relative motions of the links is possible and the motion of each relative to the others is definite. If indefinite motions of other links , it is a non-kinematic chain.

Types of kinematics chains:-

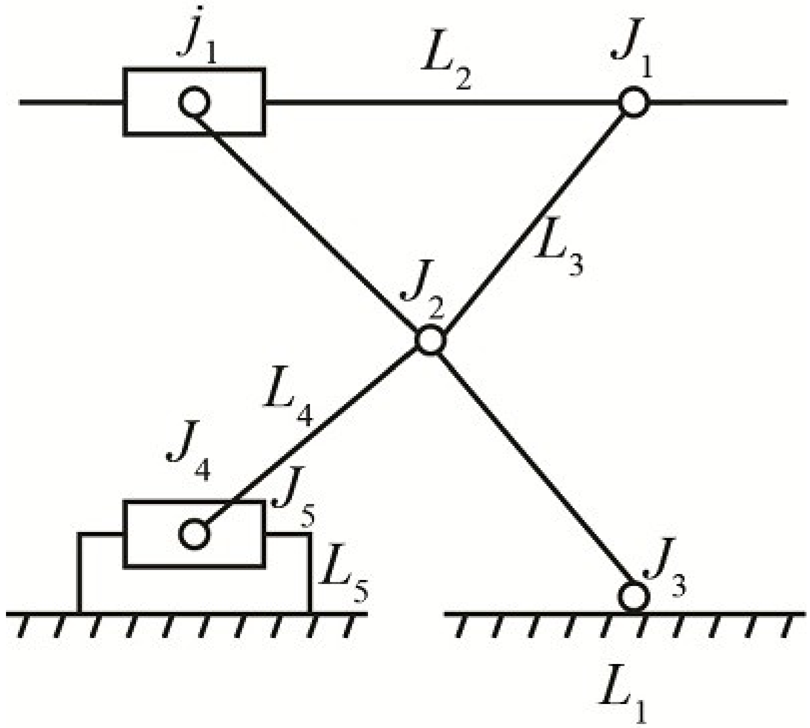
(i) Four bar chain or quadric cycle chain
(ii) Single slider crank chain
(iii) Double slider crank chain



Four bar chain

Mechanism:-

A linkage is obtained if one of the links of a kinematics chain is fixed to the ground. If motion of each link results in definite motions of the others, the linkage is known as a mechanism. If one of the links of a redundant chain is fixed, it is known as a structure. The degree of freedom of a structure is zero or less. A structure with negative degree of freedom is known as a superstructure.



Lift Table Mechanism

Result:

Experiment No : 12

GEAR TRAINS- SIMPLE, COMPOUND, REVERTED, EPICYCLIC AND DIFFERENTIAL

Aim: - To study various types of gear trains- simple, compound, reverted, epicyclic and differential.

Apparatus used: -. Arrangement of Gear train system.

Theory: -

1. Definition of. Geart rain
2. Classification of Geartrain
3. Diagrams of different types of Gear train.
4. Working & Construction of different types of Gear train.
5. Advantages & Disadvantages of Gear train
6. Applications of Gear train .
7. Examples of Gear train

Gear train:-

A gear train is a combination of gears used to transmit motion from one shaft to another. It becomes necessary when it is required to obtain large speed reduction within a small space.

The following are the main types of gear trains:

(i) Simple gear train

(ii) Compound gear train

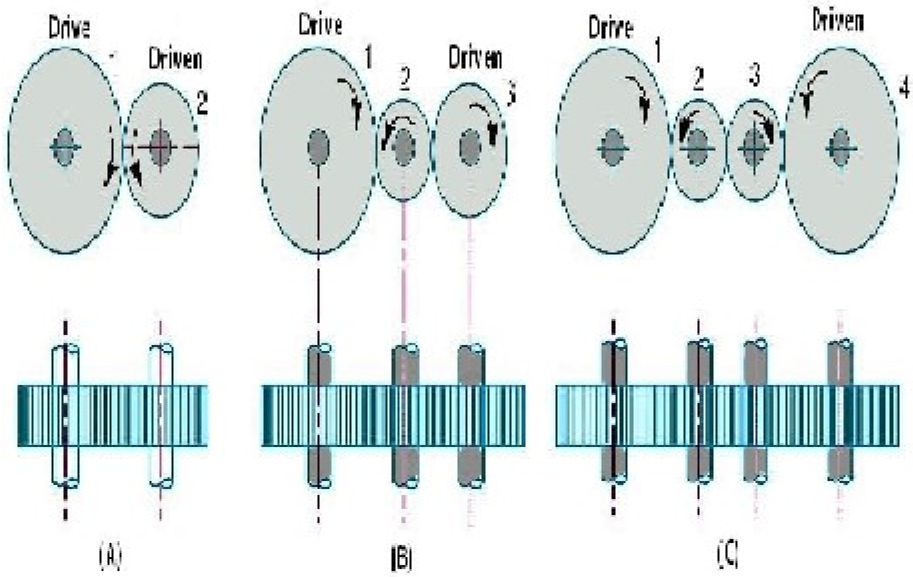
(iii) Reverted gear train

(iv) Planetary gear train

Simple gear train :-

A series of gears, capable of receiving and transmitting motion from one gear to another is called a simple gear train. In it, all the gear axes remain fixed relative to the frame and each gear is on a separate shaft.

Train Value = Number of teeth on driving gear / Number of teeth on driven gear

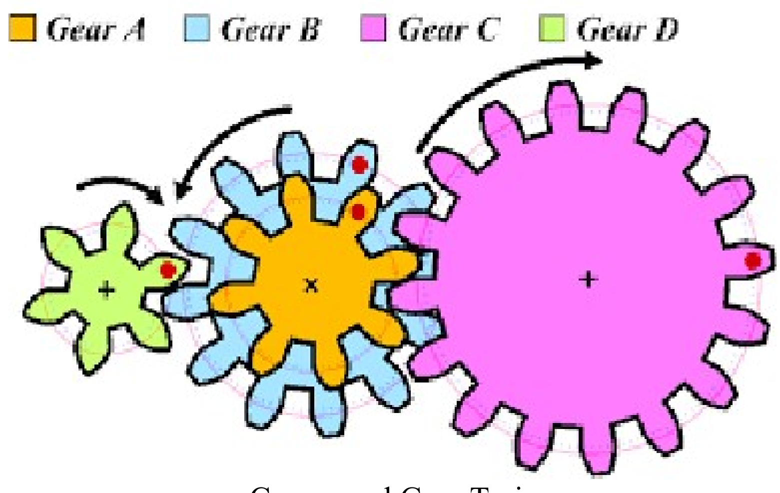


Simple Gear Train

Compound gear train:-

When a series of gears are connected in such a way that Two or more gears rotate about an axis with the same angular velocity, it is known as Compound gear train. In this type, some of the intermediate shafts.

Train Value = Product of Number of teeth on driving gear / Product of Number of teeth on driven gear

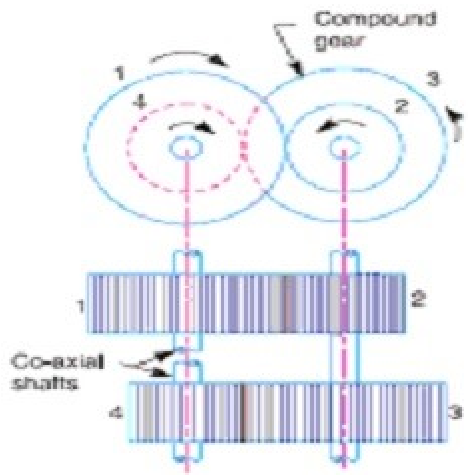


Compound Gear Train

Reverted gear train:-

If the axes of the first and last wheels of a compound gear coincide; it is called a reverted gear train. Such an arrangement is used in clocks and in simple lathes where 'back gear' is used to give a slow speed to the chuck.

Train Value = Product of Number of teeth on driving gear / Product of Number of teeth on driven gear

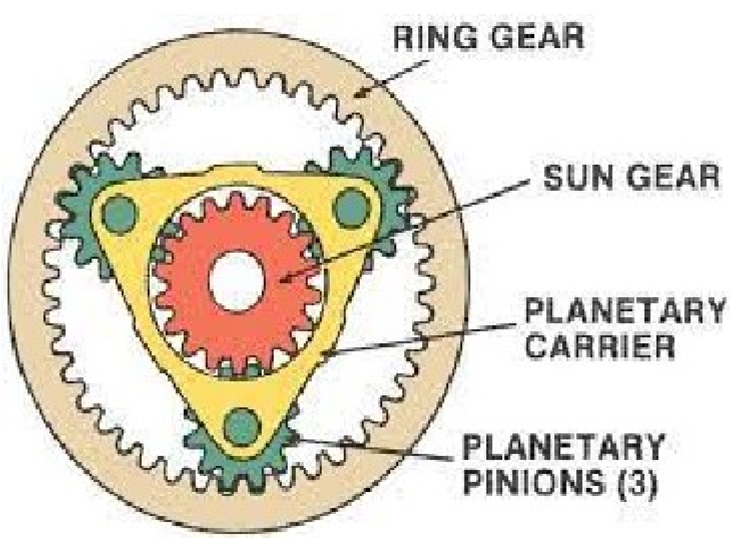


Reverted Gear Train

Planetary or epicyclic gear train: -

When there exists a relative motion of axis in gear train, it is called a planetary or an epicyclic gear train (or simply epicyclic gear or train). Thus in an epicyclic train, the axis of at least one of the gears also moves relative to the frame.

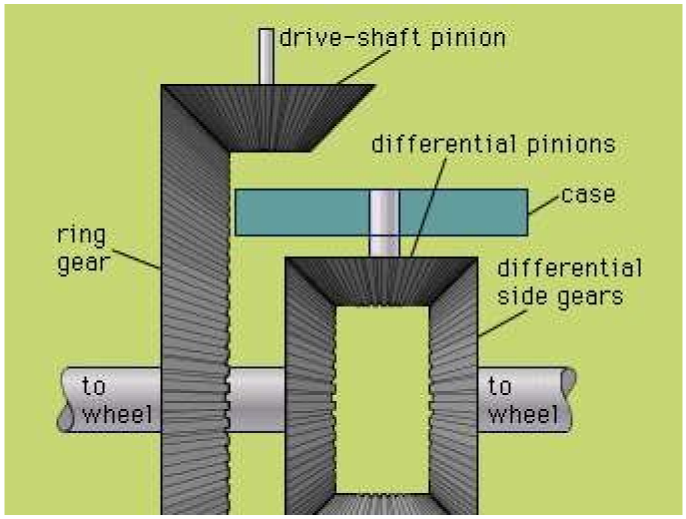
Consider two gear wheels S and P, the axis of which are connected by an arm a. If the arm 'a' is fixed, the wheels S and P constitute a simple train. However, if the wheel s is fixed so that the arm can rotate about the axis of S, the wheel P would also move around S. therefore, it is an epicyclic train.



PLANETARY OR EPICYCLIC GEAR TRAIN

Differential gear:-

When a vehicle takes a turn, the outer wheels must travel farther than the inner wheels. In automobiles, the front wheels can rotate freely on their axis and thus can adapt themselves to the conditions. Both rear wheels are driven by the engine through gearing. Therefore, some sirt of automatic device is necessary so that the two rear wheels are driven at slightly different speeds. This is accomplished by fitting a differential gear on the rear axle.



DIFFERENTIAL GEAR

Result: -

Experiment No: 13

TYPES OF CAM AND FOLLOWER ARRANGEMENTS

Aim: - To study various types of cam and follower arrangements.

Apparatus used: - Cam and follower arrangements.

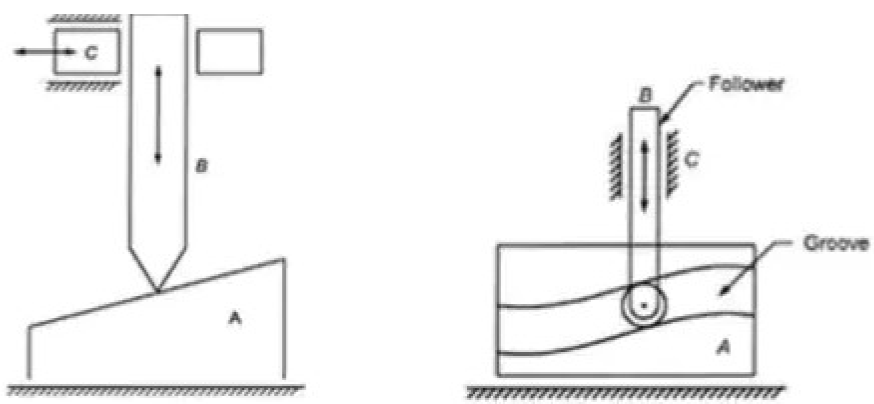
Theory: - 1. Definition of Cam & Follower.
2. Classification of Cam & Follower.
3. Diagrams of Cam & Follower.
4. Working & Construction of Cam & Follower.
5. Advantages & Disadvantages of Cam & Follower.
6. Applications of Cam & Follower. .
7. Examples of Cam & Follower.

Cam & follower: - A cam is a mechanical member used to impart desired motion to a follower by direct contact. The cam may be rotating or reciprocating whereas the follower may be rotating, reciprocating or oscillating. A cam and the follower combination belongs to the category of higher pairs.

- A driver member known as the cam.
- A driven member called the follower

Types of Cams:
A. According to shape

(i) **Wedge and flat Cams:-** A wedge cam has a wedge W which, in general, has a translational motion. The follower. The follower F can either translate or oscilate.



Wedge and flat Cams

(ii) Radial or Disc Cams: - A cam in which the follower moves radially from the Centre of rotation of the cam is known as a radial or a disc cam.
(iii) Spiral cams: - A spiral cam is a face cam in which a groove is cut in the form of a Spiral as shown in fig. the spiral spiral groove consists of teeth which mesh with a pin gear follower.

(iv) Cylindrical cams: - In a cylindrical cam, a cylinder which has a circumferential Contour cut in the surface, rotate about its axis.

(v) Conjugate cams: - A conjugate cam is a double – disc cam, the two discs being keyed together and are in constant touch with the two rollers of a follower. It is used for low noise, high speed and dynamic loads.

(vi) Globoidal cams: - A globoidal cam can have two types of surfaces, convex or concave. A circumferential contour is cut on the surface of rotation of the cam to impart motion to the follower which has an oscillatory motion.

(vii) Spherical cams: - In a spherical cam, the follower oscillates about an axis Perpendicular to the axis of rotation of the cam.

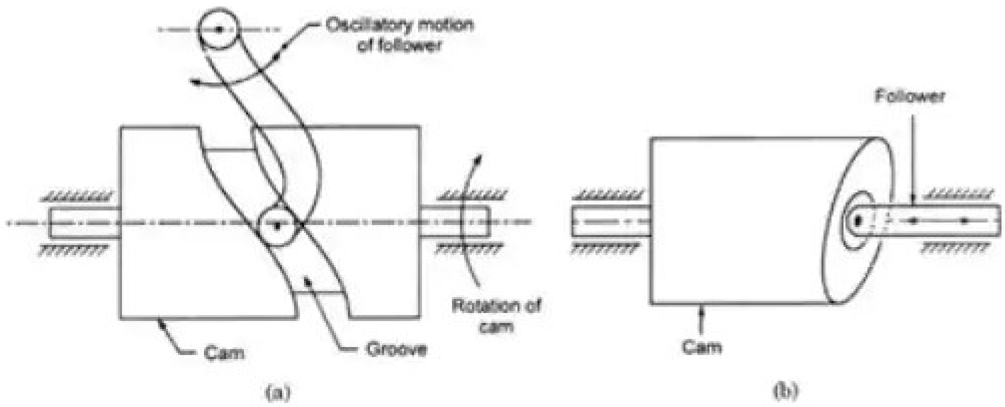


Fig.8.3 Cylindrical cams

B. According to Follower Movement

(i) Rise-Return-Rise (R-R-R) :- In this, there is alternate rise and return of the follower with no periods of dwells. Its use is very limited in the industry. The follower has a linear or an angular displacement.

(ii) Dwell-Rise-Return-Dwell (D-R-R-D):- In such a type of cam, there is rise and return of the follower after a dwell. This type is used more frequently than the RR-R type of cam

(iii) Dwell-Rise-Dwell-Return (D-R-D-R) :- It is most widely used type of cam. The dwelling of the cam is followed by rise and dwell and subsequently by return and dwell.

C. According to Manner of Constraint of the Follower

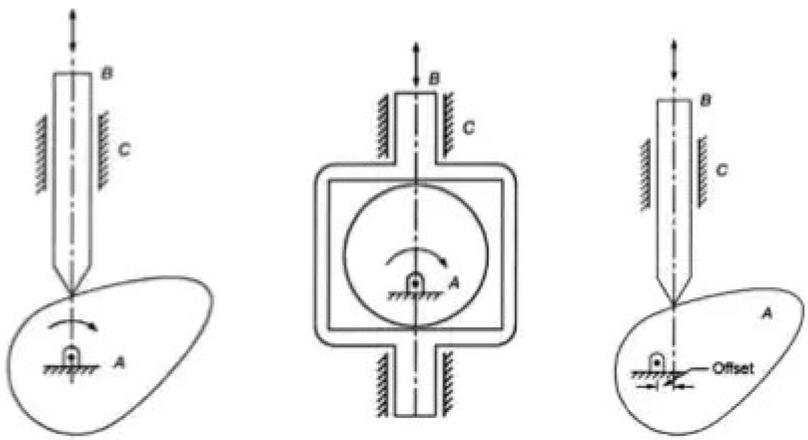
(i) Pre-loaded Spring Cam
(ii) Positive-Drive Cam
(iii) Gravity Cam

Types of Followers :-

A. According to shape
(i) Knife-edge Follower
(ii) Roller Follower
(iii) Mushroom Follower

B. According to Movement
(i) Reciprocating Follower
(ii) Oscillating Follower

C. According to Locating of Line of Movement
(i) Radial Follower
(ii) Offset Follower



(a) Knife-edge radial (b) Closed cam (c) Offset cam

Result : -

Experiment No:14

GOVERNORS

Aim: To study about different types of governors and its applications

Introduction:

Flywheel which minimizes fluctuations of speed within the cycle but it cannot minimize fluctuations due to load variation. This means flywheel does not exercise any control over mean speed of the engine. To minimize fluctuations in the mean speed which may occur due to load variation, governor is used. The governor has no influence over cyclic speed fluctuations but it controls the mean speed over a long period during which load on the engine may vary. The function of governor is to increase the supply of working fluid going to the prime mover when the load on the prime-mover increases and to decrease the supply when the load decreases so as to keep the speed of the prime-mover almost constant at different loads.

Example: when the load on an engine increases, its speed decreases, therefore it becomes necessary to increase the supply of working fluid. On the other hand, when the load on the engine decreases, its speed increases and hence less working fluid is required. When there is change in load, variation in speed also takes place then governor operates a regulatory control and adjusts the fuel supply to maintain the mean speed nearly constant. Therefore, the governor automatically regulates through linkages, the energy supply to the engine as demanded by variation of load so that the engine speed is maintained nearly constant.

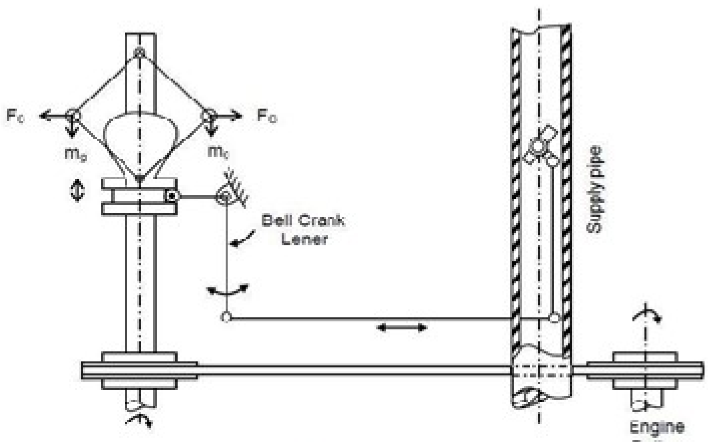


Figure 5.1 : Governor and Linkages

Types of Governors

The governors may, broadly, be classified as

1. Centrifugal governors
2. Inertia governors.
3. Pickering governors.

Centrifugal Governors

In these governors, the change in centrifugal forces of the rotating masses due to change in the speed of the engine is utilized for movement of the governor sleeve. One of this type of governors is shown in Figure. These governors are commonly used because of simplicity in operation.

Inertia and Flywheel Governors

In these governors, the inertia forces caused by the angular acceleration of the engine shaft or flywheel by change in speed are utilized for the movement of the balls. The movement of the balls is due to the rate of change of speed instead of change in speed itself as in case of centrifugal governors. Thus, these governors are more sensitive than centrifugal governors.

Pickering Governors

This type of governor is used for driving a gramophone. As compared to the centrifugal governors, the sleeve movement is very small. It controls the speed by dissipating the excess kinetic energy. It is very simple in construction and can be used for a small machine.

Types of Centrifugal Governors

Depending on the construction these governors are of two types:

1. Gravity controlled centrifugal governors, and
2. Spring controlled centrifugal governors.

Gravity Controlled Centrifugal Governors

In this type of governors there is gravity force due to weight on the sleeve or weight of sleeve itself which controls movement of the sleeve. These governors are comparatively larger in size.

Spring Controlled Centrifugal Governors

In these governors, a helical spring or several springs are utilized to control the movement of sleeve or balls. These governors are comparatively smaller in size.

Gravity controlled centrifugal governors:

There are three commonly used gravity controlled centrifugal governors:

(a) Watt governor

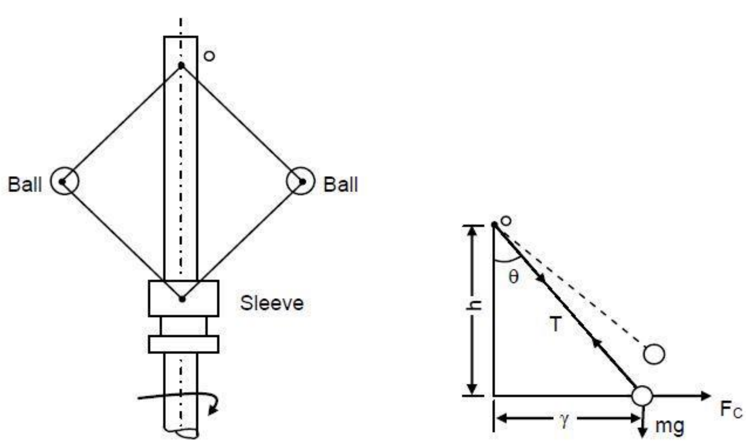
(b) Porter governor

(c) Proell governor

Watt governor does not carry dead weight at the sleeve. Porter governor and proell governor have heavy dead weight at the sleeve. In porter governor balls are placed at the junction of upper and lower arms. In case of proell governor the balls are placed at the extension of lower arms. The sensitiveness of watt governor is poor at high speed and this limits its field of application. Portergovernor is more sensitive than watt governor. The proell governor is most sensitive out of these three.

Watt Governor

This governor was used by James Watt in his steam engine. The spindle is driven by the output shaft of the prime mover. The balls are mounted at the junction of the two arms. The upper arms are connected to the spindle and lower arms are connected to the sleeve as shown in Figure.



(a) (b)

Figure 5.2 : Watt Governor

We ignore mass of the sleeve, upper and lower arms for simplicity of analysis. We can ignore the friction also. The ball is subjected to the three forces which are centrifugal force (*Fc*), weight (*mg*) and tension by upper arm (*T*). Taking moment about point *O* (intersection of arm and spindle axis), we get

$$F_C\, h - mg\, r = 0$$

Since, $$F_C = mr\,\omega^2$$

$\therefore$ $$mr\,\omega^2 h - mg\, r = 0$$

or $$\omega^2 = \frac{g}{h}$$

$$\omega = \frac{2\pi N}{60}$$

$\therefore$ $$h = \frac{g \times 3600}{4\pi^2 N^2} = \frac{894.56}{N^2}$$

where '*N*' is in rpm.

Figure shows a graph between height '*h*' and speed '*N*' in rpm. At high speed the change in height *h* is very small which indicates that the sensitiveness of the governor is very poor at high speedsbecause of flatness of the curve at higher speeds.

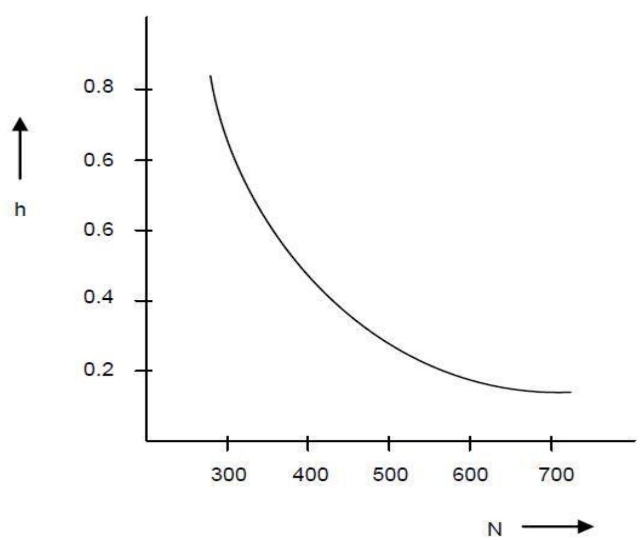


Figure 5.3 : Graph between Height and Speed

Porter Governor

A schematic diagram of the porter governor is shown in Figure 5.4(a). There are two sets of arms. The top arms *OA* and *OB* connect balls to the hinge *O*. The hinge may be on the spindle or slightly away. The lower arms support dead weight and connect balls also. All of them rotate with the spindle. We can consider one-half of governor for equilibrium.

Let *w* be the weight of the ball,

*T*1 and *T*2 be tension in upper and lower arms, respectively,

Fc be the centrifugal force,

*r*be the radius of rotation of the ball from axis, and

I is the instantaneous centre of the lower arm.

Taking moment of all forces acting on the ball about I and neglecting friction at the sleeve, we get

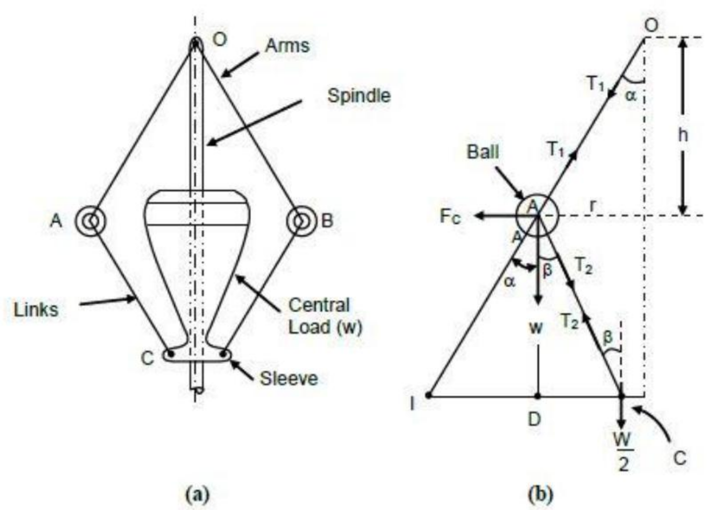


Figure 5.4 : Porter Governor

$$\omega^2 = \frac{g}{h}\left\{1 + \frac{(W \pm f)}{2w}(1 + K)\right\}$$

Spring controlled centrifugal governors

In these governors springs are used to counteract the centrifugal force. They can be designed to operate at high speeds. They are comparatively smaller in size. Their speed range can be changed by changing the initial setting of the spring. They can work with inclined axis of rotation also. These governors may be very suitable for IC engines, etc.

The most commonly used spring controlled centrifugal governors are :

(a) Hartnell governor

(b) Wilson-Hartnell governor

(c) Hartung governor

Hartnell Governor

The Hartnell governor is shown in Figure 5.5. The two bell crank levers have been provided which can have rotating motion about fulcrums *O* and *O*

. One end of each bell crank lever carries a ball and a roller at the end of other arm. The rollers make contact with the sleeve. The frame is connected to the spindle. A helical spring is mounted around the spindle between frame and sleeve. With the rotation of the spindle, all these parts rotate.

With the increase of speed, the radius of rotation of the balls increases and the rollers lift the sleeve against the spring force. With the decrease in speed, the sleeve moves downwards. The movement of the sleeve are transferred to the throttle of the engine through linkages.

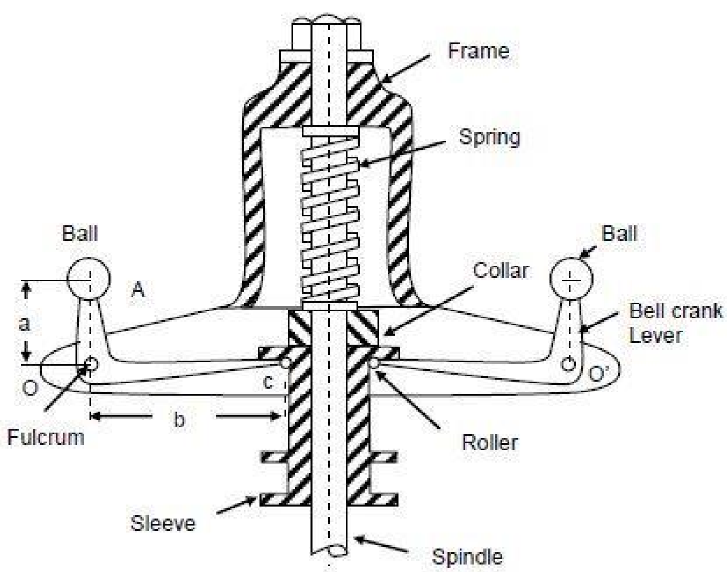


Figure 5.5 : Hartnell Governor

Characteristics of governors:

Different governors can be compared on the basis of following characteristics:

Stability

A governor is said to be stable when there is one radius of rotation of the balls for each speed which is within the speed range of the governor.

Governors Sensitiveness

The sensitiveness can be defined under the two situations:

1. When the governor is considered as a single entity.
2. When the governor is fitted in the prime mover and it is treated as part of prime mover.

(a) A governor is said to be sensitive when there is larger displacement of the sleeve due to a fractional change in speed. Smaller the change in speed of the governor for a given displacement of the sleeve, the governor will be more sensitive.

(b) The smaller the change in speed from no load to the full load, the more sensitive the governor will be. According to this definition, the sensitiveness of the governor shall be determined by the ratio of speed range to the mean speed. The smaller the ratio more sensitive the governor will be

Where $N2 – N1$ = Speed range from no load to full load.

Hunting

Whenever there is change in speed due to the change in load on the engine, the sleeve moves towards the new position but because of inertia if overshoots the desired position. Sleeve then moves back but again overshoots the desired position due to inertia. This results in setting up of oscillations in engine speed. If the frequency of fluctuations in engine speed coincides with the natural frequency of oscillations of the governor, this results in increase of amplitude of oscillations due to resonance. The governor, then, tends to intensity the speed variation instead of controlling it. This phenomenon is known as hunting of the governor. Higher the sensitiveness of the governor, the problem of hunting becomes more acute.