DAV UNIVERSITY

(Empowering Students with 21st Century Skills)

DEPARTMENT OF MECHANICAL ENGINEERING

LAB MANUAL

FOR

KINEMATICS AND DYNAMICS OF MACHINES LAB (MEC-202)

Vision of the Department

The Mechanical Engineering Department aims to be recognized as an outstanding educational centre to develop innovative engineers who are proficient in advanced fields of engineering and technology and can contribute effectively to the industry as well as for socio-economic upliftment of the society.

Mission of the Department

M1: To impart outcome-based education with a research orientation to the students to develop them as globally competitive engineers.

M2: To imbibe the students with academic, leadership and entrepreneurship skills needed by the industry in particular and society in general.

M3: To adopt flexibility and dynamism in designing the programme structures to cope up with emerging market needs.

M4: Establishment of liaison with top R & D organizations/Industries and leading educational institutions for practical exposure of the students and faculty as well as to the state of the art.

Programme Educational Outcomes (PEOs)

After the successful completion of undergraduate course, Mechanical Engineering, Graduates will be able to:

PEO1: Plan, design, construct, maintain and improve mechanical engineering systems that are technically sound, economically feasible and socially acceptable.

PEO2: Apply analytical, computational and experimental techniques to address the challenges faced in mechanical and allied engineering streams.

PEO3: Communicate effectively using conventional platforms as well as innovative / online tools and demonstrate collaboration, networking & entrepreneurial skills.

PEO4: Exhibit professionalism, ethical attitude, team spirit and pursue lifelong learning to achieve career, organizational and societal goals.

Program Outcomes (POs) - B. Tech. Mechanical Engineering

PO1: **Engineering knowledge**: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2: **Problem analysis**: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3: Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO4: Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5: Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6: The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues, and the consequent responsibilities relevant to the professional engineering practice.

PO7: Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8: Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9: Individual and teamwork: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10: Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO11: Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments

PO12: Life-long learning: Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes (PSO) - B. Tech. Mechanical Engineering

PSO1: **Academic Competence:** Apply mechanical and interdisciplinary knowledge to analyze, design and manufacture products to address the needs of the society.

PSO2: Professional Competence: Apply state of the art tools and techniques to conceptualize, design and introduce new products, processes, systems and services.

DAV UNIVERSITY

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Department of Mechanical Engineering

L	T	P	Credits
0	0	2	1

Course Code	MED202
Course Title	**KINEMATICS AND DYNAMICS OF MACHINES LAB**
Course Outcomes	On the completion of the course the student will be able to: **CO1:** To know about links,inversions of 4 Bar Mechanisms, Single and double slider crank mechanisms. **CO2:** To learn various type of cam and follower arrangements. **CO3:** To learn about various Governors and prepare performance characteristic Curves, and to find stability & sensitivity. **CO4:** To learn about the static/dynamic balancing on static/dynamic balancing machine.
Examination Mode	Practical

Assessment Tools	Continuous Assessment (CA)				MSE	MSP	ESE	ESP	Total
	Quiz	Assignment/ Project Work	Attendance	Lab Performance					
Weightage	-	-	-	20%	-	30%	-	50%	100

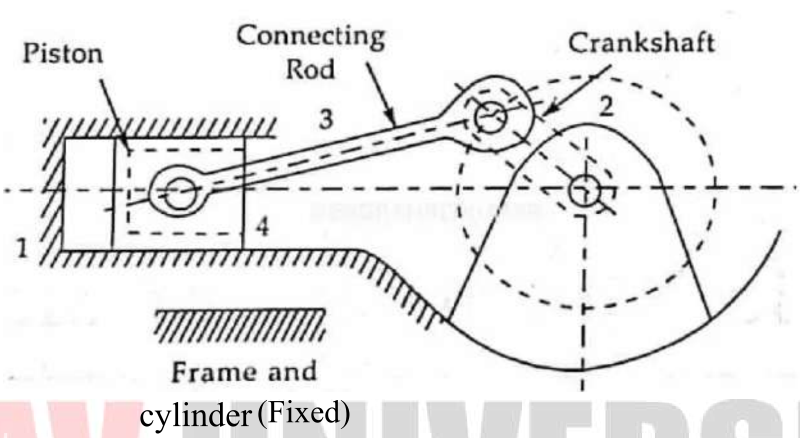
S. No.	**LIST OF EXPERIEMENTS**	**CO Mapping**
1.	To study various types of links, joints and kinematic pairs.	CO1
2.	To study inversions of 4 Bar Mechanisms.	CO1
3.	To study inversions of Single Slider Mechanisms.	CO1
4.	To study inversions of Double Slider Mechanisms.	CO1
5.	To study various type of cam and follower arrangements.	CO2
6.	To plot follower displacement vs cam rotation for various Cam Follower systems.	CO2
7.	To measure Epicyclic gear ratio, input torque, holding torque and output torque.	CO2
8.	To perform experiment on Watt Governors to prepare performance characteristic Curves, and to find stability & sensitivity.	CO3
9.	To perform experiment on Proell Governor to prepare performance characteristic curves, and to find stability & sensitivity.	CO3
10.	To perform experiment on Hartnell Governor to prepare performance characteristic Curves, and to find stability & sensitivity.	CO3
11.	To determine gyroscopic couple on Motorized Gyroscope.	CO4
12.	To perform the experiment for static balancing on static balancing machine.	CO4
13.	To perform the experiment for dynamic balancing on dynamic balancing machine.	CO4
14.	To determine critical speed or whirling speed of a rotating shaft and to verify the value theoretically.	CO4

EXPERIMENT NO: 1

Experiment 1: To study various types of links, joints and kinematic pairs.

THEORY:

1.1 Kinematic Link: A link is defined as a member or a combination of members of a mechanism connecting other members and having relative motion between them. The link may consist of one or more resistant bodies. A link may be called as kinematic link or element. Example Kinematic Link: Piston, piston rod and crosshead of a steam engine constitute one unit and hence called one link shown in the below figure. In this figure. The various link is designated as 1,2,3,4, etc.



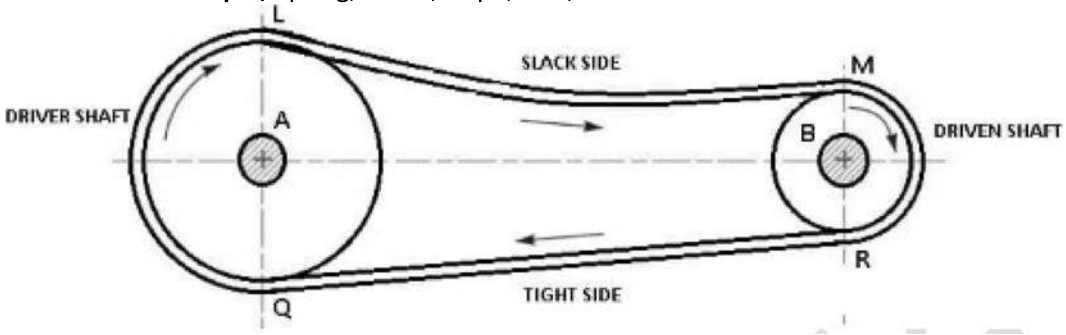
Link 1 is a fixed link that includes frame and all other stationery parts like cylinder, crankshaft bearing, camshaft bearing, etc.
Link 2 is the crankshaft, flywheel, etc all having rotation motion with respect to a fixed axis.
Link 3 is the connecting rod and
Link 4 is the piston which is having reciprocating motion. hence this is called a **4 bar mechanism.**
Link need not be a rigid body but must be a resistant body. Hence link must have the following two characteristics:

a) It must be a resistant body.
b) It must have relative motion.

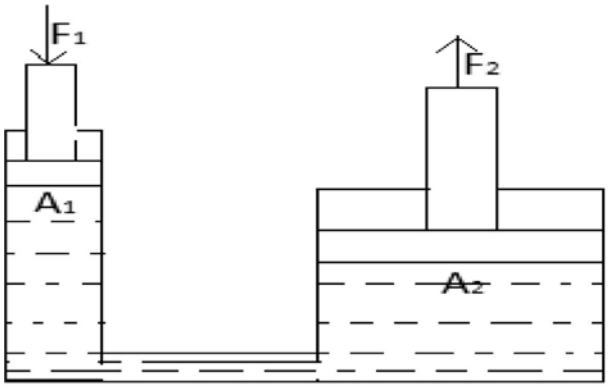
1.2 Types of Links:

a) Rigid Link: A rigid link is one that does not undergo any deformation while transmitting motion. Links, in general, are elastic in nature. They are considered rigid if they do not undergo appreciable deformation while transmitting motion**. For Example,** crank and connecting rod.

b) Flexible Link: A flexible link is one which while transmitting motion is partly deformed in a manner not to affect the transmission of motion. **For Example,** Spring, Chain, Rope, Belt, etc.



c) Fluid Link: A fluid link is one that is deformed by having fluid in a closed vessel and the motion is transmitted through the fluid by pressure**. For Example,** hydraulic press and hydraulic jack.



1.3 A link can also be classified based upon its number and end vertices:

a) Binary link: It having two vertices.
b) Ternary link: This is having three vertices.
c) Quaternary link: This having four vertices.

1.4 Kinematic Pair: When two kinematic links are connected in such a way that their motion is either— completely or successfully constrained, these two links are said to form a kinematic pair. Kinematic pairs can be classified according to: —

a) Kinematic pairs according to nature of contact:

i. Lower Pair: A pair of links having surfaced or area contact between the members is known as a lower pair. The contact surfaces of two links are similar. o Examples: Nut turning on a screw, shaft rotating in a bearing.

ii. Higher Pair: When a pair has a point or line contact between the links, it is known as a higher pair. The contact surfaces of two links are similar. o Example: Wheel rolling on a surface, Cam and Follower pair etc.

b) Kinematic pairs according to Nature of Relative Motion:

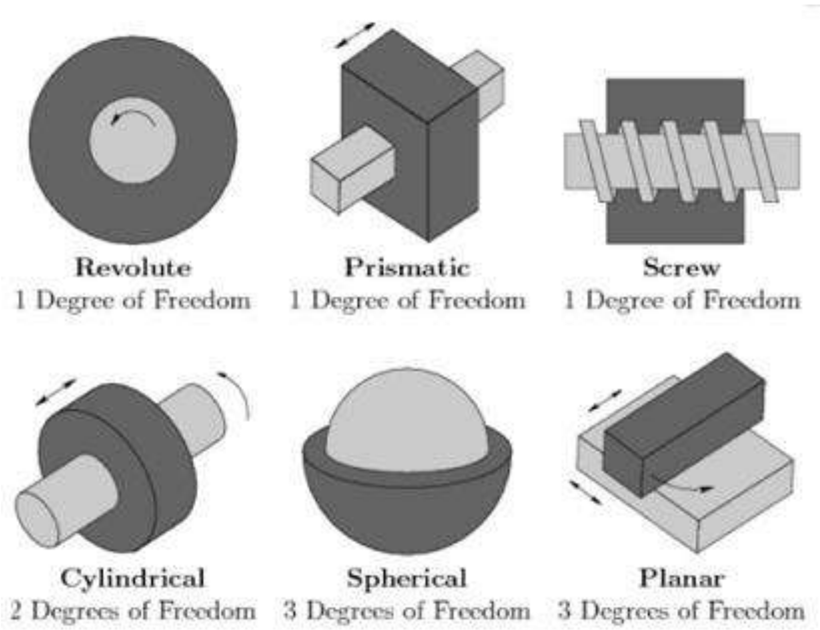
i. **Sliding/Prismatic pair**: When two links have a sliding motion relative to another; the kinematic pair is known as sliding pair.

i. Turning/Revolute pair: When one link is revolve or turn with respect to the axis of first link, the kinematic pair formed by two links is known as turning pair.

ii.Rolling/cylinderical pair: When the links of a pair have a rolling motion relative to each other, they form a rolling pair.

iii.Screw pair: If two mating links have a turning as well as sliding motion between them, they form a screw pair.

iv.Spherical pair: When one link in the form of sphere turns inside a fixed link, it is a spherical pair.

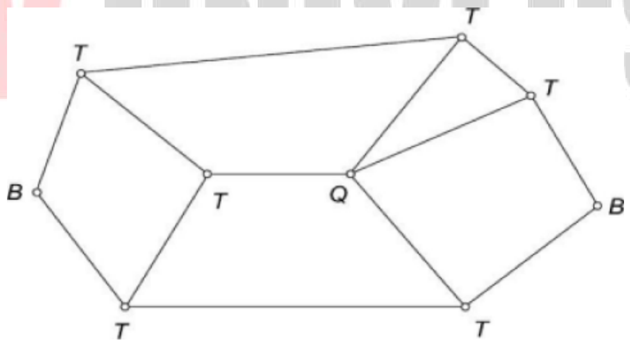


1.5 Types of Joint: The usual types of joints in a chain are: —

a) **Binary Joint:** If two links are joined at the same connection, it is called a binary joint. For example, in fig. at joint B

b) **Ternary Joint:** If three links joined at a connection, it is known as a ternary link. For example, point T in fig.

c) **Quaternary Joint:** If four links joined at a connection, it is known as a quaternary link. For example, point Q in fig.



EXPERIMENT NO: 2

Experiment 2: To study inversions of 4 Bar Mechanisms.

THEORY:

Inversion of Mechanism: When the number of links in kinematic chain is more than three, the chain is known as— mechanism. When one link of the kinematic chain at a time is fixed, give the different mechanism of the kinematic chain. The method of generating different mechanism by fixing a link is called the inversion of mechanism. The number of inversions is equal to the numbers of links in the kinematic chain.

The inversion of four-bar chain mechanism is: may be classified as: —

a) **First inversion: coupled wheel of locomotive:** The mechanism of a coupling rod of a locomotive (also known as double crank— mechanism) which consists of four links is shown in Fig.

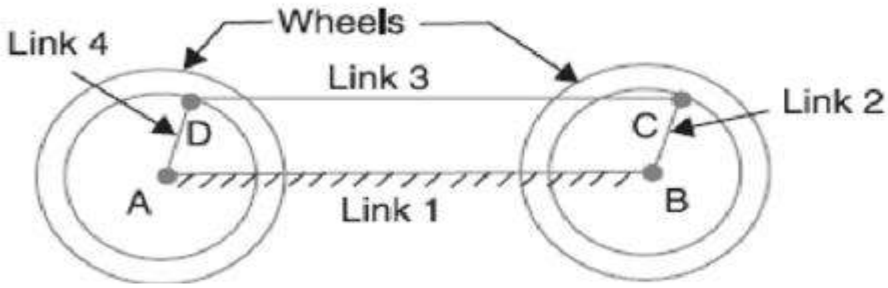


Fig Coupled wheel of locomotive

In this mechanism, the links AD and BC (having equal length) act as cranks and are connected to the respective wheels. The link CD acts as a coupling rod and the link AB is fixed in order to maintain a constant centre to Centre distance between them. This mechanism is meant for transmitting rotary motion from one wheel to the other wheel.

b) **Second inversion: Beam Engine:** A part of the mechanism of a beam engine (also known as cranks and lever mechanism) which consists of four links is shown in Fig. In this mechanism, when the crank rotates about the fixed centre A, the lever— oscillates about a fixed centre D. The end E of the lever CDE is connected to a piston rod which reciprocates due to the rotation of the crank. In other words, the purpose of this mechanism is to convert rotary motion into— reciprocating motion

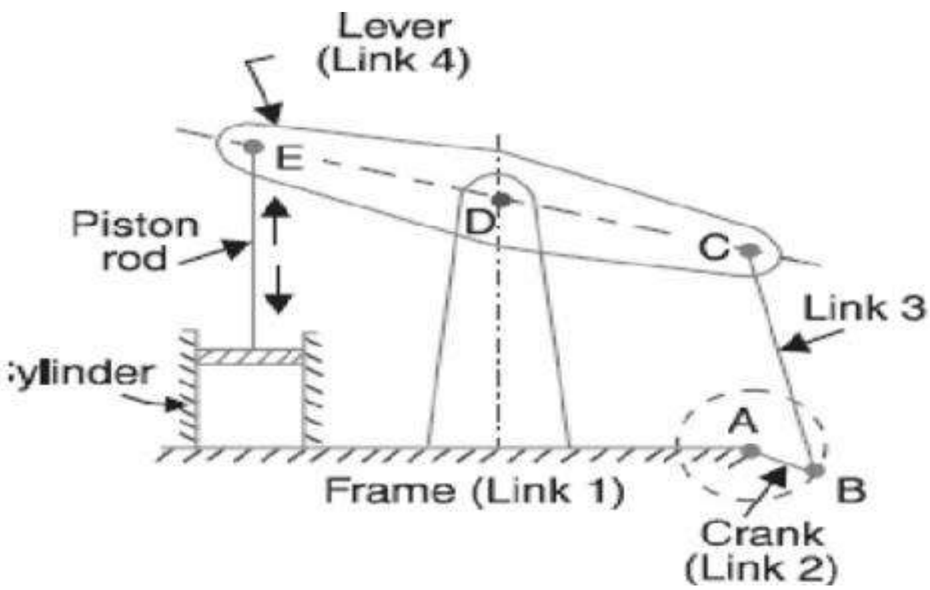


Fig. beam engine

c) **Third inversion: watts indicator mechanism:** A Watt's indicator mechanism (also known as Watt's straight-line mechanism or double lever mechanism) which consists of four links is shown in Fig. The four links are: fixed link at A, link AC, link CE and link BFD. It may be noted that BF and FD form one link because these two parts have no relative motion between them. The links CE and BFD act as levers. The displacement of the link BFD is directly proportional to the pressure of gas or steam which acts on the indicator plunger On any small displacement of the mechanism, the tracing point E at the end of the link CE traces out approximately a straight line.

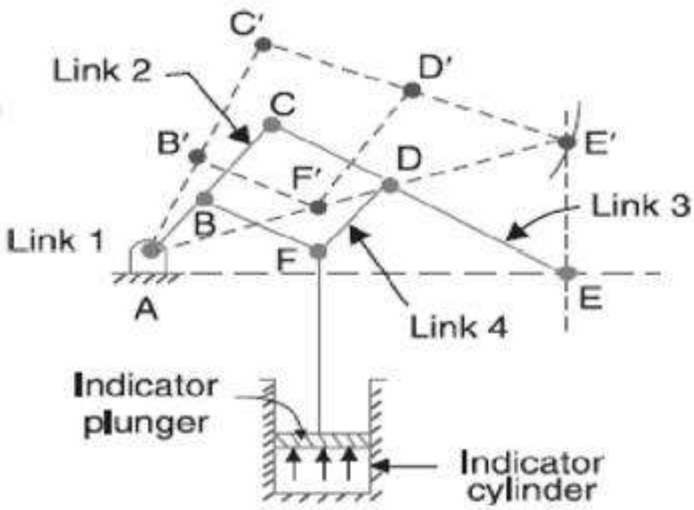


Fig. **watts indicator mechanism**

EXPERIMENT NO: 3

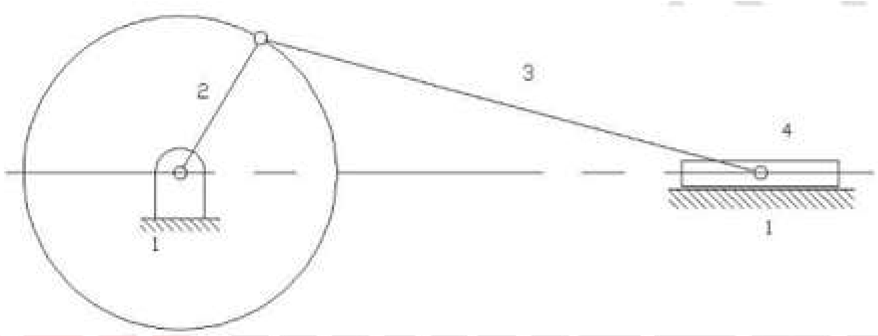
Experiment 3: To study inversions of Single Slider Mechanisms.

THEORY:

INVERSIONS OF SINGLE SLIDER-CRANK CHAIN Different mechanisms obtained by fixing different links of a kinematics chain are known as its inversions. A slider — crank chain has the following inversions: -

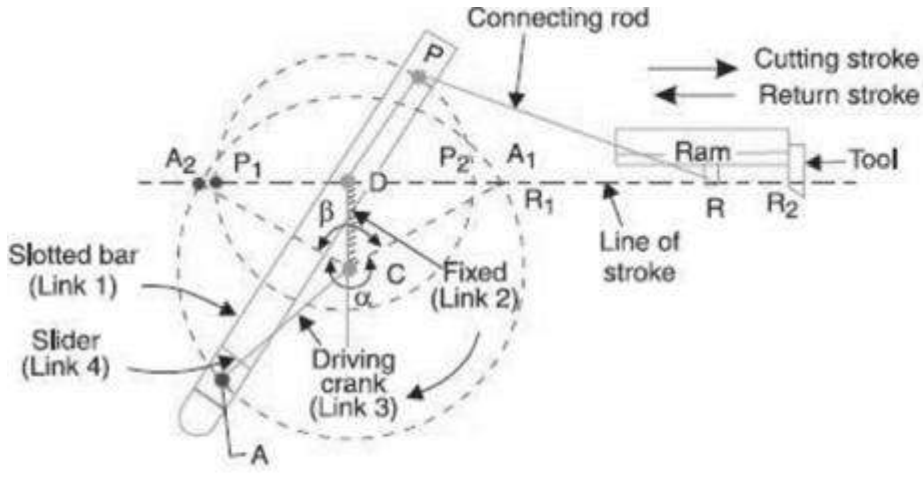
a) First inversion (i.e; Reciprocating engine and compressor)
b) Second inversion (i.e., Whitworth quick return mechanism and Rotary engine)
c) Third inversion (i.e., Oscillating cylinder engine and crank & slotted lever mechanism)
d) Fourth inversion (Hand pump)

a) First inversion: This inversion is obtained when link 1 is fixed and links 2 and 4 are made the— crank and slider respectively. (fig.a) Applications: — a Reciprocating engine b Reciprocating compressor.



b) **Second inversion** Fixing of the link 2 of a slider-crank chain results in the second inversion.
Applications: — a Whitworth quick-return mechanism b Rotary engine

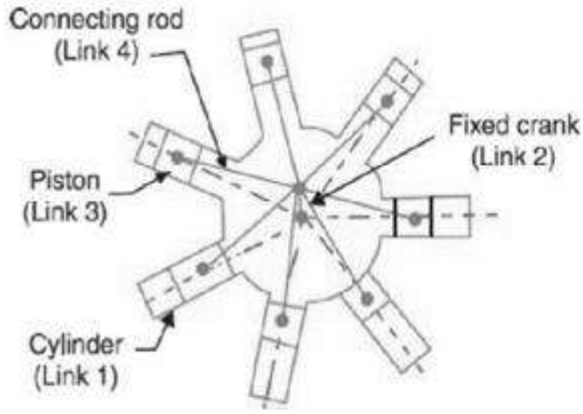
i) **Whitworth Quick-Return Mechanism:** This mechanism used in shaping and slotting machines. — In this mechanism the link CD (link 2) forming the turning pair is fixed; the driving— crank CA (link 3) rotates at a uniform angular speed and the slider (link 4) attached to the crank pin at a slides along the slotted bar PA (link 1) which oscillates at D. The connecting rod PR carries the ram at R to which a cutting tool is fixed and the— motion of the tool is constrained along the line RD produced.



$$\frac{time\ of\ return}{time\ of\ cutting} = \frac{\beta}{\alpha} = \frac{\beta}{360° - \beta} = \frac{360° - \alpha}{\alpha}$$

ii) Rotary engine Sometimes back, rotary internal combustion engines were used in aviation. But now a days gas turbines are used in its place. — It consists of seven cylinders in one plane and all revolves about fixed center D, as shown in Fig., while the crank (link 2) is fixed. In this mechanism, when the connecting rod (link

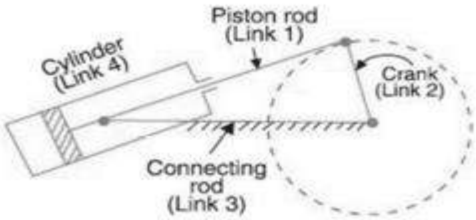
4) rotates, the piston (link 3) reciprocates inside the cylinders forming link 1



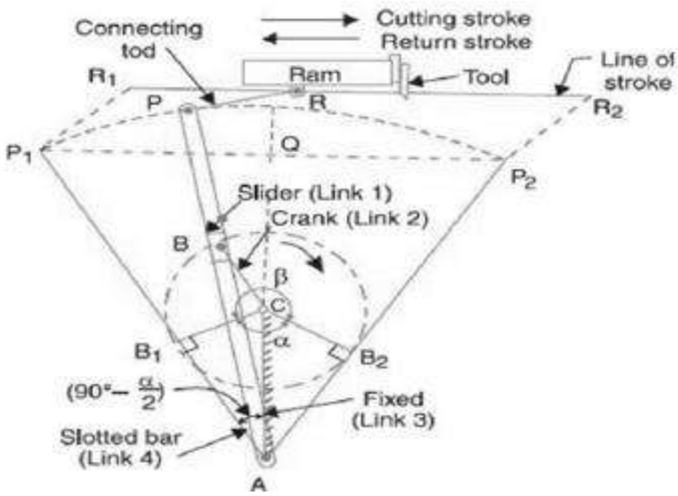
c) **Third Inversion** By Fixing of the link 3 of the slider-crank mechanism, the third inversion is— obtained. Now the link 2 again acts as a crank and the link 4 oscillates.

Applications: — a Oscillating cylinder engine b Crank and slotted-lever mechanism

i) **Oscillating cylinder engine:** The arrangement of oscillating cylinder engine mechanism, as shown in Fig. Is used— to convert reciprocating motion into rotary motion. In this mechanism, the link 3 forming the turning pair is fixed. The link 3 corresponds to the connecting rod of a reciprocating steam engine mechanism. When the crank (link 2) rotates, the piston attached to piston rod (link 1) reciprocates and the cylinder (link 4) oscillates about a pin pivoted to the fixed link at A.



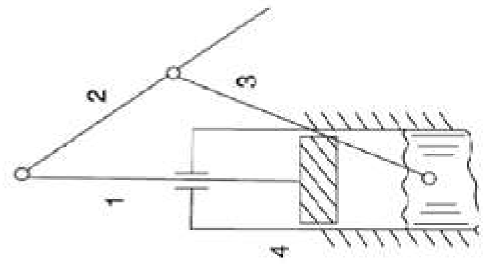
ii) **Crank and slotted-lever Mechanism** This mechanism is mostly used in shaping machines, slotting machines and in rotary— internal combustion engines. In this mechanism, the link AC (i.e. link 3) forming the turning pair is fixed, as shown— in Fig. The link 3 corresponds to the connecting rod of a reciprocating steam engine. The driving crank CB revolves with uniform angular speed about the fixed center C. A sliding block attached to the crank pin at B slides along the slotted bar AP and thus causes AP to oscillate about the pivoted point A. A short link PR transmits the motion from AP to the ram which carries the tool and— reciprocates along the line of stroke RIR2. The line of stroke of the ram (i.e. RIR2) is perpendicular to AC produced.



In the extreme positions, API and AP2 are tangential to the circle and the cutting tool is at the end of the stroke. The forward or cutting stroke occurs when the crank rotates from the position CB 1 to CB2 (or through an angle ß) in the clockwise direction. The return stroke occurs when the crank rotates from the position CB2 to CBI (or through angle u) in the clockwise direction. Since the crank has uniform angular speed therefore

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

d) Fourth Inversion If the link 4 of the slider-crank mechanism is fixed, the fourth inversion is obtained.— Link 3 can oscillates about the fixed pivot B on the link 4. This makes the end A of the link 2 to oscillate about B and the end O to reciprocate along the axis of the fixed link 4.



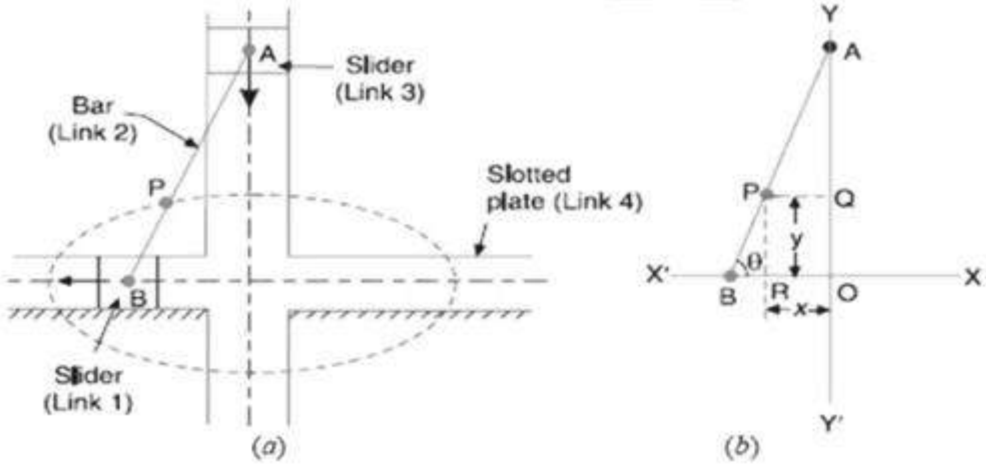
EXPERIMENT NO: 4

Experiment 4: To study inversions of Double Slider Mechanisms.
THEORY: INVERSIONS OF DOUBLE SLIDER-CRANK CHAIN

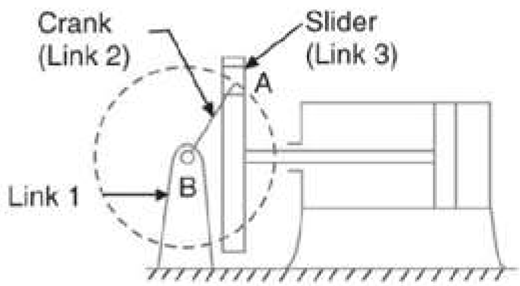
A kinematic chain which consists of two turning pairs and two sliding pairs is known as double slider chain. We see that the link2 and link 1 form one turning pair and link2, and link3 form the second turning pair. The link 3 and link4 form one sliding pair and link I and link 4 form the second sliding pair.

Inversions of Double Slider crank chain: The following three inversions of a double slider crank chain are important from the subject point of view:

1.Elliptical trammels. It is an instrument used for drawing ellipse. This inversion is obtained by fixing the slotted plate (link 4). The fixed plate or link 4 has two straight grooves cut in it, at right angles to each other. The link 1 and link 3, are known as sliders and form sliding pairs with link4. The link AB (link 2) is a bar, which forms turning pair with links 1 and 3. When the links land 3 slide along their respective grooves, any point on the link 2 such as P traces out an ellipse on the surfaces an ellipse on the surface of link4. A little consideration will show that AP and BP are the semi-major axis and semi-minor axis of the ellipse respectively.

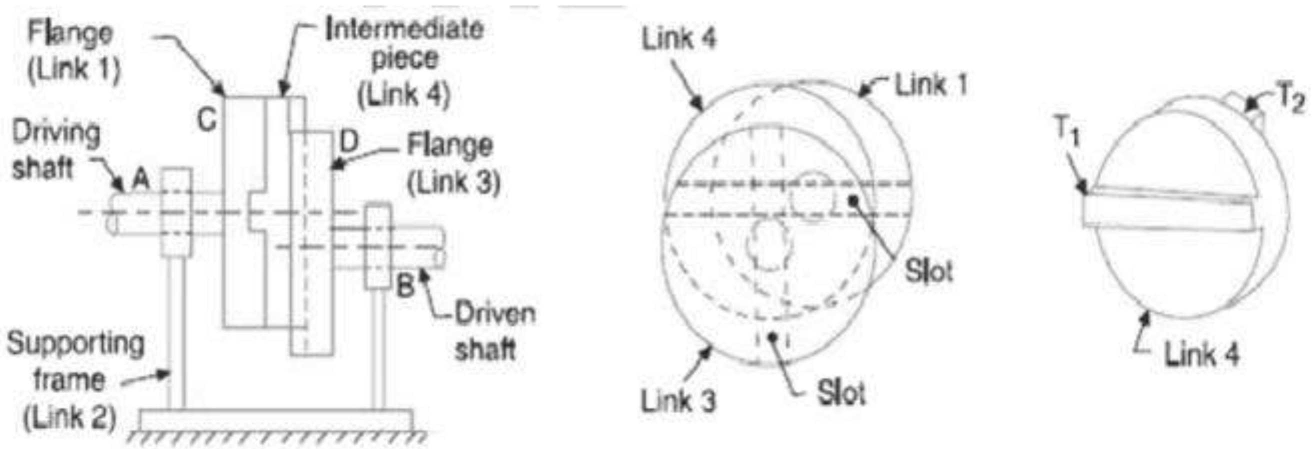


2.Scotch yoke mechanism. This mechanism is used for converting rotary motion into a reciprocating motion. The inversion is obtained by the fixing either the link 1 or link3. Link 1 is fixed. In this mechanism, when the link2 (which corresponds to crank) rotates about B as center, the link 4 (which corresponds to a frame) reciprocates. The fixed link 1 guides the frame.



Oldham's coupling. An Oldham's coupling is used for connecting two parallel shafts whose axes at a small distance apart. The shafts are coupled in such a way that if one shaft rotates, the other shaft also rotates at the same speed. The inversion is obtained by the fixing the link 2. The shafts to be connected have two flanges (link 1 and link 3) rigidly fastened at their ends by forging. The link 1 and link3 form turning pairs with link 2. These flanges have diametrical slots cut in their inner faces. The intermediate piece (link4), which is a circular disc, has two tongues (i.e. diametrical projections) Tl and T2 on each face at right angles to each other. The tongues on the link 4 closely fit into the slots in the two flanges (link 1 and link3). The link 4 can slide or reciprocate in the slots in the flanges. When the driving shaft A is rotated, the flange C (link l) causes the intermediate piece (link4) to rotate at the same angle through which the flange has rotated, and it further rotates the flange D (link3) at the same angle and thus the shafts B rotates. Hence link 1,3 and 4 have the same angular velocity at every instant. A little consideration will show, that there is a sliding motion between the link4 and each of the other link I and

3. If the distance between the axes of the shafts is constant, the center of intermediate piece will describe a circle of radius equal to the distance between the axes of the two shafts. Therefore, the maximum sliding speed of each tongue along its slot is equal to the peripheral velocity of the center of the disc along its circular path. Let o = Angular velocity of each shaft in rad/s, and r = Distance between the axes of the shafts in metres. Maximum sliding speed of each tongue (in m/s), V= ω r.



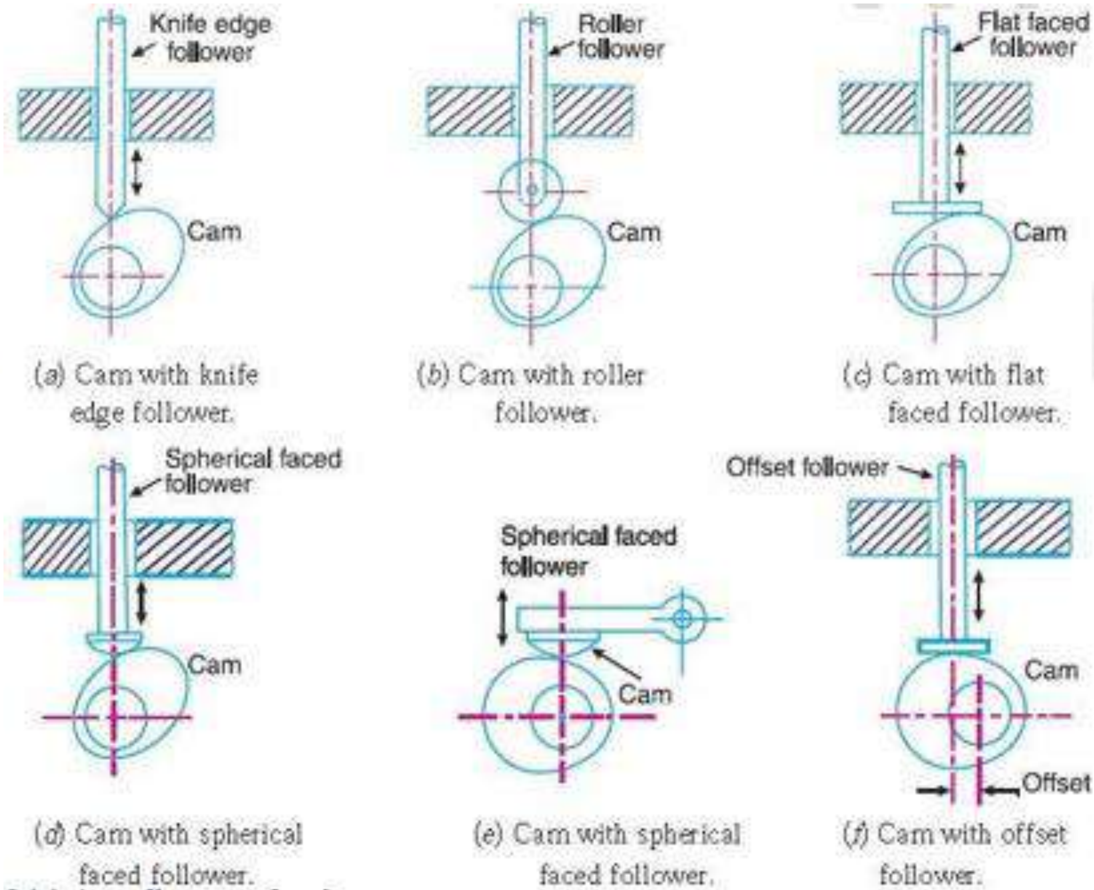
EXPERIMENT NO: 5

Experiment 5: To study various type of cam and follower arrangements.

THEORY:

A cam is a rotating machine element which gives reciprocating or oscillating motion to another element known as follower. The cam and the follower have a line contact and constitute a higher pair. The cams are usually rotated at uniform speed by a shaft, but the follower motion is pre-determined and will be according to the shape of the cam. The cam and follower is one of the simplest as well as one of the most important mechanisms found in modern machinery today. The cams are widely used for operating the inlet and exhaust valves of internal combustion engines, automatic attachment of machineries, paper cutting machines, spinning and weaving textile machineries, feed mechanism of automatic lathes etc

CLASSIFICATION OF FOLLOWERS: The followers may be classified as discussed below in fig.:



(a) Cam with knife edge follower. (b) Cam with roller follower. (c) Cam with flat faced follower. (d) Cam with spherical faced follower. (e) Cam with spherical faced follower. (f) Cam with offset follower.

ACCORDING TO SURFACE INCONTACT:

a) Knife edge follower

- When the contacting end of the follower has a sharp knife edge, it is called a knife edge follower, as shown in Fig. (a).

  The sliding motion takes place between the contacting surfaces (i.e. the knife edge and the cam surface). It is seldom used in practice because the small area of contacting surface results in excessive wear. In knife edge followers, a considerable side thrust exists between the follower and the guide.

b) Roller follower

- When the contacting end of the follower is a roller, it is called a roller follower, as shown in Fig. (b). since the rolling motion takes place between the contacting surfaces (i.e. the roller and the cam), therefore the rate of wear is greatly reduced.

- In roller followers also the side thrust exists between the follower and the guide. The roller followers are extensively used where more space is available such as in stationary gas and oil engines and aircraft engines.

c) Flat faced or mushroom follower
   - When the contacting end of the follower is a perfectly flat face, it is called a flat-faced follower, as shown in Fig. (c). It may be noted that the side thrust between the follower and the guide is much reduced in case of flat faced followers.
   - The only side thrust is due to friction between the contact surfaces of the follower and the cam. The relative motion between these surfaces is largely of sliding nature but wear may be reduced by off-setting the axis of the follower, as shown in Fig. (f) so that when the cam rotates, the follower also rotates about its own axis.
   - The flat faced followers are generally used where space is limited such as in cams which operate the valves of automobile engines.

d) Spherical faced follower
   - When the contacting end of the follower is of spherical shape, it is called a spherical faced follower, as shown in Fig. (d). It may be noted that when a flat-faced follower is used in automobile engines, high surface stresses are produced. In order to minimize these stresses, the flat end of the follower is machined to a spherical shape.

ACCORDING TO THE MOTION OF FOLLOWER:

e) Reciprocating or Translating Follower
   - When the follower reciprocates in guides as the cam rotates uniformly, it is known as reciprocating or translating follower. The followers as shown in Fig. (a) to (d) are all reciprocating or translating followers.

f) Oscillating or Rotating Follower
   - When the uniform rotary motion of the cam is converted into predetermined oscillatory motion of the follower, it is called oscillating or rotating follower. The follower, as shown in Fig (e), is an oscillating or rotating follower.

ACCORDING TO THE PATH OF MOTION OF THE FOLLOWER:

g) Radial Follower: When the motion of the follower is along an axis passing through the centre of the cam, it is known as radial follower. The followers, as shown in Fig. (a) to (e), are all radial followers.

h) Off-set Follower: When the motion of the follower is along an axis away from the axis of the cam centre, it is called off-set follower. The follower, as shown in Fig. (f), is an off-set follower.

CLASSIFICATION OF CAMS

a) Radial or Disc cam: In radial cams, the follower reciprocates or oscillates in a direction perpendicular to the cam axis. The cams as shown in Fig. are all radial cams.

b) Cylindrical cam: In cylindrical cams, the follower reciprocates or oscillates in a direction parallel to the cam axis. The follower rides in a groove at its cylindrical surface. A cylindrical grooved cam with a reciprocating and an oscillating follower is shown in Fig. (a) and (b) respectively.

(a) Cylindrical cam with reciprocating follower.

(b) Cylindrical cam with oscillating follower.

Fig. 5.2 cylindrical cam

TERMINOLOGY USED IN RADIAL CAMS

- **Base circle:** It is the smallest circle that can be drawn to the cam profile.
- **Trace point:** It is a reference point on the follower and is used to generate the pitch curve. In case of knife edge follower, the knife edge represents the trace point and the pitch curve corresponds to the cam profile. In a roller follower, the centre of the roller represents the trace point.
- **Pressure angle:** It is the angle between the direction of the follower motion and a normal to the pitch curve. This angle is very important in designing a cam profile. If the pressure angle is too large, a reciprocating follower will jam in its bearings.
- **Pitch point:** It is a point on the pitch curve having the maximum pressure angle.
- **Pitch circle:** It is a circle drawn from the centre of the cam through the pitch points.
- **Pitch curve:** It is the curve generated by the trace point as the follower moves relative to the cam. For a knife edge follower, the pitch curve and the cam profile are same whereas for a roller follower, they are separated by the radius of the roller.
- **Prime circle:** It is the smallest circle that can be drawn from the centre of the cam and tangent to the pitch curve. For a knife edge and a flat face follower, the prime circle and the base circle are identical. For a roller follower, the prime circle is larger than the base circle by the radius of the roller.
- **Lift or Stroke:** It is the maximum travel of the follower from its lowest position to the topmost position

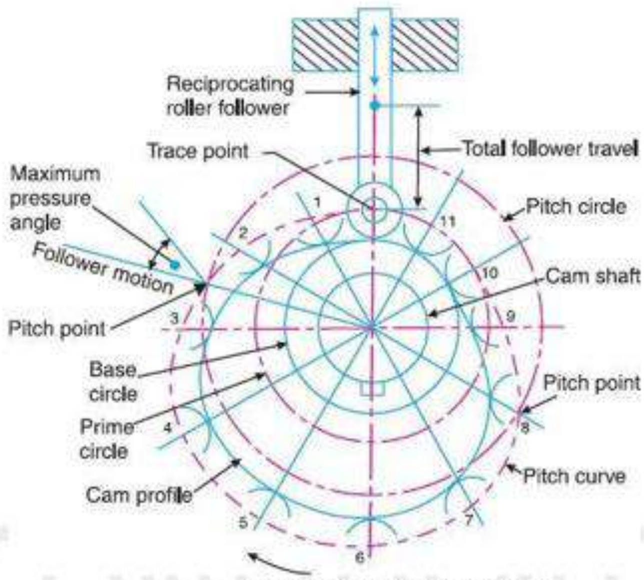


Fig. 5.3 terms used in radial cams

EXPERIMENT NO: 6

Experiment 6: To plot follower displacement vs cam rotation for various Cam Follower systems.

THEORY:

- Compression Springs

One spring is provided. The (approx.) stiffness is 4 Kg/cm

- Weights

The set of weights 200gms of 3 Nos and 100gms of 4 Nos are provided. All the wts have a central hole so that they can be accommodated in the push rod (Total weights provided should add up to 1000gms).

- **Weights of the Reciprocating Parts**

1. Push rod with lock nuts.
2. Rest plates and two lock nuts.
3. Spring seat and lock nut.

ASSEMBLY:

The unit is provided with the push rod in the two bush bearings. The same push rod is to be used for the flat face and roller follower. The unit is dissembled, for any reason while assembling following precautions should be taken.

1) The horizontality of the upper and lower glands should be checked by a spirit level.
2) The supporting pillars should be properly tightened with the lock nuts provided.

PROCEDURE:

1. Selected a suitable cam and follower combination.
2. Fix the cam on the driving shaft by seeing the rotation of the motor.
3. Fix the follower on push rod and properly tighten the check nut, such that knife-edge of follower (or axis of roller in case of roller follower) is parallel to axis of camshaft.
4. Check the upper dial to show zero without any error.
5. Rotate the cam at different angle by using handle and note down the approximate dial gauge reading.
6. Give required initial compression to the spring. In order that initial compression is not lost during operation, the check nut is to be tightened against spring seat.
7. See that the knob of dimmer stat is at zero position
8. Plot the cam profile by using dial gauge reading and angle of cam rotation.
9. Repeat the experiment by plotting different cam with different follower.
10. Finally plot graph of follower weight and jump speed

EXPERIMENTS:

Following experiments can be conducted using this machine:

1. To Plot X-O (follower displacement Vs. Angle of cam rotation) curve for different cam follower pairs. The X-O plot can be used to find out the velocity and acceleration of the follower system.

For this experiment rotate the system manually for taking reading, arrange the set up. The exact profile of the cam can be obtained by taking observations.

X Vs. O. where X – displacement of the follower from reference initial position which is readied by dial gauge and O = angle of cam rotation with reference from axis of symmetry chosen. By differentiating the X-O curve once or twice, the velocity and acceleration curves can be plotted for the follower and cam under study. Finally switch on the motor and visual observation of behaviour can be seen.

2. Speed:-To observe the phenomenon of jump by naked eye. When jump occurs the follower pounds on the cam surface giving a good thumping sound.

Upward inertia force = Downward retaining force

W/g w2r = W + s

This is the equilibrium of force equation when the jump will just start.

W = follower weight (Assembly)

S = spring force

ω = angular velocity of cam.

r = distance according to the geometry of cam.

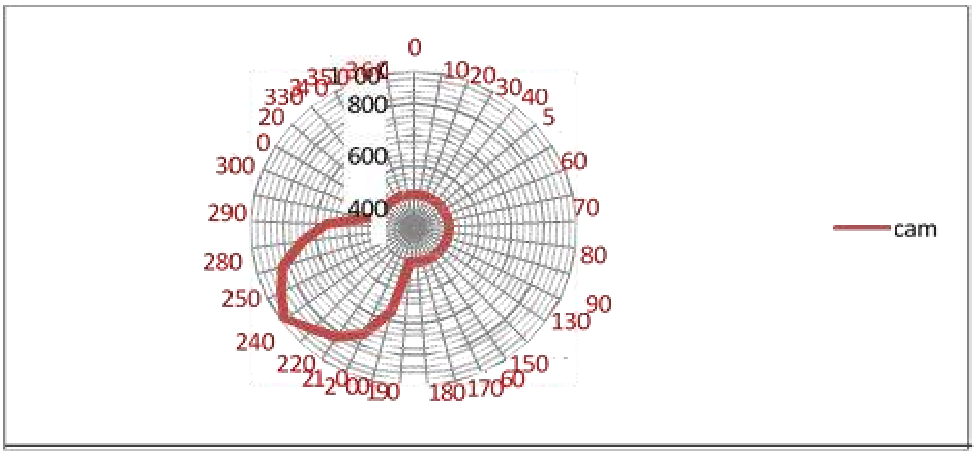
3. To study the effect of follower assembly weight on the jump speed when the spring force is kept constant. To study this effect keep the initial spring compression at a certain level and observe jump speed for different follower weights by adding them successively and plot the graph of follower weights Vs. Jump speed.

   $w = (W + s)g/w\ r$
4. This relation shows that as the follower weight increases the jump speed goes on decreases
5. To study the effect of spring compression the jump speed with constant follower weight. To study this keep the follower assembly weight the same and go on observing the jump speed for various sets of initial spring compression and plot the graph of spring force Vs Jump speed.

Tabular column

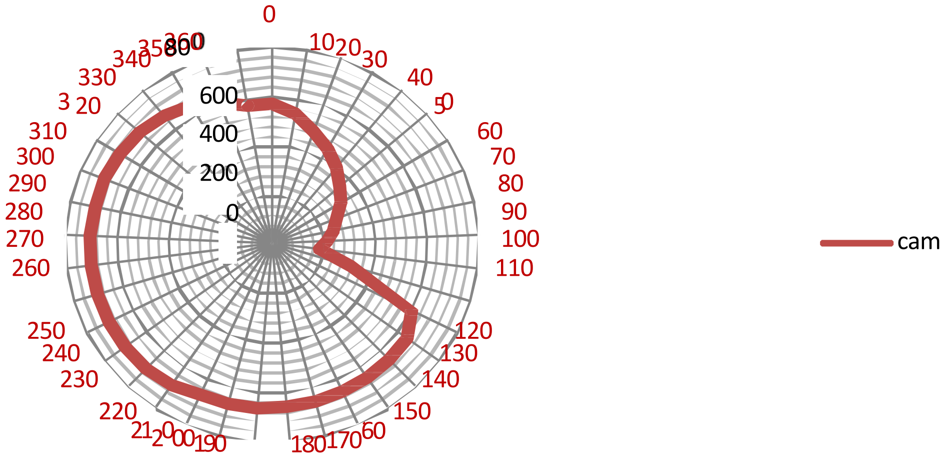
For Elliptical Cam with mushroom follower

Angle in degrees	Dial gauge reading s (div)	Angle in deg rees	Dial gaug e readi ngs (div)
0		190	
10		200	
20		210	
30		220	
40		230	
50		240	
60		250	
70		260	
80		270	
90		280	
100		290	
110		300	
120		310	
130		320	
140		330	
150		340	
160		350	
170		360	



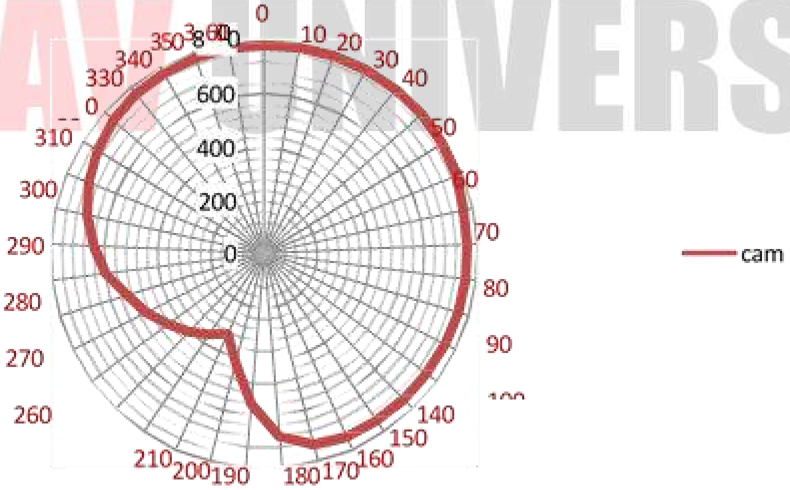
Snail Cam With Roller Follower:

Angle in degrees	Dial gauge reading s (div)	Angle in deg rees	Dial gaug e readings (div)
0		180	
10		190	
20		200	
30		210	
40		220	
50		230	
60		240	
70		250	
80		260	
90		270	
100		280	
110		290	
120		300	
130		310	
140		320	
150		330	
160		340	
170		350	
		360	



Snail Cam With Mushroom Follower

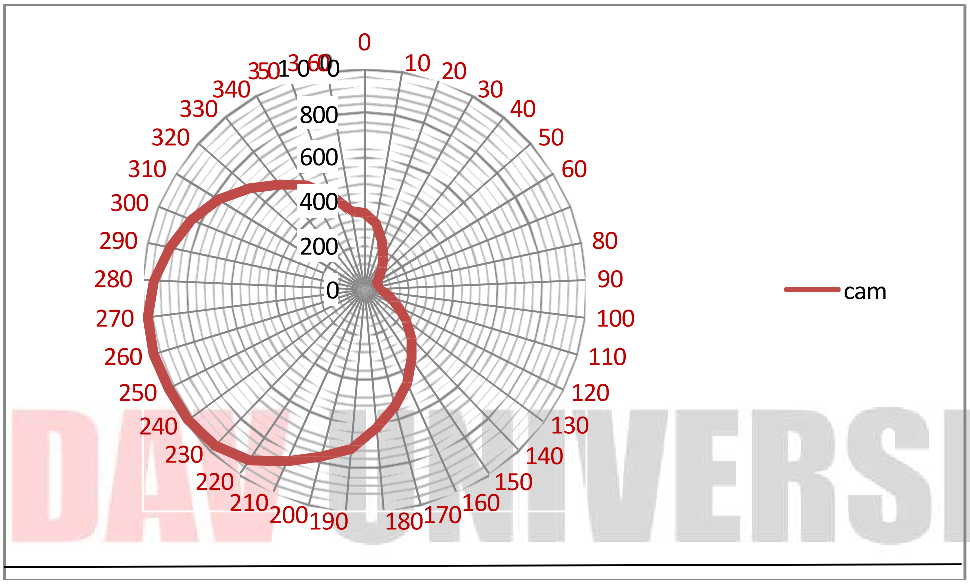
Angle in degrees	Dial gauge reading s (div)	Angle in deg rees	Dial gaug e readings(div)
0		180	
10		190	
20		200	
30		210	
40		220	
50		230	
60		240	
70		250	
80		260	
90		270	
100		280	
110		290	
120		300	
130		310	
140		320	
150		330	
160		340	
170		350	
180		360	



Eccentric Cam with Mushroom follower

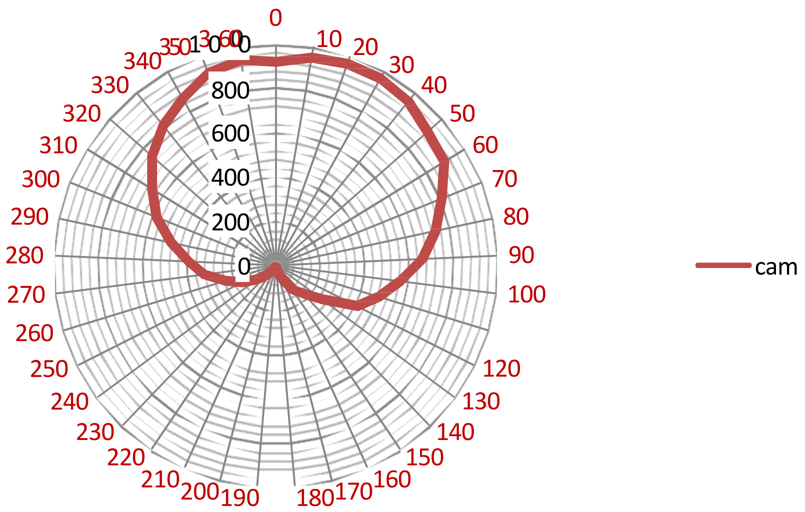
Angle in degrees	Dial gauge readin gs (div)	Angle in degrees	Dial gaug e readings (div)
0		180	
10		190	
20		200	
30		210	
40		220	
50		230	
60		240	
70		250	
80		260	

90		270	
100		280	
110		290	
120		300	
130		310	
140		320	
150		330	
160		340	
170		350	
180		360	



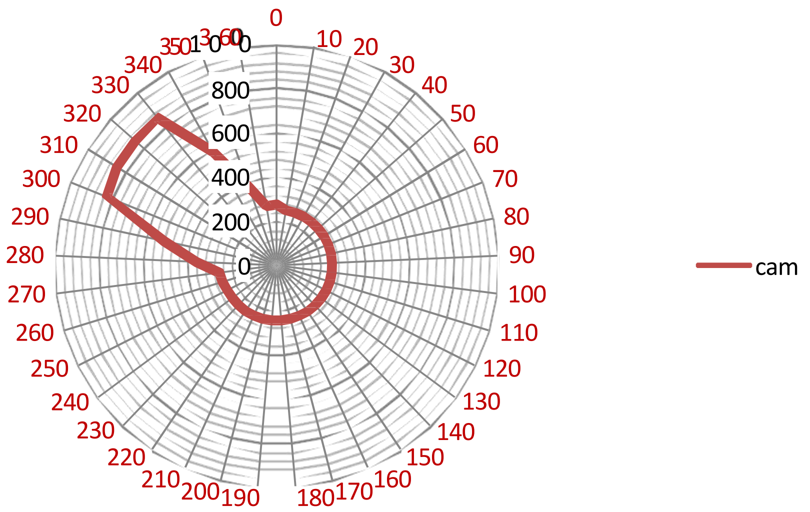
Eccentric cam With Roller follower

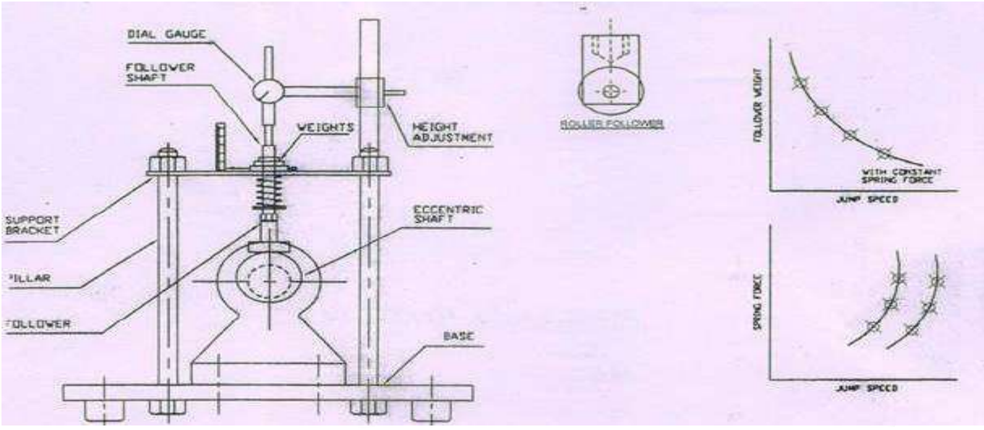
Angle in degrees	Dial gauge readin gs (div)	Angle in deg rees	Dial gaug e readings (div)
0		190	
10		200	
20		210	
30		220	
40		230	
50		240	
60		250	
70		260	
80		270	
90		280	
100		290	
110		300	
120		310	
130		320	
140		330	
150		340	
160		350	
170		360	
180			



Elliptical cam with Roller follower

Angle in degrees	Dial gauge reading s (div)	Angle in deg rees	Dial gaug e readings (div)
0		190	
10		200	
20		210	
30		220	
40		230	
50		240	
60		250	
70		260	
80		270	
90		280	
100		290	
110		300	
120		310	
130		320	
140		330	
150		340	
160		350	
170		360	





Do's

1. Check the type of cam & follower
2. Set the protector at 00
3. Fit the dial gauge at the top of the follower.
4. Rotted the coupling slowly and note down the dial gauge reading. And rotation will be 00to 3600
5. Plot the N-θ curve.
6. To attach the dimmer state to running the cam motor.
7. observe the jump speed of the follower.
8. Run the cam motor with constant speed by dimmer state to regulate the damping sound.

Don'ts

9. Do not handle the machine without proper precaution.
10. Do not run the cam motor with high speed.

Precautions:

While assembling following precautions should be taken.

a. The horizontally of the upper and lower glans should be checked by a spirit level.
b. The supporting pillars should be properly tightened with the lock nuts provided.
c. Lubrication It is imperative, that to minimize the sliding forces at the bearing surfaces, lubrication is a must. Before starting, continuous supply of oil should be provided. The cam is to be lubricated by oil before starting.

VIVA QUESTIONS:

1. Types of Cams
2. Types Of Follower.

RESULT:

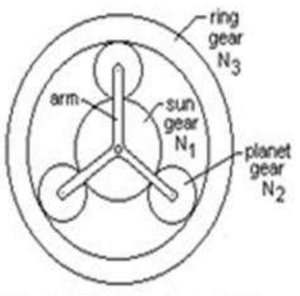
1. The exact cam profile of the cam can be obtained by taking observation θ (cam.rotation)(followerdisplacement)

EXPERIMENT NO: 7

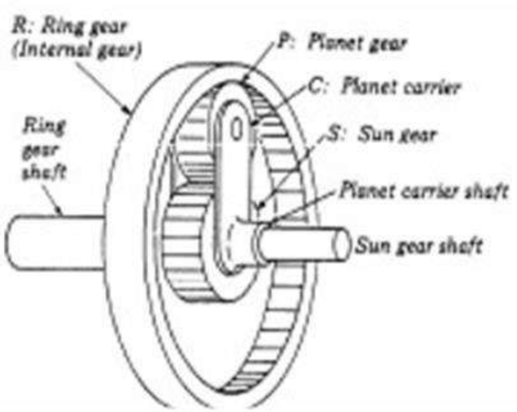
Experiment 7: To measure Epicyclic gear ratio, input torque, holding torque and output torque.

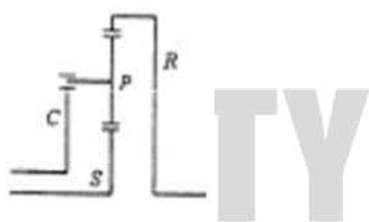
INTRODUCTION: Any combination of gear wheels by means of which motion is transmitted from one shaft to another shaft is called a gear train. In case of epicyclic gear train, the axis of the shaft on which the gears are mounted may move relatively to a fixed axis. The gear trains are useful for transmitting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

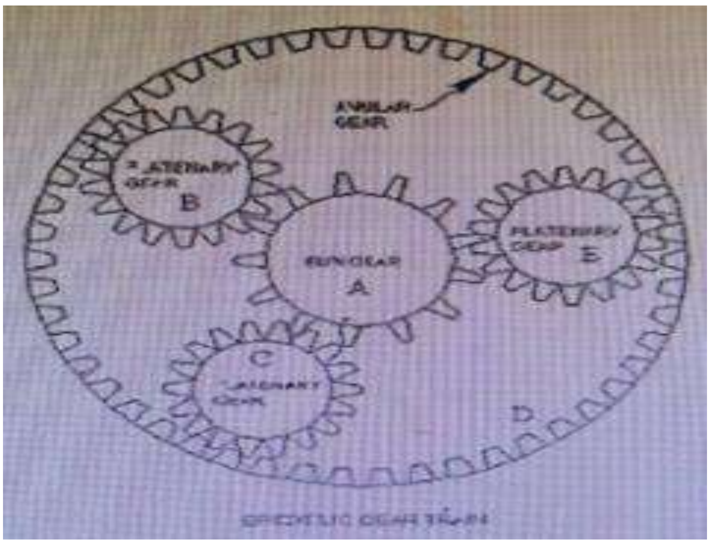
THEORY: EPICYCLIC GEARTRAIN: A simple gear train (shown in fig.) is a train in which a gear A and the arm C have a common axis at 01 about which they can rotate. The gear B meshes with gear A and has its axis on the arm at 02, about which the gear B can rotate. If the arm is fixed, the gear train is 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. 01), 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 train. The epicyclic gear train may be simple or compound.



Sun-and-Planet Epicyclic Train







GEAR RATIO OF EPICYCLIC GEAR-TRAIN: The ratio of the speed of driver wheel to the speed of the driven wheel is called the speed ratio or velocity ratio.

Gear Ratio= Speed of Driver /Speed of Driven

A compound epicyclic gear train (internal type) consists of two co-axial shafts. One sun gear (A), three planetary gears (B, C, and E) and an annular gear (D) arrange internally as shown in Fig. 1. Wheel A has 13 external teeth. B, C and E have 18external teeth. The annular gear has 50 internal teeth. The sun gear A is fixed on the input shaft. Three planetary or compound gears B. C. E are mesh with sun gear A and annular gear D.

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. These are: -

T_i the input torque on the driving member, Arm.

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

T_h the holding, or braking torque on the fixed member.

If there is no acceleration,

$$T_i+T_o+T_h=0 \quad \text{or} \quad To=-(T_i+T_h)$$

DESCRIPTION: The set up consists of an epicyclic gear train (internal type) in which sun gear is mounted on input shaft. Three planet gears are mounted on the arm that rotate freely on the fixed pins and mesh with the sun gear and internal teethes of the annular gear. ADC motor is provided for the variable RPM of input shaft controlled by dimmer stat. Digital voltmeter & ammeter is provided to measure input power and hence input torque. To measure the holding torque and output torque, rope break dynamometer with spring balances is provided. Digital RPM indicator with selector switch is provided to measure the speed of input and output shafts.

EXPERIMENTALPROCEDURE:

Starting Procedure:

1. Ensure that ON/OFF switch provided on the panel is at OFF position.
2. Set the dimmer stat to zero.
3. Switch ON the mains power shoply and switch ON the motor.
4. Set the speed of input shaft by dimmer stat.
5. Apply load on holding brake drum by spring balances just to stop its rotation.
6. Note the reading of voltmeter and ampere meter.
7. Note the readings of spring balances of the holding drum & output drum.
8. Note the RPM of the input and output shaft from RPM indicator and selector switch.
9. Apply load on output brake drum by spring balances just to stop its rotation.
10. Repeat steps 5-9 for different load on holding brake drum.
11. Repeat steps 4-10 for different speed of input shalt

Closing Procedure:

1. Reduce the load on holding and output brake drum to zero.
2. Reduce the speed of input shaft by dimmer stat to zero.
3. Switch OFF the motor and mains ON/OFF switch.

NOMENCLATURE:

η = Efficiency of motor

D_{BH} = Diameter of the holding brake drum, m.

D_{BO} =Diameter of the output brake drum, m.

D_{RH} =Diameter of rope of holding brake drum, m.

D_{RO} =Diameter of rope of output brake drum, m.

G_R =Gear ratio.

I = Ampere meter reading, amp.

N_1=Speed of driver shaft, RPM.

N_2=Speed of driven shaft, RPM.

R_{EH} =Mean effective radius oof holding brake drum, m.

R_{EO} =Mean effective radius of output brake drum, m.

T_I=Input torque, N-m.

T_o=output torque, N-m.

T_H =holding torque, N-m.
V=Voltmeter reading, volts.
W_1, W_2=Spring balances reading of holding brake drum, kg
W_3 W_4 = Spring balances reading of output brake drum, kg

OBSERVATION & CALCULATION:

DATA:

D_{BH} = 0.2 m (Diameter of the holding brake drum, m)
D_{BO}=0.2 m (Diameter of the output brake drum, m
D_{RH} =0.012m (Diameter of rope of holding brake drum, m)
D_{RO} =0.012m (Diameter of rope of cutput brake drum, m)
η= 0.8 (Efficiency of motor)

CALCULATIONS:

$$G_R = \frac{N_1}{N_2} = \text{[illegible]}$$

$$T_1 = \frac{V \times I \times \eta \times 60}{2 \times \pi \times N_1}, \text{ N-m} = \text{[illegible] N-m}$$

$$R_{EH} = \frac{D_{BH} + (2 \times D_{RH})}{2}, m = \text{[illegible] m}$$

$$T_H = (W_2 - W_1) \times g \times R_{EH}, N-m = \text{------------ N-m}$$

Epicyclic Gear Grain Apparatus

$$R_{EO} = \frac{D_{BO} + (2 \times D_{RO})}{2}, m = \text{------------ m}$$

$$T_0 = (W_4 - W_3) \times g \times R_{EO}, N-m = \text{------------ N-m}$$

CALCULATION TABLES

S NO	N_1	N_2	G_R	T_1, N-m	T_H, N-m	T_o, N-m	(T_1+T_H),N-m

OVSERVASTION TABLE:

S NO	V, Volt	I amp	N_1	N_2	W_1, Kg	W_2, Kg	W_3, Kg	W_4, Kg

PRECAUTIONS & MAINTENANCE INSTRUCTIONS:

1. Never run the apparatus if power supply is less than 180 and above 230volts.
2. Before starting the experiment ensures that there is no load on the holding and output brake drum.

3. Before starting the motor with rotary switch ensure that dimmer stat is at zero position.
4. Increase speed gradually.

PRECAUTIONS:

1. Take reading carefully.
2. Measure the angle very carefully
3. Measure the height of governor carefully

4 Speed of governor measure accurate

EXPERIMENT NO: 8

Experiment 8: To perform experiment on Watt Governors to prepare performance characteristic Curves, and to find stability & sensitivity.

THEORY:

Governors are used for maintaining the speeds of engines with in prescribed limits from no load to full load. In petrol engines, the governor controls the throttle of carburettor and in diesel engines they control the fuel pump. Most of the governors are of centrifugal type. These governors use flyweights. Depending upon the speed, the position of weights change. Which is transmitted to a sleeve through links. Ultimately the sleeve operates throttle or fuel pump. The dynamic apparatus consists of a spindle mounted in a vertical position. Four types of governors can be mounted over the spindle, namely watt, porter, proell and hartnell. A sleeve attached to governor links is lifted by outward movement of balls due to centrifugal force. Lift of sleeve is measured over a scale.

PROCEDURE:

Mount the required governor assembly over the spindle.

1. Tighten the necessary bolts.
2. Start the motor and gradually increase the speed.
3. The flyweight will fly outward due to which the sleeve will rise.
4. Note down the speed and sleeve rise or calculate by theoretical method.
5. Repeat the experiment at different speeds till the balls fly to maximum position.
6. Bring back the sleeve down by reducing the speed gradually and stop.

Specifications

Watt &Porter Governor
Weight of 3 Balls=2.580 Kg
Initial height ho=220mm
Length of the link L=150mm

Proell Governor:
Length of the link L=150mm
Initial height ho=220mm

Hartnell Governor
Initial height ho=220mm
Length of the link L=100mm

Table:

S.No	Sleeve lift in cm	Rpm N	Radius of rotation	Centrifugal force F

a = raise of sleeve in cm

h_o = initial height

w = weight of balls

L = length of the link

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

N=Speed in rpm

Height of balls where link centre lines intersect h = m

$$h = \frac{h_0 + X}{2}$$

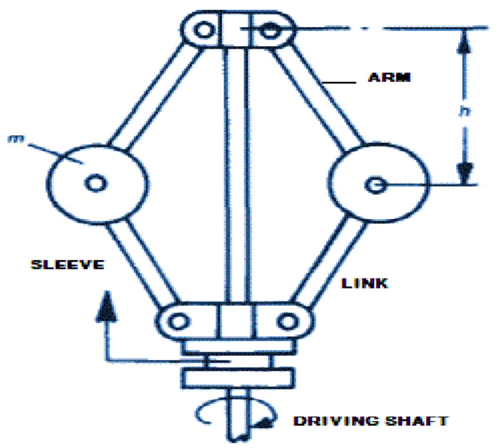
Initial radius of rotation = r_1

$$r_1 = \sqrt{L^2 - h^2}$$

$$r = r_1 + 0.16$$

Centrifugal force $F = (w/g)\ \omega 2\ r \rightarrow \text{kg f}$

Watt Governor (Without weight)



WATT GOVERNOR

SL. NO.	LIFT "X" IN m	SPEED IN RPM	h IN m	r1 IN m	r IN m	ω IN rad/sec	CENTRIFUGAL FORCE IN Kgf
1							
2							
3							
4							
5							

Guidance calculation:

1. Height of balls where link centre lines intersect h = m
2. Initial radius of rotation = r_1
3.
4. Angular speed
5. Centrifugal force

Precautions:

- DO NOT KEEP THE MAINS ON when trial is complete
- Increase the speed gradually.
- Take the sleeve displacement reading when the pointer remain steady.
- See that at higher speed the load on sleeve does not hit the upper sleeve of the governor.
- while closing the test bring the dimmer to zero position and then switch OFF

VIVA –QUESTIONS:

1. What is the function of a governor?
2. How does it differ from that of a flywheel?
3. State the different types of governors.
4. What is the difference between centrifugal and inertia type governors?
5. Explain the term height of the governor.
6. What are the limitations of a Watt governor?
7. What is the stability of a governor?
8. Define the Sensitiveness of governor.
9. Which of the governor is used to drive a gramophone?
10. The power of a governor is equal to RESULT:

EXPERIMENT NO: 9

Experiment :9 To perform experiment on Proell Governor to prepare performance characteristic curves, and to find stability & sensitivity.

THEORY:

Governors are used for maintaining the speeds of engines with in prescribed limits from no load to full load. In petrol engines, the governor controls the throttle of carburettor and in diesel engines they control the fuel pump. Most of the governors are of centrifugal type. These governors use flyweights. Depending upon the speed, the position of weights change. Which is transmitted to a sleeve through links. Ultimately the sleeve operates throttle or fuel pump. The dynamic apparatus consists of a spindle mounted in a vertical position. Four types of governors can be mounted over the spindle, namely watt, porter, proell and hartnell. A sleeve attached to governor links is lifted by outward movement of balls due to centrifugal force. Lift of sleeve is measured over a scale.

PROCEDURE:

Mount the required governor assembly over the spindle.

1. Tighten the necessary bolts.
2. Start the motor and gradually increase the speed.
3. The flyweight will fly outward due to which the sleeve will rise.
4. Note down the speed and sleeve rise or calculate by theoretical method.
5. Repeat the experiment at different speeds till the balls fly to maximum position.
6. Bring back the sleeve down by reducing the speed gradually and stop.

Specifications

Watt &Porter Governor
Weight of 3 Balls=2.580 Kg
Initial height ho=220mm
Length of the link L=150mm

Proell Governor:
Length of the link L=150mm Initial
height ho=220mm

Hartnell Governor
Initial height ho=220mm
Length of the link L=100mm

Table:

S.No	Sleeve lift in cm	Rpm N	Radius of rotation	Centrifugal force F

a = raise of sleeve in cm

h_o = initial height

w = weight of balls

L = length of the link

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

N=Speed in rpm

Height of balls where link centre lines intersect h = m

$$h = \frac{h_0 + X}{2}$$

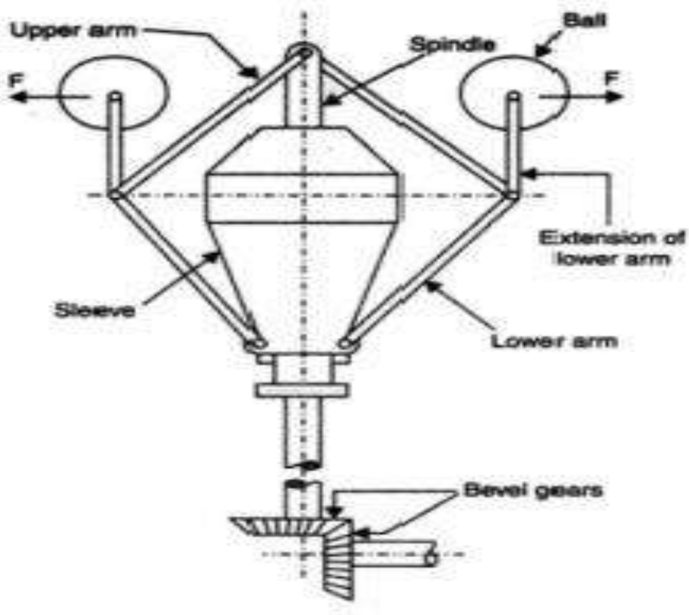
Initial radius of rotation = r_1

$$r_1 = \sqrt{L^2 - h^2}$$

$$r = r_1 + 0.16$$

Centrifugal force $F = (w/g)\ \omega 2\ r \rightarrow kg\ f$

<u>Proell governor</u>



Proell governor.

SL. NO.	LIFT "X" IN m	SPEED IN RPM	h IN m	r1 IN m	r IN m	ω IN rad/sec	CENTRIFUGAL FORCE IN Kgf
1							
2							
3							
4							
5							

1. Height of balls where link centre lines intersect h = m

$$h = \frac{h_0 + X}{2}$$

2. Initial radius of rotation = r_1

$$r_1 = \frac{h \times 0.06}{L}$$

3. $r = r_1 + 0.16$

4. Angular speed $\omega = \frac{2\pi N}{60}$

5. Centrifugal Force

$$F = \frac{W}{g} \times \omega^2 \times r$$

Precautions:

- DO NOT KEEP THE MAINS ON when trial is complete
- Increase the speed gradually.
- Take the sleeve displacement reading when the pointer remain steady.
- See that at higher speed the load on sleeve does not hit the upper sleeve of the governor.
- while closing the test bring the dimmer to zero position and then switch OFF

VIVA –QUESTIONS:

1. What is the function of a governor?
2. How does it differ from that of a flywheel?
3. State the different types of governors.
4. What is the difference between centrifugal and inertia type governors?
5. Explain the term height of the governor.
6. What are the limitations of a Watt governor?
7. What is the stability of a governor?
8. Define the Sensitiveness of governor.
9. Which of the governor is used to drive a gramophone?
10. The power of a governor is equal to

RESULT:

EXPERIMENT NO: 10

Experiment 10: To perform experiment on Hartnell Governor to prepare performance characteristic Curves, and to find stability & sensitivity.

THEORY:

Governors are used for maintaining the speeds of engines with in prescribed limits from no load to full load. In petrol engines, the governor controls the throttle of carburettor and in diesel engines they control the fuel pump. Most of the governors are of centrifugal type. These governors use flyweights. Depending upon the speed, the position of weights change. Which is transmitted to a sleeve through links. Ultimately the sleeve operates throttle or fuel pump. The dynamic apparatus consists of a spindle mounted in a vertical position. Four types of governors can be mounted over the spindle, namely watt, porter, proell and hartnell. A sleeve attached to governor links is lifted by outward movement of balls due to centrifugal force. Lift of sleeve is measured over a scale.

PROCEDURE:

Mount the required governor assembly over the spindle.

1. Tighten the necessary bolts.
2. Start the motor and gradually increase the speed.
3. The flyweight will fly outward due to which the sleeve will rise.
4. Note down the speed and sleeve rise or calculate by theoretical method.
5. Repeat the experiment at different speeds till the balls fly to maximum position.
6. Bring back the sleeve down by reducing the speed gradually and stop.
7.

<u>**Specifications**</u>

Watt &Porter Governor
Weight of 3 Balls=2.580 Kg
Initial height ho=220mm
Length of the link L=150mm

Proell Governor:
Length of the link L=150mm Initial
height ho=220mm

Hartnell Governor
Initial height ho=220mm
Length of the link L=100mm

Table:

S.No	Sleeve lift in cm	Rpm N	Radius of rotation	Centrifugal force F

a = raise of sleeve in cm

h_o = initial height

w = weight of balls

L = length of the link

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

N=Speed in rpm

Height of balls where link centre lines intersect h = m

$$h = \frac{h_0 + X}{2}$$

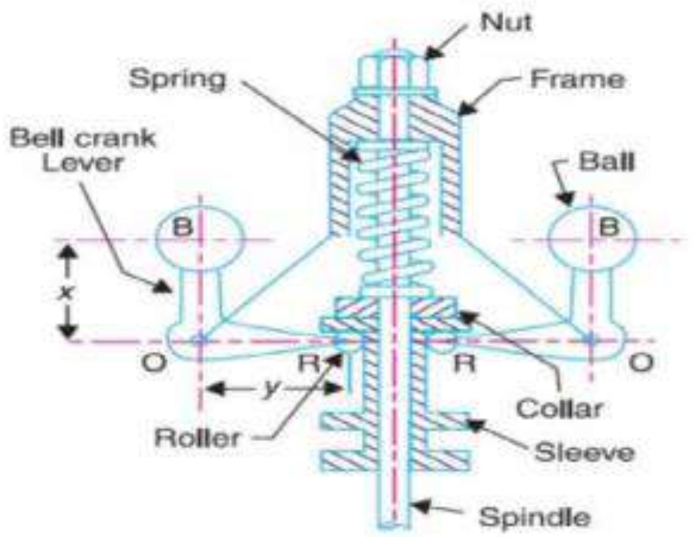
Initial radius of rotation = r_1

$$r_1 = \sqrt{L^2 - h^2}$$

$$r = r_1 + 0.16$$

Centrifugal force $F = (w/g)\ \omega 2\ r \rightarrow kg\ f$

Hartnell governor



SL. NO.	LIFT "X" IN m	SPEED IN RPM	h IN m	r1 IN m	r IN m	ω IN rad/sec	CENTRIFUGAL FORCE IN Kgf
1							
2							
3							
4							

1. Height of balls where link centre lines intersect h = m

$$h = \frac{h_0 + X}{2}$$

2. Initial radius of rotation = r_1

$$r_1 = \frac{h \times 0.06}{L}$$

3. $r = r_1 + 0.16$
4. Angular speed

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

5. Centrifugal Force

$$F = \frac{W}{g} \times \omega^2 \times r$$

Precautions:

1. DO NOT KEEP THE MAINS ON when trial is complete
2. Increase the speed gradually.
3. Take the sleeve displacement reading when the pointer remain steady.
4. See that at higher speed the load on sleeve does not hit the upper sleeve of the governor.
5. while closing the test bring the dimmer to zero position and then switch OFF

VIVA –QUESTIONS:

1. What is the function of a governor?
2. How does it differ from that of a flywheel?
3. State the different types of governors.
4. What is the difference between centrifugal and inertia type governors?
5. Explain the term height of the governor.
6. What are the limitations of a Watt governor?
7. What is the stability of a governor?
8. Define the Sensitiveness of governor.
9. Which of the governor is used to drive a gramophone?
10. The power of a governor is equal to

RESULT:

EXPERIMENT NO: 11

Experiment 11: To determine gyroscopic couple on Motorized Gyroscope.

Apparatus:

Gyroscope, Weight, Stopwatch.

Definitions

Gyroscope: A gyroscope is a spinning body mounted universally to turn with an angular velocity of precession in a direction at right angles to the direction of the moment causing it but its center of gravity will be in a fixed position

Precession

When a force is applied to the gyroscope about the horizontal axis, it may be found that the applied force meets with resistance and that the gyro, instead of turning about its horizontal axis, turns about its vertical axis and vice versa. It follows right hand thumb (screw) rule. Thus the change in direction of plane of rotation of the rotor is known as precession.

Gyroscopic Couple

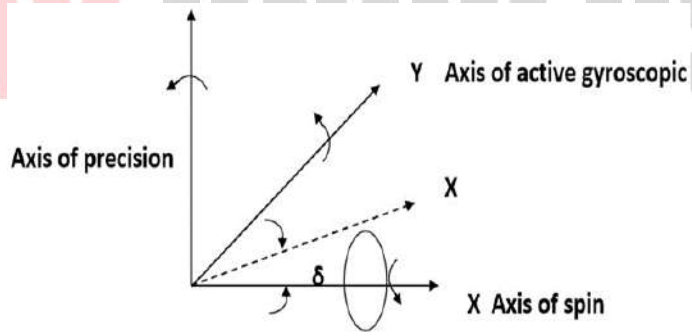
It is applied couple needed to change the angular momentum vector of rotating disc/Gyroscope when it processes. It acts in the plane of coupe which is perpendicular to both the other planes (plane of spin and plane of precession) it is given as:-

$$T = I \times \omega \times \omega p$$

Where, I= Moment of inertia of rotor.

ω= Angular velocity of rotor.

ωp= Angular velocity of precession



Theory

The gyroscope has three degrees of freedom. The first axis is OX called spin axis on which the body is spinning (revolving). The second axis is OY called Torque&OZ axis is called precession axis on which the body moves opposing the original motion. It may be observed that these entire three axis are mutually perpendicular such a combined effect is known as precession (or) Gyroscopic effect.

The analysis of the gyroscopic principles is based on Newton's laws of motion and inertia. When the torque is spinned, the gyroscope exhibits the following two important characteristics.

Gyroscopic inertia

Precession

Gyroscopic Inertia:

It requires a high degree of rigidity and its axle keeps pointing in the same direction no matter how much the base is turned about.

It depends upon angular velocity (ω) weight (w) at which the weight is concentrated. When its principle weight concentrated near the rim, rotating at high speed, the maximum gyroscopic inertia effect will be obtained.

Wd = mg x N = Weight of disc

Let Wd= weight of disc =mg,N (or) Kgm/s2

D = Diameter of disc, m

M = mass of disc, = Wd/g, (N-s2)/m or Kg
g = gravitational acceleration, 9.81 m/s¬2
For disc

For disc

$$I = \frac{1}{2} \times \frac{W_d \times (D/2)^2}{g} = \frac{W_d \times (D)^2}{8g} \quad \text{in } Nms^2 \text{(or) } Kg-m^2$$

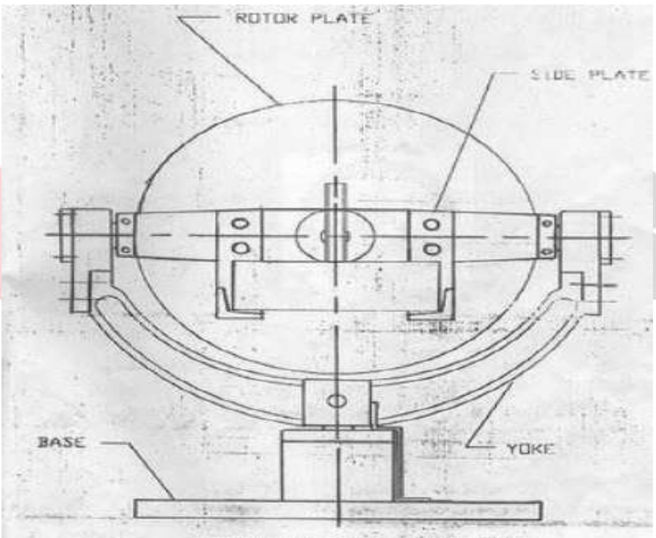
Velocity of spin $\omega = \frac{2\pi N}{60}$ rad/sec

The angular velocity of rotor is called velocity of spin

Where n= speed of motor in rpm

Velocity of precession $(\omega_p = \frac{d\theta}{dt} = \frac{\pi\theta}{180\,t}$ rad/s

Let dθ is the angle of precession and dt is the time taken for the corresponding precession, then the angular velocity of rotation of the rotor about an axis (OZ) perpendicular to both spin and couple axis is called velocity of precession.



FRONT VIEW OF GYROSCOPE

GYROSCOPIC COUPLE: (C = Iωωp, in Nm)

The couple generated due to change of direction of angular velocity of rotor is called gyroscopic couple. It gives rise from gyroscopic acceleration.

Applied torque = (C = wa ,Nm)

The torque applied to change the direction of angular velocity of rotor is called applied torque. Numerically it is the product of weigh (w) placed in the weight stud and its distance (a) from the center of the disc.

PROCEDURE:

1. Connect the motor of the gyroscope to an AC supply through dimmer stat.
2. Adjust the balance weight slightly if required using the bottom clamp screws.
3. Set the dimmerstat to zero position and put on the supply
4. Start the motor by speed controller and adjust the rotor speed.
5. Note down the rotor speed with the help of digital indicator when it becomes steady (it may take around 5 min to stabilize). Take care not to exert pressure on rotor shaft.
6. Place the required weight on the weight stud and at the same instant start the stop watch. Note down the time required for θ degree (say 450) precession.
7. Repeat the procedure for different weights and precessions.

8. Measure and record the distance between the center of disc and center of weight stud.
9. Tabulate the results

Observation Table:

Speed	Angle in degree	Angle in Radian	Time taken	Wt in Kg	w in N	Linear velocit y of disc	Experimental linear velocity of precision	Theoretical linear velocity of precision	Torqu e exp	Torque theoritical

Disc rotor Thickness = 10mm.
Disc rotor Diameter = 250mm
Distance between the center of disc and center of weight stud =195mm
Density =7820 Kg/m3
Moment of inertia of disc, I= Mr2 /2

Formula Used:

1. Area of Rotor $= \frac{\pi d^2}{4}$

Where,

D = disc rotor dia in m

2. Angle in radian $= \frac{\theta\pi}{180}$

3. Applied Torque, $T_{Exp} = I\omega\omega_P$

Where,

$I = \frac{Mr^2}{2}$

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

$\omega_P = \frac{d\theta}{dt}$ inradians

4. $T_{Theo} = WxL$

5. LinearVelocityofDisc $= \omega = \frac{2\pi N}{60}$

6. $\omega_{P(Exp)} = \frac{d\theta}{dt}$ inradians

7. $\omega_{P(Theo)} = M_t xL$

Safety Precautions:

Set the dimmer stat to zero position and put on the supply

Take care not to exert pressure on rotor shaft.

VIVA –QUESTIONS:

1. Write a short note on gyroscope.
2. What do you understand by gyroscopic couple? Derive a formula for its magnitude.
3. Explain the application of gyroscopic principles to aircrafts.
4. Discuss the effect of the gyroscopic couple on a two wheeled vehicle when taking a turn.

RESULT:

EXPERIMENT NO: 12

Experiment 12: To perform the experiment for static balancing on static balancing machine.

Apparatus:

Static Balancing m/c, weighing m/c

Theory

A system of rotating masses is said to be in static balance if the combined mass centre of the system lies on the axis of rotation. Whenever a certain mass is attached to a rotating shaft, it exerts some centrifugal force, whose effect is to bend the shaft and to produce vibrations in it. In order to prevent the effect of centrifugal force, another mass is attached to the opposite side of the shaft. The process of providing the second mass in order to counteract the effect of the centrifugal force of the first mass, is called balancing of rotating masses.

The following cases are important from the subject point of view:

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 different masses rotating in the same plane.
4. Balancing of different masses rotating in different planes.

Procedure:

Remove the belt, the value of weight for each block is determined by clamping each block in turn on the shaft and with the cord and container system suspended over the protractor disc, the number of steel balls, which are of equal weight are placed into one of the containers to exactly balance the blocks on the shaft. When the block becomes horizontal, the number of balls N will give the value of wt. for the block.

For finding out W, during static balancing proceed as follow:

1. Remove the belt.
2. Screw the combined hook to the pulley with groove. This pulley is diff. than the belt.
3. Attached the cord end of the pans to above combined hook.
4. Attached the block no.-1 to the shaft at any convenient position and in vertical downward direction.
5. Put steel balls in one of the pans till the blocks starts moving up. (upto horizontal position).
6. Number of balls give the W, value of block-1, repeat this for 2-3 times and find the average no. of balls.
7. Repeat the procedure for other blocks.

S No	Plane	Mass(m) Kg	Radius m	Cent. Force/ω^2 (m.r) Kg m	Distance from Plane x(l) m	Couple/ω^2 (m.r.l) Kg m^2

Calculation:

The balancing masses and angular positions may be determined graphically as given below:-

1. First of all, draw the couple polygon from the data which are calculated in table to some suitable scale. The vector distance represents the balanced couple. The angular position of the balancing mass is obtained by drawing, parallel to vector distance. By measurement will be find the angle.
2. Then draw the force polygon from the data, which are calculated in table to some suitable scale. The vector distance represents the balanced force. The angular position of the mass is obtained by drawing, parallel to vector distance. By measurement will be find the angle in the clockwise direction from mass.

Precautions:

1. Couple should be represented by a vector drawn perpendicular to the plane of the couple.
2. Angular position measure carefully in clockwise direction.
3. Vector diagram should be represent with suitable scale.

Calculations:

Results and Discussions:

Analysis of Results

Discussions:

Conclusions: Static balancing of shaft is successfully made using dynamic balancing machine.

EXPERIMENT NO: 13

Experiment 13: To perform the experiment for dynamic balancing on dynamic balancing machine.

Apparatus:

Static Balancing m/c, weighing m/c

Theory:

When several messes rotates in different planes, the centrifugal force, in addition to being out of balance, also forms couples. A system of rotating masses is in dynamic balance when there does not exit any resultant centrifugal force as well as resultant couple.

Pivoted-cradle Balancing M/C :

In this type of m/c., the rotor to be balanced is mounted on half-bearing in a rigid carriage and is rotated by a drive motor through a universal joint. Two balancing planes A and B are chosen on the rotor. The cradle is provided with pivots on left and right sides of the rotor which are purposely adjusted to coincide with the two correction planes. Also the pivots can be put in the locked or unlocked position. Thus, if the left pivot is released, the cradle and the specimen are free to oscillate about the locked (right) pivot. At each end of the cradle, adjustable springs and dashpots are provided to have a single degree of freedom system. Usually, their natural frequency is tuned to the motor speed.

Procedure:

1. First either of the two pivots say left is locked so that the readings of the amount and the angle of location of the correction in the right hand plane can be taken. These readings will be independent of any unbalance in the locked plane as it will have no moment about the fixed pivot.
2. A trial mass at a known radius is then attached to the right hand plane and the amplitude of oscillation of the cradle is noted.
3. The procedure is repeated at various angular positions with the same trial mass.
4. A graph is then plotted of amplitude Vs angular positions of the trial mass to know the optimum angular position for which amplitude is minimum. Then at this position, the magnitude of the trial mass is varied and the exact amount is found by trial and error which reduces the unbalance to almost zero.
5. After obtaining the unbalance in one plane, the cradle is locked in the right hand pivot and released in the left hand pivot. The above procedure is repeated to obtain the exact balancing mass required in that plane.
6. Usually, a large number of test runs are required to determine the exact balance masses in this type of machine. However, by adopting the following procedure, the balance masses can be obtained by making only four test runs:

First make a test run without anaching any trial mass and note down the amplitude of the cradle vibrations. Then attach a trial mass m at some angular position and note down the amplitude of the cradle vibrations by moving the rotor at the same speed. Next detach the trial mass and again attach it at 90° angular position relative to the first position at the same radial distance. Note down the amplitude by rotating the rotor at the same speed. Take the last reading in the same manner by fixing the trial mass 180°. Let the four reading be

S No	Trial Mass	Amplitude
1	0	
2	m at 0°	
3	m at 90°	
4	m at 180°	

Calculation and Construction:

Draw a triangle OBE by taking $OE=2X_1$,$OB=X_2$, and $BE=X_4$ Mark the mid-point A on OE. Join AB.

Now, OB=OA+AB

Where, OB=Effect of unbalance mass+ Effect of the trial mass at 0°

OA-Effect of unbalanced mass

Thus, AB represents the effect of the attached mass at 0°. The proof is as follows

Extend BA to D such that AD =AB. Join OD and DE. Now when the mass m is attached at 180° at the same radial distance and speed, the effect must be equal and opposite to the effect at 0° ie if AB resents the effect of the attached mass at 0°, AD represents the effect of the attached mass at 180°.

Since, OD =OA+AD

OD must represent the combined effect of unbalance mass and the effect of the trial mass at 180° (X_4)

Now, as the diagonals of the quadrilateral OBED bisect at each other at A it is a parallelogram which means BE is parallel and equal to OD. Then, BE also represents the combined effect of unbalance mass and the effect of the trial mass at 180° or X_4, which is true as it is made in the construction.

Now as OA represents the unbalance, the correction has to be equal and opposite of it or AO. Thus, the correction mass is given by

M_c=m.OA/AB at an angleϴ from the second reading at 0°

For the correction of the unbalance, the mass m_c has to be put in the proper direction relative to AB which may be found by considering the reading X_3.

Draw a circle with A as centre and AB as the radius. As the trial mass as well as the speed of the test run at 90° is the same, the magnitude must equal to AB or AD and AC or AC' must represent the effect of the trial mass. If OC represents X_3, then angle is opposite to the direction of angle measurement. If OC' represent X_3, then angle measurement is in taken in the same direction.

Precautions:

1. Measure the amplitude carefully.
2. Draw the triangle and parallelogram in correct scale
3. Vector diagram should be represent with suitable scale.

Precautions:

1. Couple should be represented by a vector drawn perpendicular to the plane of the couple.
2. Angular position measure carefully in clockwise direction.
3. Vector diagram should be represent with suitable scale.

Calculations:

EXPERIMENT NO: 14

Experiment 14: To determine critical speed or whirling speed of a rotating shaft and to verify the value theoretically.

Apparatus:

Shafts, variable, Speed motor

Theory:

Whirling speed is also called as Critical speed of a shaft. It is defined as the speed at which a rotating shaft will tend to vibrate violently in the transverse direction if the shaft rotates in horizontal direction. In other words, the whirling or critical speed is the speed at which resonance occurs.

At certain speed, a rotating shaft has been found to exhibit excessive lateral Vibrations (transverse vibrations). The angular velocity of the shaft at which this occurs is called a critical speed or whirling speed or whipping speed.

The frame will support motor, sliding block and shafts. When the gears or pulleys are mounted on a shaft the centre of gravity of the mounted element does not coincide with the centre line of the bearing (or) axis of the shaft. Due to this the shaft is subjected to a centrifugal force. This further increases the distance of centre gravity from the axis of rotation and hence the centrifugal force increases this effect is cumulative and ultimately the shaft fails.

At critical speed the shaft deflection becomes excessive and may cause permanent deformation or structural damage. Hence a machine should not be operated close the critical speed. To determine critical speed of a shaft which may be subjected to point loads. UDL or a combination of both, since the frequency of transverse vibration is equal to critical speed in rpm, calculate the frequency of transverse vibration.

PROCEDURE:

1. Fix the shaft properly at both ends
2. Check the whole apparatus for tightening the screw etc.
3. First increase the voltage slowly for maximum level and then start slowing down step by step
4. Observe the loops appearing on the shaft and note down the number of loops and the speed at which they are appearing
5. Slowly bring the shaft to rest and switch of the supply.
6. Repeat the same procedure for different shaft
6. since both the ends have double ball bearing hence both the ends are assumed fixed.

FOR UNIT LENGTH

ϕ 4mm - 0.096Kg/m

ϕ 5mm - 0.16Kg/m

ϕ 6mm - 0.24Kg/m

TABULAR COLUMN

S No	End Condition	Dia Of Shaft (Mm)	Speed (Rpm)Expt		A	Angular Speed	Speed (Theo)	% Error
			Bending	Twisting			For Bending	
1	Fixed-Fixed	4						
2	Fixed-Fixed	5						
3	Fixed-Fixed	6						
4	Fixed-Hinged	4						
5	Fixed-Hinged	5						

FORMULA USED

1. For bending mode

Angular speed (ω) = 22 ∗ a/L2

Where a = JE∗I/M

Theoritical speed = Angular speed (ω) ∗ 60/2 ∗ π

% error = theo. speed − expt speed ∗ 100/theo. speed

1. For twisting mode

Angular speed (ω) = 61.7 ∗ a/L2

Where a = JE∗I/M

Theoritical speed = Angular speed (ω) ∗ 60/2 ∗ π

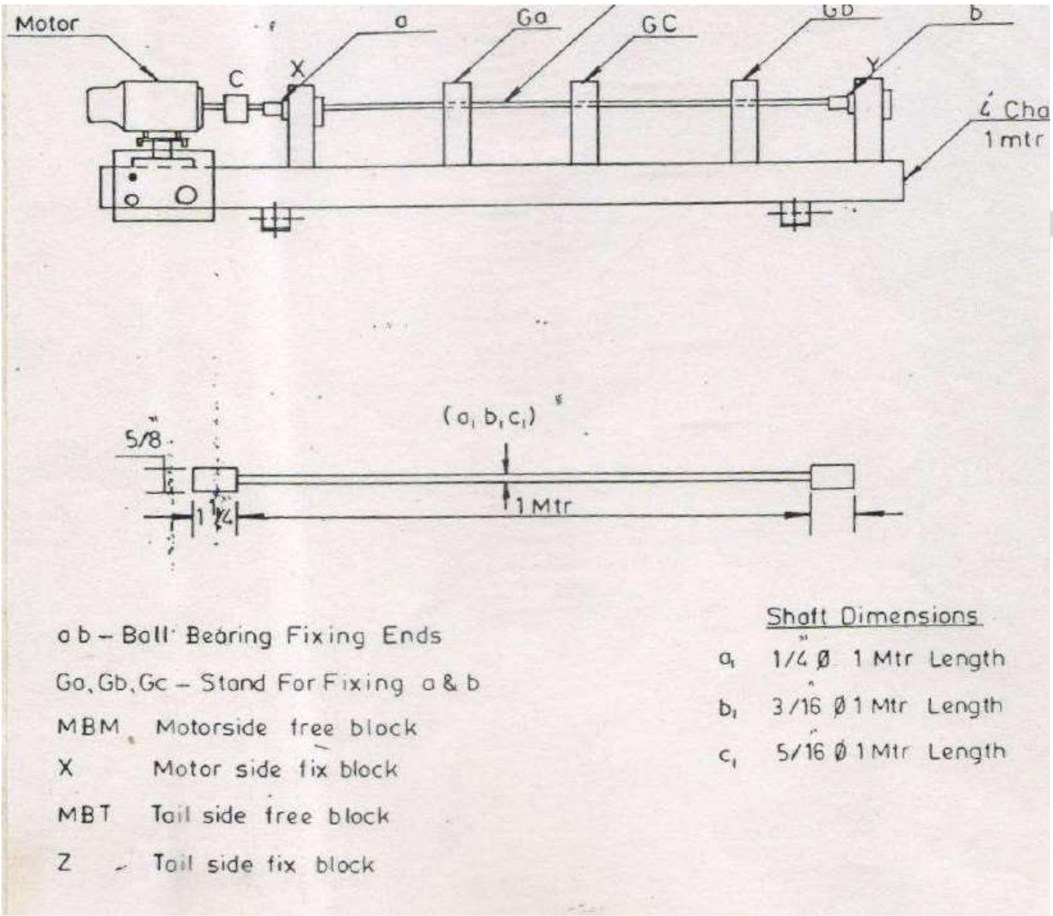
% error = theo. speed − expt speed ∗ 100/theo. speed

TERMS USED

E → Youngs modulus of the material = 2 *1011Gpa m → mass of the shaft = Kg/m

L→ length of the shaft = m d→ dia of the shaft in m

I → moment of inertia of the shaft in m4 = f∗d4/64



RESULT: -