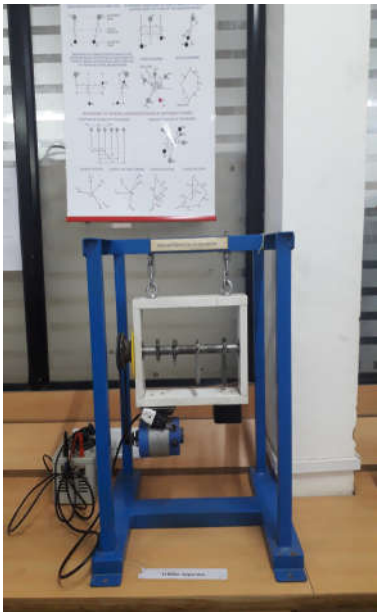
Department of Mechanical Engineering
DYNAMICS OF MACHINE

Laboratory Incharge

Prof. Sharad Shukla

Laboratory Technician

Mr. Suraj Kalsekar






List of Equipments with Price

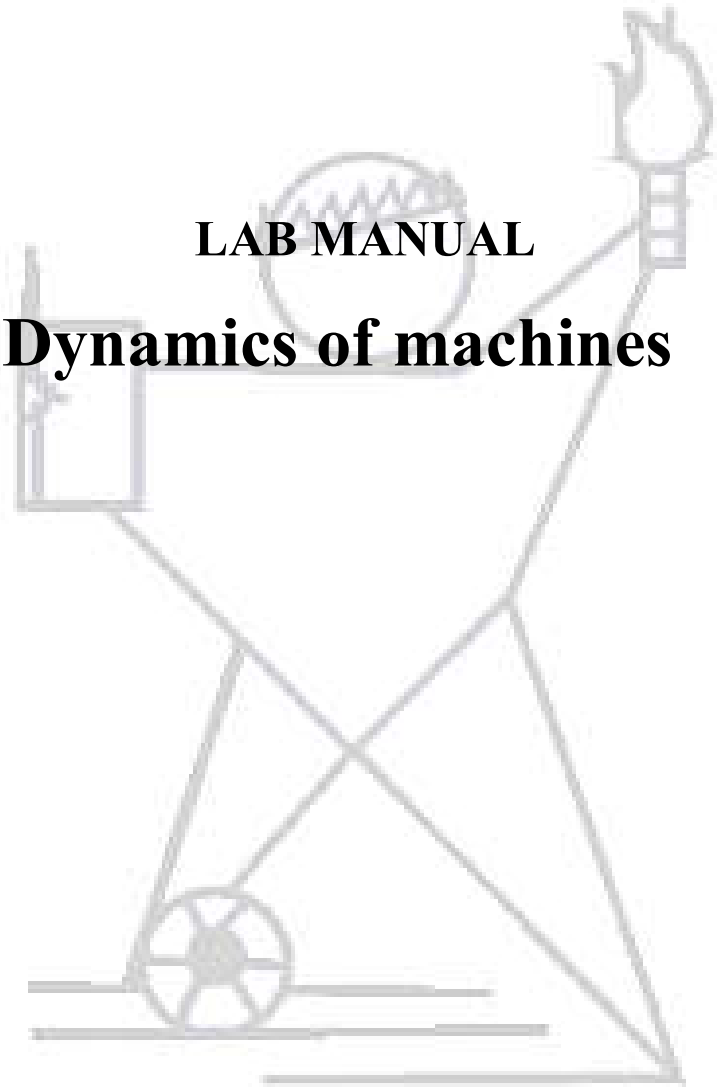
S. No.	List of Equipments	Date	Price (in Rs.)
1.	Universal Governor	12.01.2015	18375/-
2.	Static and Dynamic Balancing Machine	12.01.2015	18375/-
3.	Centrifugal Force Apparatus	01.02.2018	8307/-
4.	Reciprocating Masses Apparatus	01.02.2018	46215/-
5.	Turn Table Apparatus	01.02.2018	50400/-
6.	Trifillar Apparatus	01.02.2018	7605/-
7.	Prony Brake Dynomometer	04.03.2016	3030/-

List of Major Equipments with Price

S. No.	List of Equipments	Date of Purchase	Price (in Rs.)
1.	Universal Governor	12.01.2015	18375/-
2.	Static and Dynamic Balancing Machine	12.01.2015	18375/-
3.	Reciprocating Masses Apparatus	01.02.2018	46215/-
4.	Turn Table Apparatus	01.02.2018	50400/-

List of Equipments purchased in Last Three Years with Price

S. No.	List of Equipments	Date of Purchase	Price (in Rs.)
1.	Centrifugal Force Apparatus	01.02.2018	8307/-
2.	Reciprocating Masses Apparatus	01.02.2018	46215/-
3.	Turn Table Apparatus	01.02.2018	50400/-
4.	Trifillar Apparatus	01.02.2018	7605/-



LAB MANUAL

Dynamics of machines

IPS Academy, Indore

Institute of Engineering & Science
Mechanical Engineering Department

LAB MANUAL
Dynamics of Machines
(ME-5005)

Name …….

Session ……Semester …….

Enrollment No. ……..

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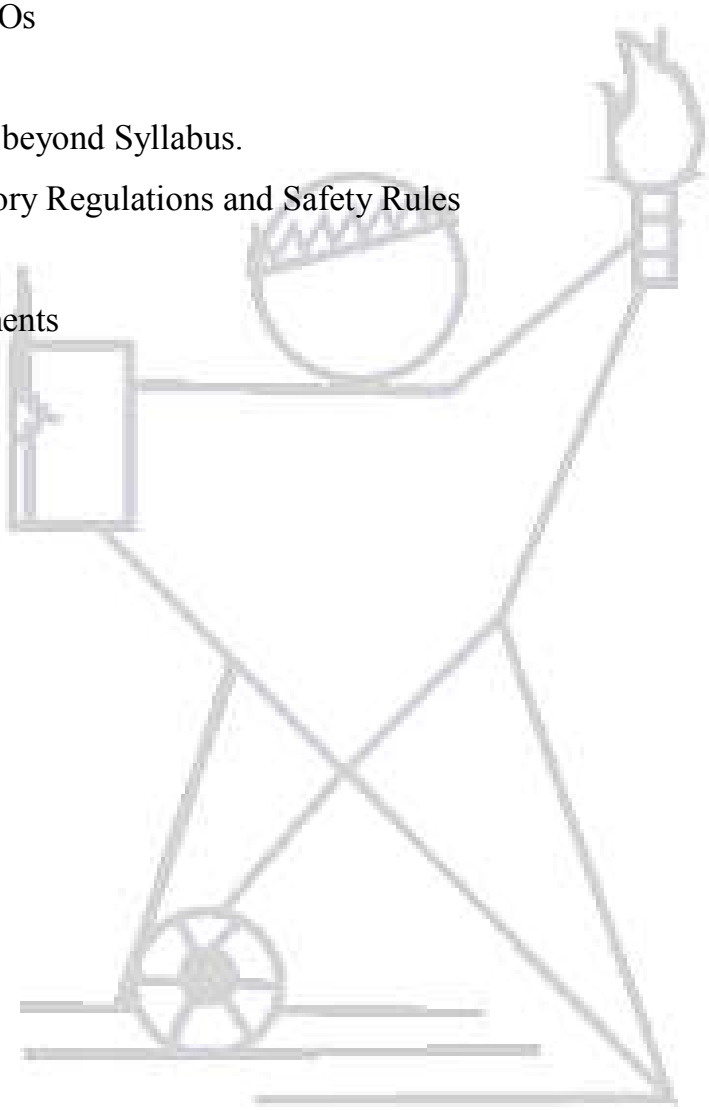


Vision of the Institute

To be the fountainhead of novel ideas & innovations in science & technology & persist to be a foundation of pride for all Indians.

Mission of the Institute

M1: To provide value based broad Engineering, Technology and Science where education in students are urged to develop their professional skills.

M2: To inculcate dedication, hard work, sincerity, integrity and ethics in building up overall professional personality of our student and faculty.

M3: To inculcate a spirit of entrepreneurship and innovation in passing out students.

M4: To instigate sponsored research and provide consultancy services in technical, educational and industrial areas.

Vision of the Department

To be a nationally recognized, excellent in education, training, research and innovation that attracts, rewards, and retains outstanding faculty, students, and staff to build a Just and Peaceful Society.

Mission of the Department

M1: Imparting quality education to the students and maintaining vital, state-of-art research facilities for faculty, staff and students.

M2: Create, interpret, apply and disseminate knowledge for learning to be an entrepreneur and to compete successfully in today's competitive market.

M3: To inculcate Ethical, Social values and Environment awareness.

Program Education Objectives (PEOs)

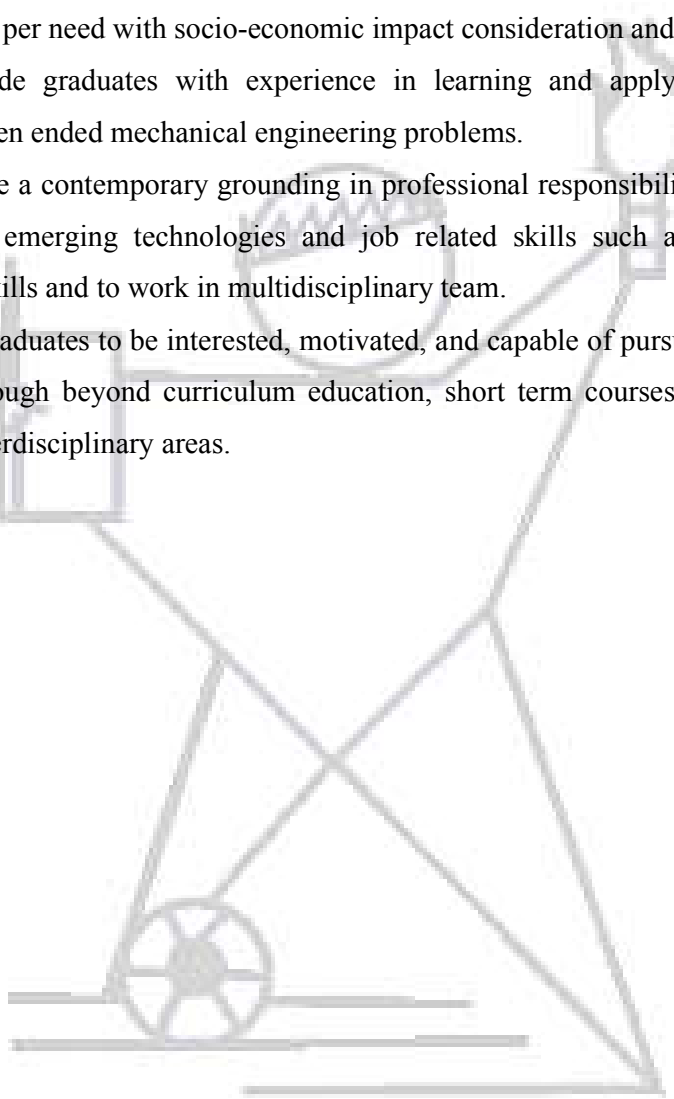
PEO1: To enrich graduates with fundamental knowledge of Physics, Chemistry and advanced mathematics for their solid foundation in Basic Engineering science.

PEO2: To provide graduates to design the solution of engineering problems relevant to mechanical engineering design through the process of formulating, executing & evaluating a design solution as per need with socio-economic impact consideration and related constraints.

PEO3: To provide graduates with experience in learning and applying tools to solve theoretical and open ended mechanical engineering problems.

PEO4: To provide a contemporary grounding in professional responsibility including ethics, global economy, emerging technologies and job related skills such as written and oral communication skills and to work in multidisciplinary team.

PEO5: Prepare graduates to be interested, motivated, and capable of pursuing continued life-long learning through beyond curriculum education, short term courses and other training programme in interdisciplinary areas.



Program Outcomes (POs)

Engineering Graduates will be able to:

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

PO2: Problem analysis: Identify, formulate, and analyze mechanical engineering problems to arrive at substantiated conclusions using the principles of mathematics, and engineering sciences.

PO3: Design/development of solutions: Design solutions for mechanical engineering problems and design system components, processes to meet the specifications with consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO4: Conduct investigations of complex problems: An ability to design and conduct experiments, as well as to analyze and interpret data.

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

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

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

PO8: Ethics: An understanding of professional and ethical responsibility.

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

PO10: Communication: Ability to communicate effectively. Be able to comprehend and write effective reports documentation.

PO11: Project management and finance: Demonstrate knowledge and understanding of engineering and management principles and apply this to Mechanical engineering problem.

PO12: Life-long learning: ability to engage in life-long learning in the broadest context of technological change.

Program Specific Outcomes (PSOs)

PSO1: Engage professionally in industries or as an entrepreneur by applying manufacturing and management practices.

PSO2: Ability to implement the learned principles of mechanical engineering to analyze, evaluate and create advanced mechanical system or processes.

Course Outcomes (COs)
Dynamics of Machines (ME-5005)

After completion of the course the students are able to-

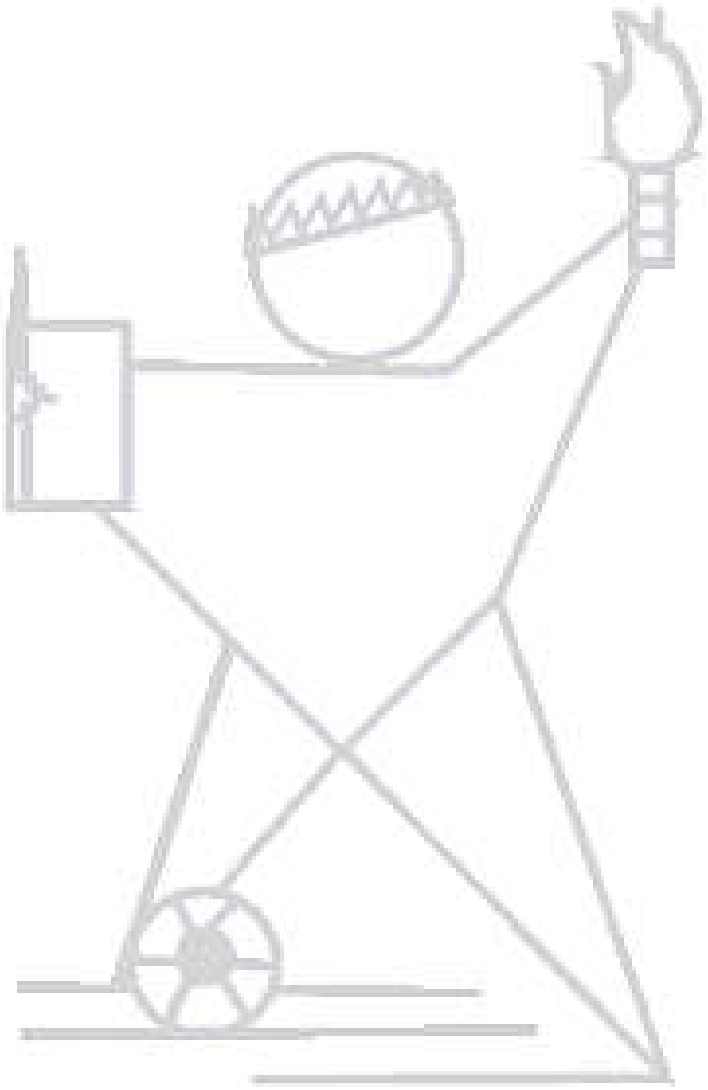
CO1. Apply an understanding of analytical and graphical approach to engineering problems of turning moment.

CO2. Understanding the theoretical and practical concepts behind working of Governors and their application for various functions.

CO3. Analyzing the balancing of rotating masses that can be used in different machineries.

CO4.Understanding the working principle of clutches and frictional behaviour of these clutches.

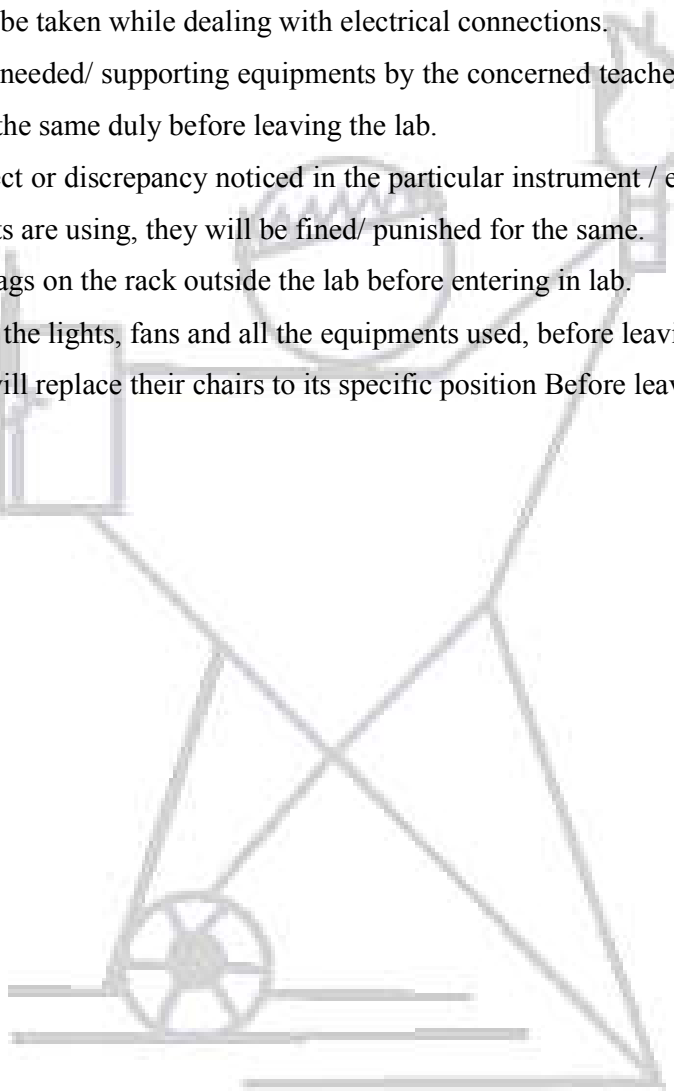
CO5. Students will be able to understand about different power transmitting modes and also function of different brakes and cams.



Laboratory Regulations and Safety Rules

Instructions for Student

1. Read the instructions mentioned in the manual carefully and then proceed for the experiment.
2. Mishandling of lab equipment will not be tolerated at all. If any student is found guilty; he/she should be punished/ discarded from the lab.
3. Care must be taken while dealing with electrical connections.
4. Issued the needed/ supporting equipments by the concerned teacher/lab. Technician & return the same duly before leaving the lab.
5. If any defect or discrepancy noticed in the particular instrument / equipment while the students are using, they will be fined/ punished for the same.
6. Put your bags on the rack outside the lab before entering in lab.
7. Switch off the lights, fans and all the equipments used, before leaving lab.
8. Students will replace their chairs to its specific position Before leaving the lab



INDEX

S. No.	Name of Experiment	Date	Grade	Signature
1.	Determine displacement, velocity & acceleration of various parts steam engine using analytical method.			
2.	To perform experiment on watt and Porter Governors to prepare performance characteristic Curves, and to find stability & sensitivity.			
3.	To perform experiment on Proell Governors to prepare performance characteristic Curves, and to find stability & sensitivity.			
4.	To perform experiment Hartnell Governors to prepare performance characteristic Curves, and to find stability & sensitivity.			
5.	To perform the experiment for static balancing on static balancing machine.			
6.	To perform the experiment for dynamic balancing on dynamic balancing machine.			
7.	To perform the experiment for measuring the power by prony brake dynamometer and study various types of dynamometers.			
8.	To study working of friction clutches using models.			
9.	Determine displacement, velocity & acceleration of various parts steam engine using analytical method.			
10.	To find out jump phenomenon of Cams and followers with the help of test kit..			

EXPERIMENT No: 01

AIM: -Study of displacement, velocity & acceleration of various parts steam engine using analytical method.

APPARATUS USED: - Models of Reciprocating Engine

THEORY:- Kinematics deals with study of relative motion between the various parts of the machines. Kinematics does not involve study of forces. Thus motion leads study of displacement, velocity and acceleration of a part of the machine. Study of Motions of various parts of a machine is important for determining their velocities and accelerations at different moments.

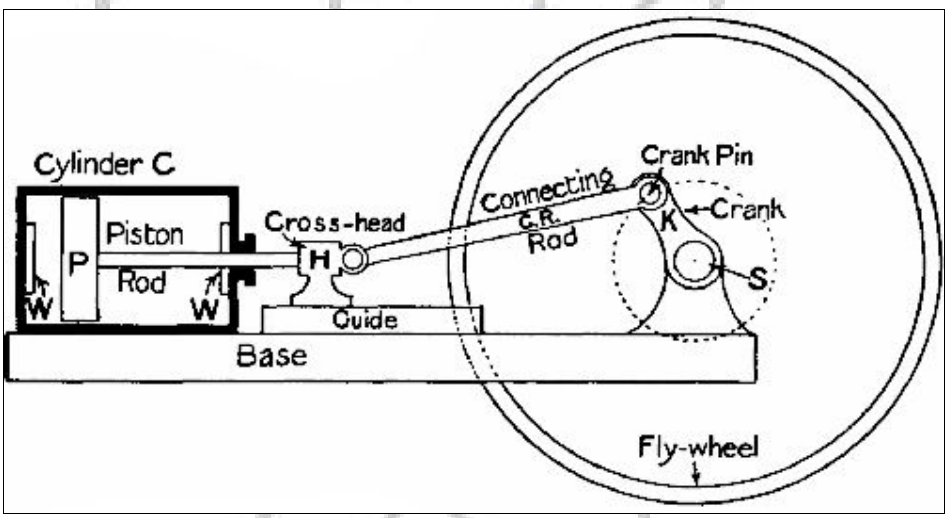


Fig. Various Parts of Reciprocating Engine

As dynamic forces are a function of acceleration and acceleration is a function of velocities, study of velocity and acceleration will be useful in the design of mechanism of a machine. The mechanism will be represented by a line diagram which is known as configuration diagram. The analysis can be carried out both by graphical method as well as analytical method.

Displacement: All particles of a body move in parallel planes and travel by same distance is known, linear displacement and is denoted by 'x'. A body rotating about a fired point in such a way that all particular move in circular path angular displacement and is denoted by

'θ'.

Let x =displacement of piston from inner dead center

$$x = r\left[(1-\cos\theta) + \left(n - \sqrt{n^2 - sin^2\theta}\right)\right]$$

The equation converts to $x = r(1-\cos\theta)$

This is the expression for a SHM. Thus the piston executes SHM when connecting rod is large.

Velocity: Rate of change of displacement is velocity. Velocity can be linear velocity of angular velocity.

Linear velocity is Rate of change of linear displacement=$v = \frac{dx}{dt}$

Angular velocity is Rate of change of angular displacement = ω = $\frac{d\theta}{dt}$

Relation between linear velocity and angular velocity

x = r×θ

$$\frac{dx}{dt} = r\frac{d\theta}{dt}$$

i.e. V = r. ω where ω= $\frac{d\theta}{dt}$

$$v = \frac{dx}{dt} = \frac{dx}{d\theta} \times \frac{d\theta}{dt}$$

$$= r\omega\left[sin\theta + \frac{sin2\theta}{2\sqrt{n^2 - sin^2\theta}}\right]$$

if is large compared to 2 n 2 sin θ then

$$v = r\omega\left[sin\theta + \frac{sin2\theta}{2n}\right]$$

If $\frac{sin2\theta}{2n}$ can be neglected (when n is quite less) then

$$v = r\omega sin\theta$$

Acceleration: Rate of change of velocity

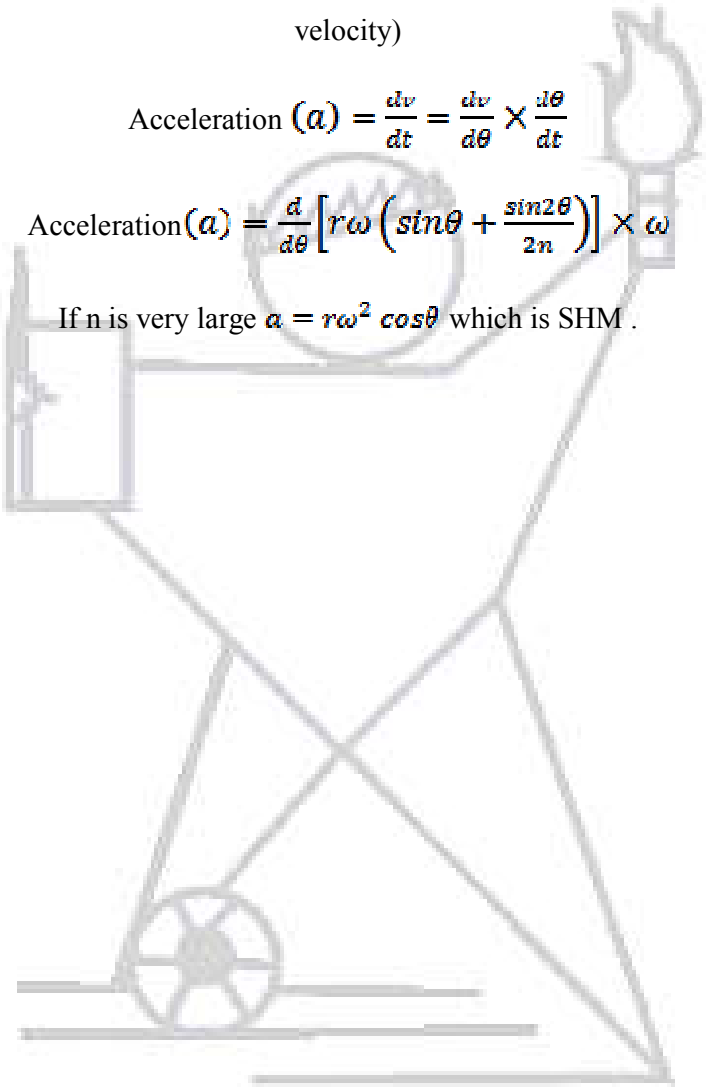
$f = \frac{dv}{dt} = \frac{d^2x}{dt^2}$ Linear Acceleration (Rate of change of linear velocity)

Thirdly $\alpha = \frac{d\omega}{dt} = \frac{d^2\theta}{dt^2}$ Angular Acceleration (Rate of change of angular velocity)

Acceleration $(a) = \frac{dv}{dt} = \frac{dv}{d\theta} \times \frac{d\theta}{dt}$

Acceleration $(a) = \frac{d}{d\theta}\left[r\omega\left(sin\theta + \frac{sin2\theta}{2n}\right)\right] \times \omega$

If n is very large $a = r\omega^2 cos\theta$ which is SHM .



Questions:

Q. Explain Turning Moment Diagram.
Ans:
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Q. Function of Flywheel.
Ans:
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Q. What is punching Press?
Ans:
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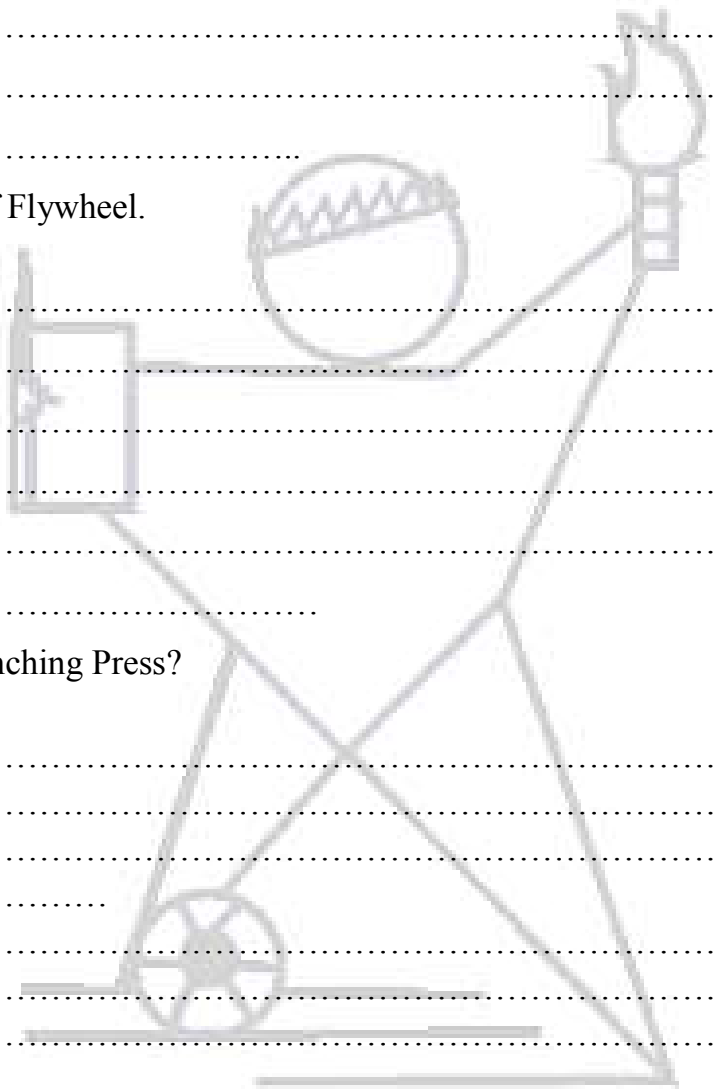


EXPERIMENT No: 02

AIM: - To perform experiment on watt and Porter Governors to prepare performance characteristic Curves, and to find stability & sensitivity.

APPARATUS USED: - Watt and Porter Governors

THEORY: - The function of a governor is to regulate the mean speed of an engine, when there are variations in the load e.g. when the load on an engine increases, its speed decreases, therefore it becomes necessary to increase the supply of working fluid. When the load on the engine decreases, its speed increases and thus less working fluid is required. The governor automatically controls the supply of working fluid to the engine with the varying load conditions and keeps the mean speed within certain limits.

The governors may, broadly, be classified as

(1). Centrifugal governor

(2). Inertia governor

The centrifugal governors may further be classified as follows:

(1). Pendulum type (Watt governor)

(2). Loaded type

(a) Dead weight governor (Porter governor and Proell governor)

(b) Spring controlled governors (Hartnell governor, Hartung governor, Wilson-Hartnell governor and Pickering governor)

Watt Governor: - The simplest form of a centrifugal governor is a Watt governor. It is basically a conical pendulum with links attached to a sleeve of negligible mass. The arms of the governor may be connected to the spindle in the following three ways:

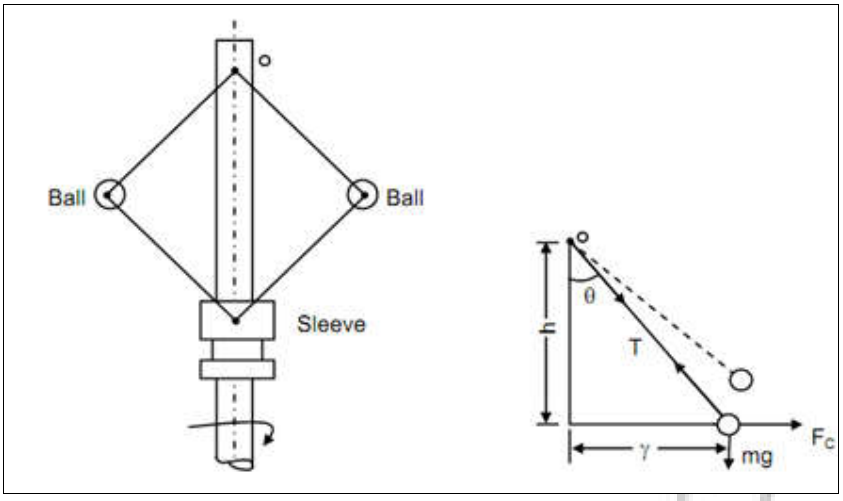


Fig. Watt Governor

(1). The pivot P, may be on the spindle axis.

(2). The pivot P, may be offset from the spindle axis and the arms when produced intersect at O.

(3). The pivot P, may be offset, but the arms crosses the axis at O.

Porter Governor: - The porter governor is a modification of a Watt's governor, with central load attached to the sleeve. The load moves up down the central spindle.

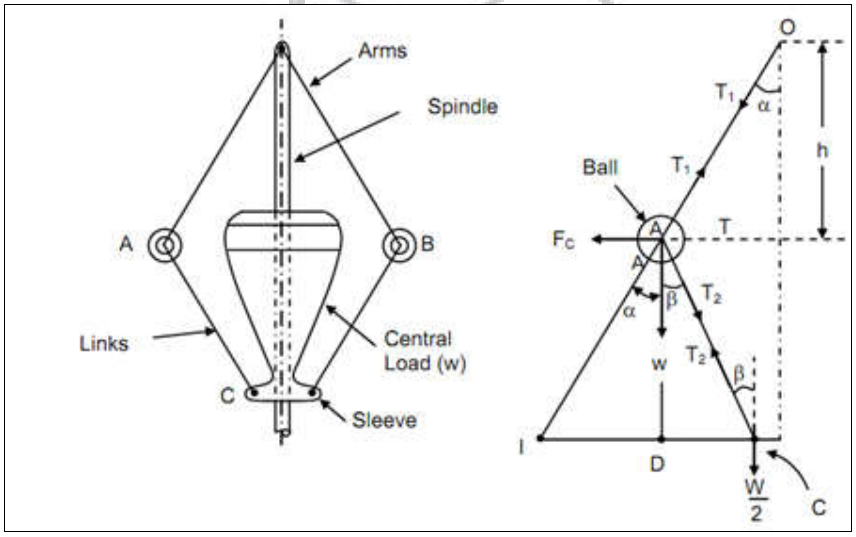


Fig. Porter Governor

This additional downward force increases the speed of revolution required to enable the balls to rise to any to any pre-determined level.

OBSERVATION TABLE FOR WATT GOVERNOR: -

S. No.	Motor Speed (N)	Speed in RPM ($\omega=2\pi N/60$)	Sleeve Displacement (X)	Height (H)	Cos α = h/l	Radius of Rotation (r)	Force ($F=mr\omega^2$)

OBSERVATION TABLE FOR PORTER GOVERNOR: -

S. No.	Motor Speed (N)	Speed in RPM ($\omega=2\pi N/60$)	Sleeve Displacement (X)	Height (H)	Cos α = h/l	Radius of Rotation (r)	Force ($F=mr\omega^2$)

CALCULATION: -

- Mass of the ball (m) = ----------kg.
- Weight of the ball (w)=----------Newtons
- Height of the governor (h) = ------- metres
- Minimum equilibrium speed (N1) = ------ r.p.m.
- Minimum equilibrium speed (N2) = ------ r.p.m.
- Frictional force (F) = ---------- Newtons
- Mean equilibrium speed (N) = (N1 + N2)/2 in r.p.m
- Mass of the central load = ---------kg.
- Weight of the central load (W) = --------N
- Angle of inclination of the arm to the vertical (α) = -----
- Angle of inclination of the link to the vertical (β) = ------

$N^2 = \frac{895}{h}$ (For watt governor)

$N^2 = \frac{m+\frac{M(1+q)}{2}}{m} \times \frac{895}{h}$ (For porter governor), where $q = \frac{\tan\beta}{\tan\alpha}$

Sensitiveness of Governor $= \frac{2(N_1 - N_2)}{N_1 + N_2} = \frac{2(\_ - \_)}{\_ + \_}$

A governor is said to be stable when for every speed within the working range there is a definite configuration i.e; there is only one radius of rotation of the governor balls at which the governor is in equilibrium. For a stable governor, if the equilibrium speed increases, the radius of governor balls must also increase.

RESULT:-

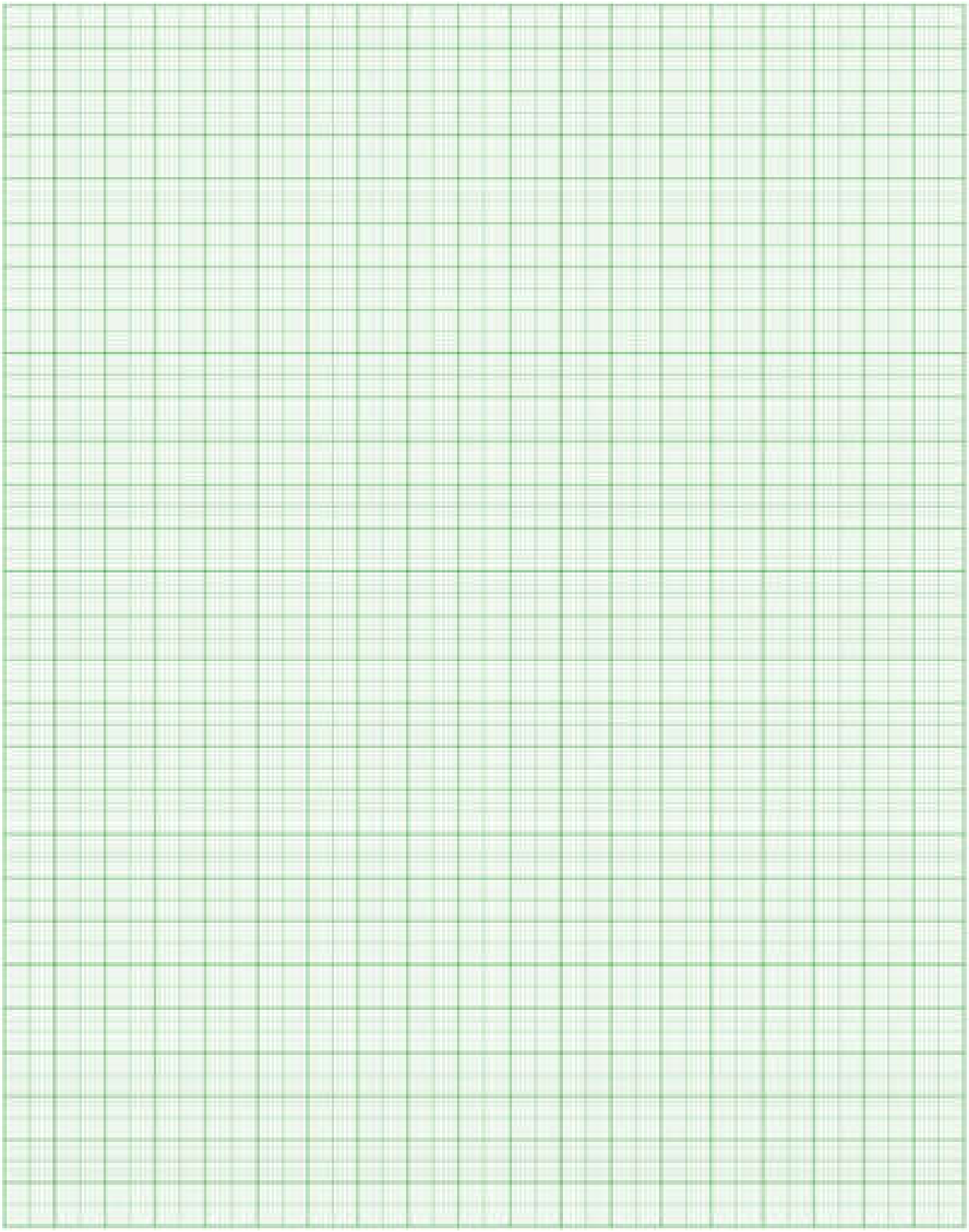
PRECAUTIONS:-

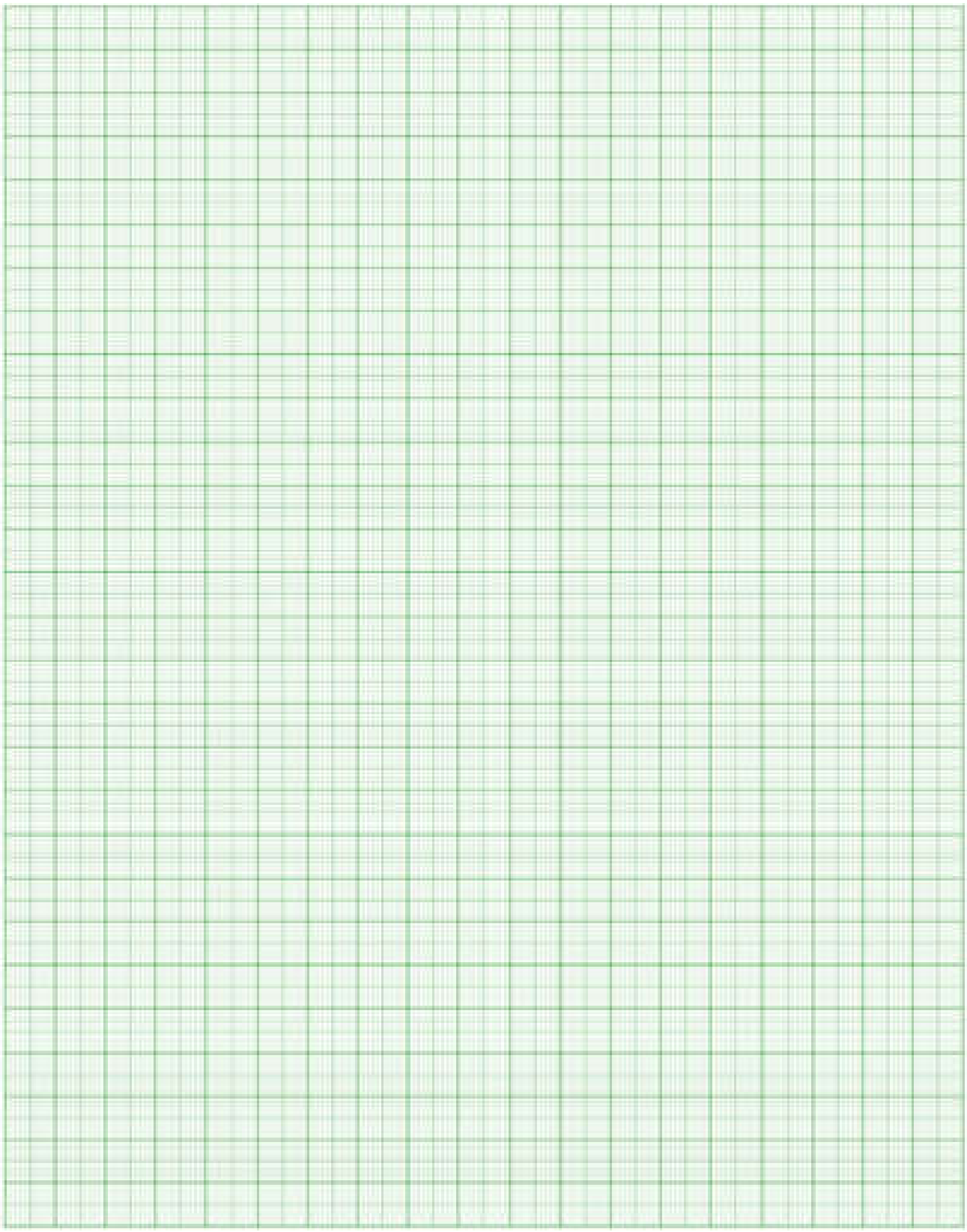
(1) Take reading carefully.

(2) Measure the angle very carefully.

(3) Measure the height of governor carefully.

(4) Speed of governor measure accurate.





EXPERIMENT No: 03

AIM: - To perform experiment on Proell Governors to prepare performance characteristic Curves, and to find stability & sensitivity.

APPRATUS USED: - Proell Governors

THEORY: - The function of a governor is to regulate the mean speed of an engine, when there are variations in the load e.g. when the load on an engine increases, its speed decreases, therefore it becomes necessary to increase the supply of working fluid. When the load on the engine decreases, its speed increases and thus less working fluid is required. The governor automatically controls the supply of working fluid to the engine with the varying load conditions and keeps the mean speed within certain limits.

The governors may, broadly, be classified as

(1). Centrifugal governor

(2). Inertia governor

The centrifugal governors may further be classified as follows:

(1). Pendulum type (Watt governor)

(2). Loaded type

(a) Dead weight governor (Porter governor and Proell governor)

(b) Spring controlled governors (Hartnell governor, Hartung governor, Wilson-Hartnell governor and Pickering governor)

Proell Governor :- The porter governor is known as a Proell governor if the two balls (masses) are fixed on the upward extensions of the lower links which are in the form of bent links (as show in fig.).

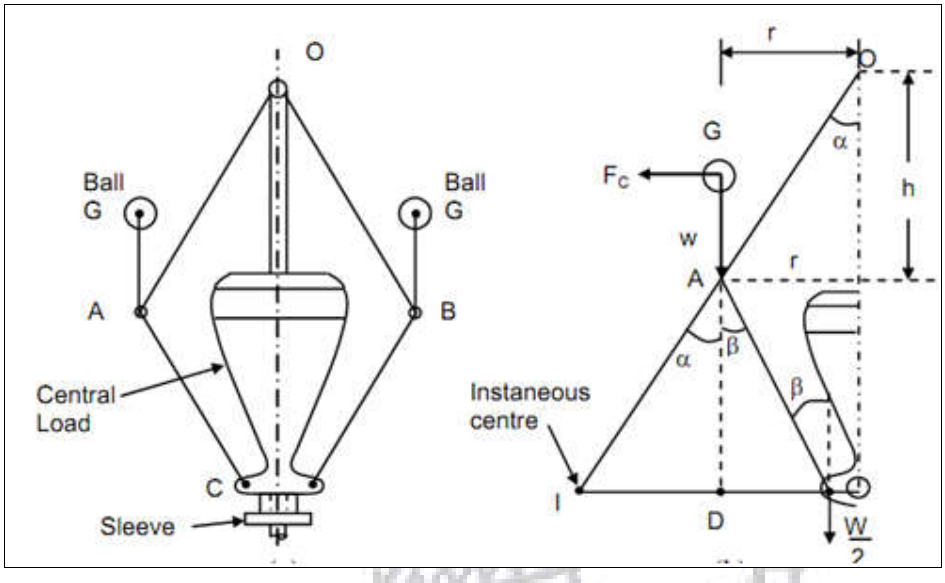


Fig. Proell Governors

OBSERVATION TABLE FOR PROELL GOVERNOR: -

S. No.	Motor Speed (N)	Speed in RPM ($\omega=2\pi N/60$)	Sleeve Displacement (X)	Height (H)	Cos α = h/l	Radius of Rotation (r)	Force ($F=mr\omega^2$)

CALCULATION: -

- Mass of the ball (m) = ----------kg.
- Weight of the ball (w)=----------Newton

- Height of the governor (h) = ------- metres
- Minimum equilibrium speed (N_1) = ------ r.p.m.
- Minimum equilibrium speed (N_2) = ------ r.p.m.
- Frictional force (F) = ---------- Newton
- Mean equilibrium speed (N) = (N_1 + N_2)/2 in r.p.m
- Mass of the central load = ---------kg.
- Weight of the central load (W) = --------N
- Angle of inclination of the arm to the vertical (α) = -
- Angle of inclination of the link to the vertical (β) = --

$$N^2 = \frac{895}{h}$$

$$N^2 = \frac{AD}{DG} \times \frac{m+\frac{M(1+q)}{2}}{m} \times \frac{895}{h}$$ (For porter governor),

where $q = \frac{\tan\beta}{\tan\alpha}$

$$\text{Sensitiveness of Governor} = \frac{2(N_1 - N_2)}{N_1 + N_2} = \frac{2(_2 - _1)}{_2 + _1}$$

A governor is said to be stable when for every speed within the working range there is a definite configuration i.e; there is only one radius of rotation of the governor balls at which the governor is in equilibrium. For a stable governor, if the equilibrium speed increases, the radius of governor balls must also increase.

RESULT:-

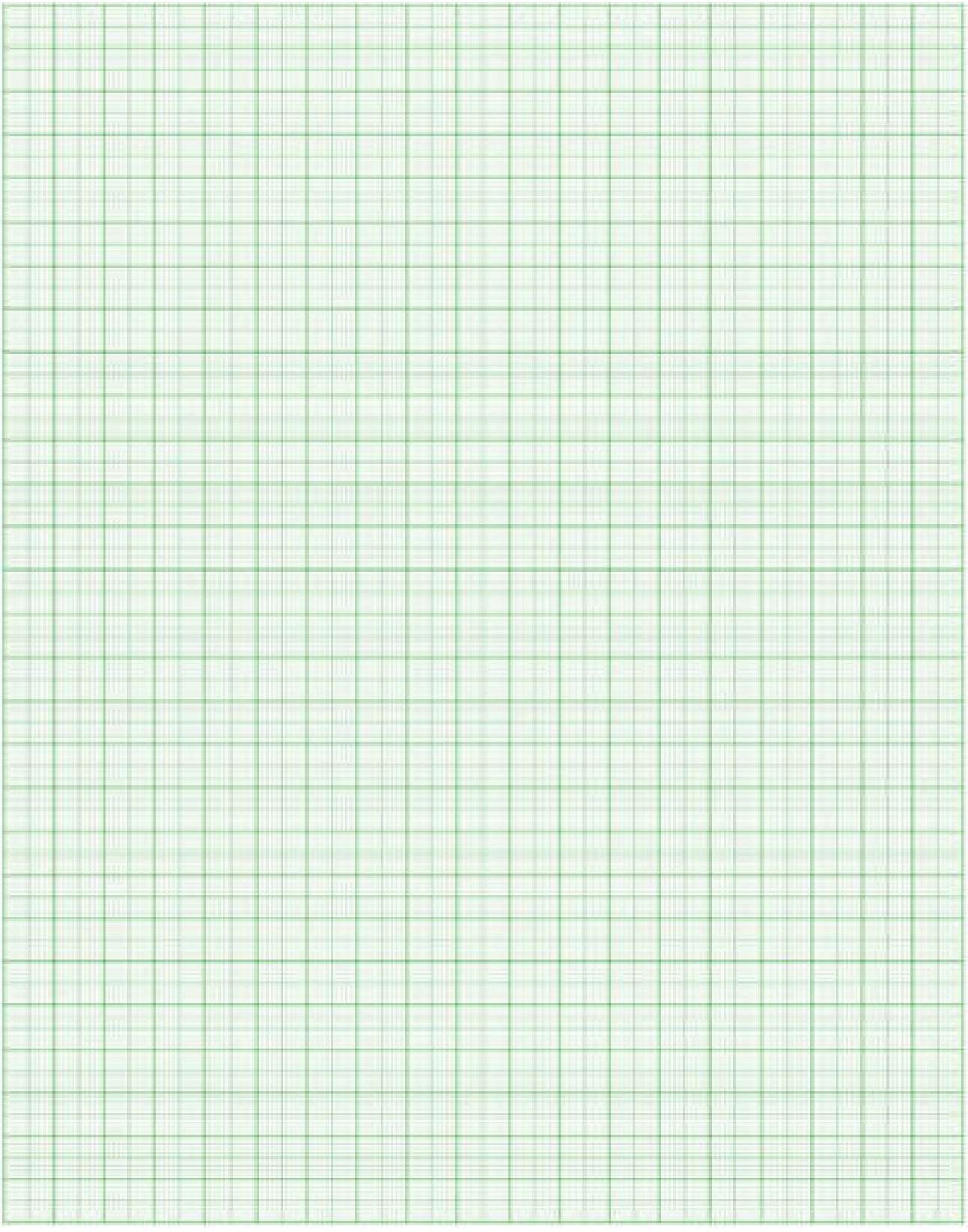
PRECAUTIONS:-

(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: 04

AIM: - To perform experiment Hartnell Governors to prepare performance characteristic Curves, and to find stability & sensitivity.

APPARATUS USED: - Hartnell Governor

THEORY: - The function of a governor is to regulate the mean speed of an engine, when there are variations in the load e.g. when the load on an engine increases, its speed decreases, therefore it becomes necessary to increase the supply of working fluid. When the load on the engine decreases, its speed increases and thus less working fluid is required. The governor automatically controls the supply of working fluid to the engine with the varying load conditions and keeps the mean speed within certain limits.

The governors may, broadly, be classified as

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The centrifugal governors may further be classified as follows:

(1). Pendulum type (Watt governor)

(2). Loaded type

(a) Dead weight governor (Porter governor and Proell governor)

(b) Spring controlled governors (Hartnell governor, Hartung governor, Wilson-Hartnell governor and Pickering governor)

Hartnell Governor: - A Hartnell governor is a spring loaded governor as shown in fig.-A. It consists of two bell crank levers pivoted at the points O,O to the frame. The frame is attached to the governor spindle and therefore rotates with it. Each lever carries a ball at the end of the vertical arm OB and a roller at the end of the horizontal arm OR. A helical spring in compression provides equal downward forces on the two rollers through a collar on the sleeve. The spring force be adjusted by screwing at nut up or down on the sleeve.

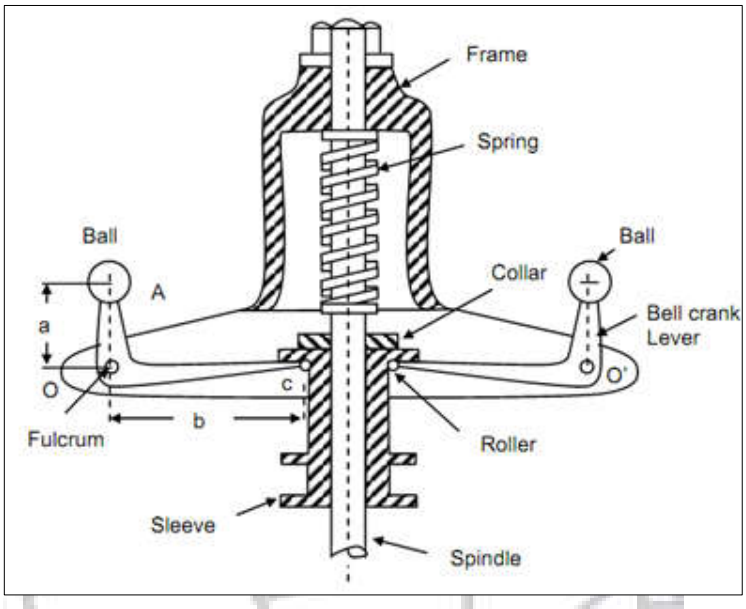


Fig. Hartnell Governors

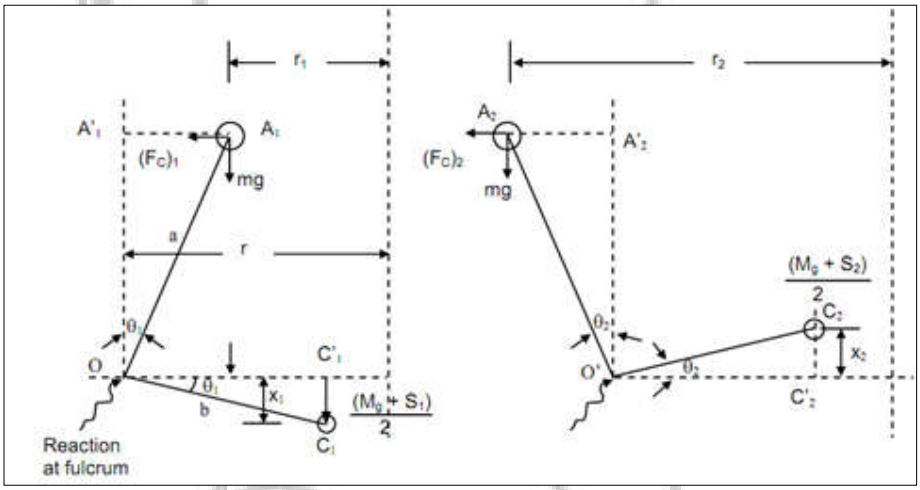


Fig. Hartnell Governors

OBSERVATION TABLE FOR HARTNELL GOVERNOR: -

S. No.	Motor Speed (N)	Speed in RPM ($\omega=2\pi N/60$)	Sleeve Displacement (X)	Height (H)	Cos α = h/l	Radius of Rotation (r)	Force ($F=mr\omega^2$)

CALCULATION:-

- Mass of the each ball (m) = ----------kg.
- Mass of the sleeve (M)=----------Newton
- Minimum radius of rotation (r_1) = ------- meters
- Maximum radius of rotation (r_2) = ------- meters
- Angular speed of the governor at minimum radius (ω_1) =……..rad./s
- Angular speed of the governor at maximum radius (ω_2) = ------rad./s
- Spring force exerted on the sleeve at ω_1 (S_1) = ---------- N
- Spring force exerted on the sleeve at ω_2 (S_2) = ---------- N
- Length of the vertical or ball arm of the lever (x) = ----- meters
- Length of the horizontal or sleeve arm of the lever (y) = ------ meters.
- Distance of fulcrum 'O' from the governor axis or the radius of rotation when the governor is in mid-position (r) = ------- meters.
- Minimum equilibrium speed (N_1) = ------ r.p.m.
- Minimum equilibrium speed (N_2) = ------ r.p.m.

- Frictional force (F) = ---------- N
- Angle of inclination of the arm to the vertical (α) = ------
- Angle of inclination of the link to the vertical (β) = ------

RESULT:

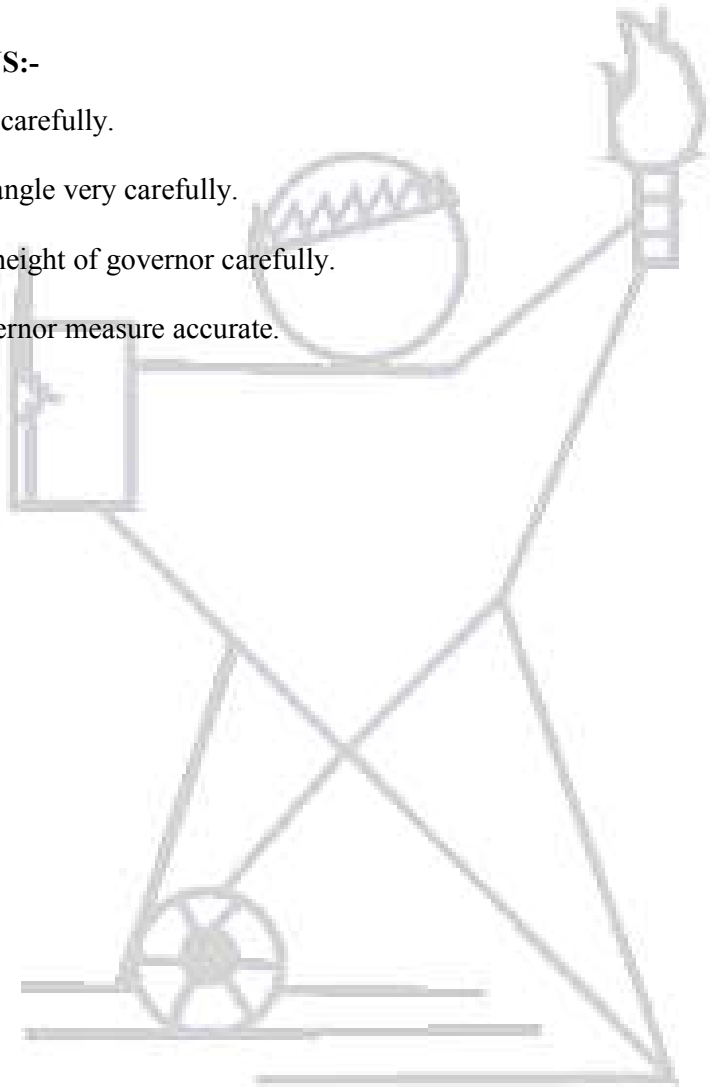
PRECAUTIONS:-

(1) Take reading carefully.

(2) Measure the angle very carefully.

(3) Measure the height of governor carefully.

(4) Speed of governor measure accurate.



Questions:

Q. Explain Function of Governor.
Ans:
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Q. Differentiate between Governor & Flywheel.
Ans:
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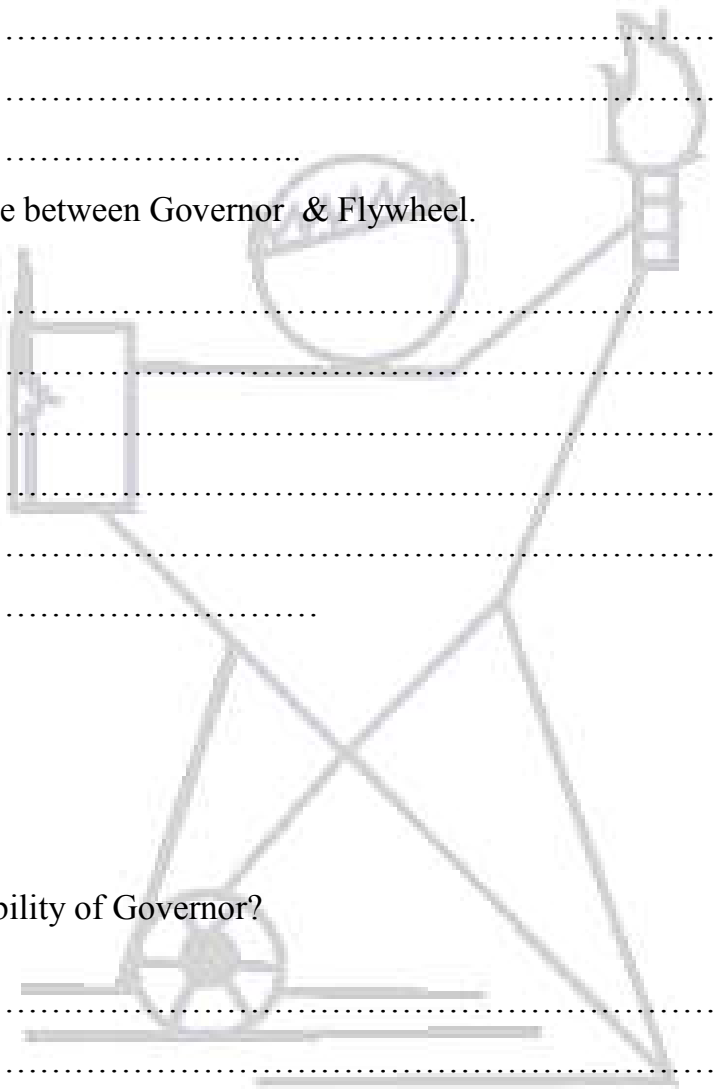

Q. What is stability of Governor?
Ans:
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Q. What is Hunting of Governor?
Ans:

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Q. Define Sensitivity of Governor

Ans:

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Q. Differentiate between Inertia and centrifugal governor

Ans:

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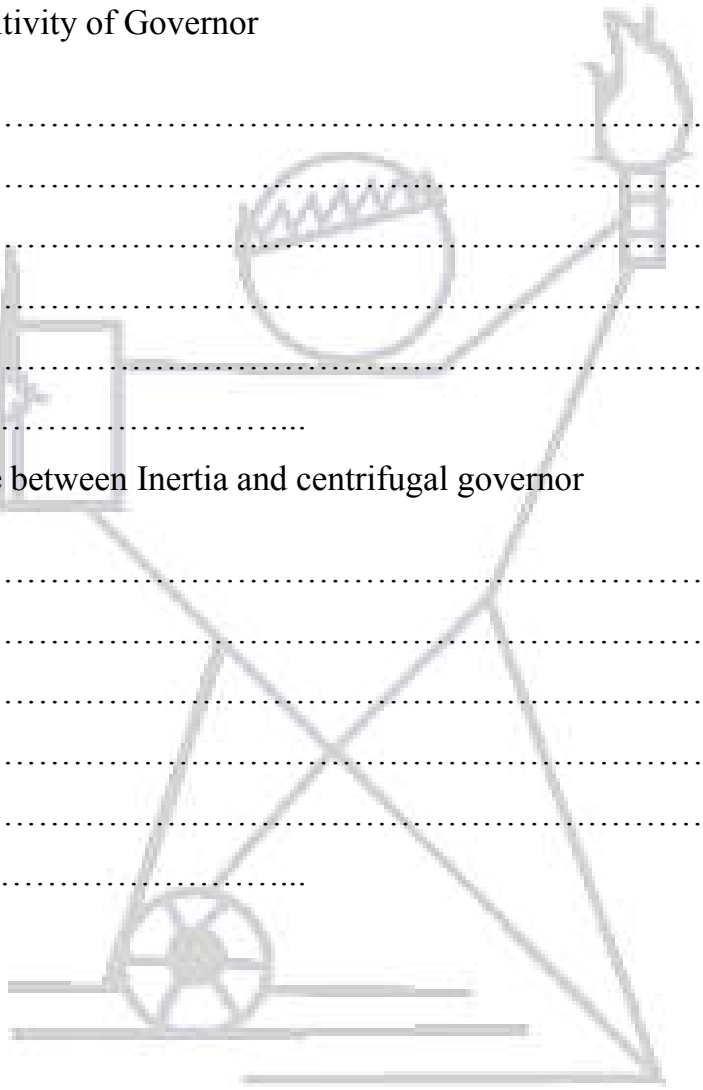
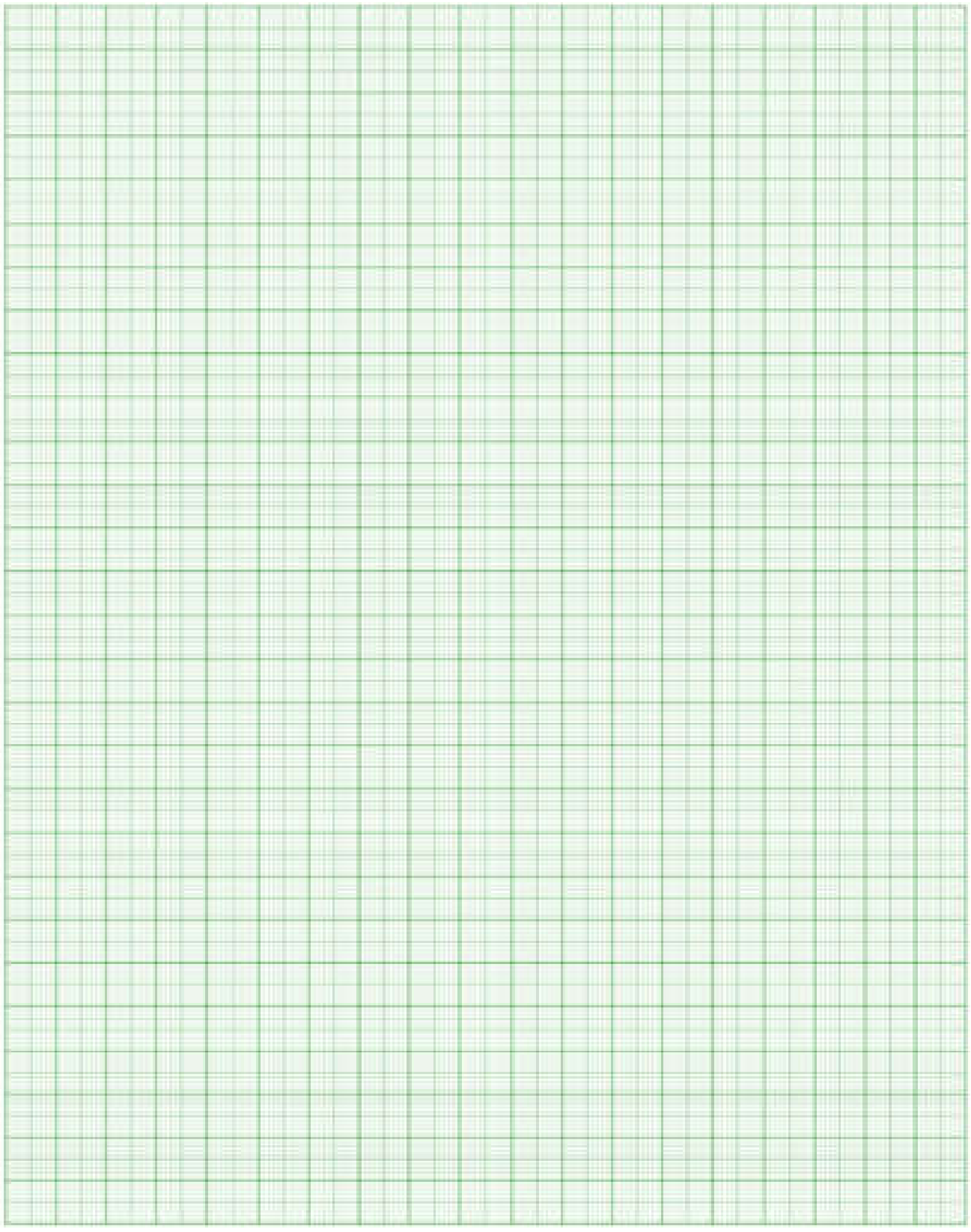




EXPERIMENT No: 05

AIM: - To perform the experiment for static balancing on static balancing machine.

APPARATUS USED: - Static Balancing Machine

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.

PROCESURE: - 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.

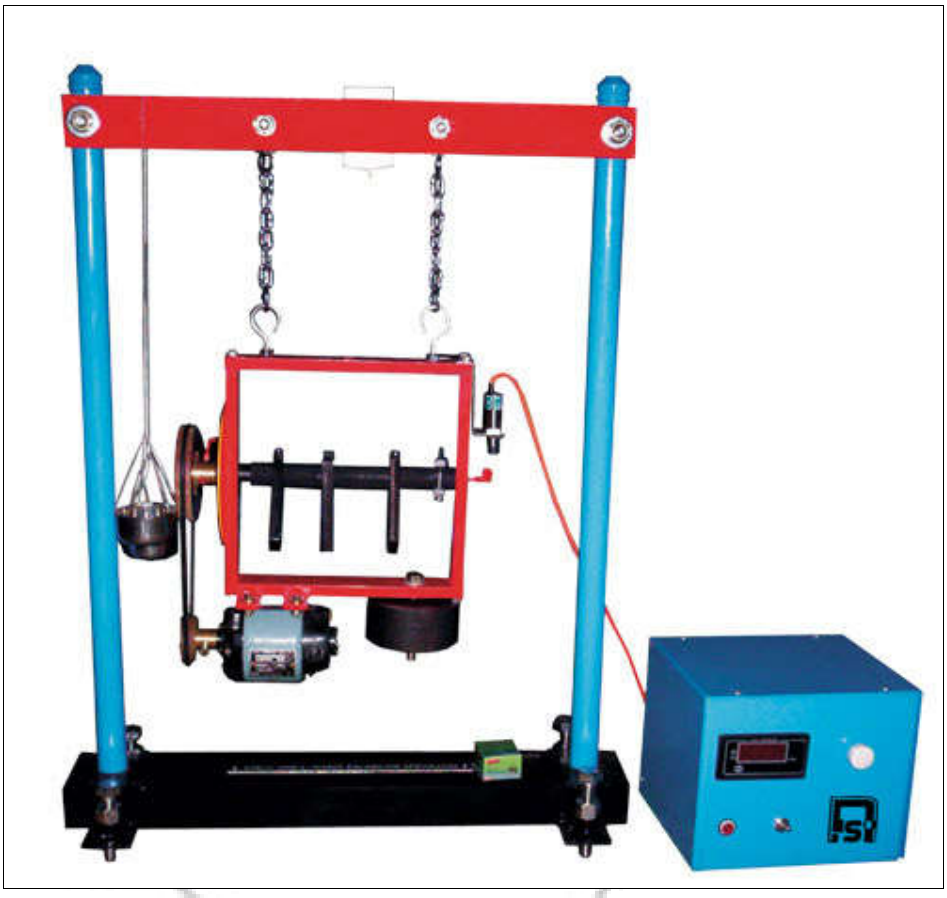


Fig. Experimental model for Static Balancing

For finding out Wr 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 pulley.

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 Wr value of block-1. Repeat this for 2-3 times and find the average no. of balls.

7. Repeat the procedure for other blocks.

OBSERVATION:-

S. No.	Plane	Mass (m) kg	Radius (r) meter	Centrifugal Force/ω^2 =(m.r) kg-m	Distance from R.P	Couple $\div\omega^2$ = (m*r*l) kg-m^2

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

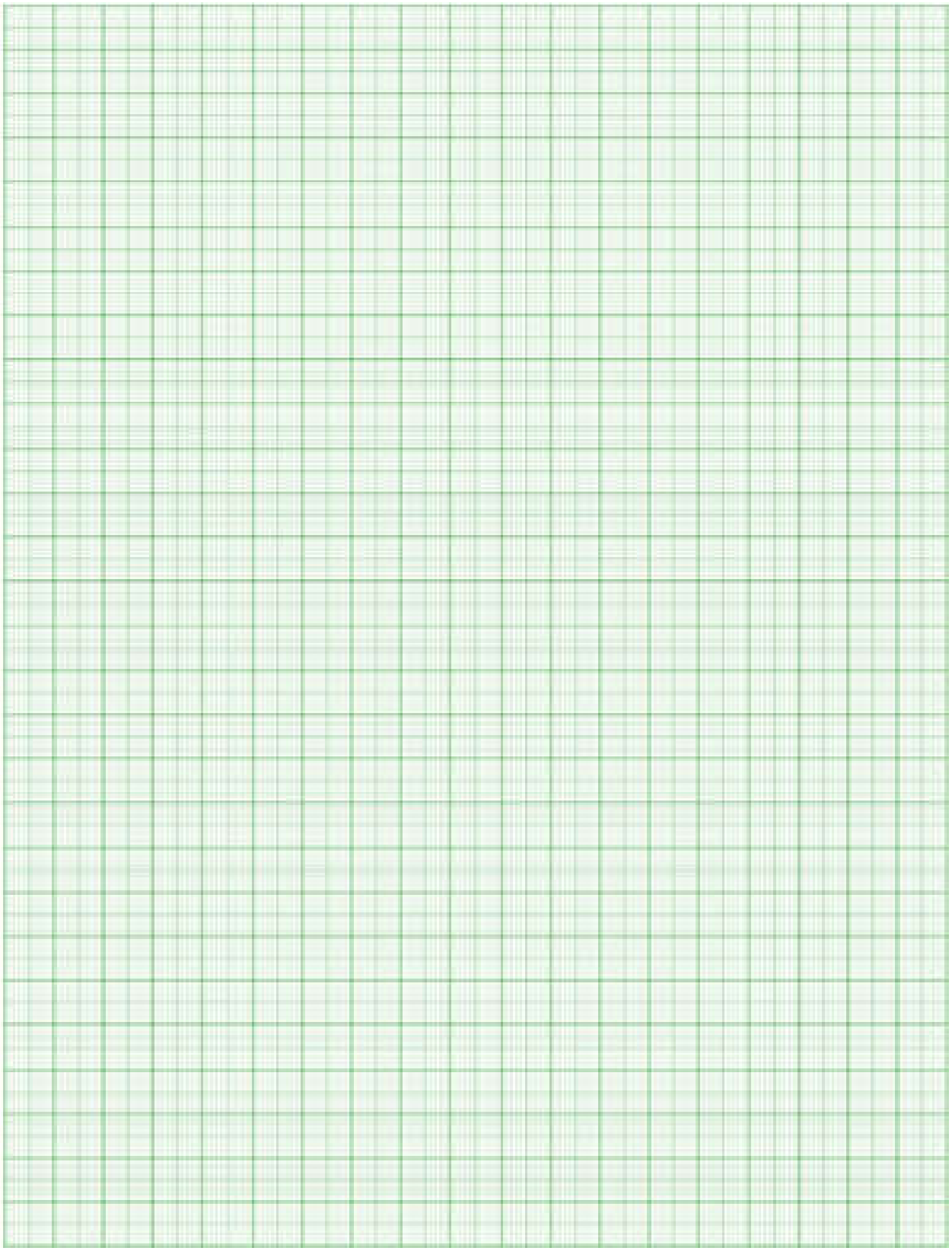
1. First of all, draw the couple polygon from the data which are calculated in table to some suitable scale. The vector distance represents the balanced couple. The angular position of the balancing mass is obtained by drawing, parallel to vector distance. By measurement will be find the angle.

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.

RESULT:-

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.



EXPERIMENT No: 06

AIM: - To perform the experiment for dynamic balancing on dynamic balancing machine.

APPARATU USED: - Dynamic Balancing Machine

THEORY: - When several messes rotate 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 Machine:-

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:

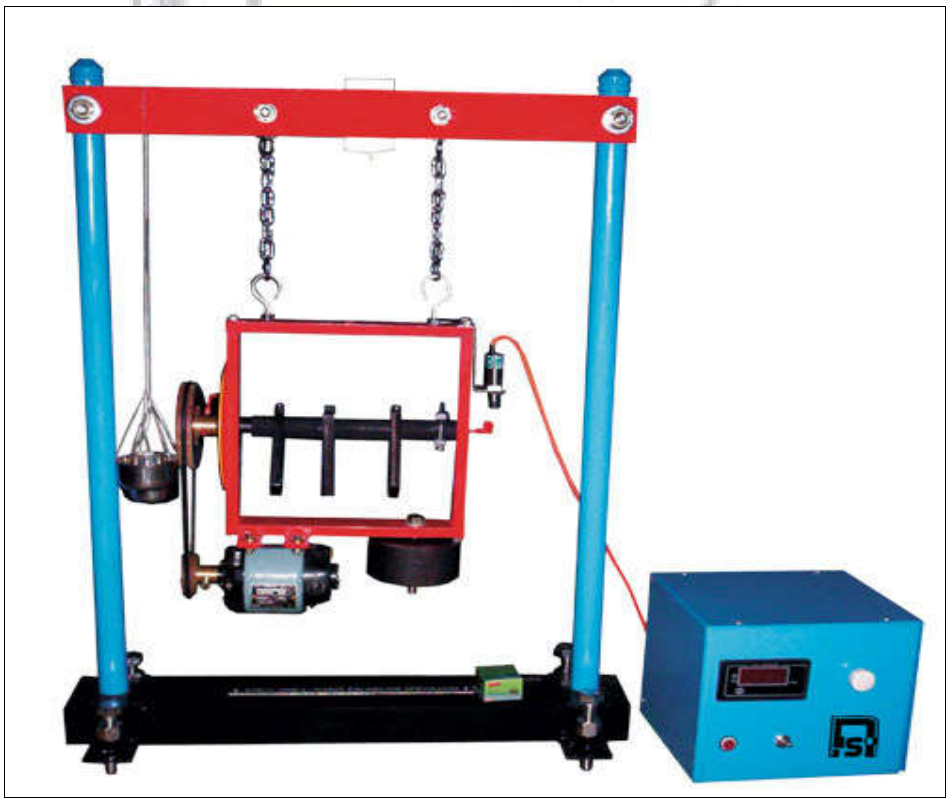


Fig. Experimental model for Dynamic Balancing

First make a test run without attaching 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

OBSERVATION TABLE:-

S No.	TRIAL MASS	AMPLITUDE

CALCULATION & CONSTRUCTION:-

Draw a triangle OBE by taking OE = 2 X_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° i.e. if AB represents the effect of the attached mass at 0°, AD represents the effect of the attached mass at180°.

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 each other at A, it is a parallelogram which means BE is parallel and equal to OD. Thus, 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

$m_c = m \times \frac{OA}{AB}$ at an angle θ from the second reading at 0°

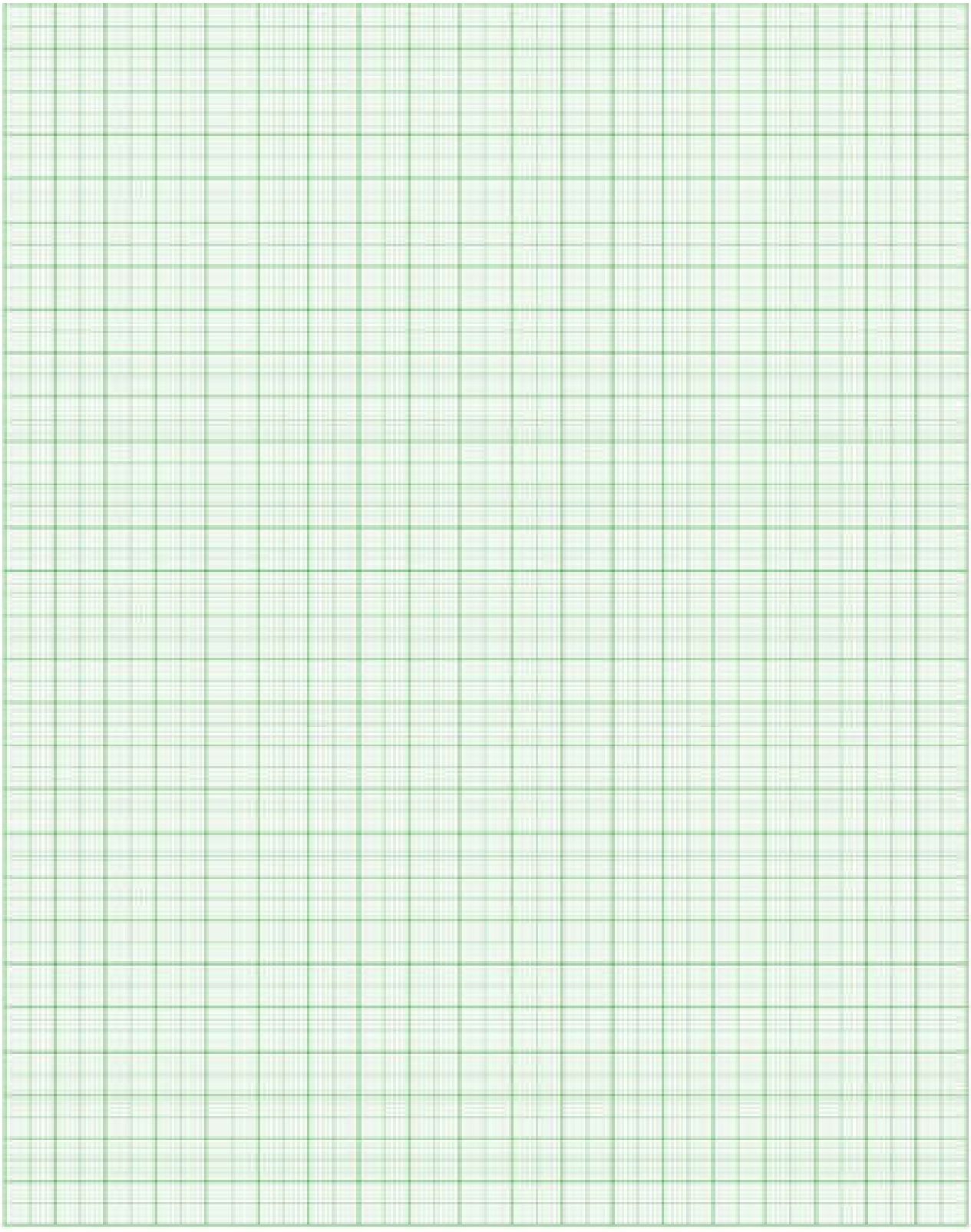
For the correction of the unbalance, the mass mc has to be put in the proper direction relative to AB which may be found by considering the reading X_3.

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' represents X_3, then angle measurement is in taken in the same direction.

RESULT:-

PRECAUTIONS:-

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



Questions:

Q .Why balancing is necessary for high speed engines.
Ans:

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Q. Differentiate between Static and Dynamic balancing.
Ans:

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Q. Why reciprocate mass is partially balanced?
Ans:

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Q. What is variation of tractive force?
Ans:

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Q. Define Swaying Couple.

Ans:

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Q. What is Hammer Blow .

Ans:

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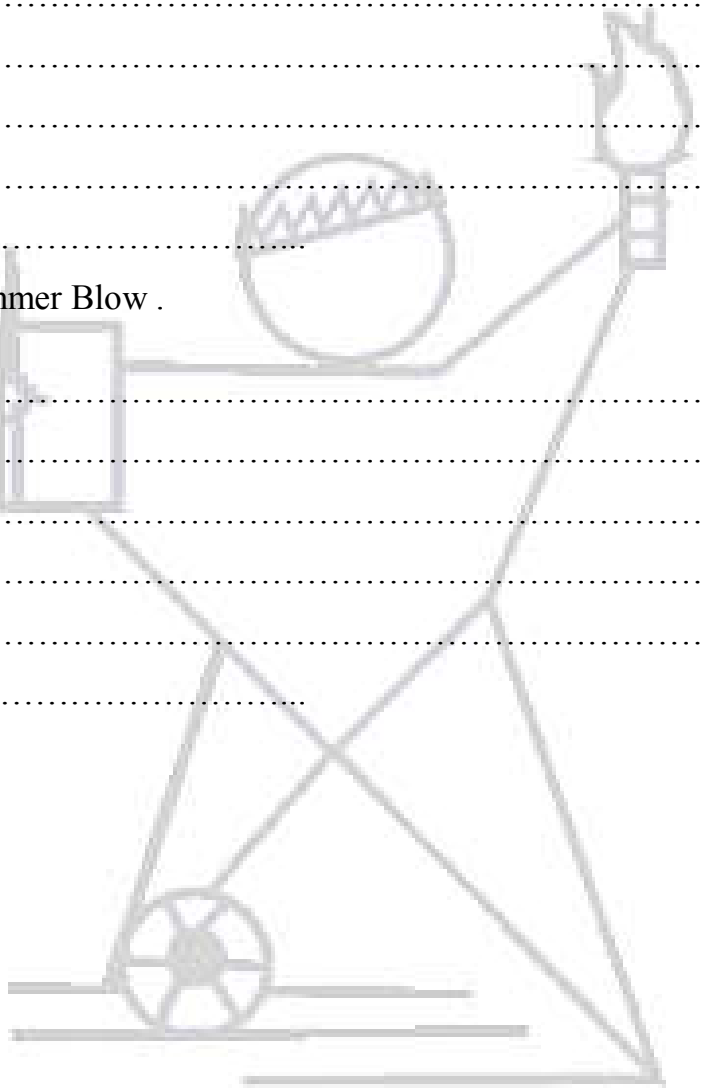

EXPERIMENT No: 07

AIM: - To perform the experiment for measuring the power by prony brake dynamometer and study various types of dynamometers.
APPARATUS: - Models of dynamometer.

THEORY:- The dynamometer is a device used to measure the torque being exerted along a rotating shaft so as to determine the shaft power.
Dynamometers are generally classified into:

1) Absorption dynamometers (i.e. Prony brakes, hydraulic or fluid friction brakes, fan brake and eddy current dynamometers)
2) Transmission dynamometers (i.e. Torsion and belt dynamometers and strain gauge dynamometer)
3) Driving dynamometers (i.e. Electric cradled dynamometer)

PRONY BRAKE: - The prony and the rope brakes are the two types of mechanical brakes chiefly employed for power measurement. The prony brake has two common arrangements in the block type and the band type. Block type is employed to high speed shaft and band type measures the power of low speed shaft.

BLOCK TYPE PRONY BRAKE DYNAMOMETER: - The block type prony brake consists of two blocks of wood of which embraces rather less than one half of the pulley rim. One block carries a lever arm to the end of which a pull can be applied by means of a dead weight or spring balance. A second arm projects from the block in the opposite direction and carries a counter weight to balance the brake when unloaded. When operating, friction between the blocks and the pulley tends to rotate the blocks in the direction of the rotation of the shaft. This tendency is prevented by adding weights at the extremity of the lever arm so that it remains horizontal in a position of equilibrium.

Torque, $T = W*l$ in Nm

Power $P = 2\pi N* T/60$ in N-m/s

$= 2\pi N * W*l/60* 1000$ in kW Where, W= weights in Newton
l = Effective length of the lever arm in meter and
N = Revolutions of the crankshaft per minute.

OBSERVATION TABLE:-

S.N.	SPEED (RPM)	WEIGHT(KG)	DISTANCE OF WT. FROM PULLY CENTER (M)	BRAKING TORQUE(T)

BAND TYPE PRONY BRAKE DYNAMOMETER: - The band type prony brake consists of an adjustable steel band to which are fastened wooden block which are in contact with the engine brake-drum. The frictional grip between the band the brake drum can be adjusted by tightening or loosening the clamp. The torque is transmitted to the knife edge through the torque arm. The knife edge rests on a platform or communicates with a spring balance.

Frictional torque at the drum = F*r

Balancing torque = W*l

Under equilibrium conditions, T = F*r = W*l in Nm. Power = $2\pi N^* T/60$ in N-m/s
$= 2\pi N * W*l/60* 1000$ in kW

ROPE BRAKE DYNAMOMETERS: - A rope brake dynamometers consists of one or more ropes wrapped around the fly wheel of an engine whose power is to be measured. The ropes are spaced evenly across the width of the rim by flywheel. The upward ends of the rope are connected together and attached to a spring balance, and the downward ends are kept in place by a dead weight. The rotation of flywheel produces frictional force and the rope tightens. Consequently a force is induced in the spring balance.

Effective radius of the brake R = (D+ d)/2

Brake load or net load = (W-S) in Newton Braking torque T = (W-S) R in Nm. Braking torque $=2\pi N^* T/60$ in N-m/s
$= 2\pi N * (W-S)R/60* 1000$ in kW D= dia. Of drum
d = rope dia.

S = spring balance reading

FLUID FRICTION (HYDRAULIC DYNAMOMETER):- A hydraulic dynamometer uses fluid-friction rather than friction for dissipating the input energy. The unit consists essentially of two elements namely a rotating disk and a stationary casing. The rotating disk is keyed to the driving shaft of the prime-mover and it revolves inside the stationary casing. When the brake is operating, the water follows a helical path in the chamber. Vortices and eddy-currents are set-up

in the water and these tend to turn the dynamometer casing in the direction of rotation of the engine shaft. This tendency is resisted by the brake arm and balance system that measure the torque.

Brake power = W*N/k,
Where W is weight as lever arm, N is speed in revolutions per minute and k is dynamometer constant.
Approximate speed limit = 10,000rpm

Usual power limit = 20,000kW

BEVIS GIBSON FLASH LIGHT TORSION DYNAMOMETER: -This torsion dynamometer is based on the fact that for a given shaft, the torque transmitted is directly proportional to the angle of twist. This twist is measured and the corresponding torque estimated the relation:

$T=I_P * C*\theta / l$

Where $I_p = \pi d^4/32$ = polar moment of inertia of a shaft of diameter d

θ = twist in radians over length l of the shaft

C = modulus of rigidity of shaft material

Questions:

Q. What is Dynamometer?

Ans:

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Q. Explain different types of Dynamometer.

Ans:

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Q. Function of Rope Break Dynamometer.

Ans:

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Q. Function of Pony Break Dynamometer?

Ans:

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What is Torsional Dynamometer?

Ans:

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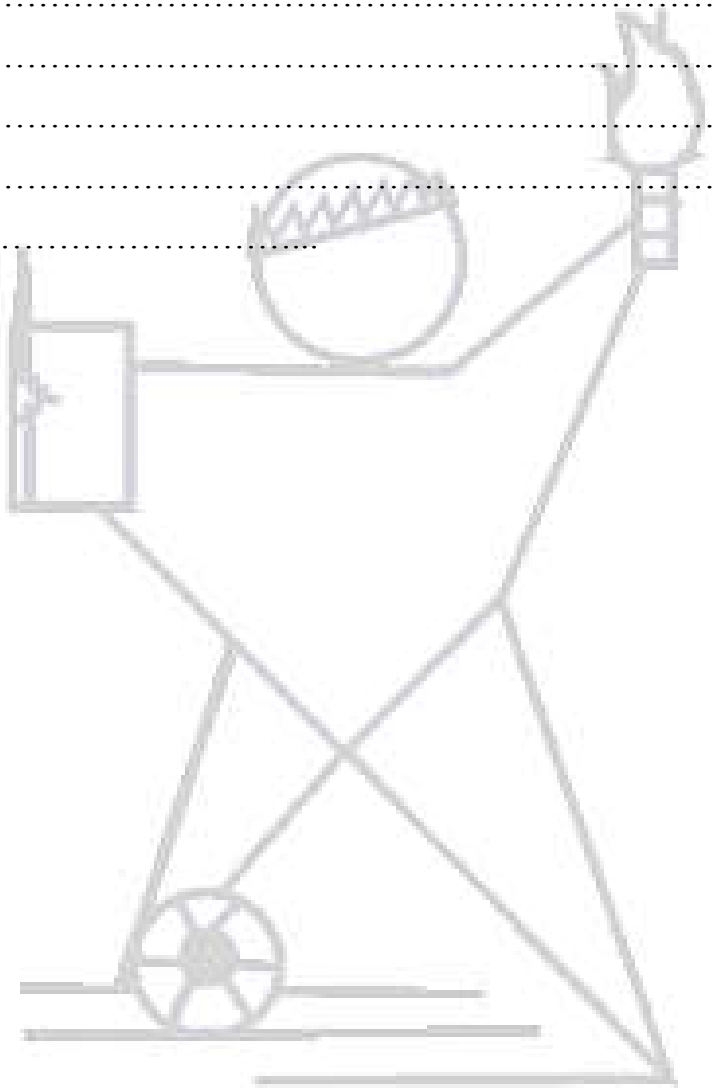


EXPERIMENT No: 08

AIM: - To study working of friction clutches using models

APPRATUS USED: - friction clutches models

THEORY:- A Clutch is a machine member used to connect the driving shaft to a driven shaft, so that the driven shaft may be started or stopped at will, without stopping the driving shaft. A clutch thus provides an interruptible connection between two rotating shafts Clutches allow a high inertia load to be stated with a small power. A popularly known application of clutch is in automotive vehicles where it is used to connect the engine and the gear box. Here the clutch enables to crank and start the engine disengaging the transmission Disengage the transmission and change the gear to alter the torque on the wheels. Clutches are also used extensively in production machinery of all types.

Mechanical Model:- Two inertia's I_1 and I_2 and traveling at the respective angular velocities ω_1 and ω_2, and one of which may be zero, are to be brought to the same speed by engaging. Slippage occurs because the two elements are running at different speeds and energy is dissipated during actuation, resulting in temperature rise. To design analyze the performance of these devices, a knowledge on the following are required.

1. The torque transmitted 2. The actuating force. 3. The energy loss 4. The temperature rise

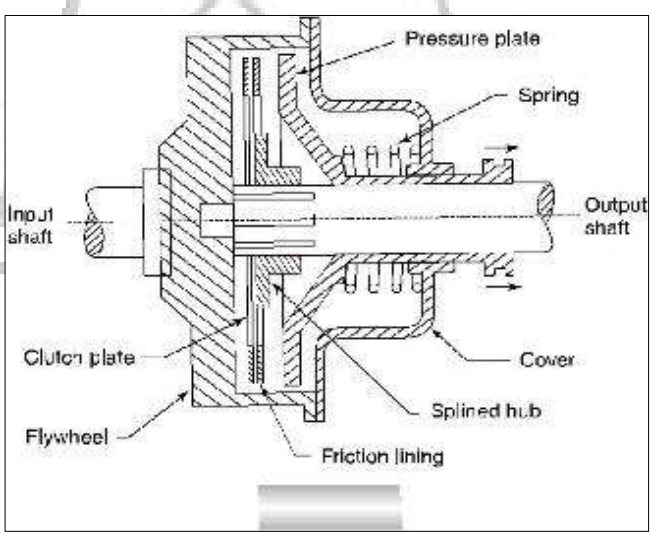


Fig. Mechanical Model of Clutch

Friction Clutches:-

As in brakes a wide range of clutches are in use wherein they vary in their are in use their working principle as well the method of actuation and application of normal forces. The discussion here will be limited to mechanical type friction clutches or more specifically to the plate or disc clutches also known as axial clutches.

Frictional Contact axial or Disc Clutches An axial clutch is one in which the mating frictional members are moved in a direction parallel to the shaft. A typical clutch is illustrated in the figure below. It consist of a driving disc connected to the drive shaft and a driven disc connected to the driven shaft. A friction plate is attached to one of the members. Actuating spring keeps both the members in contact and power/motion is transmitted from one member to the other. When the power of motion is to be interrupted the driven disc is moved axially creating a gap between the members as shown in the figure.

METHOD OF ANALYSIS: - The torque that can be transmitted by a clutch is a function of its geometry and the magnitude of the actuating force applied as well the condition of contact prevailing between the members. The applied force can keep the members together with a uniform pressure all over its contact area and the consequent analysis is based on uniform pressure condition-

Uniform Pressure and wear:- However as the time progresses some wear takes place between the contacting members and this may alter or vary the contact pressure appropriately and uniform pressure condition may no longer prevail. Hence the analysis here is based on uniform wear condition.

WORKING PRINCIPLE & CONSTRUCTIONAL DETAILS

Single Plate Clutch:- A simplified sketch of a single plate clutch is given in fig 1 Friction plate is held between the flywheel and the pressure plate. There are springs (the number may vary, depending upon design) arranged circumferentially, which provide axial force to

keep the clutch in engaged position. The friction plate is mounted on a hub which is splined from inside and is thus free to slide over the gear box shaft. Friction facing is attached to the friction plate both sides to provide two annular friction surfaces for the transmission of power.

A pedal is provided to pull the pressure plate against the spring force whenever it is required to be disengaged. Ordinarily it remains in engaged position as is shown in fig.9.2.When the clutch pedal is pressed, the pressure plate is moved to the right against the force of the springs. This is achieving by means of a suitable linkage and a thrust bearing. With this movement of the pressure plate, the friction plate is released and the clutch is disengaged.

In actual practice the construction of the clutch differs. The pressure plate, the springs, the release levers and the cover form a sub assembly, called the cover assembly which can be mounted directly to the engine block, of course, placing the clutch plate in between the flywheel and the pressure plate with the clutch shaft inserted in this arrangement.

Advantages:-

1 With the single plate clutch, gear changing is easier than with the cone clutch, because the pedal movement is less in this case.

2 It does not suffer from disadvantages of cone clutch i.e. bindings of cones etc. and hence it is more reliable.

Disadvantages: - As compared to cone clutch, the springs have to be more stiff and this means greater force require to be applied by the driver while disengaging. In the assembled position releases lever rest against the centre opening of the cover pressing there is an eyebolt nut which causes the strut to pull the pressure plate against the springs, thus holding together the assembly. When the cover is bolted onto the flywheel, the pressure plate is further pushed back against the springs, causing them to be compressed further, which

relaxes the release levers. Anti rattle springs serve to prevent the undesirable noise due to release levers when the clutch is in the engaged position.

Diaphragm Spring Type Single Plate Clutch: - The construction of this type of clutch is similar to that of the single plate type of clutch described above except that here diaphragm springs (also called Belleville springs) are used instead if the ordinary coil springs. In the free condition, the diaphragm spring is of conical form but when assembled, it is constrained to an approximately flat condition because of which it exerts a load upon the pressure plate. A diaphragm spring type clutch is shown in fig. where shows the clutch in the engaged position and in the disengaged position.

It is seen from the above figures that the diaphragm spring is supported on a fulcrum retaining ring so that any section through the spring can be regarded as a simple lever. The pressure plate E is movable axially, but it is fixed radically with respect to the cover. This is done by providing a series of equally spaced lugs cast upon the back surface of the pressure plate. The drive from the engine flywheel is transmitted through the cover, pressure plate and the friction plate to the gear box input shaft.

The clutch is disengaged by pressing the clutch pedal which actuates the release fingers by means of a release ring. This pivots the spring about its fulcrum, relieving the spring load on the outside diameter, thereby disconnecting the drive. In this clutch, three straps of spring steel are placed equilaterally so that their outer ends are riveted to the cover, while their centers are riveted to the pressure plate. Drive is transmitted from the cover to the pressure plate via the straps along lines of action through the strap rivet centers. Spring flexure of the straps permits the axial movement of the pressure plate relative to the cover.

Advantages:-This type of clutch has now virtually superseded the earlier coil spring design in many countries in clutch sizes ranging upto 270 mm, in diameter, although in case of heavy vehicles, the coil spring type clutches are still being used because of the difficulty to

provide sufficient clamping force by a single diaphragm spring. The diaphragm spring however, offers certain distinct advantages.

(1) It is more compact means of storing energy. Thus compact design results in smaller clutch housing.

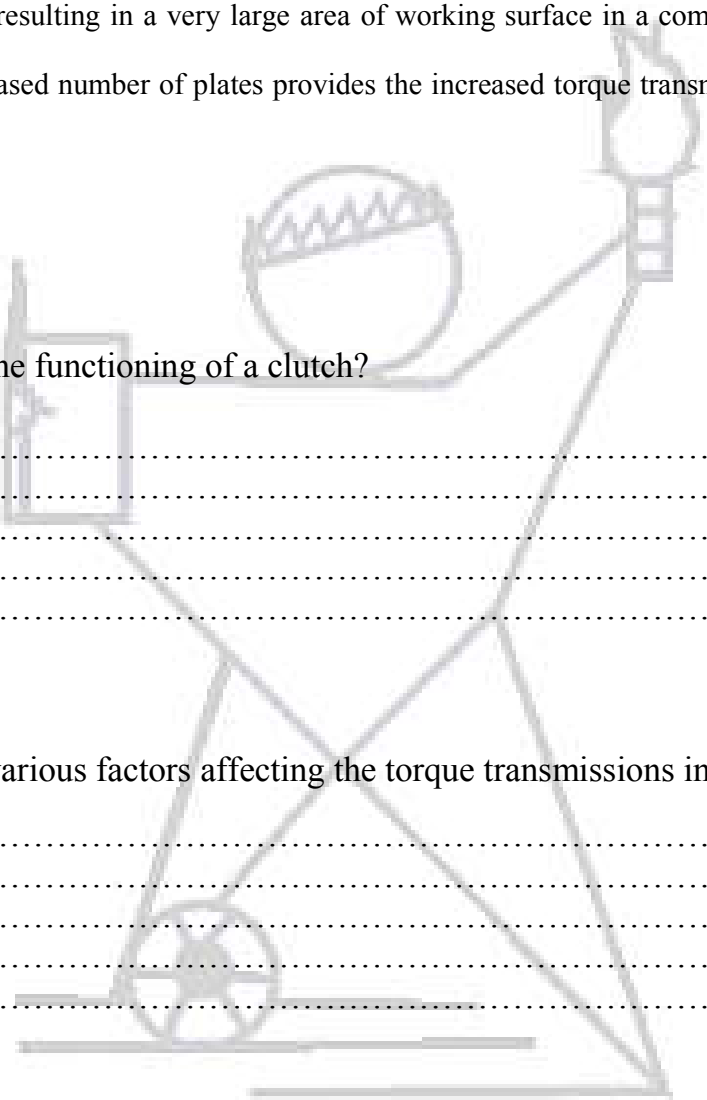
(2) As the diaphragm spring is comparatively less affected by the centrifugal forces, it can withstand higher rotational speeds. On the other hand, coil springs have tendency to distort in the transverse direction at higher speeds.

(3) In case of coil springs, load deflection curve is linear. Therefore, with the wear of the clutch facing the springs has less deflection due to which they would apply less force against the clutch plate. On the other hand, in case of diaphragm spring, the load deflection curve is not linear therefore, in this case, as the clutch facing wears, force on the plate gradually increases, which means that even in the worn out condition, the spring force is not less than its value in case of new clutch. Further, it is also seen that the load deflection curve depends upon the ratios h/t where h is the free dish height and t is the thickness of the spring. Therefore, in this case with suitable design, the load deflection curve can be improved to give lower release loads.

(4) The diaphragm acts as both clamping spring and release levers. Therefore, many extra parts like struts, eye bolts, levers etc. are eliminated in the diaphragm spring, because of which the loss of efficiency due to friction wear of these parts also does not occur, which results in the elimination of squeaks and rattles.

Multiplate clutch: - These clutches are used in heavy commercial vehicles, racing cars and motor cycles for transmitting high torque. In comparison to single plate type, these switches are smoother and easier to operate due to their assembly of friction surfaces contact. They may be used where space is very limited, i.e. in automatic transmission and motor cycles. In the latter cases a multiplate clutch of small operator transmits approximately the same torque as a single plate clutch of twice that diameter. These are also

used in cases where very large torques are to be transmitted i.e. in heavy commercial vehicles, cars, special purpose military and agricultural vehicles. These clutches may be dry or wet. When the clutch of this type is operated in a bath of oil, it is called a wet clutch. But these oil immersed or wet clutches are generally used in conjunction with or as a part of the automatic transmission. It consists of a number of thin plates connected alternately to input and output shaft resulting in a very large area of working surface in a comparatively small space. The increased number of plates provides the increased torque transmitting ability of the clutch.



Questions:-

1. What is the functioning of a clutch?

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2. Discuss various factors affecting the torque transmissions in a clutch.

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3. Explain the working of multi plate dry clutch.

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4. What are the essential properties required for a clutch facing materials.

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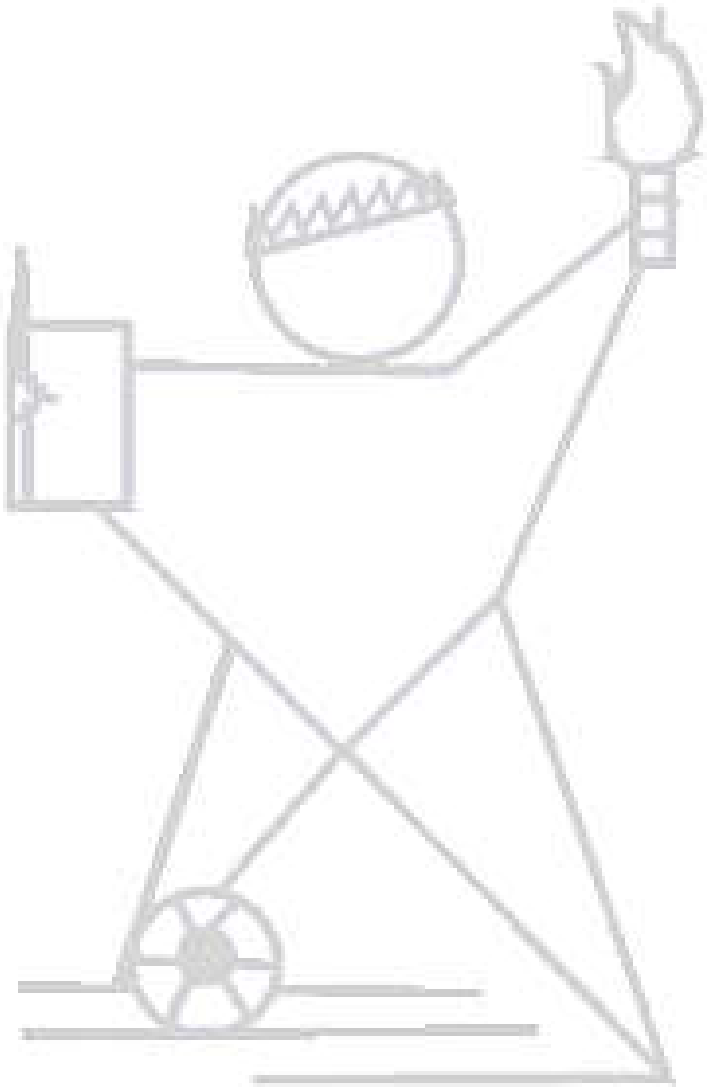


EXPERIMENT No: 09

AIM:- To find out jump phenomenon of Cams and followers with the help of test kit.

APPRATUS USED:- Cams and followers test kit.

THEORY:- The machine is a motorized unit consisting of a cam shaft driven by a DC motor. The shaft runs in a double ball bearing. At the end of the cam shaft a cam can easily mounted. As the follower is properly guided in gun metal bushes and the type of the follower can be changed to suit the cam fitted to note the follower displacement for the angle of CAM rotation. A spring is used to provide controlling force to the system. Weights on the follower rod can be adjusted as per requirements. The arrangement is provided to vary the speed of cam shaft. The machine is particularly very useful for testing the cam performance for jump phenomenon during operation. This machine clearly shows the effect of change of inertia forces on jump action of cam follower during the operation. It is used for testing various cam and follower pairs, i.e. (1) Circular arc cam with mushroom follower, (2) Tangent cam with roller follower, and (3) An eccentric cam with knife edge follower.

Cam Jump: - In cam follower system, the follower is pressed against the cam surface by means of a Retaining spring .Due to inertia of follower and beyond a particular speed, during a part of cam rotation the follower may lose contact with the cam this phenomenon is known as cam jump ors are bounce which is a type of vibration. This is a transition condition, which occurs only with high speed, highly flexible cam follower system. With jump, cam and followers separate owing to exclusive unbalanced force excluding the spring force during the period of negative acceleration. This is absolutely undesirable, as the fundamental function of cam follower system is to constrain and to produce desired follower motion. But due to jump it cannot be achieved. Also the life of cam flank surface reduces due to hammering action of followers on cam and noise is generated which further result in

vibrations of this system. The jump phenomenon can be avoided by limiting the speed of cam or by increasing the stiffness of retaining spring.

Assembly: - The unit is provided with the push rod in two bush bearings. The same unit is to be used for the flat face and roller follower. While assembling the unit following precautions should be taken.

1. The horizontality of the upper and lower glands should be checked by spirit level.

2. The supporting pillers should be properly tightened with the lock nuts.

Specifications:

A. The following Types of cams are selected to very jump speed

a) Circular Arc cam, b) Eccentric cam and c) Tangent cam

B. The following type of followers are selected to verify jump speed

a) Mashroom follower, b) Roller follower and c) Knife edge follower

Compression Springs

The approximate stiffness are 4.5 kg/cm and 5.5 kg/cm for the bigger and smaller spring respectively.

Weights

a. All weights have a central hole so that they can be accommodated in the push rod. Total weight provided is 1600 gms.

b. The weights of the reciprocating parts are as follows –

i. Push rod with lock nut _____ Kg

ii. Rest plate and two lock nuts – 784 kg

iii. Spring, seat and lock nut _____Kg

iv. Weight of spring – _____ (1/3 of the spring weight is to be taken as reciprocating weight)

v. Roller follower – _____ gms

vi. Mushroom follower – _____ gms

vii. Knife edge follower – _____ gms

PROCEDURE:-

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

2. For this experiment, arrange the set up as shown in fig. The exact profile of the cam be obtained by taking observations n Vs. θ. Where n= displacement of the follower from rotation initial position and θ = angle of cam rotation with reference from axis of symmetry chosen. By differentiating the n- θ curve once and twice, the velocity and acceleration curves can be plotted for the follower and cam under study.

3. Speed – To observe the phenomenon of jump. For this, use of a stroboscope is necessary. The speed of cam rotation and stroboscope frequency on neon lamp are gradually and simultaneously increased and at the time jump to occur the follower is seen to loose contact with the cam. When jump occurs the follower pounds on the cam surface giving a good thumping sound.

Upward inertia force = Downward retaining force

$$\frac{w\omega^2 r}{g} = (W + S)$$

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

Where,

W = Follower assembly weight.

S = Spring force

ω = Angular velocity of cam

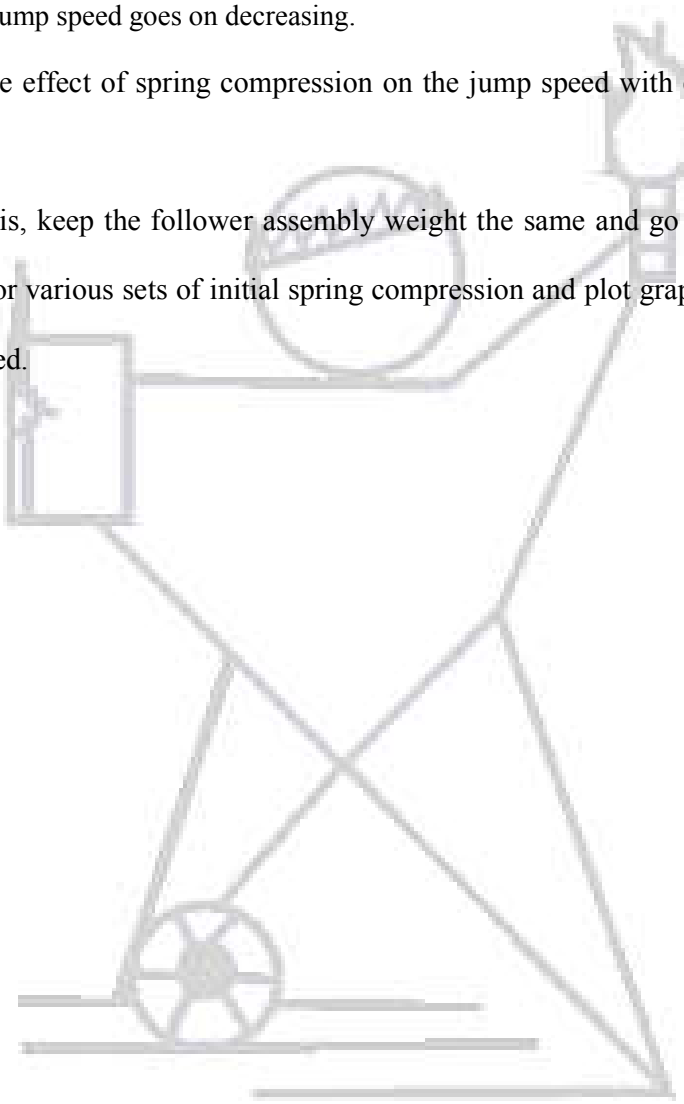
r = Distance according to geometry of cam.

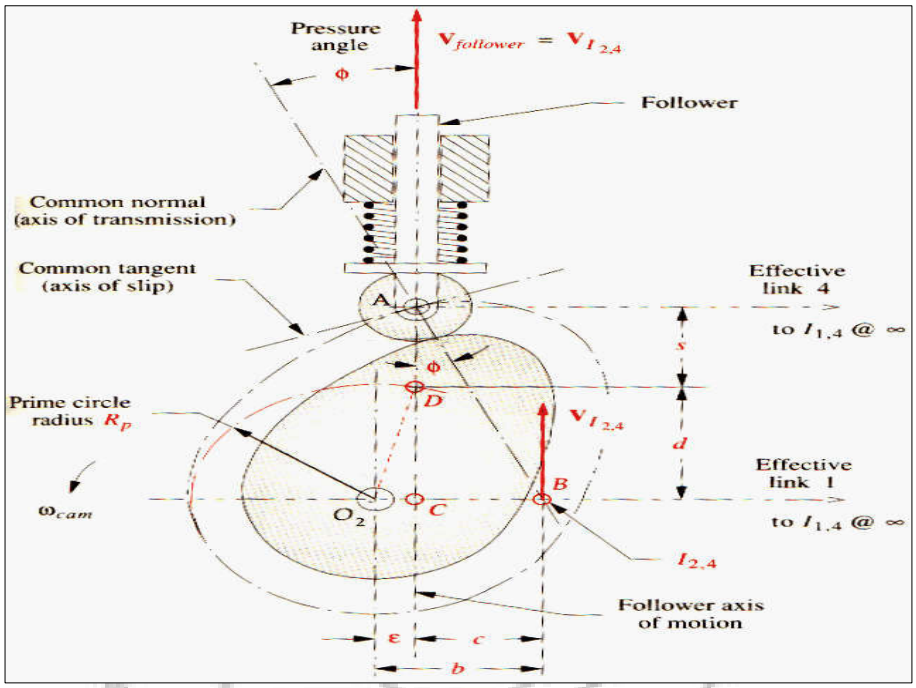
1.To study the effect of follower assembly weight on the jump speed when spring force is kept constant.

2.To study this effect keep the initial spring compression at a certain level and observe jump speed for different follower weights by adding successively and plot the graph of follower weights Vs. jump speed. This relation shows that as the follower weights increases the jump speed goes on decreasing.

3.To study the effect of spring compression on the jump speed with constant follower weight.

4.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 graph of spring force Vs. jump speed.





OBSERVATION:-

Result Table without load

Speed of camshaft for different followers

Type of cam	Roller	Mushroom	Knife edge
Eccentric			
Circular arc			
Tangent			

Result Table with load = 1 kg

Speed of camshaft for different followers

Type of cam	Roller	Mushroom	Knife edge
Eccentric			
Circular arc			
Tangent			

RESULT:-

APPLICATION:-

(i) Cams are used in Automatic machines

(ii) In internal combustion engine

(iii) In machine tools

(iv) Printing Control mechanisms

QUESTIONS:-

(i) Define about cam & follower, Classification of cam & follower, advantage & disadvantage, Applications.

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(ii) Define Disc cam nomenclature.

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(iii) Define the cut off-set position of follower motion.

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