SRI VENKATESHWARAA
COLLEGE OF ENGINEERING AND TECHNOLOGY

(Approved by AICTE & Affiliated to Pondicherry University)
Ariyur, Puducherry-605 102.

DEPARTMENT OF MECHANICAL ENGINEERING

B.TECH –Sixth semester

DYNAMICS Of MACHINE LAB/ MEP62

LAB MANUAL

Prepared by

Mr. G.PALANIVEL, M.E.

AP/MECH

CONTENTS

Expt. No	Date	Title of Experiment	Page No.	Mark	Signature
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					

Completed date:

Average Mark: **Completed / incomplete** **Signature of Staff- in- charge**

MEP62 DYNAMICS OF MACHINES LABORATORY (0 0 3 2)

LIST OF EXPERINMENTS

1. Compound pendulum
2. Radius of gyration, moment of inertia by Bi-Filar suspension
3. Radius of gyration, moment of inertia by Tri-Filar suspension
4. Single rotor system (Un-damped)
5. Double rotor system (Un-damped)
6. Watt Governor
7. Porter Governor
8. Proell Governor
9. Hartnell Governor
10. Verification of gyroscopic relation
11. Spring mass system
12. Natural frequency of combination of springs – springs in parallel, springs in series
13. Critical shaft of Whirling of shafts
14. Cam profile analysis

COMPOUND PENDULUM

EX.NO: **DATE:**

Aim:

To determine the radius of gyration and mass moment of inertia of the given rectangular rod experimentally.

Apparatus required:

1. Vertical frame, 2. Rectangular rod, 3. Stop watch and 4. Steel rule etc

Description of the set up :

The compound pendulum consists of a slotted steel bar. The bar is supported in the hole by the knife-edge. It is possible to change the length of suspended pendulum by loosening the nut.

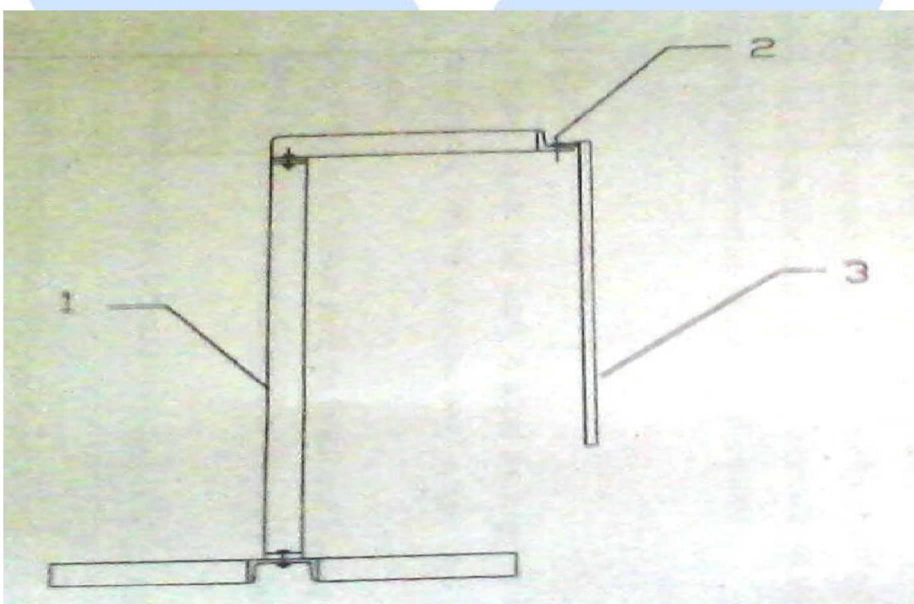
Procedure:

1) Support the rod in any desired length.
2) Note the length of suspended pendulum and determine 'OG'.
3) Allow the bar to oscillate.
4) Find out time 't' for say 10 oscillation.
5) Determine periodic time 'T' experimentally by the formula.
6) Also find out periodic time 'T' theoretically by given formula.
7) Find out moment of Inertia experimentally and theoretically.
8) Repeat the experiment with different length of suspension.
9) Complete the observation table given below.

Observation table:

Sl. No.	Length of pendulum in m. 'L'.	Dist. of C.G. i.e. 'OG' in cm.	No. of oscillation 'n'	Time for 'n' no. of oscillation 't' sec.	Periodic time 'T' (Exp.)	Experimental 'k'	Theoretical 'k'

Diagram:



Calculations:

i) Find ‘k’ experimental from the relation

$$T = 2\pi \sqrt{\frac{K^2 + (OG)^2}{g\,(OG)}}$$

Where, T = Periodic time. = t/n

t = Time for ‘n’ oscillation.

n = No. of oscillation.

g= 9.81 m/sec^2

OG = Distance of the C.G of rod from support :400mm

L =Free length of suspended pendulum : 750mm. Wt. of beam :2.2 Kgs.

Find K_{Exp}

$$K_{ther} = \frac{L}{2\sqrt{3}}$$

Compare values ‘k’ obtained theo. And Expt.

Result:

GOVERNOR (WATT, PORTER GOVERNOR)

EX.NO: **DATE:**

Aim:

To determine the characteristic curves of the given governor.

Apparatus Required:

1. Digital rpm indicator
2. Sleeve weights
3. Porter arm setup
4. Measuring tape

Description of the setup:

The drive unit consists of a DC electric motor connected through belt and pulley arrangement. Motor and test setup are mounted on a M.S. fabricated frame. The governor spindle is driven by motor through V belt and is supported in a ball bearing.

The optional governor mechanisms can be mounted on spindle. Digital speed is controlled by the electronic control unit. A rpm indicator with sensor to determine the speed. A graduated scale is fixed to the sleeve and guided in vertical direction. Sleeve displacement is to be noted on the scale provided.

The centre sleeve of the Porter and Proell governors incorporates a weight sleeve to which weights may be added. The Hartnell governor provides means of varying spring rate and initial compression level and mass of rotating weight. This enables the Hartnell governor to be operated as a stable or unstable governor.

DC motor with drive: ½ HP motor and DC drive control for speed variation. Separate linkages for governor arrangements (Porter, Proell and Hartnell) are provided using same motor and base.

Experimental procedure :

The control unit is switched on and the speed control slowly rotated, increasing the governor speed until the center sleeve rises off the lower stop and aligns with the first division on the graduated scale. The sleeve position and speed are then recorded. Speed may be determined using hand tachometer on the spindle. The governor speed is then increased in steps to give suitable sleeve movements, and readings repeated at each stage throughout the range of sleeve movement possible.

The result may be plotted as curves of speed against sleeve position. Further tests are carried out changing the value of one variable at a time to produce a curve.

1) WATT GOVERNOR:

Arrangement is shown in fig.

Dimensions

a) Length of each link L = 0.125 m.
b) Initial height of governor h_0 = 0.115 m.
c) Initial radius of rotation r_o = 0.117 m.
d) Weight of each ball assembly w = 0.5 Kgs.

Go on increasing the speed gradually and take the readings for speed of rotation 'N' and corresponding sleeve displacement 'X' radius of rotation 'r' at any position could be found as follows –

i) Find height $h = h_0 - x/2$ mtr.
ii) Find 'α' by using Cos α = h / L in degrees
iii) Then r = 0.05 + L Sin α mtr.
iv) Angular Velocity '$\omega = 2\pi N/60$ rad/sec

Observation table :

Sr. No.	Speed in RPM $\omega=2\pi N/60$	Sleeve displacement (X)	Height (h)	Cos α = h / l	Radius of rotation (r)	Force F = $w\omega^2 r/g$ (Kg)

Following graphs may then be plotted to study governor characteristics

1) Force v / s radius of rotation.
2) Speed v / s Sleeve displacement.

2) PORTER GOVERNOR :

Arrangement is shown in fig.

Dimensions:

a) Length of each link L = 0.125 m
b) Initial height of governor h_0 = 0.115 m
c) Initial radius of rotation r_0 =0.117 m
d) Weight of each sleeve = 0.5 Kg
e) Weight of each ball W =0.5 Kg.

1) Take the actual weight of sleeve weight w
2) Go on increasing the speed gradually and take the reading of speed of rotation 'w' and corresponding sleeve displacement 'x'.

Radius of rotation 'r' at any position could be found as follows:-

1) Find Height, $h = h_0 – x/2$.
2) Find, $\alpha= \cos^{-1} (h/L)$ in degrees
3) Then, $r = 0.05+L \sin \alpha$ mtr.
4) Angular Velocity 'ω' $=2 \pi N/60$ rad/sec
5) $F = W. \omega^2 .r/g$

Observation table:

WEIGHT OF SLEEVE = 0.5 KG (Adding weight=1 kg (0.5+0.5))

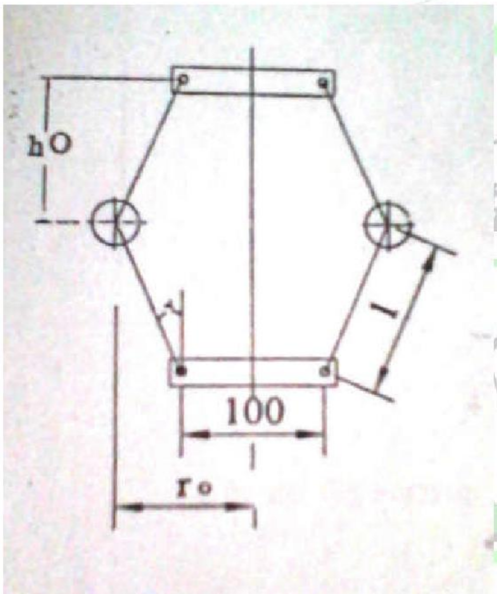
Sr. No.	**Motor Speed N**	**Speed in RPM $\omega=2\pi N/60$**	**Sleeve displacement (X)**	**Height (h)**	**$\cos \alpha$ = h / l**	**Radius of rotation (r)**	**Force F = $w \omega^2 r / g$ (Kg)**

Following graphs may then be plotted to study governor characteristics.

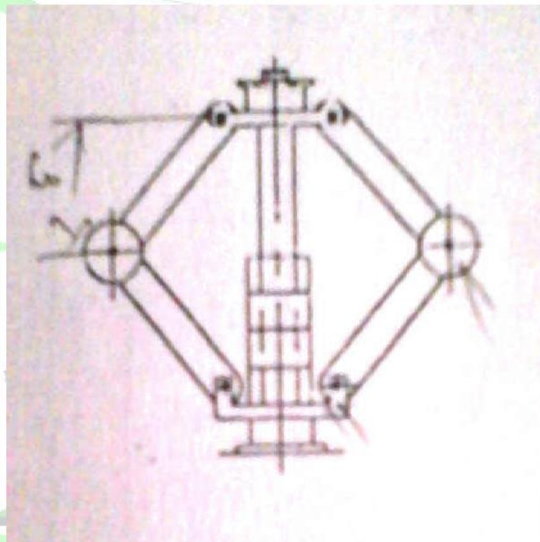
I. Force v / s Radius of rotation.

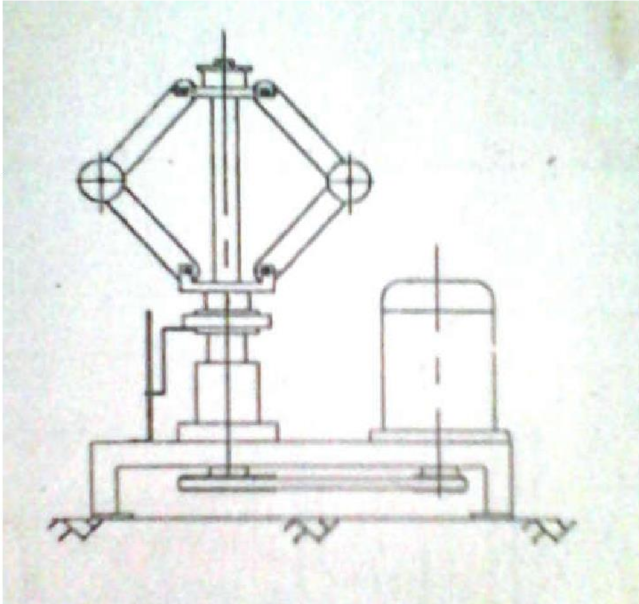
II. Speed v /s Sleeve displacement.

Diagram:



Watt Governor


Porter Governor



Watt Governor Fig. No. 5.1

Model calculation:

Result:

Thus the characteristic curves of the porter governor are determined.

VERIFICATION OF GYROSCOPIC RELATION

EX.NO: **DATE:**

Aim:

To determine the active and reactive gyroscopic couples and compare them.

Apparatus Required:

1. Gyroscopic setup. 2. Weight 3. Tachometer

Technical data:

1) Weight of Rotor = 4.2 Kg.
2) Rotor Diameter = mm
3) Rotor Thickness = 10 mm
4) Moment of Inertia of the disc, coupling and motor rotor about central axis = 0.67 Kg/cm.sec^2
5) Distance of bolt of weight pan from disc center = mm
6) Motor – AC / DC Fractional H.P. single phase. 6000 rpm

Procedure:

1. The disc as made to rotate at a constant speed at a specific time using variable voltage transformer.
2. The speed of the (N) disc is measured using a tachometer or a stroboscope.
3. A weight /mass is added on the extending platform attached to the disc.
4. This causes an active gyroscopic couple and the whole assembly (rotating disc, rotor and weight platform with weight) is standing to move in a perpendicular plane to that of plane of rotating of disc. This is called gyroscopic motion.
5. The time taken (t) to traverse a specific angular displacement (φ =60°) is noted.

Formula used:

2 2 Mass moment of inertia of the disc, I = md /8, kg-m , m-mass of the disc and d-dia of the disc.

Angular velocity of the disc, $\omega = 2\pi N / 60$, rad/s, N-speed of disc in rpm

Reactive gyroscopic couple, $C_r = I.\omega.\omega_p$ Nm and Active gyroscopic couple, $C_a = W \times L$,

W-weight added = mg, N and L-distance between centers of weight to center plane of disc.

Sl no	Speed of disc, N, rpm	Weight added m, kg	Time taken for 60° precision t, sec	Active couple $C_a = W \times L$ Nm	Reactive couple $C_r = I.\omega.\omega_p$ Nm

Graph:

1. Active couple Vs. Reactive couple
2. Weight added Vs. Reactive couple

Model calculation:

Result:

Thus the active and reactive gyroscopic couples are calculated and compared

DETERMINATION OF WHIRLING SPEED OF SHAFTS

EX.NO: **DATE:**

Aim:

To determine the whirling speed for various diameter shafts experimentally and compare it with the theoretical values.

Apparatus Required:

1) Shaft
2) AC voltage regulator
3) Digital tachometer
4) chuck key

Description of the setup:

The apparatus is used to study the whirling phenomenon of shafts. This consists of a frame in which the driving motor and fixing blocks are fixed. A special design is provided to clear out the effects of bearings of motor spindle from those of testing shafts.

Procedure:

1) The shaft is to be mounted with the end condition as simply supported.
2) The speed of rotation of the shaft is gradually increased.
3) When the shaft vibrates violent in fundamental mode the speed is noted down.
4)The above procedure is repeated for the remaining shafts

Observation:

Young's modulus, E = , N / m2
Length of the shaft, L = , m

Formula:

Theoretical whirling speed, Nctheo = {0.4985 / [sqrt (δs / 1.27)] } x 60 , rpm

Static deflection due to mass of the shaft (UDL), $\delta s = (5wL^4) / (384\ EI)$

Where,

w = weight of the shaft per metre , N/m

L = Length of the shaft, m

E = Young's modulus for the shaft material, N/m2

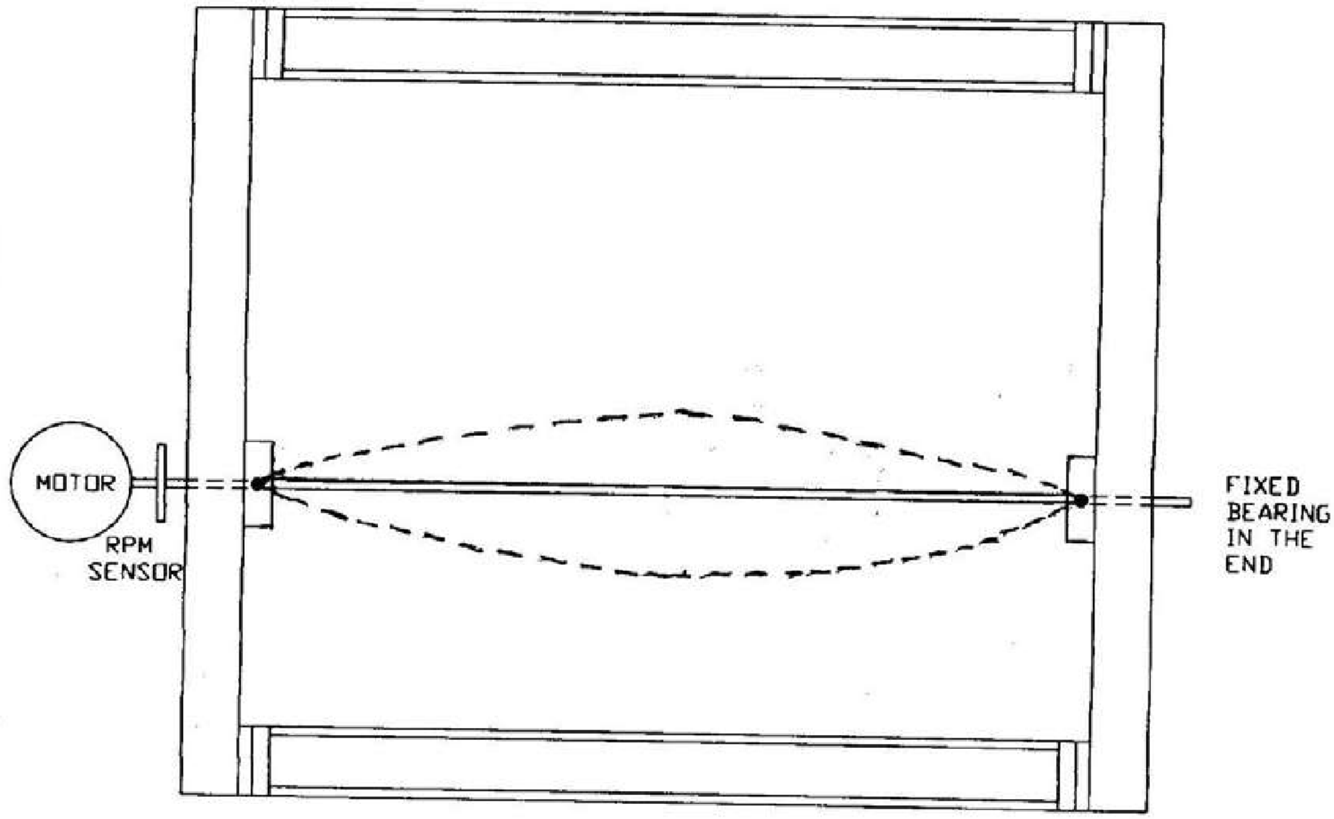
I = Mass moment of inertia of the shaft

$=(\pi/64)d^4$, m^4

Tabulation:

s.no	Diameter of shaft (m)	Mass moment of inertia of the shaft I (m^4)	Weight of the shaft per m, W (N/m)	Whirling speed (rpm)	
				N_{exp}	N_{the}
1					

Diagram:



Model calculation:

Result :

The whirling speed for various diameter shafts are determined experimentally and verified with the theoretical values.

CAM ANALYSIS

EX.NO: **DATE:**

Aim:

To draw the profile of the given cam and follower arrangement using the given apparatus.

Description:

The machine is a motorized unit consisting of a cam shaft driven by a AC/DC motor. The shaft runs in a ball bearing. At the free end of the cam shaft a cam can be easily mounted. The follower is properly guided in gun metal bushes. A graduated circular protractor is fitted co-axial with the shaft and a dial gauge can be fitted to note the follower displacement for the angle of cam rotation. A spring is used to provide controlling force to the follower system. Weights on the follower rod can be adjusted as per the requirements. The arrangement of speed regulation is provided.

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 forces on jump action of cam follower during operation. It is used for testing various cam follower pairs, i.e., (a) Circular arc cam with flat follower, (b) An eccentric cam with flat follower, (c) Sharp edged cam with flat follower.

The unit is provided with the push rod in the two bush bearings. Should the unit be disassembled, for any, reason while assembling following precautions should be taken: (a) the horizontality of the upper and lower glands should be checked by a spirit level. (b) The supporting pillars should be properly tightened with the lock nuts provided.

Observation:

Base circle radius or minimum radius of the cam, r_1 = mm

Nose radius, r_2 = mm

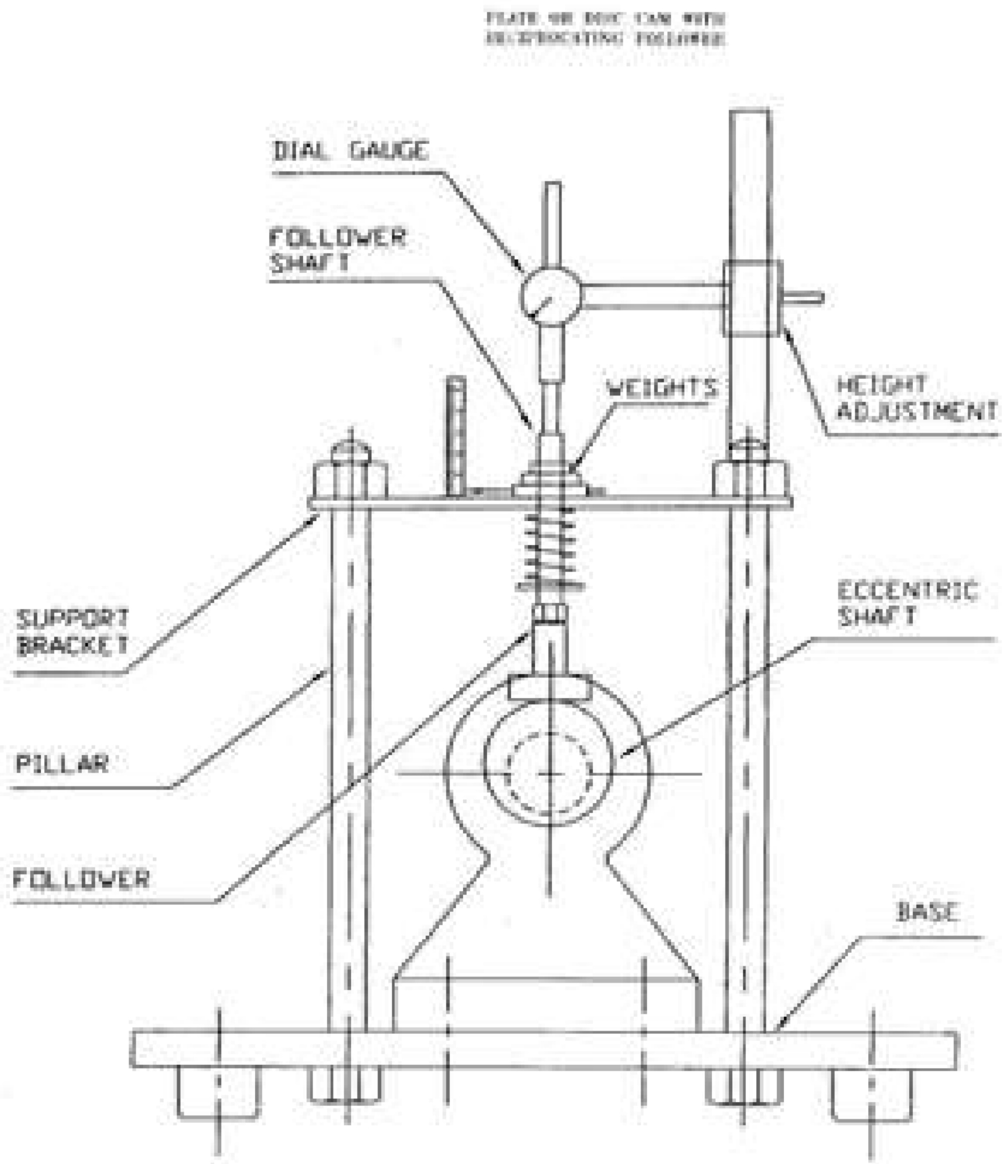
Procedure:

Rotate the cam shaft with the help of the hand through some angle and note down the angle of cam rotation indicated on the protractor and the corresponding follower displacement indicated in the dial gauge. Continue the experiment for different angles of cam rotation and draw the graph X vs θ. The exact profile of the cam can be obtained by taking observations X vs θ, where X = displacement of the follower from reference initial position and θ = angle of cam rotation with reference from axis of symmetry chosen.

Tabulation

	Forward stroke	Dwell	Return stroke
Angle in degree			
Follower lift in mm			

Diagram:


DIAL GAUGE
FOLLOWER SHAFT
WEIGHTS
HEIGHT ADJUSTMENT
SUPPORT BRACKET
ECCENTRIC SHAFT
PILLAR
FOLLOWER
BASE

Displacement diagram:

Cam profile:

Result:

Thus the profile of the given cam and follower arrangement has been drawn.

TORSIONAL VIBRATION OF SINGLE ROTOR SYSTEM

EX.NO: **DATE:**

Aim:

To determine the natural frequency of vibration theoretically and experimentally.

Description of set up :

One end of the shaft is gripped in the chuck and heavy flywheel free to rotate in ball bearing is fixed at the other end of the shaft.

The bracket with fixed end of shaft can be clamped at any convenient position along lower beam. Thus length of the shaft can be varied during the experiments. Specially designed chucks are used for clamping ends of the shaft. The ball bearing support to the flywheel provides negligible damping during experiment. The bearing housing is fixed to side member of mainframe.

Procedure:

1) Fix the bracket at convenient position along the lower beam.
2) Grip one end of the shaft at the bracket by of chuck.
3) Fix the rotor on the other end of the shaft.
4) Twist the rotor through some angle & release.
5) Note down the time required for 10, 20 oscillation.
6) Repeat the procedure for different length of shaft.
7) Make the following observation –

   a) Shaft Dia. = mm.

   b) Dia. of Disc = mm.

   c) Wt. of the disc = kg.

   d) Modulus of rigidity for shaft = 0.8×10^6 kg / cm^2

Tabulation:

Sr. No.	Length of shaft L cm.	No. of oscillation ‘n’	Time for ‘n’ oscillation in sec.	Periodic time T = t / n (Expt.)

Formula:

1) Determine of torsional stiffness K_t

$$K_t = \frac{G\, I_p}{L}$$

L = Length of shaft

I_p = polar M. I. of shaft = πd^4 / 32. d = Shaft diameter.

2) Determine T_{the}

$$T = 2\pi \sqrt{\frac{I}{K_t}}$$

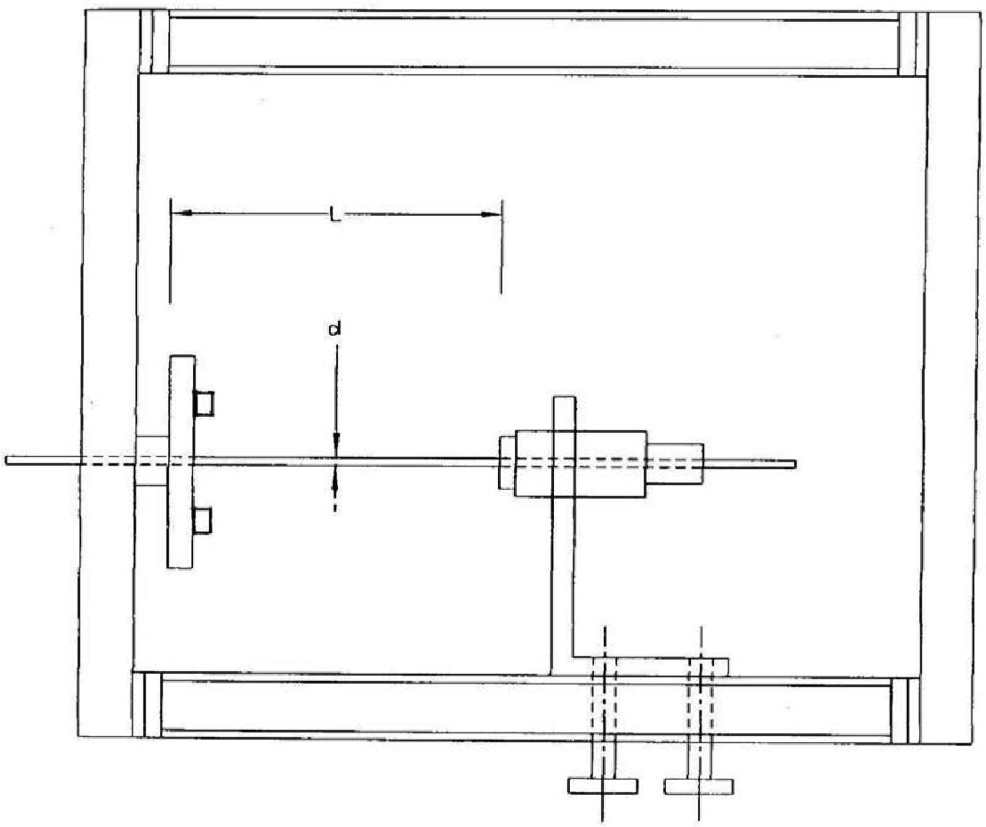
Where, I = M. I. of disc = $\frac{W D^2}{g\ 8}$

3) Determine T_{exp}

$$T = \frac{\text{Time for n sec}}{\text{No. of oscillation}} \text{ sec.}$$

4) $F_{Theo} = 1/ T_{theo}$ $F_{expt} = 1/ T_{expt}$

Diagram:



Model calculation:

Result:

Thus the natural frequency of vibration theoretically and experimentally calculated.

TORSIONAL VIBRATION OF TWO ROTOR SYSTEM

EX.NO: **DATE:**

Aim:

To determine the natural frequency of vibration theoretically and experimentally.

Description of set up:

Two discs having different mass moment of inertia are clamped one at each and of shaft by means of collect and chucks. Attaching the cross lever weights can change Mass moment of inertia of any disc. Both discs are free to oscillate in the ball bearings. This provides negligible damping during experiment.

Procedure:

1) Fix two discs to the shaft and fit the shaft in bearings.
2) Deflect the discs in opposite direction by hand and release.
3) Note down time required for particular number of oscillations.
4) Fit the cross arm to one of the discs say B and again note down time.
5) Repeat the procedure with different equal masses. attached to the end of cross arm and note down the time.

Observations:

1) Dia. of Disc = A = mm.
2) Dia. of Disc = B = mm.
3) Wt. of the Disc = A = kg.
4) Wt. of the Disc = B = kg.
5) Wt. of arm (with nut bolt) = kg.
6) Length of cross arm = cm.
7) Dia. of shaft = mm.
8) Length of shaft between rotors = L =

Tabulation:

Sr. No.	I_A	I_B	No. of oscillations ‘n’	Time required for ‘n’ oscillation ‘t’ in sec.	T Expt. = t/n secs.	T_{the}.

Formula:

1) Find K_t of shaft as follows

$$K_t = \frac{GI_p}{L}$$

Where, G = modulus of rigidity of shaft.

= 0.8×10^6 kg / cm^2. $I_p = \pi d^4 / 32$.

Let I_A = M. I. of disc, A.

I_B = M. I. of disc, B. (With wt on cross arm)

d = shaft dia.

L = Length of shaft

Then

$$I_A = \frac{W_A}{g} \times \frac{D_A^2}{8} + \frac{2W1}{g} \times \frac{R^2}{8}$$

$$I_B = \frac{W_B}{g} \times \frac{D_B^2}{8}$$

(Neglecting effect of cross arm)

Where, W1 = Wt. attached to the cross arm.

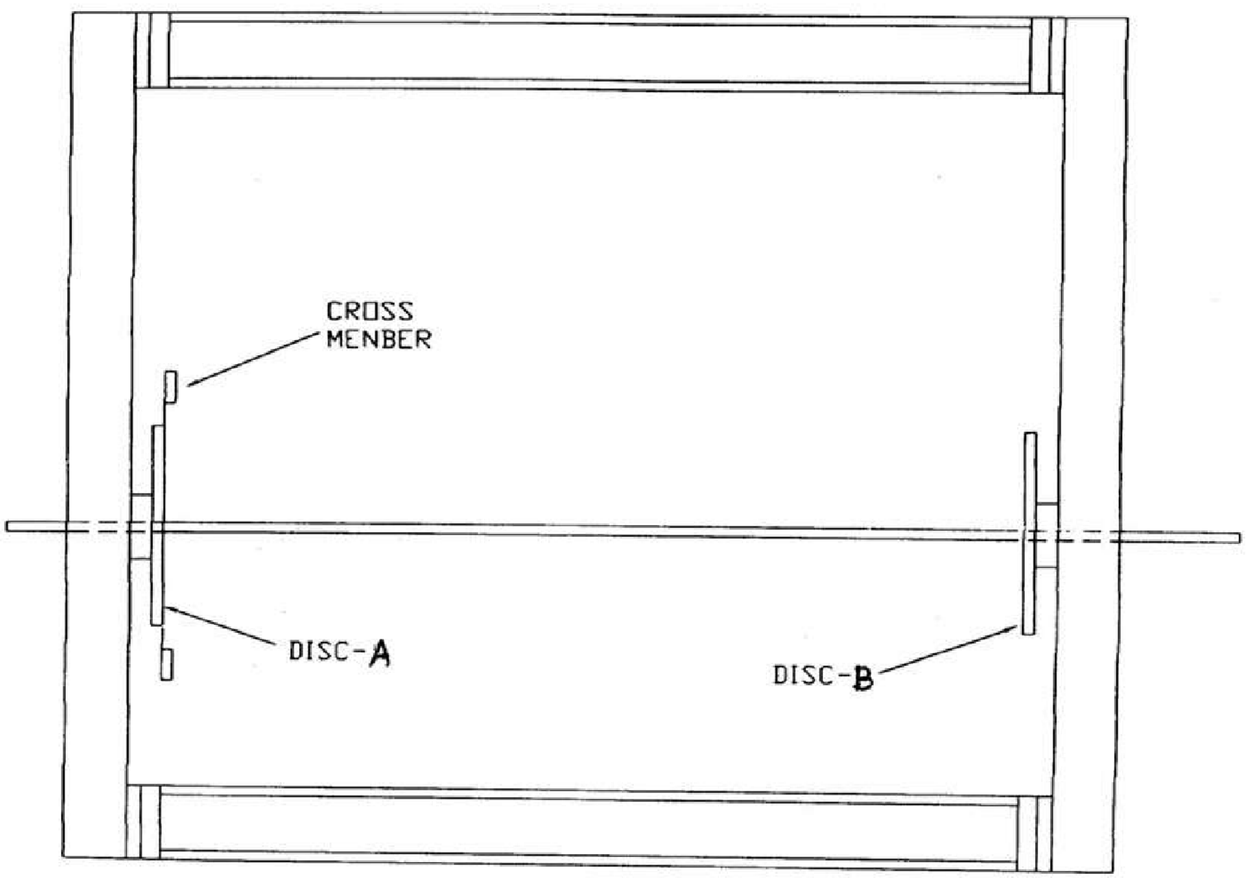
R = Radius of fixation of wt. on the arm.

$$T_{the} = 2\pi \sqrt{\frac{I_A \times I_B}{K_t (I_A + I_B)}}$$

$$T_{exp} = \frac{\text{Time for n osc.}}{\text{No. of osc. n}} \text{ sec.}$$

$F_{EXP.} = 1 / T_{EXP.}$ $F_{Ther.} = 1 / T_{Ther.}$

Diagram:



Model calculation:

Result:

Thus the natural frequency of vibration theoretically and experimentally calculated.

LONGITUDINAL VIBRATIONS OF HELICAL SPRING

EX.NO: **DATE:**

Aim:

To determine the frequency or period of vibration (oscillation) theoretical and actually by experiment.

Description of set up:

One end of open coil spring is fixed to the screw, which engages with screwed hand wheel. The screw can be adjusted vertically in any convenient position and then clamped to upper beam by means of lock nuts. Lower end of the spring is attached to the platform carrying the weights. The whole unit can be clamped by using the upper and lower clamping nuts. Thus, the design of the system incorporates vertical positioning of the unit to suit the convenience.

Procedure:

1) Fix one end of the helical spring to the upper screw.
2) Determine free length.
3) Put some weight to platform & note down the deflection.
4) Stretch the spring through some distance & release.
5) Count the time required (in sec) for some say 10, 25, 50 oscillations.

Observations:

1) Length of Spring =
2) Mean Diameter of Spring =
3) Wire Diameter =

Tabulation No 1 (For Finding K_m)

Sr. No.	Weight attached in Kg. 'W'	Deflection of spring in cm. (δ)	$K = w / \delta$

Tabulation Table No 2

Sr. No.	Weight attached Kg. W	No of oscillations 'n'	Time required for 'n' oscillations.	Periodic time & $T_{Expt.} = t / n$.

Formula:

1) Find K_m (mean stiffness) of the spring as follows :

$$K_m = \frac{K1 + K2 + K3}{n} \text{ Kg / cm.}$$

Where, $K_1 = W_1 / \delta_1$, $K_2 = W_2 / \delta_2$, $K_3 = W_3 / \delta_3$, etc.

n = No. of readings.

2) Find 'T' Theoretical by using relation :

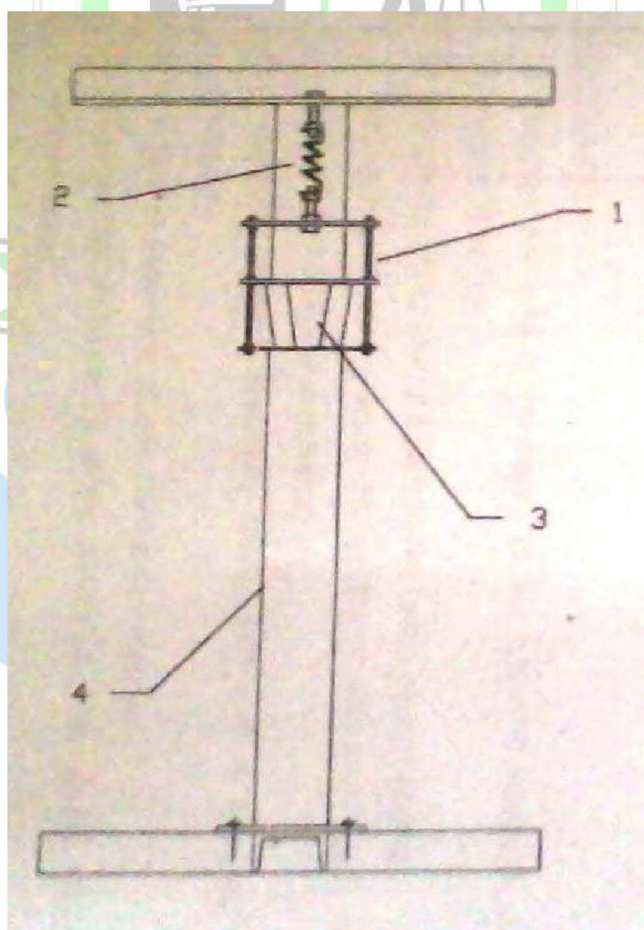
$$T_{The} = 2\pi \sqrt{\frac{W}{K_m \times g}}$$

3) Check with experimental value T experiment = t / n

Hence, $f_{theoretical} = 1 / T_{The}$

And $f_{Experimental} = 1 / T_{Exp}$

Diagram:



Model calculation:

Result:

Thus the determined the frequency or period of vibration (oscillation) theoretical and actually by experiment.

BIFILAR SUSPENSION

EX.NO: **DATE:**

Aim:

To determine the radius of gyration and the moment of Inertia of a given rectangular plate.

Apparatus required:

Main frame, bifilar plate, weights, stopwatch, thread

Description of set up :

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

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

Procedure:

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

Observation table :

Sr. No.	Length of bar in cm. 'L'.	Distance bet^n two wires '2a' in cm.	No. of oscillation 'n'	Time for 'n' oscillation 't' sec.	Periodic time 'T_{exp}'. in sec = t / n	Radius of gyration K_{exp}	Radius of gyration $K_{the.}$

Formula:

For Bi-filar suspension

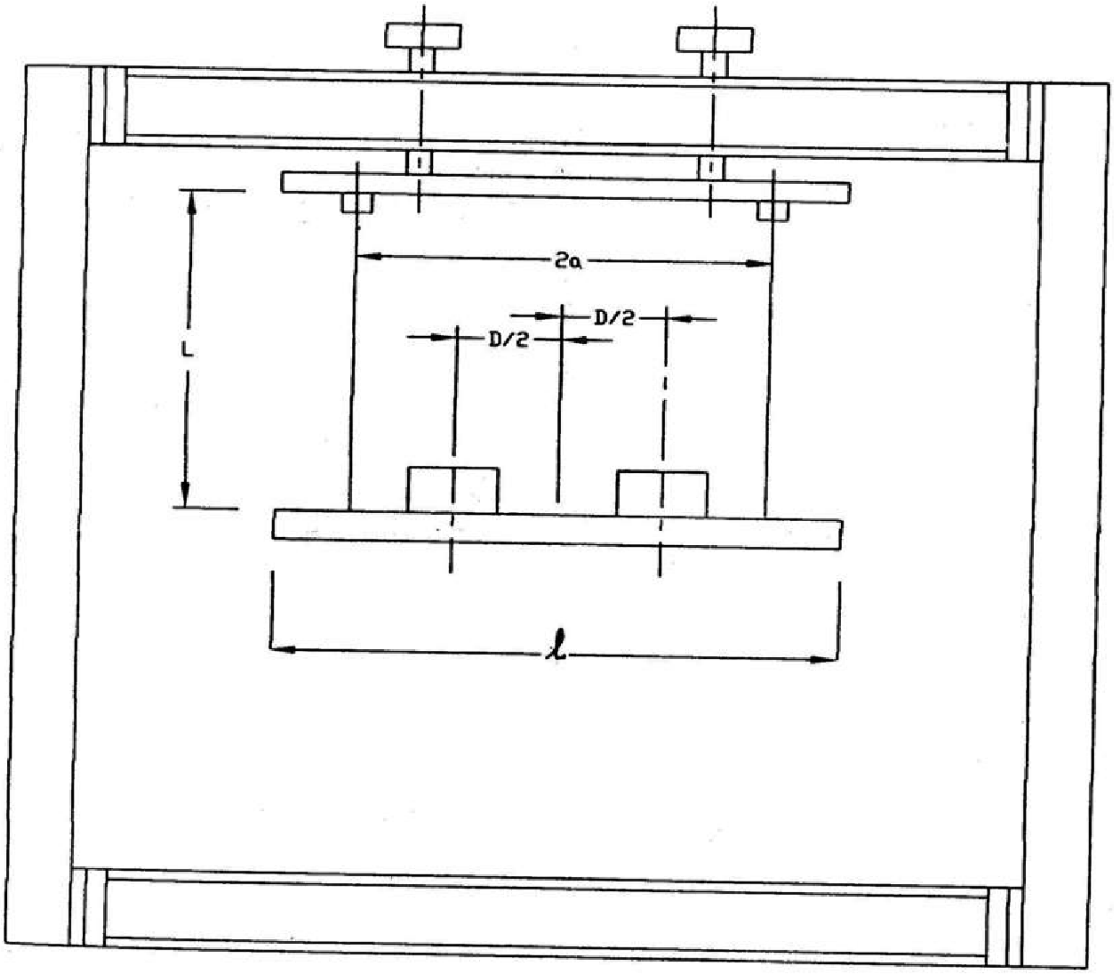
$$T = 2\pi \frac{k}{a}\sqrt{\frac{L}{g}}$$

Where 2a = Distance between two wires in cm.

k = Radius of gyration of bi-filar suspension.

$$k_{theo} = \frac{L}{2\sqrt{3}}$$

Diagram:



Model Calculation:

Result:

Thus the radius of gyration and the moment of Inertia of a given rectangular plate is calculated.