QMP 7.1 D/F

Channabasaveshwara Institute of Technology
(An ISO 9001:2008 Certified Institution)
NH 206 (B.H. Road), Gubbi, Tumkur – 572 216. Karnataka.

Department of Mechanical Engineering

Design Laboratory

(10MEL77)

VII Semester

Lab Manual 2016-17

Name : ____________________________________

USN : ____________________________________

Batch : ________________ Section : ____________

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Design Laboratory Manual

August 2016

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DEPARTMENT OF MECHANICAL ENGINEERING

DESIGN LAB SYLLABUS

Sub Code: 10MEL77	**IA Marks : 25**	**Hrs/ Week: 04**
Exam Hours: 03	**Total Hrs. 42**	**Exam Marks: 50**

PART – A

1. Determination of natural frequency, logarithmic decrement, damping ratio and damping coefficient in a single degree of freedom vibrating systems (longitudinal and torsional).
2. Balancing of rotating masses.
3. Determination of critical speed of a rotating shaft.
4. Determination of Fringe constant of Photo elastic material using.
   a) Circular disc subjected to diametral compression.
   b) Pure bending specimen (four point bending).
5. Determination of stress concentration using Photo elasticity for simple components like plate with a hole under tension or bending load, circular disk with circular hole under compression, 2D Crane hook.

PART - B

6. Determination of equilibrium speed, sensitiveness, power and effort of Porter/Proell / Hartnel Governor (Only one or more).
7. Determination of Pressure distribution in Journal bearing.
8. Determination of Principal Stresses and strains in a member subjected to combined loading using Strain rosettes.
9. Determination of stresses in Curved beam using strain gauge.
10. Experiments on Gyroscope (Demonstration only)

Scheme of Examination:

One question from Part A - 20 Marks (05 Write up +15)

One question from Part B - 20 Marks (05 Write up +15)

Viva - Voce - 10 Marks

Total: 50 Marks

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Sl. No	Name of the Experiment	Date			Manual Marks (Max . 25)	Record Marks (Max. 10)	Signature (Student)	Signature (Faculty)
		Conduction	Repetition	Submission of Record				
Average								

Note:

- **If the student fails to attend the regular lab, the experiment has to be completed in the same week. Then the manual/observation and record will be evaluated for 50% of maximum marks.**

Course Objectives and Outcomes

OBJECTIVES

The objectives of Design laboratory is

- ✓ To demonstrate the concepts discussed in Design of Machine Elements, Mechanical Vibrations & Dynamics of Machines courses.
- ✓ To observe, analyse and modify mechanical system components so as to perform safely their intended functions in harmony with other components of the system.
- ✓ To observe and analyse vibration behaviour of mechanical systems.
- ✓ To visualize and understand the development of stresses in structural members and experimental determination of stresses in members utilizing the optical method of reflected photo-elasticity.

OUTCOMES

The expected outcome of Design laboratory is that the students will be able

- ✓ To practically relate to concepts discussed in Design of Machine Elements, Mechanical Vibrations & Dynamics of Machines courses.
- ✓ To understand the working principles of machine elements such as Governors, Gyroscopes etc.,
- ✓ To identify forces and moments in mechanical system components.
- ✓ To identify vibrations in machine elements and design appropriate damping methods.
- ✓ To measure strain in various machine elements using strain gauges.
- ✓ To determine strain induced in a structural member using the principle of photo-elasticity.

SAFETY PRECAUTIONS

- ✓ Laboratory uniform, shoes & safety glasses are compulsory in the lab.
- ✓ Do not touch anything with which you are not completely familiar. Carelessness may not only break the valuable equipment in the lab but may also cause serious injury to you and others in the lab.
- ✓ Please follow instructions precisely as instructed by your supervisor. Do not start the experiment unless your setup is verified & approved by your supervisor.
- ✓ Do not leave the experiments unattended while in progress.
- ✓ Do not crowd around the equipment's & run inside the laboratory.
- ✓ During experiments material may fail and disperse, please wear safety glasses and maintain a safe distance from the experiment.
- ✓ If any part of the equipment fails while being used, report it immediately to your supervisor. Never try to fix the problem yourself because you could further damage the equipment and harm yourself and others in the lab.
- ✓ Keep the work area clear of all materials except those needed for your work and cleanup after your work.

Sem. & Sec.: **VII** Subject: **DESIGN Lab** Sub.Code: **10MEL77**

CONTENTS

CALCULATIONS:

1. Theoretical Frequency, $f_{n\,th} = \frac{1}{2\pi}\sqrt{\frac{g}{\Delta L}}$ Hz

   Where,

   g : Acceleration due to gravity, m/s^2

   ΔL : Spring deflection, mm

   $\Delta L = L_2 - L_1$

   L_1 : Initial length of the spring, mm

   L_2: Final length of the spring, mm

2. % Error = $\left(\frac{f_{n\,th} - f_{n\,exp}}{f_{n\,th}}\right) \times 100$

   Where,

   $f_{n\,th}$: Frequency theoretical

   $f_{n\,exp}$: Frequency experimental

3. Theoretical time period , $T_{th} = 2\pi\sqrt{\frac{\Delta L}{g}}$

4. Actual Time period, $T_{exp} = \frac{1}{f_{n\,exp}}$

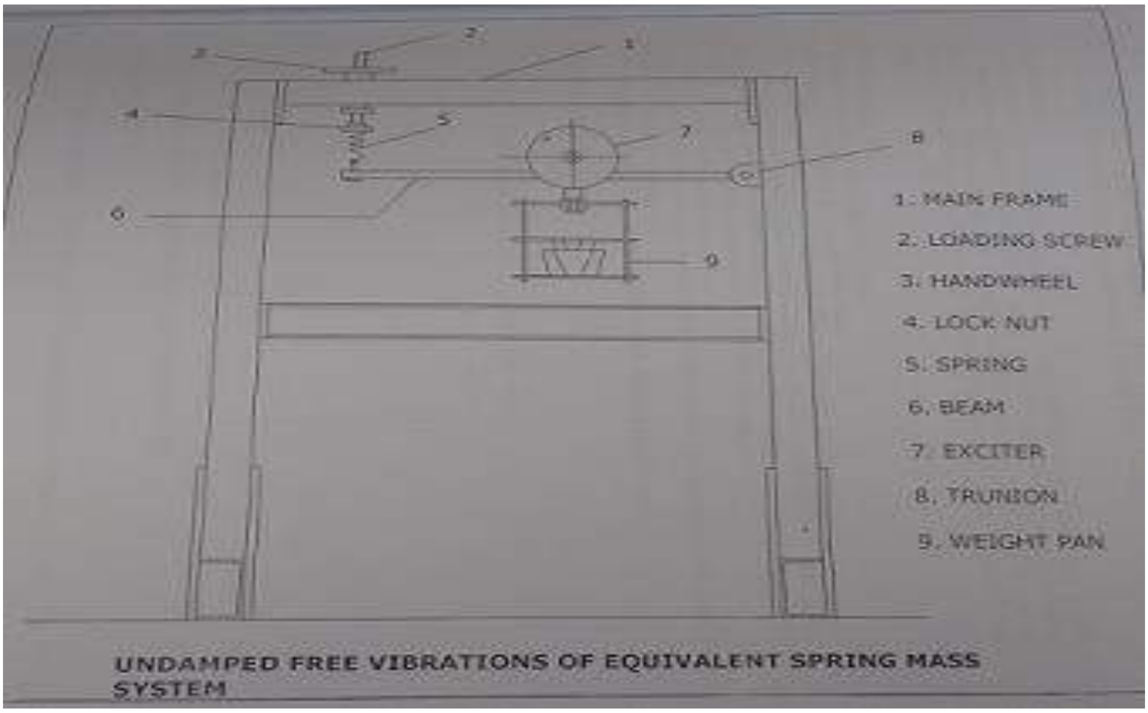


Figure 1.1 UNDAMPED FREE VIBRATION OF EQUIVALENT SPRING MASS SYSTEM

PART-A

EXPERIMENT NO: 1A

UNDAMPED FREE VIBRATION OF EQUIVALENT SPRING MASS SYSTEM

AIM: To determine time period and natural frequency of undamped free vibrations of equivalent spring mass system.

DESCRIPTION:

The arrangement is designed to study free undamped vibrations. It consists of M.S rectangular beam supported at one end by a trunion pivoted in ball bearing. The bearing housing is fixed to the side member of the frame. The other end of beam is supported by the lower end of helical spring; upper end of helical spring is attached to screw. The exciter unit can be mounted at any position along the beam. Additional known weights may be added to the weight platform under side exciter.

PROCEDURE:

1. Support one end of beam in the slot of trunion and clamp it by means of screw.
2. Attach the other end of the beam to lower end of spring.
3. Adjust the screw to which the spring is attached such that beam is horizontal in position.
4. Weigh the exciter assembly along with discs, bearings and weight platform.
5. Clamp the assembly at any convenient position.
6. Measure the distance L_1 of the assembly from pivot. Allow system to vibrate freely.
7. Measure the time for any 10 oscillations and find periodic time and natural frequency of vibration.
8. Repeat the experiment by varying L_1 and by also putting different weights on platform.

OBSERVATIONS:

1. Distance of m_1 from the pivot,l_1= ___________mm
2. Length of beam from pivot, l= _____________mm
3. Mass of the weight platform, m_1 = ____________kg
4. Mass of the beam with exciter assembly, M = ________________kg

TABULAR COLUMN:

Sl. No	Time for 10 oscillations in 't' seconds	Time for 1 oscillation $T = \frac{t}{10}$ in seconds	Natural frequency $f_{nexp} = \frac{1}{T}$ Hz

RESULT:

The percentage error of the system between theoretical and experimental natural frequency is _________

OBSERVATIONS:

1. Mass attached to the spring, m_1= ____________kg
2. Mass of the beam with exciter, M = __________kg
3. Initial length of the spring, L_1 = _____________mm
4. Final length of the spring, L_2 = ______________mm
5. Distance of ‘m_1’ from the pivot, l_1=___________mm
6. Length of beam for pivot, l=_________________mm
7. Time for ‘n’ oscillations, t =_________________s
8. Number of oscillations, n=__________________

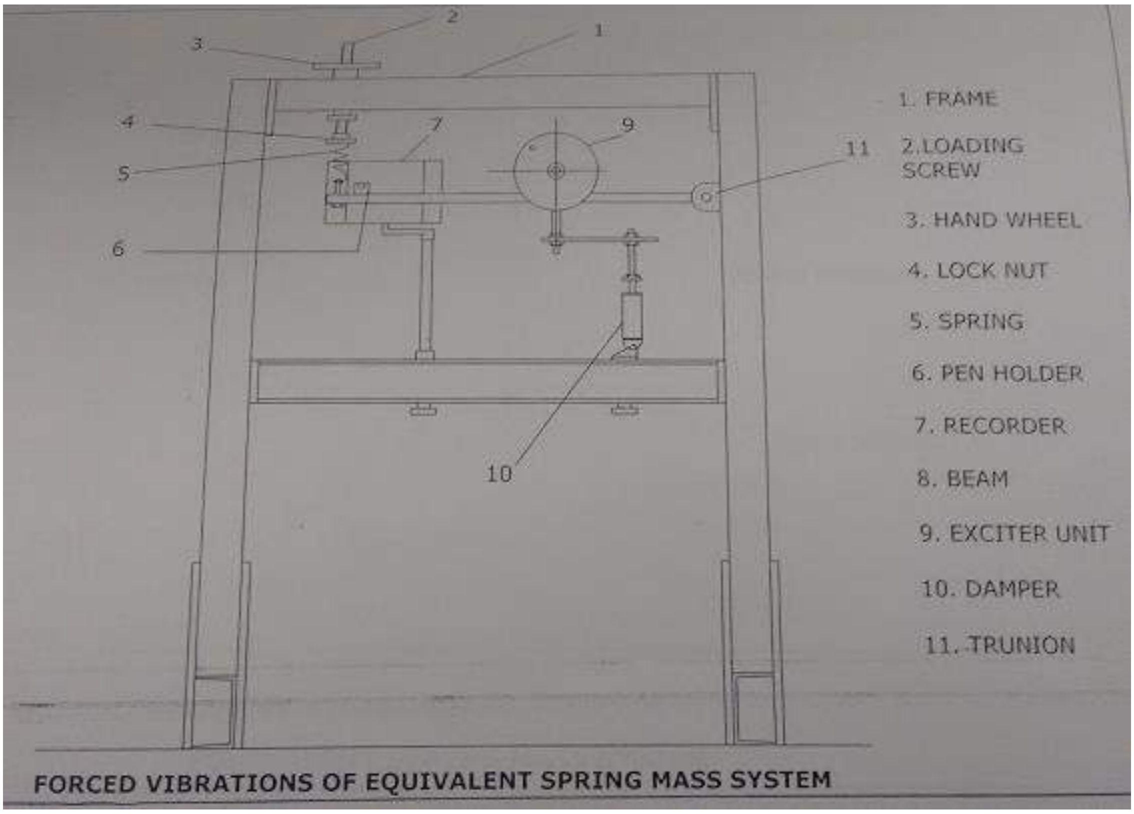


Figure 1.2 : FORCED DAMPED VIBRATION OF SPRING MASS SYSTEM

EXPERIMENT NO: 1B

FORCED DAMPED VIBRATION OF SPRING MASS SYSTEM

AIM: To study the forced vibrations of equivalent spring mass system and to determine logarithmic decrement, damping ratio and damping coefficient for the damped vibrations.

DESCRIPTION:

It consists of M.S rectangular beam supported at one end by a trunnion pivoted in ball bearing. The bearing housing is fixed to the side member of the frame. The other end of beam is supported by the lower end of helical spring; upper end of helical spring is attached to screw.

The exciter unit can be mounted at any position along the beam. Additional known weights may be added to the weight platform under side exciter.

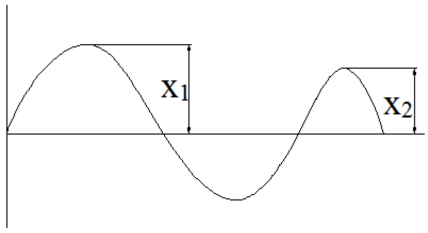
The exciter unit is coupled to D.C variable speed motor. Speed of motor can be varied with the speed control unit provided. Speed of rotation can be known from speed indicator on control panel. It is necessary to connect the damper unit to the exciter. Amplitude of vibration can be recorded on strip chart recorder.

PROCEUDRE:

1. Support one end of beam in the slot of trunnion and clamp it by means of screw.
2. Attach the other end of the beam to lower end of spring.
3. Adjust the screw to which the spring is attached such that beam is horizontal in position.
4. Weigh the exciter assembly along with discs, bearings and weight platform.
5. Clamp the assembly at any convenient position.
6. Start the motor and allow the system to vibrate.
7. Wait for 1 to 2 minute for amplitude to build the particular forcing frequency.
8. Adjust the position of strip chart recorder. Take the record of amplitude vs. time on strip chart recorder by starting recorder motor. Press recorder platform on the pen gently. Avoid excessive pressure to get good results.
9. Take record by changing forcing frequencies.
10. Repeat the experiment for different damping. Damping can be changed by adjusting the holes on the piston of damper.
11. Plot the graph of amplitude vs. frequency for each damping condition.

CALCULATIONS:

From Graph



1. Experimental time period , $T_{exp} = \frac{t}{n}$ seconds
2. Natural frequency , $f_{n\,exp} = \frac{1}{T_{exp}}$ Hz
3. Angular Velocity, $\omega_n = 2\pi f_n$ rad/s
4. Logarithmic decrement, $\delta = \ln\frac{X_1}{X_2}$
5. Damping ratio, $\zeta = \frac{\delta}{\sqrt{4\pi^2+\delta^2}}$
6. Damped angular velocity, $\omega_d = \omega_n\sqrt{1-\zeta^2}$ rad/s
7. Damped frequency, $f_d = \frac{\omega_d}{2\pi}$ Hz
8. Equivalent mass at the spring, $m_{eq} = m\left(\frac{l_1}{l}\right)^2$

   Where, Total mass, m= m_1+ M kg
9. Critical damping coefficient, $C_c = 2m_{eq}\,\omega_n$ N-s/mm
10. Damping Co-efficient, C= $C_c \times \zeta$ N-s/mm

TABULAR COLUMN:

Sl. No	Length of shaft 'l'	Number of oscillations 'n'	Time for 'n' oscillations 't' sec	Time period [Experimental] 't_p' sec

CALCULATIONS:

1. Torsional stiffness of the shaft, $q = \frac{G.J}{l}$ Nm

   Where,

   G= Modulus of rigidity for the shaft material,

   J= Polar moment of inertia of the shaft cross-section $= \frac{\pi d^4}{32}$

   l= Length of the shaft

2. Time period, $t_p = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{I}{q}}$ sec [Theoretical]

   Where,

   I= Mass moment of inertia of the disc in kg.m^2

   $= \frac{W}{g} \times \frac{D^2}{8}$

   Where,

   W= Weight of the disc

   D= Diameter of the disc

3. Time period, $t_p = \frac{\text{Time for 'n' oscillations}}{\text{Number of oscillations}}$ sec [Experimental]

4. Natural frequency , $f_n = \frac{1}{T}$ Hz

EXPERIMENT NO: 1C

TORSIONAL VIBRATION OF SINGLE ROTOR SYSTEM

AIM: To study the undamped torsional vibrations of single rotor system

DESCRIPTION:

The general arrangement for carrying out the experiment; One end of the shaft is gripped in the chuck & heavy flywheel free to rotate in ball bearing is fixed at the other end of the shaft. The bracket with the fixed end of the shaft can be clamped at any convenient position along lower beam. Thus length of the shaft can be varied during the experiments. The ball bearing support to the flywheel provides negligible damping during the experiment. The ball bearing housing is fixed to side member of the main frame.

PROCEDURE:

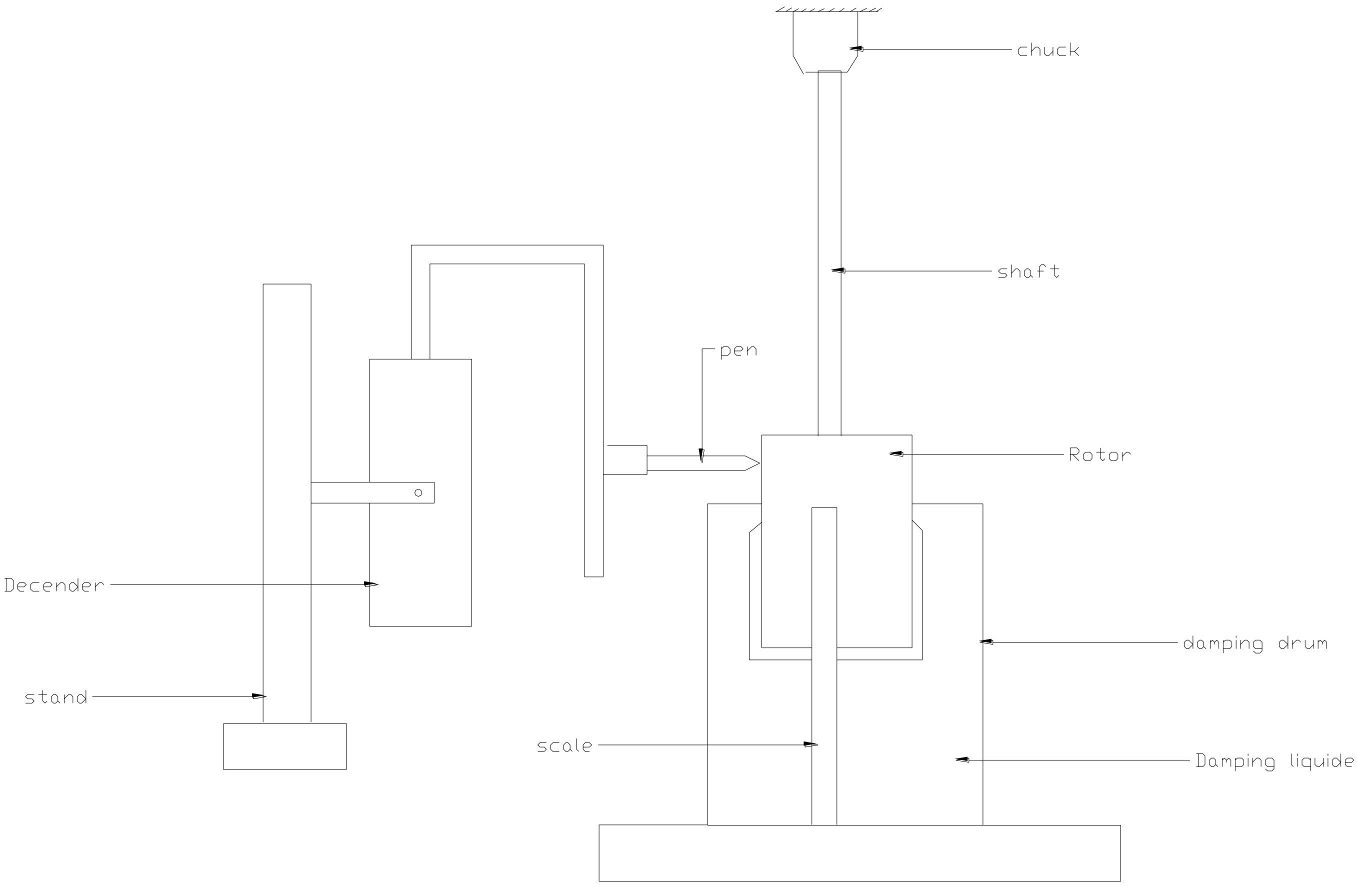
1. Fix the bracket at convenient position along the lower beam.
2. Grip one end of the shaft at the bracket by chuck.
3. Fix the rotor on other end of the shaft.
4. Twist the rotor through some angle and release.
5. Note down the time required for 10, 20 oscillations.
6. Repeat the procedure for different length of shaft.
7. Determine time period and natural frequency using the formulae given.

OBSERVATIONS:

1. Shaft diameter = 3 mm
2. Diameter of disc = 225 mm
3. Weight of the disc = 2.8 kg
4. Modulus of rigidity of the shaft = 0.8×10^{11} N/mm^2

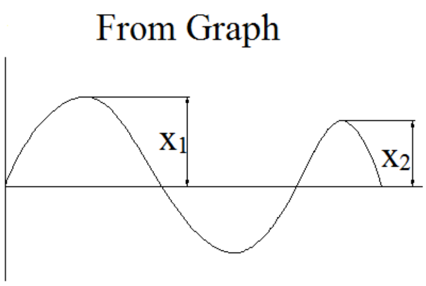
RESULT:

Sl. No	Length of shaft	Torsional stiffness	Time period [Theoretical]	Time period [Experimental]	Natural frequency [Theoretical]	Natural frequency [Experimental]



Figur 1.4: Torsional vibration of single rotor sytem (undamped)

CALCULATIONS:



1. Linear velocity of recording drum, $V = \frac{\pi d N}{60} m/s$
2. Experimental time period , $T_{exp} = \frac{Y}{V}$ seconds
3. Natural frequency , $f_{n\,exp} = \frac{1}{T_{exp}}$ Hz
4. Angular Velocity, $\omega_n = 2\pi f_n$ rad/s
5. Logarithmic decrement, $\delta = \ln \frac{X_1}{X_2}$
6. Damping ratio, $\zeta = \frac{\delta}{\sqrt{4\pi^2 + \delta^2}}$
7. Damped angular velocity, $\omega_d = \omega_n \sqrt{1 - \zeta^2}$ rad/s
8. Damped frequency, $f_d = \frac{\omega_d}{2\pi}$ Hz
9. Equivalent mass at the spring, $m_{eq} = m \left(\frac{l_1}{l}\right)^2$

   Where, Total mass, $m = m_1 + M$ kg
10. Critical damping coefficient, $C_c = 2 m_{eq} \omega_n$ N-s/mm
11. Damping Co-efficient, C= $C_c \times \zeta$ N-s/mm

EXPERIMENT NO: 1D

DAMPED TORSIONAL VIBRATION

AIM: To study the damped torsional vibration

DESCRIPTION:

It consists of a long shaft gripped at the upper end by chuck in the bracket. The bracket is clamped to upper beam of the main frame. A heavy steel flywheel clamped at the lower end of the shaft suspends from bracket. Damping drum is fixed to the lower face of the flywheel. This drum is immersed in oil which provides damping. Rotor can be taken up and down for varying the depth of immersion of damping drum. Depth of immersion can be read from scale. Recording drum is mounted on the upper face of the flywheel. Paper is to be wrapped around the recording drum. Oscillations are recorded on the paper with the help of specially designed piston of dashpot. The piston carries the attachment for fixing marker.

PROCEDURE:

1. With no oil in the container allow the flywheel to oscillate and measure the time for some oscillation.
2. Put thin mineral oil in the drum and rote the depth of immersion.
3. Put the sketching pen in the bracket.
4. Allow the flywheel to vibrate.
5. Allow the pen to descend and see that it is in contact with the paper.
6. Measure the time for some oscillations by means of stop watch.
7. Determine amplitude (Xn) at any position and amplitude(X) after 'Y' cycles

OBSERVATION:

1. Diameter of recording drum, d=____mm
2. Speed of recording drum, N=_____rpm
3. Modulus of rigidity, G= 0.8×10^{11} kg/m^2
4. Length of the shaft, L=_____mm
5. Mass of the disc, m=_____kg
6. Diameter of the disc, D_d=_____mm
7. Diameter of the shaft, D_s=_____mm
8. Distance covered in one wave motion, Y= X_1-X_2 mm

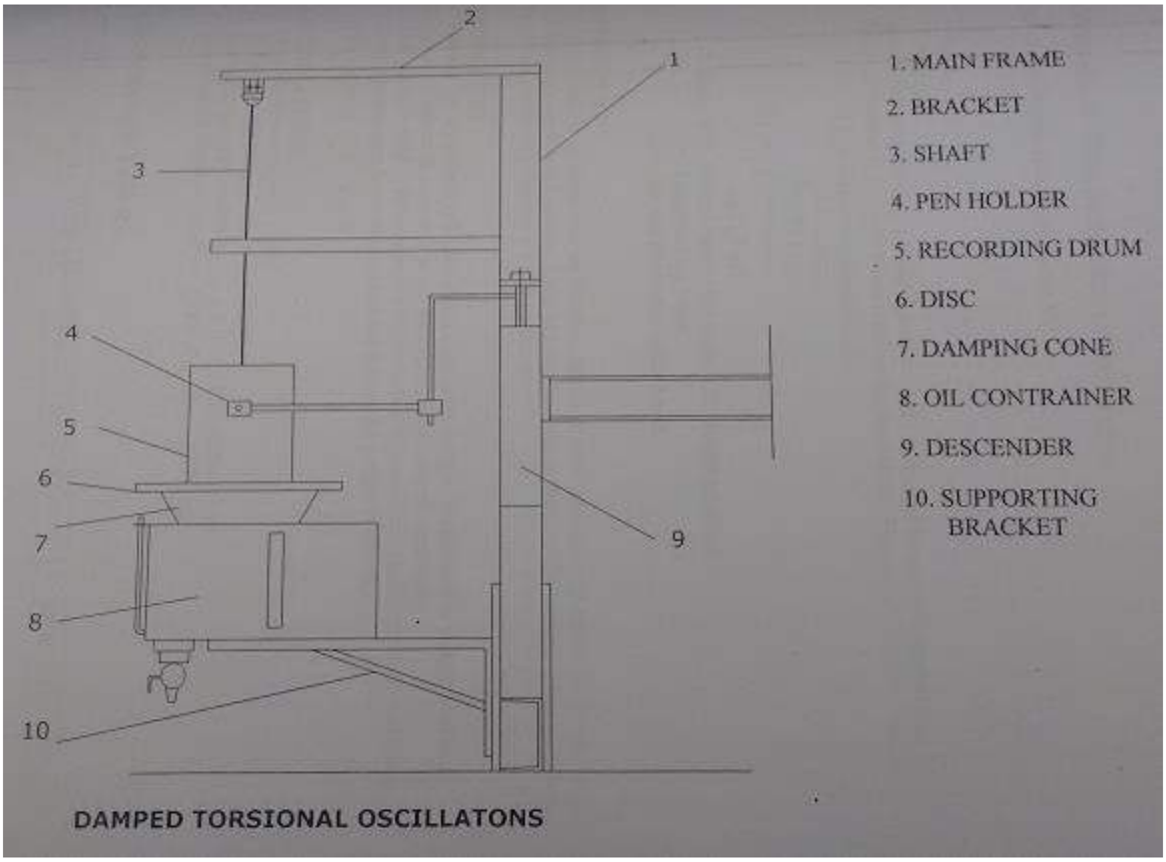


Figure 1.5: Damped Torsional vibration apparatus

RESULT:

Sl No.	Distance D in mm	Amplitude		fn in Hz (experimental)	fd in Hz (theoretical)
		X1 in mm	X2 in mm		

OBSERVATIONS:

1. Length of the shaft, L = 0.9 m, density of shaft(ρ)=8000 kg/m^3
2. Young's Modulus, E= $210 \times 10^9\ N/m^2$
3. Moment of inertia, $I = \frac{\pi d^4}{64}\ m^4$; where, d is diameter of shaft = 0.004m
4. Acceleration due to gravity, g= 9.81m/s^2
5.

End conditions	Value of K	
	1st Mode	2nd Mode
Supported, Supported	1.57	6.28
Fixed, Supported	2.45	9.80
Fixed, Fixed	3.56	14.24

TABULAR COLUMN: for each end conditions of shaft write and fill up the following table

Mode	$N_{exp\ crit}$	$f_{n\ exp\ crit}$	$f_{n\ theor\ crit}$	$N_{theor\ crit}$
Mode1				
Mode 2				

CALCULATIONS:

m = mass of the shaft, kg
L= length of the shaft, m
I = mass moment of inertia in Kg/m^2
E = young`s modulus N/m^2
g = 9.81 m/s^2

1. Natural frequency, $f_n = K\sqrt{\frac{EI}{mL^4}}$ Hz $= f_{n\ theor\ crit}$

m=(πd^2 /4) ρ_{shaft}

$f_{n\ exp\ crit} = N_{exp\ crit} / 60$ Hz; $N_{theor\ crit} = 60 \times f_{n\ theor\ crit}$

EXPERIMENT NO: 2

WHIRL PHENOMENON OF SHAFT

AIM: To study the whirl phenomenon of a given shaft

APPARATUS: Whirling of shaft apparatus

DESCRIPTION: This apparatus is designed to study and observe the whirl phenomenon of shafts with different end conditions. The apparatus consists of a frame to support driving motor, end fixing blocks, sliding blocks and variable speed motor with speed control unit. The unit is supplied with the following shafts:

1. Diameter-0.4cm, length-90 cm, Weight-280gms
2. Diameter-0.6cm, length-90 cm, Weight-416gms
3. Diameter-0.8cm, length-90 cm, Weight-582gms

END FIXING ARRANGEMENT:

Guards D1 & D2 can be fixed at any position on the supporting bars.

At motor end as well as tail end, different end conditions can be developed by making use of different fixing blocks.

1. Supported end condition: Make use of end block with single self aligning bearing.
2. Fixed end condition: Make use of end block with double bearing

PROCEDURE:

1. Choose the required size of the shaft.
2. Mount the two fixing ends on the frame to obtain the desired condition.
3. Fix the shafts between two ends.
4. Switch on the motor and allow the shaft to rotate.
5. Gradually increase the motor speed by operating the dimmer stat and allow the shaft to rotate forming a single loop, which is called the first loop [The amplitude of vibrations in lateral direction starts and mode shape can be observed].
6. Note down the speed and mode shape.
7. To observe second mode shape, increase the speed of the shaft.
8. Note down the speed and the mode shape.
9. The procedure is followed for different shafts and different end conditions.
10. Determine the natural frequency using the formula given.

Experimental set up

Expt.No.	End Fixings	Mode of whirl
1	Supported – fixed	
2	Supported – fixed	
3	Supported – Supported	
4	Supported – Supported	

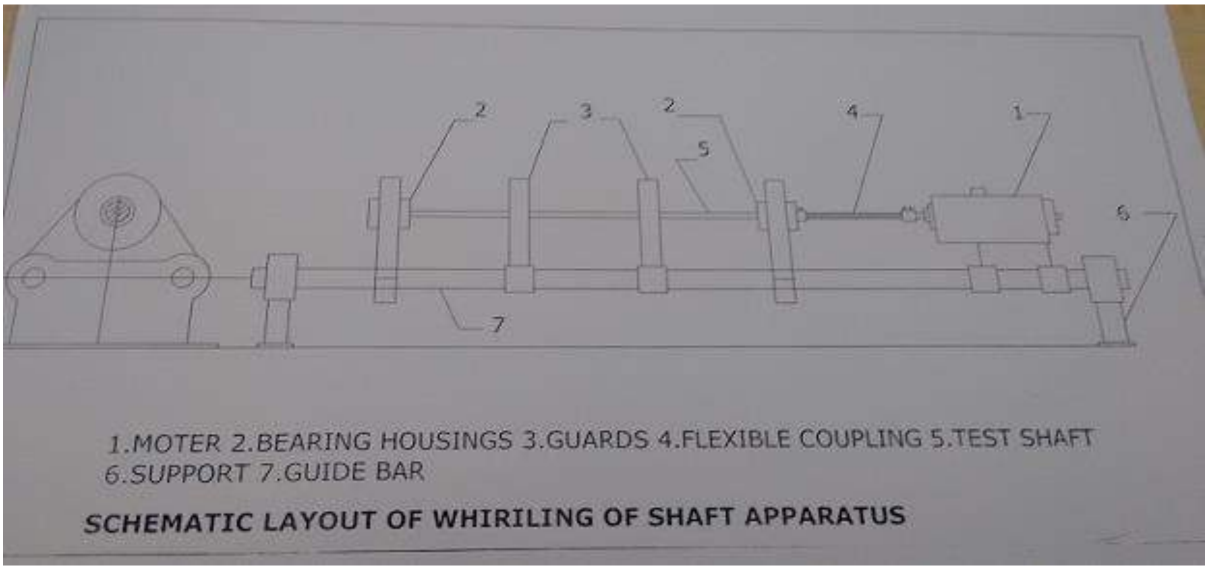


Figure 2: Schematic layout of Whirling of Shaft

TABULAR COLUMN:

Plane	Mass [kg]	Radius [m]	Centrifugal force [kg.m]	Distance from reference plane [m]	Couple [kg.m^2]
A					
B					
C					
D					

COUPLE POLYGON:

FORCE POLYGON:

ANGULAR POSITIONS:

EXPERIMENT NO: 3

STATIC & DYNAMIC BALANCING APPARATUS

AIM: To balance rotating mass system statically & dynamically

DESCRIPTION:

The apparatus basically consists of a steel shaft mounted in ball bearings in a stiff rectangular main frame. A set of five blocks of different weights is provided and may be clamped in any position on the shaft, and also be easily detached from the shaft.

A disc carrying a circular protractor scale is fitted to one side of the rectangular frame. Shaft carries a disc and rim of this disc is grooved to take a light cord provided with two cylindrical metal containers of exactly the same weight. A scale is fitted to the lower member of the main frame and when used in conjunction with the circular protractor scale, allows the exact longitudinal and angular position of each adjustable block to be determined. The shaft is driven by a 230 volts single phase 50 cycles electric motor, mounted under the main frame, through a belt.For static balancing of individual weights the main frame is suspended to the support frame by chains and in this position the motor driving belt is removed.

For dynamic balancing of the rotating mass system the main frame is suspended from the support frame by two short links such that the main frame and the supporting frame are in the same plane.

THEORY:

If the centre of gravity of the rotating disc does not lie on the axis of rotation but at a distance away from it, we say that the disc is out of balance. When such a disc rotates, a centrifugal force, $\mathbf{F_c = m\omega^2 r}$ is setup in which, `m' the mass of the disc, `r' the distance of the center of gravity of the disc from the axis of rotation and `ω' the angular velocity. This rotating centrifugal force acts on the bearing in a constantly changing directions and results in a vibrating load. The process of providing or removing the mass to counteract the out of balance is called balancing. Generally all rotating machine elements such as pulleys, flywheels, rotors etc. are designed to rotate about a principal axis of inertia and theoretically require no balancing. However, lack of material homogeneity and inaccuracies in machining and assembly may cause an unintentional shifting of the centre of gravity of the rotor from the axis of rotation. The centrifugal forces resulting from the unbalance increase as the square of the rotational speed and hence it is important that all revolving and reciprocating parts should be completely balanced as far as possible.

BALANCING OF FOUR BLOCKS:

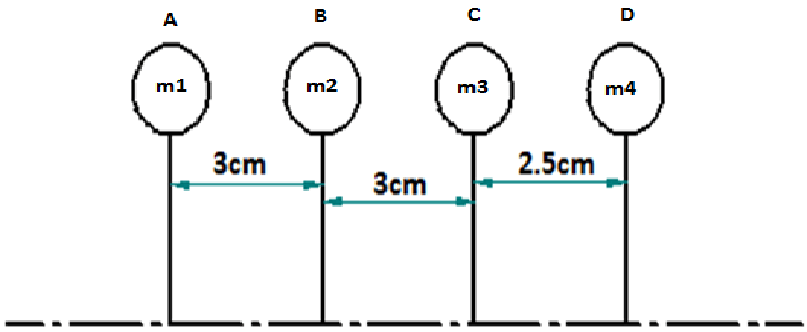


Fig 3.1: Space diagram

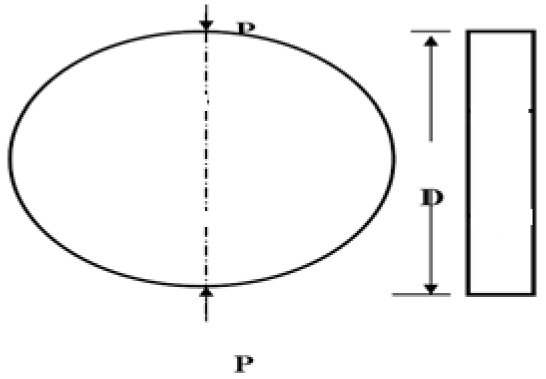
PROCEDURE:

1. Consider one of the planes, say 'A' as the reference plane. The distance of all the other planes to the left of the reference plane may be regarded as negative, and those to the right as positive.

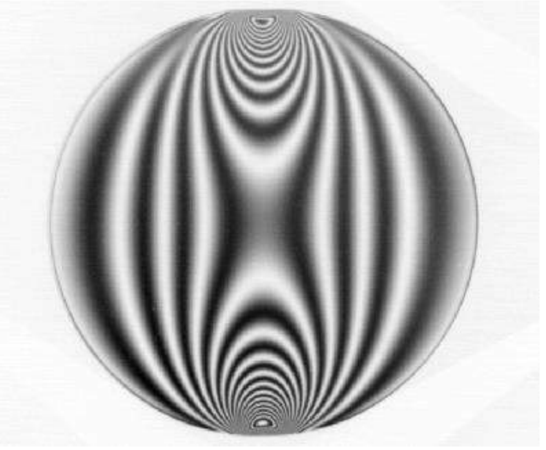
2. Tabulate the data in the table shown below. The planes are tabulated in the same order in which they occur, reading from left to right. Since the magnitude of the centrifugal forces are proportional to the product of the mass and its radius, the product 'mr' can be calculated and tabulated.

3. Now draw the couple polygon considering the value of couple for each plane. Since the angular distance between masses is not given, consider position of mass 2 as horizontal, i.e. angle is zero. The value of couple for reference plane is zero. By drawing the couple polygon angular position of mass 3 and mass 4 with respect to mass 2 can be found out.

4. Now draw the force polygon considering the value of centrifugal force and angular positions of masses 2, 3 & 4. From the force polygon weight of mass 1 and its angular position can be found out.
5. Considering the values of angular positions of masses, fix them on the shaft of the apparatus and check for static and dynamic balance.



CIRCULAR RING UNDER COMPRESSION



Circular ring showing fringes

Polariscope Apparatus

TABULAR COLUMN:

Load Applied 'm' Kg On Load Cell	Load on Model $P = \frac{m.Y}{X}$	Fractional Fringe Order N at center			Material Fringe Order $f_\sigma = \frac{8P}{\pi DN}$	Average fσ Kg/m
		Lowest Fringe Order	Higher Fringe Order	Average Fringe Order		

EXPERIMENT NO: 4A

FRINGE CONSTANT OF PHOTOELASTIC MATERIAL (Circular ring)

AIM: Calibration of Photo Elastic Model Material by using circular disc under diametrical compression.

APPARATUS:

1) Circular disc prepared out of Photo elastic model material.
2) Universal Loading Frame
3) 12” Diffused Light Transmission Polariscope.

PROCEDURE

1. Load the disc in universal loading frame, under diametrical compression by putting pin on 2^{nd} hole on right hand side and 7^{th} hole on left hand side.
2. The distances ‘X’ and ‘Y’ must be measured initially.
3. Apply light load and Plain Polariscope (D) arrangement.
4. Observe the isoclinic fringe pattern and note the isoclinic reading for the point of interest ‘P’ on the model.
5. In this case as the point of interest ‘P’ which is at the center of the disc, the isoclinic reading automatically becomes zero.
6. Now apply known value of load at the end of lever and set to circular polariscope (M) arrangement.
7. Use white light and identify the fringe order at the point ‘P’
8. Use Tardy’s Method, if required, to find fractional fringe order at the center point ‘P’
9. Go on increasing the load in steps and note down fractional fringe order at the center point ‘P’.
10. After measuring the diameter of the disc proceed to calculate material fringe value.

OBSERVATION:

1. Distance ‘X’ = _______________ m
2. Distance ‘Y’ = _______________ m
3. Diameter of Disc, D = ____________ m
4. Thickness of disc, b = _________________m

CALCULATIONS:

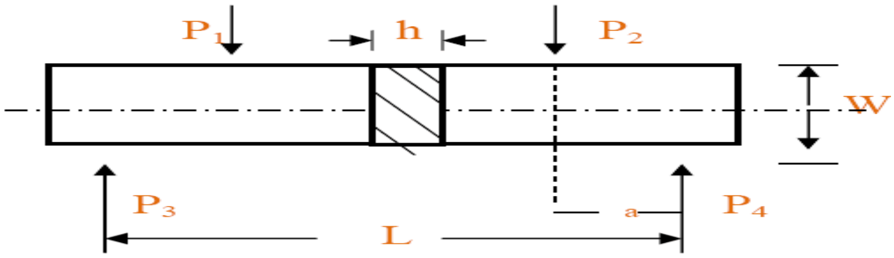
1. Load on Model, $P = \frac{m.Y}{X}$

2. For a disc under diametrical compression;
   Material fringe order, $f_\sigma = \frac{8P}{\pi DN}$

$$f_\sigma = \frac{\text{8 x Load on Model in Kg}}{\pi \text{ x Dia.of disc in m x fractional fringe order at center}}$$

3. Stress, $\sigma_1 - \sigma_2 = \frac{f_\sigma N}{b}$
   Where, b= Thickness of the disc, m

RESULT:



FOUR POINT LOADING CALIBRATION SPECIMEN

TABULAR COLUMN:

Sl. No	Distance from Neutral axis [Y]	Fringe order f_σ	Average Fringe order

EXPERIMENT NO: 4B

FRINGE CONSTANT OF PHOTOELASTIC MATERIAL (Rectangular beam)

AIM: Calibration of photo elastic model material by using a beam subjected to pure bending.

APPARATUS:

1. 12” Diffused Light Transmission Polariscope
2. Universal Loading frame.
3. Beam model prepared out of photo elastic sheet

PROCEDURE:

1. Load the beam at four points by applying known force. Put the loading lever on pinhole no. 3 on right hand side and other pin in hole no. 6 on left hand side.
2. Use white light with circular polariscope arrangement and identify fringe order.
3. The trace of material surface is identified by zero order fringe.
4. Shift to monochromatic light and carefully measure the distance ‘Y’ [From the neutral axis] of the fringe orders 1, 2, 3 etc.
5. The middle section of the beam is subjected to a pure bending moment, M_b= P×L
6. Assuming that only σ_X is acting, $\sigma_1 - \sigma_2 = \sigma_X = \frac{M.Y}{I}$
7. Use relation, $\sigma_1 - \sigma_2 = \frac{N f_\sigma}{b}$
   Calculate value of f_σ for N=1,2,3 etc.
8. Find out average value of ‘f_σ’

<u>OBSERVATION:</u>

1. Thickness of beam model, b = ___________m.
2. Depth of beam model, h =_______________m.
3. Distance of fringe from neutral axis Y = _________m.
4. Load applied, P = ______________kg
5. Distance of point load application, L = _______________m.

<u>CALCULATION:</u>

1. Material fringe order, $f_\sigma = \frac{12PL}{h^3} \times \frac{Y}{N}$
2. Stress, $\sigma_1 - \sigma_2 = \frac{f_\sigma N}{b}$
   Where, b= Thickness of the disc

OBSERVATION TABLE:

Sl. No	Load in pan Kg	Load on strip 'p' Kg	Fringe order			Experimental stress
			N-Lower	N-Higher	N-Average	
1						
2						
3						

CALCULATIONS:

1. Theoretical stress = $\frac{P}{(W-d)X}$
2. Experimental stress = $\frac{N f_\sigma}{n}$
3. Stress concentration factor, K_t= $\frac{Experimental\ stress}{Theoretical\ stress}$

EXPERIMENT NO. 5

DETERMINATION OF STRESS CONCENTRATION FACTOR

AIM: Determination of stress concentration using Photo elasticity for a plate with a circular hole under tension

APPARATUS:

1. 12” Diffused Light Transmission Polariscope.
2. Loading Frame with suitable shackles to apply uniform tensile load.
3. Photoelastic model.

PROCEDURE

1. Prepare model of uniform thickness as per the sketch shown.
2. Apply (by means of suitable shackles) load using universal loading frame
3. Now from the observation it is clear that the specimen is loaded axially.
4. In this case white light source must be used with plane polariscope arrangement.
5. It is clear that the material fringe value is independent of thickness of material. Knowing the fringe order and corresponding load, the material fringe value can be easily found out. The value of the material fringe order of $f\sigma$ can be determined by relation.

PRECAUTIONS

1. Do not oil the gears of polariser and analyzer assembly.
2. If the ‘Zero’ setting of load cell is disturbed use the knob gently to make it zero.
3. Do not exceed load more than 18 Kg on load indicator.
4. Do not use the sodium lamp continuously more than 30 min.
5. If sodium lamp is switched off while in operation, it will not start immediately. It requires 15 to 20 minutes for cooling the lamp.
6. Always cover analyzer and polarizer assembly when unit is not in use.

OBSERVATION:

1. Outer diameter of plate = _____________
2. Thickness of plate = ________________
3. Diameter of hole = __________________

TABULAR COLUMN:

Sl. No	Load in pan Kg	Load on strip 'p' Kg	Fringe order			Experimental stress
			N-Lower	N-Higher	N-Average	
1						
2						
3						

CALCULATIONS:

4. Theoretical stress = $\frac{P}{(W-d)X}$
5. Experimental stress $= \frac{N f_{\sigma}}{n}$
6. Stress concentration factor, $K_t = \frac{\text{Experimental stress}}{\text{Theoretical stress}}$

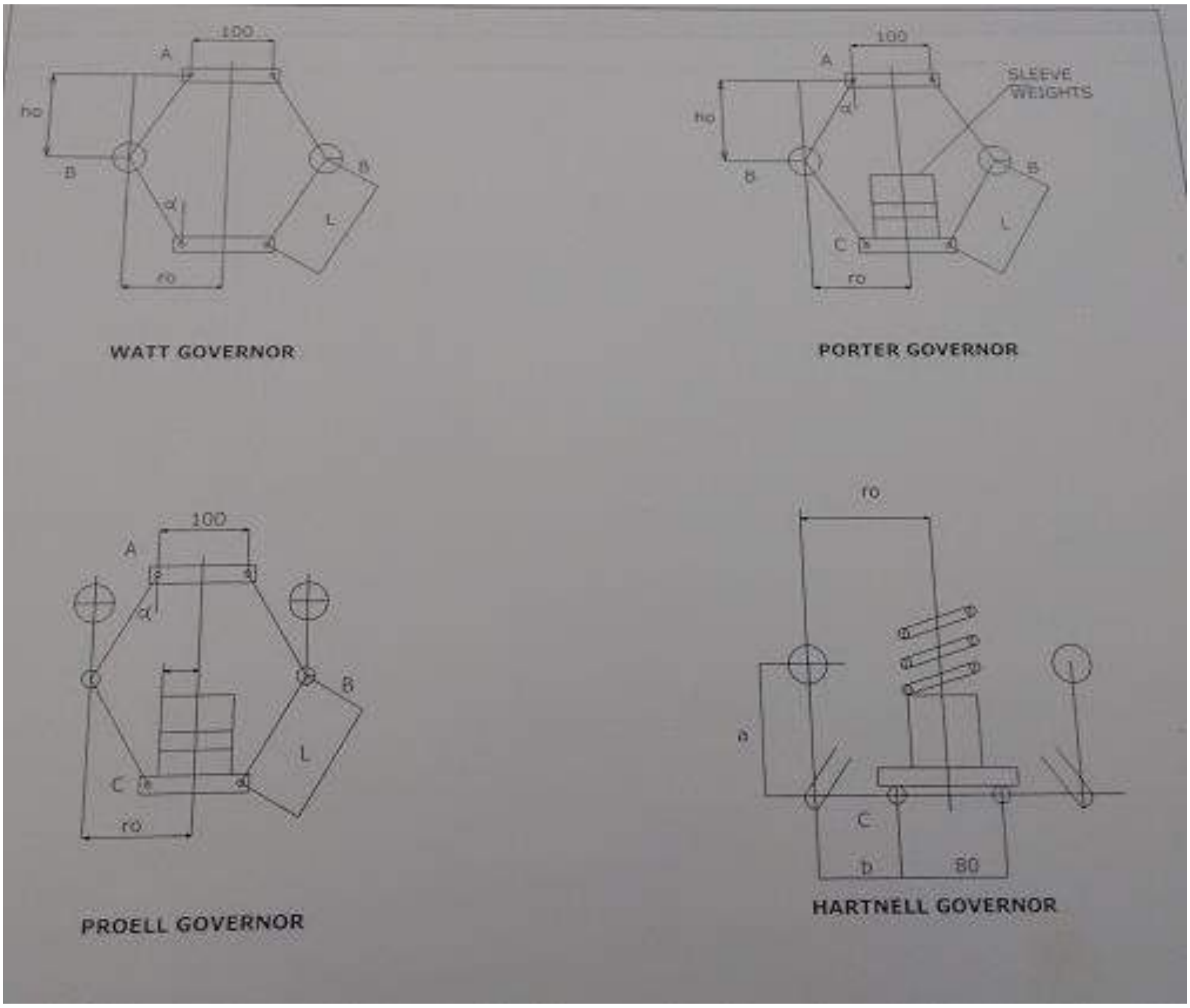


Figure 6.1: Centrifugal Governors

PART-B

EXPERIMENT NO: 6

UNIVERSAL GOVERNOR

AIM: To perform experiment on Porter,Watt and Proell governors to prepare performance characteristic curves and to find stability and sensitivity.

Apparatus used: Universal Govenor

Introduction & 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. If the load on the engine decreases, it's 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
      i. Dead weight governor (Porter and Proell governor)
      ii. Spring controlled governors (Hartnell governor, Hartung governor, Wilson-Hartnell governor and Pickering governor)

Watt governor: The simplest form of a centrifugal governor is 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:

1. The pivot P may be on the spindle axis.
2. The pivot P may be offset from spindle axis and arms when produced intersect at O.
3. The pivot P may be offset but the arms cross the axis at O.

Porter governor: The porter governor is a modification of a watt governor, with central attached to the sleeve. The load moves up down the central spindle. This additional downward force increases the speed of revolution required to enable the balls to rise to any pre-determined level.

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.

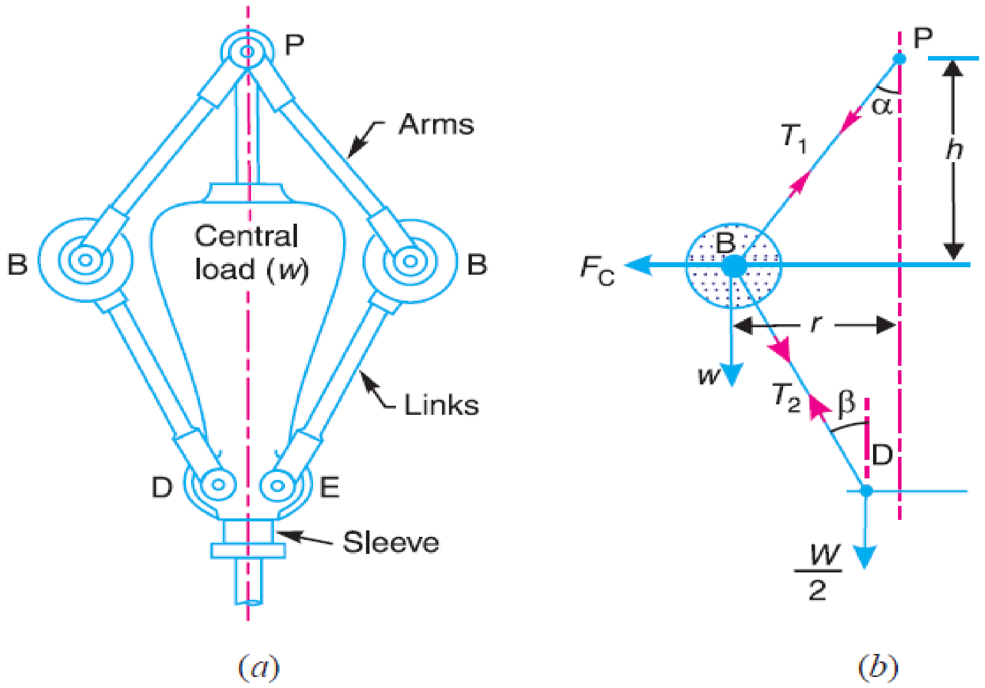


Fig: 6.1 Porter Governor

CALCULATIONS:

1. Controlling Force, F= $m\omega^2 r$ N

   Where , $\omega = \frac{2\pi N}{60}$ rad/s

1. Effort, Q= C (M+m)g N

   Where, c: change of speed [Take c = $(N_2 - N_1) / N_1$]

1. Power, P= Q×X N-mm
2. Sensitiveness of the governor

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

Where, N_1=Minimum equilibrium speed

N_2= Maximum equilibrium speed

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

EXPERIMENT NO: 6A

PORTER GOVERNOR

AIM: To study the performance characteristics of Porter governor

PROCEDURE:

1. Arrange the governor mechanism under test as per required configuration. This can be done by fitting chosen sleeve & weights as per required configuration. Connect the motor to speed control unit using four ways cable provided. Switch on the supply.
2. Measure and note down, initial radius of rotation, length of link and initial height of the governor.
3. Increase the speed gradually using dimmer stat provided until the center sleeve rises off the lower stop and aligns with the first division on the graduated scale. Record the sleeve position and speed.
4. Increase the speed gradually to have suitable sleeve movements, and note down the sleeve displacement and speed accordingly throughout the range of sleeve movement possible.
5. Calculate the value of stability and sensitiveness of the governor.
6. Plot the governor characteristic curves using the data tabulated in the tabular column.

PRECAUTIONS

1. Increase the speed gradually.
2. Take the sleeve displacement when the pointer is steady.
3. Ensure that the load on sleeve does not hit the upper sleeve of the governor.
4. Bring dimmer to zero position then switch off the unit.

OBSERVATION :

a) Length of each link, l = 130mm

b) Initial height of governor, h_o = 90mm

c) Initial radius of rotation, r_o = 135mm

d) Mass of the Ball Assembly, m= 0.5Kg

e) Mass of sleeve, M= 1kg

f) Minimum equilibrium speed, N_1= _______rpm

g) Maximum equilibrium speed, N_2= _______rpm

Radius of rotation at any position can be found using formulae given below:

1) Find height h = ho- $\frac{X}{2}$

2) α = $\cos^{-1}\frac{h}{l}$ °C

3) Radius of rotation, r = 50 + *l* Sinα mm

TABULAR COLUMN:

Sl. No	Sleeve lift 'X' mm	Speed in rpm	Height 'h' in mm	'α' in ˚C	Radius of Rotation 'r' mm	Force F F= $m\omega^2 r$ N	Effort 'Q' in N	Power 'P' in N-mm

GRAPH:

1. Sleeve displacement vs. Speed
2. Controlling force vs. Radius of rotation

RESULT:

1. Sensitiveness of governor = _____________
2. Governor effort = ______________________

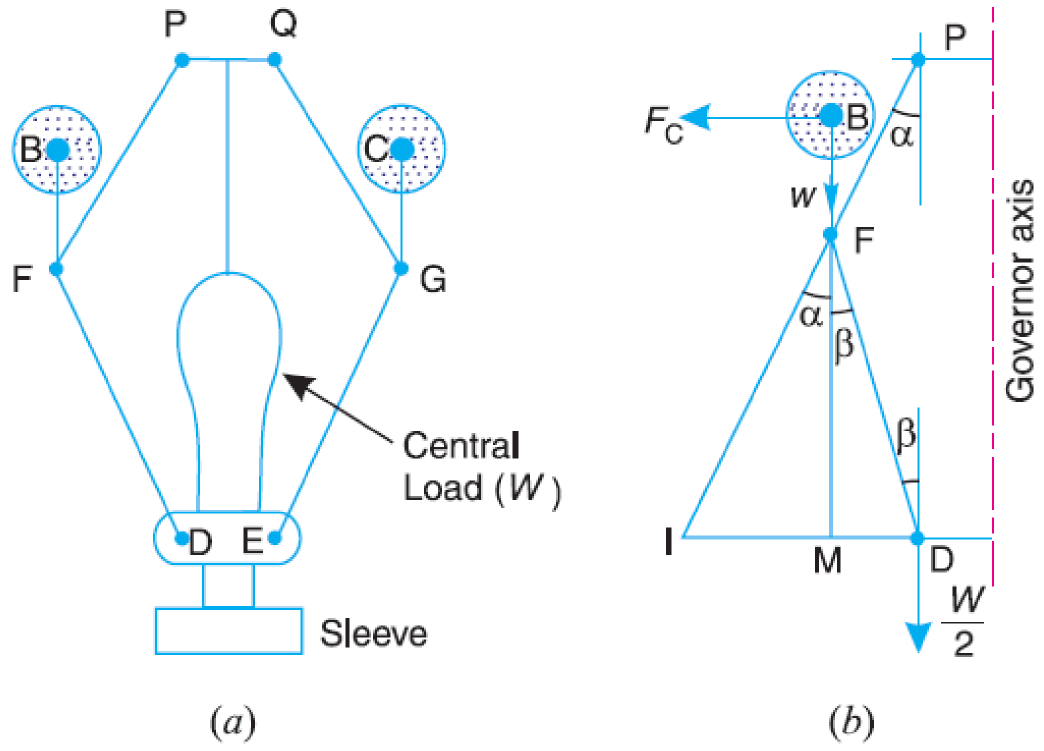


Fig: 6.2 Proell governor.

TABULAR COLUMN:

Sl. No	Sleeve lift 'X' mm	Speed 'N' in rpm	Height 'h' in mm	'α' in °C	Radius of Rotation 'r' mm	Force F F= $m\omega^2 r\ N$	Effort 'Q' in N	Power 'P' in N-mm

CALCULATIONS:

2. Controlling Force, F= $m\omega^2 r\ N$

   Where , $\omega = \frac{2\pi N}{60}\ rad/s$

2. Effort, Q= C (M+m)g N

   Where, c: change of speed [Take c = $(N_2 - N_1) / N_1$]

3. Power, P= Q×X N-mm

EXPERIMENT NO: 6B

PROELL GOVERNOR

AIM: To study the performance characteristics of Proell governor

PROCEDURE:

1. Arrange the governor mechanism under test as per required configuration. This can be done by fitting chosen sleeve & weights as per required configuration. Connect the motor to speed control unit using four ways cable provided. Switch on the supply.
2. Increase the speed gradually using dimmer stat provided until the center sleeve rises off the lower stop and aligns with the first division on the graduated scale. Record the sleeve position and speed.
3. Increase the speed gradually to have suitable sleeve movements, and note down the sleeve displacement and speed accordingly throughout the range of sleeve movement possible.
4. Calculate the value of stability and sensitiveness of the governor.
5. Plot the governor characteristic curves using the data tabulated in the tabular column.

NOTE: With the use of fly weights the governor becomes highly sensitive. Under this condition large displacement is observed for vary small change in speed. In order to make it stable, it is necessary to carry out the experiments by using half ball flyweight on each side.

PRECAUTIONS:

1. Increase the speed gradually.
2. Take the sleeve displacement when the pointer is steady.
3. Ensure that the load on sleeve does not hit the upper sleeve of the governor.
4. Bring dimmer to zero position then switch off the unit.

OBSERVATION:

a) Length of each link, l = 125mm

b) Initial height of governor, h_o = 90mm

c) Initial radius of rotation, r_o = 138mm

d) Extension of length, BG = 75mm

e) Mass of the Ball Assembly, m= 0.5Kg

f) Mass of sleeve, M= 1kg

g) Minimum equilibrium speed, N_1= _______rpm

h) Maximum equilibrium speed, N_2= _______rpm

4. Sensitiveness of the governor

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

Where,

N_1=Minimum equilibrium speed

N_2= Maximum equilibrium speed

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

GRAPH:

1. Sleeve displacement vs. Speed
2. Controlling force vs. Radius of rotation

RESULT:

3. Sensitiveness of governor = ____________
4. Governor effort = ____________________

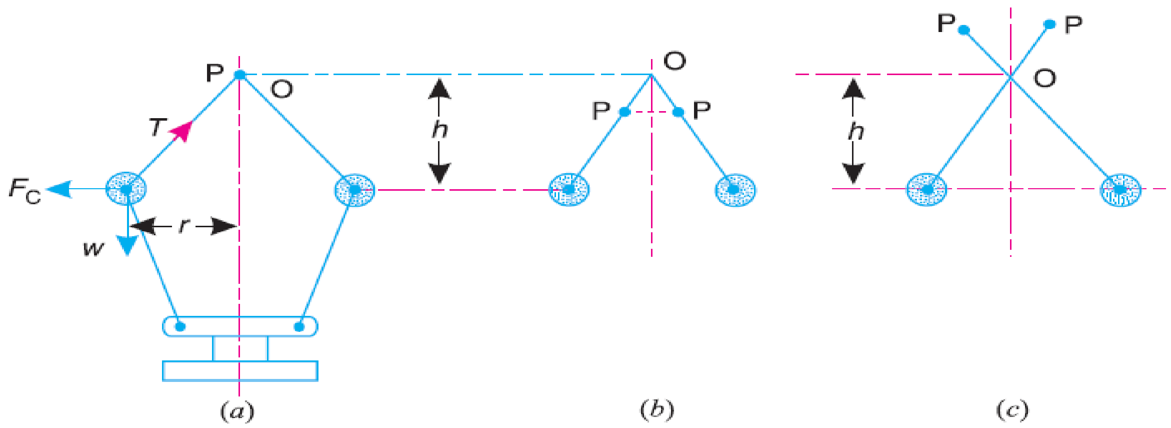


Fig: 6.3 Watt Governor

TABULAR COLUMN:

Sl. No	Sleeve lift 'X' mm	Speed 'N' in rpm	Height 'h' in mm	'α' in °C	Radius of Rotation 'r' mm	Force F F= $m\omega^2 r$ N	Effort 'Q' in N	Power 'P' in N-mm

OBSERVATION:

a) Length of each link, l = 130mm

b) Initial height of governor, h_o = 90mm

c) Initial radius of rotation, r_1 = 135mm

d) mass of the Ball Assembly= 0.5Kg

e) Minimum equilibrium speed, N_1= ____________

f) Maximum equilibrium speed, N_2= ____________

g) Maximum radius of rotation, r_2= __________mm

Radius of rotation at any position can be found using formulae given below:

1) Find height h = ho- $\frac{X}{2}$

2) Cosα = h/l

3) Radius of rotation, r = 50 + l Sinα

EXPERIMENT NO: 6C

WATT GOVERNOR

AIM: To study the performance characteristics of Watt governor

PROCEDURE:

1. Arrange the governor mechanism under test as per required configuration. This can be done by fitting chosen sleeve & weights as per required configuration. Connect the motor to speed control unit using four ways cable provided. Switch on the supply.
2. Measure and note down, initial radius of rotation, length of link and initial height of the governor.
3. Increase the speed gradually using dimmer stat provided until the center sleeve rises off the lower stop and aligns with the first division on the graduated scale. Record the sleeve position and speed.
4. Increase the speed gradually to have suitable sleeve movements, and note down the sleeve displacement and speed accordingly throughout the range of sleeve movement possible.
5. Calculate the value of stability and sensitiveness of the governor.
6. Plot the governor characteristic curves using the data tabulated in the tabular column.

PRECAUTIONS

1. Increase the speed gradually.
2. Take the sleeve displacement when the pointer is steady.
3. Ensure that the load on sleeve does not hit the upper sleeve of the governor.
4. Bring dimmer to zero position then switch off the unit.

CALCULATIONS:

3. Controlling Force, F= $m\omega^2 r\ N$

   Where , $\omega = \frac{2\pi N}{60}\ rad/s$

4. Effort, Q= C (M+m)g N

   Where, c: change of speed [Take c = $(N_2 - N_1) / N_1$]

5. Power, P= Q×X N-mm

6. Sensitiveness of the governor

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

Where,

N_1=Minimum equilibrium speed

N_2= Maximum equilibrium speed

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

GRAPH:

1 Sleeve displacement vs. Speed

2 Controlling force vs. Radius of rotation

RESULT:

1 Sensitiveness of governor = ____________

2 Governor effort = ____________________

PART I:

Observation:

1. Mass of rotating disc (M) = 6.3 kg
2. Diameter of disc = 300 mm; r = radius of disc = 150 mm.
3. L = 200 mm.

PART II:

TABULAR COLUMN:

Sl. No	Spin speed 'N' rpm	Weight 'W' Kg	Angle turned Degrees (dθ)	Time Seconds (dt)	Direction of rotation
				.	

CALCULATIONS:

1. **Gyroscopic couple**

   Gyroscopic couple for a planar disc, $\mathbf{G = I \times \omega \times \omega_p}$

   Where,

   i. **I** = Mass moment of Inertia of disc = $M \times r^2/2$ kg m^2

   ii. **ω** = Angular velocity of precession of disc radians per second

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

   Where, **N**= speed of disc in rpm

   iii. $\boldsymbol{\omega_p}$ = Angular velocity of precession of yoke about vertical

   $= \frac{d\theta}{dt}$ rad/sec

   Where, **dθ** = Angle of precession in radiands and

   dt = Time in seconds required for this precession

2. **Applied torque**

   Applied torque, $\mathbf{G_E = W \times L}$ Nm

Where,

W = Weight on pan &

L = Distance of Weight

EXPERIMENT NO: 7

MOTORIZED GYROSCOPE

AIM: To study the gyroscopic principle and verify the relation between the applied torque, Spin velocity and Precessional velocity in case of free precession and forced precession.

DESCRIPTION:

The motor is coupled to the disc rotor, which is balanced. The disc shaft rotates about XX axis in two ball bearing housed in the frame No. 1. This frame can swing about Y - Y axis in bearings provided in the yoke type frame No.2. In steady position, frame No. 1. is balanced by providing a weight pan on the opposite side of the motor. The yoke frame is free to rotate about vertical axis Z-Z. Thus freedom of rotation about three perpendicular axis is given to the rotor.

TECHNICAL DATA:

1. Weight of Rotor: **6.3Kg**
2. Rotor Diameter: **300mm**
3. Rotor Thickness: **________mm**
4. Distance of bolt of Weight pan from disc Center : **20cms**
5. Motor-Fractional H.P. single phase/6000 rpm -AC/DC

PROCEDURE:

Part I:

The spinning body exerts a torque or a couple in such a direction which tends to make the axis of spin coincides with that of the precession. To study the phenomenon of forced precession following procedure is adopted.

1. Balance initial horizontal position of rotor.
2. Start the motor and adjust the voltage to get the constant speed.
3. Press the yoke frame about the vertical axis by applying the necessary force by hand in the clockwise direction viewed from the top.
4. It will be observed that rotor frame swing about the horizontal axis so that the motor side moves upwards.

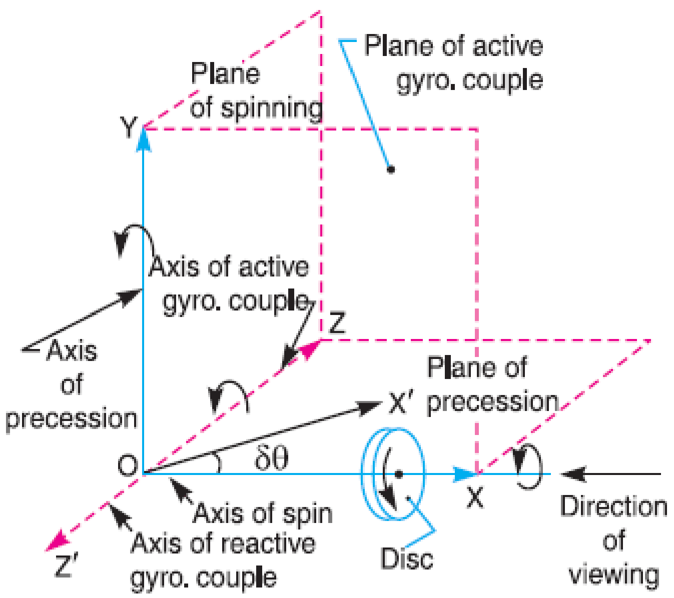
5. Rotating the yoke axis in the opposite direction causes the rotor frame to move in the opposite direction.

Part II:

The spinning body precesses in such a way that to make the axis of spin to coincide with that of the applied couple.

The direction is verified by following the procedure given below and using the apparatus as well as the relation for the magnitude of the couple.

1. Balance the rotor in the horizontal plane.
2. Start the motor and adjust the speed with the help of voltage regulation. The speed is measured using a tachometer.
3. Put weights on the side opposite to the motor.
4. The yoke start precessing.
5. Note down the direction of precession.
6. Verify this direction.
7. Measure the velocity of precession using the pointer provided the yoke and stop watch.
8. Verify the relation given for gyroscopic couple, G.



Gyroscopic couple

RESULT: For a particular load and particular rpm

Sl. No	Gyroscopic couple (G) $G = I \times \omega \times \omega p$ Nm	Actual Torque (G_E) $G_E = W \times L$ Nm

OBSERVATIONS:

1. Diameter of Journal, d= 50 mm
2. Diameter of bearing, D= 55 mm
3. Length of Bearing, L= 68 mm
4. Weights: 1 kg, 0.5 kg
5. Speed of journal, N=_____rpm
6. Viscosity of oil, η = 125×10^{-3} Pa-second
7. Eccentricity Ratio, ε =____
8. Motor control: Dimmer stat
9. Recommended oil: SAE 40 or 40/20 oil, 5 litre.

CALCULATIONS:

1. Є = eccentricity ratio = e/C

Where, Diameter of the bearing (D) = 75 mm

Diametrical clearance (C) = 0.5 mm

h = oil film thickness

e =eccentricity of journal (distance between journal and bearing centers when oil film is established)

Ψ = attitude angle (angle at h_{min} from load line)

2. Linear speed of the journal, $V= \frac{\pi dN}{60} \frac{m}{s}$
3. Diameteral Clearance ratio, $\psi = \frac{c}{d}$
4. Load carrying capacity, $W = \frac{\eta VL}{\psi^2} \frac{12\pi\varepsilon}{(2=\varepsilon^2)\sqrt{1-\varepsilon^2}} N$
5. Frictional force, $F_\mu = \frac{4\pi\eta VL}{\psi}\left[\frac{1+2\,\varepsilon^2}{(2+\varepsilon^2)\sqrt{1-\varepsilon^2}}\right] N$
6. Co-efficient of friction, $\mu = \frac{F_\mu}{W}$
7. Power loss in viscous friction, $N = \frac{F_\mu V}{1000}\ kW$

EXPERIMENT NO: 8

JOURNAL BEARING APPARATUS

AIM: To study the pressure distribution in Journal bearing and to draw experimental pressure curves.

DESCRIPTION:

The major objective of lubrication of journal bearings is to induce and maintain a film of lubricant between the journal and the bearing. The purpose of this film of lubricant is to keep the two surfaces separate at all times and thus prevent metal to Hydrodynamic lubrication is the most common method of lubrication of journal bearings. In this method, as the shaft rotates it will, due to the load applied to it (as well as its own weight), take a slightly eccentric position relative to the bearing. The eccentric rotation of the shaft in the bearing acts some-what like a rotary pump and generates a relatively high hydrodynamic pressure in the con-verging zone. The hydrodynamic pressure for a properly designed bearing is responsible for supporting the shaft without allowing it to come in contact with the bearing. Metal or dry contact which otherwise will create bearing failure.

PROCEDURE:

1. Fill the oil tank by using SAE 40 oil and position the tank at desired height.
2. Drain out the air from all tubes on the manometer & check the level balance with supply level.
3. Check that some oil leakage is there in the bearing. Leakage is necessary for cooling purpose.
4. Check the direction of rotation and increase the speed of motor slowly.
5. Set the speed and put the load on bearing if desired so and let the journal run for about 20 minutes until the oil in the bearing warms and check the steady oil level at various tubes on manometer.
6. See that the balancing rod horizontal position and observe steady levels.
7. When manometer levels have settled down, take the pressure readings on 16 manometer tubes.
8. Repeat the experiment for various speeds and loads.
9. After the test is over set the dimmer to zero & switch off the power.
10. Keep the oil tank at lower position so that there will be least leakage in idle period.

TABULAR COLUMN:

Tube No.	Angular position θ in degrees	Initial Head of oil h_1 in cm of oil	Final Head of oil h_f in cm of oil	Actual head, $h = h_f - h_1$ in cm of oil

RESULT:

1. Load carrying capacity = ______N
2. Co-efficient of friction, μ = ______
3. Power loss in viscous friction, N = ______ kW

GRAPH:

Graph to be plotted for pressure head of oil above the supply head in mm of oil, at angular intervals of 30˚ of oil film.

Figure 8: Journal Bearing Apparatus

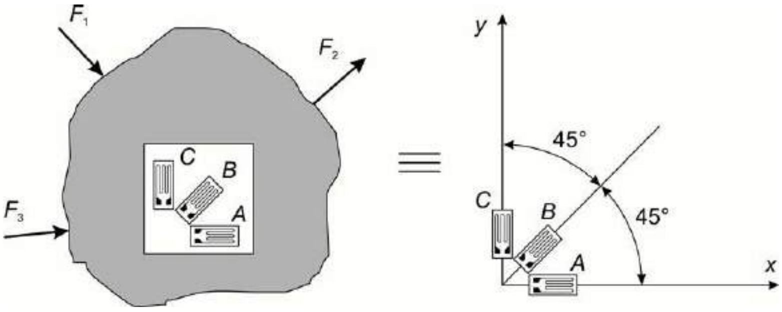


Fig 9.1 Three Element Rectangular rosette

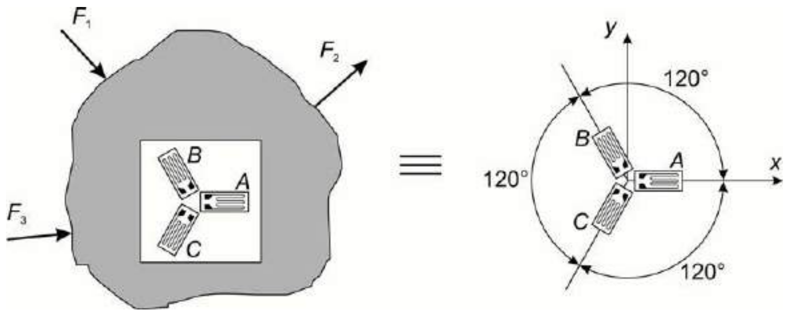


Fig 9.2: Delta rosette

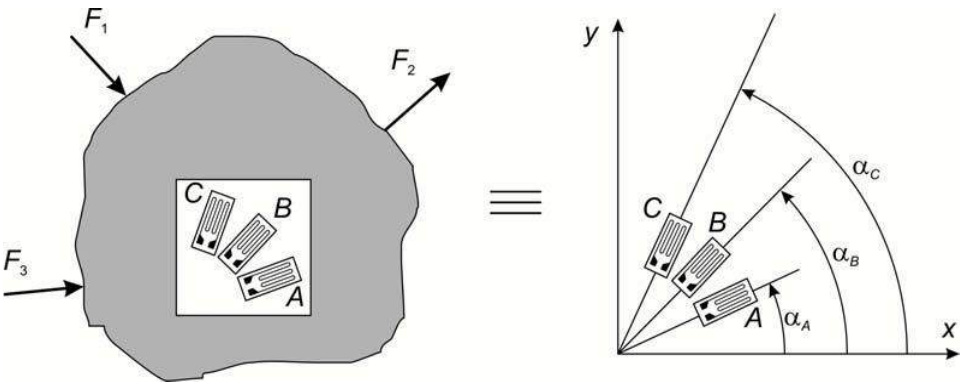


Fig 9.3 Three element rosette

EXPERIMENT NO: 9

STRAIN ROSETTE

AIM: To determine principle stress and strain in a member subjected to combined loading using strain rosette.

DESCRIPTION:

This setup has been designed to study the application of rosette strain gauge and to find out maximum principal stress value and direction. In strain gauge technique a very thin wire of the order of 5 to 10 micron diameter is pasted on a metal part by means of suitable adhesive. The metal part is then subjected to load, which finally results induction of strain in it. By knowing the strain values, stress values are calculated by using standard strength of material relations. Hence the values of stresses at various points of interest can be found out experimentally, resulting into complete stress picture of the metal part under investigation.

For investigating the stresses in metal part the entire cases can be categorized in two groups:

- When direction of stresses is known
- When direction of stresses is unknown

In first case it is easy to analyze because the direction in which the maximum principle stress occurs is known and stain gauges can be oriented in already known direction and single element strain gauges serve the purpose. However in second case single element strain gauge will not serve the purpose, as such, three-element rosette type gauges are used.

Set-up consists of a hollow cylinder pasted with rosette strain gauge. This cylinder can be pressurized by using foot pump. A multichannel strain indicator is provided to measure output of each strain gauge. Students can find out values of maximum stress at various pressures and compare the same with theoretical values.

THEORY:

The purpose of strain rosette apparatus is to determine the magnitudes and directions of principal stresses σ_1 & σ_2 under bi-axial state of stress (plane stress condition).

A group of 3 to 4 strain gauges arranged in some configuration is called a rosette. The different arrangements are:

1. 3 element rectangular rosette
2. 3 element delta rosette
3. 4 element rectangular rosette

Strain gauges are placed at certain angular positions. Theoretically, gauges in the rosette can be placed at any angle but due to practical considerations, 2 or 3 sets of values are used. In the 3-element strain rosette, the rectangular & delta configurations are employed. In the former, 2 gauges are placed at right angles while the 3rd gauge makes an angle of 45° with both gauges. In the delta configuration gauges are placed at an angle of 60°. It is necessary to measure 3 strains at a point completely defined by either stress or strain fields.

THREE ELEMENTS RECTANGULAR ROSETTE ARRANGEMENT

Let, α_A=0°, α_B= 45° & α_C= 90°

The three element rectangular rosette employs gages placed at 0°, 45° and 90° positions, as indicated in Fig 9.1.

$$\varepsilon_{xx} = \varepsilon_{A,}\ \varepsilon_{yy} = \varepsilon_C, \gamma_{xy} = 2\varepsilon_B - \varepsilon_A - \varepsilon_C \qquad \textbf{9.1}$$

By measuring the strains $\varepsilon_A, \varepsilon_B$ & ε_C, the Cartesian components of strains ε_{xx}, ε_{yy} and γ_{xy} can be determined by using above equation.

The principal strains and principal directions can be calculated using following equations:

$$\varepsilon_1 = \frac{1}{2}(\varepsilon_{xx} + \varepsilon_{yy}) + \frac{1}{2}\sqrt{(\varepsilon_{xx} - \varepsilon_{yy})^2 + \gamma_{xy}^2} \qquad \textbf{9.2}$$

$$\varepsilon_2 = \frac{1}{2}(\varepsilon_{xx} + \varepsilon_{yy}) - \frac{1}{2}\sqrt{(\varepsilon_{xx} - \varepsilon_{yy})^2 + \gamma_{xy}^2} \qquad \textbf{9.3}$$

$$\theta_1 = \frac{1}{2}\tan^{-1}\frac{\gamma_{xy}}{\varepsilon_{xx} - \varepsilon_{yy}}\ ^\circ C,\ \theta_2 = 90 + \theta_1\ ^\circ C \qquad \textbf{9.4}$$

The solution for Eq.9.4 yields two values for the angle θ. They are θ_1, which refers to the angle between the x-axis and the axis of maximum principal strain ε_1 and θ_2, which is the angle between the x-axis and the axis of minimum principal strain ε_2.

The principal stresses can be calculated using equations below:

$$\sigma_1 = \frac{E}{1-v^2}(\varepsilon_1 + v\varepsilon_2) \qquad \textbf{9.5}$$

$$\sigma_2 = \frac{E}{1-v^2}(\varepsilon_2 + v\varepsilon_1) \qquad \textbf{9.6}$$

TABULAR COLUMN:

Sl. No	Load N	Measured strain		
		ε_A	ε_B	ε_C

PROCEDURE:

1. Note down the young's modulus and Poisson's ratio of the material.
2. Make the necessary connection to the digital strain flow indicator from and corresponding strain gauge.
3. Connect the instrument to power outlet and switch on the instrument.
4. Adjust the indicator to zero for all strain gauges.
5. Load the specimen by placing weights on the loading pan.
6. Note down the strain in microns by turning the knob towards each strain indicator.
7. Among the three readings one will be negative and the other two will be positive.
8. Repeat the above procedure for different load in steps.
9. Determine the required parameters by using the suitable equations.

After completion of the experiment:

1. Remove the weights on the loading pan.
2. Switch off the instrument.
3. Disconnect the instrument from the power outlet.
4. Remove the connections from strain indicator.

OBSERVATION:

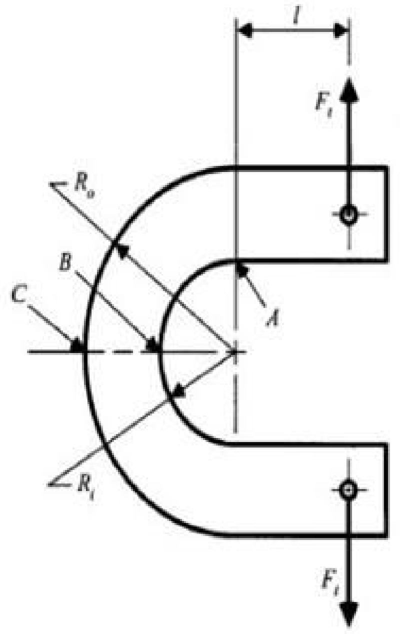
Young's modulus of shaft material: _______________

Poisson's ratio of the shaft material: _______________

Gauge factor of the strain gauges: _________________

RESULT TABLE:

Sl. No	Principal strain		Principal stress MPa		Orientation	
	ε_1	ε_2	σ_1	σ_2	θ_1	θ_2



Total Applied Force $F_c = (M_{weight} + M_{fixture} + M_{pan})g$ (N)	
Outer radius r_o (mm)	
Inner radius r_i (mm)	
Height $h_c = r_o - r_i$ (mm)	
Thickness, b (mm)	
Average radius $r_{ave} = \bar{r} = (r_o + r_i)/2$ (mm)	
Straight leg length l (mm)	

Fig 10.1: Curved beam

TABULAR COLUMN:

Sl. No	Load In kg	Measured strain $'\varepsilon'$	Stress at inner layer, σ_i	Stress at outer layer, σ_o	Experimental Stress σ

EXPERIMENT NO: 10

CURVED BEAM

AIM: To determine principle stress and strain in a member subjected to combined loading using strain gauges.

DESCRIPTION:

A beam in which the neutral axis in the unloaded condition is curved instead of straight or if the beam is originally curved before applying the bending moment, are termed as "Curved Beams

Curved beams find applications in many machine members such as c – clamps, crane hooks frames of presses, chains, links, and rings

PROCEDURE:

1. Measure dimensions of the curved beam and the location and the orientation of each strain gauge.
2. Number strain gauges and connect them to the strain gage indicator in the same order.
3. Balance the circuit for each strain gage. If it is not possible to set zero in the indicator, record the initial reading.
4. Set the gage factor for the strain gages used in this experiment.
5. Apply load gradually on the curved beam by adding weights and record the final strain readings at that load.
6. Determine the stresses at inner and outer layer of beam.

OBSERVATION:

1. Outer radius of beam, r_o=_______ mm
2. Inner radius of beam, r_i=________mm
3. Radius of beam to central axis, r_c=______mm
4. Young's modulus, E= 210GPa

CALCULATIONS:

1. Neutral radius, $r_n = \frac{h}{\ln\frac{r_o}{r_i}}$ mm
2. Eccentricity, e = r_c-r_n mm
3. Distance from neutral axis to inner radius, C_i = r_n-r_i , mm
4. Distance from neutral axis to outer radius, C_o = r_o-r_n , mm
5. Stress at inner layer, $\sigma_i = \frac{m_b C_i}{me\ r_i}\ N/mm^2$
6. Stress at outer layer, $\sigma_o = \frac{m_b C_o}{me\ r_o}\ N/mm^2$
7. Experimental stress, $\sigma = E\times\varepsilon$ N/mm^2

Result:

Compare theoretical and experimental stress in curved beam.

VIVA VOCE QUESTIONS

1. **What is stress?**

   The internal resistance by which offers load.

2. **What is the difference between stress & pressure?**

   Stress is defined as force per unit area. Pressure is special variety of stress .However stress is much more complex quantity than pressure because it varies both with direction and with the surface it acts on.

3. **What is Strain?**

   The strain is defined as the amount of deformation obtained due to stress.

4. **What is Strain gauge?**

   A strain gauge is a device is a device used to measure the strain of an object.

5. **Name the different type of strain gauges?**

   Electrical and optical strain gauges.

6. **Explain the working principle of electrical strain gauges?**

   The electrical strain gauges consist of an insulating flexible backing with supports a metallic foil pattern. The gauge is attached to the object by the suitable adhesive. As the object is deformed the foil is also deformed, causing the electrical resistance to change. This electrical resistance change is usually measured using Wheatstone bridge.

7. **Define gauge factor?**

   Gauge factor or Strain factor of a strain gauge is a ratio of relative change in the electrical resistance to the mechanical strain, which is a relative change in length.

8. **Name some Strain gauge adhesives or Bonding materials?**

   Cyanoacrylate, Epoxy, Phenol, Polyamide

9. **Define Young's Modulus?**

   Young's modulus is defined as tensile stress is directly proportional to the tensile strain within the elastic limit.

10. **What is the Bulk Modulus?**

    It is defined as the ratio of Normal stress to the Volumetric strain and is denoted by K

11. **Define Rigidity Modulus?**

    It is defined as the ratio of shear stress & shear strain and is denoted by C.

12. What is Strain Rosette?

The strain rosette is an arrangement of two or more closely positioned gage grids, separately oriented to measure the normal strain along different directions.

13. What is the difference between the Strain Gauge and strain rosettes?

A strain gauge can effectively measure strain in only one direction. In case of strain rosette it is also made up of strain gauges allowing to measure more than one direction.

14. Define stress concentration factor?

A sudden change in the geometric form of a part give raise to additional stress over the calculated stress is known as stress concentration.

15. Name some causes for stress concentration factor?

Geometric discontinues causes an object to experience a local increase in intensity of stress field.

E.g.: Cracks, sharp corners, holes, Changes in the cross sectional area of the object. High local stress can cause objects to fail more quickly.

16. Define the Poison's ratio?

It is the ratio of lateral strain to longitudinal strain.

17. What is Photo elasticity?

Photo elasticity is an experimental method to determine the stress distribution in a material.

18. What is Plain and Circular Polariscope?

It is an instrument for detecting polarized light or for observing objects under polarized light, for detecting strain in transparent materials. First the light is pass through the first polarizes which converts light in to plane polarized light. In circular polariscope, we have to place first quarter wave plate between the polarizer and specimen then the second quarter wave plate is placed between the specimen and the analyzer. So that we can get circular polarized light passing through the sample.

19. Name the Photo elastic material used in our lab?

Araldite

20. How vibrations are classified?

Free, Forced, Self Excited vibrations.

21. Define Frequency, Time period, Simple Harmonic motion

Frequency: It is the number of cycles per unit time

Time period is the time required for one complete cycle

Simple Harmonic motion (SHM) is a periodic motion with acceleration always directed towards the equilibrium position.

22. State & Explain the types of free vibrations?

Longitudinal Vibration: The particle of the shaft moves parallel to the axis of the shaft.

Lateral Vibration: The particle of the shaft moves perpendicular to the axis of shaft.

Tensional Vibration: The particle of the shaft moves circular about the axis of shaft.

23. Define Under damping & Critical damping.

Under damping system: Yields an experimentally decreasing sinusoidal output in response to a step input.

Critical damping: The minimum amount of damping that will yield a non oscillatory output in response to step input.

24. Why balancing is necessary?

Balancing is the correction of phenomena by the removal or addition of mass to the component to compensate the center line error.

25. Explain the static and dynamic balancing?

The balancing of rotating masses is important to avoid vibration. Static balancing occurs when there is no resultant centrifugal force and the centre of gravity is on the axis of rotation.

In dynamic balancing any resultant centrifugal force and couple does not exist.

26. Balancing of single revolving mass requires minimum two balancing weights, what happen when the different weights are placed?

The net dynamic force acting on the shaft must be equal to zero, i.e. the centre of the masses of the system must lie on the axis of rotation and the net couple due to the dynamic forces acting on the shaft must be equal to zero I.e. the algebraic sum of the movements about any point in the plane must be zero.

27. Explain the terms Primary and Secondary balancing?

Primary balancing: - In the single cylinder engine primary force generated due to the reciprocating mass of piston & connecting. to balance by adding weights to the counter web.

Secondary balancing:- it can be balanced in some multi cylinder engines by appropriate selection of the phase of motion of individual cylinders.

28. Explain the various reasons for the partial balancing of reciprocating masses?

Due to the partial balancing there is an unbalanced primary force along the line of stroke Variation in tractive force of stroke & Sawing couple and unbalanced primary force perpendicular to the line of action to produce variation of rails which results in hammering action on rails.

29. What is line engines & how they are balanced?

The cylinders mounted in a straight line along the crankcase with all the pistons driving a common crankshaft. The primary forces may be completely balanced by suitably arranging the crank angles. The algebraic sum of secondary forces must be equal to zero.

30. What are V Engines? How they are balancing?

V- Engine is an internal combustion engine, the cylinders and pistons are aligned in two separate planes so they are appear in a ‘V’ when view along the axis of the crank shaft. These engines can be balanced by adding counterweight to the crankshaft.

31. Explain the term torsion ally equivalent shaft?

A shaft having diameter for different length can be theoretically replaced by an equivalent shaft of uniform diameter such that they have the same total angle of twist when equal opposing torques re applied at their ends. Such a theoretically replaced shaft is known as torsion ally equivalent shaft.

32. State Dunkerley’s rule?

Dunkerley’s method is used to determine the critical speed of shaft rotor system.

33. Define the terms Stiffness, Deflection, Critical speed?

Stiffness is the rigidity of an object

Deflection is the degree to which a structural element is displaced under load.

The speed at which resonance occurs is called critical speed.

34. State the total energy and Rayleigh’s method.

The concept of total energy of the system, which is the sum of Kinetic energy (T) and Potential energy (V) remains constant. The Rayleigh’s method is equated the maximum kinetic energy of the system to the maximum potential energy of the system.

35. Explain Equivalent mass & Stiffness?

In certain systems more than one spring or mass has to be used and to convert this system in to equivalent mathematical models, it is necessary to find out equivalent stiffness and equivalent mass.

36. Distinguish between the Free, Force & Torsional vibration?

Free or Natural vibrations: When no external force acts on the body, after giving it an initial displacement. then the body is said to be under forced under free vibration

Forced vibrations:-When the body vibrates under the influence of external force, then the body is said to be under forced under forced vibration.

Torsional vibration:- It may be free or forced vibrations the particles of a shaft or disc move in a circle about the axis of the shaft.

37. Distinguish between Linear & Non linear vibrations?

When the vibrations are represented by linear differential equations and laws of super position are applicable for linear systems.

In case of Non linear vibrations when large amplitudes are encountered and laws of superposition is not applicable.

38. Define Damping ratio & Logarithmic decrement?

The damping ratio is a parameter characterizes the frequency response of a second ordinary differential equation.

The logarithmic decrement is the natural log of the ratio of the amplitudes of any two successive peaks under damping system.

39. Explain the factors affecting the critical speed?

Material properties , Diameter , Length

40. Name the types of Damping?

Viscous damping, Coulomb damping, Solid or Structural damping & slip or interfacial damping.

41. What is gyroscopic effect?

Gyroscopic effect to a body revolving about an axis say OX , if a couple represent by a vector OY perpendicular to OX is applied then the body tries to process about an axis OZ which is perpendicular to both OX & OY. Thus the plane of spin, plane of precession two planes of gyroscopic couple are mutually perpendicular. The above combined effect is known as gyroscopic effect.

42. Explain the Right hand thumb rule?

To determine the direction of spin, Precision and Torque or Vector couple Right hand thumb rule is used. The fingers represent the rotation of the disc And the thumb shows the direction of the spin, precision and torque vector.

43. Define Steering, Pitching and Rolling?

Steering is the turning of a complete ship in a curve towards left or right while it moves forward.

Pitching is the movement of a complete ship up and down in a vertical plane about transverse axis.

Rolling is the movement of ship in a linear fashion.

44. What is the effect gyroscopic couple on rolling ship?

The gyroscopic couple acts only when the axis of precession is perpendicular to the axis of spin for all positions. In case of rolling of ship the axis of precession is parallel to the axis of spin hence there is no effect of the gyroscopic couple on the rolling of ship.

45. Explain the effect of gyroscopic couple in case of Two wheeler when it taking turn?

The gyroscopic couple will act over the vehicle outward. The tendency of this couple is to overturn the vehicle in the outward direction.

46. How the governors are classified?

a. Centrifugal Governors:

i) Pendulum type Ex: - Watt governor

ii) Gravity controlled type Ex:- Porter & proell governors

iii)Spring controlled type :- Hartnell & Hartung governors

b. Inertia governors.

47. Define the terms Sensitiveness, Hunting & Effort with respect to governors?

The sensitiveness is defined as the ratio of the mean speed to the difference between the maximum & minimum speed. The governor is said to be sensitive, when it really responds to the small change in speed.

The phenomenon of the continuous fluctuation in the speed of the engine to the mean speed is known as Hunting.

The mean force acting on the sleeve for a given percentage change of speed for lift of the sleeve is known as the governor effort.

48. Explain the term the stability of the governor?

The governor is said to be stable if there is only one radius of rotation for all equilibrium speeds of the balls with in the working range. If the equilibrium speed increases the radius of governor ball must be increase.

49. What do you mean by isochronous condition in governors?

A governor with zero range of speed, when the equilibrium speed is constant for all the radii of rotation of the balls within the working range, then the governor is said to be isochronous.

50. Name the material used in polarizer, analyzer & quarter wave plate material?

Polaroid

51. Define Principle plane?

Principle plain may be defined as the plane on which normal stress attains its maximum & minimum value.

52. In what condition the Dark & Light fields will obtain in polariscope?

Polarizing axis is crossed to the axis of the polarizer the Dark field of Chromatic pattern is formed. Polarizing axis is parallel to the axis of the polarizer then the light field of chromatic pattern is formed.

53. Define the principle stress & principle strain?

The principle stress is the normal stresses on the orthogonal planes of zero shear stress. The elongation or compression of one of the principle axis of strain relative to its original length is called principal strain.

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