WEST GODAVARI INSTITUTE OF SCIENCE & ENGINEERING

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AVAPADU, **PRAKASARAOPALEM** – 534 112, W.G.Dist., A.P

TOM LAB MANUAL-R20

DEPARTMENT OF MECHANICAL ENGINEERING

II B.TECH II SEMESTER

JAWAHARLAL NEHRU TECHNOLOGICAL UNIVERSITY KAKINADA

KAKINADA–533003, Andhra Pradesh, India

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Experiment Number: Date:

Critical or Whirling Speed of a Rotating Shaft

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

APPARATUS:

1. Shafts
2. Variable Speed Motor

THEORY: Whirling speed is also called as Critical speed of a shaft. It is defined as the speed at which a rotating shaft will tend to vibrate violently in the transverse direction if the shaft rotates in horizontal direction. In other words, the whirling or critical speed is the speed at which resonance occurs.
At certain speed, a rotating shaft has been found to exhibit excessive lateral Vibrations (transverse vibrations). The angular velocity of the shaft at which this occurs is called a critical speed or whirling speed or whipping speed.

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

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

PROCEDURE:

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

S. No	End Condition	Dia. of Shaft (Mm)	Speed (RPM)Expt.		a	Angular Speed	Speed (Theo.)	% Error
			Bending	Twisting		For Bending		
1.								
2.								
3.								
4.								
5.								
6.								
7.								
8.								

FORMULAE:

1. For Bending Mode

Angular speed (ω) = $\frac{22 * a}{L^2}$

Where a = $\sqrt{\frac{E * I}{M}}$

Theoretical speed = $\frac{\text{Angular Speed}(\omega) * 60}{2 * \pi}$

% error = $\frac{\text{theo. speed} - \text{expt.speed}}{\text{theo .speed}} \times 100$

2. For Twisting Mode

Angular speed (ω) = $\frac{61.7 \times a}{L^2}$

Where a = $\sqrt{\frac{E * I}{M}}$

Theoretical speed = $\frac{\text{Angular Speed}(\omega) * 60}{2 * \pi}$

% error = $\frac{\text{theo. speed} - \text{expt.speed}}{\text{theo .speed}} * 100$

TERMS USED:

E → Young's modulus of the material = 2 *10^{11} Gpa
m → mass of the shaft = Kg/m
L → length of the shaft = m
d → diameter of the shaft in m
I → moment of inertia of the shaft in m^4 = $\frac{\pi * d^4}{64}$

PRECAUTIONS:

1. The speed of the shaft should be increased gradually.
2. If the speed of the shaft increased large it may lead to violent instability.

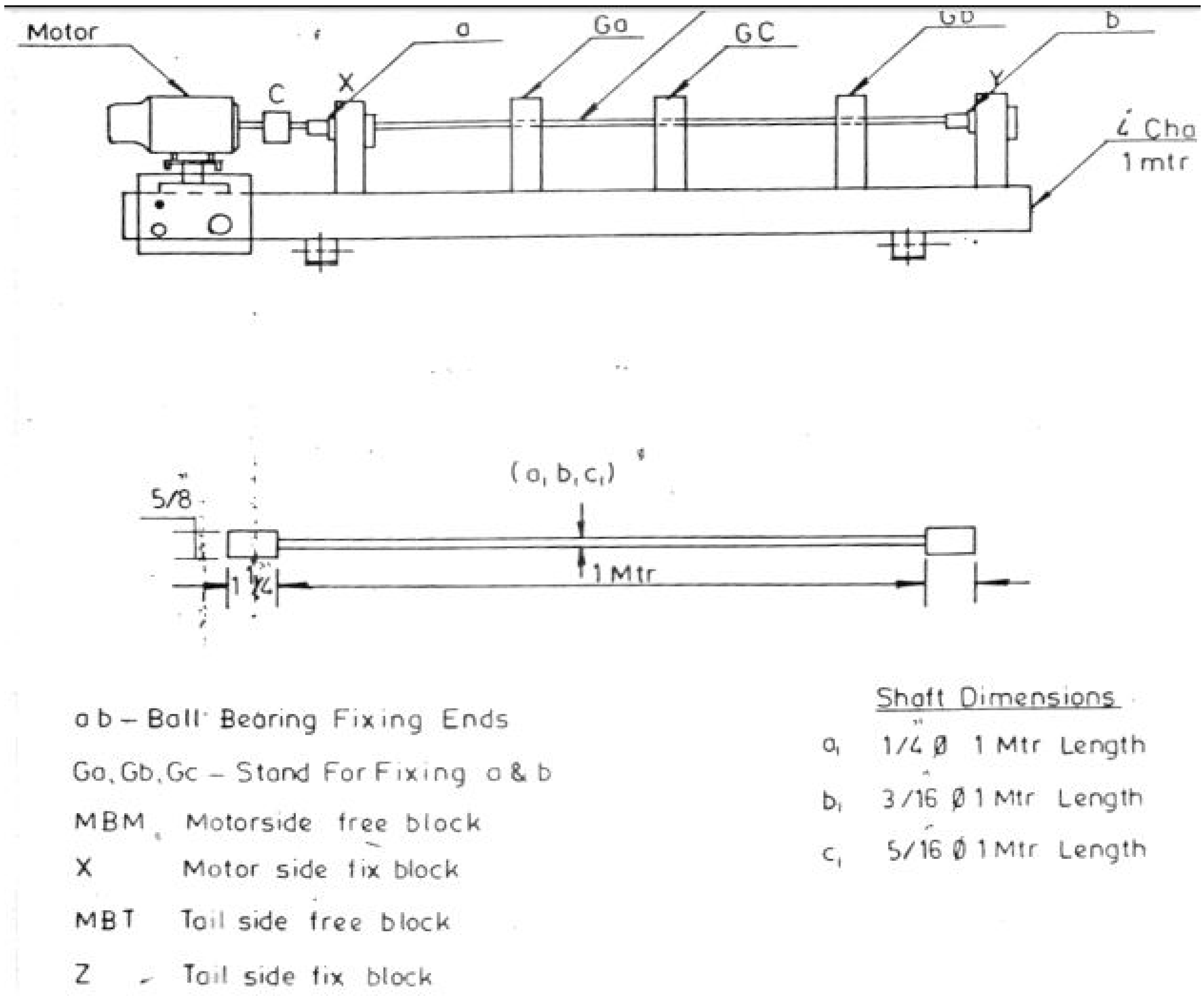


Fig. Whirling of Shafts

RESULT:-

VIVA VOICE:

1. What is meant by whirling of shaft?
2. What is the difference between Critical Speed and Whirling Speed?How do you achieve the hinged end conditions for a rotating shaft?
3. What are the nodes observed while studying whirling phenomenon?
4. How does the material of shaft affects the whirling speed?

Experiment Number: Date:

Hartnell Governor

AIM: To determine the position of sleeve against controlling force and speed of a Hartnell governor and to plot the characteristic curve of radius of rotation.

APPARATUS: Hartnell governor, scale, graph sheet.

THEORY:

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

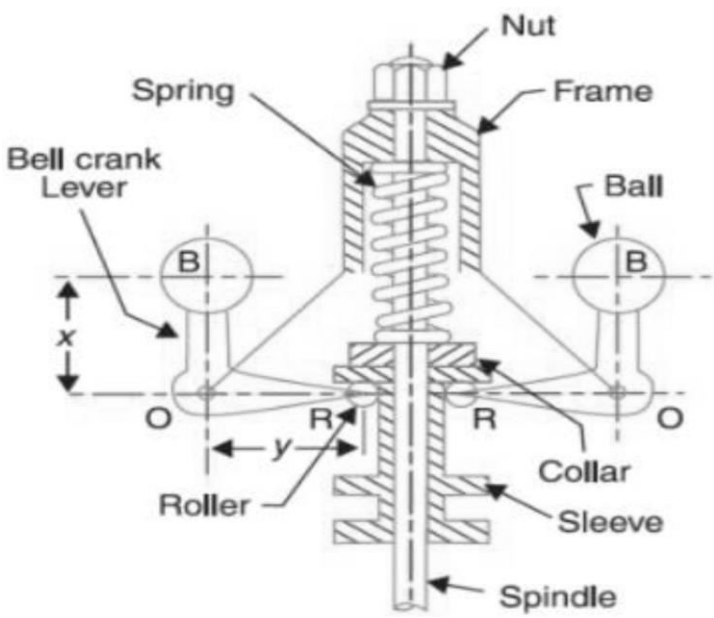


Fig : Hartnel Governor

PROCEDURE:

Mount the required governor assembly over the spindle.

1. Tighten the necessary bolts.
2. Start the motor and gradually increase the speed.
3. The flyweight will fly outward due to which the sleeve will rise.

4. Note down the speed and sleeve rise or calculate by theoretical method.
5. Repeat the experiment at different speeds till the balls fly to maximum position.
6. Bring back the sleeve down by reducing the speed gradually and stop.

SPECIFICATIONS:

Hartnell Governor

Initial height h_o= 150 mm

Length of the link L = 150 mm

For Hartnell governor

S.No.	Lift "X" in m	Speed in RPM	h in m	r in m	ω in rad/sec	Centrifugal Force in Kgf
1						
2						
3						
4						
5						
6						
7						
8						

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

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

2. Initial radius of rotation = r_1

$$r_1 = \frac{h \times 0.075}{L}$$

3.

$$r = r_1 + 0.016$$

4. Angular speed

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

5. Centrifugal force

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

CONCLUSION:

Plot the graph of:
1. Speed Vs Sleeve displacement.
2. Force Vs Radius of rotation. Comment on the relation between the variables from the graph.

PRECAUTIONS:
1. Check the electrical connections properly.
2. Use of safety guard is compulsory.
3. Increase the speed of motor gradually.

Result:

Viva Voice:

1. What is meant by governor?
2. What is meant by sensitivity of governor?
3. What are classifications of governors?
4. What is meant by centrifugal governor?
5. What is meant by inertia governors?

Experiment Number: Date:

Gyroscope

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

APPARATUS:

a. Gyroscope,
b. Weight,
c. Stopwatch.
d. Voltage Regulator.

DEFINITIONS:

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

Precession

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

Gyroscopic Couple

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

$$T = I \times \omega \times \omega_p$$

Where, I = Moment of inertia of rotor.
ω = Angular velocity of rotor.
ω_p = Angular velocity of precession

THEORY:

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

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

1. Gyroscopic inertia

2. Precession

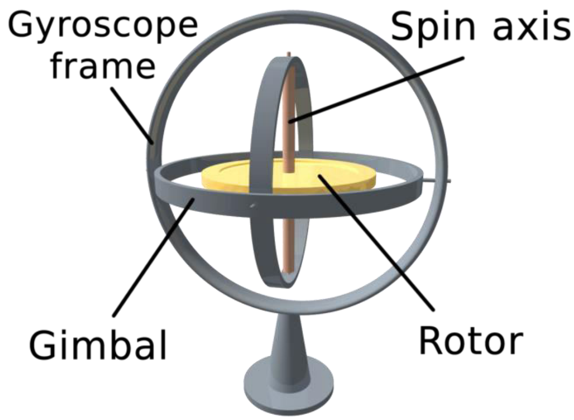


Fig: Motorised Gyroscope

Gyroscopic Inertia:

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

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

$$W_d = \text{mg x N} = \text{Weight of disc}$$

Let Wd= weight of disc =mg,N (or) Kgm/s^2

D = Diameter of disc, m

M = mass of disc, = Wd/g, $(N\text{-}s^2)/m$ or Kg

g = gravitational acceleration, 9.81 m/s^2

For disc

$$I = \frac{1}{2} \text{ x } \frac{W_d \text{ x } \left(D/2\right)^2}{g} = \frac{W_d \text{ x } (D)^2}{8g} \quad \text{in } N - ms^2 \text{(or) } Kg - m^2$$

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

The angular velocity of rotor is called velocity of spin

Where n= speed of motor in rpm

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

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

GYROSCOPIC COUPLE: ($C = I\omega\omega_p$, in N-m)

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

Applied torque = ($C = w \times a$, N-m)

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

PROCEDURE:

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

Observation Table:

S.No	Speed	Angle in degree	Angle in Radian	Time taken	W_t in Kg	w in N	Linear velocity of disc (ω)	Experimental linear velocity of precision (ω_p)	Torque exp	Torque theoretical

Disc rotor Thickness = 10 mm.
Disc rotor Diameter = 250 mm
Distance between the center of disc and center of weight stud =195mm
Density =7820 Kg/m^3
Moment of inertia of disc, I= Mr^2/2

Formula Used:

1. $\text{AreaofRotor} = \frac{\pi d^2}{4}$ Where, D = disc rotor dia in m
2. $\text{Angle in radian} = \frac{\theta\pi}{180}$
3. $\text{AppliedTorque}, T_{Exp} = I\omega\omega_P$ Where, $I = \frac{Mr^2}{2}$ $\omega = \frac{2\pi N}{60}$ $\omega_P = \frac{d\theta}{dt}$ in radians
4. $T_{Theo} = W * L$
5. $\text{Linear Velocity of Disc} = \frac{\pi\theta}{180}$
6. $\omega_{P(Exp)} = \frac{d\theta}{dt}$ inradians
7. $\omega_{P(Theo)} = M_t * L$

PRECAUTIONS:

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

Result:

Viva Voice:

1. What is meant by gyroscope?
2. What is meant by gyroscope couple?
3. What is meant by inertia governors?

Experiment Number: Date:

Damped and Undamped Free Vibration

AIM: To determine the frequency of undamped free vibration of an equivalent spring mass system.

APPARATUS:

- Vibration beam setup
- Nodal hammer
- Mass hanger
- Weight
- Sensor
- Frequency Indicator
- Vibration or Amplitude Indicator

THEORY:

When particles of the beam move parallel to the axis of the beam then the vibration is known as longitudinal vibration.

$$F_{n(Theo)} = \left(\frac{1}{2\pi}\right) \times \sqrt{\frac{K}{M}} \ \text{Hz}$$

Where,

$K = \text{Stiffness } \left(\frac{F}{\delta}\right) \text{ in N/m}$

$F = \text{Disturbing Force in N}$

$\delta = \text{Deflection of Beam (Amplitude)}$

$M = \text{Mass attached to the Beam in Kg}$

$g = \text{Acceleration due to gravity} = 9.81 \text{ m/s}^2$

Description on Setup:

The vibration of beam setup to study the free undammed vibrations consists of a rectangular cross section beam of mild steel supported as cantilever. A known weight of 200g with weighing hanger along with slider with hook is provided to apply a known mass to the beam and can be placed at any position along the length of the beam.

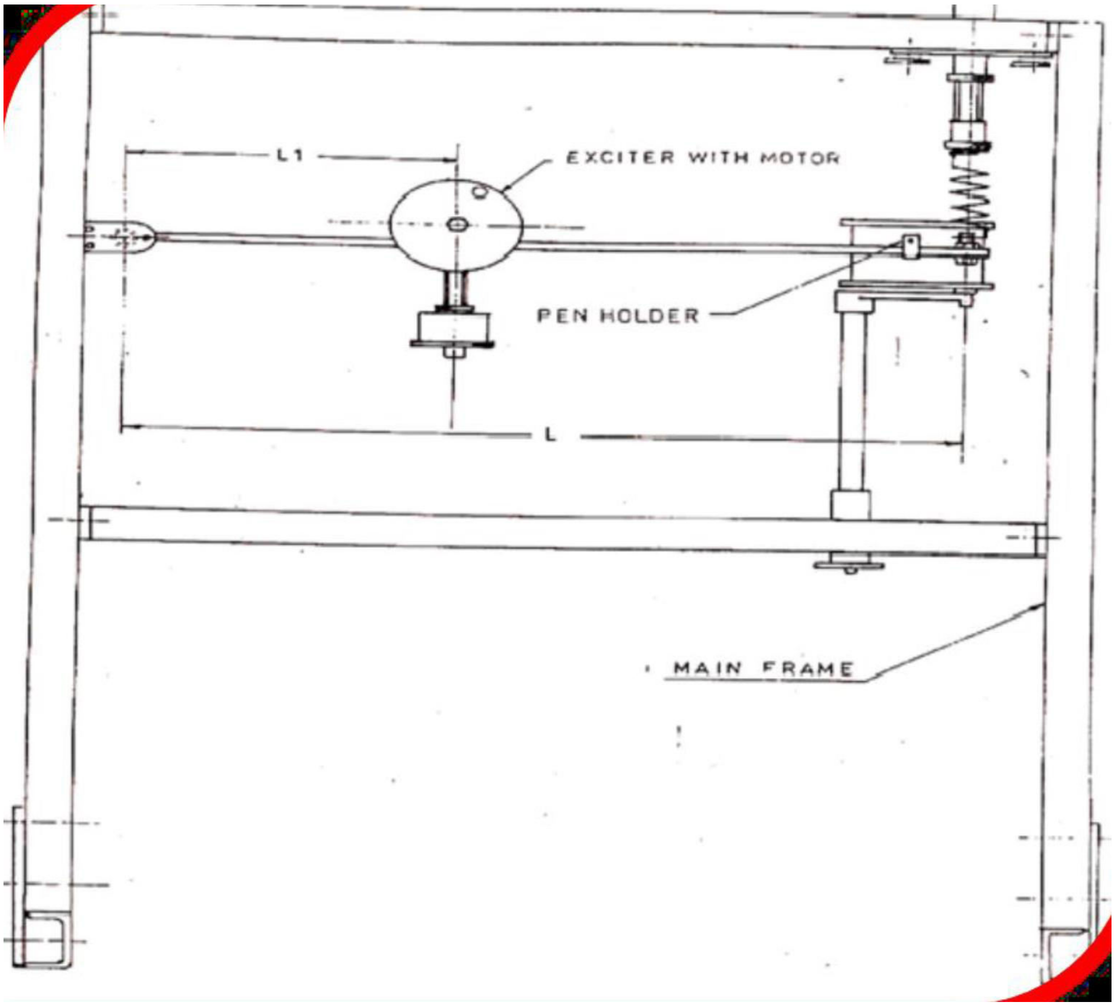


Fig.: Damped and Undamped Free Vibration Arrangement

Specifications

- Beam Material = Mild Steel
- Length of Cantilever Beam = 500 mm
- Width of the Beam = 25mm
- Thickness of the Beam = 6 mm
- Young's Modulus Mild Steel = $210 \times 10^3\ \mathrm{N/mm^2}$
- Density of the Mild Steel = 7850 $\mathrm{Kg/m^3}$
- Frequency Measurement = Digital Frequency Indicator
- Amplitude Measurement = Digital Amplitude Indicator with Sensor
- Speed Measurement = Digital Speed Indicator with Proximity Sensor

Procedure:

1. Initially fix the beam with Cantilever condition
2. Switch ON the console and change the toggle switch to free vibration condition.
3. Meanwhile switch-ON the computer & keep it ready with the observation menu.
4. Support one end of the cantilever beam in the slot of trunion/fixed plate and clamp it by means of knob.

5. Neglect the initial reading of the sensor (amplitude and frequency) because due to some sensitive vibration.
6. Place the sensor at the end of beam.
7. Now vibrate the beam setup by using nodal hammer.
8. Note down the frequency and amplitude with varying speed in digital indicator

List of Formulae

To Find Disturbing Force

$$\mathrm{F} = \mathrm{Volume}\ \times \text{density of the material} \times 9.81 \text{ in N}$$

T o Find Stiffness

$$\text{Stifness}\ ,\mathrm{K} = \frac{\mathrm{F_0}}{\delta}\ \text{in}\ \mathrm{N/m}$$

Where, $\mathrm{F_0}$ = Disturbing or Centrifugal Force in N,

δ = Deflection of Beam (Amplitude) in m

To Find Theoretical Frequency

$$\text{Theoretical Frequency}, \mathrm{F_{theo}} = \frac{1}{2\pi} \times \sqrt{\frac{\mathrm{K}}{\mathrm{M}}}$$

Where,

K = Stiffness in N/m

M = Mass in Kg = 0.4 Kg

Sample Readings and Calculations

Sl.No.	Boundary Condition	Vibration Type	Stiffness of Beam, N/m	Amplitude (mm)	Practical Freq. (Hz)	Theoretical Freq. (Hz)
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						

Result:

1. The theoretical natural frequency is____________________
2. The experimental natural frequency is__________________

It is to conclude that the theoretical and experimental natural frequency of vibration

Viva Voice:

1. Define vibration?
2. Name different types of vibrations?
3. Define free vibrations?
4. What is meant by degrees of freedom in a vibrating system?
5. Define resonance?

Experiment Number: Date:

Damped and Undamped Force Vibration

AIM: To determine the frequency of damped force vibration of a spring mass system

THEORY:

When the external forces act on a vibrating system during its motion, it is termed forced vibration. Under this condition, the system will tend to vibrate at its own natural frequency superimposed upon the frequency of the exiting force. After a short time, the system will vibrate at the frequency of the exiting force only regardless of the initial condition or natural frequency of the system. The later case is termed steady state vibration. In fact, most of the vibrations phenomena present in life are categorized under force vibration. When the exiting frequency is very close to the natural frequency of the system, vibration amplitude will be large and damping will be necessary to maintain the amplitude at a certain level. The later case is called "resonance" and it is very dangerous upon mechanical and structural parts. Thus, care must be taken when designing a mechanical system by selecting proper natural frequency that is sufficiently spaced from the exiting frequency.

SPECIFICATIONS:

- Beam Material = Mild Steel
- Length of the Beam = 1000 mm
- Width of the Beam = 25mm
- Thickness of the Beam = 6 mm
- Mass of the Exciter = 3.235 Kg
- Mass of Eccentricity Load = 0.03 Kg
- Young's Modulus Mild Steel = $210 \times 10^3\ \mathrm{N/mm^2}$
- Density of the Mild Steel = 7850 $\mathrm{Kg/m^3}$
- Frequency Measurement = Digital Frequency Indicator
- Amplitude Measurement = Digital Amplitude Indicator with Sensor
- Speed Measurement = Digital Speed Indicator with Proximity Sensor

Description on Setup

The vibration of beam setup consists of a rectangular cross section beam of mild steel supported at either end by knobs to conduct experiment under fixed- fixed condition. A variable speed DC motor is connected through a flexible shaft to the exciter for vibrating the beam setup. Amplitude sensor with magnet in it can be placed along the length of the beam and same can be used for free vibration

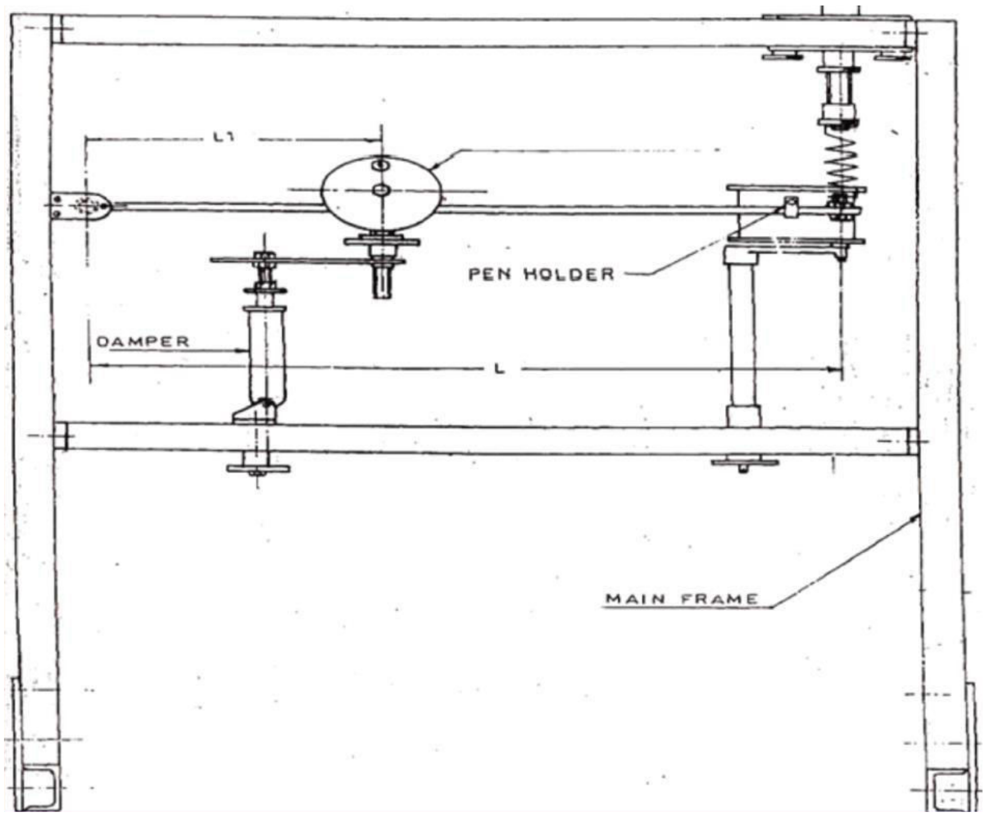


Fig. Spring Mass System

Procedure:

1. Initially fix the beam with fixed-fixed condition.
2. Switch ON the console and change the toggle switch position to forced vibration.
3. Support one end of the cantilever beam in the slot of fixed plate and clamp it by means of knob and place exciter assembly on the beam and tighten it by using a knob.
4. Neglect the initial reading of the sensor (amplitude and frequency) because due to some sensitive vibration.
5. Place the sensor at the center of the beam.
6. Now put ON the motor and set required speed by using speed controller and allow the system to vibrate
7. Note down the frequency and amplitude with varying speed in digital indicator

Note:

It is necessary to screw properly the weight to the disc.

List of Formulae

To Find Disturbing Force (Centrifugal Force)

Distribution force , $F_o = mr\omega^2$ in $Kg.m/s^2$ (or) N

Where,

m = Mass of Eccentricity load in Kg

r = Distance between middle of the shaft to the middle of eccentricity load in m = 0.045m

$$\omega = \frac{2\pi N}{60} \text{ in rad/s}$$

N = Speed of the Motor in RPM

To Find Stiffness

$$\text{Stifness}, K = \frac{F_0}{\delta} \text{ in N/m}$$

Where,

F_0 = Disturbing or Centrifugal Force in N

δ = Deflection of Beam (Amplitude)in m

To Find Theoretical Frequency

$$\text{Theoretical Frequency}, F_{theo} = \frac{1}{2\pi} \times \sqrt{\frac{K}{M}}$$

Where,

K = Stiffness in N/m

M = Mass of the Exicter in Kg

Result:

1. From the graph it can be observed that the amplitude of vibration decreases with time.
2. Amplitude of vibration is less with damped system as compared to undamped system.

Viva Voice:

1. Name different types of free vibrations?
2. Define longitudinal vibrations?
3. Define transverse vibrations?
4. What type of motion is exhibited by a vibrating system when it is critically damped?
5. Define time period related to vibratory motion?
6. Define time cycle related to vibratory motion?

Sample Readings and Calculation (For Reference)

S.No.	Boundary Condition	Vibration Type	Speed RPM	Centrifugal Force N	Angular Speed rad/sec	Stiffness of Beam N/m	Amplitude mm	Practical Freq. Hz	Theoretical Freq. Hz
1.									
2.									
3.									
4.									
5.									
6.									
7.									
8.									
9.									
10.									

Experiment Number: Date:

Balancing of Masses

AIM: To balance the given masses statically by drawing force polygon and couple polygon and dynamically by trial and error method on a shaft.

THEORY:

If a weight is attached to a revolving shaft motion is disturbed due to the centrifugal force exerted on the shaft by the weight. So to counter this a single weight in plane parallel to the plane of a rotation of the disturbing mass can be attached so as balance the force exerted by the disturbing mass, as a minimum of two balancing weights must be introduced and the three weights must be so arranged that the resultant that lines of action of the centrifugal forces shall be in three parallel planes and the algebraic sum of moments about any point in the same plane should be zero so that we can say the shaft is dynamically or statically balanced.

EQUIPMENT:

The APPARATUS basically consists of main steel shaft mounted in ball bearings on either side in a rectangular frame. Set of four blocks of rigid different weights are provided and it can be clamped in any position on the shaft: which can also be easily detached.

A protractor scale is fitted to one side of the rectangular frame shaft carriers a disc and rim of this disc is grooved to locate the weighting balance card provided with two metal containers of equal weight.

A scale is fixed to the bottom member of the frame and when used along 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 fractional HP AC motor, fixed below the frame with rubber belt. For Static Balancing of individual weights the frame is rigidly fixed to the support frame by nut bolts and at that position the driving belt is disconnected. No. of balls give the value of w_r of that block.

For dynamic balancing of the rotating mass system the frame is suspended by the support frame by two chains in which the frame in same place in horizontal proportion.

EXPERIMENTAL PROCEDURE:

The experiment is divided into three parts:

1. Observation of the phenomenon

2. Calculation of a solution to a posed problem

3. Implementation of the solution

TABULAR COLUMN:

Select scale 20 balls = 1 cm

S.No.	Weight No.	Specimen weight in (gms)	Scale for Force polygon $\frac{weight * 2}{100}$	Distance from weight	Couple polygon	Scale for Couple polygon = $\frac{couple\ polygon}{200}$	Angular position of Weight

Plane of Mass W_1r_1 = (20 /5) = 4, similarly for otherwise. (W_2r_2, W_3r_3, W_4r_4) must calculate

PROCEDURE TO FINDOUT wr. BY STATIC BALANCING METHOD:

1. Attach the balance frame to main frame firmly. Insert the thread Card with pan to the grooved pulley provided. Set the weight holder to 0^0 position(to vertical).
2. Values of Static balancing for all the weights will be arrived when we are conducting the experiment of Dynamic Balancing.

TO CONDUCT THE STATIC BALANCE:

a. Place the weight 1 with weight holder on the shaft and set it to vertical position.
b. Add the balls slowly in the pan and hit the shaft by fore finger till the weight holder rotates 90^0 (i.e. horizontal).
c. Count the number. Of balls and note down in the tabular column.

d. Repeat the experiment for the remaining weights and note down in the tabular column.
3. Draw the force, couple polygon (FP/CP)

PROCEDURE TO DRAW FORCE POLYGON (FP):

A. Select a scale 5 balls = 1 cm
   - By dividing with the above scale
   - Point 1-2 measures 5 cm, i.e (25 balls/ 5 (scale) = 5)
   - Point 2-3 measures 5.4 cm (27/5 = 5.4)
   - Point 3-4 measures 6.8 cm (34/5 = 6.8) and
   - Point 4-1 measures 4 cm (20/5= 4).

B. Draw a force polygon (Fp)
   - Draw horizontal line point 1-2measure 5cm along x axis .
   - Select a vertical line i.e. y axis (90°) point1-4→ which measures 4cm,
   - Point2-3 measures 5.4cm and draw an arc from point 2 by using compass.
   - point 3-4 measure 6.8cm, draw an arc from point 4 and which intersects arc drawn from point 2
   - joinpoints2-3 & points 3-4

PROCEDURE TO DRAW COUPLE POLYGON (CP):

a. Select a scale 10 balls = 1cm
b. Assume $W_2r_2 = 0$
c. $W_1r_1l_1$= 20 balls x 3 cm(assumingl_1)
   l_1=3 cm
   $l_2 = 0$

From point 'O'

- Draw a parallel line from point 1-4 of CP to point 'O' of FP which is equal to 4 cm
- Draw a parallel line from point 4-3 and point 1-3of FP with respect to point 2-3 and 4-3which intersects at point 3 in FP .
- Measure point 1-3 and point 4-3
- Point 1-3 = $W_3r_3l_3$ = 4.4 cm
- Point 4-3 = $W_4r_4l_4$ = 1.8 cm

d. Couple polygon is obtained.
e. From couple polygon we can obtain
f. $\theta_1 = 90^0$
   $\theta_2 = 0^0$
   $\theta_3 = 305^0$
   $\theta_4 = 258^0$

4. How to find the angular positions which is to be fixed on the shaft
   A. Select a point O and then draw a line in Y axis that indicates the angular position of the first weight holder i.e 0^0 (reference)
   B. Draw a perpendicular line from point O i.e $W_2r_2 = 90^o$ (X axis)

C. Draw parallel line from the force polygon line 1-3 from reference 'O' which is equal to 305^0 with reference to first weight holder.

5. Draw parallel line from the force polygon line 3-4 from reference 'O' 258^0in anti clock wise direction
6. Fix 2nd weight holder to 4cm (reference) from left side of the shaft and 1st weight holder to 3cm to the left of 2nd weight holder i.el_1 = 3 cm.

TO FIND THE DISTANCE BETWEEN THE WEIGHT HOLDERS

a. Thus the distance between 3rd weight with reference to 2nd is given as
$W_3r_3l_3$= distance 1-3 in couple polygon

$\Rightarrow 5.4 \times l_3 = 4.4$

$\Rightarrow l_3 = 0.81$ cm

$W_4r_4l_4$= distance 3-4 in couple polygon

$\Rightarrow 6.8 \times l_4 = 1.8$

$\Rightarrow l_4 = 0.26$ cm

Distance between the weights with reference to 2nd weight is

l_1 = 3cm to the left side from reference (l_2)

l_{22} = 0 (REFERENCE)(l_2)

l_3= 0.81cm to the right side from reference (l_2)

l_4 =0.26 cm to the right side from reference (l_2)

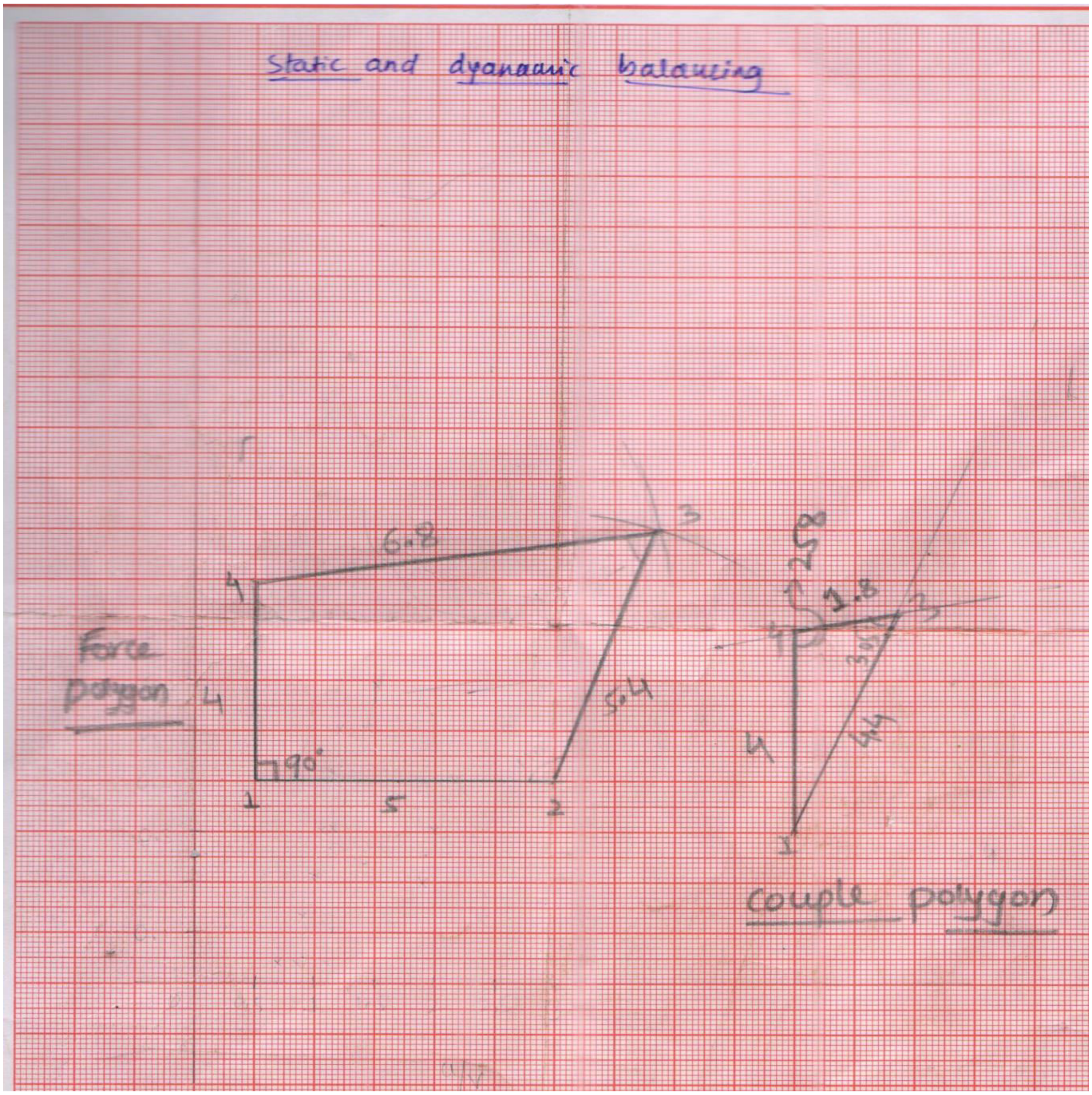
.

7. Hang the frame by chain and couple to motor by belt
8. Run the motor by using electronic dimmer to a rated speed say 700-1100rpm.

Observe the system for non vibration.

If the calculation is not correct then the system will vibrate. That indicates there is something calculation mistake at the time of drawing force and couple polygon.

Graph:



Demonstration of Static and Dynamic Balance:

For this part of the experiment the four blocks will be used without the inserts. This provides four identical eccentric masses for use in demonstration of static and dynamic balance.

Step 1 - Static Imbalance

Lock the plate to the base. Attach one of the blocks securely to the shaft near the pulley. The mark on the protractor should align with zero when the block is positioned against the guide. Slide the guide clear of the block. Rotate the shaft and observe the behavior. Record your observations.

Step 2 - Static Balance

Attach a second block near the opposite end of the shaft. Align this block such that the protractor reads 180°. Rotate the shaft and observe the behavior. Record this and compare with step 1.

Step 3 - Dynamic Imbalance

Release the plate and secure the clamps clear of the plate. Attach the belt between the motor and the pulley on the end of the shaft. Ensure that all loose components are removed from the equipment and then place the safety cover over the motor and shaft. Switch on the motor controller and the motor. Slowly increase the speed of the motor and observe the behavior of the shaft and plate. Record your observations. Switch off both the motor & controller and allow the shaft to come to rest before removing cover.

Step 3 - Dynamic Balance

There are three steps to this part of the experiment

1. Preparation of the imbalances

Clamp the plate and remove the blocks from the shaft. Insert the four circular imbalances into the blocks and clamp them securely. Attach one of the blocks to the shaft with the protractor reading 0°. Remove the drive belt from the motor and attach the pulley extension to the shaft so that the pulley overhangs the end of the bench. Loop the string and buckets around the pulley so that there is no slip. Add ball bearings to one bucket until the protractor reads 90°. At this point the moment due to the bearings is equal to the eccentric moment of the block. Record the number of bearings and repeat for the other three blocks.

2. Calculation of the solution

The problem for solution must be posed carefully if a satisfactory solution is to be found in the time available. The relative axial position and angular orientation of the two largest eccentricities should be selected first and will represent the dynamic imbalance to be corrected. An axial spacing of 100 mm and relative angle of 150° provide a reasonable starting point. The main limitations are the total length of the shaft and the thickness of each block. The solution is calculated graphically in two parts. Initially, the static balance of the system is obtained by

a. Draw vectors representing the two imbalances set above. These have a length proportional to the number of ball bearings and a direction relative to the angular orientation. The vector should go from the center of the shaft along the block. The drawing should like Figure SDB 3b with the m1r1 and m^2r^2 vectors only.

b. On the graph, knowing the lengths of the other two imbalances, complete the four sided closed polygon. Record the angular orientation of the two balancing vectors. The axial position of the two balancing masses needs to be calculated next. In this case, it is simplest to take the largest eccentricity as the reference axial location, eliminating it from this part of the calculation.

c. On a new diagram draw a vector representing the axial turning moment of the second eccentricity. The length is proportional to the number of ball bearings and the axial distance from the reference.

d. Complete the closed triangle using the directions for the balancing eccentricities found in b. From the scale calculate the axial distance associated with each eccentricity. Assemble all the information into a table indicating the eccentricity (mr) of each block, its axial location (l) and its angular orientation (θ).

3. Test the result

Carefully attach the blocks to the shaft at the locations and orientations in the table. Remove the pulley from the system and reattach the motor drive belt. Release the platform clamps and secure them to the base. Put safety cover in place and run motor. Record whether dynamic balance has been achieved and if necessary revise calculations.

Result:

Viva Voice:

1. Write the importance of balancing?
2. What is meant by balancing of rotating mass? Why balancing of a dynamic force is necessary?
3. Differentiate: static and dynamic balancing.
4. Why complete balancing is not possible in reciprocating engine?
5. Can a single cylinder engine be fully balanced? Why?

Experiment Number: Date:

Moment of Inertia of a Flywheel

AIM: To find the moment of inertia of a flywheel

APPARATUS:
Fly wheel, weight hanger, slotted weights, stop watch, metre scale.

THEORY:
The flywheel consists of a heavy circular disc/massive wheel fitted with a strong axle projecting on either side. The axle is mounted on ball bearings on two fixed supports. There is a small peg on the axle. One end of a cord is loosely looped around the peg and its other end carries the weight-hanger

Let "m" be the mass of the weight hanger and hanging rings (weight assembly).When the mass "m" descends through a height "h", the loss in potential energy is

$$P_{loss} = mgh$$

The resulting gain of kinetic energy in the rotating flywheel assembly (flywheel and axle) is

$$K_{Flywheel} = \frac{1}{2} I w^2$$

Where

I - Moment of inertia of the flywheel assembly

ω - Angular velocity at the instant the weight assembly touches the ground.

The gain of kinetic energy in the descending weight assembly is,

$$K_{Weight} = \frac{1}{2} m V^2$$

Where v is the velocity at the instant the weight assembly touches the ground.

The work done in overcoming the friction of the bearings supporting the flywheel assembly is

$$W_{Friction} = n W_f$$

Where

n - number of times the cord is wrapped around the axle

W_f - work done to overcome the frictional torque in rotating the flywheel assembly completely once

Therefore from the law of conservation of energy we get

$$P_{Loss} = K_{Flywheel} + K_{Weight} + W_{Friction}$$

On substituting the values we get

$$mgh = \frac{1}{2} I w^2 + \frac{1}{2} m V^2 + n W_f$$

Now the kinetic energy of the flywheel assembly is expended in rotating N times against the same frictional torque. Therefore

$$N\, W_f = \frac{1}{2}\, I\, w^2$$

$$W_f = \frac{1}{2 *\ N}\, I\, w^2$$

If r is the radius of the axle, then velocity v of the weight assembly is related to r by the equation

$$V = \omega * r$$

Substituting the values of v and W_f we get:

$$mgh = \frac{1}{2}\, I\, w^2 + \frac{1}{2}\, mr^2\, \omega^2 + \frac{n}{N} * \frac{1}{2}\, I\, w^2$$

Now solving the above equation for I

$$I = \frac{N * m}{N + n}\left(\frac{2\, g\, h}{\omega^2} - r^2\right)$$

Where, I = Moment of inertia of the flywheel assembly
N = Number of rotation of the flywheel before it stopped
m = mass of the rings
n = Number of windings of the string on the axle
g = Acceleration due to gravity of the environment.
h = Height of the weight assembly from the ground.
r = Radius of the axle.

Now we begin to count the number of rotations, N until the flywheel stops and also note the duration of time t for N rotation. Therefore we can calculate the average angular velocity $\omega_{average}$in radians per second.

$$W_{Average} = \frac{2 *\ \pi * N}{t}$$

Since we are assuming that the torsional friction W_f is constant over time and angular velocity is simply twice the average angular velocity

$$\omega = \frac{4\pi N}{t}$$

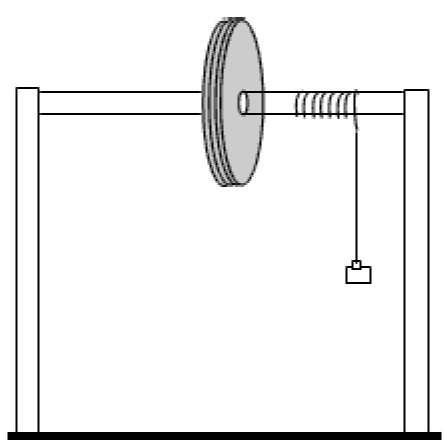


Fig. Flywheel Arrangement

Procedure

1. The length of the cord is carefully adjusted, so that when the weight-hanger just touches the ground, the loop slips off the peg.
2. A suitable weight is placed in the weight hanger
3. A chalk mark is made on the rim so that it is against the pointer when the weight hanger just touches the ground.
4. The other end of the cord is loosely looped around the peg keeping the weight hanger just touching the ground.
5. The flywheel is given a suitable number (n) of rotation so that the cord is wound round the axle without overlapping.
6. The height (h) of the weight hanger from the ground is measured.
7. The flywheel is released.
8. The weight hanger descends and the flywheel rotates.
9. The cord slips off from the peg when the weight hanger just touches the ground. By this time the flywheel would have made n rotations.
10. A stop clock is started just when the weight hanger touches the ground.
11. The time taken by the flywheel to come to a stop is determined as t seconds.
12. The number of rotations (N) made by the flywheel during this interval is counted.
13. The experiment is repeated by changing the value of n and m.
14. From these values the moment of inertia of the flywheel is calculated using equation

$$I = \frac{g * r}{4\pi} * \frac{mt_2}{\left(1+\frac{n_2}{n_1}\right) * n_2} \text{ N-m}$$

Where r = Radius of disc

n_1 = No. of Thread revolutions = 2

n_2 = No. of Fly wheel revolutions

g = Acceleration due to gravity

m = Mass of the body

S.No	Mass in Kg	No. of thread revolutions (n_1)	No. of Fly wheel revolutions (n_2)	Time in sec	Moment of Inertia N-m

Mean value of moment of inertia, I =………kg-m^2

Result

Moment of inertia of the fly wheel =……… kg-m^2

Viva Voice:

1. What do you understand by MOI?
2. What are advantages of having elliptical section of the flywheel arm?
3. What are main considerations for the selection of material of a flywheel?
4. What is fluctuation of speed?

Experiment Number: Date:

Cam Follower Displacement

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

1. To find out the cam and follower behavior at different follower movement
2. To study the different types of cam and follower with their practical uses.
3. To find out the cam follower displacement curve at different motion.
4. To find out jump phenomenon.

THEORY:

Jump Phenomenon:

The Jump phenomenon occurs in case of cam operating under the action of compression spring load. This is transient conditions that occur only with high speed, highly flexible cam-follower systems. With jump the cam and the follower separate owing to excessively unbalanced forces exceeding the spring force during the period of negative acceleration. This is undesirable since the fundamental function of the cam-follower system; the constraint and control of follower motion are not maintained. Also related are the short life of the cam flank surface, high noise, vibrations and poor action.

Jump and Crossover Shock:

A cam-follower retained against the cam with a compression retaining spring will under certain conditions, jump or bounce out of contact with the cam. This condition is most likely to occur with low values of damping and with high speed cams or quite flexible follower trains.

Crossover shock occurs in a positive drive cam mechanism when contact moves from one side of the cam to the other. Clearance and backlash are taken up during the crossover, and impact occurs. Crossover takes place on the rise or return motion when the acceleration changes sign and when the velocity is at its peak. The effects can be reduced by preloading the system to remove backlash, by designing for a low peak velocity, and by using rigid follower train. Roth art states that jump will not occur in high speed systems if at least two full cycles of vibration occur during the positive acceleration time-interval of the motion. If a smaller number of cycles exist during this period then, he states, the system should be investigated mathematically to determine if jump exists. This condition can be expressed by the equation:-

$$\frac{BIK}{360} \geq 2$$

l = length of spring

Where Bl is the angle through which the cam rotates during positive acceleration period. This figure can probably be reduced slightly for appreciable amounts of damping.

Spring loses compression when jump begins and is carried in motion with the mass. The resulting motion now gets rather complicated because the mass, too, must be redistributed. Probably a good first approximation could be obtained by concentrating a portion of the mass at the bottom of spring and treating the motion as a system of two degrees of freedom. It must be noted, through that the system will vibrate at a new frequency after jump begins and then analysis of the motion using the old frequency after jump begins and that an analysis of the motion using the old frequency is not a true description of the motion.

Spring K_2 losses its compression whenever X exceeds by the amount K_2 was initially compressed during assembly. Thus to set up a criteria for jump, it is necessary to calculate the pre-compression of K_2.

DESCRIPTION:

The machine is a motorized unit consisting of a cam shaft driven by a D.C. motor. The shaft runs in a double ball bearing. At the free end of the cam shaft a cam can be easily mounted. The follower is properly guided in bushes and the type of the follower can be changed to suit the cam under test. A graduated circular protractor is fitted coaxial 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.

SPECIFICATIONS:

- **Types of Cams**

  1. Elliptical cam
  2. Eccentric cam
  3. Jump cam

- **Type of Followers**

  1. Roller follower
  2. Mushroom follower

- **Compression Springs**
  One spring is provided. The (approx.) stiffness is 4 Kg/cm

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

- **Weights of the Reciprocating Parts**

  1. Push rod with lock nuts.

2. Rest plates and two lock nuts.
3. Spring seat and lock nut.

ASSEMBLY:

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

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

PROCEDURE:

1. Selected a suitable cam and follower combination.
2. Fix the cam on the driving shaft by seeing the rotation of the motor.
3. Fix the follower on push rod and properly tighten the check nut, such that knife-edge of follower (or axis of roller in case of roller follower) is parallel to axis of camshaft.
4. Check the upper dial to show zero without any error.
5. Rotate the cam at different angle by using handle and note down the approximate dial gauge reading.
6. Give required initial compression to the spring. In order that initial compression is not lost during operation, the check nut is to be tightened against spring seat.
7. Choose suitable amount of weight to be added to the follower. Weights With central hole can be inserted from the top end of push rod. A rest plate for the weights should be firstly screwed to the lowest position, tightened against it, so that there will be no loosening of the rest plate after adding required weights. Tighten the second nut from the top to secure the weights tightly to the push rod.
8. See that the knob of dimmer stat is at zero position
9. Plot the cam profile by using dial gauge reading and angle of cam rotation
10. Repeat the experiment by plotting different cam with different follower.
11. Finally plot graph of follower weight and jump speed

EXPERIMENTS:

Following experiments can be conducted using this machine:

1. To Plot X-O (follower displacement Vs. Angle of cam rotation) curve for different cam follower pairs. The X-O plot can be used to find out the velocity and acceleration of the follower system.
   For this experiment rotate the system manually for taking reading, arrange the set up. The exact profile of the cam can be obtained by taking observations.

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

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

   Upward inertia force = Downward retaining force

$$\frac{W}{g}\,\omega^2 r = W + S$$

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

   W = follower weight (Assembly)

   S = spring force

   ω= angular velocity of cam.

   r = distance according to the geometry of cam.

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

$$\omega = \frac{(\mathrm{W} + \mathrm{s})\mathrm{g}}{\mathrm{w\,r}}$$

4. This relation shows that as the follower weight increases the jump speed goes on decreases

5. To study the effect of spring compression the jump speed with constant follower weight. To study this keep the follower assembly weight the same and go on observing the jump speed for various sets of initial spring compression and plot the graph of spring force Vs Jump speed.

Tabular column

For Elliptical Cam with mushroom follower

S.No.	Angle in degrees	Dial gauge readings (div)	Angle in degrees	Dial gauge readings (div)
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				
16.				
17.				
18.				
19.				
20.				

Snail Cam with Roller Follower

S.No.	Angle in degrees	Dial gauge readings (div)	Angle in degrees	Dial gauge readings (div)
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
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16.				
17.				
18.				
19.				
20.				

Snail Cam With Mushroom Follower

S.No.	Angle in degrees	Dial gauge readings (div)	Angle in degrees	Dial gauge readings (div)
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				
16.				
17.				
18.				
19.				
20.				

Eccentric Cam with Mushroom follower

S.No.	Angle in degrees	Dial gauge readings (div)	Angle in degrees	Dial gauge readings (div)
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				
16.				
17.				
18.				
19.				
20.				

Eccentric cam With Roller follower

S.No.	Angle in degrees	Dial gauge readings (div)	Angle in degrees	Dial gauge readings (div)
1.				
2.				
3.				
4.				
5.				
6.				
7.				
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12.				
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17.				
18.				
19.				
20.				

Elliptical cam with Roller follower

S.No.	Angle in degrees	Dial gauge readings (div)	Angle in degrees	Dial gauge readings (div)
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
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Result:

Viva Voice

1. What is the use of cam?
2. What are types of cam?
3. What are the types of follower available?
4. What is meant by camp jump phenomenon?

Experiment Number: Date:

Velocity Diagram for Slider Crank Mechanism

AIM: To study velocity diagram for slider crank mechanism.

THEORY: Velocity of a point on a link by Relative Velocity Method The relative velocity method is based upon the relative velocity of the various points of the link. Consider two points A and B on a link. Let the absolute velocity of the point A i.e.VA is known in magnitude and direction and the absolute velocity of the point B i.e. VB is known in direction only. Then the velocity of B may be determined by drawing the velocity diagram. The velocity diagram is drawn as follows: 1. Take some convenient point o, known as the pole. 2. Through o, draw oa parallel and equal to VA' to some suitable scale. 3. Through a, draw a line perpendicular to AB. This line will represent the velocity of B with respect to A, i.e. VBA. 4. Through o, draw a line parallel to VB intersecting the line of VBA at b. 5. Measure ob, which gives the required velocity of point B (VB), to the scale.

Velocities in Slider Crank Mechanism

The relative velocity method for the velocity of any point on a link, whose direction of motion and velocity of some other point on the same link is known. The same method may also be applied for the velocities in a slider crank mechanism.

In slider crank mechanism the slider A is attached to the connecting rod AB. Let the radius of crank OB be r and let it rotates in a clockwise direction, about the point o with uniform angular velocity ω rad/s. Therefore the velocity of B i.e.V_B is known in magnitude and direction. The slider reciprocates along the line of stroke AO. The velocity of the slider A (i.e.V_A) may be determined by relative velocity method as discussed below: 1. From any point o, draw vector ob parallel to the direction of V_B (or perpendicular to OB) such that ob=V_B =ω.r, to some suitable scale. 2. Since AB is a rigid link, therefore the velocity of A relative B is perpendicular to AB. Now draw vector ba perpendicular to AB to present the velocity of A with respect to B i.e. VAB. 3. From point o,draw vector oa parallel to the path of motion of the slider A (which is along AO only). The vectors ba and oa intersect at a. Now oa represents the velocity of the slider A i.e. V_A' to the scale. The angular velocity of the connecting rod AB (ω_{AB}) may be determined as follows:

$$\omega_{AB} = \frac{v_{BA}}{BA} = \frac{ab}{BA} \text{ (Anticlock Wise about A)}$$

The direction of vector ab (or ba) determine the sense of ωAB which shows that it is anticlockwise.

$$v_B = \omega r$$

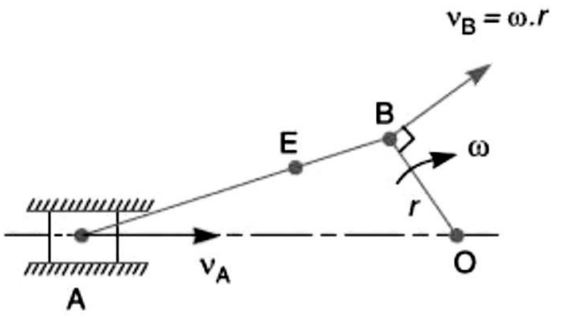


Fig.: Slider Crank Mechanism

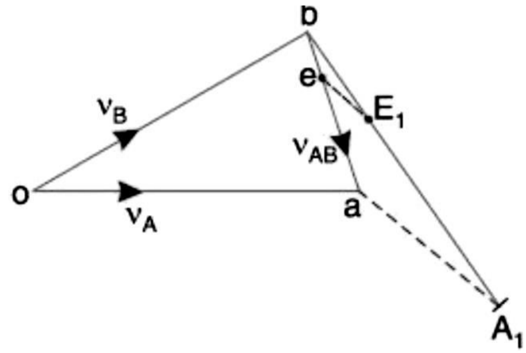


Fig.: Velocity Diagram

Result:

Viva Voice:

1. What is meant by slider crank mechanism
2. Applications of slider crank mechanism
3. What are the types of inversion of single slider crank mechanism
4. A Slider Crank is a ___________________________ type of Mechanism
5. In order for the crank to rotate fully the condition___________________ must be satisfied where R is the crank length, L is the length of the link connecting crank and slider and E is the offset of slider.

Experiment Number: Date:

Coefficient of Friction Between Belt & Pulley

AIM: To find coefficient of friction between belt and pulley.

APPARATUS: Belt & Pulley System.

THEORY:

Belt: Power is transmitted from one to another by means of belts.

- Belts are used where the distance between the shafts is large.
- Belts are flexible type of connectors.
- The flexibility of belts and ropes is due to the property of their materials.
- Belts transmit power due to friction between them and the pulleys.
- If the power transmitted exceeds the force of friction, the belt slips over the pulley.
- Belts are strained during motion as tensions are developed in them.
- Owing to slipping and straining action, belts are not positive type of drives.

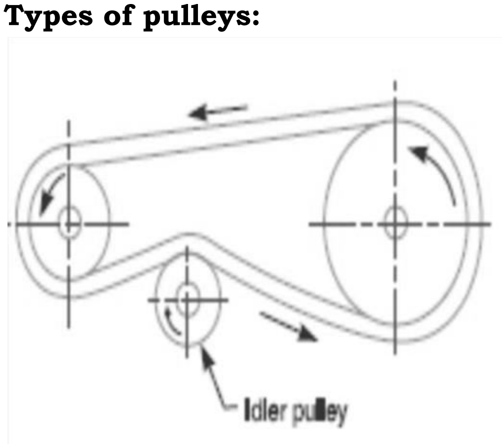
TYPES OF BELTS:

1. Flat belt
2. V-belt

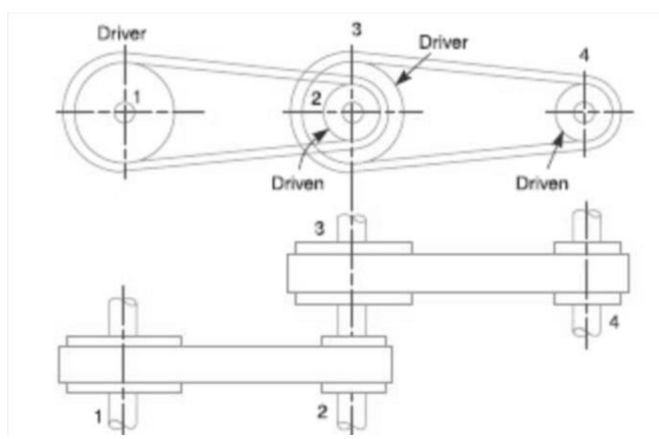
MATERIAL FOR BELTS: Usual materials are leather, canvas, cotton and rubber.

PULLEY: Pulley are mounted on the two shafts. The speed of the driven shaft can be varied by varying the diameters of the pulleys.

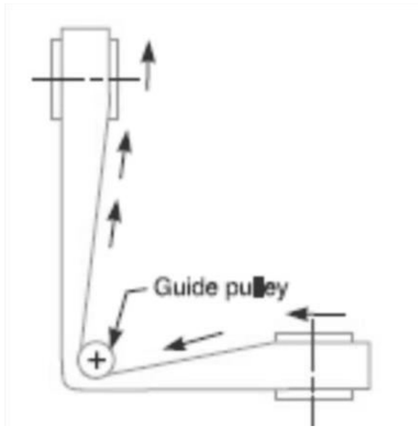
Types of pulleys:



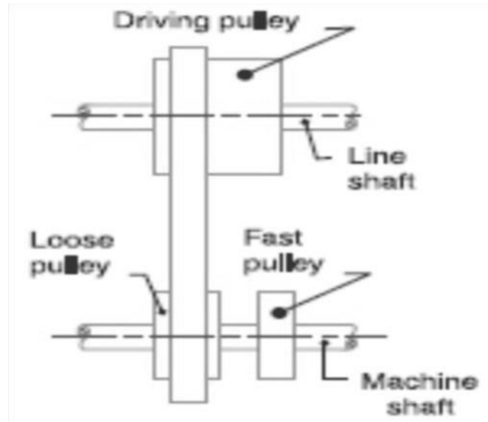
Idler pulleys



Intermediate pulleys



Loose and fast pulleys



Guide pulleys

FORMULAE USED:

Power consumption in motor is given by:

$$P = \frac{2 * \pi r_2 * n_2 (T_1 - T_2)}{60} \text{ Watts}$$

Where T_1 = Tension at the tight side of the belt (N/m^2)

T_2 = Tension at the slack side of the belt (N/m^2)

r_1 = Radius of Larger pulley

r_2 = Radius of Smaller pulley

n_1 = Speed of Larger pulley

n_2 = Speed of Smaller pulley

$$T_1 - T_2 = \frac{P * 60}{2 * \pi r_2 * n_2}$$

Total Force acting on the Pulley:

$$\text{Total force} = \frac{P * \eta_{motor}}{V} = T_1 + T_2$$

$$V = \frac{2 * \pi r_1 * n_1}{60}$$

$$T_1 + T_2 = \frac{P}{\frac{2 * \pi r_1 * n_1}{60}} = \frac{60 * P}{2 * \pi r_1 * n_1}$$

$$\frac{T_1 - T_2}{T_1 + T_2} = \frac{\frac{P * 60}{2 * \pi r_2 * n_2}}{\frac{60 * P}{2 * \pi r_1 * n_1}} = \frac{r_1 * n_1}{r_2 * n_2}$$

$$T_1 + T_2 = \frac{r_2 * n_2}{r_1 * n_1} (T_1 - T_2)$$

Co-efficient of Friction is given by

$T_1 / T_2 = e^{\mu \theta}$ For $\theta \leq 45^0$

$\frac{T_1}{T_2} = e^{\theta \mu^1}$ For $\theta > 45^0$

where $\mu^1 = \mu \left[\frac{4 \sin\frac{\theta}{2}}{\theta + \sin\theta} \right]$

μ = Co-efficient of Friction between belt and pulley

θ = Arc of contact (rad)

θ_1 = Arc of Contact of Larger pulley = $\pi + 2\ \sin^{-1}\left(\frac{r_1 - r_2}{C}\right)$

θ_2 = Arc of Contact of Smaller pulley = $\pi - 2\ \sin^{-1}\left(\frac{r_1 - r_2}{C}\right)$

C = Distance between centers of two pulleys

OBSERVATION TABLE

S. No.	Speed of Larger pulley (rpm) n_1	Speed of Smalley pulley (rpm) n_2	Co-efficient of friction (μ)
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

PROCEDURE:

1. Note the angle of contact.
2. Hang some weight on one side of the belt and put some weight on other side of the belt, till the belt just slide.
3. Note down the values of T1 and T2.
4. Vary T1 and correspondingly determine the values of T2.
5. Now calculate the value of μ.

Result: μ (Co-efficient of Friction between belt and pulley) =

Viva Voice:

1. What are the advantages of a belt drive?
2. Why the slack side of the belt of a horizontal belt drive is preferable to place on the top side?
3. Which one should be the governing pulley to calculate tension ratio?
4. Coefficient of Friction Between Belt & Pulley

Experiment Number: Date:

Screw Jack Efficiency

AIM: To study simple and compound screw jack and determine the mechanical advantage, velocity ratio and efficiency

APPARATUS USED: Screw jack

THEORY:

Screw Jack: It is a device employed for lifting heavy loads with help of a small effort applied at its handle. The loads are usually centrally loaded upon it. Screw jacks of three types:

1. Simple screw jack
2. Compound Screw jack
3. Differential Screw jack

A simple screw jack consists of a nut, a screw square threaded and a handle fitted to the head of the screw.

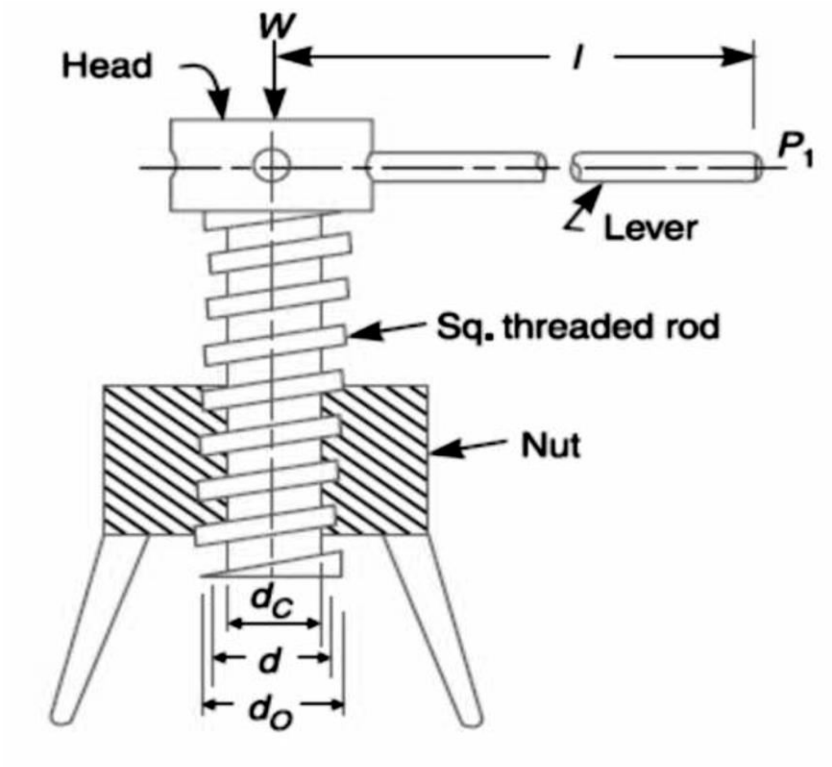
The nut also forms the body of the jack. The load to be lifted is placed on the head of the screw. Here the axial distance between corresponding points on two consecutive threads is known as pitch. If ‘p’ be the pitch of the screw and‘t’ is the thickness of thread, then p = 2t.

V.R. = Distance moved by the effort/Distance moved by the load = $2\pi l$ / p

Now M.A. = W / P

PROCEDURE:

When we are moving the handle horizontal direction the screw is also moved it attached with screw and load is lifted by pitch of the screw, in one revolution of the handle.



(*a*) Screw jack.

OBSERVATION:

For simple Screw Jack:

S.No.	Load (W) in Nt.	Effort (P) (P) in Nt.	Length of Lever	Pitch of screw	V.R.	M.A.	Efficiency
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							
9.							
10.							

CALCULATION:

M.A. = W/P

V.R. = Distance moved by effort/Distance moved by load

Efficiency = M.A. / V.R.

RESULT: Hence the efficiency of screw jack is _________.

Viva Voice:

1. What is a screw jack? How does it work? Which principle of physics does it use?
2. Define efficiency of screw jack
3. What is the condition in term of efficiency for a machine to be self locking?
4. Define mechanical advantage.

Experiment Number: Date:

Various Types of Gears

AIM: To study various types of gears- Spur, Helical, Worm and Bevel Gears

APPARATUS Used: Arrangement of gear system.

THEORY:

Classification of Gear: Gears can be classified according to the relative position of their shaft axis are follows:

A: Parallel Shaft

(i) Spur gear
(ii) Spur rack and pinion
(iii) Helical gears or Helical spur gear
(iv) Double - helical and Herringbone gear

B: Inter Secting Shaft

(i) Straight bevel gear
(ii) Spiral bevel gear
(iii) Zerol bevel gear

C: Skew Shaft

(i) Crossed- helical gear
(ii) Worm gears(Non-throated, Single throated, Double throated)

Spur Gear: They have straight teeth parallel to the axes and thus are not subjected to axial thrust due to teeth load. Spur gears are the most common type of gears. They have straight teeth, and are mounted on parallel shafts. Sometimes, many spur gears are used at once to create very large gear reductions. Each time a gear tooth engages a tooth on the other gear, the teeth collide, and this impact makes a noise. It also increases the stress on the gear teeth. ***Spur gears*** are the most commonly used gear type. They are characterized by teeth, which are perpendicular to the face of the gear. Spur gears are most commonly available, and are generally the least expensive.

Helical Gears: In helical gears, the teeth are curved, each being helical in shape. Two mating gears have the same helix angle, but have teeth of opposite hands. At the beginning of engagement, contact occurs only at the point of leading edge of the curved teeth. As the gears rotate, the contact extends along a diagonal line across the teeth. Thus the load application is gradual which result in now impact stresses and reduction in noise. Therefore, the helical gears can be used at higher velocities then the spur gears and have greater load – carrying capacity. The teeth on helical gears are cut at an angle to the face of the gear. When two teeth on a helical gear system engage, the contact starts at one end of the tooth and gradually spreads as the gears rotate, until the two teeth are in full engagement. This gradual engagement makes helical gears operate much more smoothly and quietly than spur gears. For this reason, helical gears are used in almost all car transmission. Because of the angle of the teeth on helical gears, they create a thrust load on the gear when they mesh. Devices that use helical gears have bearings that can support this thrust load.

Double Helical and Herring Bone Gears : A- double- helical gear is equivalent to a pair of helical gears secured together, one having a right – hand helix and the other a left hand helix. The tooth of two raw is separated by a grooved used for too run out.
If the left and the right inclinations of a double – helical gear meet at a common apex and there is no groove in between, the gear is known as herring bone gear.

Crossed – Helical Gear: The used of crossed helical gear or spiral gears is limited to light loads. By a suitable choice of helix angle for the mating gears, the two shaft can be set at any angle.

Worm Gear: Worm gear is a special case of spiral gear in which the larger wheel, usually, has a hollow or concave shape such that a portion of the pitch diameter is the other gear is enveloped on it. The smaller of two wheels is called the worm which also has larger spiral angle. Worm gears are used when large gear reductions are needed. It is common for worm gears to have reductions of 20:1, and even up to 300:1 or greater.

Bevel Gear: Kinematically, the motion between two intersecting shafts is equivalent to the rolling of two cones, assuming no slipping. The gears, in general, are known as bevel gear. When teeth formed on the cones are straight, the gear are known as straight bevel and when inclined, they are known as spiral or helical bevel.

Viva Voice:

1. What are the functions of gears?
2. What is the difference between addendum and dedendum?
3. Which gears are used to connect the shafts which intersect at same angle?
4. Which gears are used to connect the shafts lying in the same plane?
5. Explain rack and pinion