

1. ROCKWELL HARDNESS TEST

I. **AIM:** To determine the Rockwell Hardness of a given test specimen

II. **APPARATUS:** Rockwell Hardness testing machine, Test specimen.

III. THEORY:

HARDNESS-It is defined as the resistance of a metal to plastic deformation against Indentation, scratching, abrasion or cutting.

The hardness of a material by this Rockwell hardness test method is measured by the depth of Penetration of the indenter. The depth of Penetration is inversely proportional to the hardness. Both ball or diamond cone types of indenters are used in this test. There are three scales on the machine for taking hardness readings. Scale "A" with load 60 kgf or 588.4 N and diamond indenter is used for performing tests on thin steel and shallow case hardened steel.

Scale "B" with load 100 kgf or 980.7 N and 1.588 mm dia ball indenter is used for performing tests on soft steel, malleable iron, copper and aluminum alloys.

First minor load is applied to overcome the film thickness on the metal surface. Minor load also eliminates errors in the depth of measurements due to spring of the machine frame or setting down of the specimen and table attachments.

The Rockwell hardness is derived from the measurement of the depth of the impression

E_p = Depth of penetration due to Minor load of 98.07 N.

E_a = Increase in depth of penetration due to Major load.

E = Permanent increase of depth of indentation under minor load at 98.07 N even after removal of Major load.

This method of test is suitable for finished or machined parts of simple shapes.

IV. PROCEDURE:

1. Select the load by rotating the Knob and fix the suitable indenter.
2. Clean the test-piece and place n the special anvil or work table of the machine.
3. Turn the capstan wheel to elevate the test specimen into contact with the indenter point.
4. Further turn the wheel for three rotations forcing the test specimen against the indenter. This will ensure that the Minor load of 98.07 N has been applied
5. Set the pointer on the Scale dial at the appropriate position.
6. Push the lever to apply the Major load. A Dash Pot provided in the loading mechanism to ensure that the load is applied gradually.
7. As soon as the pointer comes to rest pull the handle in the reverse direction slowly. This releases the Major, but not Minor load. The pointer will now rotate in the reverse direction.
8. The Rockwell hardness can be read off the scale dial, on the appropriate scale, after the pointer comes to rest.

V. OBSERVATIONS:

Material of test piece =

Thickness of test piece =

Hardness Scale used =

Minor Load =

Major Load =

Test No.	1	2	3	4
Hard ness value				

VI. PRECAUTIONS:

1. For testing cylindrical test specimen, use V-type platform.
2. Calibrate the machine occasionally using standard test blocks.
3. For thin metal pieces place another sufficiently thick metal piece between the test specimen and the platform to avoid any damage which may likely occur to the platform.
4. After applying Major load, wait for sometime to allow the needle to come to rest. The waiting time vary from 2 to 8 seconds.
5. The surface of the test piece should be smooth and even and free from oxide scale and foreign matter.
6. Test specimen should not be subjected to any heating or cold working.
7. The thickness of test piece or of the layer under test should be at least 8 times the permanent increase of depth of "E".
8. The distance between the centers of two adjacent indentation should be at least 4 indentation to the edge of the test piece should be at least 2.5 times the diameter of the indentation.

VII. VIVA QUESTIONS:

1. Define Hardness.
2. Applications of Rockwell Hardness A – Scale, B-Scale, C-Scale.
3. Type of Indentor used in the Three Different Scales of Rockwell Hardness Test.
4. Different Types of Hardness Testing Methods.
5. Size of the Ball to be used in Ball Indentor of Rockwell Hardness Test.
6. Diameters of the different Balls used in Brinell Hardness Test.
7. Selection of Load in Brinell Hardness Test.
8. Selection of Load in Rockwell Hardness Test.

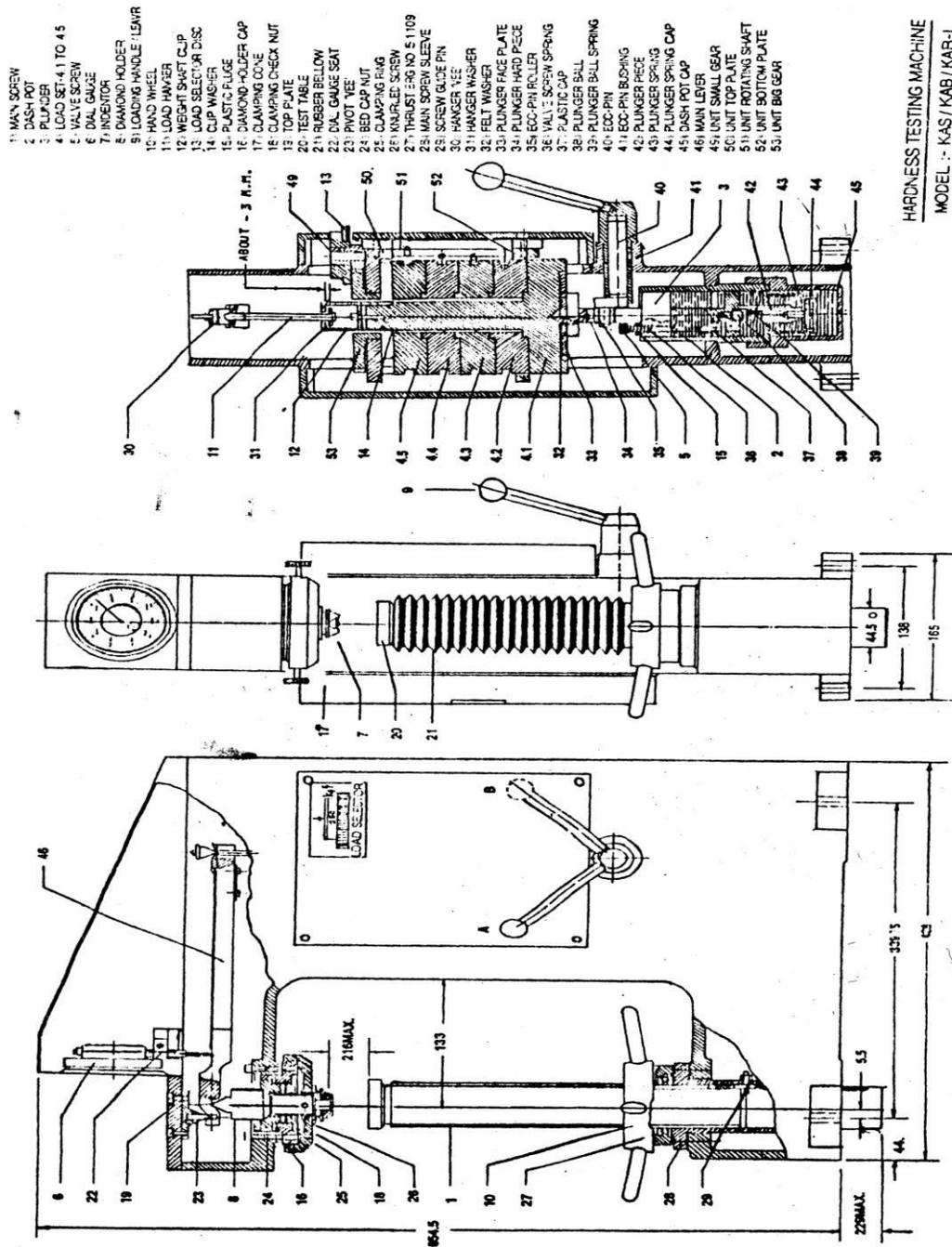


Figure: Hardness Testing Machine

2. BRINELL HARDNESS TEST

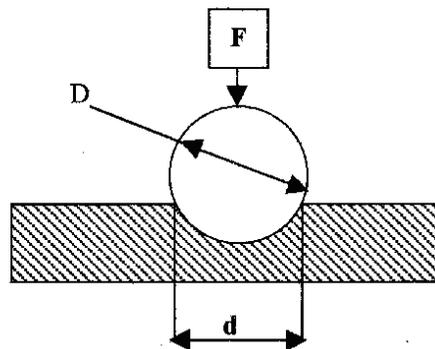
- I. AIM:** To determine the Brinell hardness of the given test specimen.
- II. APPARATUS:** Brinell hardness machine, test specimen. Brinell Microscope

III. THEORY:

INDENTATION HARDNESS-A number related to the area or to the depth of the impression made by an indenter or fixed geometry under a known fixed load.

This method consists of indenting the surface of the metal by a hardened steel ball of specified diameter D mm under a given load F (kgf) and measuring the average diameter d mm of the impression with the help of Brinell microscope fitted with a scale. The Brinell hardness HB is defined, as the quotient of the applied force F divided by the spherical area of the indentation

$HB = \text{Test load in kgf/surface area of indentation}$



$$= \frac{2F}{\pi D(D - \sqrt{D^2 - d^2})} \text{ kg/mm}^2$$

IV. PROCEDURE:

1. Select the proper size of the ball and load to suit the material under test
2. Clean the test specimen to be free from any dirt and defects or blemishes.
3. Mount the test piece surface at right angles to the axis of the ball indenter plunger.
4. Turn the platform so that the ball is lifted up.
5. By shifting the lever apply the load and wait for some time.
6. Release the load by shifting the lever.
7. Take out the specimen and measure the diameter of indentation by means of the Brinell microscope.

8. Repeat the experiment at other positions of the test piece.
9. Calculate the value of HB.

V. OBSERVATIONS:

Test Piece Material =
 Diameter of Ball "D" =
 Load selection F/D^2 =
 Test Load F =
 Load application time =
 Least count of Brinell Microscope =

$$HB = \frac{2F}{\pi D(D - \sqrt{D^2 - d^2})} \text{ kg/mm}^2$$

Sl.No.	Impression Diameter			F in kG	T in sec	D in mm	HB Kg/mm ²
	d ₁	d ₂	$\frac{d_1 + d_2}{2}$				

Average value of HB =

VI. PRECAUTIONS:

1. The surface of the test piece should be clean.
2. The testing machine should be protected throughout the test from shock or vibration.
3. The test should be carried out at room temperature.
4. The distance of the center of the indentation from the edge of the test piece should be at least 2.5 times the diameter of the indentation and the distance between the center of two adjacent indentations should be at least 4 times the diameter of the indentation.

5. The diameter of each indentation should be measured in two directions at right angles and the mean value of the two readings used for the purpose of determining the hardness number.

LIST OF PARTS

- | | |
|-----------------------|----------------------|
| 1. MAIN LEVER | 2. HANGER |
| 3. HANGER VE (FEMALE) | 4. HANGER VEE (MALE) |
| 5. WEIGHT HANGER | 6. WEIGHT |
| 7. BOTTOM WEIGHT | 8. COVER |
| 9. FRAME | 10. OPERATING LEVER |
| 11. SPINDLE SPRING | 12. SPINDLE SHAFT |
| 13. MAIN KNIFE EDGE | 14. PIVOT VEE |
| 15. PIVOT KNIFE EDGE | 16. SPINDLE BUSHING |
| 17. SPINDLE | 18. BALL HOLDER |
| 19. FLAT ANVIL | 20. ADAPTOR |
| 21. ELEVATING SCREW | 22. ADAPTOR |
| 23. HAND WHEEL | 24. METERING VALVE |

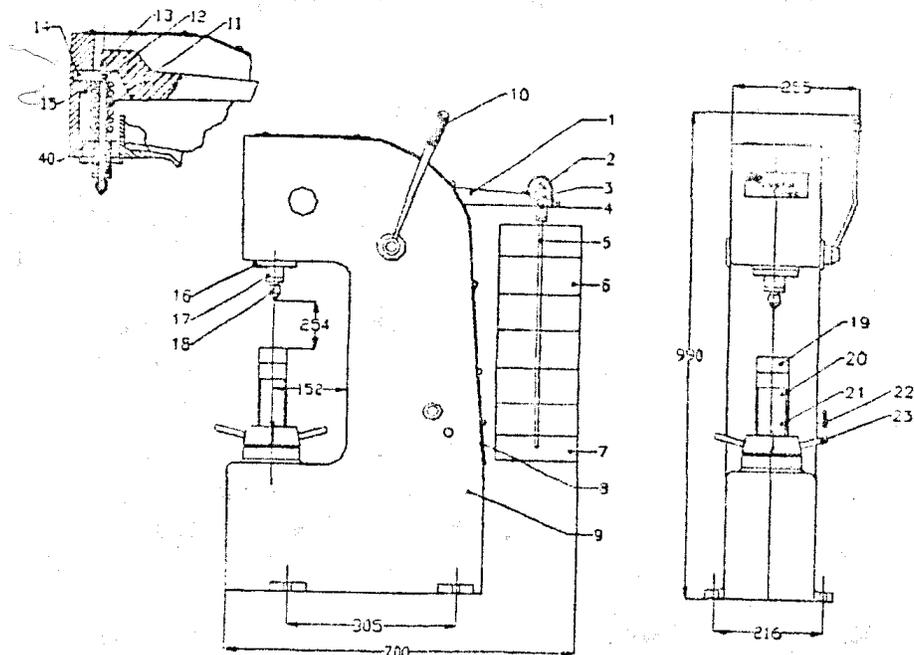


FIGURE: BRINELL HARDNESS TESTING MACHINE

3. IZOD IMPACT TEST

- I. AIM:** To perform the Izod Impact test on Metals.
- II. APPARATUS:** Izod impact testing machine, test specimen, vernier caliper, steel rule
- III. THEORY:**

IMPACT STRENGTH: The high resistance of material to fracture under suddenly applied loads.

The types of test pieces are used for this test as given.

- i. Square cross-section ii. Round cross-section

The specimens may have single, two or three notches. The testing machine should have the following specifications. Angle between top face of grips and face holding the specimen vertical = 90° Angle of tip of hammer = $75^\circ \pm 1^\circ$

Angle between normal to the specimen and the underside face of the

Hammer at striking point	=	$10^\circ \pm 1^\circ$
Speed of hammer at impact	=	3.99 m/sec
Striking energy	=	168 N-M or Joules.
Angle of drop of pendulum	=	90°
Effective weight of pendulum	=	21.79 kg.
Minimum value of scale graduation	=	2 Joules.
Permissible total friction loss of corresponding energy	=	0.50%
Distance from axis of rotation of distance between base of specimen notch and the point of specimen hit by the hammer	=	$22 \text{ mm} \pm 0.5 \text{ mm}$.

The longitudinal Axis of the test piece shall lie in the plane of swing of the center of gravity of the hammer. The notch shall be positioned so that it is in the plane of the hammer. The notch shall be positioned so that its plane of symmetry coincides with the top face of the grips. For setting the specimen. The notch impact strength I is calculated according to the following relation.

$$I = K/A$$

Where I = Impact Strength in Joules/m²

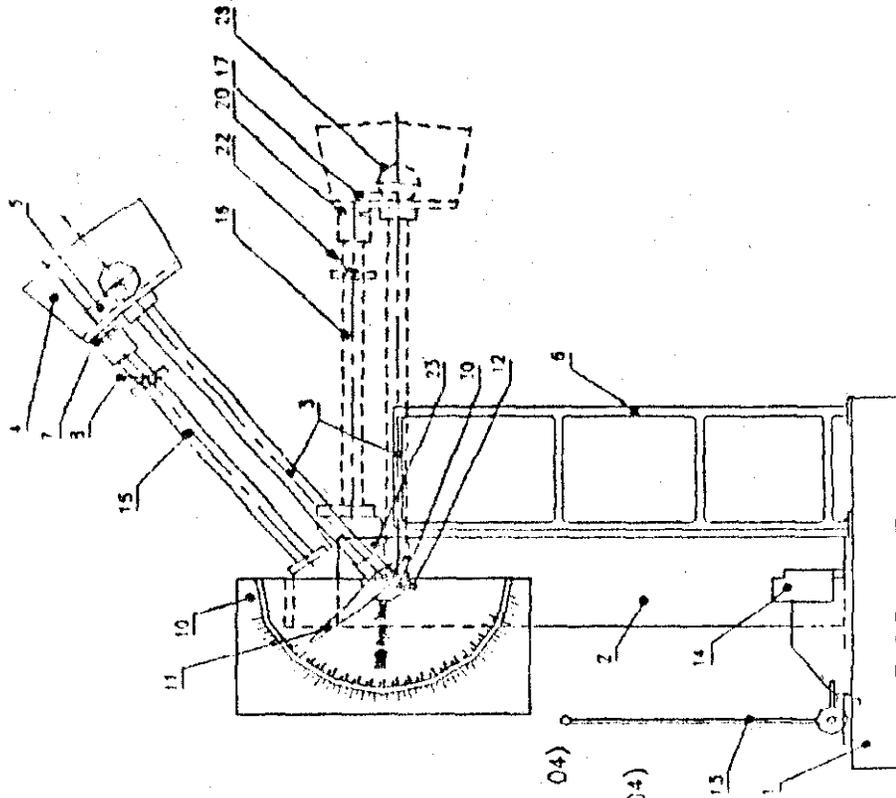
IV. PROCEDURE:

1. For conducting Izod test, a proper striker is to be fitted firmly to the bottom of the hammer with the help clamping piece.
2. The latching take for Izod test is to be firmly fitted to the bearing housing at the side of the columns.
3. Adjust reading pointer along with pointer carrier on 168 J reading on the dial when the pendulum is hinging free vertically.
4. The frictional loss of the machine can be determined by free fall test. Raise the hammer by hands and latch in. Release the hammer by operating liver, the pointer will then indicate the energy loss due to friction. From this reading confirm that the friction loss is not exceeding 0.5% of the initial potential energy. Otherwise friction loss has to be added to the final reading.
5. Now raise the pendulum by hands and latch in with latch
6. The specimen for Izod test is firmly fitted in the specimen support with the help of clamping screw and élan key. Care is to be taken that the notch on the specimen should face to pendulum striker.
7. After ascertaining that there is no person in the range of swinging pendulum. Release the pendulum to smash the specimen.
8. Carefully operate the pendulum brake when returning after one swing to stop the oscillations.
9. Read off position of reading pointer on dial and not indicated value.
10. Remove the broken specimen by loosening the clamping screw.

The notch impact strength depends largely on the shape of the specimen and the notch. The values determined with other specimens therefore may not be compared with each other.

V. OBSERVATION TABLE:

Sl.No.	A Area of Cross-section of Specimen	K Impact Energy Absorbed	I Impact Strength



3. LIST OF PARTS OF THE MACHINE.

1. Base with specimen support fitted.
2. Column.
3. Pendulum Pipe.
4. Pendulum Hammer.
5. Striker for Charpy Test. (Ref. Dwg. 03)
6. Guard.
7. Latch for Charpy Test.
8. Lever to release the Pendulum.
9. Dial
10. Dial
11. Reading Pointer.
12. Pointer Carrier.
13. Break for Pendulum.
14. Specimen Support. (Ref. Dwg. 03 & 04)
15. Latching tube for Charpy Test.
16. Latching tube for Izod Test.
17. Striker for Izod Test.
18. Clamping Screw for Izod Specimen. (Ref. Dwg. 04)
19. Izod Specimen. (Ref. Dwg. 04)
20. Latch for Izod Test.
21. Setting Gauge for Izod Specimen. (Ref. Dwg. 04)
22. Lever to release the pendulum.
23. Bearing Housing.
28. Setting gauge for Charpy specimen.
30. Pendulum shaft.

FIGURE : IZOD & CHARPY IMPACT TEST

4. DEFLECTION TEST ON A SIMPLY SUPPORTED BEAM

III. AIM:

- This experiment is to demonstrate the effect of span of a simply supported beam on deflection of the beam.
- The effect of young's modulus of the material of the beam using different materials bars.
- The effect of type of cross section on the deflection because of the effect of moment of inertia of the beam.

III. THEORY:

A beam with a span L and is supported at both ends by knife edges. Let the moment of inertia of the Beam is 'I' about it's neutral axis and the Young's Modulus be 'E'.

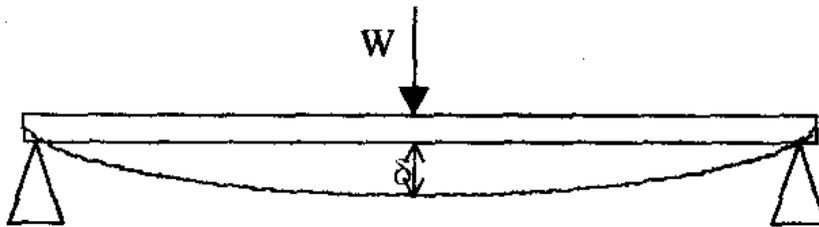


Figure:

$$\text{Moment of Inertia about the neutral axis } I = \frac{bh^3}{12}$$

Deflection at the center of span where the load is acting = δ

The deflection at the center (Max deflection) δ is related to the load 'W'. Span 'L' moment of Inertia 'I', and Young's Modulus 'E' through the equation.

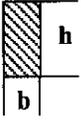
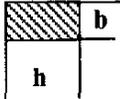
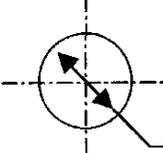
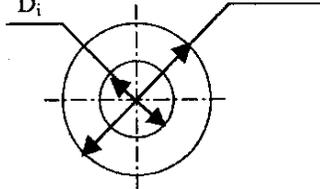
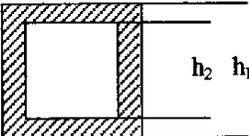
$$\delta = \frac{WL^3}{48EI}$$

We can observe that

- If load is doubled deflection will also be doubled
- If span is doubled deflection increases by 8 times.

- iii. If Young's Modulus of material is more, then deflection will be less.
 iv. If Moment of Inertia is increased the deflection will reduced.

The relations for Moment of Inertia area as follows.

Sl.No.	Cross Section	Moment of Inertia
1.	Rectangular 	$\frac{bh^3}{12}$
2.	Rectangular 	$\frac{hb^3}{12}$
3.	Circular 	$\frac{\pi d^4}{64}$
4.	Hollow Circular 	$\frac{\pi(D_o^4 - D_i^4)}{64}$
5.	Box 	$\frac{(h_1^4 - h_2^4)}{12}$

Cases of Hollow sections with same cross sectional area of solid sections.

- i. Hollow Circular Section: Let $D_o = 2 D_i$

$$\begin{aligned} \text{Cross Section Area} &= \frac{\pi(D_o^2 - D_i^2)}{4} = \frac{\pi[(2D_i^2 - D_i^2)]}{4} \\ &= \frac{\pi(4D_i^2 - D_i^2)}{4} = \frac{\pi(3D_i^2)}{4} \end{aligned}$$

- ii. Solid Circular Section: Let 'd' be the diameter of solid circular section with the same cross-sectional area.

$$\frac{\pi d^2}{4} = \frac{\pi(3D_i^2)}{4}$$

$$d^2 = 3D_i^2 \text{ or } d = \sqrt{3} D_i$$

Moment of Inertia for Hollow Section

$$\begin{aligned} I_{\text{hollow}} &= \frac{\pi(D_o^4 - D_i^4)}{64} = \frac{\pi[(2D_i^2 - D_i^2)]}{64} \\ &= \frac{\pi(16D_i^4 - D_i^4)}{64} = \frac{\pi(15D_i^4)}{64} \end{aligned}$$

Moment of Inertia for Solid Section

$$I_{\text{solid}} = \frac{\pi(d^4)}{64} = \frac{\pi[\sqrt{3}D_i]^4}{64} = \frac{\pi[9D_i^4]}{64}$$

∴ Hollow section has more 'I' than solid section with same cross-sectional area.

Some comments on sections of Beams & Materials.

- i. Hollow section with same cross sectional area of a solid section; will have more load carrying capacity and hence more stiffness.
- ii. Beams area used with depth longer than width because of more Moment of Inertia for the same cross-sectional area.
- iii. Mild Steel is stiffer than Aluminum because the Young's Modulus of the former material is bigger.

Concept of stiffness of Beam's in Bending (K_b)

Stiffness of component in bending is defined as the ration of load required for unit deflection in bending.

$$\text{Bending stiffness } K_b = W/\delta$$

In the case of Simply supported Beam with control loading the Stiffness

$$K_b = \frac{48EI}{L^3}$$

Hence

- i. If E is doubled Stiffness will be doubled.
- ii. If Moment of Inertia is doubled Stiffness will be doubled.
- iii. If the Distance of load is doubled the Stiffness reduced by 1/8 times.
- iv. Higher the Stiffness lesser will be the deflection of beam for the same load applied.

IV. EXPERIMENTAL SET-UP: The set-up contains the following

1. Two knife edges and supporting stands for beam.
2. Beams of different section
3. Loading arrangement along with different weights
4. Dial gauge with magnetic stand.
5. Measuring tape or Steel Scale.

XIII. PROCEDURE:

- i. Set the beam horizontally on the two knife edges.
- ii. Measure the span of Beam L (distance from clamp end to loading point)
- iii. Fix the dial gauge under the beam at the loading point middle of the span to Read down-ward moment and set to zero.
- iv. Hang the loading Pan at the mid point of the beam span.
- v. Load the Beam with different loads(W) and note the dial gauge readings (δ).

- vi. Change the span of beam for two more different lengths repeat the experiment.
- vii. Change the position of Beam and repeat the experiment for the other value of I for rectangular cross-section.

XIV. PRECAUTIONS :

- i. Beam should be positioned Horizontally
- ii. The span of the Beam should be measured properly
- iii. The dial gauge spindle knob should always
- iv. Loading hanger should be placed at center of the Beam length.
- v. All the errors should be eliminated while taking readings.
- vi. Elastic limit of the Beam should not exceeded.

XV. OBSERVATIONS:

- a) Independent Variables: 1. Load
2. Span
3. Moment of Inertia (By choosing different sections)
4. Young's Modulus (By choosing different Materials)

Sl. No.	Beam Material	Cross Section	Y.M. E N/mm ²	M.I. I mm ⁴	Span L mm	Load W in N	Deflection δ in mm	Bending Stiffness N/mm

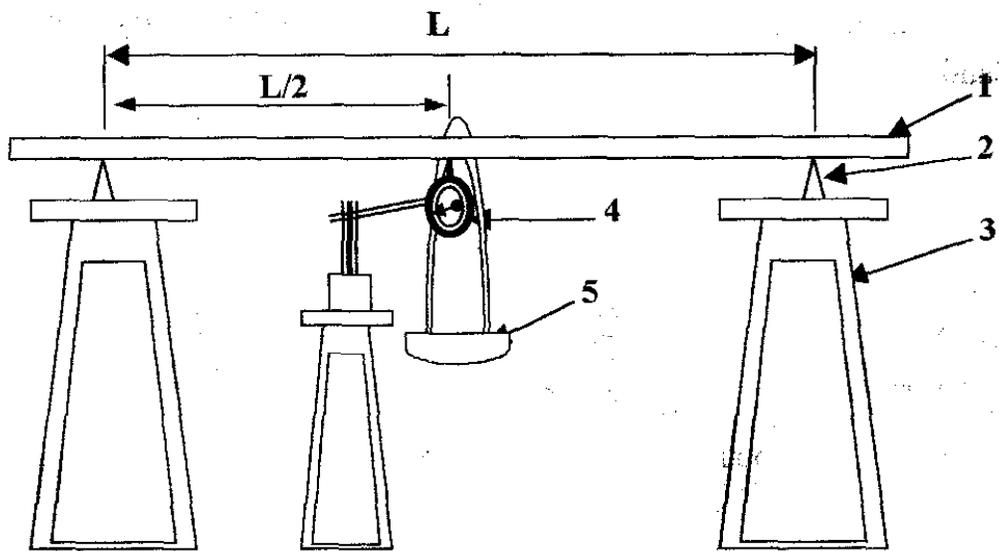
XVI. GRAPHS:

Deflection Vs W, L, I and E
Stiffness Vs W, L, I and E

XVII. CONCLUSION:

XVIII. VIVA QUESTIONS:

1. Give Equation for maximum Deflection, Maximum Bending Moment, Maximum Slope in the case of Cantilever, Simply Supported Beam, Fixed Beam and a Continuous Beam with Three Supports.
2. For the same cross sectional area and span give in the increasing order the values of i) Square Section, ii) Rectangular Section with ' $h > b$ ' and ' $h < b$ ', iii) Hollow Square Section, iv) Circular Section.
3. Define Point of Contraflexure, Stiffness, Shear Force and Shear Stress in Beams in Bending.



1. Beam for test
2. Knife Edge
3. M.S. Stand
4. Dial Gauge
5. Loading Pan

Fig 4. 1

DEFLECTION TEST ON A SIMPLY SUPPORTED BEAM

5. DEFLECTION TEST ON CANTILEVER BEAM

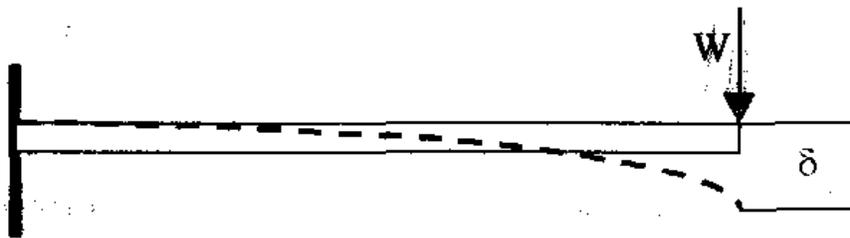
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- This experiment is to demonstrate the effect of distance at which the load acting from the fixed end on deflection of the beam
- The effects of young's modulus of the material of the beam using different materials bars.
- The effect of type of cross section on the deflection because of the effect of moment of inertia of the beam.

II. THEORY:

A Cantilever is a Beam one end of which is clamped and other end is free.

A beam with a length L and is fixed at one end and the other end is free. Let the moment of inertia of the Beam is 'I' about it's neutral axis and the Young's Modulus be 'E'.



Moment of inertia about the neutral axis $I = \frac{bh^3}{12}$

Deflection at the end where point load is acting = δ

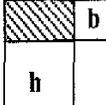
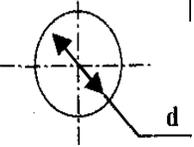
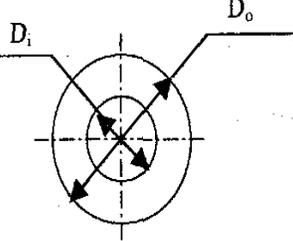
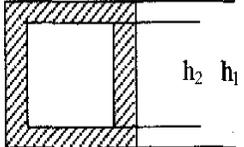
The deflection at the end (Max deflection) δ is related to the load 'W', length 'L' moment of Inertia 'I' and Young's Modulus 'E' through the equation.

$$\delta = \frac{WL^3}{3EI}$$

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Cases of Hollow sections with same cross sectional area of solid sections.

- i. Hollow Circular Section: Let $D_o = 2 D_i$

$$\begin{aligned} \text{Cross Section Area} &= \frac{\pi(D_o^2 - D_i^2)}{4} = \frac{\pi[(2D_i)^2 - D_i^2]}{4} \\ &= \frac{\pi(4D_i^2 - D_i^2)}{4} = \frac{\pi(3D_i^2)}{4} \end{aligned}$$

- ii. Solid Circular Section: Let 'd' be the diameter of solid circular section with the same cross-sectional area.

$$\frac{\pi d^2}{4} = \frac{\pi(3D_i^2)}{4}$$

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Moment of Inertia for Hollow Section

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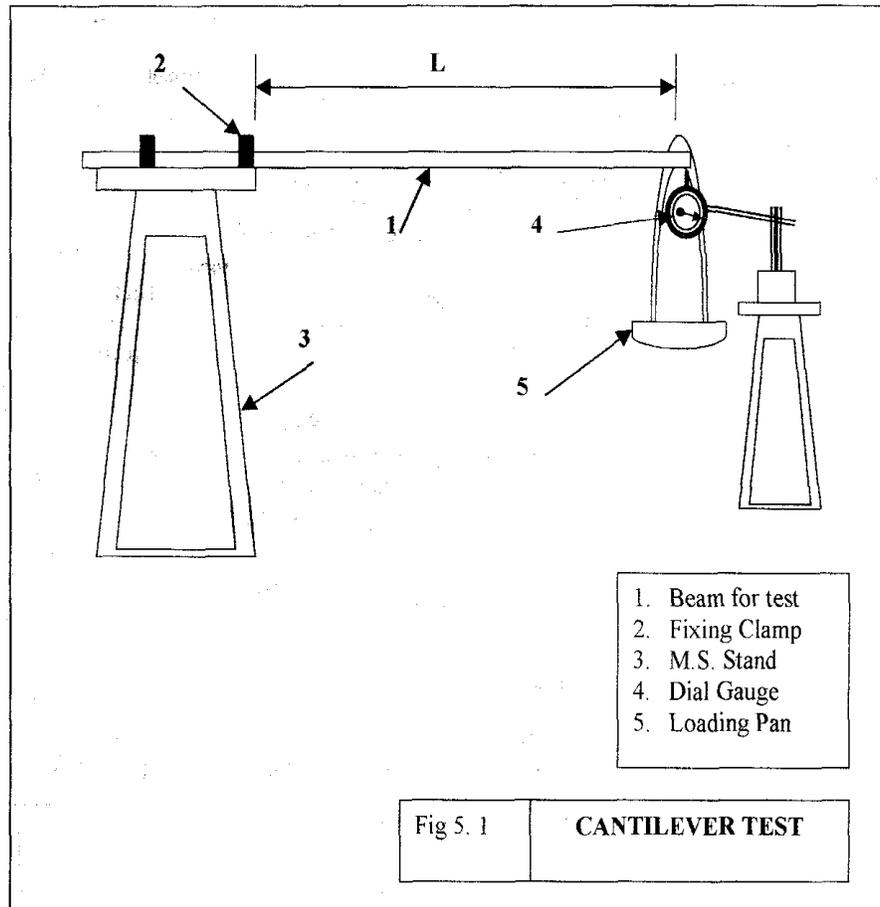
$$K_b = \frac{3EI}{L^3}$$

Hence

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- iii. If the Distance of load is doubled the Stiffness reduced by 1/8 times.
- iv. Higher the Stiffness lesser will be the deflection of beam for the same load applied.

IV. EXPERIMENTAL SET-UP: The set-up contains the following

- i. One rigid clamping support for fixing one end of the beam.
- ii. Beams of different section
- iii. Loading arrangement along with different weights.
- iv. Dial gauge with magnetic stand.
- v. Measuring tape or Steel Scale



6. SPRING TEST

I. AIM: To determine the stiffness of the Spring and Modulus of Rigidity of the Spring Wire.

II. MATERIAL AND EQUIPMENT:

- i) Spring testing machine
- ii) Springs for testing
- iii) Micrometer
- iv) Vernier Caliper.

III. THEORY: Springs are elastic members which distort under load and regain their original shape when load is removed. They are used in railway carriages, Motor Cars, Scooters, Motor Cycles, Rickshaws, Governors etc.

Types of Springs:

1. Close-coiled helical springs & Tension helical springs with circular cross-section
2. Open-coiled springs & Compression helical springs with square cross-section
3. Full-elliptical leaf springs.
4. Semi-elliptical laminated springs.
5. Cantilever leaf springs
6. Circular Springs.

According to their uses, the springs perform the following function:

- i. To absorb shock or impact loading as in carriage springs.
- ii. To store energy as in clock springs.
- iii. To supply forces to and to control motions as in brakes and clutches.
- iv. To measure forces as in spring balances.
- v. To absorb the vibrations, characteristic of a member as in flexible mounting of motors.

The springs are usually made of either high carbon steel (0.7% to 1.0%) or Medium carbon alloy steels. Phosphor bronze, Brass and 18/8 Stain less steel. Other metal alloys are used for corrosion resistance.

Analysis of Close-Coiled Helical Springs: (Circular Section wire)

- W Axial load applied (N)
- R_m Mean radius of the Coil(mm)
- D_o Outer Diameter of Coil (mm)
- D_m (D_o-d) Mean diameter of the Coil (mm)
- d Diameter of the wire of the Coil (mm)
- δ Deflection of coil (m) under the load 'W'
- C Modulus of rigidity (N/mm^2)
- n Number of coils or turns.
- L Lenth of wire = $2\pi R_m n$ (mm)
- t Shear stress (N/mm^2)

T Torque (N-mm)

I_p Polar Moment of Inertia of wire = $\pi d^4/32$ (mm^4)

Spring index = D_m/d

Torsion Equation: $\frac{T}{I_p} = \frac{C\theta}{L} = \frac{\tau}{r}$

a) For circular section of spring with dia = d

$$T = \frac{\tau I_p}{r} = \frac{\tau \pi d^4}{32} \times \frac{2}{d} = \frac{\tau \pi d^3}{16} \text{ Nmm}$$

$$\tau = \frac{16T}{r} = \frac{16WR_m}{\pi d^3} = \frac{8WD_m}{\pi d^3} \text{ (where } T=WR_m \text{ \& } R_m = D_m/2\text{)}$$

We have $\frac{T}{I_p} = \frac{C\theta}{L}$

$$\theta = \frac{TL}{CI_p} = \frac{WR_m 2R_m n 32}{C \pi d^4} = \frac{64WR_m^2 n}{Cd^4} \text{ (Radians)}$$

Deflection $\delta = R_m \theta$ (mm)

$$\delta = \frac{64WR_m^3 n}{Cd^4} = \frac{8WD_m^3 n}{Cd^4} \text{ (mm)}$$

or Modulus of Rigidity $C = \frac{8WD_m^3 n}{\delta d^4} \text{ (N/mm}^2\text{)}$

b) For Rectangular Cross-section wire (Width = b and Thickness = h)

$$C = \frac{7\pi WR_m^3 n}{\delta} \left[\frac{b^2 + h^2}{b^3 h^3} \right] \text{ N/mm}^2$$

c) For Square cross-section wire when 'b' is the side of square

$$C = \frac{14\pi WR_m^3 n}{\delta b^4} \text{ (N/mm}^2\text{)}$$

d) For Open coiled helical spring with circular cross-section wire, With the angle of Helix = α ,

Deflection of spring (α) due to axial load

$$\delta = \frac{64WR_m^3 n \cdot \sec \alpha}{d^4} \left[\frac{\cos^2 \alpha}{C} + \frac{2 \sin^2 \alpha}{E} \right]$$

Stiffness of spring = W/δ

IV. PROCEDURE:

1. By using micrometer measure the diameter of the wire of spring (d)
2. By using the vernier caliper measure the outer diameter of spring coil (D_o),
3. Count the number of turns (n),
4. Insert the spring in the spring testing machine and load spring by a suitable weight and note the corresponding axial deflection in tension or compression.
5. Increase the load and take the corresponding axial deflection readings.
6. Plot a curve between load and deflection, shape of the curve gives the stiffness of the spring.
7. Calculate modulus of rigidity C in N/mm^2 from the readings obtained within the elastic limit.

V. OBSERVATIONS AND CALCULATIONS:

Sl.No.	Outer dia D_o	Wire dia d .	No. of Turns 'n'	Mean dia D_m	Load W (N)	Deflection δ (mm)	Stiffness W/δ	Modulus of Rigidity $C(N/mm^2)$

VI. GRAPHS & RESULTS:

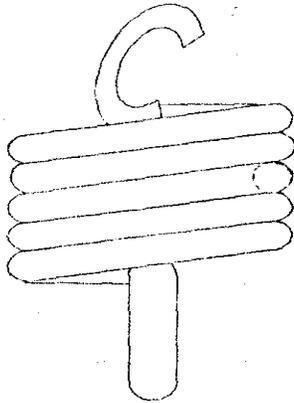
Load Vs Deflection
Stiffness Estimation

VII. VIVA QUESTIONS:

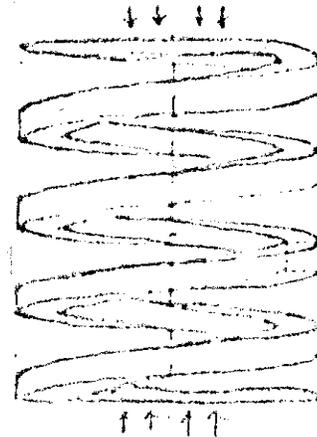
1. Types of Springs.
2. State Different Functions of Springs.

Fig. 5.1 TYPES OF SPRINGS

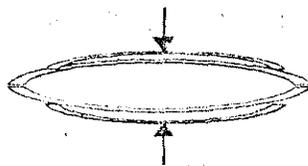
a). Close-coiled Helical Spring & Tension Helical Spring with Circular cross-section.



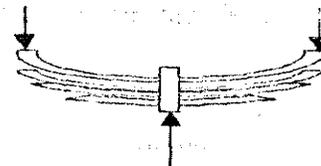
b). Open-coiled Helical Spring & Compression Helical Spring With Square cross-section.



3. Full-Elliptical Leaf Spring



4. Semi-Elliptical Laminated Spring



5. Cantilever Leaf Springs



6. Circular Springs



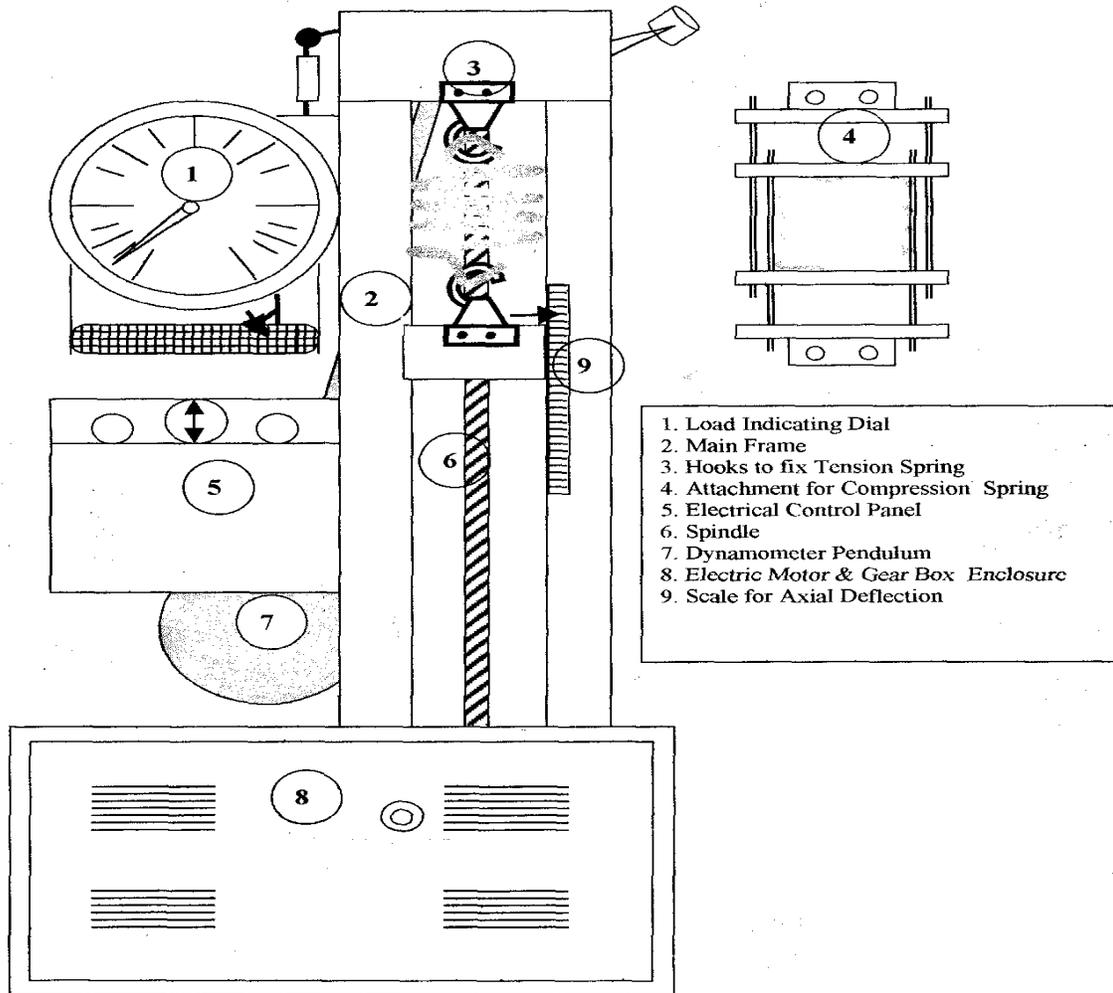


Fig 6. 2

SPRING TESTING MACHINE

7. TORSION TEST

I. AIM: To conduct torsion on mild steel or cast iron specimens to find out Modulus of Rigidity or to find angle of twist of the materials which are subjected to Torsion

II. MATERIAL AND EQUIPMENT:

1. A Torsion testing machine along with angle of twist measuring attachment
2. Standard specimen of mild steel or cast iron.
3. A steel rule.
4. Vernier caliper or Micrometer.

III. THEORY: For transmitting power through a rotating shaft it is necessary to apply a turning force. The force is applied tangentially and in the plane of transverse cross-section. The torque of twisting moment may be calculated by multiplying to two opposite turning moments, it is said to be in pure torsion and it will exhibit the tendency of shearing off at every cross-section which is perpendicular to longitudinal axis.

Torsion Equation:

If T = Maximum Twisting Torque (Nmm)

$$= \frac{P \times 60}{2\pi N} \times 10^6 \quad \text{where Power (P) Transmitted by shaft in kW}$$

and N is Revolutions per minute of shaft.

D = Diameter of a solid shaft (mm)

D_o = Outer diameter of hollow shaft (mm)

D_i = Inner diameter of hollow shaft (mm)

I_p = Polar Moment of Inertia (mm⁴)

For Solid shafts I_p = πD⁴/32 (mm⁴)

For Hollow shafts I_p = π(D_o⁴ - D_i⁴)/32 (mm⁴)

τ = Shear Stress (N/mm²)

C = Modulus of Rigidity (N/mm²)

θ = The angle of twist in radians

L = Length of shaft under Torsion (mm)

Torsion Equation is $\frac{T}{I_p} = \frac{\tau}{R} = \frac{C\theta}{L}$ Where R = D/2 in mm for Solid shaft

R = D_o/2 in mm for Hollow shaft

Torque applied T = WR (Nmm) Where W is tangential load applied.

The value of Modulus of Rigidity can be found by $C = \frac{TL}{I_p\theta}$ in N/mm²

Or Angle of Twist per unit Length $\frac{\theta}{L} = \frac{T}{I_p C}$ (Radian/mm Length)

Assumptions made for getting Torsion Equation

1. The material of the shaft is uniform throughout
2. The shaft, circular in section remain circular after loading.
3. Plane sections of shaft normal to its axis before loading remain plane after the torque have been applied.
4. The twist along the length of shaft is uniform throughout.
5. The distance between any two normal – sections remains the same after the applications of torque.
6. Maximum Shear Stress induced in the shaft due to application of Torque does not exceed its Elastic Limit.

IV. PROCEDURE:

1. Select suitable grips to suit the size of the Specimen and clamp it in the machine by adjusting sliding Jaw.
2. Measure the diameter at about three places and take average value.
3. Choose the appropriate loading range depending upon specimen.
4. Set the maximum load pointer to zero.
5. Carry out straining by rotating the hand wheel or by switching on the motor.
6. Load the member in suitable increments, observe and record strain readings.
7. Continue till failure of specimen.
8. Calculate the value of Modulus of Rigidity C by using $C = TL/I_p\theta$ taking values of T & θ within Elastic Limit.
9. Plot a Torque – Twist graph (T Vs θ).
10. For known value of C, θ per unit length $\theta/L = T/I_pC$

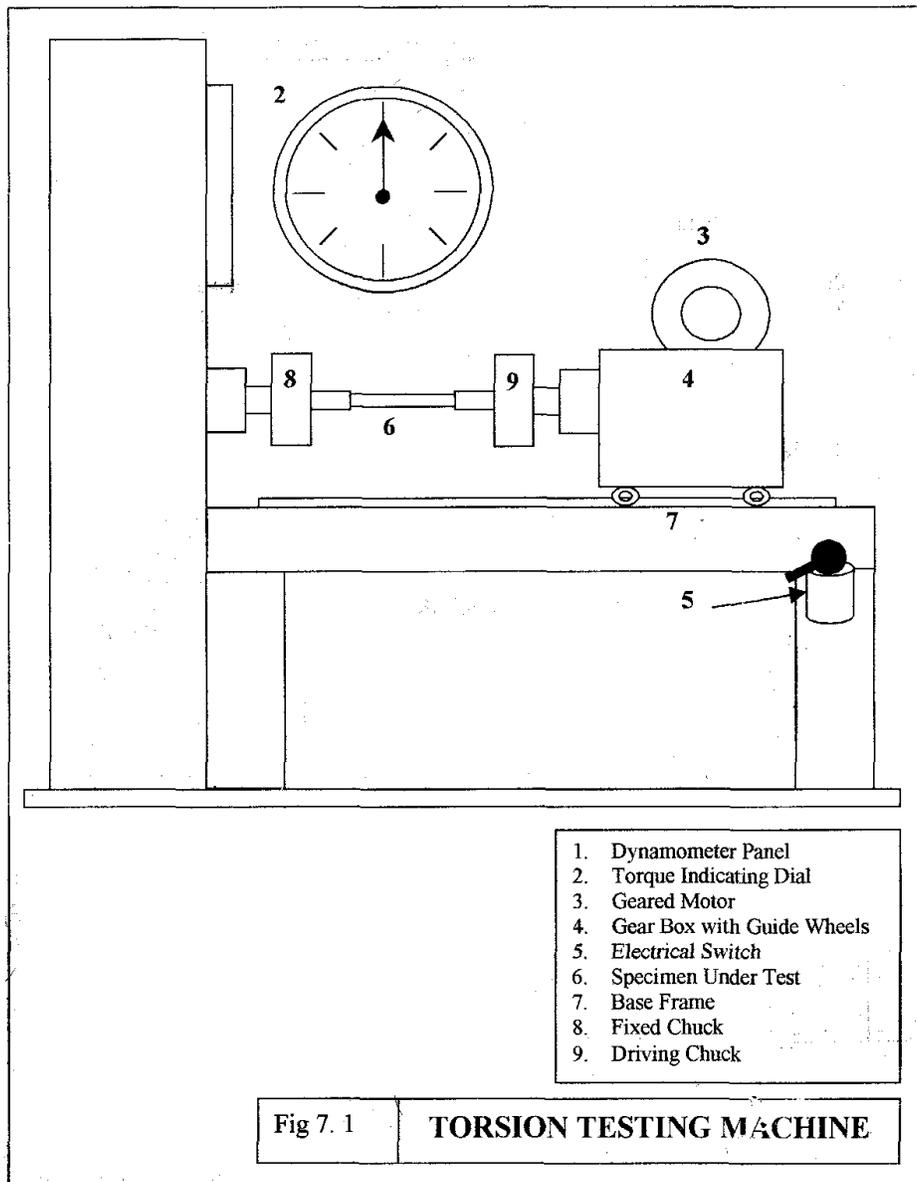
V. OBSERVATIONS:

Gauge length (L)	=	mm.
Diameter of the Specimen (D)	=	mm.
Weight (W)	=	Newtons,
Torque (T)	=	WD/2 N-mm.
Angle of twist (θ)	=	θ^0 in degrees.
(θ)	=	$\theta^0 \times \pi/180$ in radians.
Polar Moment of Inertia I_p	=	$\pi D^4/32$ mm ⁴ ,
Modulus of Rigidity C	=	TL/ $I_p \theta$ N/mm ²

Sl. No.	L (mm)	D (mm)	W (N)	T (N-mm)	θ		I_p (mm ⁴)	C (N/mm ²)
					Degrees	Radians		

VI. CONCLUSIONS:

- i. Modulus of Rigidity calculated will be a constant for given material, irrespective of L, D, W & T. The differences must be explained for.
- ii. Angle of twist per unit length can be calculated for known values of Torque, Diameter of specimen and Modulus of Rigidity.



8. TENSILE TEST

I. AIM: To conduct tensile test on a mild steel specimen and determine the following:

- | | |
|----------------------------------|---------------------------------------|
| i) Limit of proportionality | ii) Upper yield point |
| iii) Ultimate strength | iv) Lower yield point |
| v) Ultimate strength | vi) Fracture Strength |
| vii) Young's modulus | viii) Percentage elongation |
| ix) Percentage reduction in area | x) Ductility |
| xi) Toughness | xii) True-Stress & true-strain values |
| xiii) Malleability | |

II. MATERIAL & EQUIPMENT:

- | | |
|----------------------------|---------------------|
| i) Tensile testing machine | ii) Specimen |
| iii) Steel rule | iv) Vernier caliper |
| v) Micrometer | |

III. THEORY:

The tensile test is not applied one of all mechanical tests. In this test, a test specimen is fixed into grips connected to a Straining device and to a load-measuring device. (one end in stationary grips and the other in movable grips). If the applied load is small enough, the deformation of any solid body is entirely elastic. An elastically deformed solid will return to its original form as soon as load is removed. However if the load is too large, the material can be deformed permanently. The initial part of the tension curve, which represents the manner in which solid undergoes plastic deformation is termed plastic. The stress below which the deformation is essentially entirely elastic is known as the elastic limit of material. In some materials like mild steel the onset of plastic deformation is denoted by a sudden drop in load indicating both an upper and lower yield point. However some materials do not exhibit a sharp yield point. During plastic deformation, at larger extensions, strain hardening cannot compensate for the decrease in section and thus the load passes through a maximum and then begins to decrease. At this stage the **ULTIMATE STRENGTH** which is defined as the ratio of the load on the specimen to original cross-sectional area, reaches a maximum value. Until this point the deformation is uniform at all sections of the specimen. Further loading will eventually

Usually a tension test is conducted at room temperature. And the tensile load is applied slowly. During this test either round or flat specimens may be used. The load on the specimen is applied mechanically or hydraulically depending on the type of testing machine.

- 3.1) **Nominal/Engg. Stress and Nominal/Engg Strain:**
 Original C/S are = A_0 (mm^2) Nominal Stress = P/A_0 (N/mm^2)
 Original gauge length = L_0 (mm) Nominal Strain = $\delta L_0/L_0$
- 3.2 **Limit of Proportionality (Point A in Fig 9)**
 Stress is proportional to strain upto this point.
 Nominal Stress = P_A/A_0
 Nominal Strain = $(\delta L_0)_A/L_0$
- 3.3 **Elastic Limit (Point B in Fig.9)**
 When the load is removed at “B”, the specimen will go back to original dimension
 i.e. L_0 and δA_0
 Nominal Stress = P_0/A_0
- 3.4 **Upper Yield (point C in Fig.9)**
 Nominal Stress = P_0/A_0
 Nominal Strain = $(\delta L_0)_C/L_0$
- 3.5 **Lower Yield point (Point D in Fig.9)**
 Nominal Stress = P_D/A_0
 Nominal Strain = $(\delta L_0)_D/L_0$
- 3.6 **Ultimate Load or Maximum Load Point (Point E in Fig.9)**
 Nominal Ultimate Stress = P_E/A_0
 Nominal Strain = $(\delta L_0)_E/L_0$
- 3.7 **Fracture Load Point F(Point F in Fig.9)**
 Nominal Fracture stress = P_F/A_0
 Nominal Strain at fracture = $(\delta L_0)_F/L_0$
- 3.8 **Young's Modulus (E)**
 Young Modulus (E) = Stress / strain
 (in the elastic region limit of Proportionality
 = Nominal Stress at A/Nominal Strain at A
- 3.9 **Modulus of Resilience** = $(\text{Nominal stress at elastic limit})^2/2E$
 (Area under Engg. Stress-Strain diagram upto elastic limit)
- 3.10 **Resilience** = Modulus of Resilience X Volume of specimen undergoing tensile stress.
- 3.11 **Yield Point Elongation**
 Elongation taking place in the specimen from C to D'. This is taking place without increase in stress.
- 3.12 **Modulus of toughness**
 Area under Engineering stress-strain diagram upto fracture.
- 3.13 **Toughness** = Modulus of toughness x Volume of specimen

This indicates the amount of energy absorbed by the specimen before fracture takes place.

3.13 Malleability:

It is the ability of the material to undergo plastic deformation prior fracture under Compressive Loading conditions. In a tensile test it is approximated as percentage reduction in cross sectional area of the specimen.

$$\text{Malleability} = (A_0 - A_f)/A_0 \times 100$$

4. True Stress – True strain diagram

Engineering stress is calculated based on original cross sectional area (A_0) but not on the actual cross sectional area at load 'P'.

$$\text{True stress} = P/A = P/A_0 \times A_0/A$$

Since volume remains constant during plastic deformation we have $A_0L_0 = A_L$

$$\text{True Stress} = P/A_0 \times L/L_0$$

$$= P/A_0 \times (L_0 + \delta L_0) / L_0$$

$$= P/A_0 \times (1 + \delta L_0) / L_0 = p(1+e)$$

$$= \text{Normal stress (1+Nominal strain)}$$

$$\text{True Strain} = \epsilon = \ln(1+e)$$

These relations are valid upto ultimate load ie. Upto which the strain is uniform all along the gauge length.

4.1 True Stress at Upper Yield Point

= Nominal stress at upper yield point (1+ e_c)

$$\text{True strain C} = \ln(1+e_c)$$

4.2 True Stress at Ultimate Load (Point E₁)

= Nominal ultimate stress (1+ e_E)

$$\text{True strain at ultimate load} = \ln(1+e_E)$$

4.3 True Stress at Fracture (At point F₁)

True stress at fracture = P_f/A_f

Where A_f is the area of cross section at fracture can be measured.

$$\text{True strain at Fracture} = \ln (A_0/A_f)$$

Area relation is taken instead of lengths because the strains are localized in the region between ultimate load point and Fracture point.

4.4 Strain Hardening

From lower yield point onwards increase in load is required for increase in strain. Thus the stress required for further deformation is more. This phenomenon is called strain hardening.

4.5 True-Stress-True Strain Curve in log-log co-ordinates

When the True – stress and True strain are plotted on log-log co-ordinates the curve looks as in Fig.2 i.e. Straight line.

4.6 Ductile and Brittle Materials

If a material fails without much plastic deformation it can be called brittle. If the percentage elongation at fracture is less than 2.5 the material is classified as brittle. Ex Grey Cast Iron

- Usually the metals with F.C.C and CPH structures are highly ductile. Ex Al, Cu, Ag, Au etc.

IV. PROCEDURE:

1. Measure the original gauge length and diameter of the specimen.
2. Insert the specimen into grips of the test machine
3. Begin the load application and record load versus elongation data
4. Take readings more frequently as yield point is approached
5. Measure elongation values
6. Continue the test till fracture occurs.
7. By joining the two broken halves of the specimen together measure the final length and diameter of specimen at fracture.

V. RESULTS & DISCUSSIONS

- a) Plot the Engg. Stress strain curve and determine the following

- i) Limit of proportionality = (N/mm²)
- ii) Yield strength = (N/mm²)
- iii) Ultimate Strength = (N/mm²)
- iv) Young's modulus = (N/mm²)
- v) Percentage Elongation = %
(Ductility)
- vi) Percentage reduction in area = %
- vii) Fracture Strength = (Nominal / Engg)
- viii) Toughness = area under Stress-Strain curve up to fracture
- ix) Malleability

- b) Plot True-Stress, True-strain curve after calculating true-Stress and True-strain values at various points.

- Estimate
- i) Strength coefficient
 - ii) Strain hardening coefficient

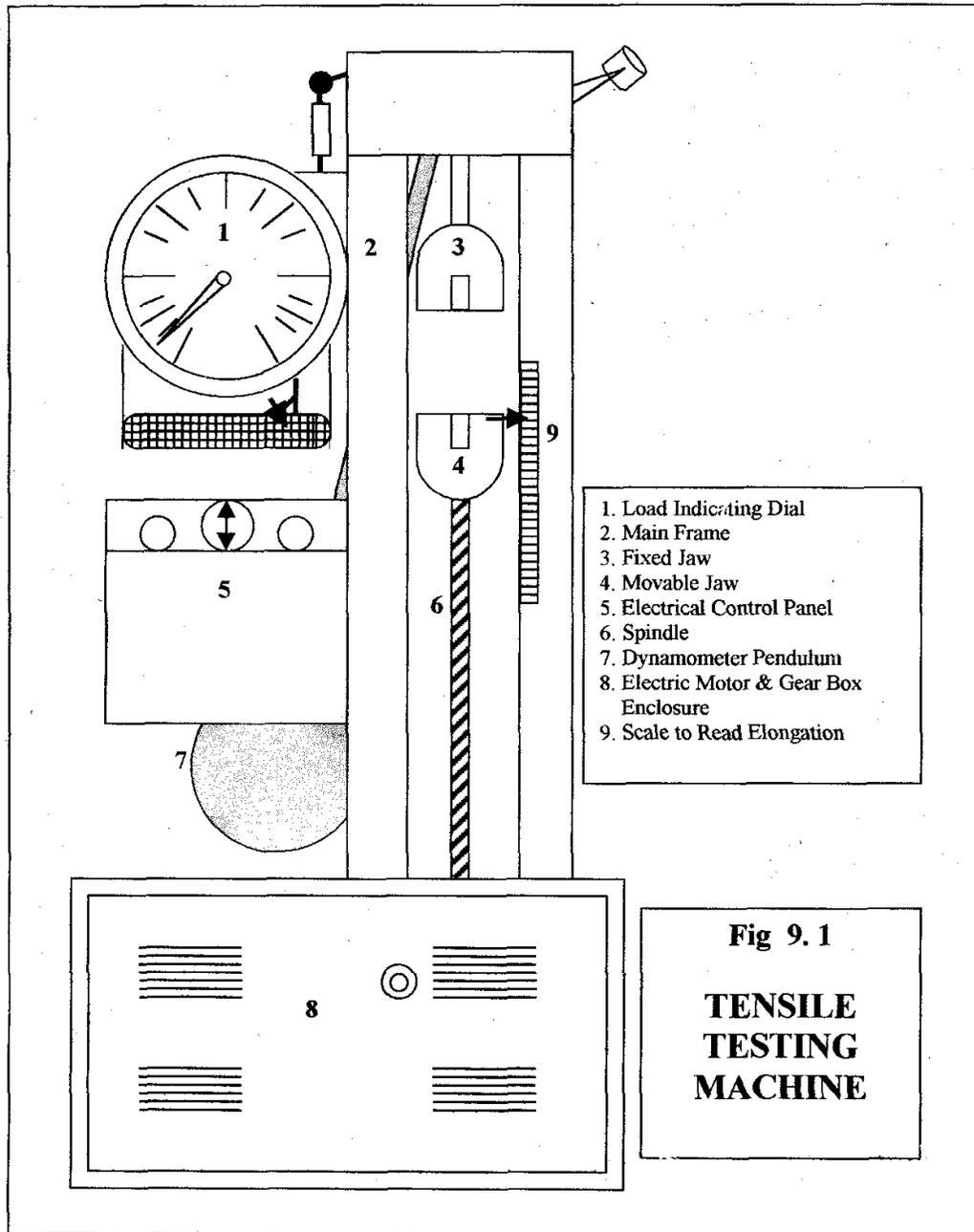
- c) Determine whether the material is Ductile or Brittle?
- d) Comment on the results.

VI. PRECAUTIONS:

VII. VIVA QUESTIONS:

Define the following terms

1. Elasticity.
2. Plasticity
3. Rigidity
4. Ductility
5. Toughness
6. Brittleness
7. Stress.
8. Strain
9. Tensile Stress
10. Shear Stress
11. Limit of Proportionality
12. Elastic Limit
13. Yield Point
14. Upper Yield Point
15. Lower Yield Point
16. Strain Hardening.
17. Proof Stress.
18. Modulus of Resilience.
19. Resilience.
20. Percentage Elongation
21. Percentage Reduction in Area
22. True Stress
23. True Strain
24. Ultimate Strength
25. Breaking Strength
26. Elastic Constants
27. Young's Modulus
28. Shear Modulus or Modulus or Rigidity
29. Bulk Modulus
30. Poissons/Ratio
31. Modulus of Elasticity for Mild Steel, Copper, Aluminum, Cost Iron etc.
32. Examples for Ductile Materials
33. Examples for Brittle Materials
34. Examples for Malleable Materials
35. Failure of Ductile Material under Tension
36. Failure of Brittle Material under Tension.



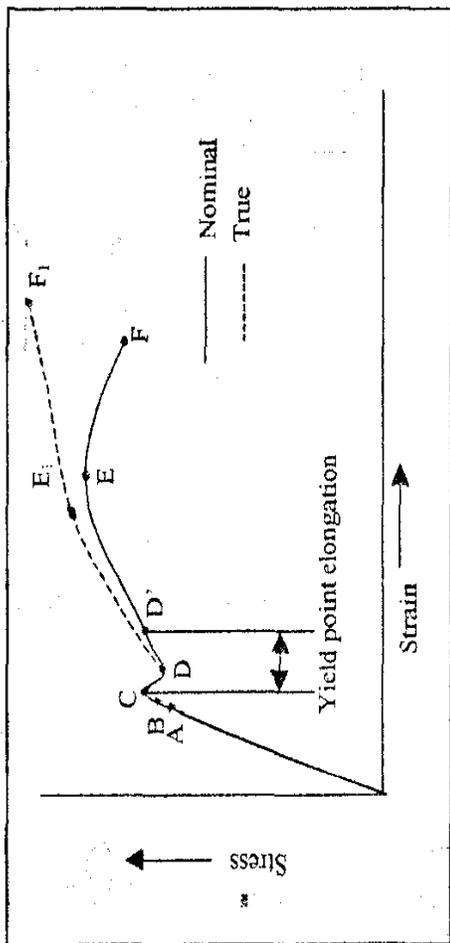


Fig.9 Stress - Strain curve

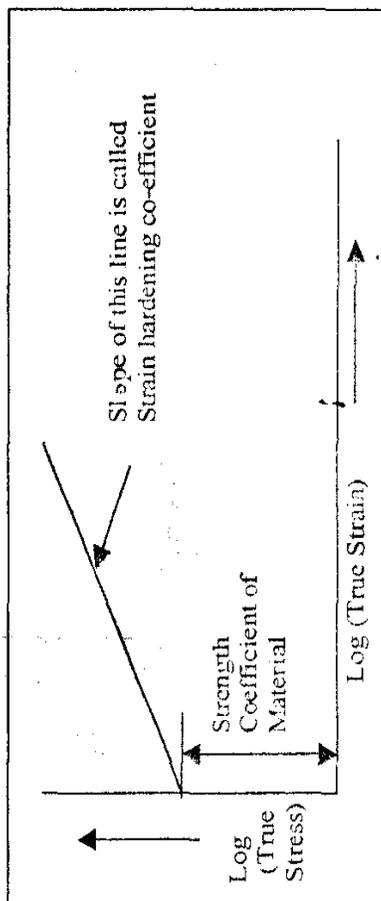


Fig. 10 True Stress- True Strain in log - log co-ordinates

9. SLOPE MEASUREMENT ON CANTILEVER BEAM

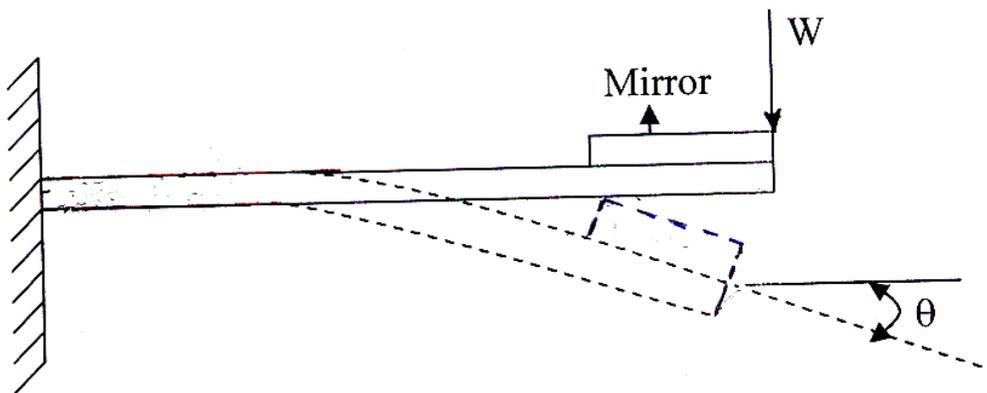
I. AIM :

The aim of this experiment is to-

- Study the variation of slope at the end of a cantilever beam with the load applied at the free end
- Infer the modulus of elasticity of the material of the beam
- Learn the use of lamp, mirror and scale arrangement for angle measurement.

II. THEORY :

To a first level of approximation and confined to the realm of linear elastic mechanics, the slope of a cantilever at the end when loaded transversely at the end is a function of the applied load, length of the beam, sectional moment of inertia, and the modulus of elasticity of the material of the beam.



The relationship is expressed as (Fig. 1)

$$(dy / dx) = \tan \theta \sim \theta \text{ (for small values of } \theta \text{)}$$

and,

$$\tan \theta = (W L^2) / 2 E I$$

where, θ is the slope of the beam at the free end,

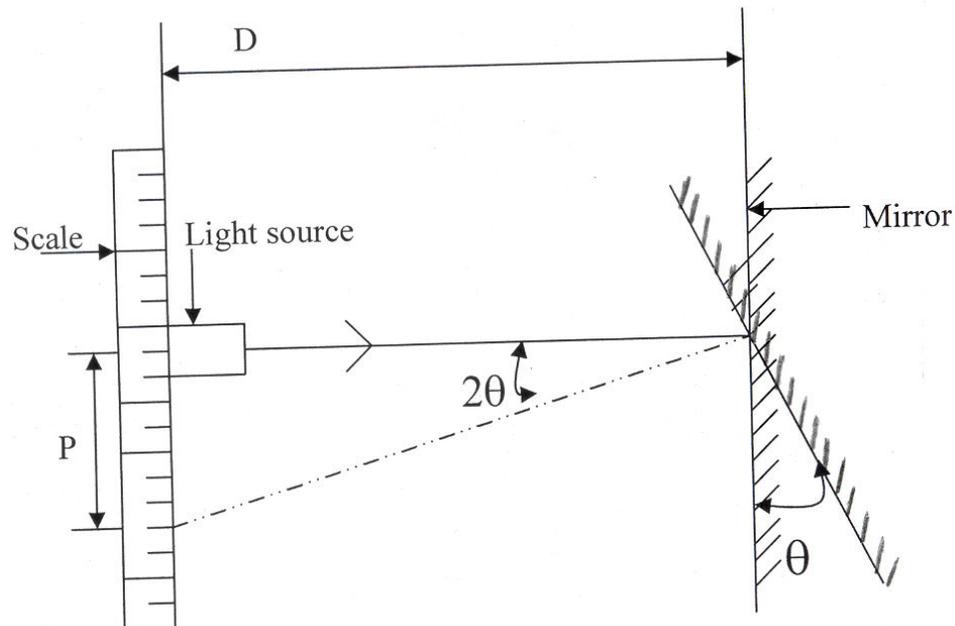
W is the applied load,

L is the length of the beam,

I is the moment of inertia of the section, ($= b.d^3 / 12$), and,

E is the modulus of elasticity of the material of the beam

The principle of measurement is as follows



In this experiment we measure the slope at the free end of the beam using a 'Lamp, mirror and scale arrangement' (Fig. 2)

If the screen is at a distance of 'D', from the mirror mounted on the object, an angle ' θ ' turned by the object results in a turn of 2θ of the light beam.

Therefore, $\theta = (1/2) \times$ measured angle of the turn of the beam

For small values of θ

$$\tan \theta = \frac{1}{2} \tan (2\theta) = \frac{p}{2 \cdot D}$$

If θ is measured experimentally, and other parameters measured, we can find out E as follows.

$$E = (W/p) \cdot (L^2 \cdot D / I)$$

III. EXPERIMENTAL SET UP :

The set up consists of the following

- i. A rigid clamping support for fixing the cantilever beam at one end.
- ii. Loading arrangement with different weights
- iii. Light source in the form of a thin laser beam mounted on stand
- iv. A screen to receive the reflected light
- v. A scale to measure the displacement of the reflected beam

IV. PROCEDURE :

1. Clamp the beam at the desired location
2. Measure the length of the cantilever beam (distance from clamped end to the centre of the mirror) and its cross section dimensions
3. Measure the distance between the mirror mounted on the beam and the screen.
4. Fix the laser light to receive the image of the beam reflected back on the screen.
5. Mark the position of the beam on the scale.
6. Apply load on the beam in steps.
7. For every load step, mark the position of the reflected beam on the scale and measure its distance

IV. PRECAUTIONS :

1. The beam should be clamped rigidly and horizontally
2. Displacement of the light beam to be measured accurately
3. The size of cross section of the beam to be measured accurately with Vernier scale.
4. Loading of the beam to be within elastic limit.

V. OBSERVATIONS :

- a) Independent variables :
1. Load
 2. Beam Span
 3. Moment of Inertia
 4. Distance of beam from the screen
- b) Dependent variables:
1. Displacement of the light beam

S. No.	Distance D mm.	Length of Span L mm.	Depth of beam d mm.	Width w of beam mm.	Load W kg	Beam movement mm.	Remarks

VI. GRAPHS :

1. Load v/s displacement of the light beam

VII. CONCLUSION: