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1. DEFLECTION OF SIMPLY SUPPORTED BEAM

1.1 OBJECT

To conduct a deflection test on a simply supported beam and analyze its results.

1.2 REQUIREMENTS

Loading Bar, Meter Scale, Vernier Scale, Deflection meter, Steel beam, and Wooden beam

1.3 THEORY

1.3.1 Deflection at Mid Span Point Load

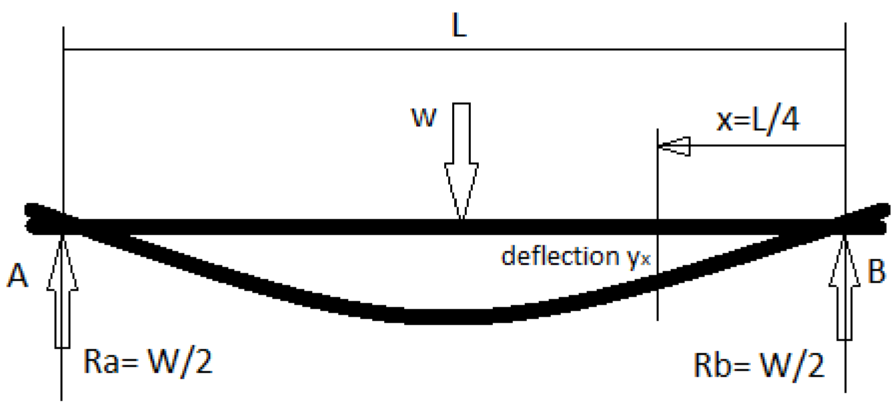

Figure 1.1 A point-loaded simply supported beam

$$EI\frac{d^2y}{dx^2} = M_{xx} = \frac{W}{2}\times x \qquad [1.1]$$

On integrating once,

$$EI\frac{dy}{dx} = \frac{Wx^2}{4} + C_1$$

To find C_1, apply condition, at x= L/2, where angle of deflection is zero, i.e dy/dx= 0. Which gives C_1= $-WL^2/16$

Now eqn [2.1] becomes,

$$EI\frac{dy}{dx} = \frac{Wx^2}{4} - \frac{WL^2}{16} \qquad [1.2]$$

On integrating eq.2, $$EIy_{xx} = \frac{Wx^3}{12} - \frac{WL^2x}{16} + C_2$$

To find C_2, apply condition, at x= 0, where deflection is zero, i.e y_{xx} = 0. Which gives C_2= 0.

Hence the final equation is,

$$EIy_{xx} = \frac{Wx^3}{12} - \frac{WL^2 x}{16}$$

On substituting x= L/4 we get

$$y_{xx=L/4} = \frac{-11WL^3}{768EI}$$

1.3.2 Deflection under Self-Weight.

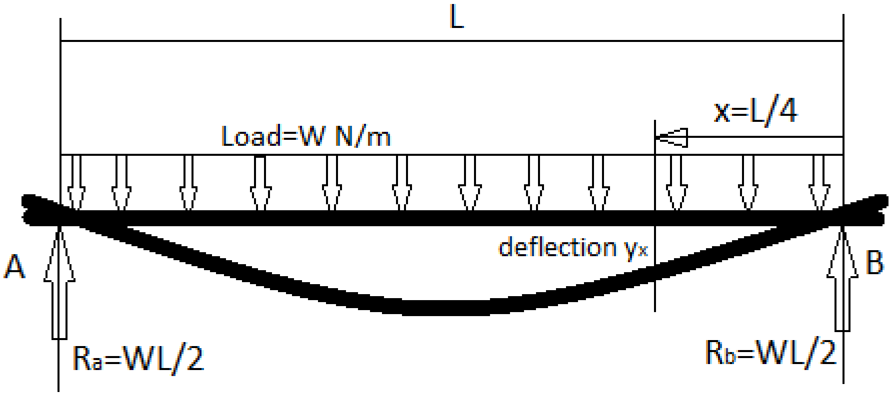

Figure 1.2 Deflection of simply supported beam on its own weight.

Assume a constant load w N/m through-out the length of beam.

$$EI\frac{d^2y}{dx^2} = M_{xx} = \frac{wL}{2} \times x - wx \times \frac{x}{2} \quad \text{\_\_\_\_\_\_\_\_\_\_\_\_\_\_}[1.3]$$

On integrating once,

$$EI\frac{dy}{dx} = \frac{wLx^2}{4} - \frac{wx^3}{6} + C_1$$

To find C_1, apply condition, at x= L/2, where angle of deflection is zero, i.e dy/dx= 0. Which gives C_1= $-wL^3/24$

Now eqn [2.3] becomes,

$$EI\frac{dy}{dx} = \frac{wLx^2}{4} - \frac{wx^3}{6} - \frac{wL^3}{24} \quad \text{\_\_\_\_\_\_\_\_\_\_\_\_}[1.4]$$

On integrating eq.2,

$$EIy_{xx} = \frac{wLx^3}{12} - \frac{wx^4}{24} - \frac{wL^3x}{24} + C_2$$

To find C_2, apply condition, at x= 0, where deflection is zero, i.e y_{xx} = 0. Which gives C_2= 0.

Hence the final equation is,

$$EIy_{xx} = \frac{wLx^3}{12} - \frac{wx^4}{24} - \frac{wL^3x}{24}$$

On substituting x= L/4 we get

$$y_{xx=L/4} = \frac{-57wL^4}{6144EI} \qquad [1.5]$$

Total deflection is the sum of deflection due to point load and deflection due to self-weight.

$$y_{(xx=L/4)total} = \frac{11WL^3}{768EI} + \frac{57wL^4}{6144EI} \qquad [1.6]$$

Where,

E= Young's modulus of elasticity

Flexural rigidity (K) = EI N/mm^2

W=Load (N)

L=Length of beam (mm)

δ=deflection (mm)

I=moment of inertia (mm^4)

1.4 APPLICATIONS

The problem of bending probably occurs more often than any other loading problem in design. Shafts, axles, cranks, levers, springs, brackets, and wheels, as well as many other elements must often be treated as beams in the design and analysis of mechanical structures and system.

1.5 PROCEDURE

- Length, breadth and thickness of the beam is measured using metric scale.
- Deflection meter is arranged at the bottom of the beam at one fourth the length of one end of the support.
- Load is applied at the center of the beam with weights of 0.5,1,2,……5kg.
- Readings of the deflection is taken from the deflection meter and tabulated.
- Young's Modulus is calculated for each of the reading and average found. Graph is drawn with deflection on X-axis and load on Y-axis

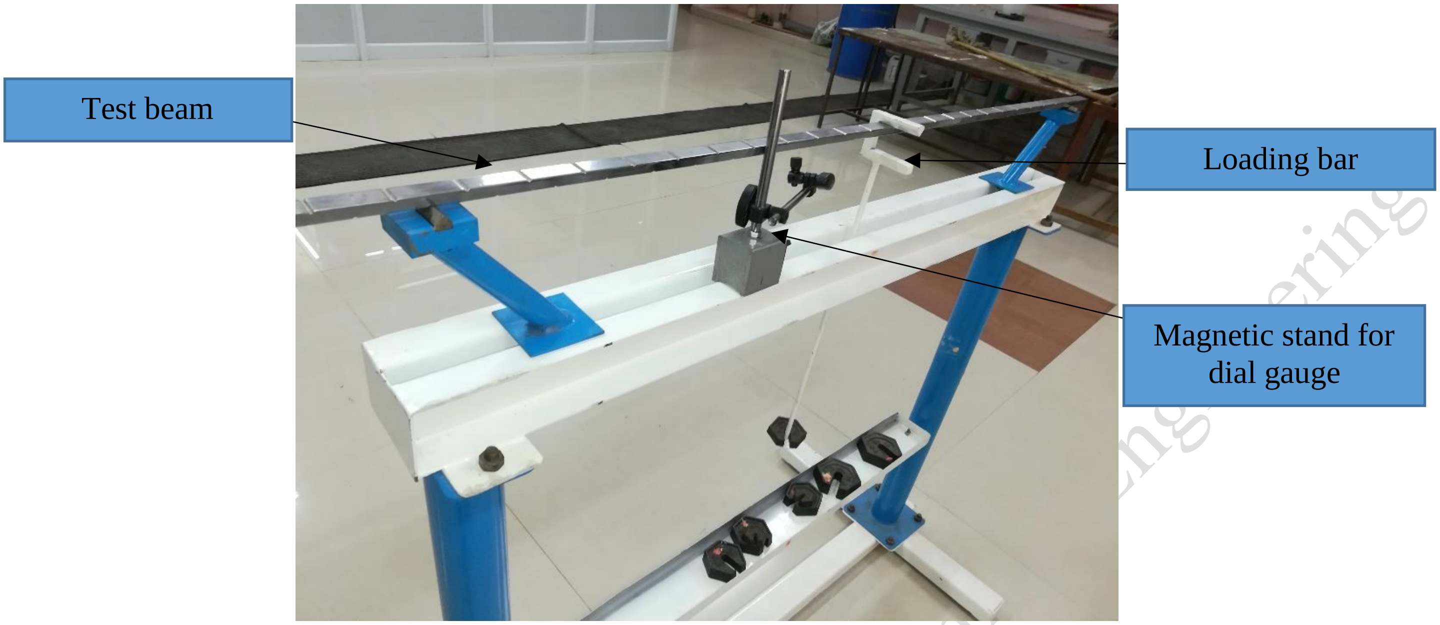

Figure 1.3 Experimental set up of simply supported beam.

1.6 TABULATION (SAMPLE)

Sl.no	Load(W) kg	Deflection meter Readings			Deflec - tion (mm)	Young's Modulus (N/mm^2)
		Loading	**Unloading**	**Mean**		
						Mean E=

1.7 SAFETY PRECAUTIONS

- Handle the standard weights carefully to avoid falling on your feet.
- Keep the work area clear of all materials except those needed for your work.
- Do not use any equipment unless you are trained and approved as a user by your supervisor.
- Use dial indicator with utmost care.
- Do not bend the test bar with your might.
- Prescribed attire for lab must be followed.

1.8 ASSIGNMENT QUESTIONS

- Derive the equation to determine deflection of beam with square cross section when load W acts at a distance x from one end of the beam.
- Explain the working principle of dial indicator you have used.
- Explain how the weights are calibrated.

2. TENSION TEST

2.1 OBJECT

To determine tensile strength, elastic and inelastic properties of ductile steel and to study its behaviour.

2.2 REQUIREMENTS

Universal testing machine, Extensometer, Vernier calipers, Meter scale, Punch for making gauge length.

2.3 THEORY

E= Young's modulus (N/mm^2)
σ= Direct stress (N/mm^2)
ε = Strain

Area of rod $A = \frac{\pi}{4} d^2$

d= Diameter of the rod (mm).
Ultimate stress (N/mm^2) = Ultimate Load / Area of cross section.
nominal breaking stress (n/mm^2) = breaking load / area of cross section.

Actual breaking stress (N/mm^2) = Breaking Load / Final area of cross section.

Percentage elongation = $\left(\frac{l' - l}{l}\right) \times 100$

where l= Initial length (mm) l'= Final length (mm)

Percentage reduction in area = $\frac{(\pi/4)d^2 - (\pi/4)d'^2}{(\pi/4)d^2} \times 100$

where d'= Final diameter of rod (mm) and d = initial diameter of rod (mm)

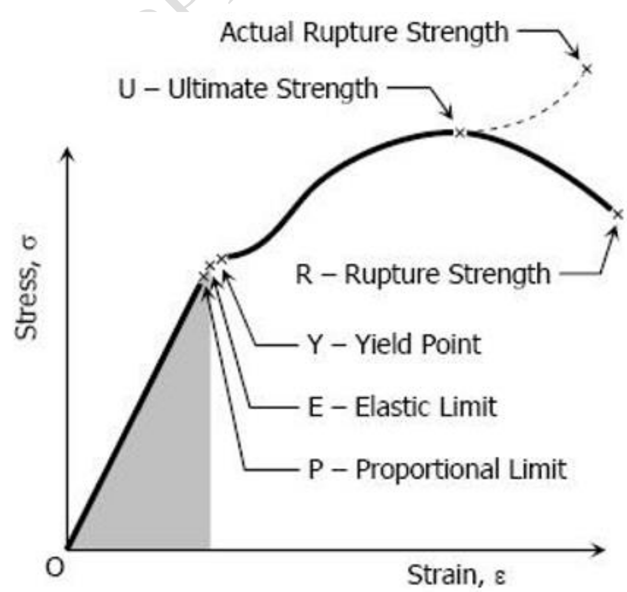

Figure 2.1 Stress strain curve for a typical mild steel

2.4 MAKE THE FOLLOWING MEASUREMENTS/ CALCULATIONS ON THE GIVEN SPECIMEN

Material Diameter of the rod, Length of the rod, Area of cross section of rod, Density of the rod, Weight of the rod, Gauge length, Final length, Final diameter, Extensometer gauge length, Least count of extensometer, and others as appropriate.

2.5 APPLICATIONS

Tensile testing is a most significant and popular test procedure which is performed in different production verticals to measure the elongation strength and durability of the products even in harsh working conditions. The test method provides the complete detail about the behaviour of the material when a material is subjected to tensile forces. The test is performed to measure the point at which the sample fails when an extensive amount of tensile force is applied to the sample. This helps the engineers to determine the **factor of safety** of the materials. Using the test procedure, the engineers can measure the maximum force a material can tolerate to its maximum before it ruptures and helps to decide the **suitability of the material** for a particular application.

2.6 PROCEDURE

The given rod is weighed and its length is measured. The average diameter d mm is determined using the density of specimen. The centre point of rod is marked using the punch and marks are made on either side of mark at distance of 5d mm. The given rod is fixed on tension grip of the UTM such that the top and the bottom marks already made coincides with exactly the top and bottom of the wedge grips respectively. The extensometer is fixed firmly to the specimen so that its axis coincides with that of specimen. Extensometer readings are taken from different increment in the loads that are applied within the elastic limits. Loads is applied until yield point is reached. The extensometer is removed and ultimate and breaking loads are noted. The final diameter ‘d’ of rod is measured between the previously marked punch marks.

Figure 2.2 Electronic Universal Testing Machine

2.7 TABULATION

SL NO	LOAD (TONNES)	EXTENSOMETER READING			AVG extensometer LC(mm)	Stress (N/mm^2)	Strain $*10^{-5}$	Young's modulus $*10^5$ (N/mm^2)
		LEFT	RIGHT	AVG				

Breaking load=

Ultimate load=

Extensometer gage length=

2.8 SAFETY PRECAUTIONS

- Care must be taken to set the rod properly in the wedge grips in line with the markings for uniform distribution of load.
- Ultimate load of mild steel specimen with 11mm diameter comes around 7.5 tonnes. So expect the specimen failure in that range.
- Handle the punch tools carefully to avoid hurting your fingers.
- If the strain measuring device is an extensometer it should be removed before necking begins.
- Keep the work area clear of all materials except those needed for your work.
- Do not use any equipment unless you are trained and approved as a user by your supervisor.
- Prescribed attire for lab must be followed.

2.9 ASSIGNMENT QUESTIONS

- Explain the principle of working of extenso meter
- Explain with a neat sketch the use of Vernier caliper in length measurement.
- Where do you use yield point, ultimate strength, and rupture point? Discuss.
- Explain the difference between true strain and engineering strain.
-

3. TORSION TEST

3.1 OBJECT

To find and analyze the modulus of rigidity, and shear stress of the given shaft.

3.2 REQUIREMENTS

Torsion testing machine, Specimen (shaft), Vernier calipers.

3.3 THEORY

A torsion test measures the strength of any material against maximum twisting forces. It is an extremely common test used in material mechanics to measure how much of a twist a certain material can withstand before cracking or breaking. This applied pressure is referred to as torque. There are three broad categories under which a torsion test can take place: failure testing, proof testing and operational testing. Failure testing involves twisting the material until it breaks. Proof testing observes whether a material can bear a certain amount of torque load over a given period of time. Operational testing tests specific products to confirm their elastic limit before going on the market.It is critical for the results of each torsion test to be recorded. Recording is done through creating a stress-strain diagram with the angle of twist values on the X-axis and the torque values on the Y-axis. Using a torsion testing apparatus, twisting is performed at quarter-degree increments with the torque that it can withstand recorded. The strain corresponds to the twist angle, and the stress corresponds to the torque measured.

General Torsion Equation for circular shaft

Φ=shear angle=shear strain

Θ=Angular deflection

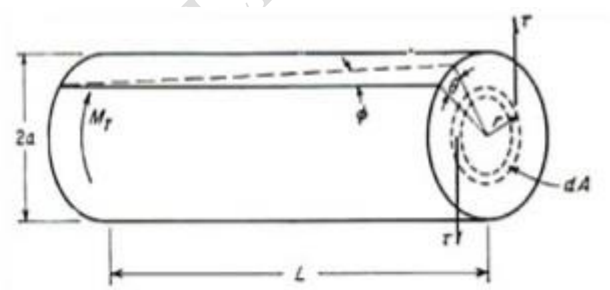

Figure 3.1 Circular shaft under twisting moment.

$$\tan\phi = \phi = r\theta / L$$

$$\phi = r\theta / L$$

$$\phi / r = \theta / L$$

According to hooke's law in shear

$$\tau = c\phi$$

$$\tau = cr\theta / L$$

$$\tau / r = c\theta / L$$

Moment of resistance created by 2 equal and opposite forces developed above and below neutral axis over the cross section

$$T = F * \perp$$

$$dT = dF * r$$

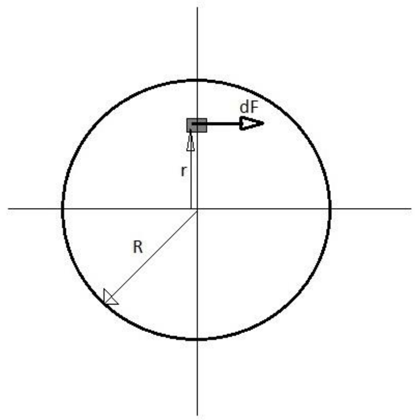

Figure 3.2 Force acting on elemental area in circular cross section.

Shear stress at distance r from centre is τ’

Shear stress at distance R from centre is τ

$$\tau' = \tau * (r / R)$$

$$\int dT = \int \tau' \, dA r$$

$$\int dT = \int (r / R) \tau r dA$$

$$\int dT = \tau / r * J$$

$$ie T / J = \tau / R = c\theta / L$$

T=torque applied over the cross section

J=polar moment of inertia

τ=torsional shear stress

R=radius of the shaft

C=modulus of rigidity

Θ=angular deflection in radians

L=length of the shaft

3.4 APPLICATIONS

Materials typically used in the manufacturing industry, such as metal fasteners and beams, are often subject to torsion testing to determine their strength under torsional load.

3.5 PROCEDURE

- The specimen is placed in the machine at a proper position.
- The torsion dial gauge is set to zero.
- The machine is operated manually.
- The handle connected to the spindle that holds the specimen is rotated in the clockwise direction for a twist of angle 5^o and appropriate corresponding torque is recorded.
- This is repeated for a twist of angle 10^o and 15^o .
- The entire procedure is repeated for 5^o ,10^o ,15^o .
- The modulus of rigidity is calculated using the formula.
- Graph is drawn for angle of twist vs torque and the graphical result is obtained.
- It is taken that twist does not exceed the maximum limit.

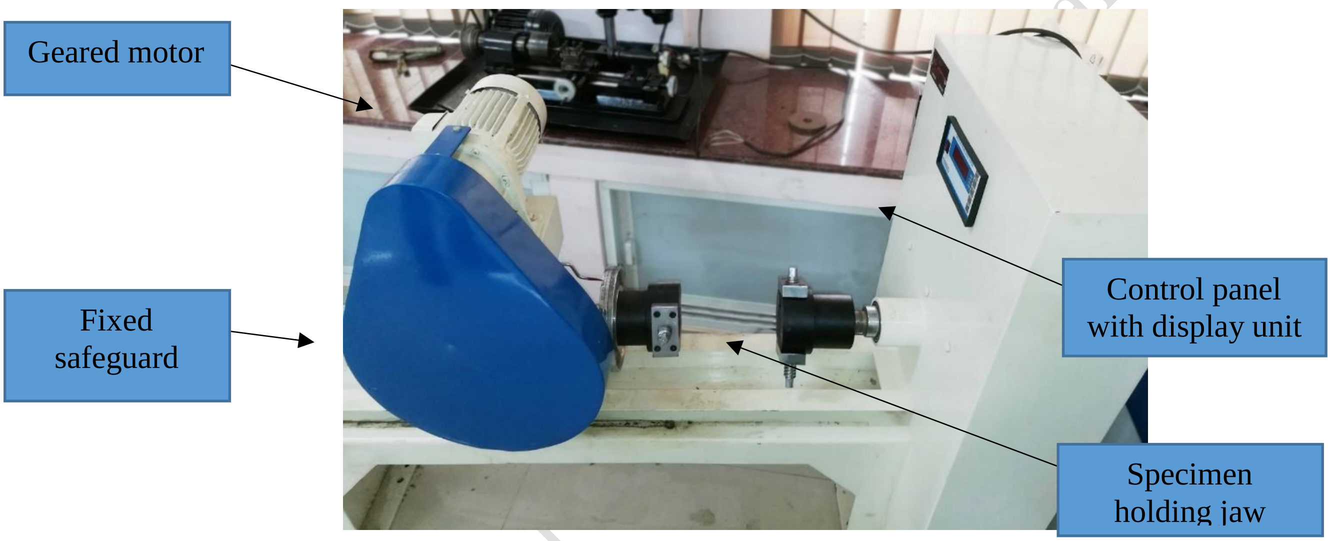

Figure 3.3 Torsion testing machine.

3.6 TABULATION

Sl No	Clockwise			Anti-Clockwise			Mean torque (kg-m)	Modulus of rigidity(N/mm²)	Shear stress (N/mm²)
	Angle of twist		Torsion (kg-m)	Angle of twist		Torsion (kg-m)			
	degree	radian		degree	radian				

3.7 SAFETY PRECAUTIONS

- Do not load the specimen above 8 kgf-m torque.
- Keep the work area clear of all materials except those needed for your work.
- Do not use any equipment unless you are trained and approved as a user by your supervisor.
- Prescribed attire for lab must be followed.

3.8 ASSIGNMENT QUESTIONS

- What are shafts and axles?
- Discuss why torsion test is performed.

4. TEST ON CLOSED COILED SPRING

4.1 OBJECT

To conduct test on a given closed coil spring.

4.2 REQUIREMENTS

Spring testing machine, Meter scale, Vernier calipers.

4.3 THEORY

Springs are employed in machines as elastic elements. They take the work of the external forces and transform it into the work of elastic deformation of the material of which they are made. After a spring is relieved from load, its deflection disappears and the work expended previously is almost completely restored. In order to derive a necessary formula which governs the behaviour of springs, consider a closed coiled spring subjected to an axial load W.

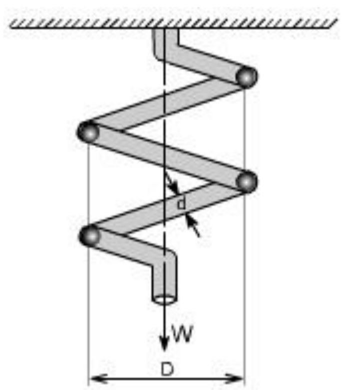

Figure 4.1 Helical spring with circular cross section

Let
W = axial load
D = mean coil diameter
d = diameter of spring wire
n = number of active coils
C = spring index = D / d For circular wires
l = length of spring wire
G = modulus of rigidity
x = deflection of spring
q = Angle of twist

when the spring is being subjected to an axial load to the wire of the spring gets be twisted like a shaft.

If q is the total angle of twist along the wire and x is the deflection of spring under the action of load W along the axis of the coil, so that
x = D / (2*q)
again l = p D n [consider ,one half turn of a close coiled helical spring]

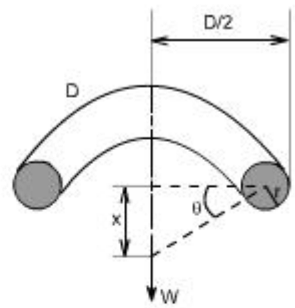

Figure 4.2 Helical spring

Assumptions: (1) The Bending & shear effects may be neglected (2) For the purpose of derivation of formula, the helix angle is considered to be so small that it may be neglected. Any one coil of such a spring will be assumed to lie in a plane which is nearly perpendicular to the axis of the spring. This requires that adjoining coils be close together. With this limitation, a section taken perpendicular to the axis the spring rod becomes nearly vertical. Hence to maintain equilibrium of a segment of the spring, only a shearing force V = F and Torque T = F. r are required at any X – section. In the analysis of springs it is customary to assume that the shearing stresses caused by the direct shear force is uniformly distributed and is negligible so applying the torsion formula.

Using the torsion formula i.e

$$\frac{T}{J} = \frac{\tau}{r} = \frac{G\theta}{l}$$

And substituting,

$$J = \frac{\pi d^4}{32}; T = w \times \frac{d}{2}; .\theta = \frac{2 \times x}{D}; l = \prod \times D \times x$$

On simplifying, rigidity modulus is obtained as

$$G = \frac{8wD^3 n}{xd^4}$$

Spring constant

$$k = \frac{W}{x}$$

4.4 APPLICATIONS

Springe are employed in machines and devices as (i) power elements ensuring a definite effort over an assigned distance, (ii) shock absorbers, (iii) drivers of mechanism, (iv) sensitive elements of instruments used to measure the forces.

4.5 PROCEDURE

The length of the spring, the inner, and outer diameter are noted.

The spring is placed in its correct position.

The least count of the dial gauge is noted.

Load is applied and deflection of the spring is noted down for every 10 kg of load.

The deflection is measured from the scale attached to the machine.

The deflection is measured for each step of unloading the spring.

The spring constant and the modulus of rigidity are calculated analytically.

4.6 TABULATION

S. No.	Load, W (kg)	Axial Deformation (mm)			Spring Constant K, (N/mm)	Modulus of Rigidity, N (N/mm)
		Loading	Unloading	Average		
1						
2						
. .						

4.7 SAFETY PRECAUTIONS

- Place the spring with utmost care in proper position for uniform loading.
- Maximum load applied must be limited to 50kg.
- After loading make sure the spring is in stable position before noting the reading from the scale.
- Keep the work area clear of all materials except those needed for your work.
- Do not use any equipment unless you are trained and approved as a user by your supervisor.
- Prescribed attire for lab must be followed.

4.8 ASSIGNMENT QUESTIONS

- How are springs classified? Discuss.

5. TEST ON OPEN COILED SPRING

5.1 OBJECT

To conduct test on a given closed coil spring to determine the rigidity modulus and spring constant.

5.2 REQUIREMENTS

Spring testing machine, Meter scale, Vernier calipers.

5.3 THEORY

The bending moment will tend to wind he coils of the spring more tightly, and to a smaller modulus of curvature. The axial extension of the spring may be most easily calculated by equating the work done by the load to the internal strain energy of the material.

δ = Deflection of the spring as a result of axial load
W =Axial load on the spring
R = Mean radius of the spring coil
n = No. of turns of coils
α =Angle of helix
C =Modulus of rigidity for the spring materials
I_p=Polar moment of inertia of spring wire
I= Area moment of inertia of spring with radius R
$l = 2\pi R \sec\alpha \times n$ = wire length

The couple applied to the material under the applied load W will be WR, and at each pole along the centre line of wire this couple may be resolved into two components , one of torsion and one of bending.

The couple producing torsion, $M = WR\cos\alpha$

The couple producing bending. $M = WR\sin\alpha$

The strain energy due to bending $= \dfrac{M^2 l}{2El}$

The strain energy for twisting $= \dfrac{T^2 l}{2CI_p}$

Therefore, where the deflection is δ, work done by load is equal to the total strain energy

$$\frac{1}{2}W.\delta = \frac{T^2 l}{2CI_p} + \frac{M^2 l}{2El} = \frac{W^2 R^2 \cos^2\alpha . l}{2CI_p} + \frac{W^2 R^2 \sin^2\alpha . l}{2EI}$$

$$= \frac{W^2 R^2 l}{2}\left[\frac{\cos^2\alpha}{2CI_p} + \frac{\sin^2\alpha}{2EI}\right]$$

$$= \frac{W^2 R^2 2\pi R n \sec\alpha}{2}\left[\frac{\cos^2\alpha}{2CI_p} + \frac{\sin^2\alpha}{2EI}\right]$$

Therefore deflection, $\delta = 2WR^3 n\pi \sec\alpha \left[\frac{\cos^2\alpha}{2CI_p} + \frac{\sin^2\alpha}{2EI} \right]$

5.4 PROCEDURE

Figure 5.1 Experimental setup with open coil spring

- The length of the spring, the inner, and outer diameter are noted.
- The spring is placed in its correct position.
- The least count of the dial gauge is noted.
- Load is applied and deflection of the spring is noted down for every 10 kg of load.
- The deflection is measured from the scale attached to the machine.
- The deflection is measured for each step of unloading the spring.
- The spring constant and the modulus of rigidity are calculated analytically.

5.5 EXPERIMENTAL OBSERVATION

On the given specimen
Number of turns (n) =
Length of spring (L) =
Diameter of coil (d) =
Inner diameter of spring (D_1) =
Outer diameter of spring (D_2) =
Mean diameter D = D_1 + D_2 =
Radius of coil = d/2 =
Pitch = L/n = Material:

Table 5.1 Observation

S. No.	Load, W (kg)	Axial Deformation (mm)			Spring Constant K, (N/mm)	Modulus of Rigidity, N (N/mm)
		Loading	Unloading	Average		

5.6 SAFETY PRECAUTIONS

- Place the spring with utmost care in proper position for uniform loading.
- Maximum load applied must be limited to 100kg
- After loading make sure the spring is in stable position before noting the reading from the scale.
- Keep the work area clear of all materials except those needed for your work.
- Do not use any equipment unless you are trained and approved as a user by your supervisor.
- Prescribed attire for lab must be followed.

5.7 ASSIGNMENT QUESTIONS

- What is Wahl's factor?
- Explain the difference between closed and open coiled helical springs.

6. HARDNESS TEST

6.1 OBJECT

To determine different hardness.

6.2 REQUIREMENTS

Digital hardness tester, Mild steel specimen, Aluminium specimen.

6.3 THEORY

Hardness is a characteristic of a material, not a fundamental physical property. It is defined as the resistance to indentation, and it is determined by measuring the permanent depth of the indentation. More simply put, when using a fixed force (load) and a given indenter, the smaller the indentation, the harder the material.

Rockwell hardness number is directly obtained as output on digital display of the equipment. Brinell hardness number is obtained from Brinell hardness chart (provided in equipment manual) using the measured diameter of indentation. It can also be calculated using the equation

$$BHN = \frac{2P}{\pi D(D - \sqrt{D^2 - d^2})} \qquad [6.1]$$

where:

BHN = Brinell Hardness Number (kgf/mm^2)

P= applied load in kilogram-force (kgf)

D= diameter of indenter (mm)

d= diameter of indentation (mm)

6.4 APPLICATIONS

Hardness testing is done to check the suitability of material for a specific application while designing products. It is also done as a part of quality checking to ensure that the material is hardened enough to resist scratches and can work in rough environment.

6.5 PROCEDURE

For carrying out test, the following procedure should be adopted very carefully. Any negligence may lead damage to the Indentor.

1. Adjust the weights on plunger of dash-pot according to the Rockwell scale required as shown in charts given in equipment manual, by using weight selector disc. For "Twin" model (Thin sheets) adjust minor load 3 kgf for rockwell superficial tests. Use 10 kgf for Rockwell test and brinell test. No miner load adjustment is necessary for other models.
2. The surface of the test specimen is polished with smooth emery sheet.
3. Place specimen securely on testing table.
4. Turn the hand wheel clockwise, so that specimen will push the indentor and show a load reading as 300 on the display. The test will begin automatically when the load becomes 300.
5. Record the hardness value obtained, and repeat the experiment at different part of the same specimen.

6. Conduct 5 test on same specimen and neglect first two readings (to eliminate errors) as standards recommend.
7. For obtaining brinell hardness number, measure the diameter of indentation and identify the BHN from the chart provided with equipment manual.
8. Repeat the test on a different specimen.

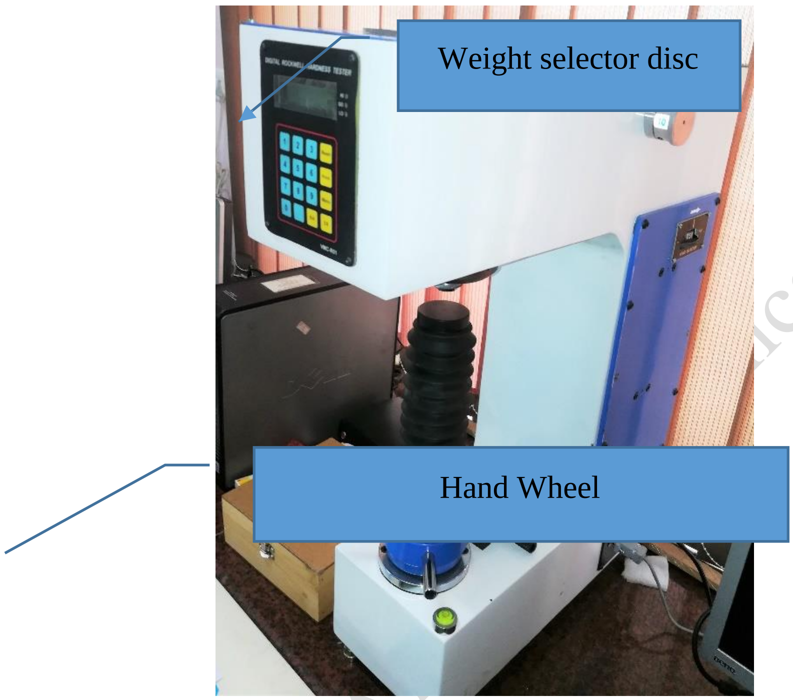

Figure 6.1 Hardness tester

6.6 TABULATION

Sl No	Material	Trial No.	Brinell Hardness Number	Rockwell Hardness Number	Shore Hardness Number
1		1			
		2			
		3			
2		1			
		2			
		3			

6.7 SAFETY PRECAUTIONS

- The specimen must be properly supported at base.
- While operating the hand wheel keep your face at a safe distance.
- Increase the load using hand wheel slowly till 300. Care must be taken to avoid exceeding much beyond this value.
- Use the specific indenter for the selected specimen material by referring to the operating manual provided by equipment supplier.
- For "Twin" model (Thin sheets) adjust minor load 3 kgf for rockwell superficial tests.
- Do not use any equipment unless you are trained and approved as a user by your supervisor.
- Prescribed attire for lab must be followed.

6.8 ASSIGNMENT QUESTIONS

- Derive the equation [6.1] above.
- Is it possible to identify the material specification of the specimen used comparing hardness with the standard? Explain.

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