Rajiv Gandhi University of Knowledge Technologies

Catering to the Educational Needs of the Gifted Rural Youth of AP

STRENGTH OF MATERIALS LABORATORY MANUAL (CE)

(II B.TECH CIVIL 1st SEM)

DEPARTMENT OF CIVIL ENGINEERING

RAJIV GANDHI UNIVERSITY OF KNOWLEDGE TECHNOLIGIES

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EXPERIMENT -1

STRESS STRAIN CHARACTERISTICS OF MILD STEEL BAR BY UTM

Object:

To study the stress strain characteristics of mild steel by Universal Testing Machine

Equipment:

Universal testing machine, dial gauge, meter rule, dividers and scale, Mild Steel specimen

Theory:

In tension test of ductile metals, the properties usually determined are yield strength, ultimate tensile strength, modulus of elasticity, percentage of elongation etc. For brittle materials only compressive strength is determined.

The tension test is normally carried out in a Universal Testing Machine (UTM). The specimen can be in the form of a rod or a plate. The dimensions of standard specimen can be known from accepted specifications.

The following properties can be determined from the stress strain curve of the material:

1) Proportional limit: is that point on the stress strain curve at which the curve deviates from linearity, i.e. from the relation

   Stress = Young's modulus x strain $\Rightarrow \sigma = E\varepsilon$

2) Elastic limit: is the point on the stress strain curve above which plastic deformation (that is permanent deformation) starts.

3) Yield strength: is the stress required to produce a small amount of permanent or plastic deformation.

   In some materials such as mild steel, where there is occurrence of sharp yield point on the stress-strain curve, the stress value at the lower yield point is taken as the yield strength. In some materials like tor steel which do not have a sharp yield point, the offset yield strength or proof stress is taken as the measure of the yield strength. This is the stress at which a line drawn parallel to the initial portion of the curve, offset by a specified strain, intersects.

   The offset value is usually a strain of 0.002 (0.2% strain). The value of the yield strength is of great importance in design calculations.

4) Tensile strength or ultimate tensile strength (UTS) is the maximum load divided by the original cross sectional area of the specimen. U.T.S. corresponds to the peak or the highest stress value in the stress-strain curve.

5) Ductility**:**

   It is usually measured as percentage elongation in length or percentage reduction in area. These measures of ductility are obtained after fracture, by keeping together the two broken parts of the specimen, and measuring the gauge length at fracture, and area of cross section at fracture.

$$\text{Percentage elongation } \textit{in length} = \frac{(L_f - L_0)}{L_0} \times 100$$

$$\text{Percentage R}\textit{eduction in area} = \frac{A_f - A_0}{A_0} \times 100$$

Where,

L_O and A_O are initial gauge length and initial area of cross section respectively.

L_f and A_f are measured gauge length at fracture and area of cross section at fracture respectively.

Description:

UTM serves for conducting tests in *tension, compression, bending, Brinell hardness and shear*. The testing machine is operated hydraulically. Driving is performed with the help of electric motor.

The machine essentially consists of two units, loading unit and control panel. The specimen is tested or loaded on the loading unit and the corresponding readings are taken from the dial fixed to the control panel. The main hydraulic cylinder is fitted in the center of the base and the piston slides in the cylinder when the machine is under operation. A lower table is rigidly connected to an upper cross-head by the two straight columns. This assembly moves up and down with the main piston. The mechanical power drive of the upward and downward motion of the movable cross-head consists of electric motor and of two worm gear trains connected to the columns. Tensile test is conducted by fixing the specimen in between lower and upper crossheads by the jaws inserts. Compression test is conducted by putting the specimen in between lower table and lower crosshead. An elongation scale is also kept sliding, which is fixed between lower table and the upper crosshead. The elongation indicating pointer is fixed to the lower crosshead.

The right side valve is a pressure flow control valve and left side valve is a return valve to allow the oil from the cylinder to go back to the tank. Control panel also consists of dynamometer; which measures and indicates the load on the specimen.

Before testing, adjust the pendulum weight according to the capacity test piece in order to get the accurate range. Adjustment can be done as follows:

CAPACITY	METHOD OF INCREASING LOAD
$1/10^{th}$ of max. capacity	only pendulum
$1/4^{th}$ of max.	pendulum + A
½ max capacity	pendulum + A + B
Full	pendulum + A + B + C

Adjust the corresponding range on the dial gauge with the range adjoining adjusting the knob.

Procedure:

1) Mark the gauge length on the test piece.
2) Measure the diameter of the test piece at several sections by Vernier calipers and note down the mean diameter.
3) Fix the specimen firmly to the jaws of the testing machine.
4) Mount the dial gauges on the specimen so that screw points engage with the center of gauge marks at the extremities of gauge length.
5) Gradually increase the tensile load and note down the dial gauge corresponding to different loads until the yield point is attained.
6) Note down the yield point corresponding to which the pointer (load) will suddenly stop recording the load while the reading in the dial gauge moves on.
7) Remove the dial gauge from the specimen and continue loading until fracture occurs. Measure the extension by means of dividers and steel rule. Load increases gradually and attains a max value called ultimate load.

a = proportionality limit
b = elastic limit
c = Yield point
d = Ultimate stress
e = Breaking stress

A = Yield stress

After reaching the ultimate load the needle of the dial moves back quickly and the specimen will be broken at some load, which is lower than the ultimate load. It may also be noted that there will be neck formation on the test specimen when the load starts falling.

8) Remove the fractured specimen from the machine and measure its diameter and the final gauge length.
9) Plot the graph between stress vs strain and determine the limit of proportionality, yield stress and Young's modulus E.

Observations and Calculations:

Mean diameter, d =
Initial area of cross $A_o = \pi d^2/4$ =
Gauge length = L_o =

S.No.	Load (kg)	Dial gauge reading		Elongation	stress	strain
		Initial	Final	ΔL	P/A	$\Delta L/L_o$

Discussion:

Compare the experimental results with the theoretical values for mild steel, comment on any reason for discrepancy, comment on any instrumental/experimental errors, area of application.

Theoretical values:

Yield of mild steel = 250 N/mm^2

QUESTIONS

1) Define Hooke's law, Young's modulus, stress, strain, yield stress, ultimate stress, percentage elongation and percentage of reduction in area.
2) Define working stress and how it can be determined.
3) Draw (not to the scale) the hypothetical stress-strain relationship for mild steel.
4) Differentiate between True Stress and Engineering Stress.
5) Draw the sample true stress strain curve for mild steel.
6) What do you understand by proof stress?
7) Define ductility and brittleness.
8) Why this machine is called Universal Testing Machine.
9) Does the original gauge length depend on the original diameter of the specimen? If yes, how?
10) Differentiate between Upper and Lower yield points.
11) Does the specimen fracture at maximum load? If not, why?
12) How does Mild Steel differ structurally from Cast Iron?

EXPERIMENT – 2

DOUBLE SHEAR TEST

Object:

Determination of ultimate shear strength of mild steel specimen by double shear test.

Equipment:

Shear tool assembly, specimen to be tested, Vernier calipers, and compressive testing machine.

Need and scope of the experiment:

For rivets in trusses, plate girders etc., mild steel and high tensile steels are used. Rivets are subjected to bearing and shearing stresses. The behavior of the steel rod under shear is investigated experimentally.

Procedure:

1) Find the diameter of the given rod with the help of Vernier calipers. Measure the diameter of the specimen at three sections.
2) Depending on the diameter of the rod, select circular discs.
3) Place circular discs in the shear box and place the specimen passing through all the circular discs.
4) Now keep the shear box assembly in the compression testing machine.
5) Turn the anvil of the machine until it touches the shear box.
6) Start the machine and open the inlet valve. Up to certain stage, load gradually increases and thereafter starts receding.
7) Note the maximum reading on the dial gauge of compression testing machine. Let it be 'P'.
8) Observe the number of pieces into which the specimen is cut. The specimen breaks into 3 pieces i.e. the specimen is cut into two sections. Shear force is developed in the specimen during loading is called double shear.
9) Shear strength can be calculated as below:

$$\text{Shear strength} = \frac{\text{load(P)}}{2 \text{ x Area of cross section of the specimen}}$$

10) Examine the nature of the failure of the specimen. The shear surface will be smooth.

Observations and Calculations:

1. Calculation of the diameter (Mild Steel) :

Least Count of Vernier Calipers =

S.No.	M.S.D.	V.S.D.	M.S.D. + (V.S.D. x L.C.)
1			
2			
3			

Average = mm

Average diameter of the specimen (d) = mm

$$\text{Area of the specimen} = \frac{\pi}{4}d^2 = \quad mm^2$$

2. Shear Strength:

Specimen particulars	S.No.	Ultimate Load (P) (kN)	Ultimate Shear Strength (N/mm^2) (P/2A)
Mild steel	1 2 3		

Average =

Result:

Average ultimate shear strength of given mild Steel specimen = N/mm^2

QUESTIONS

1) What is meant by double shear?
2) In what manner material fails in double shear?
3) What is the capacity of a compression testing machine you have used?
4) Compression testing machine is electrically operated or hand operated or both.
5) Why generally, compression testing machines are having very large capacity?
6) What is ultimate shear stress?
7) Define Hooke's law using shear stress?
8) What do you measure on dial of compression testing machine?
9) What are you determining in Double shear test?

EXPERIMENT - 3

BRINELL HARDNESS TEST

Objective:

To determine the hardness of a given material by Brinell's hardness testing machine.

Equipment:

Brinell's hardness testing machine, microscope and specimen

General theory for hardness test:

Hardness may be defined as resistance of the metal plastic deformation by indentation. However, the term may also refer to stiffness or temper or to resistance to scratching, abrasion or cutting. Mainly there are three types of hardness tests.

1) Indentation test
2) Abrasion or wear test
3) Scratch test.

Of these the most important tests are based upon the principles of indentations and are the Brinell's, Rockwell and Vickers's hardness tests. In each case the material under test is indented by another body to which a static load is applied.

Theory for Brinell hardness test:

In this test, a standard hardened steel ball is pressed into the surface of the specimen by gradually applied load, which is maintained in the test piece for a definite time. The indentation or the impression so obtained is then measured by a micrometer microscope. The Brinell's hardness number is found out by the equation given below. The Brinell hardness number gives the comparative hardness of a body.

Here,

P = the load in Kg

D = diameter of the ball in mm

d = the diameter of indentation in mm

Y = the depth of indentation in mm

$$Y = (D/2) - \sqrt{(D/2)^2 - (d/2)^2}$$

The Brinell's hardness number is given by

$$\text{B.H.N.} = \frac{P}{Sperical\ area\ of\ indentation}$$

Where, Spherical area of indentation = area of projection on the ball circle

$$= \pi D Y$$

$$= \pi D \left(\frac{D}{2} - \sqrt{\left(\frac{D}{2}\right)^2 - \left(\frac{d}{2}\right)^2} \right)$$

Spherical area of indentation = $\frac{\pi D}{2}\left(D-\sqrt{D^2-d^2}\right)$

Substituting for spherical area

$$B.H.N. = \frac{2P}{\pi D(D-\sqrt{D^2-d^2})}$$

If the ball diameter or the pressure is varied for indentation in the same material, the hardness number will be different. For the purpose of comparison of results it is therefore necessary to specify diameter and the pressure applied during the test, further it is found that the time during which the load is maintained is also important.

Extensive work was carried out by 'Mayer' to establish the effects of variation of ball diameter and load which leads to the conclusion that for similar indentation in the material.

$$P/D^2 = \text{Constant}$$

For the standard conditions given to hard materials

$$P/D^2 = 3000/100 = 30$$

Hence, for a comparative test using a ball diameter D_1 mm. We must apply a load P_1 such that

$$\frac{P_1}{D_1^2} = \frac{P}{D^2} = 30 \text{ or } P_1 = 30\, D_1^2$$

According to ASTM specifications, a 10mm, diameter ball is used for indentation. Lower loads are applied for measuring hardness of soft materials and vice versa.

Loads and indenters for Brinell hardness test on various metals:

Ball diameter	Load in Kg			
	Ferrous materials	Non Ferrous materials		
	Steel & Iron $30\,D^2$	Brass $10\,D^2$	Aluminum $5\,D^2$	Soft bearing metals $2.5\,D^2$
10 mm	3000	1000	500	250
5 mm	750	250	---	---
2.5 mm	187.5	----	---	---

Procedure:

For the Brinell hardness test, the surface of the specimen of which the impression is to be made should be flat. The surface on which the impression is made as well as the surface in contact with the support should be smooth, clean, dry and free from oxide scales and pits. The standard indenters supplied may only be used for hardness up to 450 HB. For carrying out test the following procedure should be adopted very carefully. Any negligence may lead to spoil the indenter as well as the machine.

1) Select the proper diameter of ball and put proper weights on the weight hanger such that the combination will suit the materials being tested. There are ten loose weights each weight is 250 kg, the initial weight applied by the main lever is 250 kg, and the hanger, weight of shaft, and bottom weight is equivalent to 250 kgf (total 3000 kg).

2) Start the motor by pushing the green button of the starter and allow the oil to circulate for few minutes. Operate the hand lever form A to B several times to raise and lower the weights in order to eliminate the air from hydraulic system.
3) Keep the hand lever at position at A.
4) Start the motor and wait until the weight hanger reaches its top position.
5) Place the specimen securely on testing table.
6) Turn the hand wheel in clockwise direction, so that the specimen will push the indenter and will show a reading on dial gauge. The movement is continued until the long pointer will stop at 'O' and small pointer at red dot, when the initial load of 250 kgf is applied. If little error exists the same can be adjusted by rotating the outer ring of dial gauge.
7) Turn the hand lever from position A to B so that the total load is brought into action.
8) When the long pointer of dial gauge reaches a steady position the load may be released for normal testing, or may be maintained up to 15 seconds for accurate work. For releasing the load, take back the lever to 'A' position. The weights are lifted off and the indicator will come to rest at the required depth reading. Thus only the initial load is remaining active.
9) Turn back the hand wheel and remove the specimen.
10) For accurate tests, measure the diameter of impression by Brinell microscope and find out the Brinell hardness number by calculation.
11) Carry the same procedure for further specimens.

Precautions:

1) The diameter of each indentation shall be measured in two directions at right angles to each other and the mean value of the two readings shall be used for the purpose of determining the hardness number.
2) The test load is maintained for a period of 15 seconds for brass, and 30 seconds for steel.
3) The center of impression shall not be less than two and a half times the diameter of the impression from any edge of the test piece.
4) The thickness of the test piece should be such that no marking showing the effect of the load shall appear on the underside.
5) This test should not be used for steel with hardness exceeding BHN 450 as no dent (impression) will be left on the surface.
6) It is desirable to conduct the test at a temperature of $27^{o} \underline{+} 2^{o}$ as per I.S. Code.

S.No.	Material	d_1 (mm)	d_2 (mm)	Average 'd' (mm)	Diameter of Indenter D(mm)	load applied P (Kgf)	BHN
01	Steel 1 2						
02	Brass 1 2						

Result:

Average Brinell's Hardness Number of steel =

Average Brinell's Hardness Number of Brass =

QUESTIONS

1) Define hardness of a material.
2) Why is hardness test required to be performed? Or what is the importance of hardness test?
3) Discuss the effect of surface roughness and oily surface of a specimen on the hardness number.
4) Show by drawing figure, how to measure depth and diameter of indentation. How will you find out hardness number from this data?
5) State the type of Hardness testing machine used. State the principle on which this machine is working.
6) For which type of materials, hardness test is recommended.
7) What type of indenter generally is used?
8) How, the data obtained from the test result will be useful in the field?

ROCKWELL HARDNESS TEST

Objective: To determine the Rockwell hardness for the given metal specimen.

Equipments Required:

1. Rockwell Hardness Testing Machine.
2. Metal Specimen.

Description:

Hardness may be defined as resistance of metal to plastic deformation usually by indentation. However the term may also refer to stiffness or temper or resistance to scratch, abrasion or cutting. There are three general types of hardness measurements depending upon the manner in which the test is conducted.

1. Scratch hardness measurement.
2. Rebound hardness measurement.
3. Indentation Hardness measurement.

In scratch hardness method the materials are rated on their ability to scratch one another and mineralogists use it. In rebound hardness measurement, a standard body is usually dropped on to the material surface and the hardness is measured in terms of the height of its rebound. The general means of judging the hardness is the resistance of a material to indentation.

Indentation hardness may be measured by various hardness tests such as Brinell, Rockwell, etc. Rockwell hardness testing differs from Brinell testing. In Rockwell testing, the indenters and loads are smaller and therefore the resulting indentation on the specimen is smaller and shallower. Rockwell testing is suitable for materials having hardness beyond the scope of Brinell testing. Rockwell testing is faster as compared to Brinell testing, because the diameter of the indentation need not be measured. The Rockwell machine gives arbitrary direct reading, Unlike Brinell testing, Rockwell testing needs no surface preparation (Polishing) of the specimen whose hardness is to be measured.

There are two scales on Rockwell testing specimen. i.e B scale and C scale. B scale uses a steel ball indenter where as a diamond cone penetrate is employed for measuring Hardness on C scale. B scale is for testing materials of medium hardness such as low and medium carbon steels in the annealed condition. The working range of this scale is from 0 to 100. C scale is used for testing materials harder than B-100. C scale is commonly used for testing the hardness of alloy cast irons.

In Rockwell hardness testing, the minor load for all cases is 10 Kg. whereas major loads for scales C and B are 150 Kg and respectively, including minor load.

Test requirements:

1. The test should be carried out in an ambient temperature of $20^o \pm 2^o$ C in temperate climate and $27^o \pm 2^o$ C in tropical climates.
2. The testing machine shall be protected throughout the test from shock and vibrations.
3. The test piece shall be placed on a rigid support. The contact surfaces shall be clean and free from foreign matter. (Such as oil and dust)
4. The thickness of the test piece shall be at least 8 times the permanent indentation of depth. No deformation shall be visible at the back of the test piece after the test.
5. The distance between the centers of the two adjacent indentations shall be at least 4 times the diameters of the indentation and the distance from the centre of any indentation to the edge of the test piece shall be at least 2.5 times the diameter of the indentation unless agreed otherwise.

Precautions:

1. Successive impressions should not be superimposed on another nor be made too close together when making hardness determinations.
2. Nor should a measurement be made too close to the edge , or on a specimen so thin that the impression comes through the other side.
3. Small irregularities, dirt, and scale should be avoided because of the great sensibility of the Rockwell test.

Procedure:

1. Test piece is placed upon the machine. The dial may be showing any reading.
2. Hand wheel is turned; thereby raising the test piece up against the steel ball indenter till the needle of the small dial is against the red mark. This applies minor load.
3. Major load is applied by pressing the crank provided on the right hand side of the machine. Time is given as 30 sec so as to make the load reach specimen fully.
4. When the penetration is completed, the crank is turned in the reverse direction thereby with drawing the minor load but the leaving the major load applied.
5. The pointer moves further and becomes stand still. This reading is taken as Rockwell Hardness Number – C scale.(HRC)
6. Hand wheel is rotated and the test piece is lowered.

EXPERIMENT - 4

DETERMINATION OF YOUNG'S MODULUS USING SIMPLY SUPPORTED BEAM SETUP

Objective:

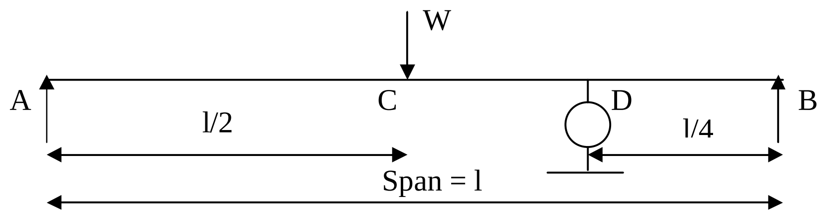
Determination of the Young's modulus of a given material by conducting test on simply supported beam and verification of Maxwell's reciprocal theorem.

Apparatus:

Simply supported beam, scale, dial gauge, hanger and weights.

Formulae:

Concentrated load at center and deflection measured at quarter span.



Deflection is measured at D is given by

$$\mathbf{Y_D} = \frac{11}{768}\,\mathbf{x}\,\frac{\mathbf{Wl^3}}{\mathbf{EI}}$$

Procedure:

1) Measure the width and depth of given beam (steel or wood) by Vernier calipers.
2) Measure the distance between the two supports (span) with a scale.
3) Set the dial gauge at 'D' and adjust its value on the outer ring to zero by turning it.
4) Find the weight of the hanger and keep it at the center of the beam.
5) Find the deflection in dial gauge.
6) Increase the weight on the hanger and find out the corresponding deflection.
7) Find the deflection while unloading also. Get the mean of deflections found in step 6 and 7.
8) Draw a graph between load on y-axis and deflection on x-axis.
9) For verification of Maxwell's reciprocal theorem, interchange the loading and dial gauge positions and repeat the above procedure.

Observations:

Breadth of Beam (b):

Least count of Vernier calipers =

S.No.	M.S.D.	V.S.D.	M.S.D. + (V.S.D.x L.C.) (mm)

Average breadth of beam (b) = mm.

Depth of the beam (d):
Least count of Vernier calipers =

S.No.	M.S.D.	V.S.D.	M.S.D. + (V.S.D.x L.C.) (mm)

Average depth of the beam (d) = mm

Moment of inertia, $\mathbf{I} = \frac{\mathbf{bd}^3}{12} =$ $\mathbf{mm}^4$

S.No.	Load (W) @ C in Kg	Dial gauge reading @ D		Mean	Deflection @ D = mean x L.C.(mm)
		Loading	Unloading		
1					
2					
3					
4					
5					
6					
7					
8					

Graph:

Draw a graph between load and deflection. From Graph find the Young's modulus of the given material.

Result:

Young's modulus of the given material E_{Steel} = N/mm^2

E_{Wood} = N/mm^2

QUESTIONS

1) What is meant by beam?
2) Draw a neat sketch of experimental set-up and show position of load applied on the beam.
3) How deflection is measured?
4) How will you determine modulus of Elasticity of a beam material from load-deflection curve?
5) Compare your result with the standard modulus of elasticity.
6) What is meant by simple supported beam?
7) Define the terms concentrated load and distributed load.
8) Name the type of internal stresses for which a transversely loaded beam is subjected.
9) What is meant by pure bending?
10) State Maxwell's reciprocal theorem.

EXPERIMENT -5

CHARPY IMPACT TEST

Object:

Determination of the energy absorbed and impact strength of steel using Charpy impact testing machine.

Need and scope of the experiment:

The necessity for impact tests has arisen due to the failure of materials used in high speed machinery under repeated forces of impulsive character, even when such material has shown satisfactory strength and deformation in a static tensile test. Various forms of impact test has been devised, of which Izod impact test is the only one to try to determine the imperfections in material likely to fracture by "shock".

Although the Izod impact test has long been used as the standard form of test for checking the brittleness of metals, the need has arisen for test at elevated and subzero temperatures. For this purpose the CHARPY IMPACT test is more convenient. The specimen need not be clamped and it can be quickly positioned without significant change of temperature.

The standard shape of the test specimen is as shown in fig, which is being tested in bending with a standard notch in this Charpy test. Under this test, the notch on the specimen sets up stress concentrations, which ensures that fracture, does occur.

Apparatus:

(i) Charpy impact testing machine

(ii) Charpy specimen of 10mm x 10mm. square cross section and 55mm length, with a V-notch 45^o angle, 2mm deep and 0.25 mm root radius along the middle of the length. For a U-notch specimen, the dimensions are 5mm deep, 2mm width and 1mm root radius. The specimen is kept as a simply supported beam in horizontal position and loaded behind the notch by the impact of a heavy swinging pendulum (16 kg). The angle of drop of pendulum is 14^o. The impact velocity is approximately 5.3465m/sec. The specimen bends and fractures at high strain rate.

Procedure:

Without the specimen in the machine, swing the pendulum to ensure free movement and to check the scale. For this lift the pendulum to its starting position by the aid of hand crank and release the pendulum by lifting the spring loaded safety handle in anti-clock wise direction and turning it simultaneously as the pendulum swings it carries the pointer on the scale with it and leaves back the pointer when it returns. Note the reading on the scale against the pointer, which gives the initial error if any. Now lift the pendulum again to its starting position. Keep the specimen on the supports of the machine such that the notch portion of the specimen is away from the striking edge as shown in fig. Release the pendulum as before. The hammer strikes the specimen breaks it and moves the needle in clockwise direction. Note the reading against the pointer. The difference of the two readings gives the energy absorbed by the specimen.

$$\text{Charpy value or impact strength} = \frac{\text{Energy absorbed N-m}}{\text{C/S. area at notch (mm}^2)}$$

Observations:

Specimen I:

Breadth (b):

Least count of Vernier calipers =

S.No.	M.S.D.	V.S.D.	M.S.D. + (V.S.D.x L.C.) (mm)

Average breadth (b) = mm.

Depth (d):

S.No.	M.S.D.	V.S.D.	M.S.D. + (V.S.D.x L.C.) (mm)

Average depth (d) = mm

Specimen II:

Breadth (b):

Least count of Vernier calipers =

S.No.	M.S.D.	V.S.D.	M.S.D. + (V.S.D.x L.C.) (mm)

Average breadth (b) = mm.

Depth (d):

S.No.	M.S.D.	V.S.D.	M.S.D. + (V.S.D.x L.C.) (mm)

Average depth (d) = mm

S.No.	Initial Energy (J)	Final Energy (J)	Energy absorbed By specimen (J)
1			
2			
3			

Calculations:

Specimen I:

Specimen II:

Results:

Specimen I:

Energy required to fracture the specimen, U = J

Charpy value = Nm/mm^2

QUESTIONS

1) What is strain energy?
2) The machine on which you have performed test for measuring energy required to fracture the specimen is _____.
3) How do you measure the toughness of a material?
4) Why notch is prepared in the specimen?
5) Draw a neat sketch of specimen for Charpy impact test.
6) How will you determine Charpy impact value for a given material?
7) Will the energy require for fracture the specimen remains same by increasing or decreasing the height of hammer?
8) What is instantaneous stress?
9) What is the difference between impact produced by gradually applied load and by suddenly applied load on a body or a specimen?
10) Why impact test is required for a material?
11) What property of metal does the impact test measure?
12) What is the difference between Izod's and Charpy's tests?

IZOD IMPACT TEST

Objective: To determine the impact modulus of the given specimen by izod test.

Equipments Required:

1. Impact Testing Machine with IZOD arrangement.
2. Specimen
3. Vernier caliper.

Description;

Many machines or machine components are subjected to a suddenly applied load, which is called as impact blow. For determining the suitability of a material to resist the impact blow. For determining the suitability of a material to resist the impact, IZod and charpy test are carried out.

EXPERIMENT – 6

TORSION TEST

Objective:

To find the modulus of rigidity of a given specimen.

Equipment:

Torsion testing machine, specimen, Vernier calipers and metal rule.

Specimen for the test:

The specimen should be of such size as to permit the desired strain measurement to be made with sufficient accuracy. It should be of such properties that the stress due to gripping ends does not affect the portion of the specimen on which measurements are made. The ends of the specimen should be such that they can be securely gripped without any local failure at the grips.

Theory:

For a shaft subjected to a torque 'T', the relation between torque, shear stress and angle of twist is given by

$$\frac{T}{I_P} = \frac{f_s}{R} = \frac{G\theta}{L}$$

Where T = torque in N-mm

I_p = polar moment of inertia of specimen in mm^4

f_s = shear stress at a radius R of the specimen, N/mm^2

R = radius of the shaft in mm

G = modulus of rigidity in N/mm^2

θ = angle of twist in radians (1 degree = 0.01745rad)

L = length of the shaft in mm

Hence, $G = \frac{T}{I_p} x \frac{L}{\theta}$

For a solid circular shaft of diameter'd', $I_p = \pi d^4/32$.

For how circular shaft of external diameter D and internal diameter'd',

$I_p = \pi (D^4 - d^4) / 32$

Procedure:

1. Measure the diameter of mild steel specimen using vernier calipers.
2. Measure the gauge length of the specimen.
3. Hold the specimen in between the plates with a dog holder in position by rotating the hand wheel till the indication dial is just on the point showing the action of the pointer.
4. Adjust the circular main scale with zero of the vernier scale.

5. Apply an increasing torque to the specimen in suitable increments by turning the hand wheel.
6. Continue the test and record the corresponding readings of torque and angle of twist, until fracture occurs.

Plot a graph of torque vs angle of twist and determine the Modulus of Rigidity.

Observations:

Diameter of the specimen ‘d’ =

Gauge length ‘L’ =

Polar moment of inertia I_p =

S.No.	Angle of twist θ in degrees	Angle of twist θ in radians	Torque(T) Kg-cm

Precautions:

1) The test piece should, as far as possible, be straight and of sufficient length to provide the desired length between the grips.

2) Any straitening should be done by hand without damaging the test piece.

3) The free length between the grips should be provided strictly to I.S.code: 1717-1971.

4) If the failure of the specimen takes place with in twice the diameter of the grips, the test should be considered as invalid and should be repeated.

5) The surface of the test piece after failure should be examined so that it is free from cracks.

EXPERIMENT – 7

TEST ON SPRINGS

OBJECTIVE

To determine the Shear Modulus (or) Modulus of Rigidity of the given spring material.

APPARATUS

Spring Testing Machine 2000 kgf

PROCEDURE:

1) Note the particulars of the spring such as mean diameter of the spring, mean diameter of the spring wire, number of turns.

2) Place the spring below the platon in such a way that the axis of the spring is truly vertical and exactly below the centre of the loading frame. Rotate the handle of the loading frame and bring down the proving ring to touch the spring and rest over it without applying any load. Any further rotation of the hand wheel causes application of load on to the spring.

3) Fix the deflection measuring dial gauge below the bottom plate of the proving ring. Pull down the needle of the dial gauge and leave it and ensure that all times the deflection gauge shows the same reading.

4) Note the initial reading of the deflection gauge and the calibrated value of the proving ring (i.e., 1 div = _____ kg).

5) Apply the required amount of load by rotating the hand wheel and bringing the proving ring dial needle to the calibrated reading. Note the deflection gauge reading.

6) Repeat step (5) by increasing the load on the spring. Take at least 15 sets of readings.

PRECAUTIONS:

1. Load should be applied on the spring without any eccentricity.
2. Deflection gauge needle should touch the bottom plate of the providing ring and should be vertical.
3. Gently apply the load by rotating the hand wheel, without any vibrations either in the spring or in the loading frame.

OBSERVATIONS:

Mean radius of the spring, R = cm

Number of turns in the spring, n =

Mean diameter of the spring wire, d = cm

Modulus of rigidity of the given spring, $C = \frac{64\ W\ R^3\ n}{d^4}$,

where, W – Load applied on the spring (kg)

- Deflection of the spring (cm)

Initial deflection gauge reading = mm

S.No.	Applied load (kg)	Deflection Gauge reading (mm)	Net deflection (cm)	Shear Modulus, C ($\times 10^5$ kg/cm^2)
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				

Average C = $\times 10^5$ kg/cm^2

RESULTS:

Average Shear Modulus of the given spring, C = $\times 10^5$ kg/cm^2

EXPERIMENT – 8

STRESS ANALYSIS BY STRAIN GAGES AND STRESS CONCENTRATION

Objective:

a) Determination of bi-axial state of stress at a point on the surface of an object.

b) Determination of stress concentration around notches and openings.

c) Evaluation of material properties for known load and deflection.

d) Use of transducers such as load cell and accelerometer.

Apparatus: Strain measuring instrument, scale, soldering iron, abometer, load cell.

Materials: Strain gages, acetone, adhesive, load cell, plate with hole, beam specimen.

Procedure:

1) For fixing the strain gage on any surface, first the surface of the specimen is to be polished carefully and then cleaned with acetone. The gage is applied on the cleaned surface with the help of epoxy cement or cellulose nitrate by pressing it gently.
2) The adhesive is allowed to cure for 24 hours. The insulation of the gage to the specimen is checked. The continuity of the gage wire is also checked.

A. Determination of material properties.

Objective: To measure the modules of elasticity (E) and the Poisson's ratio of a material from the strain records of a cantilever beam. The experimental set up is as shown in **Fig. 9.1**

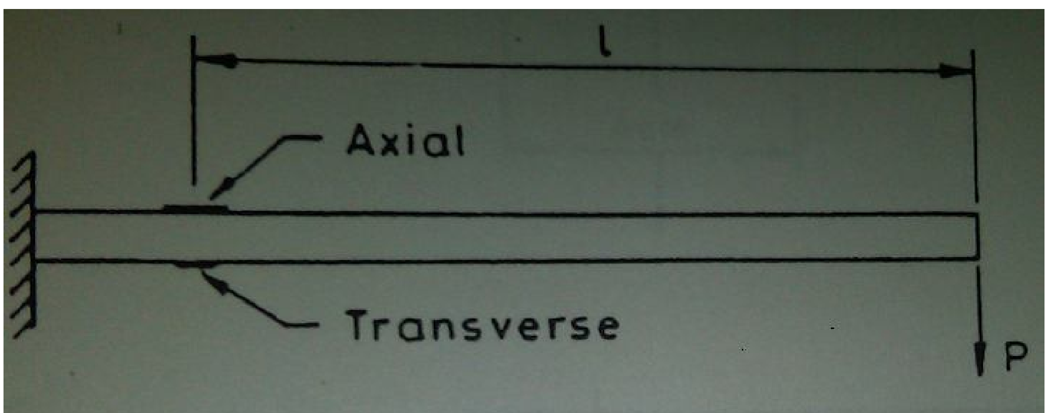


Fig. 9.1: Beam Specimen

Apparatus: As mentioned above

Materials: Strain gages, Beam Specimen.

Procedure:

1) Connect the gages to the strain recorder through channel selector.
2) Set the gage factors on strain recorder
3) Set the initial reading to zero or note the initial readings.
4) Load the specimen at least at three stages.
5) Note the final readings.

Observations:

Record the strain increments in **Table. 9.1**

Load	Gage No.	Gage factor	Initial reading	Final reading	Increase/ decrease	Remarks
1	1					
	2					
2	1					
	2					
3	1					
	2					

Results: Gage Factor – Gage A:

Gage B:

Length of cantilever (l) =

Width of Beam =

Depth of Beam =

Second moment of area (I) =

Bending moment =

Bending stress (σ_x) =

Modulus of elasticity (E) = $\dfrac{\sigma_x}{\varepsilon_x}$ =

Poisson's ratio (μ) = $\dfrac{|\varepsilon_x|}{|\varepsilon_y|}$ =

Discussions: Discuss in respect to (a) Usage and advantages of electrical strain gages over other type; (b) Effect of temperature etc. on results

Precautions: As relevant to experiment

B. Determination of stress concentration factor by strain gages.

Objective: 1) Determination of material constants.
2) Evaluation of stress concentration factor.

Apparatus: As mentioned above

Materials: Strain gages, Application kit, Plate specimen with hole.

Procedure: 1) Fix the gage and complete the connections.
2) Load the specimen and record the strain in **Table. 9.2**

Table 9.2

Specimen	Gage No.	Gage factor	Initial reading	Final reading	Increase/ Decrease	Remarks
I	1					
	2					
	3					
	4					
II	1					
	2					
	3					
	4					

Results:

Resistance = Load =

Gage factor =

Gage length =

Type of wire =

1. **Material properties:**

E = Modulus of elasticity =

μ = Poisson's ratio =

2. **Stress Concentration Factor**

$\sigma_{average}$ =

σ_{actual} =

K (SCF) =

Discussions: Discuss in respect to (a) Stress concentration factor; (b) Material properties

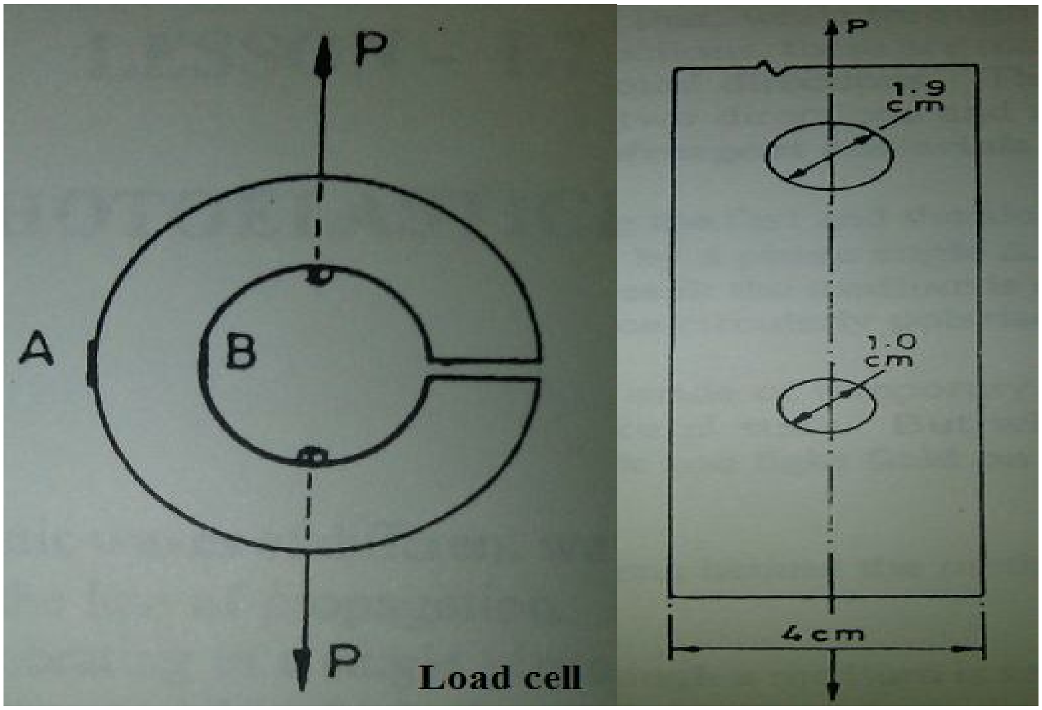
Precautions: As relevant to experiment

C. Calibration of load cell.

Objective: Load cells are used in series with the applied force to measure the force directly. The objective of this experiment is to calibrate such load cells against known loads.

Apparatus: Strain measuring instrument.

Materials: A ring of brass with gages fixed in the inside and outside edges as shown in Fig. 9.2, strain gages



Procedure: 1) An approximate working range is estimated from theoretical considerations.

2) At least five known load levels are to be used to calibrate the cell.

3) Data are to be recorded in the **Table. 9.3**

Table 9.3

Load	Gage A	Gage B	Increment In A	Increment In B	σ_A	σ_B

Discussions: Discuss in respect to (a) Type of load cells; (b) fixing of gages.

Precautions: As relevant to the experiment performed

Questions:

1. What is load cell?
2. What is meant by calibration?
3. What are the different types of strain gages generally used?
4. What is the principle on which electrical resistance strain gages work?

Appendix – 1: Electrical Resistance Strain Gages

Introduction

A wire or a foil called strain gage is bonded to specimen (Fig. A1) such that the deformations of the specimen surface and the gage are same. Due to the changes in length and cross sectional area the resistance of the gage changes. The change in resistance, which is measured by the principle of Wheatstone bridge, is related to strain through a Gage Factor (G).

$$G = \text{Gage Factor} = \frac{(\Delta R / R)}{\varepsilon} \qquad (1)$$

Where R is the resistance of the gage, ε is the strain and ΔR is the change in resistance of gage due to strain ε .

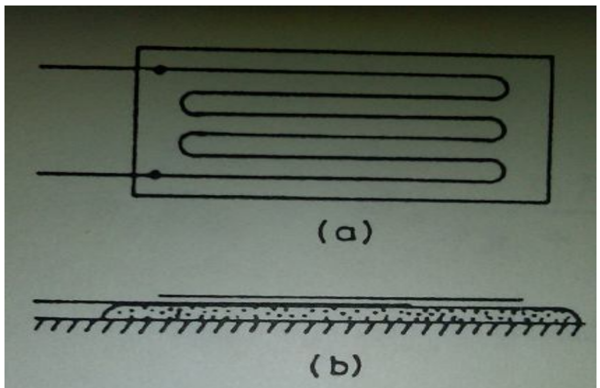


Fig. A1 : Bonded Wire Gauge

Theory

Two leads from the strain gage are connected to the arm AB of the Wheatstone bridge (Fig. A2). If the voltage across AB is measured,

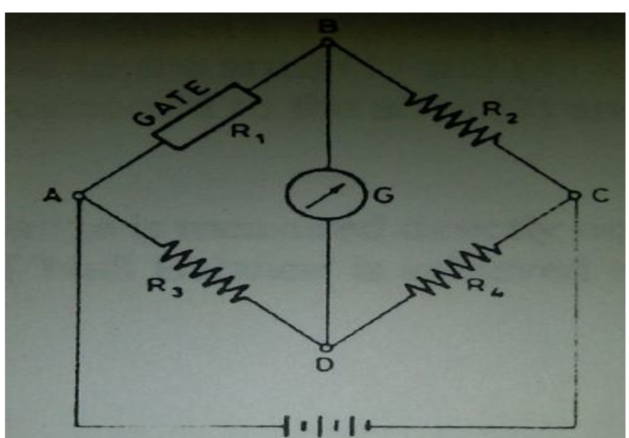


Fig. A2: Wheatstone Bridge

$$\text{Current through } R_1 = I_{AB} = \frac{E}{(R_1 + R_2)}$$

$$\text{Voltage drop across } R_1 = E_{AB} = \frac{ER_1}{(R_1 + R_2)}$$

Where E is the voltage drop between A and C

The change in the voltage due to $\Delta R_1 = \Delta E_{BD} = \frac{ER_2}{(R_1 + R_2)^2}\Delta R_1$

Hence the voltage drop in B relative to D is $= \frac{ER_2}{(R_1 + R_2)^2}\Delta R_1$

According to the definition of gage factor (G) = $\frac{\Delta R_1 / R_1}{\varepsilon_1}$

And the voltage drop in rewritten as $E_{BD} = GE\frac{R_1 R_2}{(R_1 + R_2)^2}\varepsilon$

If four similar gages are placed in four different arms of Wheatstone bridge, it can be shown that

$$E_{BD} \approx GE\left\{\frac{R_1 R_2 \varepsilon_1}{(R_1 + R_2)^2} + \frac{R_1 R_2 \varepsilon_2}{(R_1 + R_2)^2} - \frac{R_3 R_4 \varepsilon_3}{(R_3 + R_4)^2} + \frac{R_3 R_4 \varepsilon_4}{(R_3 + R_4)^2}\right\}$$

The physical interpretation of the preceding equation is often utilized to increase the sensitivity of measurement. For example, if a short column is subjected to an axial load, two of the four gages may be aligned axially and connected to the arms (1) and (4) whereas other two gages may be applied in transverse direction connected to the arms (2) and (3). $\varepsilon_1 = \varepsilon_4 = \varepsilon,\ \varepsilon_2 = \varepsilon_3 = -\varepsilon,$ measures the unbalance.

For dynamic analysis the voltage change is measured directly on the oscilloscope. But for static analysis a more accurate method of ‘Null Balance’ is achieved with the help of a potentiometer across BD (Fig.A2).

Precautions

There are several factors, which influence the accuracy of strain gage measurements and precautions must be taken to compensate the effects. Most important amongst there are

1) Temperature
2) Gage Current
3) Time
4) Adhesives
5) Humidity

Material Properties

To determine the properties such as modulus of elasticity and poison's ratio of particular material, flexural specimens made out of such material may be tested. **Fig. 9.1** shows one such specimen used for determining the material properties. A cantilever beam specimen is loaded at its tip and strain gages are used in a location closer to support, wherein appreciable strain can be obtained due to bending. From the gage position, bending stress is evaluated for a known loading condition. The ratio of computed stress to the measured longitudinal strain will be in the modulus of elasticity. The negative of the ratio of lateral strain to longitudinal strain is defined as poison's ratio.

Calibration of Load Cell

One of the potential uses of strain gages is in the calibration of load cells. Load cells are the elements used in series with the applied force to measure the force directly. Strain gages are fixed in the locations of a ring load cell as shown in fig. Strains are calibrated against as known loads. An approximate range is estimated from theoretical considerations and the measured strain values are compared for a check.

Stress Concentration

Formulae from strength of materials permit us to compute the stress distribution across a cross section of a member subjected to axial force, bending moment, shear and torsion. But if the cross section changes abruptly or if there are some irregularities such as a hole or a notch, stress distribution changes locally to conform to the boundary condition (**Fig. A3**). In most of these cases there is marked increase in local stresses.

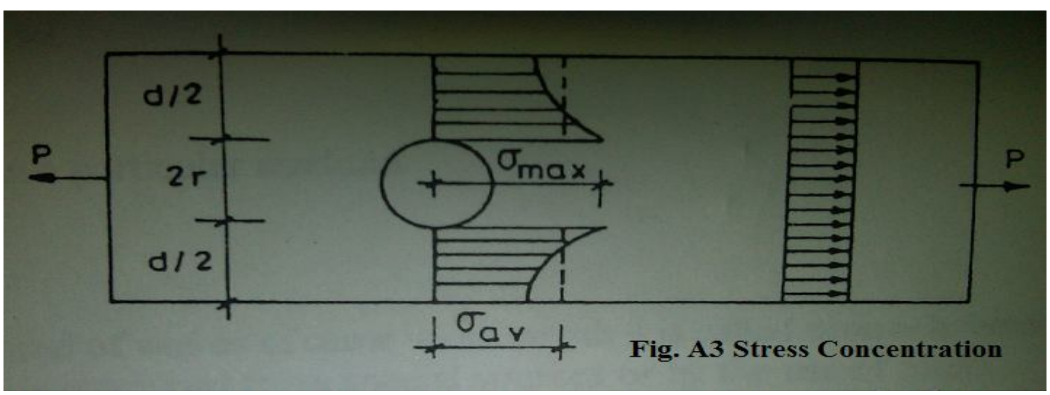


Fig. A3 Stress Concentration

Actual stresses in the vicinity of these irregularities may be analysed only by exact method of the theory of elasticity and that too for comparatively simpler cases. For practical applications, actual stresses at the stress concentration regions are determined experimentally for a large number of specimens with varying geometric parameters and materials. Results are represented in graphical forms.