LABORATORY MANUAL
FOR **Strength of Materials**

Subject Code: **CEP 1301**

DEPARTMENT OF CIVIL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY MIZORAM

LIST OF EXPERIMENTS

EXPERIMENT NO. 01

TENSILE STRENGTH TEST

AIM: To determine tensile behaviour of a given specimen using Universal Testing Machine (UTM).

OBJECT: To conduct a tensile test on a mild steel specimen and determine the following:

(i) Limit of proportionality
(ii) Elastic limit
(iii) Yield strength
(iv) Ultimate strength
(v) Young's modulus of elasticity
(vi) Percentage elongation
(vii) Percentage reduction in area.

THEORY:

The strength of a material depends on its ability to sustain a load without undue deformation or failure. This property is inherent in the material itself and must be determined by experiments. As a result, several types of tests have been developed to evaluate a material's strength under loads that are static, cyclic, or impulsive. One of the important tests to perform is the tension test. The tension test is used primarily to determine the relationship between the average normal stress and the normal strain in many engineering materials such as metals, ceramics, polymers, and composites. To perform this test, a specimen of the material is made into a "standard" shape and size, which is used as the basis for calculating the average strain. Before testing, two small marks are identified along the specimen's length. The distance between the marks is termed as the gauge length of the specimen. These marks are located away from the ends of the specimen because the stress distribution at the ends is somewhat complex due to the gripping at the connections where the load is applied.

The specimen is said to respond elastically if it returns to its original shape or length when the load acting on it is removed. In elastic region the stress is proportional to strain and the slope of the straight line in this region gives the Young's modulus E. The upper stress limit to this relationship is called the proportional limit. If the stress slightly exceeds the proportional limit, the material may still respond elastically, however the curve tends to be non-linear causing a greater increment of strain for corresponding increment of stress. This continues until the stress reaches the elastic limit. A slight increase in stress above the elastic limit will cause the specimen to deform permanently. This behaviour is called yielding and the stress at which yielding begins is called the yield stress and the permanent deformation that occurs is called plastic deformation. A further load beyond the yield stress applied to the specimen, causes the force–deformation curve to rise continuously with decreasing slope until it reaches a maximum stress referred to as the ultimate stress. The rise in the curve in this manner is called strain hardening.

APPARATUS:

(i) Universal Testing Machine (UTM)
(ii) Mild steel specimens
(iii) Graph paper
(iv) Scale
(v) Vernier Caliper

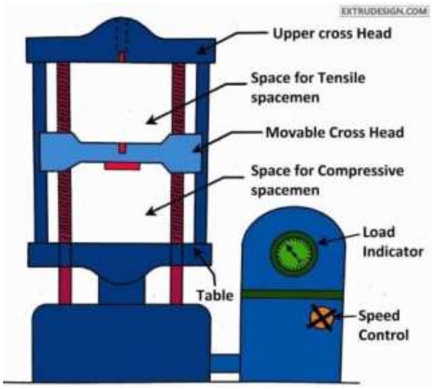

Figure: Universal Testing Machine

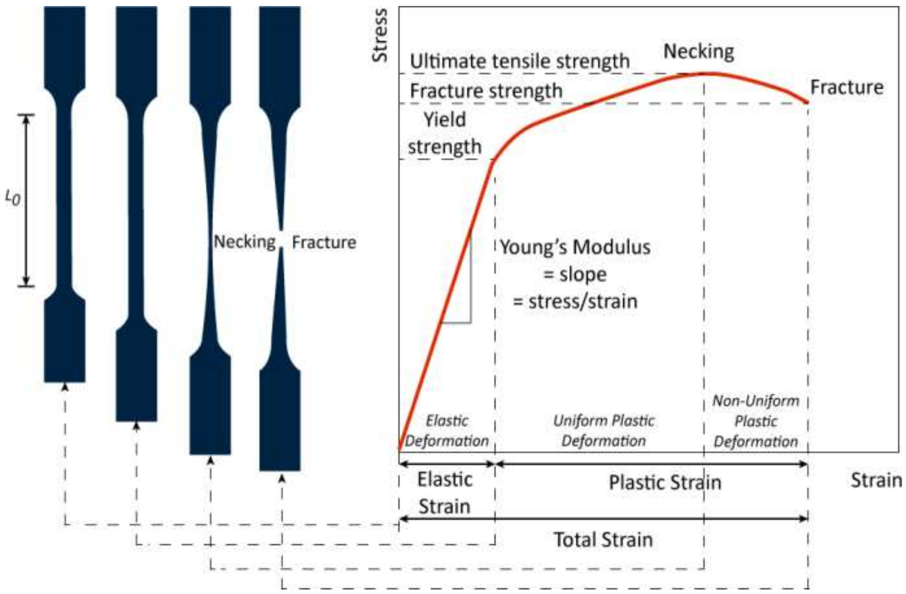

Figure: Typical stress-strain curve of a material obtained from tensile testing

PROCEDURE:

1. Measure the original length and diameter of the specimen. The length may either be length of gauge section which is marked on the specimen with a preset punch or the total length of the specimen
2. Insert the specimen into grips of the test machine and attach strain-measuring device

to it

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 with the help of dividers and a ruler.
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.

OBSERVATIONS:

(a) Initial diameter of specimen	d1 =
(b) Initial gauge length of specimen	L1 =
(c) Initial cross-section area of specimen	A1 =
(d) Load of yield point	F_t =
(e) Ultimate load at fracture	F =
(f) Final length after specimen breaking	L_2 =
(g) Diameter of specimen at breaking place	d2 =
(h) Cross section area at breaking place	A2 =

CALCULATION:

Stress (σ) and strain (ε) are calculated using the formula given below:

σ = Force/Area

ε = Change in length/Original length

RESULTS:

- Ultimate tensile strength = N/mm^2
- Elastic Limit = N/mm^2
- Yield Strength = N/mm^2
- Modulus of Elasticity = N/mm^2

- Percentage of Elongation = %
- Percentage Reduction in area = %
- Young's Modulus (E) = N/mm^2

PRECAUTIONS:

1. The specimen should be prepared in correct dimensions.
2. The specimen should be fixed properly between the jaws.
3. Take reading carefully.

QUESTIONS

1. What general information is obtained from tensile test regarding the properties of a material?
2. Which stress have you calculated: nominal stress or true stress? What is the difference between true stress and nominal stress?
3. What kind of fracture has occurred in the tensile specimen and why?
4. What does the typical stress-strain curve of mild steel look like?

EXPERIMENT NO. 02

SPRING STIFFNESS TEST

AIM: Spring stiffness test to determine properties of the spring

OBJECT: To conduct an experiment on spring to find the spring constant for the given spring and to compare the values with theoretical values.

THEORY:

Experimental determination of the force-deformation behaviour of a spring is simple and straight forward. If the force-deformation behaviour is linear then one has a linear spring. In such a case the amount of force required to produce a unit deflection is called the spring constant of the spring. In other words,

$$F = k\delta$$

where F is the force in Newton, k is the spring constant or stiffness of the spring (N/mm) and δ is the spring deformation (elongation or compression in mm).

The spring constant of a spring can also be computed analytically. The geometric details of the spring and the elastic properties of the material of the spring are needed to compute this. However, the computational approach is not quite simple. When force is applied, spring as a whole is compressed or elongated but this overall deformation comes about due to torsional/bending deformation of the spring wire. Knowledge of torsion and bending is essential to understand the analytical procedure.

When the diameter of the wire (r) is small in comparison with the radius of the coil (R), an element of the spring between two closely adjoining sections through the wire can be considered as a straight circular bar subjected to torsion for the external loading configuration as shown. The spring stiffness is given by

$$k = \frac{Gr^4}{4nR^3}$$

where *G* is the shear modulus of the spring material (GPa), *n* is the number of active coils, *r* isthe spring wire radius (mm) & *R* is the mean radius (mm) of the spring.

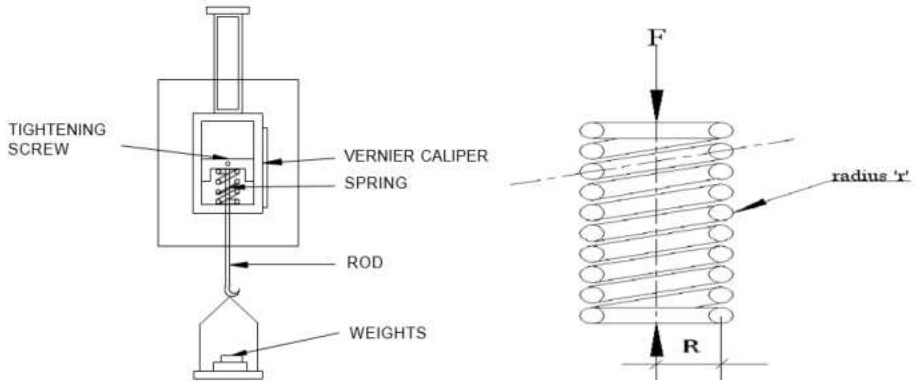

Figure: Spring loading apparatus and geometric details of the spring

APPARATUS:

1. Helical springs of different diameters
2. Spring loading apparatus

PROCEDURE:

1. Measure the dimensions of the spring radius *R* and *r* (wire radius) using the verniercalipers.
2. Place the spring in the loading setup and then clamp it by tightening the screw.
3. Note down the vernier scale reading for no load condition.
4. Load the spring in steps of 0.5 kg of weight up to 2.5 kg, and note down the readings fromthe vernier scale.
5. Remove the loads one by one when the loading is over and note down the deflection wheneach load is removed.
6. Take the spring out of the setup and repeat experiment on the other two springs.
7. Calculate the spring stiffness using the above readings.

OBESRVATIONS AND CALCULATIONS:

Spring No. _____________, Mean Radius (R)________________ Free length___________

Wire radius (r)_______________, Number of coils (n) _______________

Initial reading of vernier _____________________, Least count of vernier______________

Sl. No.	Load		Loading		Unloading	
	kg	N	Vernier reading	Deflection	Vernier reading	Deflection

RESULT: Draw a graph between load and deflection of the springs. Compare the stiffness values with that of theoretical values for all the springs and provide your comments.

QUESTIONS:

1. How will the spring constant change with wire diameter?
2. How will the spring stiffness change if the spring diameter is halved?

EXPERIMENT NO. 03

BRINELL HARDNESS TEST

AIM: To determine the hardness of the given specimen using Brinell hardness test.

OBJECT: To conduct a hardness test on a specimen and determine the hardness of the material.

THEORY:

Hardness is defined as the resistance to indentation, and it is determined by measuring the permanent depth of the indentation. The Brinell hardness test method as used to determine Brinell hardness is defined in ASTM E10. Most commonly it is used to test materials that have a structure that is too coarse or that have a surface that is too rough to be tested using another test method, e.g., castings and forgings.

Brinell testing often use a very high-test load (3000 kgf) and a 10mm diameter indenter so that the resulting indentation averages out most surface and sub-surface inconsistencies. The Brinell method applies a predetermined test load (F) to a carbide ball of fixed diameter (D) which is held for a predetermined time period and then removed. The resulting impression is measured with a specially designed Brinell microscope or optical system across at least two diameters – usually at right angles to each other and these results are averaged (d).

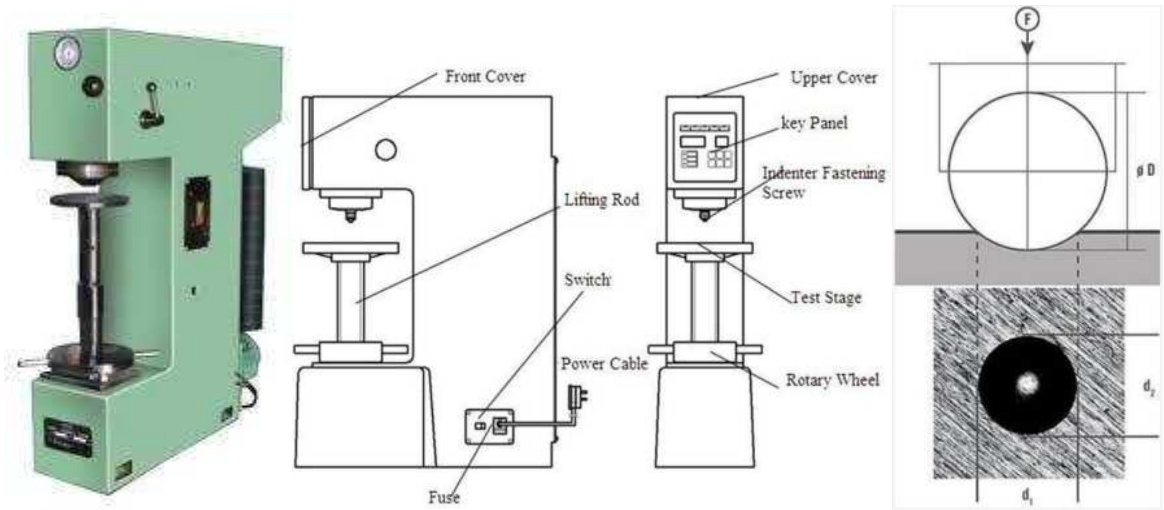

Figure: Brinell Hardness Testing apparatus

APPARATUS:

3. Brinell hardness testing machine,
4. Metallic specimen,
5. Ball indenter.

PROCEDURE:

1. Insert ball of diameter 'D' in the ball holder of machine.

2. Make the specimen surface clean by oil, grease, dust etc.
3. Make contact between the specimen surface and ball using jack adjusting wheel.
4. Push the required button for loading.
5. Pull the load release level and wait for 15 seconds.
6. Remove the specimen from the support table and locate the Indentation.
7. View the indentation through microscope and measure the diameter 'd' of the indentation using micrometer fixed on the microscope.
8. Repeat the procedure.

OBESRVATIONS AND CALCULATIONS:

Test piece material =

Load application time =

S.No	Ball Diameter (D) in mm	Load applied F in kgf	Indentation diameter		Average Diameter of indentation (d=0.5*(d1+d2))
			d1	d2	

BHN = Load applied/spherical surface area of indentation

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

RESULT AND CONCLUSIONS: Brinell hardness number (BHN) of the specimen is _____________

PRECAUTION:

1. Load should not be removed instantly
2. Clean the specimen surface before testing
3. Loding time of test load should be kept less than 15 seconds.

QUESTIONS:

1. What is hardness of a material?
2. What are advantages and disadvantages of Brinell Hardness Test?

EXPERIMENT NO. 04

ROCKWELL HARDNESS TEST

AIM: To determine the hardness of the given Specimen using Rockwell hardness test.

OBJECT: To conduct a hardness test on a specimen and determine the hardness of the material.

THEORY:

Hardness represents the resistance of material surface to abrasion, scratching and cutting, hardness after gives clear indication of strength. In all hardness tests, a defined force is mechanically applied on the piece, indenter varies in size and shape for different tests. Common indenters are made of hardened steel or diamond.

In hardness testing according to Rockwell, the total test force is applied in two steps. This is intended to eliminate effects from the roughness of the specimen surface (e.g., grooves on the specimen) as well as measurement errors caused by the play of the indentation depth measurement. Rockwell hardness tester presents direct reading of hardness number on a dial provided with the machine. Although there are many scales having different combinations of load and size of indenter but commonly 'C' scale is used and hardness is presented as HRC. Here the indenter has a diamond cone at the tip and applied force is of 150kgf. Soft materials are often tested in 'B' scale with a 1.58mm dia. steel indenter at 100kgf.

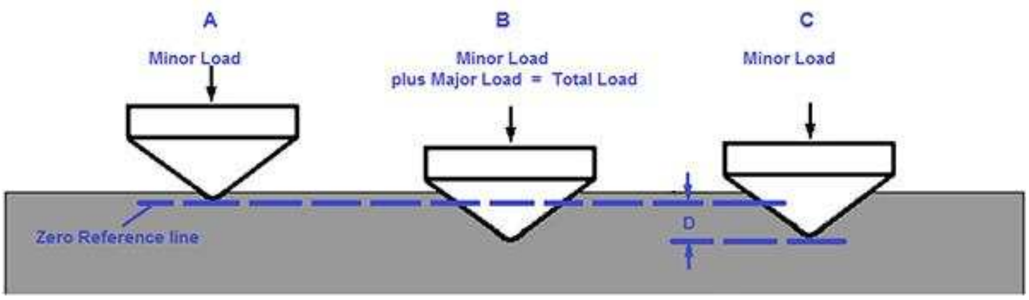

Figure: Hardness testing in HRA & HRC scale

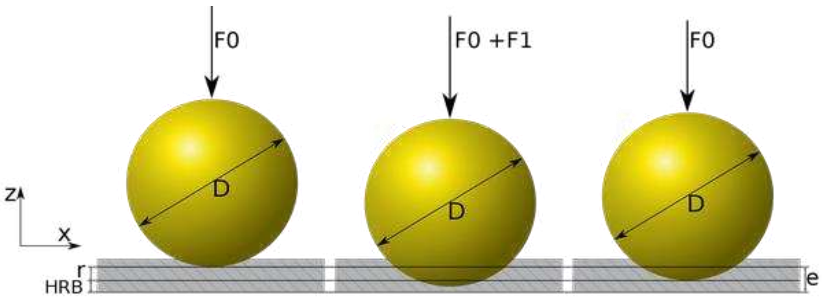

Figure: Hardness testing in HRB scale

APPARATUS:

1. Rockwell hardness testing machine
2. specimen of mild steel or other material.

PROCEDURE:

1. Insert the indenter in the holder of the machine.
2. Make the specimen surface clean by removing dust, dirt, oil and grease etc.
3. Make contact between the specimen surface and the ball by rotating the jack adjusting wheel.
4. Push the required button for loading.
5. Wait for minimum 10 second. The load will automatically apply gradually.
6. Remove the specimen from support table and locate the indentation so made.
7. View the indentation through microscope and measure the hardness value.
8. Repeat the entire operation 3 times.

OBSERVATION AND CALCULATIONS:

Sl.No.	Load Applied	H-V

RESULT AND CONCLUSION: Hardness of the material in Rockwell scale is ___________ HRA/HRB/HRC.

PRECAUTIONS:

1. The specimens should be cleaned properly.
2. Take readings carefully and correctly.
3. Place the specimen properly.
4. Adjusting wheel should be moved slowly.
5. Measure diameter carefully.

QUESTIONS:

1. Define Hardness
2. Size of the Ball to be used in Ball Indenter of Rockwell Hardness Test.
3. Different Types of Hardness Testing Methods.
4. Applications of Rockwell Hardness scales – Scale A, Scale B, Scale C

EXPERIMENT NO. 05

VICKERS HARDNESS TEST

AIM: To study the Vickers hardness testing machine & perform the Vickers hardness test.

OBJECT: To conduct a hardness test on a specimen and determine the hardness of the material.

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. Indentation hardness value is obtained by measuring the depth or the area of the indentation using one of over different test methods.

The Vickers hardness test method, also referred to as a micro hardness test method, is mostly used for small parts, thin sections or case depth work. The Vickers method is based on an optical measurement system. The Micro hardness test procedure, AS'I'M 15-384, specifies a range of light loads using a diamond indenter to make an indentation which is measured and converted to a hardness value. The indenter used in the Vickers test method is a diamond pyramid with a square base, whose opposite sides meet at the apex at an angle of α = 136°. It is applied to the specimen with a test force (to standard starting at 10 g) and held according to the holding time. The lengths of both diagonals of the residual test indentation are optically measured. The Vickers hardness is then calculated from the average of the diagonals and the test force applied.

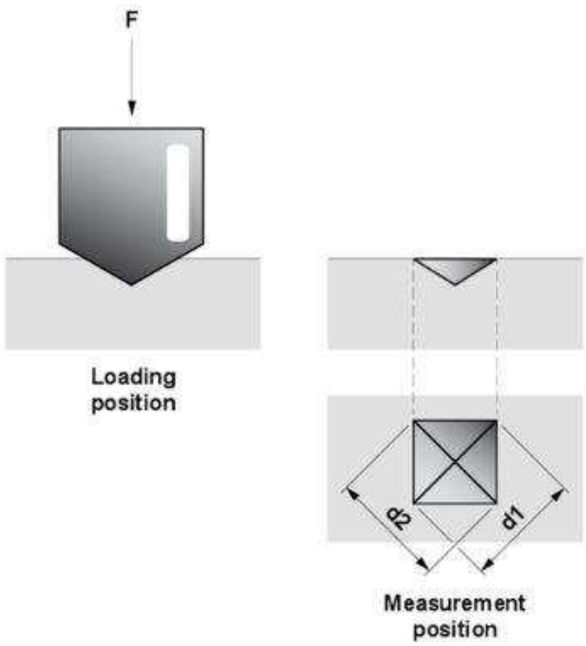

Figure: Indentation made by a Vickers indenter

APPARATUS:

1. Vickers Hardness Testing Machine.
2. Diamond cone indenter.
3. Specimen.

PROCEDURE:

1. Insert the diamond indenter in the holder of the machine.
2. Make the specimen surface clean by removing dust, dirt, oil and grease etc.
3. Make contact between the specimen surface and the ball by rotating the jack adjusting wheel.
4. Push the required button for loading.
5. Wait for minimum 10 second. The load will automatically apply gradually.
6. Remove the specimen from support table and locate the indentation so made.
7. View the indentation through microscope and measure the hardness value.
8. Repeat the entire operation 3 times.

OBSERVATION AND CALCULATIONS:

Sl.No.	Load applied P in Kg-f	Diagonal length (mm)		Average diagonal length l (mm)	VHN
		1	2		

Vickers Hardness Number (VHN) = $\frac{0.1891\ P}{l^2}$

RESULT AND CONCLUSION:

The hardness of the material in Vickers hardness scale is __________________

PRECAUTIONS:

1. The specimen should be cleaned properly.
2. Take reading carefully and correctly.
3. Place the specimen properly.
4. Adjusting wheel should be moved slowly.
5. Measure diameter carefully.

EXPERIMENT NO. 06

IZOD IMPACT TEST

AIM: To determine impact test of a given specimen using Izod impact test.

OBJECT: To conduct an impact test on a specimen and determine the toughness of the material.

THEORY:

The IZOD impact test is used to determine the impact resistance (toughness) of a material, or the material's tendency to resist breaking when subjected to a sudden force or impulse. The IZOD impact test method, also known as the notched IZOD test, is standardized under the ASTM International test procedure.

To determine impact resistance (toughness) using an IZOD impact test, a weighted pendulum is dropped from a prescribed height and strikes a notched test specimen. When the specimen breaks, the energy absorbed and the material's impact resistance can be related back to the potential energy of the pendulum before it is released. Impact testing machine consists of a pendulum suspended from a short shaft that rotates in ball bearing and swings midway between two rigid upright stands supported on a rigid base near the bottom of which are the specimen supports anvils. The knife-edge or striking edge is slightly rounded. The pendulum can be raised to any desired height and rested at that position. It is supported in the starting position by a catch and can be released by a trigger. The mechanism is so designed that the pendulum is not disturbed when the catch is released. The test specimen is clamped into the specimen support in a position so that the notched end of the specimen is facing the striking edge of the pendulum.

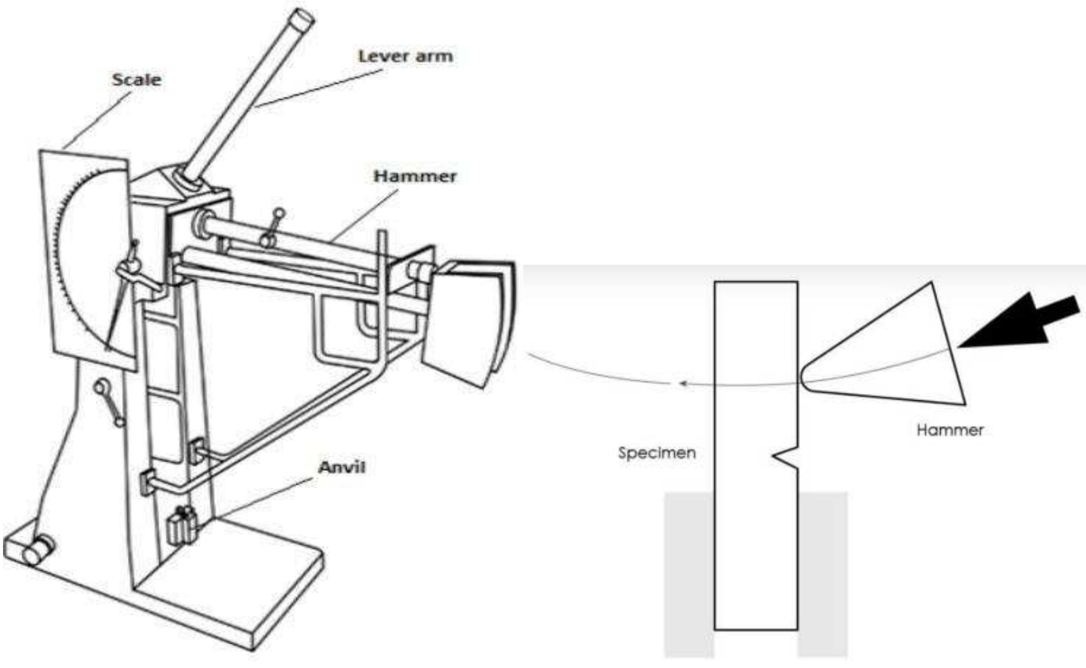

Figure: Impact testing machine and specimen for Izod Impact Test

APPARATUS:

1. Impact testing machine.
2. A steel specimen 75mm X 10mm X 10mm

PROCEDURE:

1. With the striking hammer (pendulum) in safe test position, firmly hold the steel specimen in impact testing machine's vice in such a way that the notch face the hammer and is half inside and half above the top surface of the vice.
2. Bring the striking hammer to its top most striking position unless it is already there, and lock it at that position.
3. Bring indicator of the machine to zero, or follow the instructions of the operating manual supplied with the machine.
4. Release the hammer. It will fall due to gravity and break the specimen through its momentum, the total energy is not absorbed by the specimen. Then it continues to swing. At its topmost height after breaking the specimen. The indicator stops moving, while the pendulum falls back. Note the indicator at the top most final position.
5. Again, bring back the hammer to its idle position and back.

OBSERVATION:

Impact value of Mild Steel = _____ N-m

RESULT:

Impact strength of the specimen is ______________.

PRECAUTIONS:

1. Measure the dimensions of the specimen carefully.
2. Hold the specimen (Izod test) firmly.
3. Note down readings carefully.

QUESTIONS:

1. What are the factors that affect Impact strength?
2. What is the effect of temperature on the values of rupture energy and notch impact strength?

EXPERIMENT NO. 07

CHARPY IMPACT TEST

AIM: To determine impact test of a given specimen using Charpy Impact Test.

OBJECT: To conduct an impact test on a specimen using Charpy test and determine the toughness of the material.

THEORY:

In a Charpy impact test to ISO 148-1, a notched metal specimen is severed using a pendulum hammer. For the test, the metal specimen is centered on the supports in the pendulum impact tester. The notch is exactly across from the point at which the pendulum hammer strikes the specimen. This impact test is used to determine the absorbed impact energy.

The pendulums hammer strikes the specimen with a defined energy and fractures (destroys) it with a single hit. As the specimen is fractured, the pendulum hammer transfer part of its kinetic energy and is therefore unable to return to its original drop height. The measured height difference is the value for the absorbed energy, the impact energy W in joules.

Since the impact energy on metals if often temperature dependent, a test temperature of 23 °C is specified for Charpy impact tests at ambient temperature. Deviating test temperatures are permitted under standard-compliant conditions.

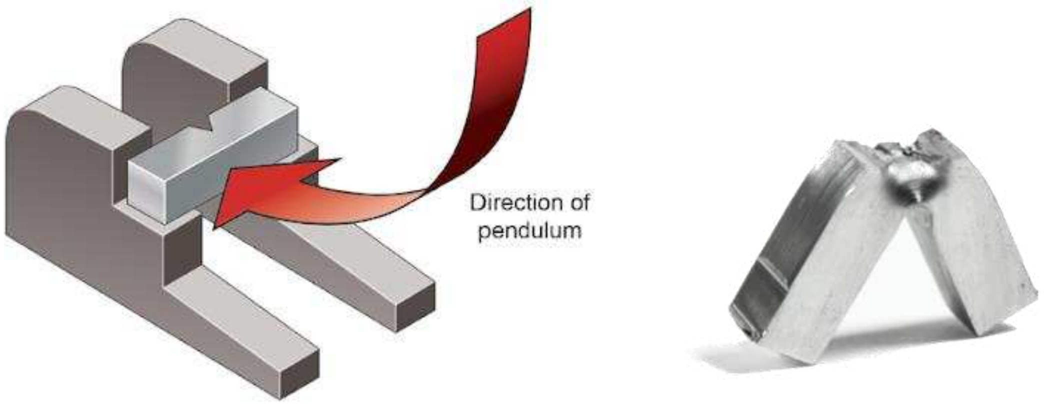

Figure: Set up of Charpy test specimen and specimen after testing

APPARATUS:

1. Impact test machine
2. Test specimen

PROCEDURE:

1. With the striking hammer (pendulum) in safe test position, firmly hold the steel specimen in impact testing machine's vice

2. Bring the striking hammer to its top most striking position unless it is already there, and lock it at that position.
3. Bring indicator of the machine to zero, or follow the instructions of the operating manual supplied with the machine.
4. Release the hammer. It will fall due to gravity and break the specimen through its momentum, the total energy is not absorbed by the specimen. Then it continues to swing. At its topmost height after breaking the specimen. The indicator stops moving, while the pendulum falls back. Note the indicator at the top most final position.
5. Again, bring back the hammer to its idle position and back.

OBSERVATION AND RESULT: Impact value of mild steel specimen is ________ N-m

PRECAUTIONS:

1. Measure the dimensions of the specimen carefully.
2. Locate the specimen (Charpy test) in such a way that the hammer strikes it at the middle.
3. Note down readings carefully.

RESULT: The Impact strength of material by Charpy test is _________________.

QUESTIONS:

1. What is the basic difference of Izod and Charpy impact test method?

EXPERIMENT NO. 08

TORSION TEST

AIM: To conduct torsion test on mild steel specimen and verify the torsional formula

OBJECT: To conduct a torsion test on a specimen and evaluate modulus of rigidity or shear modulus of the shaft material.

THEORY:

In many applications, such as axles, coil springs, and derives shafts; an engineering material must have good resistance to stresses induced by twisting (TORSION). The stress resulting from such torsion load can be determined by means of the torsion test. This test resembles the tension test in that a load deflection curve is also developed (which is transformed to a shear-strain curve). In a torsion test, a solid or hollow cylindrical specimen is twisted and the resultant deformation, measured as the angle through which the bar is twisted. The test then consists of measuring the angle of twist, Φ (rad) at selected increments of torque, T (N.m). Expressing Φ as the angular deflection curve per unit gage length, one is able to plot a T-Φ curve that is analogous to the load deflection curve of the torsion test. To be useful for engineering purpose, its necessary to convert this T-Φ curve to the shear stress τ, and shear strain γ. Once the shear stress – strain curve is obtained, we can easily evaluate several engineering properties such as modulus of rigidity or shear modulus, modulus of resilience and modulus of rupture. For a circular shaft of constant diameter transmitting a uniform torque, the torsion formula is

$$\frac{T}{I_p} = \frac{C\theta}{L} = \frac{\tau}{R}$$

where, T is the twisting moment applied, I_p is the polar moment of inertia od cross section, τ is the shear stress developed due to torsion, R is the radius of element being considered, C is shear modulus of material, θ is angle of twist and L is length of the uniform shaft.

PROCEDURE:

1. Select the 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 the 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 members in suitable increments, observe and record strain reading.
7. Continue till failure of the specimen.

8. Calculate the modulus of rigidity C by using the torsion equation.

9. Plot the torque –twist graph (T vs θ)

OBSERVATIONS AND CALCULATIONS:

Gauge length L =

Polar moment of inertia I_p =

Modulus of rigidity C = $\frac{TL}{I_p\theta}$

Sl. No	Twisting Moment N-mm	Angle of Twist (Degrees)	Twist (Radians)	Modulus of rigidity (C)

RESULT: The modulus of rigidity C of the given test specimen material is ___________.

QUESTIONS:

1. What is torque? How is Torque related to shear stress?
2. What is modulus of rigidity or shear modulus? How is it calculated?
3. How is the mathematical relation of Young's modulus and shear modulus?