



DEPARTMENT OF MECHANICAL ENGINEERING
Haldia, Purba Medinipur, West Bengal
HALDIA INSTITUTE OF TECHNOLOGY

PRACTICAL MANUAL
(Assessment Instrument and Instruction Items)

Course Name	Strength of Materials Lab
Course Code	PC-ME 491
Laboratory Name	Strength of Materials Lab & Materials Testing Lab
Programme	B. Tech in Mechanical Engineering
Semester / Year	4 th Semester / 2 nd Year
Academic Session	2026–27

Faculty-in-Charge & Technical Staff

Faculty-in-Charge	Dr. Sourav Pattanayak
Co-Faculty (if any)	Dr. Ashoke Kumar Bera
Technical Staffs	



Vision

To impart quality, industry-relevant teaching-learning that blends knowledge and skill to produce industry-ready mechanical engineering graduates.

Mission Statements

M1: To create qualified and proficient technocrats having contemporary skills through outcome-based and self-learning strategies.

M2: To encourage innovation-oriented and problem-based research capabilities among young engineers through higher studies, in order to nurture the progress of society.

M3: To instill strong ethical values and good professional behaviour, enabling graduates to adopt and absorb emerging changes in the engineering profession.

Program Educational Objective

Graduates of B. Tech. Mechanical Engineering program, four years after graduation will

PEO1: Specify, design, supervise, test, and evaluate engineering skills to design, develop, and implement innovative solutions, systems, and applications in Mechanical Engineering and allied industries.

PEO2: Utilize Mechanical Engineering knowledge to address real-world and societal challenges while pursuing higher studies, research, and professional development.

PEO3: Demonstrate effective individual and collaborative capabilities in multidisciplinary professional environments, with a commitment to lifelong learning and adaptability to evolving technological, industrial, and societal requirements.

Program Specific Outcomes (PSOs)

PSO1: Design, analyze and evaluate mechanical components and systems such as thermal, fluid, manufacturing, design systems and allied engineering solutions.

PSO2: Utilize and evaluate modern engineering tools, software, and techniques to model, analyze, and solve real-world mechanical engineering problems.

PSO3: Demonstrate professional and ethical responsibility, effective communication, and the ability to work in multidisciplinary teams to address societal, industrial, and environmental challenges through sustainable mechanical engineering solutions.



Course Code: PC-ME 491	Category: Professional Core courses	PCIE Marks	40
Course Name: Strength of Materials Laboratory	Semester: Fourth	PSEE Marks	60
L-T-P: 0-0-3	Credit: 1.5	Total Marks	100
Pre-Requisites: ES ME 301 Engineering Mechanics			
Examination (PSEE): Theory/ Drawing Assignment/ Practical/ Viva-voce/ Team work/ others			

Course Content:

Unit	Topics	Hours	CO
UNIT I	Tension and elastic property testing, including the Tension Test, Spring Stiffness determination, and Torsion Test on mild steel, aimed at finding yield strength, UTS, % elongation, Young's modulus, and modulus of rigidity using a Universal Testing Machine.	12	CO1
UNIT II	Formability and ductility testing through Bend and Re-bend Tests and the Cupping (Erichsen) Test, evaluating a specimen's ductility, soundness, and sheet metal drawability based on bend angle and cracking behavior.	6	CO2
UNIT III	Hardness testing using Brinell and Rockwell hardness testing machines, covering their principles, procedures, and determination of BHN and HRB/HRC values within standard tolerances.	6	CO3
UNIT IV	Impact and fatigue testing, including Charpy and Izod impact tests to determine toughness, and fatigue testing to evaluate endurance limit and fatigue life under cyclic loading.	9	CO4
UNIT V	Metallography and heat treatment, covering sample preparation (cutting, mounting, grinding, polishing, etching), various heat treatment processes, and microstructural examination to correlate structure with composition and properties.	6	CO5
UNIT VI	Non-Destructive Testing (NDT) methods—Dye Penetration for detecting and classifying surface defects as per standard acceptance criteria.	3	CO6
Total		42	

Suggested Reference Books

1. "Mechanical Metallurgy" by George E. Dieter.
2. "Materials Science and Engineering: An Introduction" by William D. Callister Jr. & David G. Rethwisch.
3. "A Textbook of Material Science and Metallurgy" by O.P. Khanna.



Course Outcomes:

Upon successful completion of the course, students will be able to:

CO CODES	CO Statement	Knowledge Categories	Cognitive Level
PC-ME 491.1	Determine the mechanical properties (yield strength, UTS, % elongation, Young's modulus) of a mild steel specimen using a Universal Testing Machine, within acceptable engineering tolerance.	P	Ap
PC-ME 491.2	Evaluate the ductility and soundness of a flat metal specimen by conducting bend and re-bend tests, ensuring the specimen withstands the specified bend angle without visible cracking.	P	E
PC-ME 491.3	Determine the hardness of a given metal specimen using Brinell and Rockwell hardness testing machines, within acceptable standard tolerance.	P	Ap
PC-ME 491.4	Determine the impact strength (toughness) and fatigue strength (endurance limit) of a given metal specimen by conducting Charpy, Izod, and fatigue tests using standard testing machines.	P	An
PC-ME 491.5	Examine the microstructure of a metal specimen through sample preparation, heat treatment, and metallographic observation, correlating results with its composition and treatment history.	C	An
PC-ME 491.6	Detect and classify surface defects in a metal specimen using Dye Penetration testing methods, as per standard acceptance criteria.	P	Ap



ALIGNING OF COs IN [CL x KC] METRIC

Cognitive Levels (CL)	Knowledge Categories (KC)							
	Factual	Conceptual	Procedural	Meta-cognitive	Fundamental Design Principles	Criteria & Specifications	Practical Constraints	Design instrumentalities
Remember (R)								
Understand (U)								
Apply (Ap)			CO1, CO3, CO6					
Analyze (An)		CO5	CO4					
Evaluate (E)			CO2					
Create (C)								

Assessment Pattern and Assessment Instruments for PCIE & PSEE										
Marks allotted	PCIE								PSEE (60)	
	PCAI (40)				PCAII (40)					
	10	10	10	10	10	10	10	10	40	20
CO	EX1	EX 2	EX 3	VIVA I	EX 4	EX 5	EX 6	VIVA II	GR-A	GR-B (Viva)
CO1	10			10/3					40/6	20/6
CO2		10		10/3					40/6	20/6
CO3			10	10/3					40/6	20/6
CO4					10			10/3	40/6	20/6
CO5						10		10/3	40/6	20/6
CO6							10	10/3	40/6	20/6

CO-PO & CO-PSO Articulation Matrix

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PSO1	PSO2	PSO3
PC-ME 491.1	3	1	1	3	2	–	–	2	1	–	1	2	1	1
PC-ME 491.2	2	1	1	3	2	–	–	2	1	–	1	2	1	1
PC-ME 491.3	2	1	1	3	2	–	–	2	1	–	1	2	1	1
PC-ME 491.4	2	2	1	3	2	1	–	2	2	–	2	3	2	1
PC-ME 491.5	2	2	1	3	3	–	–	2	2	–	2	3	2	1
PC-ME 491.6	2	2	–	3	3	2	1	2	2	–	2	2	3	2
Average	2.17	1.50	1.00	3.00	2.33	1.50	1.00	2.00	1.50	–	1.50	2.33	1.67	1.17





STRENGTH OF MATERIALS LABORATORY (PC-ME 491)
LIST OF ASSESSMENT ITEMS, INSTRUCTION ITEMS

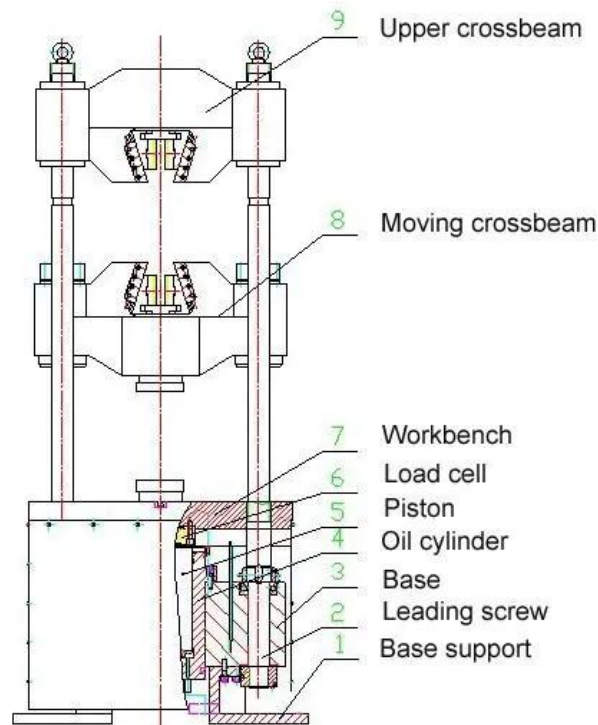
Experiment No.	Name of the experiment	Instruction Item	CO Congruence
EX1-I	Determination of Mechanical Properties of a Metal Specimen Under Uniaxial Tensile Load.	II1 Static Mechanical (Strength & Elastic Property) Tests	CO1: Determine the mechanical properties (yield strength, UTS, % elongation, Young's modulus) of a mild steel specimen using a Universal Testing Machine, within acceptable engineering tolerance.
EX1-II	Determination of Stiffness (Spring Constant) of a Helical Spring.		
EX1-III	Determination of Modulus of Rigidity of Mild Steel Rod by Torsion Test.		
EX2-I	Determination of Ductility and Soundness of Flat Metal Specimens by Bend and Re-bend Test.	II2 Formability / Ductility Tests	CO2: Evaluate the ductility and soundness of a flat metal specimen by conducting bend and re-bend tests, ensuring the specimen withstands the specified bend angle without visible cracking.
EX2-II	Determination of Drawability of Sheet Metal by Cupping Test (Erichsen Test).		
EX3-I	Determination of Hardness of a Metal Specimen by Brinell Hardness Test.	II3 Hardness Tests	CO3: Determine the hardness of a given metal specimen using Brinell and Rockwell hardness testing machines, within acceptable standard tolerance.
EX3-II	Determination of Hardness of a Metal Specimen by Rockwell Hardness Test.		
EX4-I	Determination of Impact Strength of a Metal Specimen by Charpy and Izod Impact Tests.	II4 Dynamic Loading Tests	CO4: Determine the impact strength (toughness) and fatigue strength (endurance limit) of a given metal specimen by conducting Charpy, Izod, and fatigue tests using standard testing machines.
EX4-II	Determination of Fatigue Strength (Endurance Limit) of a Metal Specimen by Fatigue Testing.		
EX5-I	Study of Microstructure of Metals through Sample Preparation, Heat Treatment, and Metallographic Examination.	II5 Metallurgical / Microstructural Examination	CO5: Examine the microstructure of a metal specimen through sample preparation, heat treatment, and metallographic observation, correlating results with its composition and treatment history.
EX6-I	Detection of Surface Defects in Materials by Non-Destructive Testing (Dye Penetrant) Method.	II6 Non-Destructive Testing (NDT)	CO6: Detect and classify surface defects in a metal specimen using Dye Penetration testing methods, as per standard acceptance criteria.



INSTRUCTION ITEM-1(II-1): Static Mechanical (Strength & Elastic Property) Tests		
Experiment No.	Name of the experiment	CO Congruence
EX1-I	Determination of Mechanical Properties of a Metal Specimen Under Uniaxial Tensile Load	[CO1]
EX1-II	Determination of Stiffness (Spring Constant) of a Helical Spring	
EX1-III	Determination of Modulus of Rigidity of Mild Steel Rod by Torsion Test	

EX1-I: Determination of Mechanical Properties of a Metal Specimen Under Uniaxial Tensile Load

Preamble: The tensile test is one of the most widely used mechanical tests to evaluate the behavior of materials under uniaxial loading. In this test, the ends of a standard specimen are firmly gripped in a Universal Testing Machine (UTM), where one end is connected to a straining (loading) device and the other to a load-measuring system. A gradually increasing tensile load is applied until the specimen ultimately fails.



When the applied load is relatively small, the material undergoes elastic deformation, meaning it returns to its original shape and dimensions upon removal of the load. This region is known as the elastic region of the stress-strain curve. However, beyond a certain load, the material experiences permanent deformation, known as plastic deformation, and does not fully recover its original dimensions after unloading.

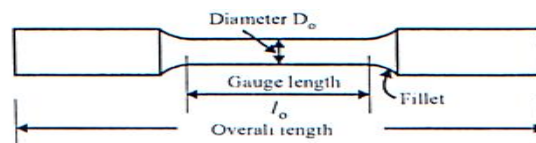
The stress corresponding to the transition from elastic to plastic behavior is called the yield strength of the material. In mild steel, this transition is clearly observed through distinct upper and lower yield points, often accompanied by a sudden drop in load. However, some materials do not exhibit a sharp yield point, and their yield strength is determined using an offset method. As loading continues in the plastic region, the material undergoes strain hardening, where it becomes stronger with increasing deformation. However, at



larger extensions, the reduction in cross-sectional area becomes significant, and strain hardening can no longer compensate for it. As a result, the load reaches a maximum value known as the ultimate load, and the corresponding stress (based on the original cross-sectional area) is called the ultimate tensile strength (UTS). Beyond this point, localized reduction in area, known as necking, begins. The specimen continues to elongate with a decreasing load until it eventually fractures. The complete stress–strain curve thus provides essential mechanical properties such as modulus of elasticity, yield strength, ultimate tensile strength, and ductility of the material.

The engineering stress (σ) and strain (ϵ) are defined as: $\sigma = P/A_0$ and $\epsilon = \Delta L/L_0$ where P is the applied load, A_0 is the original cross-sectional area, ΔL is the change in length, and L_0 is the original gauge length. The slope of the initial linear portion of the stress–strain curve gives the modulus of elasticity (E), which represents the stiffness of the material.

The specimen is typically cylindrical or flat with enlarged ends for gripping. The central portion is of uniform cross-section, called the gauge length, where deformation is measured.



Apparatus: -

1. Universal Testing Machine (UTM)
2. Mild steel specimen (standard dimensions)
3. Vernier caliper
4. Scale

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

Initial Measurements

Original diameter (d_0) = _____ mm

Original gauge length (L_0) = _____ mm

Load vs Extension Data

Sl. No.	Load (kN)	Extension (mm)

Final Measurements



Final gauge length (L_f) = _____ mm

Minimum diameter at neck (d_f) = _____ mm

Calculation:

Original cross-sectional area: $A_o = \left(\frac{\pi}{4}\right) \cdot d_o^2$

Stress: $\sigma = P/A_o$

Strain: $\varepsilon = \Delta L/L_o$

Percentage elongation: % Elongation = $[(L_f - L_o)/L_o] \times 100$

Percentage reduction in area: % Reduction = $[(A_o - A_f)/A_o] \times 100$

To plot the stress strain curve and determine the following:

$$\text{Limit of proportionality} = \frac{\text{Load at limit of proportionality}}{\text{Original cross – sectional area}}$$

Modulus of Elasticity: $E = \sigma/\varepsilon$ (within elastic limit)

$$\text{Yield strength} = \frac{\text{Yield load}}{\text{Original area of cross – sectional area}}$$

$$\text{Ultimate tensile strength: } UTS = \frac{\text{Maximum Load}}{A_o}$$

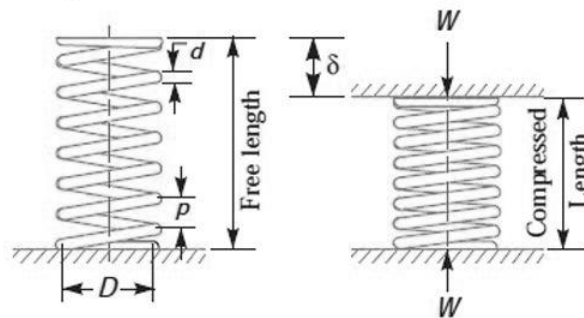
Precautions: -

1. Keep a safe distance from machine.
2. Do not touch any part of the machine while experiment is going on.
3. Load valve should operate gradually and carefully.



EX1-II: Determination of Stiffness (Spring Constant) of a Helical Spring

Preamble: A spring is an elastic machine element that deforms under load and regains its original shape when the load is removed. Closely coiled helical springs are widely used in automobiles, railway carriages, shock absorbers, clutches, brakes, weighing machines, and vibration isolation systems. When an axial load is applied to a closely coiled helical spring, the wire of the spring is subjected mainly to torsional shear stress, producing axial deflection in the spring. Within the elastic limit, the deflection of the spring is directly proportional to the applied load. Hence, the graph between load and deflection is a straight line. The stiffness of the spring is defined as the load required to produce unit deflection and is equal to the slope of the load-deflection curve. The modulus of rigidity of the spring material can be determined using the dimensions of the spring and the experimentally obtained stiffness.



Apparatus:

1. Spring Testing Machine
2. Test Spring
3. Vernier Caliper
4. Steel Rule

Procedure

1. Measure the diameter of the spring wire d using a micrometer screw gauge at three different locations and calculate the average value.
2. Measure the outer diameter of the spring using a vernier caliper and determine the mean coil diameter D .
3. Count the number of active turns n of the spring.
4. Mount the spring properly in the spring testing machine.
5. Apply a small initial load to remove any slackness in the spring and set the deflection indicator to zero.
6. Apply load gradually in suitable increments and note the corresponding deflection of the spring for each load.
7. Continue the loading within the elastic limit of the spring and record all observations in the observation table.
8. Remove the loads gradually and check whether the spring regains its original position.
9. Plot a graph between load W , on the Y-axis and deflection δ , on the X-axis.
10. Draw the best fit straight line through the plotted points.
11. Determine the slope of the straight line from the graph:

$$m = \frac{W}{\delta}$$

12. Calculate the spring stiffness k from the slope of the load-deflection graph:

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

13. Substitute the value of stiffness in the modulus of rigidity equation and calculate G :

$$G = \frac{8kD^3n}{d^4}$$

14. Record the final values of spring stiffness and modulus of rigidity.



Observation and Observation Table:

Diameter of spring wire, $d =$ _____ mm

Outer diameter of spring coil, $Do =$ _____ mm

Mean coil diameter, $D = Do - d$

Number of active turns, $n =$ _____

SI No	Load (W) (N)	Deflection (δ) (mm)

Spring Stiffness

The stiffness of the spring is obtained from the slope of the load-deflection curve:

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

Modulus of Rigidity

For a closely coiled helical spring, the modulus of rigidity is given by:

$$G = \frac{8kD^3n}{d^4}$$

Where:

k = Spring stiffness (N/mm)

W = Applied load (N)

δ = Deflection of spring (mm)

G = Modulus of rigidity (N/mm²)

D = Mean coil diameter (mm)

d = Diameter of spring wire (mm)

n = Number of active coils

δ = Deflection (mm)

Precautions

1. The spring should be loaded gradually without shock.
2. Readings should be taken carefully to avoid parallax error.
3. The spring should not be loaded beyond its elastic limit.
4. Measuring instruments should be checked for zero error before use.
5. Deflection readings should be noted accurately.



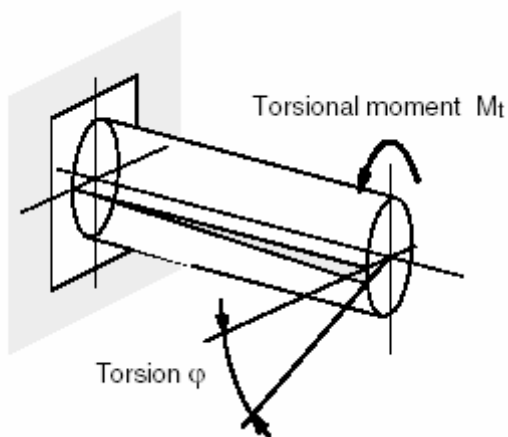
EX1-III: Determination of Modulus of Rigidity of Mild Steel Rod by Torsion Test

Preamble: When a circular shaft is subjected to a torque (twisting moment) about its longitudinal axis, every cross-section of the shaft experiences a state of pure shear. The torsion equation, derived on the assumptions that the material is homogeneous, isotropic, and obeys Hooke's law within the elastic limit, and that plane sections remain plane and circular after twisting, is given by:

$$T/J = \tau/r = G\theta/L$$

where T is the applied torque, J is the polar moment of inertia of the shaft cross-section, τ is the shear stress at radius r, G is the modulus of rigidity (shear modulus) of the material, θ is the angle of twist (in radians) over a gauge length L.

Within the elastic range, the angle of twist is directly proportional to the applied torque, and a plot of torque versus angle of twist is a straight line whose slope gives the torsional stiffness of the shaft. The product GJ is termed the torsional rigidity of the shaft, and it represents the torque required to produce a unit angle of twist per unit length. Beyond the elastic limit, the torque-twist relationship becomes non-linear as the material undergoes plastic deformation, and the shaft ultimately fails either by shearing (in ductile materials, typically along a plane perpendicular to the axis) or by a helical fracture (in brittle materials, along planes of maximum principal tensile stress).



Apparatus: -

1. Torsion Testing Machine
2. Mild steel specimen (circular cross-section, standard dimensions)
3. Vernier caliper
4. Twist (angle) indicator
5. Steel rule / scale

Procedure: -

1. Measure the diameter of the specimen at several points along its length using a vernier caliper and take the average value. Mark the gauge length over which the angle of twist is to be measured.
2. Fix one end of the specimen rigidly in the fixed chuck of the torsion testing machine and grip the other end in the load chuck connected to the torque-measuring unit.
3. Set the twist (angle) indicator to zero before starting the test.
4. Apply torque gradually in suitable increments using the loading handwheel/worm gear arrangement.
5. At each increment of torque, record the corresponding angle of twist from the twist indicator.
6. Continue loading until the material reaches its elastic limit and, if required, up to failure, noting the maximum torque and the nature of fracture.



7. Plot a graph of torque (T) versus angle of twist (θ) and identify the straight-line (elastic) portion of the curve.

Observations:

Initial Measurements

Diameter of specimen (d) = _____ mm

Gauge length (L) = _____ mm

Torque vs Angle of Twist Data

Sl. No.	Torque, T (N-m)	Angle of twist, θ (radian)

Calculation:

Polar moment of inertia: $J = \left(\frac{\pi}{32}\right) \cdot d^4$

Modulus of rigidity: $G = \frac{TL}{J\theta}$ (using values from the linear/elastic portion of the $T - \theta$ curve)

Slope of the $T - \theta$ curve, $m = \frac{\Delta T}{\Delta \theta}$

Modulus of rigidity from slope: $G = \frac{mL}{J}$

Torsional rigidity of the shaft = GJ

Precautions: -

1. Ensure the specimen is properly and rigidly gripped in both chucks before starting the test.
2. Apply the torque gradually and steadily; avoid sudden or jerky loading.
3. Set the twist indicator to zero carefully before beginning observations.
4. Keep a safe distance from the machine while it is in operation.

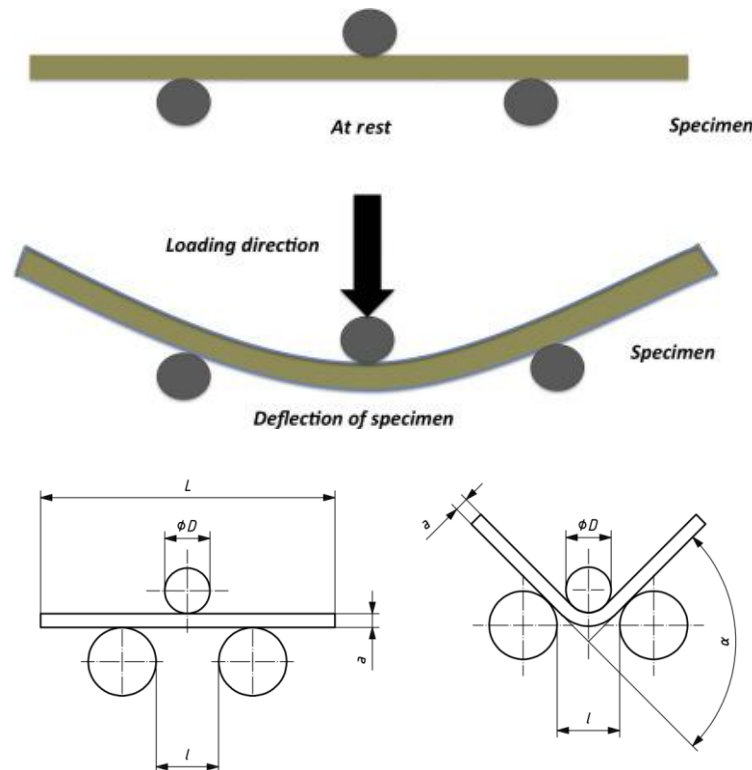


INSTRUCTION ITEM-2(II-2): Formability / Ductility Tests		
Experiment No.	Name of the experiment	CO Congruence
EX2-I	Determination of Ductility and Soundness of Flat Metal Specimens by Bend and Re-bend Test	[CO2]
EX2-II	Determination of Drawability of Sheet Metal by Cupping Test (Erichsen Test)	

EX2-I: Determination of Ductility and Soundness of Flat Metal Specimens by Bend and Re-bend Test

Preamble: The bend test is a simple and widely used qualitative test to assess the ductility and soundness (freedom from surface and internal defects) of a metal, particularly of welds and rolled or forged flat products. In this test, the flat specimen is bent through a specified angle over a former (mandrel) of specified diameter, either by a continuous steady pressure or by a series of blows. The bent surface is then examined for the presence of cracks, tears, or other surface defects.

The re-bend test is performed to assess the ability of the material to withstand cold working and to reveal any embrittlement introduced during a previous operation such as welding or cold forming. In this test, the specimen is first bent through a specified angle, then straightened, and subsequently re-bent in the opposite direction through a specified angle. The specimen is considered to have passed the test if no cracks or fractures appear on the outer (tension) surface of the bend during either operation. The bend and re-bend tests thus provide a practical measure of the ductility of the material and its ability to sustain plastic deformation without failure, which is directly related to the bending stress the material can withstand before the onset of surface cracking.



Apparatus: -

1. Universal Testing Machine with bend test attachment



2. Flat test specimen (as per relevant standard, e.g., IS 1599 / IS 2062)
3. Mandrel / former of specified diameter
4. Vernier caliper
5. Steel rule / protractor

Procedure: -

1. Prepare the flat test specimen with the specified width, thickness, and edge condition as per the relevant standard.
2. Measure and record the width and thickness of the specimen using a vernier caliper.
3. Place the specimen on the supports of the bend testing machine/attachment, with the former (mandrel) of specified diameter positioned centrally.
4. Apply the bending load steadily and bend the specimen through the specified angle (e.g., 90° or 180°) over the former.
5. Examine the outer (convex/tension) surface of the bend for cracks, tears, or other defects, and record the observation.
6. Straighten the specimen and re-bend it in the opposite direction through the specified re-bend angle over the same or a specified former diameter.
7. Again, examine the outer surface of the re-bend for cracks or fracture and record the observation along with the corresponding load.

Observations

Initial Measurements

Width of specimen (b) = _____ mm

Thickness of specimen (t) = _____ mm

Diameter of former/mandrel (D) = _____ mm

Bend and Re-bend Test Data

Sl. No.	Type of Test (Bend / Re-bend)	Angle of Bend	Load at Bend, P	Observation (Crack / No Crack)

Calculation:

Bending stress at the outer fibre (for a rectangular specimen bent as a simply supported beam under central load): $f = 3PL/(2bt^2)$, where P is the applied load, L is the span between supports, b is the width, and t is the thickness of the specimen.

Minimum bend radius ratio: r/t , where r is the radius of the former and t is the thickness of the specimen, is used to express the ductility requirement as per the applicable standard.

Result:

Record whether the specimen withstood the specified bend and re-bend angles without any visible cracks, and comment on the ductility and soundness of the material accordingly.

Precautions: -

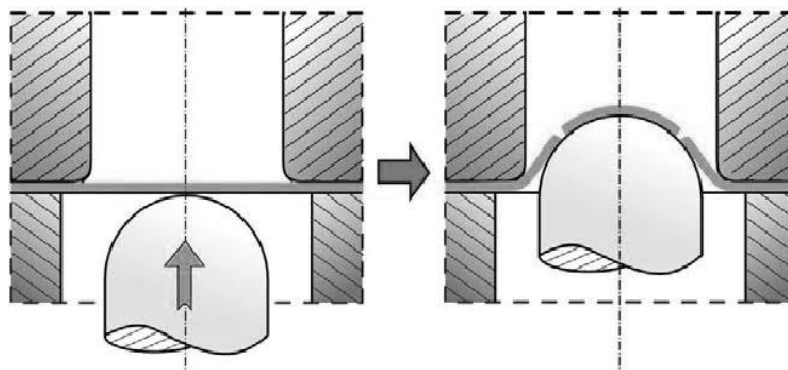
1. Ensure the former diameter and bend angle used correspond to the specified standard for the material and thickness under test.
2. Apply the bending load gradually and uniformly to avoid sudden fracture.
3. Examine the bend surface carefully, preferably with a magnifying glass, for fine surface cracks.
4. Keep hands and fingers clear of the bending former and supports during the test.



EX2-II: Determination of Drawability of Sheet Metal by Cupping Test (Erichsen Test)

Preamble: Sheet metals are extensively used in the manufacture of automobile bodies, utensils, and other pressed components through deep drawing and stamping operations. The suitability of a sheet metal for such forming operations, referred to as its formability or drawability, depends on its ability to undergo severe plastic (biaxial stretching) deformation without cracking or tearing.

The Erichsen cupping test is a simple and widely used index test to evaluate this property. In this test, a sheet metal specimen is firmly clamped between a die and a blank holder, and a hemispherical-ended punch is forced steadily into the sheet from the underside, causing the sheet to stretch and form a cup-shaped indentation. The punch travel continues until the first visible crack appears on the outer (convex) surface of the cup, at which point the depth of the cup (measured on a built-in dial gauge) is recorded as the Erichsen cupping value (or Erichsen index), expressed in millimetres. A higher Erichsen value indicates greater ductility and better drawability of the sheet metal, since the material is able to undergo a greater amount of biaxial plastic stretching before the onset of localized necking and fracture.



Apparatus: -

1. Erichsen Cupping Testing Machine
2. Sheet metal specimen
3. Vernier caliper

Procedure: -

1. Measure and record the thickness of the sheet metal specimen using a micrometer at several points.
2. Clean the surface of the specimen and place it between the die and the blank holder of the cupping testing machine, ensuring it is centred over the die opening.
3. Clamp the specimen firmly by tightening the blank holder to prevent lateral drawing-in of the sheet during the test.
4. Set the dial gauge (cup-depth indicator) to zero.
5. Operate the machine so that the hemispherical punch advances steadily and at a controlled, uniform rate into the sheet, forming a cup.
6. Observe the outer (convex) surface of the forming cup continuously and stop the punch travel immediately when the first visible crack appears.
7. Record the depth of the cup at the instant of cracking, which is the Erichsen cupping value.
8. Repeat the test on at least two more specimens of the same material and take the average value.

Observations

Initial Measurements

Thickness of sheet specimen (t) = _____ mm

Cupping Test Data



Sl. No.	Thickness, t (mm)	Erichsen Index / Cup depth at fracture (mm)	Observation

Calculation / Result:

$$\text{Average Erichsen cupping value} = \frac{\text{Sum of individual cup - depth readings}}{\text{Number of specimens tested}}$$

Comment on the drawability of the sheet metal based on the average Erichsen value obtained: a higher value indicates better formability and greater suitability for deep-drawing operations, while a lower value indicates limited ductility and formability.

Precautions: -

1. Ensure the specimen is clamped uniformly and firmly to prevent any drawing-in of material from the edges during the test.
2. Keep the punch surface clean and adequately lubricated (as specified) to minimise friction effects.
3. Advance the punch at a slow, steady, and uniform rate as specified by the standard.
4. Observe the cup surface carefully and stop the test the instant the first crack appears, to obtain an accurate reading.



INSTRUCTION ITEM-3(II-3): Hardness Tests		
Experiment No.	Name of the experiment	CO Congruence
EX3-I	Determination of Hardness of a Metal Specimen by Brinell Hardness Test	[CO3]
EX3-II	Determination of Hardness of a Metal Specimen by Rockwell Hardness Test	

EX3-I: Determination of Hardness of a Metal Specimen by Brinell Hardness Test

Preamble: Hardness is the resistance of a material to localized plastic deformation, such as indentation, scratching, or abrasion. In engineering practice, hardness is commonly measured by indentation tests, where a harder indenter is pressed into the material surface and the resistance offered is evaluated. *Hardness* does not indicate any single mechanical characteristic (like tensile strength) in absolute terms. It is a relative comparison of different materials with reference to the particular kind of resistance evaluated in a particular machine.

Brinell hardness test: This method consists in forcing a hardened steel ball of 2.5, 5 or 10 mm diameter, at a constant load P into a flat surface of the material. When the load is removed an impression (indentation) remains on the surface.

The *Brinell hardness* number is the ratio of the load applied to the surface area of the impression. In terms of the ball diameter D and the diameter d of the impression, the Brinell hardness number is expressed as.

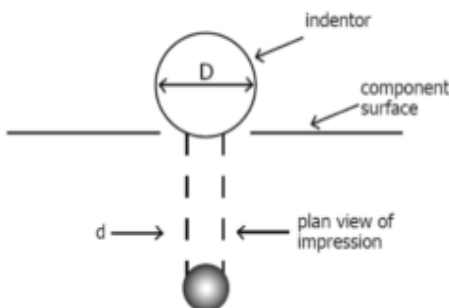
$$BHN = \frac{2P}{\pi D(D - \sqrt{D^2 - d^2})}$$

Where,

P = load applied, kgf.

D = diameter of steel ball indenter, mm.

d = diameter of impression, mm.



In practice, the diameter ' d ' of the impression is measured under a microscope and the Brinell hardness number is read directly from tables. It is not advisable to employ the Brinell tests for metals of hardness exceeding BHN 450 as the ball may be deformed, thereby introducing errors into the test results. The ball diameter D and the load P are selected to suit the composition of the metal, its hardness and the thickness of the test specimen.

LOADS AND INDENTERS:

Ball Diameter (D)	Load P (kgf)			
	Steel & Iron ($30D^2$)	Brass, Aluminium Alloys ($10D^2$)	Aluminium ($5D^2$)	Soft bearing Metals ($2.5D^2$)
10mm	3000	1000	500	250
5mm	750	250	125	62.5
2.5mm	187.5	62.5	31.25	15.625



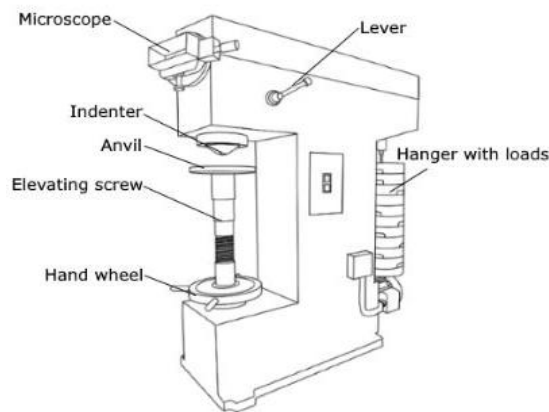
Apparatus:

1. Brinell Hardness Testing Machine
2. Test Specimen
3. Hardened Steel Ball Indenter (2.5, 5, or 10 mm)
4. Optical Microscope / Brinell Microscope
5. Surface Grinder/Polishing Paper (for specimen preparation)

Test Specimen Features:

The selected specimen shall have a thickness at least 8 times the depth of indentation to avoid the deformation to be extended to the opposite surface of a specimen. After the test, no deformation shall be there on the surface of the test piece opposite to the indentation. The surface of the test specimen shall be smooth and even, free from oxide scale, foreign matter and, in particular completely free from lubricants.

The Testing machine: Brinell Hardness Tester model TKB – 3000 is a direct reading hardness testing machine, suitable for measuring the Brinell hardness of steels and other metals whether flat, round, or irregular in shape. The machine is provided with a dial indicator which measures the difference in the depth of indentation produced by minor or major loads. After the application of minor load to the specimen, the dial gauge is automatically set to zero. Final depth reading is taken after the application and removal of major load with minor load of 250 kgf still applied.



Machine specification:

Load range	250 kgf to 3000 kgf
Optical microscope	25 X magnification
Impression depth measurement	Dial gauge (diameter 80 mm)
Drive	Electric motor, 0.5 HP
Maximum test height	410 mm
Depth of throat	200 mm
Maximum depth of spindle below base	180 mm
Mains supply	400/ 440 V, 3phase, 50 Hz
Oil used	Servo 32

Test procedure:

The surface of the specimen on which the impression is to be made should be flat. Measurements obtained on curved surface are only comparative values. The surface should also be smooth clean, dry and free from oxides, scale and pits. Ball holder with steel ball of 10 mm or 5mm diameter and one of the load ranges 3000, 500, 750 and 250 kgf are to be applied in the test.

1. Select the proper diameter ball and put the proper weights such that the combination will suit the material being tested.



2. Start the motor by switching green button of starter and allow the oil to circulate for few minutes. Operate the hand lever from 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 B
4. Start the motor & then take hand –lever from position b to position A and wait until the weight hanger reaches at its top position.
5. Place the specimens on testing table.
6. Turn the hand wheel in clockwise direction so that specimen will push the indicator 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 a 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 reaches a steady position of the load may be maintained for upto 15 seconds. For releasing load, take back the lever to 'A' position. The weights are lifted off and 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. Measure the diameter of impression by Brinell microscope and find out the Brinell Hardness Number referring to the chart.

Observations:

SI No	Material	Diameter of indenter D (mm)	Load P (Kg)	Diameter of indentation d (mm)	BHN	Average BHN
1						
2						
3						

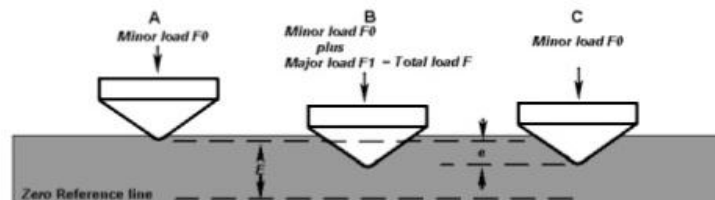
Precautions:

1. Ensure the test surface is clean, flat, and free from scale or oil.
2. Select the correct ball size and load for the material.
3. Maintain adequate specimen thickness to avoid edge effects.
4. Apply the load gradually and hold for the specified dwell time.



EX3-II: Determination of Hardness of a Metal Specimen by Rockwell Hardness Test

Preamble: In a Rockwell test, the hardness is determined by the depth of the indentation and not by its diameter (as in case of Brinell Test). The indenter is a diamond cone with an apex angle of 120° , or a hardened steel ball, 1.5875 mm in diameter. The diamond cone or ball is pressed by two consecutive loads: the minor load P_0 (10 kgf) and the additional load P_1 .



Rockwell hardness is related to an axial travel of the penetrator equal to 0.002 mm. The Rockwell hardness number is,

$$R_A \text{ or } R_C = 100 - e \text{ (For A and C scales)}$$

and

$$R_B = 130 - e \text{ (For B scale)}$$

$$\text{Where, } e = (h - h_0) / 0.002$$

h_0 = depth of penetration of the indenter when only the minor load P_0 is applied

h = depth of penetration of the indenter due to the major (total) load P_1

Measured after removing the additional load P_1 , leaving the minor load P_0 still applied.

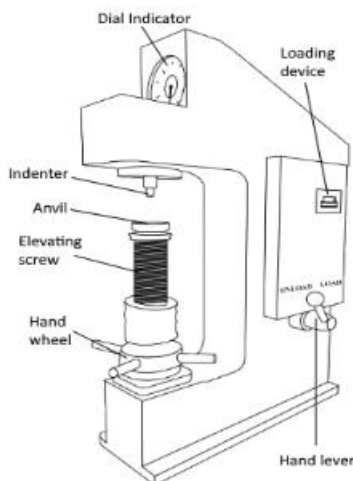
The hardness tester is of cast iron body. The enclosed type design protects the internal operating parts from dust. For normal Rockwell Hardness testing, major load of 60, 100 or 150 kgf is applied including the minor load of 10 kgf. The elevating screw is protected by a rubber bellow. One end of main loading lever is located internally by two bearings and other end is free. The weights under hydraulic dash-pot system control are applied on this free end, which transmits the pressure on diamond holder and thereby on the test piece for the determination of hardness.

Machine Specification:

Model / Make	TRB 250(Fine Testing Machine)
Maximum test height	290 mm
Depth of throat	149 mm
Maximum depth of screw	295 mm
Dimensions of machine base	210 mm x 470 mm

Loads And Indentor:

Scale	Type of indenter (Dimension)	Initial load (kg)	Major load (kg)	Kind of material
A	Cone, 120°	10	50	Much harder such as carburized steel, cemented carbides
B	Ball, 1.58 mm	10	100	Soft steel, copper, aluminium, brass, grey cast iron
C	Cone, 120°	10	150	Spring steel, Ti, W, Va, etc



Apparatus:

1. Rockwell Hardness Testing Machine
2. Indenter (Diamond cone or Steel ball, as per scale used)
3. Test Specimen
4. Surface Grinder/Polishing Paper (for specimen preparation)

Procedure:

1. Keep the lever at position 'A'.
2. Select the suitable indenter according to the scale.
3. Select the weights according to the scale.
4. Place the job on testing table.
5. Turn the hand wheel to raise a job, making contact with penetrator and continue turning until the long pointer of the dial gauge has made two and half turns. Then it stops at 'O' continue turning further till the small pointer reaches at red spot. This is automatic zero setting type dial gauge and manual adjustment is not necessary. In any case small pointer should not go beyond red spot avoid dial gauge damage.
6. Turn the lever from position 'A' to 'B' so that the total load will act.
7. When the long pointer of Dial Gauge reaches a steady position take the lever to 'A' position slowly (sudden release of lever from 'B' to 'A' may show erratic readings)
8. Read off the figure against the long pointer. Outer black scale should be used for Rockwell A & C scale. The inner red scale should be used for Rockwell B scale.
9. Turn back the hand wheel and remove the job.

Observation Table:

Sl No	Material	Initial load (kg)	Major load (kg)	Scale Used	Rockwell Hardness Number (RHN)
1	Spring Steel				
2	Mild Steel				
3	Aluminium				
4	Brass				



Precautions:

1. Ensure the test surface is clean, flat, and free from scale or oil.
2. Select the correct indenter and load for the material.
3. Place the specimen perpendicular to the indenter axis.
4. Apply minor and major loads gradually and smoothly.



INSTRUCTION ITEM-4(II-4): Dynamic Loading Tests		
Experiment No.	Name of the experiment	CO Congruence
EX4-I	Determination of Impact Strength of a Metal Specimen by Charpy and Izod Impact Tests	[CO4]
EX4-II	Determination of Fatigue Strength (Endurance Limit) of a Metal Specimen by Fatigue Testing	

EX4-I: Determination of Impact Strength of a Metal Specimen by Charpy and Izod Impact Tests

Preamble: Impact tests are used to evaluate the toughness of materials under high strain rate loading conditions. They measure the energy absorbed by a specimen during fracture when subjected to a sudden blow. The test utilizes a pendulum impact testing machine. A pendulum hammer is released from a specific initial height (h_0), striking the specimen at the bottom of its swing. The energy absorbed by the specimen during fracture causes the pendulum to rise to a lower final height (h_f). The difference in potential energy before and after the strike represents the energy required to fracture the specimen. The fracture energy (E) is calculated as follows:

$$E = mg(h_0 - h_f)$$

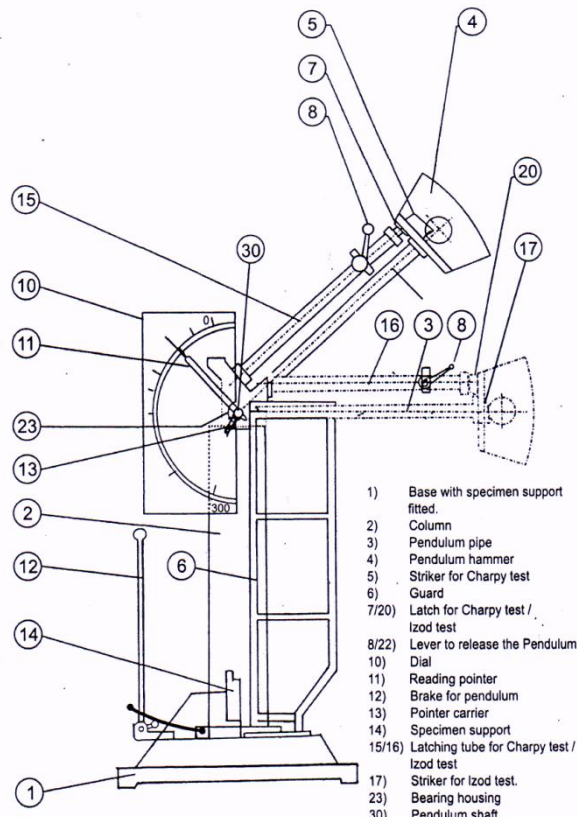
Where:

m = Mass of the hammer

g = Acceleration due to gravity

h_0 = Initial height of the pendulum

h_f = Final height after fracturing the specimen





Impact strength is defined as the energy absorbed per unit cross-sectional area at the notch. The notch creates stress concentration and ensures fracture at a specific location. Ductile materials absorb higher energy, whereas brittle materials absorb less energy.

Impact strength (I) is defined as the energy absorbed per unit cross-sectional area at the notch:

$$I = E/A$$

Where A is the cross-sectional area at the notch.

Friction Loss (E_f):

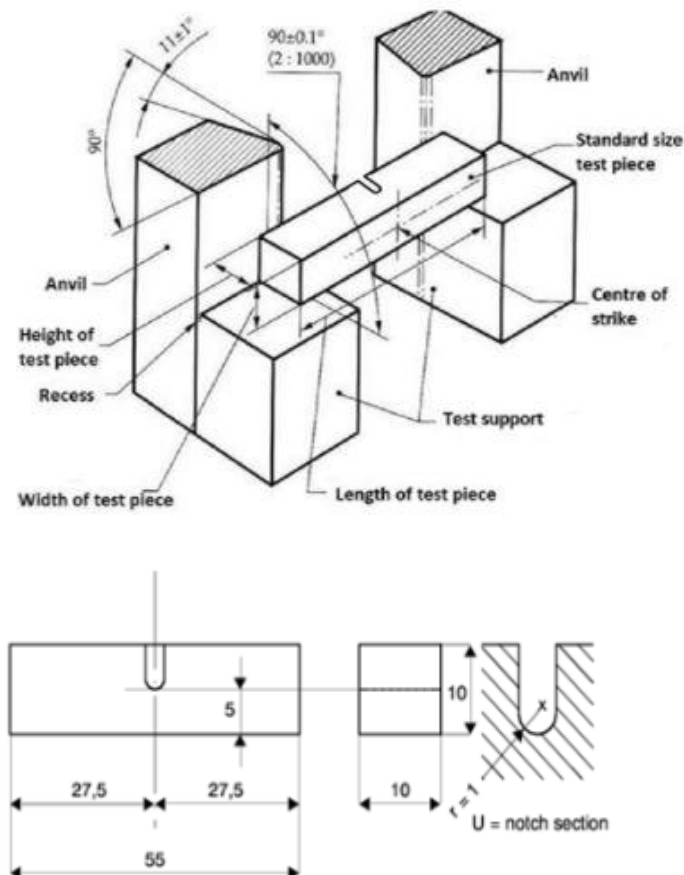
The testing machine consists of a pendulum mounted on a shaft rotating on bearings. During operation, some energy is lost due to friction in bearings and air resistance. This is determined by conducting a free swing test without specimen. The corrected energy absorbed by the specimen is:

$$E = E_t - E_f$$

where E_t is the total indicated energy.

Charpy Impact Test:

The Charpy impact test is performed on a simply supported notched specimen struck at its midpoint opposite to the notch. This test is widely used in the construction and heavy machinery industries to evaluate a material's behavior under high-strain rates and determine its ductile-to-brittle transition temperature. The standard test piece shall be machined all over and shall have a square cross-section 10 mm x 10 mm sides, 55 mm long and in the centre of the length of one face there shall be a U-notch of specified depth with 1 mm root radius.





Procedure:

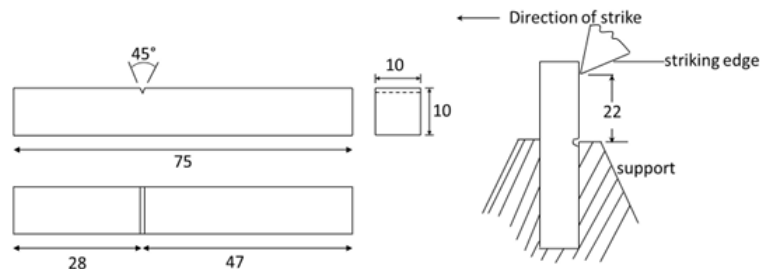
1. Position the hammer for the Charpy test and perform a free swing to measure friction error (E_f).
2. Place the specimen horizontally in the machine holder/supports with the notch facing away from the pendulum.
3. Raise the hammer to its extreme starting position and release it using the trigger.
4. After the specimen ruptures, record the energy (E_i) from the circular dial scale.

Observation Table:

Sl. No.	Material	Area, A (mm ²)	Energy loss, E_f (J)	Total Energy, E_t (J)	Energy required to before failure, $E = E_t - E_f$ (J)	Impact Strength, $I = E/A$ (J/mm ²)	Average Impact Strength
1							
2							
3							

Izod Impact Test:

The Izod test differs primarily in specimen orientation. The specimen is clamped at one end as a vertical cantilever beam. The pendulum strikes the free end at a distance of 22 mm from the notch. This test is primarily utilized in the plastics and polymers industry to assess the toughness of materials used in consumer goods and components prone to sudden impacts. Unlike the Charpy hammer (vertical plane mass distribution), the Izod hammer mass is distributed in a horizontal plane. The standard test piece of overall length of 75mm and a square cross-section of 10mm side with a standard 45° notch, 2mm deep is employed for the test. The notch is at 28mm from one end.



Apparatus Required for Charpy and Izod Impact Tests:

1. Impact Testing Machine
2. Test Specimen (notched, as per standard)
3. Specimen Support/Anvil (Charpy) or Vice/Clamp (Izod)
4. Vernier Caliper

Procedure:

1. Adjust the anvil and hammer positions specifically for the Izod test configuration.
2. Perform a free swing to measure any friction error (E_f).
3. Clamp the specimen vertically in the holder so the notch faces the direction of impact and is level with the support.
4. Release the hammer from its starting position to rupture the specimen.
5. Record the energy absorbed (E_i) from the dial.



Observation Table:

Sl. No.	Material	Area, A (mm ²)	Energy loss, E _f (J)	Total Energy, E _t (J)	Energy required to before failure, E=E _t -E _f (J)	Impact Strength, I=E/A (J/mm ²)	Average Impact Strength
1							
2							
3							

Precautions for Charpy and Izod Impact Tests:

1. Ensure correct specimen dimensions and notch as per standard.
2. Position/clamp the specimen properly.
3. Release the pendulum only after the specimen is correctly set.
4. Keep clear of the pendulum's swing path during the test.

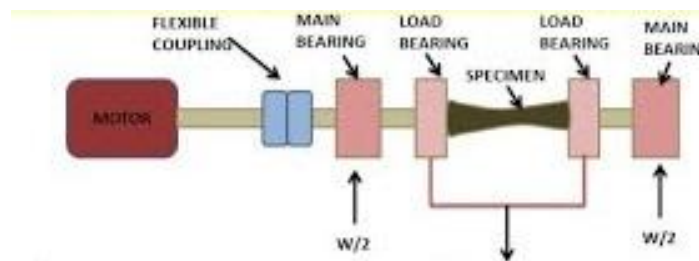


EX4-II: Determination of Fatigue Strength (Endurance Limit) of a Metal Specimen by Fatigue Testing

Preamble: Many machine components and structures are subjected not to a single static load but to loads that vary repeatedly or cyclically with time. Under such repeated or fluctuating loading, a component may fail at a stress level considerably lower than its ultimate tensile strength, and even lower than its yield strength. This phenomenon of failure under repeated or cyclic loading is known as fatigue.

Fatigue failure occurs in three distinct stages: (i) crack initiation, generally at a point of stress concentration such as a surface scratch, tool mark, fillet, or material inhomogeneity; (ii) crack propagation, during which the crack advances a small amount with every stress cycle, often leaving characteristic 'beach marks' or striations on the fracture surface; and (iii) final sudden fracture, which occurs when the remaining cross-section can no longer support the applied load.

The fatigue behaviour of a material is commonly represented by the S-N curve, a plot of the applied stress amplitude (S) against the number of cycles to failure (N), usually plotted with N on a logarithmic scale. For many ferrous materials, the S-N curve becomes nearly horizontal beyond a certain number of cycles (typically about 10^6 - 10^7 cycles), and the corresponding stress is called the endurance limit or fatigue limit — the stress below which the material can withstand an practically infinite number of load cycles without failure. In the rotating cantilever beam test, a specimen is rotated at constant speed while a static bending load is applied at the free end, so that every point on the specimen surface experiences a fully reversed (tension-compression) stress cycle with each revolution.



Apparatus: -

1. Rotating Bending Fatigue Testing Machine
2. Standard fatigue test specimen (with polished gauge section)
3. Vernier caliper / micrometer
4. Weights / loading system
5. Cycle (revolution) counter

Procedure: -

1. Measure the diameter of the specimen at the minimum (gauge) section using a micrometer.
2. Mount the specimen securely in the chuck of the rotating bending fatigue testing machine.
3. Select the desired stress level and calculate the corresponding bending load to be applied at the free end.
4. Apply the calculated load through the loading system and set the revolution counter to zero.
5. Start the machine and allow the specimen to rotate under the applied bending load; the machine automatically stops (and the counter records the cycles) when the specimen fractures.
6. Note the number of cycles to failure (N) for the selected stress level (S).
7. Repeat the test with new specimens at several different stress levels, both above and below the expected endurance limit.
8. Plot the S-N curve (stress versus number of cycles to failure, N on log scale) and determine the endurance limit of the material.



Observations

Initial Measurements

Diameter of specimen at gauge section (d) = _____ mm

Stress vs Number of Cycles Data

Sl. No.	Applied Load, W (N)	Bending Stress, S (MPa)	Number of Cycles to Failure, N

Calculation:

Section modulus of specimen: $Z = \left(\frac{\pi}{32}\right) \cdot d^3$

Maximum bending stress at the gauge section: $S = \frac{M}{Z} = \frac{W \times l}{Z}$, where l is the effective lever arm (distance from the point of load application to the critical section).

Plot the graph of S (y-axis) versus log N (x-axis) to obtain the S-N curve, and read off the endurance limit as the stress level corresponding to the flattening of the curve.

Precautions: -

1. Ensure the gauge section of the specimen is free from scratches, tool marks, and other stress raisers, as these significantly reduce fatigue life.
2. Mount the specimen accurately and check for concentricity to avoid unintended eccentric loading.
3. Do not disturb or touch the machine while the specimen is rotating under load.
4. Apply/remove the load gently to avoid shock loading of the specimen.



INSTRUCTION ITEM-5(II-5): Metallurgical / Microstructural Examination		
Experiment No.	Name of the experiment	CO Congruence
EX5-I	Study of Microstructure of Metals through Sample Preparation, Heat Treatment, and Metallographic Examination	[CO5]

EX5-I: Study of Microstructure of Metals through Sample Preparation, Heat Treatment, and Metallographic Examination

Preamble: Metallography is the study of the microstructure of metals and alloys, which is closely related to their mechanical properties, processing history, and heat treatment condition. A properly prepared metallographic specimen must have a flat, scratch-free, mirror-like surface so that the true microstructure — grain boundaries, phases, and any inclusions or defects — can be revealed and examined under a microscope. Specimen preparation broadly involves sectioning, mounting, grinding through progressively finer abrasives, polishing to a mirror finish, and finally etching with a suitable reagent, which selectively attacks grain boundaries and different phases at different rates, thereby revealing the microstructure under reflected light.

Heat treatment refers to a set of controlled heating and cooling operations applied to a metal or alloy in the solid state to alter its microstructure and, consequently, its mechanical properties, without changing its shape. For plain carbon steels, the common heat treatment processes are: annealing (heating to the austenitizing temperature followed by slow cooling in the furnace), which produces a coarse pearlite-ferrite structure and improves ductility and machinability while reducing hardness; normalizing (heating to the austenitizing temperature followed by cooling in still air), which refines the grain structure and gives a finer pearlite-ferrite structure with moderate strength and hardness; hardening (heating to the austenitizing temperature followed by rapid quenching, typically in water or oil), which produces a hard and brittle martensitic structure by suppressing diffusion-controlled transformation; and tempering (reheating the hardened steel to a temperature below the lower critical temperature and holding, followed by cooling), which relieves internal stresses and converts brittle martensite into tougher tempered martensite, with an accompanying reduction in hardness and increase in toughness.

Apparatus: -

1. Muffle furnace (with temperature controller)
2. Power hacksaw / abrasive cutting machine
3. Mounting press / cold-setting mounting resin (Bakelite)
4. Belt grinder and emery papers (grades 220 to 1200)
5. Disc polishing machine with alumina/diamond polishing paste and cloth wheel
6. Etchant (2% Nital solution)
7. Metallurgical (optical) microscope with camera attachment
8. Hardness testing machine (Rockwell / Brinell)

Procedure: -

1. Take a set of identical carbon steel specimens and heat them in the muffle furnace to the austenitizing temperature (approximately 830–870°C, depending on carbon content) and soak for the specified holding time.
2. Cool the specimens by different methods to obtain different heat-treated conditions: cool one specimen slowly inside the furnace (annealing), cool one specimen in still air (normalizing), and quench one specimen rapidly in water/oil (hardening).
3. Cut (if required) a suitably sized specimen from each heat-treated sample using a power hacksaw/abrasive cutter, ensuring the cutting operation does not overheat and alter the microstructure.
4. Mount the specimen in Bakelite (or cold-setting resin) to obtain a specimen of convenient size for handling.
5. Grind the mounted specimen successively on emery papers of progressively finer grade (220, 400, 600, 800, 1000, 1200), rotating the specimen through 90° between each grade and washing thoroughly before proceeding to the next grade.



6. Polish the ground specimen on a rotating disc polishing machine using alumina or diamond paste on a cloth wheel until a mirror-like, scratch-free surface is obtained.
7. Etch the polished specimen by swabbing with 2% Nital solution for about 10–15 seconds, then wash immediately with water and alcohol and dry.
8. Examine the etched specimen under the metallurgical microscope at suitable magnification, and note down/photograph the observed microstructure.
9. Determine the hardness of each heat-treated specimen using the Rockwell/Brinell hardness testing machine.

Observations

Metallographic and Hardness Data

Sl. No.	Heat Treatment Condition	Cooling Medium	Hardness (HRC/BHN)	Microstructure Observed

Calculation:

Tabulate and compare the hardness values obtained for the as-received, annealed, normalized, hardened, and tempered conditions of the specimen, and correlate the observed hardness with the corresponding microstructure (proportion and morphology of ferrite, pearlite, martensite, or tempered martensite present).

Precautions: -

1. Avoid excessive pressure or overheating of the specimen during cutting and grinding, as this can alter the true microstructure.
2. Wash the specimen thoroughly between successive grades of emery paper to prevent contamination by coarser abrasive particles.
3. Handle the etchant (Nital) with care, using gloves and working in a well-ventilated area/fume hood.
4. Use furnace tongs and heat-resistant gloves while handling hot specimens and while quenching, and wear safety goggles and an apron.
5. Ensure the specimen surface is completely dry before placing it under the microscope.



INSTRUCTION ITEM-6(II-6): Non-Destructive Testing (NDT)		
Experiment No.	Name of the experiment	CO Congruence
EX6-I	Detection of Surface Defects in Materials by Non-Destructive Testing (Dye Penetrant) Method.	[CO6]

EX6-I: Detection of Surface Defects in Materials by Non-Destructive Testing (Dye Penetrant) Method

Preamble: Non-destructive testing (NDT) comprises a group of inspection techniques used to evaluate the properties, detect defects, and assess the integrity of a material, component, or structure without causing any damage to it, thereby permitting the component to remain in service after testing. NDT methods are widely used for quality control during manufacture as well as for in-service inspection.

Dye penetrant testing (DPT) is used to detect defects open to the surface, such as cracks, porosity, and laps, in both ferrous and non-ferrous materials. It works on the principle of capillary action: a low-viscosity, brightly coloured (or fluorescent) penetrant liquid is applied to the cleaned surface and allowed to seep into any surface-breaking discontinuities during a dwell period; the excess penetrant is then removed from the surface, and a developer is applied, which draws the trapped penetrant back out by reverse capillary action to form a visible indication at the defect.

Apparatus: -

1. Test specimens/components with known or suspected surface defects
2. Dye penetrant test kit (cleaner, red dye penetrant, developer)

Procedure: -

1. Clean the test surface thoroughly with the cleaner/remover to free it of dirt, oil, and grease.
2. Apply the red dye penetrant liberally over the surface and allow it to remain undisturbed for the specified dwell time so that it can seep into any surface defects.
3. Remove the excess surface penetrant carefully using a clean cloth moistened with cleaner, without disturbing the penetrant trapped inside any defect.
4. Apply a thin, even coat of the white developer over the surface and allow the specified development time.
5. Inspect the surface for the appearance of red indications (bleed-out) against the white background, and record the location and pattern of any indications found.

Observations

Non-Destructive Test Results

Sl. No.	Specimen No.	Defect Location	Defect Type / Remarks

Precautions: -

1. Ensure the test surface is properly cleaned before and between each stage of the dye penetrant test.
2. Handle penetrant, cleaner, and developer chemicals with adequate ventilation and avoid prolonged skin contact; use gloves where necessary.