

LAB MANUAL

(10A61)

METALLOGRAPHY AND MATERIAL TESTING LAB



Name of the Student : _____

University Seat Number : _____

Semester : _____ Batch : _____



SS MAHAVJDYAPEETHA

SRJ JAYACHAMARAJENDRA COLLEGE OF ENGINEERING

**DEPARTMENT OF INDUSTRIAL & PRODUCTION ENGINEERING
(AUTONOMOUS SCHEME)**

INTRODUCTION

One of the principle concerns of an engineer is the analysis of materials used in structural applications. The term structure refers to any design that utilizes materials that support loads and keeps deformation within acceptable limits. Elementary mechanics of materials or strength of materials is the physical science that looks at the reaction of a body to movement and deformation due to mechanical, thermal, or other loads.

In this laboratory, students will have the opportunity to apply loads to various materials under different equilibrium conditions. The student will perform tests on materials in tension, torsion, bending, etc. These conditions and/or constraints are designed to reinforce classroom theory by having the student perform required tests, analyze subsequent data, and present the results in a professionally prepared report.

COURSE OBJECTIVES

1. To understand the behavior of material and to determine its mechanical properties, when it is subjected to various types of external loads.
2. To study the mechanical characteristics such as hardness, wear and creep of materials.
3. To study the various modes of fracture under different conditions.
4. To understand the behavior of material under various heat treatment processes.
5. To prepare the specimens and to conduct metallographic examination for identifying its microstructure.

COURSE OUTCOMES

Upon completion of the course student will demonstrate the ability to:

1. Determine materials properties based on tension, bending, torsion, etc.
2. Identify the structure under microscope and determine its characteristics and composition.
3. To carry out heat treatment process for a material and determine its hardness.
4. Perform pre-laboratory calculations to estimate experimental parameters, outcomes and limits, develop an organized and meaningful data sheet.
5. Use the laboratory equipment correctly and safely to perform all experiments.
6. Write experimental objectives and procedures.
7. Present results in an organized and clear manner, draw graphs and figures to summarize key findings.

PREREQUISITES

Elements of Mechanical Engineering, Engineering Graphics, Material Science & Metallurgy and Mechanics of Materials.

EXPERIMENT 1 - TENSILE TEST ON DUCTILE AND BRITTLE MATERIALS

AIM: To develop an understanding of stress-strain curves of materials, and learn how to use them to determine various mechanical properties of ductile (mild steel) and brittle materials (cast iron).

APPARATUS: Universal Testing Machine, mild steel/ cast iron specimen, extensometer, vernier caliper / micrometer etc.

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 materials itself and must be determined by experiment. One of the most important tests to perform in this regard is the tension test.

Although many important mechanical properties of a material can be determined from this test, it is used primarily to determine the relationship between the average normal stress and average normal strain in many engineering materials such as metals, ceramics, polymers, and composites.

To perform the tension test a specimen of the material is made into a standard shape and size as shown in Figure 1.1.

A uniaxial tensile load is applied slowly to stretch the specimen at a very slow, constant rate until it reaches the breaking point, using Universal Testing Machine (UTM). The machine is designed to read the load required to maintain this uniform stretching and display the final load at failure point. As the load continues to increase on specimen, a brittle material tends to fail suddenly with very little plastic deformation. Whereas a ductile material undergoes a substantial reduction in cross section area, known as necking, before reaching a breaking point. The two modes of failure are shown in Figure 1.2. Also the typical stress vs strain curve for mild steel and cast iron are shown in Figure 1.3.

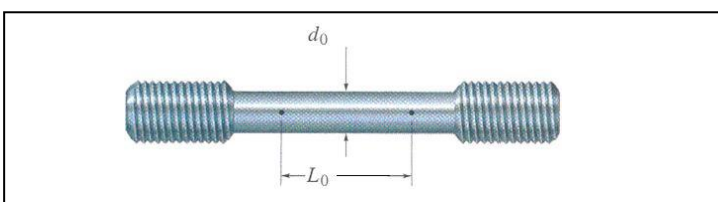


Figure 1.1 Tension test specimen

$L_0 = \text{Initial Gauge Length}$

$d_0 = \text{Initial Diameter}$



Figure 1.2. Failure in ductile and brittle materials

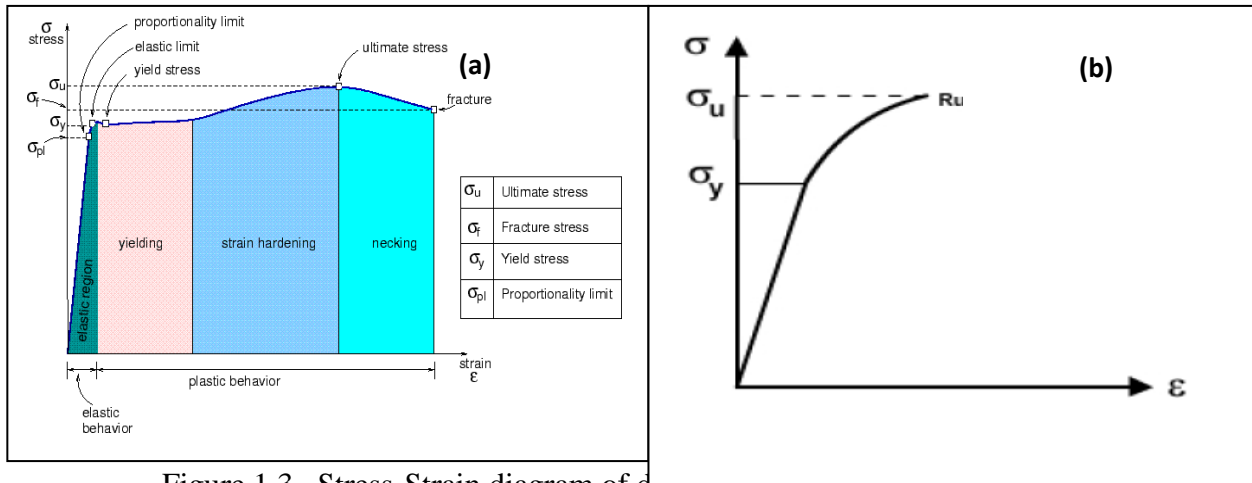


Figure 1.3 – Stress-Strain diagram of ductile (a) and brittle materials (b)

PROCEDURE

1. Measure the diameter of the test specimen by means of a screw gauge at least at three sections and obtain the mean value. Also mark and measure the gauge length.
2. Insert suitable jaws in the grips and select load scale on the testing machine.
3. Firmly grip the specimen into the jaws of upper and lower cross heads in such a way that the gauge mark faces the front of the machine.
4. Mount the extensometer on the test specimen to measure the deformation within the gauge length, and adjust dial gauge reading to zero.
5. Set also the automatic graph recording system, if desired.
6. Select suitable increments of loads to be applied so that corresponding elongation can be measured from dial gauge.
7. Start the machine for gradual application of the load at slow speed and take simultaneous observation of load and dial reading of the extensometer for particular interval of load.
8. When the increment of load leads to disproportionate extension (Indication of definite sign of yield point), stop the machine and remove the extensometer (to avoid damage to the extensometer). Again continue to load the specimen and take readings of the extension of the graduated vernier scale.
9. Record the yield point load P_y , maximum load P_{max} and load at fracture P_{fail} .
10. Remove the specimen from machine and study the fracture.
11. Fit the broken parts together and measure reduced diameter and final gage length.
12. Plot stress – strain diagram and determine all the required mechanical properties.

DATA SHEET-TENSILE TEST

OBSERVATIONS

Material : E = N/mm^2

Least count of Vernier / Micrometer = mm

Initial gauge length, $L_o =$ mm

Initial diameter, $d_o =$ mm

Original cross sectional area, $A_o = \frac{\pi}{4} d_o^2 =$ mm²

Final gauge length, $L =$ mm

Final diameter, $d =$ mm

Final cross sectional area, $A = \frac{\pi}{4} d^2 =$ mm²

Yield load, $P_{uy} = N$ $P_{ly} =$ N

Maximum load, $P_{max} = N$

Fracture load, $P_{fail} = N$

Young's Modulus, E = N/mm^2

(From slope of the linear portion of the stress-strain diagram)

Yield stress, $\sigma_y = \frac{P_y}{A_o}$ N/mm^2

Strain, $\epsilon = \frac{\sigma_y}{E} =$

Strain energy density (Modulus of resilience), $U = \frac{\sigma_y^2}{2E} =$ N-mm

Ultimate stress, $\sigma_u = \frac{P_{max}}{A_o}$ N/mm^2

Fracture stress, $\sigma_f = \frac{P_{fail}}{A_o}$ N/mm^2

Strain at fracture, $\epsilon_f =$

Toughness = $\sigma_f \epsilon_f$

Percentage elongation in length, $\frac{L - L_o}{L} \times 100 =$ %

Percentage reduction in area, $\frac{d_o^2 - d^2}{d_o^2} \times 100 =$ %

d_1			d_2			d_3		
MSR	VSR	TR	MSR	VSR	TR	MSR	VSR	TR

Tabular Column:

Sl. No.	Load P (kN)	Deflection Δ (mm)	Stress (N/mm ²) $\sigma = \frac{P}{A_0}$	Strain $\epsilon = \frac{\Delta}{L_0}$	True Stress (N/mm ²) $\sigma_{true} = \sigma(1 + \epsilon)$	True Strain $\delta = \ln(1 + \epsilon)$
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						
11.						
12.						
13.						
14.						
15.						
16.						
17.						
18.						
19.						
20.						
21.						

GRAPH: Draw graph of a) Load v/s Deflection b) Stress v/s Strain c) True stress v/s True strain

Results:

Sl.No.	Mechanical Properties	Material			
		Mild Steel	Cast Iron	Aluminum	Wood
1.	Modulus of Elasticity (Young's Modulus)				
2.	Stiffness				
3.	Yield Stress				
4.	Strain Energy Density (Modulus of Elastic Resilience)				
5.	Tensile Strength (Ultimate Stress)				
6.	Strain at Fracture				
7.	Toughness				

Experiment Evaluation

Conduction (10)	Write up (05)	Results (05)	Viva (05)	Total (25)
Faculty Signature				

EXPERIMENT 2 - IMPACT TEST

AIM : To determine the impact toughness (strain energy) through Izod test and Charpy test

APPARATUS : Pendulum type impact testing machine, setting gauge, vernier caliper.

THEORY

Many times an accidental fall of the material from our hands results in its breaking into pieces. This type of brittle behavior of materials is most undesirable for common engineering objects. A simple tensile test does not reveal the brittle nature of metals, and if only the tensile test data are relied upon and the object is put into use, failure is certain. It is, therefore, necessary to test the material under shock or sudden loading conditions.

In a impact test a specially prepared notched specimen is fractured by a single blow from a heavy hammer and energy required being a measure of resistance to impact. Impact load is produced by a swinging of an impact weight W (hammer) from a height h . Release of the weight from the height h swings the weight through the arc of a circle of radius R , which strikes the specimen to fracture at the notch as shown in Figure 2.1.

Kinetic energy of the hammer at the time of impact is $mv^2/2$, which is equal to the relative potential energy of the hammer before its release. (mgh), where m is the mass of the hammer and $\sqrt{2gh}$ is its tangential velocity at impact, g is gravitational acceleration (9.806 m/s^2) and h is the height through which hammer falls. Impact velocity will be 5.126 m/s or slightly less.

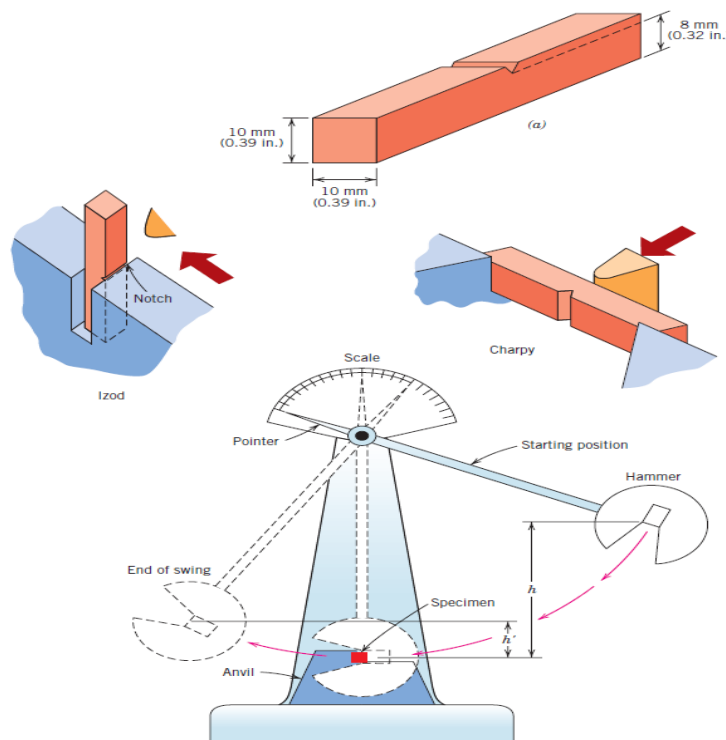


Figure 2.1. Pendulum type impact test machine.

Here it is interesting to note that height through which hammer drops determines the velocity and height and mass of a hammer combined determine the energy. Energy used can be measured from the scale given. The difference between potential energies is the fracture energy. In test machine this value is indicated by the pointer on the scale. If the scale is calibrated in energy units, marks on the scale should be drawn keeping in view angle of fall (θ) and angle of rise. Height h_1 and h_2 equals, $h_1 = R(1 - \cos\theta)$ and $h_2 = (1 - \cos\theta)$.

With the increase or decrease in values, gap between marks on scale showing energy also increase or decrease. This can be seen from the attached scale with any impact machine.

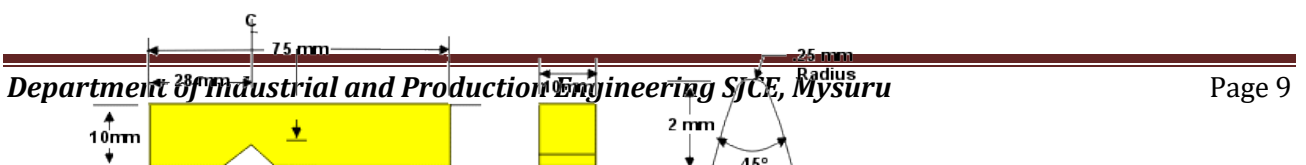
Energy used in fracturing the specimen can be obtained approximately as $(W \times h_1 - W \times h_2)$. This energy value called impact toughness or impact value, which will be measured, per unit area at the notch.

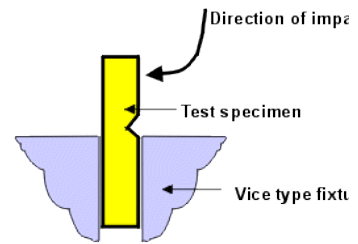
PROCEDURE

1. Measure the dimensions of a specimen. Also, measure the dimensions of the notch.
2. The latching tube is to be firmly clamped to the bearing housings at the side.
3. **Frictional loss:** Before proceeding to the actual test, the test for determining the frictional loss in the machine is to be conducted. Adjust the pointer with pointer carrier to 300 Joules (max) reading on the dial when the pendulum is hanging free vertically. For this, use socket head screw of the carrier. Now raise the pendulum hammer manually and latch in. Operate the lever so that pendulum is released and the specimen is hit. The pointer will then indicate the energy loss due to friction. From this reading, confirm that the friction loss is not exceeding 0.5 % of the initial potential energy.
4. Raise the hammer (with a proper striker secured firmly to the bottom of the hammer with the help of clamping piece) and note down initial reading from the dial, which will be energy to be used to fracture the specimen.
5. Place the specimen for test and see that it is placed center with respect to hammer. Check the position of notch (should be opposite to the direction of impact of the pendulum).
6. Release the hammer and note the final reading. Difference between the initial and final reading will give the actual energy required to fracture the specimen.
7. Compute the energy of rupture of each specimen.

DATA SHEET-IZOD IMPACT TEST

SPECIMEN





OBSERVATIONS

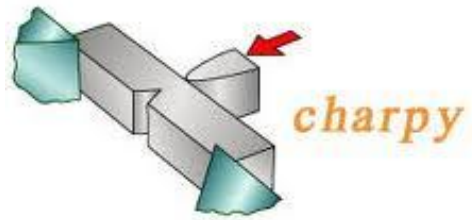
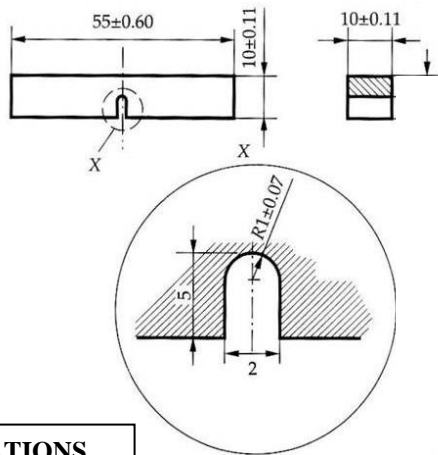
1. Original size of the specimen, $75 \times 10 \times 10$
2. Depth of V- notch, $d = 2 \text{ mm}$
3. Cross-sectional area at notch $A_{\text{notch}} = 8 \times 10 = \text{mm}^2$
4. Weight of hammer $W = \text{kg}$
5. Length/radius of pendulum $R = \text{m}$
6. Angle of notch $\theta = 45^\circ / 60^\circ$
7. Angle of fall $\alpha =$
8. Impact strength, $\frac{\text{Fracture Energy}}{A_{\text{Notch}}} = \text{N-m} / \text{m}^2$

Material	Fracture energy from scale $N-m (J)$	Impact strength of the material $N-m / m^2 (J / m^2)$

RESULT:

DATA SHEET-CHARPY IMPACT TEST

SPECIMEN



OBSERVATIONS

1. Original size of the specimen, 55 × 10 × 10
2. Depth of U - notch, d= 5 mm
3. Width of notch, b= 2 mm
4. Cross-sectional area at notch $A_{notch}=10 \times 5=$ mm²
5. Weight of hammer W = kg
6. Length/radius of pendulum R= m
7. Angle of fall $\alpha =$
8. Impact strength, $\frac{\text{Fracture Energy}}{A_{Notch}} =$ N/m

Material	Fracture energy from scale N-m (J)	Impact strength of the material N-m / m ² (J / m ²)

RESULT:

EXPERIMENT 3 - HARDNESS TEST

INTRODUCTION

Hardness is the property of a material that enables it to resist plastic deformation, usually by penetration. However, the term hardness may also refer to resistance to bending, scratching, abrasion or cutting.

There are three general types of hardness measurements

- 1) Scratch hardness: The ability of material to scratch on one another
- 2) Indentation hardness: Major important engineering interest for metals.

Different types : Brinell, Meyer, Vickers, Rockwell hardness tests.

- 3) Rebound or dynamic hardness: The indenter is dropped onto the metal surface and the hardness is expressed as the energy of impact.

APPLICATIONS

- Hardness tests can be used for many engineering applications to achieve the basic requirement of mechanical property.
- Surface treatments where surface hardness has been much improved.
- Powder metallurgy
- Fabricated parts: forgings, rolled plates, extrusions, machined parts.

A) Brinell hardness test

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

APPARATUS: Brinell hardness tester, aluminum specimen and Ball indenter.

THEORY

In Brinell hardness test, a steel ball of diameter (D) is forced under a load (F) on to a surface of test specimen. Mean diameter (d) of indentation is measured after the removal of the load (F) as shown in Figure 3.1.

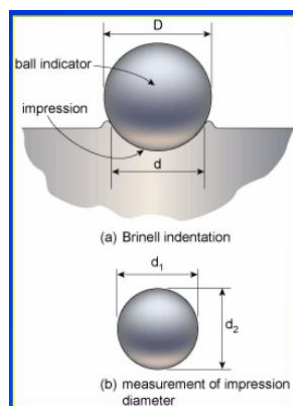


Figure 3.1. Measurement of diameter of indentation.

PROCEDURE

1. Place the specimen securely on testing table.

2. Turn the hand wheel in clockwise direction so that specimen will push the indenter and will show a reading on dial gauge.
3. Load to be applied for hardness test should be selected according to the expected hardness of the material. However test load shall be kept equal to 30 times the square of the diameter of the ball (diameter in mm) $F=30D^2$, where ball diameter, generally taken as 10 mm.
4. Apply the load for a minimum of 15 seconds to 30 seconds. [if ferrous metals are to be tested time applied will be 15 seconds and for softer metal 30 seconds]
5. Remove the load and measure the diameter of indentation using microscope (projected image)
6. Calculate Brinell Hardness Number (BHN).

Disadvantage of Brinell Hardness Test: The main disadvantage of the Brinell Hardness test is that the Brinell hardness number is not independent of the applied load. This can be realized from considering the geometry of indentations for increasing loads as shown in Figure 3.2. As the ball is pressed into the surface under increasing load the geometry of the indentation changes.

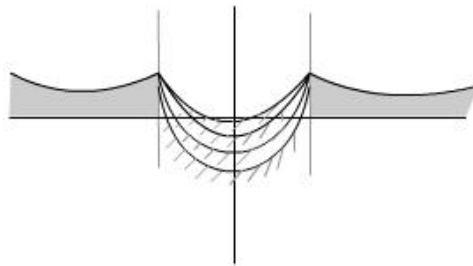


Figure 3.2. Indentation geometry w.r.t load.

Here what we mean is that the geometry of the impression should not change w.r.t. load, however the size it impresses may change.

B) Vickers hardness test

The Vickers hardness test method consists of indenting the test material with a diamond indenter, in the form of a right pyramid with a square base and an angle of 136 degrees between opposite faces subjected to a load of 1 to 100 kgf. The full load is normally applied for 10 to 15 seconds. The two diagonals of the indentation left in the surface of the material after removal of the load are measured using a microscope and their average calculated as shown in Figure 3.3. The area of the sloping surface of the indentation is calculated. The Vickers hardness is the quotient obtained by dividing the kgf load by the square mm area of indentation.

When the mean diagonal of the indentation has been determined the Vickers hardness may be calculated from the formula

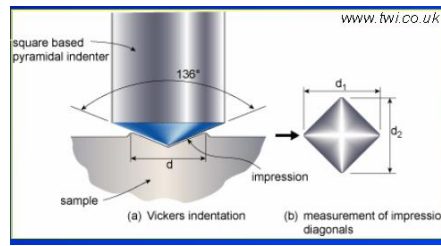


Figure 3.3 Diagonals of the indentation

The advantages of the Vickers hardness test are that extremely accurate readings can be taken, and just one type of indenter is used for all types of metals and surface treatments. The Vickers method is capable of testing the softest and hardest of materials, under varying loads.

C) Rockwell Hardness test

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

APPARATUS: Rockwell hardness testing machine, Black diamond cone indenter, Hard steel specimen.

THEORY

This test is an indentation test used for smaller specimens and harder materials. The Rockwell Hardness test also uses an indenter when is pressed into the flat surface of the test piece, but differs from the Brinell and Vicker's test in that the measurement of hardness is based on the depth of penetration, not on the surface area of indentation. The indenter may be a conical diamond of 120° included angle, with a rounded apex. It is brought into contact with the test piece, and a force F is applied.

ADVANTAGES:

1. It is quicker.
2. The dial indicator gives the hardness directly (without the necessity of using the microscope for measuring the indentation).
3. The use of diamond cone penetrator enables the test to be used for high ranges of hardness which are not possible with the Brinell test.

PRINCIPLE OF THE TEST:

This test is based on the measurement of the depth of penetration of the indenter. In order to eliminate zero error and possible surface effects due to roughness, an initial load (called the minor load) of 10 kgf is first applied to the indenter, and the depth of penetration then reached is taken as zero for further measurements as shown in Figure 3.4. The details of loads and indenters are given in Table 3.1.

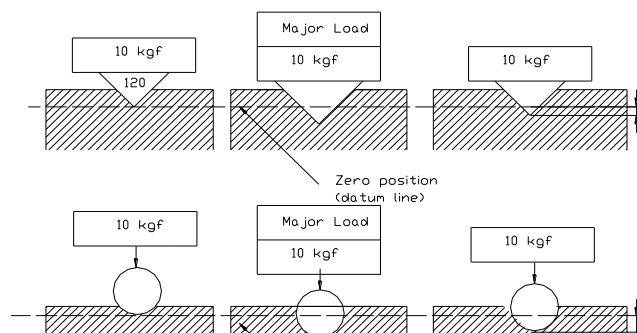


Figure 3.4.Measurement of the depth of penetration of the indenter.

Table3.1 Details of indenters, loads for B & C tests

Particulars	Rockwell B	Rockwell C
Indenter	$\frac{1}{16}$ inch(1.59 mm) dia ball	Diamond cone with 120 deg. apex angle
Minor load Kgf	10	10
Major load Kgf	90	140
Total load Kgf	100	150
Dial scale mark	Red (inner)	Black (outer)
Pointer position on dial	30 (inner scale)	00 (outer scale)

Table below gives the details of indenters, loads for B & C tests.

In direct reading hardness tester, B scale is marked in red and C scale in black. Zero of C scale is opposite to figure 30 on B scale, so that there is a difference of 30 hardness number.

Rockwell Hardness is expressed as a dimensionless number and is given by

PROCEDURE:

1. Examine hardness testing machine.
2. Place the specimen on platform of a machine. Using the elevating screw raise the platform and bring the specimen just in contact with the ball. Apply an initial load until the small pointer shows red mark.
3. Release the operating valve to apply additional load. Immediately after the additional load applied, bring back operating valve to its position.
4. Read the position of the pointer on the C scale, which gives the hardness number.
5. Repeat the procedure several times on the specimen selecting different points for indentation.

OBSERVATIONS

DATA SHEET-BHN TEST

Diameter of steel ball indenter, D= mm
 Least count of microscope = mm

$$d = \frac{d_1 + d_2}{2}$$

$$\text{BHN} = \frac{2F}{\pi D \left(D - \sqrt{D^2 - d^2} \right)} \quad \text{kgf / mm}^2$$

Where, D is the diameter of ball indenter, d is the diameter of indentation, and F is the major load

Sl. No	Material	Minor load (kgf)	Major load (kgf)	Time, t (sec)	No of trials	Indentation		Average diameter, d (mm)	BHN (kgf/mm ²)
						d ₁	d ₂		
1.	Mild Steel								
2.	Aluminum								
3.	Copper								
4.	Brass								
5.	Gun Metal								
6.	Cast Iron								

RESULT:

OBSERVATIONS

DATA SHEET-VHN TEST

Apex angle of diamond cone indenter, $\theta = 136^\circ$

Time of indentation $t =$ sec

$$d = \frac{d_1 + d_2}{2}$$

Minor load = kgf
 Major load = kgf

$$HV = \frac{2F \sin \frac{136^\circ}{2}}{d^2} \quad HV = 1.854 \frac{F}{d^2} \text{ approximately}$$

Where, d is the average length of diagonals, F is the major load

Sl. No	Material	No of trials	Indentation		Average length, d (mm)	VHN (kgf/mm ²)
			d ₁	d ₂		
1.	Mild Steel	1				
		2				
2.	Aluminum	1				
		2				
3.	Copper	1				
		2				
4.	Brass	1				
		2				
5.	Gun Metal	1				
		2				

RESULT:

OBSERVATIONS

DATA SHEET-RHN-B TEST

Indentor = Ball type

Diameter of steel ball indenter, $d =$ mm
 Minor load = kgf
 Major load = kgf
RHN-B = Dial reading + 30

Tabulation

Sl. No	Material	Time, t (sec)	No of trials	Dial reading	Average dial reading	BHN-B (kgf/mm ²)
1.	High Speed Steel (HSS)		1			
			2			
2.	Spring Steel		1			
			2			

OBSERVATIONS

DATA SHEET-RHN-C TEST

Indenter = Cone type
 Diameter of steel ball indenter, $d =$ mm
 Minor load = kgf
 Major load = kgf
RHN-B = Dial reading

Tabulation

Sl. No	Material	Time, t (sec)	No of trials	Dial reading	Average dial reading	BHN-C (kgf/mm ²)
1.	High Speed Steel (HSS)		1			
			2			
2.	Spring Steel		1			
			2			

RESULT:

EXPERIMENT 4 - TORSION TEST

AIM: To conduct torsion test on the given mild steel specimen and determine the Modulus of Rigidity, Modulus of Rupture in torsion, Yield strength, Percentage elongation in outer fiber at failure(Torsional ductility).

APPARATUS: Torsion testing Machine, micrometer, scale, specimen.

INTRODUCTION:

Torsion occurs when any shaft is subjected to a torque as shown in Figure 4.1. This is true whether the shaft is rotating (such as drive shafts on engines, motors and turbines) or stationary (such as with a bolt or screw). The torque makes the shaft twist and one end rotates relative to the other inducing shear stress on any cross section. Failure might occur due to shear alone or because the shear is accompanied by stretching or bending.

PROCEDURE:

1. Measure the overall length and the diameter at about three places and take the average value of the test specimen.
2. Draw a line down the length of the test section of the specimen with a chalk, this serves as a visual aid to the degree of twist being put on the specimen during loading.
3. Insert the test piece in the grips of the torsion testing machine. Adjust the torque and angle of twist readings to zero position.
4. Apply the torque gradually up to failure and note the torque and angle of twist at convenient intervals.
5. Note the readings at commencement of yielding and ultimate point.
6. Remove the broken pieces from the testing machine and join them properly and note the number of turns made by the line marked on the test piece.

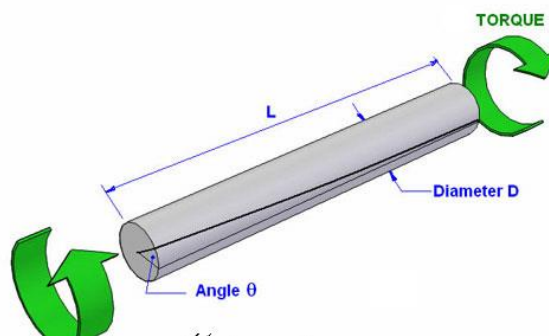


Figure 4.1 Shaft subjected to torque.

OBSERVATIONS

DATA SHEET-TORSION TEST

1. Least count of Micrometer : _____

2. Material of the test piece :
3. Parallel length of the test piece, $L =$ m
4. Diameter of the test specimen

d_1			d_2			d_3		
MSR	PSR	TR	MSR	PSR	TR	MSR	PSR	TR

Diameter $d =$ m

5. Pure Torsion Equation, $\frac{T}{I_p} = \frac{\tau}{r} = \frac{G\theta}{L}$

6. Polar Area Moment of Inertia, $I_p = \frac{\pi d^4}{32} =$ m⁴

7. Polar Section Modulus, $Z_p = \frac{\pi d^3}{16} =$ m³

8. Yield Torque, $T_y =$ N-m

9. Ultimate Torque, $T_u =$ N-m

10. Final length of the line marked on the test piece, $L_f =$ m

11. Modulus of elasticity in Shear (Modulus of Rigidity), $G =$ N/m²

Where $G =$ Slope of the initial straight portion of the shear stress V/S shear strain diagram

12. Modulus of Rupture in Torsion, $\frac{T_u}{Z_p} =$ N/m²

13. Yield Stress in Torsion, $\frac{T_y}{Z_p} =$ N/m²

14. % Elongation of outer fiber $\frac{L_f - L}{L} \times 100 =$ %

15. Torsional stiffness, $K_t = T / \theta$

(in the elastic region of Torque V/S Angular Twist diagram)

GRAPH: Draw graph of a) Torque V/S Angular Twist b) shear stress V/S shear strain

RESULT:

TABULATION:

Sl.	Torque T	Angle of Twist (θ)	Shear Stress	Shear Strain

No	(N-m)	Degree	Radian	$\tau = \frac{Tr}{I_p} N / mm^2$	$\phi = \frac{r\theta}{L} rad$
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					
11.					
12.					
13.					
14.					
15.					
16.					
17.					
18.					
19.					
20.					
21.					
22.					
23.					
24.					
25.					
26.					
27.					
28.					

EXPERIMENT 5 - SHEAR TEST

AIM: To determine shear strength in single shear and double shear.

APPARATUS: UTM, shear test attachment, vernier caliper / screw gauge.

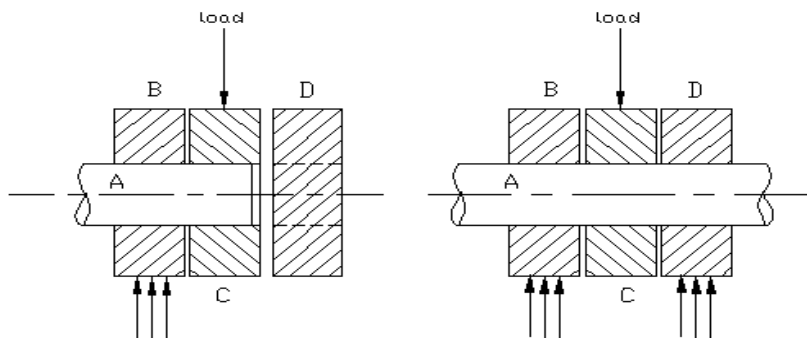
THEORY:

The form of stress in a body, part, etc., that tends to produce cutting greater than stretching or bending is called as shear stress.

A Shearing stress acts parallel to a plane whereas tensile and compressive stresses act normal to a plane. There are two main types of shear stresses used in laboratory tests. One is called direct or transverse shear stress and corresponds to the type of stress encountered in rivets, bolts, and beams. The other type of shear stress is called pure or torsion shear and represents the kind of shear stress encountered in a shaft subjected to pure torsion.

In actual practice when a beam is loaded the shear force at a section always comes to play along with bending moment. It has been observed that the effect of shearing stress as compared to bending stress is quite negligible. But sometimes, the shearing stress at a section assumes much importance in design calculations.

This test is useful for determining ultimate shear strength of most metals as well as other rigid plastic materials where the shear characteristics find importance in characterizing structural integrity of bond in form of weld, adhesive bond or friction joint delivered between two surfaces.



I

Fig-1: Single shear

Fig-2: Double shear

PROCEDURE

1. Measure the diameter of the test specimen by means of a screw gauge at least at three sections and obtain the mean value. Also measure the length of the specimen.
2. Fix the specimen in the shear attachment accordingly for single and double shear as shown in Figure 5.1.
3. The shear assembly is placed in UTM, and the load is applied, at right angle to the axis of the specimen, through the central block, and the load at shear is recorded.
4. The shape and texture of fractured surface is observed.

OBSERVATIONS

DATA SHEET-SHEAR TEST

1. Material of the specimen:

d_1			d_2			d_3		
MSR	VSR	TR	MSR	VSR	TR	MSR	VSR	TR

2. Average diameter, $d =$ mm

3. Length, $L =$ mm

4. Area of specimen, $A =$ mm^2

5. Single shear, $\tau = \frac{P}{A} =$ N/mm^2

6. Double shear, $\tau = \frac{P}{2A} =$ N/mm^2

TABULATION:

Sl. No.	Type of Shear	Shear Load, P		Shear Stress N/mm^2
		lbs	N	
1	Single Shear			
2	Double Shear			

RESULT:

DATA SHEET-SHEAR TEST

1. Material of the specimen:

2. Average diameter, $d =$ mm

3. Length, $L =$ mm

4. Area of specimen, $A =$ mm^2

5. Single shear, $\tau = \frac{P}{A} =$ N/mm^2

6. Double shear, $\tau = \frac{P}{2A} =$ N/mm^2

d_1			d_2			d_3		
MSR	VSR	TR	MSR	VSR	TR	MSR	VSR	TR

TABULATION:

Sl. No.	Type of Shear	Shear Load, P		Shear Stress N/mm^2
		lbs	N	
1	Single Shear			
2	Double Shear			

RESULT:

EXPERIMENT6 -COMPRESSION TEST

AIM: To study the behavior of the given material under compressive loading and to determine its mechanical properties.

APPARATUS: UTM, vernier caliper, specimen.

THEORY:

Compressive strength is the maximum compressive stress that a material is capable of withstanding without fracture. Structure components such as columns and struts are subjected to compressive load in applications. These components are made of high compressive strength materials. Not all the materials are strong in compression. Several materials, which are good in tension are poor in compression. Many materials poor in tension are good in compression. Cast iron is one such example. A compression test is a method for determining the behavior of materials under a compressive load. Compression tests are conducted by loading the test specimen between two plates and then applying a force to the specimen by moving the crossheads together. The compression test is used to determine elastic limit, proportionality limit, yield point, yield strength and compressive strength.

PROCEDURE:

1. Measure the diameter of the test specimen by means of a screw gauge at least at three sections and obtain the mean value. Also measure the gauge length.
2. Fix the specimen properly between the table and the cross head.
3. Fix the dial gauge on the loading platform and adjust the dial reading to zero.
4. Set the load dial of the machine to a suitable range.
5. Apply the load gradually and make simultaneous record of dial gauge reading at every equal interval of load.
6. Record the load at yield point and the maximum load in the case of ductile material and fracture load in the case of brittle material.
7. Remove the specimen (broken if it is brittle material) from the machine and observe the location and character of fracture (if brittle). Measure final diameter and length of the specimen.
8. Plot stress-strain diagram and compute all the required mechanical properties.

DATA SHEET-COMPRESSION TEST

OBSERVATIONS

d_1			d_2			d_3		
MSR	VSR	TR	MSR	VSR	TR	MSR	VSR	TR

Material : E = N/mm^2

Least count of Vernier / Micrometer = mm

Initial gauge length, $L_o =$ mm

Initial diameter, $d_o =$ mm

Original cross sectional area, $A_o = \frac{\pi}{4} d_o^2 =$ mm^2

Final gauge length, $L =$ mm

Final diameter, $d =$ mm

Final cross sectional area, $A = \frac{\pi}{4} d^2 =$ mm^2

Yield load, $P_{uy} = N$ $P_{ly} =$ N

Maximum load, $P_{max} = N$

Fracture load, $P_{fail} = N$

Young's Modulus, E = N/mm^2

(From slope of the linear portion of the stress-strain diagram)

Yield stress, $\sigma_y = \frac{P_y}{A_o}$ N/mm^2

Strain, $\epsilon = \frac{\sigma_y}{E} =$

Strain energy density (Modulus of resilience), $U = \frac{\sigma_y^2}{2E} =$ $N-mm$

Ultimate stress, $\sigma_u = \frac{P_{max}}{A_o}$ N/mm^2

Fracture stress, $\sigma_f = \frac{P_{fail}}{A_o}$ N/mm^2

Strain at fracture, $\epsilon_f =$

Toughness = $\sigma_f \epsilon_f$

Percentage elongation in length, $\frac{L - L_o}{L} \times 100 =$ %

Percentage reduction in area, $\frac{d_o^2 - d^2}{d_o^2} \times 100 =$ %

Tabular Column:

Sl. No.	Load P (kN)	Deflection Δ (mm)	Stress (N/mm ²) $\sigma = \frac{P}{A_0}$	Strain $\epsilon = \frac{\Delta}{L_0}$	True Stress (N/mm ²) $\sigma_{true} = \sigma(1 + \epsilon)$	True Strain $\delta = \ln(1 + \epsilon)$
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						
11.						
12.						
13.						
14.						
15.						
16.						
17.						
18.						
19.						
20.						
21.						

GRAPH: Draw graph of a) Load v/s Deflection b) Stress v/s Strain c) True stress v/s True strain

Results:

Sl.No.	Mechanical Properties	Material			
		Mild Steel	Cast Iron	Aluminum	Wood
1.	Modulus of Elasticity (Young's Modulus)				
2.	Stiffness				
3.	Yield Stress				
4.	Strain Energy Density (Modulus of Elastic Resilience)				
5.	Tensile Strength (Ultimate Stress)				
6.	Strain at Fracture				
7.	Toughness				

EXPERIMENT 7 - BENDING TEST

AIM: To determine the flexural modulus and flexural strength of the beam material subjected to bending load.

APPARATUS: UTM, vernier caliper, specimen.

THEORY:

A beam is typically defined as a slender bar capable of supporting transverse loading perpendicular to the bar. An applied transverse load to a beam results in internal forces of shear and bending moments.

Neutral surface or Neutral layer: Layer of fiber in a beam which remain unchanged in length even after bending.

Neutral Axis: The intersection of neutral surface with any cross sectional plane is called the neutral axis of the cross section.

Flexural equation or Pure bending equation:

$$\frac{M}{I} = \frac{\sigma}{y} = \frac{E}{R}$$

Flexural testing is predominately used in industries where materials are subject to some form of bending force. The construction industry is a typical example in that the most common test for structural steels, concrete beams, timber joists, GRC panels, ceramic tiles etc is flexural testing.

PROCEDURE:

1. Measure the width and depth of the specimen including the span length.
2. Place the bending fixture on the platform of the Universal Testing Machine.
3. Place the beam on the bending fixture.
4. Keep the dial gauge at the centre of the span.
5. Load the beam in small increments as shown in Figure 7.1 up to failure and obtain the central deflection corresponding to each load value (by using dial gauge when deflections are small and by using scale when the deflections are large).

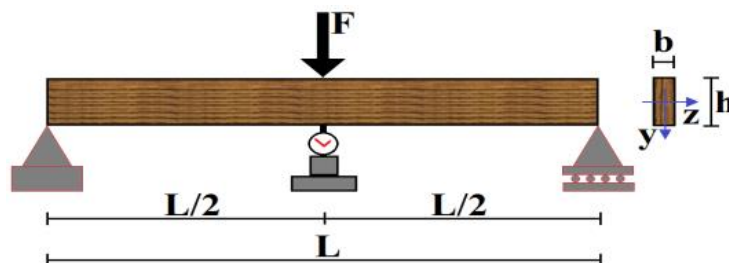


Figure 7.1 Test Configuration

6. Note the load at first crack and the load at failure.

7. Note the mode of failure.
8. Using the data of load and deflection, draw the load-deflection graph (Figure 2).
9. Find the slope of the initial straight line portion of the load-deflection curve.
10. Compute the Flexural modulus and modulus of rupture in bending.

OBSERVATIONS	DATA SHEET-BENDING TEST			
1. Beam Material	=			
2. Least count of the Dial Gauge	=			
3. Span of the beam,	L =	m		
4. Width of the beam ,	b ₁ =	m,	b ₂ =	m, b ₃ = m
Average width,	b =	m		
5. Depth of the beam ,	h ₁ =	m,	h ₂ =	m, h ₃ = m
Average depth,	h =	m		
6. Moment of inertia about neutral axis,	$I = \frac{bh^3}{12} =$			m ⁴
7. Section modulus ,	$Z = \frac{I}{y} = \frac{bh^2}{6} =$			m ³
8. Yield load W _y	=	N		
9. Maximum load, W _m	=	N		
10. Deflection at yield, δ _p	=	m		
11. Maximum deflection, δ _m	=	m		
12. Maximum bending moment at failure , M _{max}	$= \frac{W_m L}{4} =$			N-m
13. Flexural strength(Modulus of rupture), σ _f	$= \frac{M_{max}}{Z} = \frac{3Wl}{2bh^2} =$			N/m ²
14. Determine bending stiffness slope of the initial straight line portion of the load-deflection curve	k =	N/m		
15. Flexural modulus of the beam material, E	$= k \times \frac{L^3}{48I} =$			N/m ²

GRAPH: Draw graph of Load v/s Deflection

TABULATION :

Sl. No.	Load P	Deflection	Central deflection = DGR × Least count	Remarks
	N	mm		
1				
2				
3				
4				
5				

RESULT:

EXPERIMENT 8 - PREPARATION OF SPECIMEN FOR METALLOGRAPHIC EXAMINATION OF ENGINEERING MATERIALS AND STUDY THEIR MICROSTRUCTURE

AIM:To describe metallography and to study the microstructure of materials.

APPARATUS:Metallurgical microscope, polishing machine,emery papers of various grades, etchants.

THEORY:

Metallography is the study of a materials microstructure. It is basically the study of the structures and constitution of metals and alloys, using metallurgical microscopes and magnifications, so that the physical and mechanical properties of an alloy can be related to its observed microstructure.

Such microscopic studies can provide an abundance of constitutional information about the specimen under investigation, including the size and shape of the grains (crystallites), the presence of micro defects (such as segregation, hair cracks, and nonmetallic inclusions), and the nature and distribution of secondary phases.

The metallographic examination can be used in quality control, to predict and/or explain the mechanical properties and to know whether the material has been processed correctly and is therefore a critical step for determining product reliability and for determining why a material failed.

A. PREPATION OF SPECIMEN FOR METALLOGRAPHIC EXAMINATION

The process of sample preparation is schematically summarized in Figure 8.1. The preparation of a metallographic sample involves the following steps:

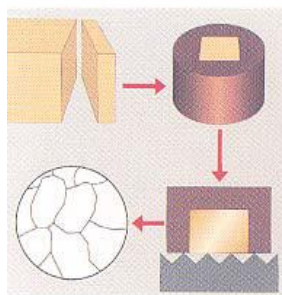


Figure 8.1 Process of sample preparation

a) Sectioning (cutting) :When cutting a specimen from a larger piece of material, care must be taken to ensure that it is representative of the features found in the larger sample, or that it contains all the information required to investigate a feature of interest.

Proper cutting requires the correct selection of abrasive type, bonding, and size; as well as proper cutting speed, load and coolant. Depending upon the material, the sectioning operation can be

obtained by abrasive cutting (metals and metal matrix composites), diamond wafer cutting (ceramics, electronics, biomaterials, minerals), or thin sectioning with a microtome (plastics).

The specimen (a square 10mm or dia 15 mm) is cut to a height of about 15 mm.

b) Mounting: Mounting of specimens is usually necessary to allow them to be handled easily. It also minimizes the amount of damage likely to be caused to the specimen itself as shown in Figure 8.2.

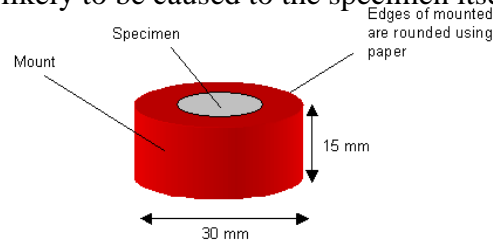


Figure 8.2 Specimen with mounting

c) Grinding: Surface layers damaged by cutting must be removed by grinding. The grinding procedure involves several stages, using a finer paper (higher number) each time. Each grinding stage removes the scratches from the previous coarser paper. This can be easily achieved by orienting the specimen perpendicular to the previous scratches. Between each grade the specimen is washed thoroughly with soapy water to prevent contamination from coarser grit present on the specimen surface.

d) Polishing: It is the process of creating a smooth and shiny surface by rubbing it or using a chemical action, leaving a surface with a significant reflection. Polishing involves the use of abrasives (usually alumina powder), suspended in a water solution, on a cloth-covered electrically powered wheel. The purpose of the polishing is to remove the damage produced during cutting and grinding.

e) Etching: Etching is used to reveal the microstructure of the metal through selective chemical attack. Microscopic examination of a properly polished, unetched specimen will reveal only a few structural features such as inclusions and cracks or other physical imperfections. Even in a carefully prepared sample, a surface layer of disturbed metal, resulting from the final polishing stage, is always present and must be removed. Etchants are usually dilute acid or dilute alkalis in a water, alcohol or some other solvent. Etching occurs when the acid or base is placed on the specimen surface because of the difference in rate of attack of the various phases present and their orientation. The etching process is usually accomplished by merely applying the appropriate solution to the specimen surface for several seconds to several minutes.

B. MICROSCOPIC EXAMINATION

Detailed viewing is done with a Metallurgical Microscope (Figure 8.3). A metallurgical microscope has a system of lenses(objectives and eyepiece) so that different magnifications (25X to 1000X) can be achieved. The important characteristics of the microscope are: (1) magnification, (2) resolution and (3) flatness of field. The resultant magnification is the product of the magnifying power of the objective and that of the ocular.

Scanning Electron Microscopes (SEMs) are capable of magnifications up to 20,000X and Transmission Electron Microscopes (TEMs) are utilized to view at magnifications up to 100,000X for highly detailed microstructural study.

The specimen is placed on the stage of the microscope so that its surface is perpendicular to the optical axis. Put on the source of light. Adjust the longitudinal and transverse movements of the table to focus the light on the specimen. Make coarse and fine adjustments to focus. Observe and record the microstructure. The microstructures of some ferrous and non ferrous alloys are shown in Figure 8.4.



Figure 8.3 Metallurgical microscope

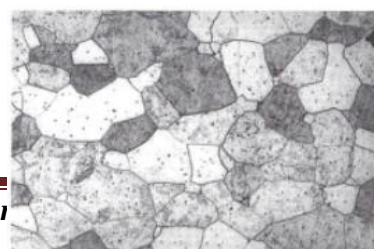
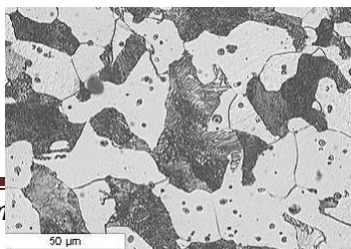
C. GRAIN SIZE CALCULATION

The micro structure of many metallic or ceramic materials consists of many grains. A grain is a portion of the material within which the arrangement of the atoms is nearly identical but the orientation or crystal structure of atoms are different.

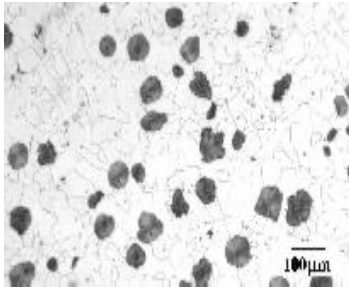
The properties of any alloy are affected not only by the character of phases present, but also by the size of grains that are present in the structure. Larger the size of the grains, greater will be the hardenability of the steel. Smaller the size of the grains greater is the strength.

The grain size is measured by comparison, under microscope with a magnification of X100, with standard charts shown in the figure. Steels with grain size number 1 to 5 are coarse grained and number 6, 7 and 8 are fine grained steels.

According to ASTM, the grain size N is given by $m = 8 \times 2^N$, where m is the number of grains per mm^2 .



Low Carbon Steel



Aluminium



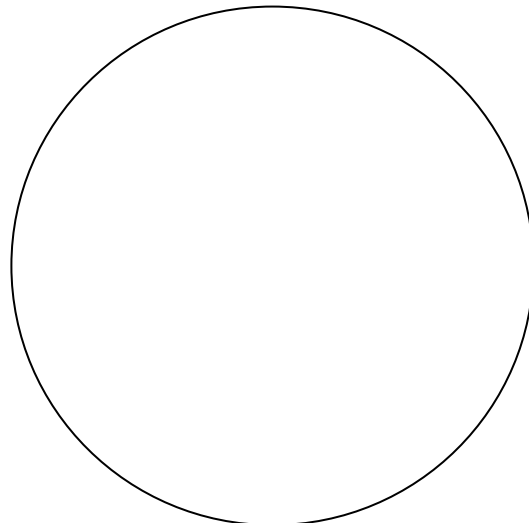
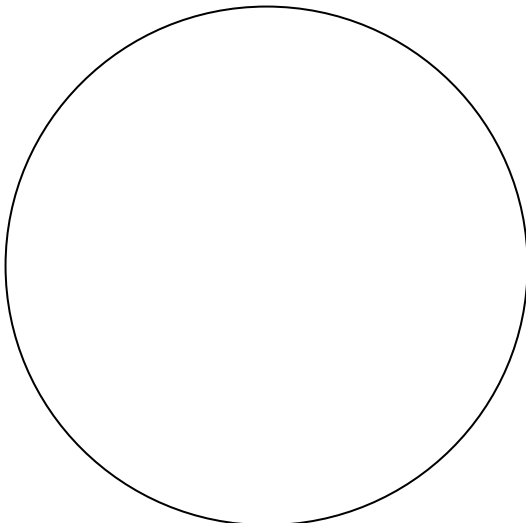
Cast Iron

Brass

Figure 8.4 Microstructures of some ferrous and non ferrous alloys.

Metallography Observation Record

Draw the microstructures you observe in your specimens.



Magnification:
Specimen:
Etchant:
Observation:

Magnification:
Specimen:
Etchant:
Observation:

Grain size number:

Grain size number:

EXPERIMENT 9 - HEAT TREATMENT OF STEEL

AIM: To heat treat the given specimen and to determine its hardness.

APPARATUS: Electric furnace, hardness testing machine.

THEORY:

The purpose of this experiment is to understand how the microstructure of low-carbon and medium-carbon steel can be altered by heat treating and then quenching to increase the mechanical strength (hardness) of steel. This is done by using the TTT diagrams and knowledge of phase transformation in order to heat the steel samples to a specific temperature, and then rapidly cooling in a specific time to get the desired hardness.

Heat Treatment: It may be defined as the operation or combination of operations involving heating and cooling of a metal or alloy in the solid state for the purpose of obtaining certain desirable conditions or properties. The usefulness of steel is largely due to the ease with which its properties may be altered by properly controlling the manner in which it is heated and cooled. Only by heat treatment, it is possible to impart high mechanical properties to steel required for the normal operation of modern machinery and tools.

Various heat treatment operations are:

1. Annealing
2. Normalizing
3. Hardening
4. Tempering
5. Carburizing

The Phase Diagram: Materials of different compositions exhibit different microstructures (and thus different material properties) at different temperatures. A phase diagram is a map of these equilibrium microstructures over composition and temperature. Figure 9.1 shows the Iron-Carbon phase diagram. However, heat-treated materials are not in equilibrium, so a TTT diagram (explained below) is needed to determine the microstructure.

The Time-Temperature-Transformation (TTT) Diagram: Materials with the same chemical composition can exhibit entirely different physical properties because of differing microstructures. This can be caused by altering the temperature of the material rapidly, without allowing the microstructure to reach its quasi-static state. A map of such transformations is called a Time-Temperature-Transformation (TTT), or an Isothermal Transformation diagram. This diagram has temperature on the Y-axis and time on the X-axis. A different TTT diagram exists for each composition. Figure 9.2 shows the TTT diagram for eutectic steel. One may graph the temperature inside a material versus time by starting the “stopwatch” when temperature transformations begin after the equilibrium phase, and tracing the changing microstructure in the material at each time using the TTT diagram.

PROCEDURE:

The materials used are carbon steels. The equipment consisted of an environmental-control furnace, tongs, and a container filled with water at room temperature (approximately 25°C). The samples were heated to 850°C in the furnace and then held at that temperature for one hour. The samples were retrieved with the tongs and, within three seconds, were plunged into the water for quenching.

Afterwards, the samples were beadblasted to remove the carbon buildup, then tempered for one hour in an oven at 400°C. When the tempering was completed, the samples were air-cooled to room temperature.

Then a test is conducted with a Rockwell hardness tester before and after the heat treatment in order to determine the hardness caused by the treatment. Testing is done with two different tips: a diamond indenter and a steel ball indenter, which are pressed into the specimen by the tester.

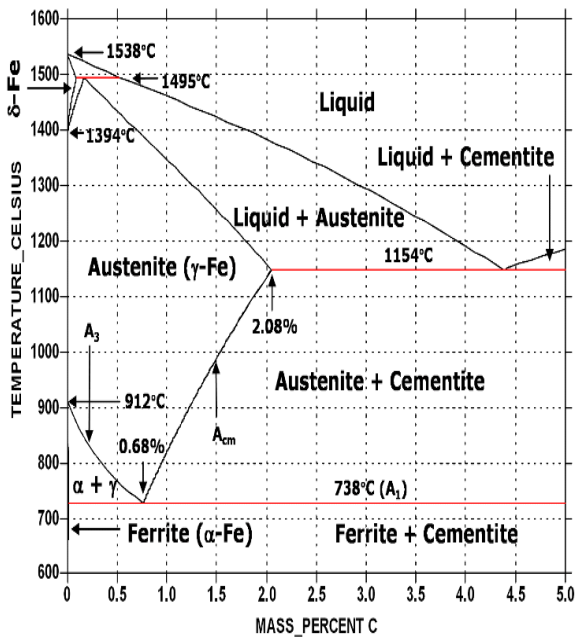


Figure 9.1 Iron-Carbon phase diagram

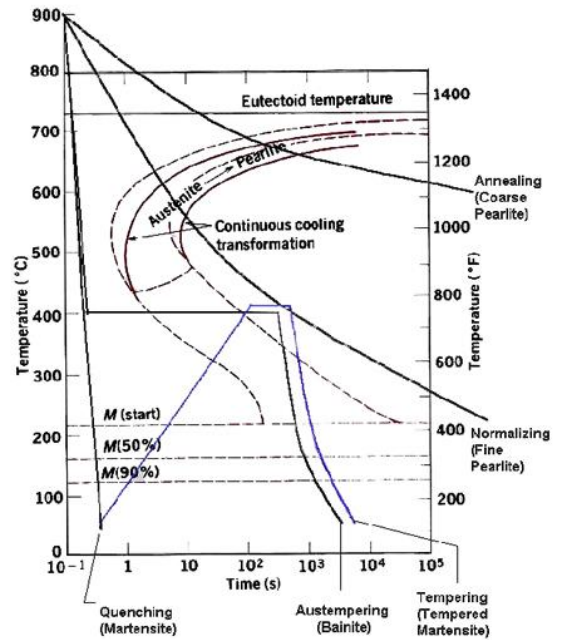


Figure 9.2 TTT diagram for eutectic steel

OBSERVATIONS

DATA SHEET-HEAT TREATMENT

Material of the specimen =

Heat treatment details:

1) Heat treatment Operation =

2) Temperature = °C

- 3) Soaking period =
- 4) Quenching medium =
(cooling in furnace, still air/water, oil)
- 5) Cooling rate =

<p>RHN-B</p> <p>Indenter = Ball type</p> <p>Diameter of steel ball indenter, d = mm</p> <p>Minor load = kgf</p> <p>Major load = kgf</p> <p>Time of indentation t = sec</p> <p>RHN-B = Dial reading + 30</p> <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 10px;"> <thead> <tr> <th style="width: 30%;"></th> <th style="width: 30%;">Dial reading</th> <th style="width: 40%;">BHN-B (kgf/mm²)</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">BEFORE</td> <td></td> <td></td> </tr> <tr> <td style="text-align: center;">AFTER</td> <td></td> <td></td> </tr> </tbody> </table>		Dial reading	BHN-B (kgf/mm ²)	BEFORE			AFTER			<p>RHN-C</p> <p>Indenter = Cone type</p> <p>Diameter of steel ball indenter, d = mm</p> <p>Minor load = kgf</p> <p>Major load = kgf</p> <p>Time of indentation t = sec</p> <p>RHN-C = Dial reading</p> <table border="1" style="width: 100%; border-collapse: collapse; margin-top: 10px;"> <thead> <tr> <th style="width: 30%;"></th> <th style="width: 30%;">Dial reading</th> <th style="width: 40%;">BHN-C (kgf/mm²)</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">BEFORE</td> <td></td> <td></td> </tr> <tr> <td style="text-align: center;">AFTER</td> <td></td> <td></td> </tr> </tbody> </table>		Dial reading	BHN-C (kgf/mm ²)	BEFORE			AFTER		
	Dial reading	BHN-B (kgf/mm ²)																	
BEFORE																			
AFTER																			
	Dial reading	BHN-C (kgf/mm ²)																	
BEFORE																			
AFTER																			

RESULT:

EXPERIMENT 10 - WEAR CHARACTERISTICS OF FERROUS, NON-FERROUS AND COMPOSITE MATERIALS FOR DIFFERENT PARAMETERS

AIM: To find the wear of the given specimen using pin-on-disc wear testing machine.

APPARATUS: Physical balance, stop watch, Pin-on-disc wear testing machine

THEORY:

Wear is the damage to a solid surface (generally involving progressive loss of material), caused by the relative motion between that surface and a contacting substance or substances. In most instances, the material removal is a gradual process and the motion is a repetitive action.

Two common types of wear that occur are wear abrasion and mar abrasion. Wear abrasion is the removal of a portion of the surface by some kind of mechanical action (e.g. rubbing or sliding back and forth of an object). Mar abrasion is the permanent deformation of a surface but the deformation does not break the surface.

Wear can be classified as abrasive, adhesive, fatigue, erosive, fretting wear etc.

Wear measurement is carried out to determine the amount of materials removed (or worn away) after a wear test, (and in reality after a part in service for a period of time). The material worn away can be expressed either as weight (mass) loss, volume loss, or linear dimension change.

Mass loss: Mass loss measurement by a precision balance is a convenient method for wear measurement, especially when the worn surface is irregular and unsymmetrical in shape. Sample to be measured is carefully cleaned, and the weight is measured before and after a wear test. The difference in weight before and after test represents the weight loss caused by wear. The unit can be gram (g) or milligram (μg).

Volume Loss: Wear volume is normally calculated from the wear track (scar) depth, length, width and/or scar profile according to the geometry of the wear track/scar. A surface profilometer, e.g. a stylus type, or sometimes a microscope with scale is used for the measurement. The reporting unit of wear volume loss is mm^3 or μm^3 . Wear volume loss enables a better comparison of wear among materials having different densities. However, it is not easy to measure volume loss when a wear track is irregular. In this case, mass loss may be measured first, and the volume loss is calculated if the materials is uniform and its density is known.

Linear dimension loss: Measuring wear by linear dimension change is very useful in many engineering situations, where certain dimension such as length, thickness or diameter is more critical to the normal function of the system. A surface profilometer, e.g. a stylus type, a micrometer or a microscope can be used. The unit for linear dimension loss can be μm or mm

A pin-on-disc wear testing machine can be used to estimate the wear of any material as shown in Figure 10.1.

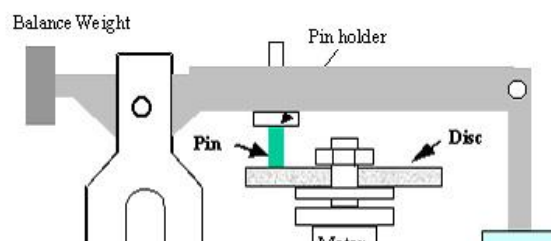


Figure 10.1 Pin-on-Disc Machine.

PROCEDURE:

1. Note down the initial weight of the specimen using a physical balance.
2. Fix the given specimen to the holding device of the machine such that the pin(specimen) touches the disc.
3. Load the machine and rotate the disc at one particular speed.
4. After few minutes (say 5 minutes) stop the machine.
5. Note down the final weight of the specimen.
6. Find the material loss.
7. Vary the load and repeat the experiment.
8. Different materials can be used to estimate their wear rate.

DATA SHEET-WEAR TEST

TABULATION:

For constant speed N =rpm

Sl.No.	Load N	Initial Weight gm	Final Weight gm	Material loss/hr gm/hr
--------	-----------	----------------------	--------------------	---------------------------

1				
2				
3				
4				
5				

For constant load $P = \dots\dots\dots N$

Sl.No.	Speed rpm	Initial Weight gm	Final Weight gm	Material loss/hr gm/hr
1				
2				
3				
4				
5				

GRAPH: Plot the graph of Weight loss Vs Load.

RESULT:

EXPERIMENT 11: FATIGUE TEST

AIM:To determine the endurance limit of given material subjected to fatigue load.

APPARATUS:Fatigue testing machine, Micrometer screw gauge.

THEORY:

A perusal of the broken parts in almost any scrap yard will reveal that the majority of failures occur at stresses below the yield strength. This is a result of the phenomenon called fatigue which has been estimated to be responsible for up to 90% of the in-service part failures which occur in industry. If a bar of steel is repeatedly loaded and unloaded at say 85% of its' yield strength, it will ultimately fail in fatigue if it is loaded through enough cycles. Also, even though steel ordinarily elongates approximately 30% in a typical tensile test, almost no elongation is evident in the appearance of fatigue fractures.

Fatigue is the condition whereby a material cracks or fails as a result of repeated (cyclic) stresses applied below the ultimate strength of the material.

The fatigue life of a component is defined by the total number of stress cycles required to cause failure.

Fatigue failures generally involve three stages:

- 1.) Crack Initiation,
- 2.) Crack Propagation, and
- 3.) Fast Fracture

The **Endurance Limit** defines the stress level below which the material will theoretically withstand an infinite number ($\sim 10^8$) of stress cycles without fracture.

Range of Stress: If σ_{\max} and σ_{\min} are the maximum and minimum values of the varying stress, then the algebraic difference $R = \sigma_{\max} - \sigma_{\min}$ is called the range of stress (Figure 11.2).

Mean Stress: The mean stress $\sigma_{\text{mean}} = \frac{\sigma_{\max} + \sigma_{\min}}{2}$

In the test, when the specimen is subjected to sagging moment, the bottom fiber is subjected to tensile stress and the top fiber to compressive stress. But, when the specimen under goes half a revolution, the fiber which was at the bottom goes to the top, and hence will be subjected to compressive stress. After another half revolution it will be again subjected to tensile stress and the cycle repeats for each revolution.

PROCEDURE:

1. Prepare a carefully polished test specimen.
2. Mount the specimen in rotating beam machine.
3. Apply the load and rotate the specimen (Figure 11.1). During first half of the rotation the bottom fibres are subjected to tensile stress and the top fiber to compressive stress, during next half top fibres are subjected to tensile stress and the bottom fiber to compressive stress, thereby the specimen is under fatigue load.

4. For each load number of cycles to failure is noted.
5. The data are condensed into an alternating stress(S), verses number of cycles to failure(N), curve which is generally referred to as a material's S-N curve as shown in Figure 11.3.

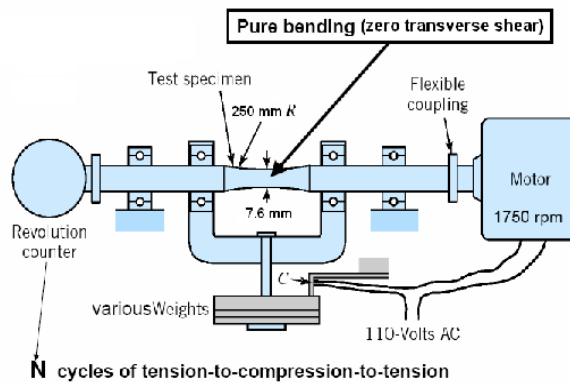


Figure 11.1 Schematic diagram for fatigue test.

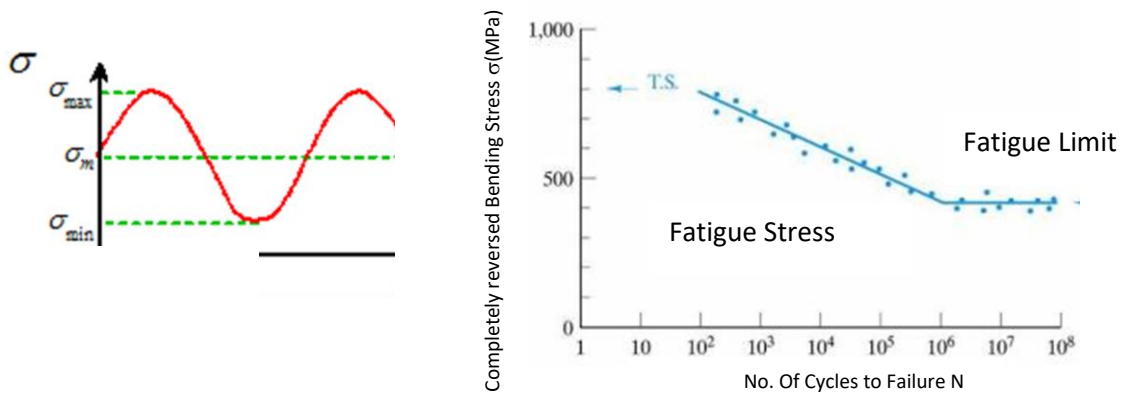


Figure 11.2 S -Cyclic stress.

Figure 11.3 S-N curve for mild steel.

OBSERVATIONS

DATA SHEET-FATIGUE TEST

1. Diameter of the specimen = mm
- Least count of micrometer = mm

Trial No.	Diameter in 1- direction, mm	Diameter in 2- direction, mm	Average Diameter mm
1			
2			

3			
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2. Moment of Inertia = mm⁴

Sl.No.	Applied B.M N-m	Bending stress N/mm ²	No. of cycles at failure
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			

RESULT:

12.VIVA QUESTIONS

Experiment-01 (TENSILE TEST ON DUCTILE AND BRITTLE MATERIALS)

1. What is mechanics of materials?
2. Define stress and strain.
3. Mention different types of loads.
4. Mention mechanical properties of materials.

5. Which steel have you tested? What is its carbon content?
6. Plot stress-strain curve for different materials.
7. In what region of a stress-strain graph do you find Young's Modulus?
8. Why do you think we remove the extensometer after yielding occurs?
9. What general information is obtained from the tensile test regarding the properties of the material?
10. Which stress have you calculated: Nominal stress or true stress?
11. What kind of fracture has occurred and why?

Experiment-02 (IMPACT TEST)

1. What is impact test?
2. Define impact toughness.
3. What is the difference between the specimens of Izod & Charpy test?

Experiment-03 (HARDNESS TEST)

1. Define hardness.
2. Mention different types of hardness test.
3. Explain the working principle of Brinell Hardness Test.

Experiment-04 (TORSION TEST)

1. Define pure torsion.
2. Mention the assumptions in the theory of pure torsion.
3. Write the torsion equation.
4. Define torsional rigidity.
5. Define torsional strength.
6. Which is stronger, solid or hollow shaft?

Experiment-05 (SHEAR TEST)

1. Define shear.
2. What is single & double shear?
3. What is unit of shear strength?

Experiment-06 (COMPRESSION TEST)

1. Define compressive stress.
2. Compression tests are generally performed on brittle materials-why?
3. Which will have a higher strength: a small specimen or a full size member made of the same material?
4. How do ductile and brittle materials differ in their behavior in compression test?
5. Define Poisson's ratio.
6. What is the difference between cast iron and mild steel?

Experiment-07 (BENDING TEST)

1. What is a beam?
2. What is pure bending?
3. Write bending equation.
4. Define flexural strength.
5. Mention the assumptions in pure bending.
6. What is neutral axis?
7. Define section modulus.

Experiment-08 (METALLOGRAPHIC EXAMINATION OF ENGINEERING MATERIALS)

1. Why should the specimen be roughly washed after each stage during either grinding or polishing?
2. What is the purpose of etching metallographic samples?
3. Briefly explain the effect of grain size on the strength of a metal.

Experiment-09 (HEAT TREATMENT OF STEEL)

1. Why materials are heat treated?
2. Briefly explain the steps involved in the following heat treatments of low alloy steels.
 - a.) Normalizing
 - b.) Quenching
 - c.) Tempering
 - d.) Austempering
 - e.) Annealing
3. What is decarburization? What causes it and how is it prevented? How does it affect the properties of heat treated steels?

Experiment-10 (WEAR TEST)

1. Define wear.
2. Mention different types of wear.
3. Explain the working principle of pin on disc machine.

Experiment-11 (FATIGUE TEST)

1. Define endurance limit.
2. Define fatigue life.
3. Mention different types of fluctuating stresses.
4. Explain rotating beam experiment.
5. Define S-N curve.
6. What is high cycle fatigue and low cycle fatigue?