MALLA REDDY
COLLEGE OF ENGINEERING & TECHNOLOGY
(AUTONOMOUS)

DEPARTMENT OF MECHANICAL ENGINEERING

MATERIAL SCIENCE AND STRENGTH OF MATERIALS LAB
LABORATORY MANUAL

B.TECH II YEAR - I SEMESTER
(2016-2017)

VISION:

To develop the department as a center for excellence with state of the art Research facilities in the field of mechanical engineering; To arise enthusiasm and intellect among the students continually in rapidly developing disciplines and enable them to involve in the research and development activities.

MISSION:

The Department of Mechanical Engineering is dedicated for transforming the students into highly competent Mechanical engineers to meet the needs of the industry, in a changing and challenging technical environment, by Providing sound knowledge in the fundamentals of engineering sciences with high level of motivation, professional skills and self-confidence for achieving excellent results in their professional pursuits.

PART-I
MATERIAL SCIENCE LAB

EXERCISE-1

SPECIMEN PREPARATION FOR METALLOGRAPHIC EXAMINATION AND STUDY OF METALLURGICAL MICROSCOPE

a. AIM:

a. To prepare the given specimen for metallographic examination.

b. To Study the constructional details of Metallurgical Microscope and observe the micro structure of the prepared specimen.

b. APPARATUS AND MATERIALS REQUIRED:

Metallurgical microscope, emery belt 1/0, 2/0, 3/0, 4/0 emery papers, lapping cloth, alumina powder, etchants, sample of metal.

c. THEORY:

The microstructure of metal decides its properties. An optical microscope is used to study the microstructure. A mirror polished surface of the metal is required for metallographic study.

d. PROCEDURE OF SPECIMEN PREPARATION:

a. Cut the specimen to the required size (small cylindrical pieces of 10 to 15mm diameter with 15mm height or 10mm cubes)

b. The opposite surfaces (circular faces in case of cylindrical pieces) are made flat with grinding or filing. A small chamfer should be ground on each edge for better handling(if the sample is small it should be mounted).

c. **Belt grinding:-** One of the faces of the specimen is pressed against the emery belt of the belt grinder so that all the scratches on the specimen are unidirectional.

d. **Intermediate:**- The sample is to be polished on 1/0, 2/0, 3/0, 4/0 numbered emery papers with increasing fineness of the paper. While changing the polish paper, the sample is to be turned by 90^0 so that new scratches shall be exactly perpendicular to previous scratches.
e. **Disc polishing (fine polishing):**- After polishing on 4/0 paper the specimen is to be polished on disc polishing machine (Buffing machine). In this disc-polishing machine a disc is rotated by a vertical shaft. The disc is covered with velvet cloth. Alumina solution is used as abrasive. Alumina solution is sprinkled continuously over the disc and the specimen is gently pressed against it. In case of Non-ferrous metals such as Brass, Brass is used instead of Alumina and water. The polishing should be continued till a mirror polished surface is obtained.
f. The sample is then washed with water and dried.
g. Etching: the sample is then etched with a suitable etching reagent, detailed in article 5.
h. After etching the specimen should be washed in running water and then with alcohol and then finally dried.
i. The sample is now ready for studying its microstructure under the microscope.

e. ETCHING:

Except for few cases a polished metallic surface can't reveal the various constituents (phases). Hence specimen should be etched to reveal the details of the microstructure i.e. a chemical reagent should be applied on the polished surface for a definite period of time. This reagent preferentially attacks the grain boundaries revealing them as this lines. Thus under the microscope the grain structure of the metal becomes visible after etching i.e. grain boundary area appears dark and grains appear bright. The rate of etching not only depends on the solution employed and composition of the material but also on the uniformity of the material. A few etching reagents, their composition and their application are given below.

S.No.	Name of Etchant	Composition	Application
1.	Nital		General structure of Iron and steel
	a)5% Nital	Nitric acid(5ml)and	
		Abs. Methyl alcohol(95ml)	
	b)2% Nital	Nitric acid(2ml) and	General structure of Iron and steel
		Abs, Methyl alcohol (98ml)	
2.	Picral	Picric acid(4gm) and	General structure of Iron and steel
		Abs ethyl alcohol(96ml)	

3.	Marbel's reagent	Copper sulphate (4gm),	Stainless steels
		Hydrochloric acid(20ml) and	
		Water (20ml)	
4.	Murakami's reagent	Potassium ferry cyanide,	
		(10grms), KOH(10grms) and	
		Water(100ml)	Stainless steels
5.	Sodium hydroxide	Sodium hydroxide(10gm) and	
		Water (90ml)	Aluminum & its alloys
6.	Keller's reagent	Hydro fluoric acid(20ml)	
		Nitric acid(10ml) and	
		Glycerin (30ml)	Aluminum & its alloys
7.	Keller's reagent	Hydro fluoric acid(1ml)	
		Hydrochloric acid(1.5ml)	
		Nitric acid(2.5ml) and Water(95 ml)	Duralumin
8.	Ammonium phosphate solution	Ammonium persulphate solution(10gms) and water (90ml)	Copper and copper alloys
9.	Fecl3 solution	feCl3 (5gms), HCl acid(2ml) and Ethyl alcohol (96gms)	brass

METALLURGICAL MICROSCOPE:

Metallurgical microscope is used for micro and macro examination of metals. Micro examinations of specimens yield valuable metallurgical information of the metal. The absolute necessity for examination arises from the fact that many microscopically observed structural characteristics of a metal such as grain size ,segregation, distribution of different phases and mode of occurrence of component phases and non metallic inclusions such as slag, sulfides etc., and other heterogeneous condition(different phases)expert a powerful influence or mechanical properties of the metal. It is possible to predict as to how metal will behave under a specific stress. Microstructure of metals at magnifications ranging from 50x to 2000x is carried out with the aid of metallurgical microscope.

a) PRINCIPLE:

A Metallurgical microscope is shown in fig.1.1.Metallurgical microscope differs with a biological microscope in a manner by which specimen of interest is illuminated .As metals are opaque their structural constituents Are studied under a reflected light. Is shown fig.1.2. a horizontal beam of light from appropriate source is directed by means of plane glass

reflects downwards and through the microscope objective on to the specimen surface. A certain amount of this light will be reflected from the specimen surface and that reflected light, which again passes through the objective, will form an enlarged image of the illuminated area.

A microscope objective consists of a number of separate lens elements which are compound group behave as positive and converging type of lens system of an illuminated object. Specimen is placed just outside the equivalent front focus point of objective. A primary real image of grater dimension than those of object field will be formed at some distance beyond the real lens element. Objective size of primary image w.r.t. object field will depend on focal length of objective and front focus point of objective. By appropriately positioning primary image w.r.t. a second optical system, primary image be further enlarged by an amount related, to magnifying power of eyepiece. As separation between objective and eye piece is fixed at same distance equivalent to mechanical tube length of microscope, primary image may be properly positioned w.r.t eye piece. By merely focusing microscope i.e. increase or decrease or the distance between object plane and front lens of objective the image is formed by objective in conjunction with field of eyepiece and microscope is so focused that primary image is located at focal point. Such precise positioning of primary image is essential in order that final image can be formed and rendered visible to observe when looking into eyepiece. If now entrance pupil of eye is made to coincide with exit pupil eyepiece. Eyepiece lens in conjunction with cornea lens will form a second real image on retina. This retrieval image will be erect, un reversed owing to the manner of response of human brain to excitation of retina. The image since it has no real existence, known as virtual image and appears to be inverted and reversed with respect to object field.

6. a) MAGNIFICATION:

The total magnification is the power of objective multiplied by power of eyepiece

$$\frac{\text{(Power of eye piece) (distance from eye piece to object)}}{\text{Focal length of object}}$$

The magnification is marked on the side objective

b) construction:

The micro scope consists of a body tube (refer fig 1.1), which carries an objective below, and an eyepiece above with plane glass vertical illuminator above the objective. Incident light from a source strikes illuminator at 45^0, part of which is reflected on to the specimen, Rays after reflection pass through the eye again, working table is secured on heavy base. The microscope has compound slide to give longitudinal and lateral movements by accurate screws having scale and verniers. Vertical movement of specimen platform is made by a screw for proper focusing. For getting perfect focusing fine adjustment of focusing can be made use of.

6.2.1 **Light Filters**: these are used in metallurgical microscope and essentially of three types

a) Gelatin sheets connected between two planes
b) Solid glass filters
c) Liquid dye solution

Solid glass filters are more preferable as they are more durable. Usually light filters are used principally to render a quality of illumination. Hence filters improve degree of resolution.

A METZ-57 model microscope is used in the laboratory.

6.2.2 Optical compilation

Eye pieces and objectives of different magnifications are available.

Huygens eyepieces: 5x, 10x

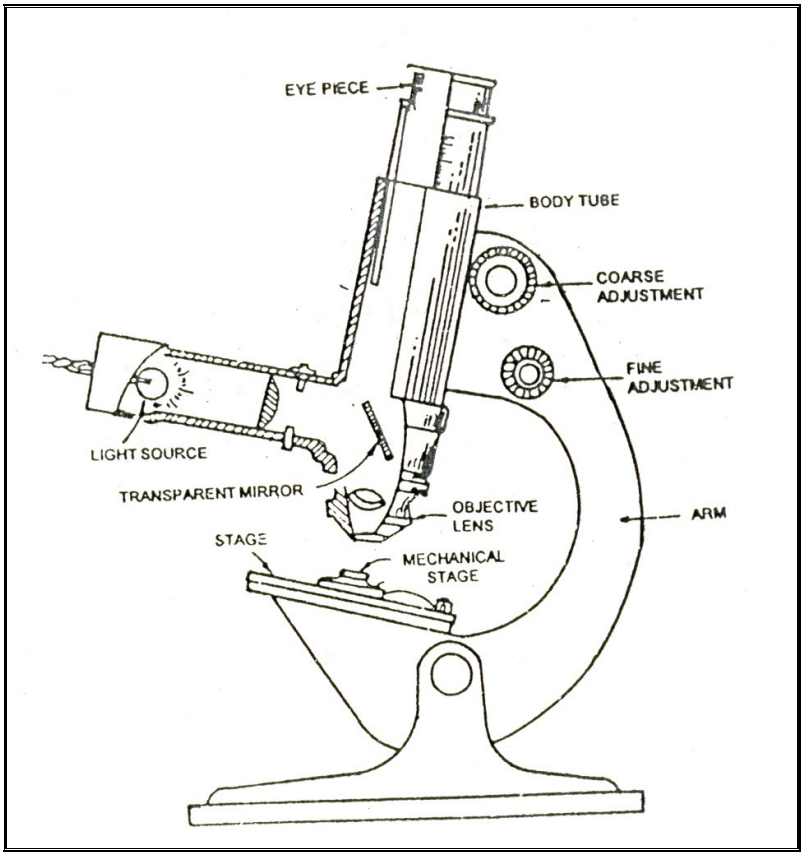
Achromatic objectives 5x, 10x, 45x

PRECAUTIONS:

a. Ensure mirror polished surface of specimen before etching.
b. Fine focusing should be done only after correct focusing has been done.
c. The glass lens should not be touched with fingers.

8.**REVIEW QUESTIONS:**

i. What is the use of micro structural study?
ii. What is the difference among 1/0, 2/0, 3/0 and 4/0 emery papers?
iii. What is lapping?
iv. Why the specimen has to be etched before in lapping?
v. What are the different abrasives used in lapping?
vi. Why the specimen has to be etched before micro structural study?
vii. What is the etchant used for mild steel?
viii. In a microstructure how the grain boundary area appears?
ix. Why specimen is to be rotated through 90(between. Polishing on 1/0 and 2/0 emery papers?
x. What is etching reagent used for duralumin?
xi. Why should a specimen be prepared following the set procedure before its observation under a microscope?
xii. Is the specimen preparation necessary at all? If not why not?
xiii. What is the difference between Metallurgical microscope and Biological microscope?
xiv. What is the magnification of the microscope?
xv. What are the different magnifications available in the microscope of our laboratory?
xvi. What are the precautions to be observed while studying microstructure under microscope?
xvii. What is the used of light filters?
xviii. How do you calculate the magnifying power of a microscope



Metallurgical Microscope

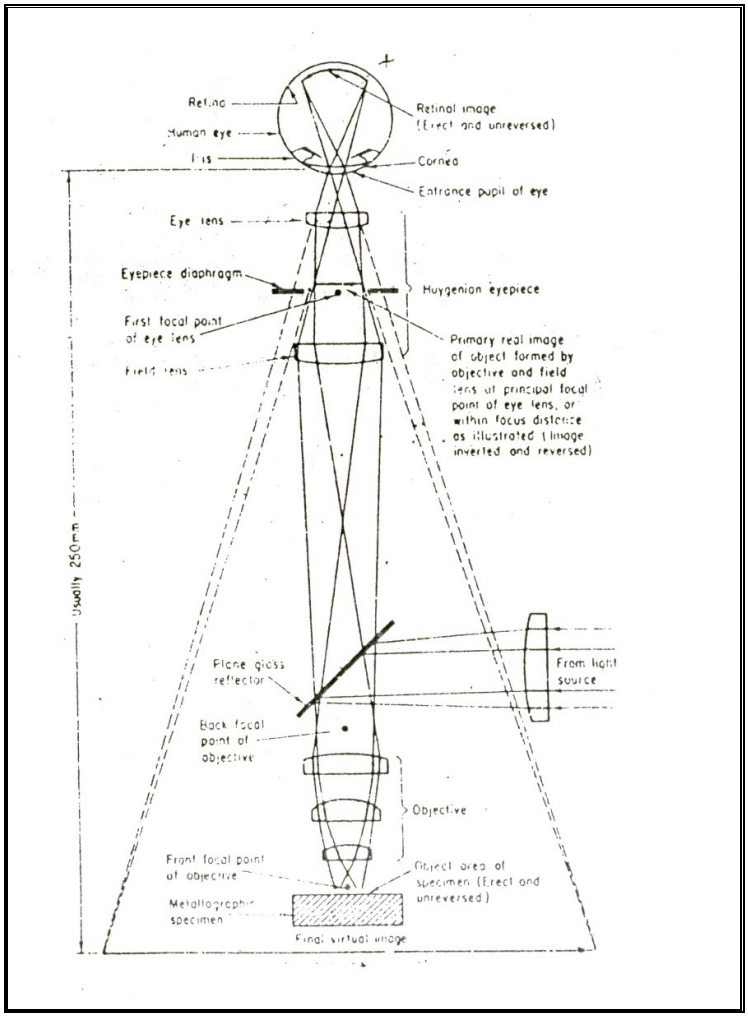


Illustration of Principle of Metallurgical Microscope

EXERCISE-2

1. AIM

To identity the different phases and to draw the microstructures of Plain Carbon Steels.

2. **APPARATUS AND SPECIMENS**:

Metallurgical Microscope, specimens of Plain carbon steel of different composition (untreated)

3. THEORY

3.1. Alloy:

Combination of two or more metals is called alloy. The substances that make the alloy are called its components. The metals are mixed together in required proportion when they are in molten form and then they are allowed to solidity together. After solidification the components of alloy may be in the form of solid solution, chemical compound, mechanical mixture.

If the constituents of the alloy completely soluble in both liquid and solid state a solid solution is formed. If constituents of the alloy are completely soluble in liquid state and completely insoluble in solid state a mechanical mixture is formed.

3.1.1 Phases

A homogeneous, Physically distinct and Mechanically separable part of the system under study is known as phase.

3.2.Cooling Curve:

For a molten metal that is cooled from state to room temperature the graph drawn between time on x-axis and temperature on Y-axis is known as cooling curve. A pure metal solidifies at constant temperature.

3.2a. Cooling Curve of Pure metal:

Cooling Curve of pure metal is show in fig.2.1. at 'A' metal is in liquid state. As metal is cooled the solidification starts at "B". As metal is further the temperature of metal remains constant but metal is converted from liquid state to solid state. Solidification is completed at point 'C'. From 'C' to 'D' there is no change in the solidified metal(except fall in temperature).

3.2b. Cooling curve of a solid solution:

If the components of the alloy are completely soluble in both liquid and solid state a solid solution is formed. Cooling curve of solid solution is shown in fig 'A' to 'B' the alloy is in liquid state. Solidification starts at 'B' and solidification ends at 'C'. From 'C' to 'D' there is no change in solid state of alloy. From 3.2 it can be observed that a solid solution alloy is solidified over a range of temperature.

3.2c. Cooling curve of an eutectic alloy:

Cooling curve of a binary eutectic alloy is shown in fig.2.3. from 'A' to 'B' the alloy is in liquid state. As alloy is further cooled from 'B' the temperature of alloy remains constant, and two solids S_1, S_2 start separating out from the liquid separaterly. The alloy gets completely

solidified at 'C' and gives a mixture of S1 and S2 (eutectic mixture). From 'C' to 'D' there is no change in the solidified alloy.

3.3 Cooling curve of pure Iron

Cooling curve of pure Iron is shown in fig.2.4 Depending on the temperature Iron exists in separate crystalline forms (α, γ, and δ). Above1539^{0}C Iron is in further cooled to 1400^{0}C Iron is in the form of δ – Iron and at1400^{0}c ALL δ-Iron is converted to γ-Iron. As the iron is still cooled from 1400^{0}C to 910^{0}C Iron is in the form of γ-Iron and at 910^{0}C all γ –Iron is converted to nonmagnetic α-Iron. If the further cooled from 910 at 7680C non magnetic α – Iron is converted to Magnetic α –Iron. If the Iron is further cooled to room temperature Iron exists as magnetic α - Iron only.

4Iron-Iron Carbide equilibrium diagram:

Iron-Iron Carbide equilibrium diagram is shown in fig.2.5

Iron carbon alloys contain less than 2% carbon are called steels and Iron carbon alloy that contains >2 % Carbon alloys cast irons. Steels having <0.8% Carbon, 0.8% carbon and >0.8 carbon are called Hypo eutectoid steels, eutectoid steels and Hyper eutectoid steels respectively.

3.4.1 Curie temperature (768^{0}C):

At curie temperature on cooling Non- magnetic α-iron becomes magnetic.

ABCD is the liquids line and AHJECF the solidus line of the system.(i.e. the alloy will be completely in liquid state at all temperatures above liquids line and will be under solid state at all temperatures below solidus line).

3.4.2 Critical points:

The temperature at which the transformation in solid state occurs are called critical points. In hypo eutectoid steels GS (A3 line) represents upper and lower critical points. In hyper eutectoid steels the line SE(Acm) and SK(A13) and SK(A13) represents upper and lower critical temperatures respectively.

3.4.3 Different phases that appear in Fe-Fe_3C diagram:

a. Ferrite(α): It is an interstitial solid solution of carbon in α-iron, maximum solubility of carbon in α-iron is 0.025% at 723^{0}C

b. Austenite (γ): It is an interstitial solid solution of carbon in γ -iron, maximum solubility of carbon in γ -iron is 0.2% at1130^{0}C

c. Cementite(Fe_3C): It is a chemical compound of Iron and carbon that contains 6.67%carbon by weight.

d. pearlite: The eutectoid mixture of Ferrite and cementite is called Pearlite.

e. Lideburite: The eutectic mixture of austenite and cementite is called Lideburite

the three horizontal lines in the diagram (HJB,ECF and PSK) indicate three isothermal reactions at fixed composition and temperature.

3.5Slow Cooling of Hypo Eutectoid steel(0.18% Carbon):

In fig 2.5 alloy 1 represents 0.18% carbon steel. Initially at X, the alloy is in completely liquid state as shown in fig 3.0a. As it is cooled when it crosses 'AB' line δ-iron neucli start forming

in liquid Iron. The Micro structure of the alloy at X_2 is shown in fig 2.6b. as alloy is further cooled cooled. When it crosses' BJ line at J liquid Iron and δ-Iron are combined together at constant temperature to form δ-iron. This reaction is known as peritectic reaction.

$$L \quad + \quad \delta \xrightarrow{\text{Cooling}} \quad \gamma$$

(Liquid) + (δ-Iron) (Austenite)

If the alloy is further cooled at X3 the microstructure of the alloy consists of homogeneous solid solution of - γ Iron as shown in fig.2.6c.

Upon slow cooling of alloy from X_3 nothing happens until 'A3' line is crossed. As alloy is cooled below' A3' line ferrite begins to form at austenite grain boundaries. The micro structure of alloy at X4 is shown if fig. 2.6d. As cooling progresses amount of ferrite increases and remaining and remaining austenite becomes richer in Carbon

On further cooling of alloy from X4 it crosses A1 line(lower critical temperature line)at X6. The microstructure of alloy 1 at X5(just above A1 line) is shown in fig 2.6e. the microstructure shows austenite (around 22%) and proeutectoid ferrite (77%).

At X6 the Austenite gets converted into ferrite and cementite(a Mechanical mixture) at constant temperature. This is known as eutectoid reaction.

$$\text{Austenite} \xrightarrow{\delta \text{ Cooling}} \text{(Ferrite + Cementite) (pearlite)}$$

The eutectoid mixture of ferrite and cementite is known as pearlite. At temperature just below X6 the micro structure shows pearlite and proeutectoid ferrite as shown in fig.2.6f.

On further cooling of the alloy to room temperature no more phase changes are observed. Hence at room temperature micro structure shows pearlite and proeutectoid ferrite.

3.6 Cooling of Eutectoid steel(0.8% Carbon):

In fig 2.5 alloy 2 represents 0.8% Carbon steel. Initially at X1 the alloy is completely in liquid state as shown on in fig.2.7a. On slow cooling once it crosses 'BC' line (liquids line) - γ-iron dendrites start forming in the liquid Iron. At X2 alloy consists of uniform solid solution of γ-iron as shown in fig.2.7c. On further cooling cooling of alloy from X3 no change is observed unit it crosses 'PSK' line (lower critical temperature (7230C) and gets converted into pearlite (mechanical mixture of ferrite and cementite).

$$\text{Austenite} \xrightarrow{\text{Cooling}} \text{(Ferrite + Cementite) (pearlite)}$$

Just below the eutectoid temperature ('PSK') at X4 the alloy consists of 100% pearlite as shown in fig. 2.7d. There is no change in microstructure on cooling of the alloy from X4, to room temperature.

3.7 Cooling of Hyper eutectoid steel (1% Carbon):

In fig 2.5 alloy 3 represents 1% carbon steel, initially at X1 the alloy is completely in liquid state as shown in fig.2.8a. on a slow cooling from observed till 'BC' line (liquid line) is crossed. Once 'BC' line is crossed on further cooling of alloy to X2 austenite crystals start neucleating from liquid iron as shown in fig.2.8b. as cooling is continued more and more amount of austenite is formed. By the time it crosses the line 'JE' all liquid iron is converted to austenite. At X3 the alloy consists of uniform solid solution of austenite as shown in fig.2.8c. On show cooling of alloy from X3 nothing happens until 'Acm' line is crossed at X4. Above X4 austenite is an unsaturated solid solution. At X4 austenite is saturated with carbon. As the temperature is decreased, carbon content of austenite (maximum amount of carbon that be disolved in austenite) decreases along grain boundaries. The micro structure of alloy at X5 in shown in fig.2.8d. On further cooling of alloy, once temperature of alloy crosses lower critical temperature line ('PSK' line) at X7 the austenite present in the alloy undergoes eutectiod reaction and gets converted into pearlite. Just below A3.1, line ('SK' line) at microstructure of alloy shows around 96% pearlite and continuous network of cementite (around 4%) as shown fig 2.8e.

3.8 Plain Carbon Steels:

The usual composition of plan carbon steel is as follows

Carbon 0.08 to 1.7%; Mn 0.3 to 1.0%; silicon 0.05 to 0.3%; Sulphur 0.05(max); Phosphorus 0.05 %(max)

In plain carbon steels, carbon percentage plays a vital role in deciding the properties of steels. Depending on the carbon percentage plain carbon steels are divided into three types.

a.Low carbon steel(Mild steel) b. Medium carbon steel c. High Carbon steel

The microstructure of low carbon steel (Mild Steel) consists of single phase ferrite, (equi axial grains) i.e., it doesn't respond much to the heat treatment. The properties don't vary to any treatment given to the mild steel. It remains mild.

4The Following specimens are to be studied for their Microstructures in this exercise

a. Mild Steel

Specimen	:	Mild Steel
Composition	:	Very low carbon(0.05%), remaining iron
Heat treatment	:	Nil
Etchant	:	Nital
Etching time	:	10 seconds

The structure is single phase equiaxed grains of ferrite.

Application: nuts, bolts, rivets, shafts etc.

b. Hypo eutectoid steel:

Specimen	:	Hypo eutectoid steel
Composition	:	0.5% carbon, remaining iron
Heat treatment	:	Nil
Etchant	:	Nital
Etching time	:	10 Seconds

The microstructure shows ferrite and pearlite.

c. Eutectoid steel:

Specimen	:	Eutectoid steel
Composition	:	0.8% carbon, remaining iron
Heat treatment	:	: Nil
Etchant	:	Natal
Etching time	:	10 Seconds

The microstructure of eutectoid steel consists of 100% pearlite

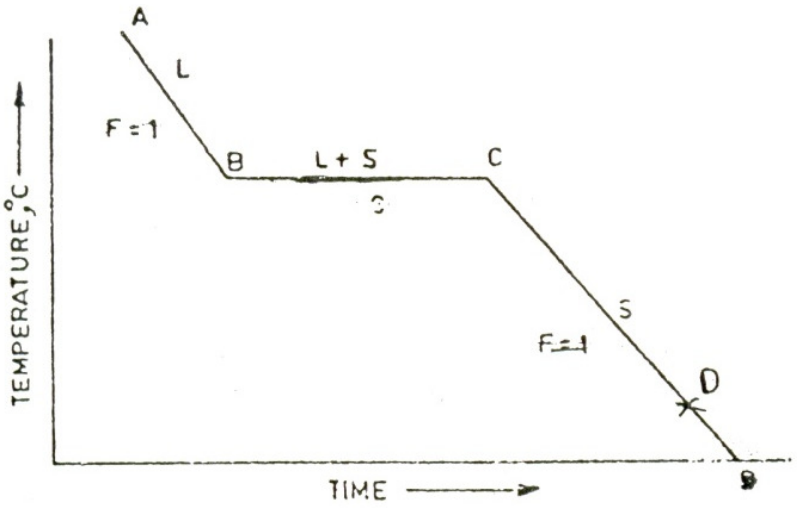
d. Hyper eutectoid steel

Specimen	:	Hyper eutectoid steel(High carbon steel)
Composition	:	1% carbon, remaining iron
Heat treatment	:	Nil
Etchant	:	Natal
Etching time	:	10 Seconds

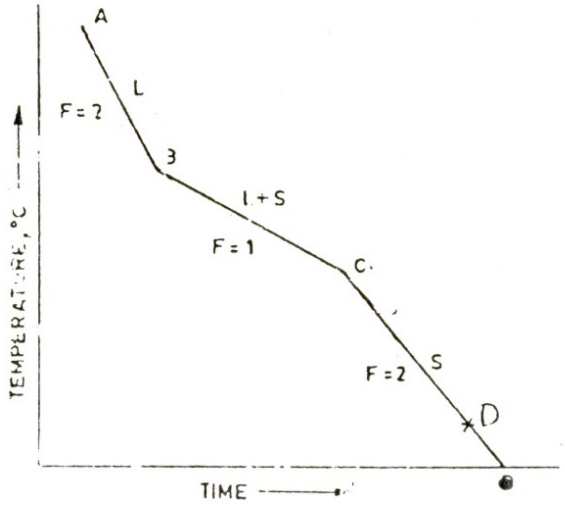
The microstructure shows continuous network of cementite along the grain boundaries of coarse pearlite.

5.REVIEW QUESTIONS:

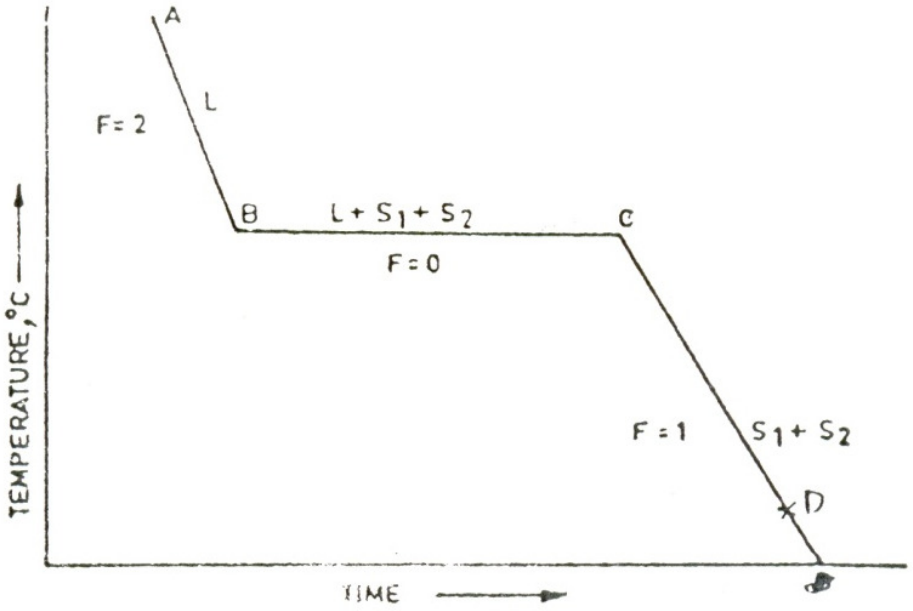
i. What is a cooling curve?
ii. What is the use of equilibrium diagram?
iii. What is curie temperature?
iv. What is the percentage of carbon in cementite?
v. What are the different phases in Fe-Fe3C equilibrium diagram?
vi. How Cast iron and steel are distinguished with respect to carbon percentage?
vii. What is eutectoid reaction?
viii. What is eutectoid reaction?
ix. What is peritectic reaction?
x. What is peritectoid reaction?
xi. Draw the microstructure of eutectoid steel?
xii. Draw the microstructure of Hypo eutectoid steel?
xiii. Draw the microstructure of Hyper eutectoid steel?
xiv. What is the maximum solubility of carbon in ferrite?
xv. What is the maximum solubility of carbon in Austenite?
xvi. What are the properties & applications of mild Steel?
xvii. What are the properties & applications of medium carbon steel(hypo eutectoid steel)?
xviii. What are the properties & applications of Eutectoid steel?
xix. What are the properties & applications of Hyper eutectoid steel?



Cooling curve of a pure metal.



Cooling curve of a solid solution alloy.



Cooling curve of an eutectic alloy.

Figure 1 Cooling curve of a pure metal

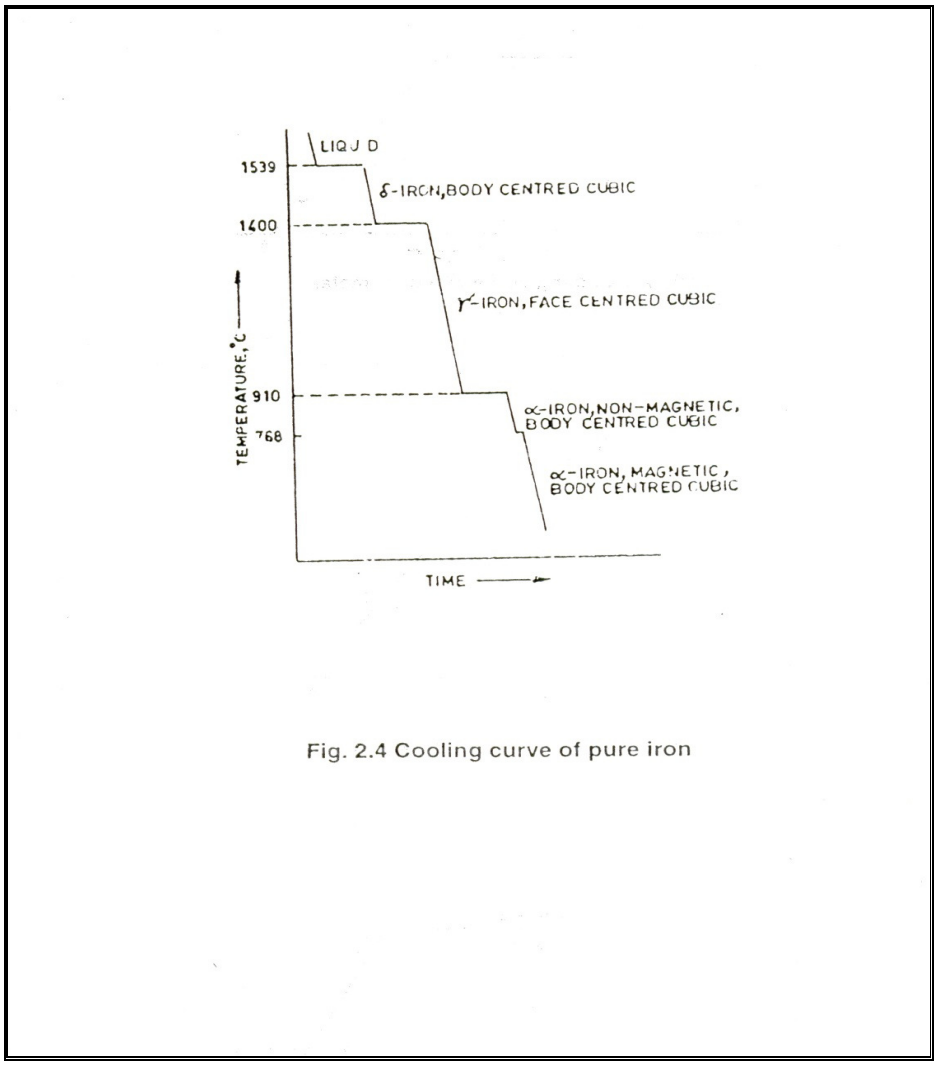


Fig. 2.4 Cooling curve of pure iron

Figure 2Cooling curve of pure Iron

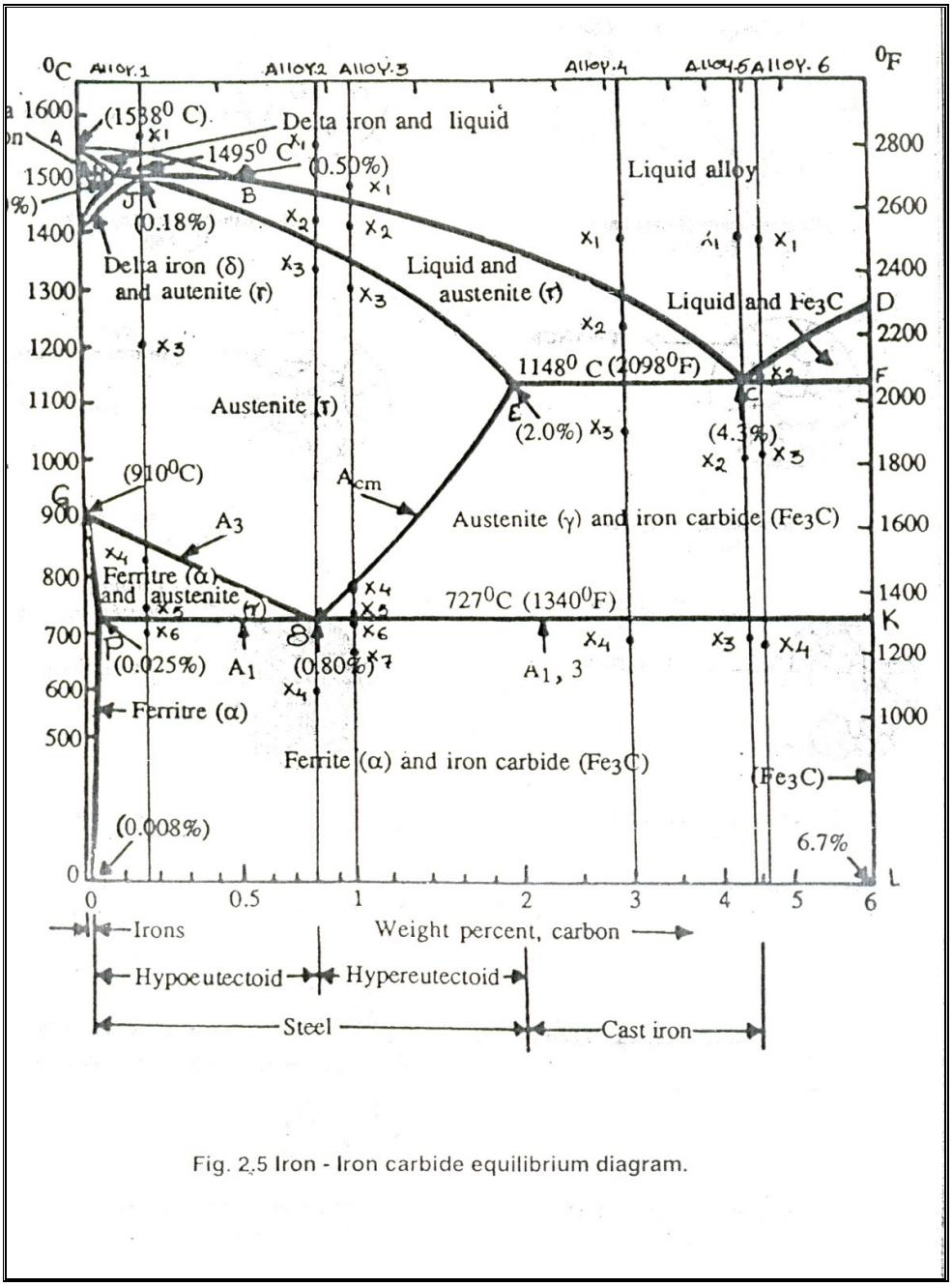
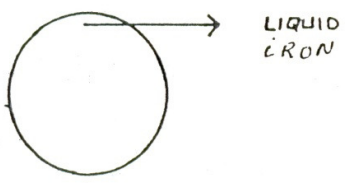
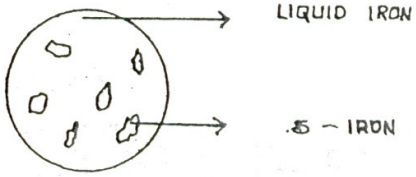


Fig. 2.5 Iron - Iron carbide equilibrium diagram.

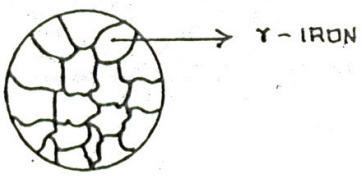
Figure 3Iron-Iron carbide equilibrium diagram



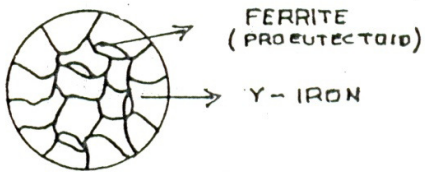
Miscrostructure of alloy 1 at X_1
Fig. 2.6a.



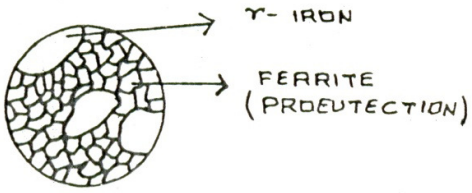
Miscrostructure of alloy 1 at X_2
Fig. 2.6b.



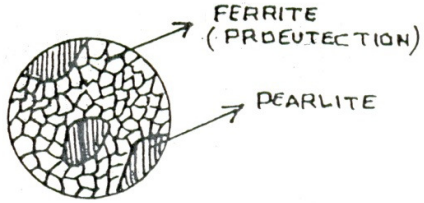
Miscrostructure of alloy 1 at X_3
Fig. 2.6c.



Miscrostructure of alloy 1 at X_4
Fig. 2.6d.

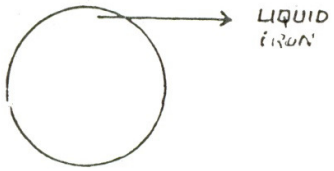


Miscrostructure of alloy 1 at X_5
Fig. 2.6e.

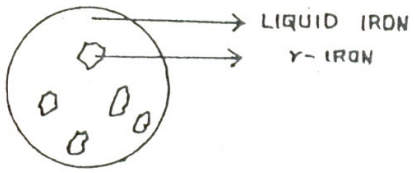


Miscrostructure of alloy 1 at X_6
Fig. 2.6f.

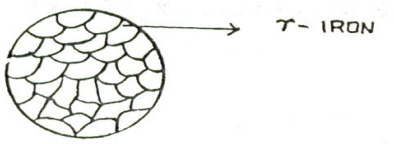
Fig. 2.6 Microstructures of alloy 1 with % of carbon is 0.18 (slowly cooled from liquid state to room temperatu at different temperature levels.



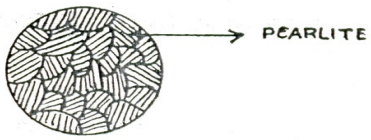
Miscrostructure of alloy 2 at X_1
Fig. 2.7a.



Miscrostructure of alloy 2 at X_2
Fig. 2.7b.

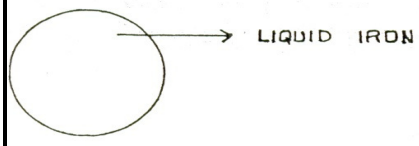


Miscrostructure of alloy 2 at X_3
Fig. 2.7c.

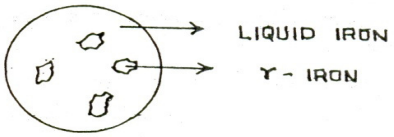


Miscrostructure of alloy 2 at X_4
Fig. 2.7d.

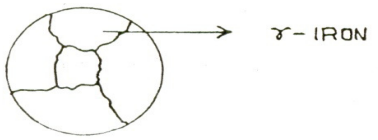
Fig. 2.7 Microstructures of alloy 2 with % of carbon is 0.8 (slowly cooled from liquid state to room temperature) at different temperature levels



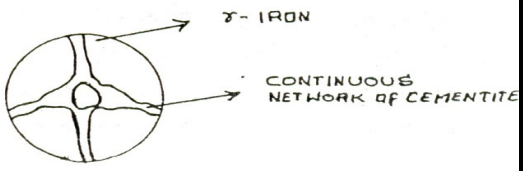
Miscrostructure of alloy 3 at X_1
Fig. 2.8a.



Miscrostructure of alloy 3 at X_2
Fig. 2.8b.



Miscrostructure of alloy 3 at X_3
Fig. 2.8c.



Miscrostructure of alloy 3 at X_5
Fig. 2.8d.

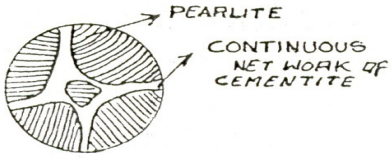


Fig. 2.8e. (Miscrostructure of alloy 3 at X_7)

g 2.8 Microstructures of alloy 3 with % of carbon is 1.0 (slowly cooled from liquid state to room temperature) at different temperatures

EXERCISE-3

STUDY OF MICROSTRUCTURES OF PLAIN CARBON STEELS (HEAT TREATED)

1.AIM:

To identify the different phases and to draw the microstructures Heat treated plain carbon steel.

2. Apparatus and specimens required:

Metallurgical microscope, specimen of high carbon steel subjected to annealing, normalizing, hardening and Hardening & tempering.

3.Theory:

3.1 Heat Treatment: It involves heating the metal to a suitable temperature within the solid state, maintaining the sample at that temperature for a specified period of time and cooling it ti room temperature in a controlled manner.

The purpose of heat treatment may be

- To relieve internal stresses and soften the metal for further deformation.
- To refine the grain size improve mechanical properties.
- To alter the surface condition
- To increase corrosion and wear resistance.

3.1.1 Different Heat treatment processes are:

a. Annealing b. Normalizing C. Hardening d. Tempering e. Surface hardening treatments

3.2 Time Temperature and Transformation Diagram(TTT diagram):

The TTT Diagram super imposed with different cooling austenitising temperature to room temperature is shown in fig.3.1

In fig. 3.1 V_1 represents annealing (with slow cooling in the furnace)

V_2 represents normalizing (a little faster cooling i.e. in air)

V_c represents Critical cooling rate (more faster cooling in a bath of a mixture)

V_5 represents Hardening (very fast cooling-dipping the specimen in oil or water)

3.3 Annealing:

The main purpose of annealing is stress relieving so that ductility of the steel can be improved to a greater extent. The annealing temperature range of steel is shown in fig.3.2

Annealing process cycle on Time-temperature diagram is show in fig.3.4 Annealing process consists of

a. Heating the specimen of steel to a temperature (above A_3 line in case of Hypo eutectoid steels and above A_3, line case of Hyper eutectoid steels)

b. Holding specimen at that temperature for a specified period of time(depending on the section thickness)

c. Then cooling the steel specimen to the room temperature in the furnace itself. The annealed structure of Hypo eutectoid steel consists of Ferrite and coarse pearlite.

3.4 Normalising: the purpose of Normalizing is to

a. Relieve the internal stresses
b. Refine the structure and improve the machinability. Normalising temperature range of steels is shown in fig.3.2 Normalizing process cycle Time-Temperature diagram is shown in fig. Normalizing process consists of

- Heating the specimen of steel to a temperature (30 to 500C above A3 line in case of hypereutectoid steels and above Acm line in case of hyper eutectoid steels.)
- Holding the specimen at this temperature for a specified period of Time.
- Then cooling the specimen to the room temperature in air. Normalized Hypo eutectoid steel consists of Ferrite and fine Pearlite.

3.5 Hardening:Main purpose of hardening is to improve the hardness & wear resistance of steels. Temperature range of hardening of steels is shown in fig.3.3

Hardening process cycle on Time-Temperature diagram is shown in fig. 3.6. Hardening process consists of

a. Heating the steel specimen to a temperature (500C higher than A3 line in case of hypo eutectoid steel and around 500C higher than A3 line in case of hyper eutectoid steel)
b. Holding at that temperature for sufficient period of time.
c. Quenching in water or oil to cool the specimen of steel to room temperature. The microstructure of hardened hyper eutectoid steel consists of fine martensite embedded with carbon network.

3.6 Tempering: Main purpose of tempering are

a. To reduce the thermal stresses.
b. To stabilized the structure of metal.
c. To reduce the hardness and brittleness.
d. To increase ductility and toughness of hardened steel specimens. Tempering process cycle on Tim-Temperature diagram is shown in fig.3.7 Tempering process consists of heating the specimen to a temperature below lower critical temperature for sufficient period of time and then slowly cooling to room temperature.

Microstructure of hardened and tempered steel consists of Ferrite and finely divided cementite.

3.7 Case hardening: For certain application hard ware resistant case and tough core is required. To get hard case and tougher core steels must be subjected to Case hardening treatment.

3.8 Case hardening methods:

Case hardening methods are broadly divided into two types.

a. Methods of case hardening by altering the surface chemical composition of the components. examples of this type are (i) carburizing (ii) Nitriding (iii) Carbonitriding.
b. Methods of case hardening without altering the surface chemical composition of the components. Examples of this type are (1) Flame hardening (2) induction hardening.

3.9 Methods of case hardening by altering surface chemical composition of the components.

3.9.1 Carburizing: the method of increasing the carbon content on the surface of a steel is called carburizing. The process of carburizing consists of heating the steel in austenite region in contact with a carburizing medium, holding at his temperature for a sufficient period and cooling to room temperature.

Depending on the medium used for carburizing it is classified into three types (i) Pack carburizing (ii) Gas carburizing (iii) Liquid carburizing.

3.9.1 a) Pack carburizing : The components to be carburized are packed with a carbonaceous medium 9carbonaceous medium consists of hard wood charcoal, coke and energizer(barium carbonat0 in a box and sealed with clay. The box is heated to austenitic region and then cooled to room temperature.

3.9.1 b) Gas Carburizing: Here the components are heated in austenetic region in the presence of a carbonaceous gas such as methane, ethane with a carrier gas such as flue gas. These gases decompose and the carbon diffuses into steel.

3.9.1 c) Liquid Carburizing: in this method carburizing id done by immersing the steel components in a carbonaceous fused salt bath medium (bath is composed of 10% sodium cyanide, sodium carbonate and sodium chloride) at a temperatures in the austenite region for sufficient time and then cooling to room temperature.

3.9.2 Nitriding: Nitriding is accomplished by heating steel in contact with a source of atomic nitrogen (ammonia gas) at a temperature of around 550^0C for sufficient time and they cooling to room temperature. The atomic Nitrogen diffuses into steel and cambiues with iron and carbon alloying elements present in steel and form respective nitrides. These nitrides increase hardness and wear resistance of steels.

3.9.3 Carbonnitriding: The components to be carbonnitrided are heated in a fused salt bath or in a gaseous medium (gaseous medium contains carbunizing gases like CH_4, C_2H_6 with 5 to 10% Ammonia) to a temperature between A_1 and A_3 temperatures of steel for sufficient period of time and are then cooled to room temperature. In this process both carbon and Nitrogen are diffused into the surface of steel.

3.10 Methods of case hardening without altering the surface chemical composition of components.

3.10.1 Flame hardening: This process consists of heating the surface layer of the component to above its upper critical temperature by means of oxyacetylene flame followed by water spray quenching or immersion quenching to transform austenite to martensite.

3.10.2 Induction Hardening: This process also increases surface hardness by heating and quenching a thin surface layer of components. Here heating is done by means of an induction coil.

4.The Micro structures of following specimens are studied in this exercise.

a. High carbon steel.

Specimen	:	High carbon steel
Composition	:	1% carbon, remaining iron
Heat treatment	:	Annealing
Etchant	:	Nital
Etching time	:	10 seconds

The annealed structure of high carbon steel consists of continuous network of cements and pearlite.

b. High carbon steel.

Specimen	:	High carbon steel
Composition	:	1% carbon, remaining iron
Heat treatment	:	Normalized
Etchant	:	Nital
Etching time	:	10 seconds

The normalizing continuous network cementite is broken. The microstructure shows cementite and pearlite.

c. High carbon steel.

Specimen	:	High carbon steel
Composition	:	1% carbon, remaining iron
Heat treatment	:	Hardened
Etchant	:	Nital
Etching time	:	10 seconds

The microstructure consists of martensite and carbon network.

d. High Carbon steel

Specimen	:	High carbon steel
Composition	:	1% carbon, remaining iron
Heat treatment	:	Hardened & Tempered
Etchant	:	Nital
Etching time	:	10 seconds

The microstructure consists of tempered martensite and epsilon carbide.

4. REVIEW, QUESTION

i. What is the Annealing temperature range of Hypo eutectoid steels?
ii. What is the hardening temperature range of Hyper eutectoid steels?
iii. Why hardened steel specimens are subjected to tempering?
iv. What is the normalizing temperature range of hyper eutectoid steels?
v. How the soaking time in furnace is decided ? Mention the times required for 1 cm thickness, 5cm thickness, 10cm thickness etc.
vi. Explain the properties of Hypereutectoid, eutectoid, Hyper eutectoid steels, before and after heat treatments?
vii. Show Time Temperature diagram for different types of plain carbon steels?

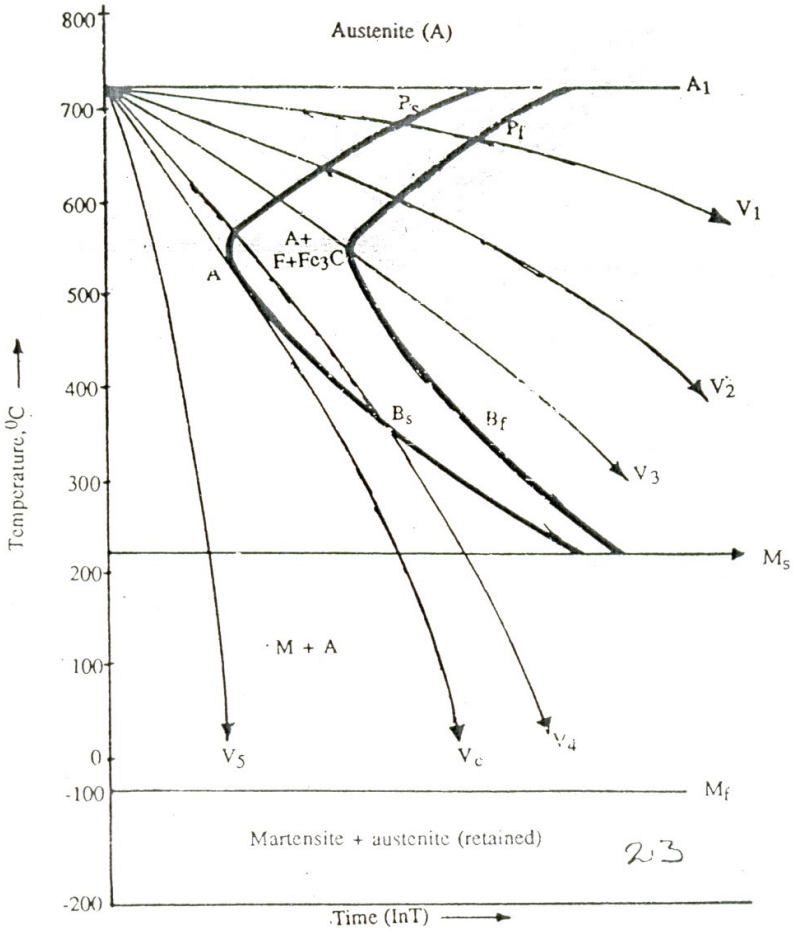


Fig. 3.1 TTT diagram (super imposed with different cooling rates)

Figure 4TTT diagram(super imposed with different cooling rates)

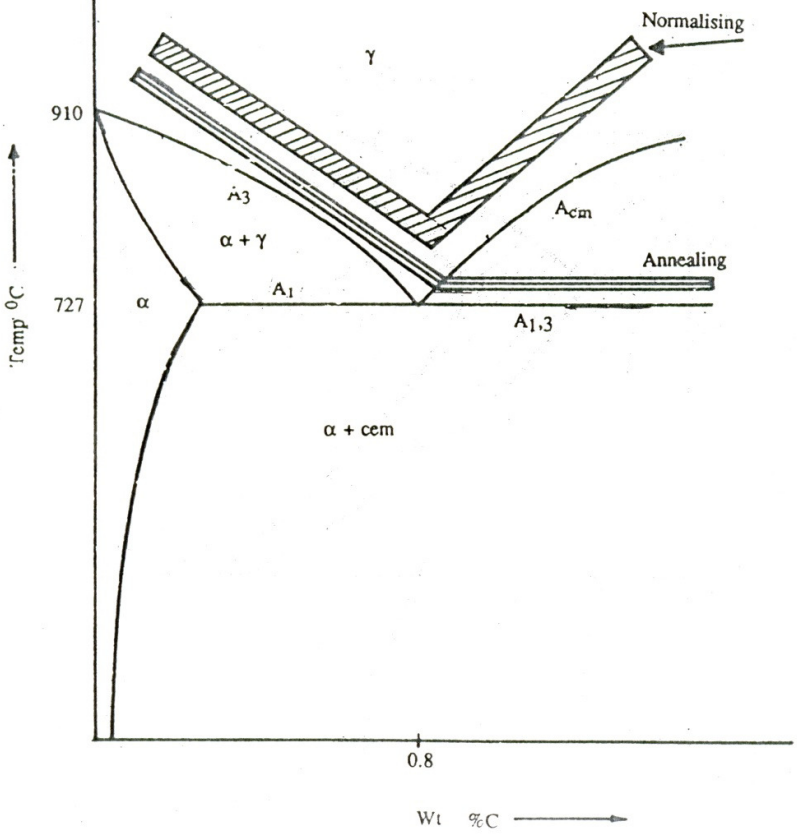


Fig. 3.2 Annealing and Normalising temperature ranges of steels

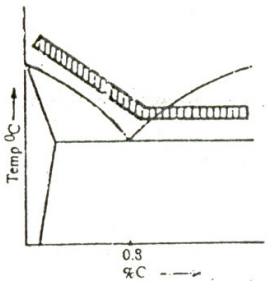


Fig. 3.3 Hardening temperature range of steels

Figure 5Hardening temperature range of steels

Figure 6Annealing and Normalising temperature ranges of steels

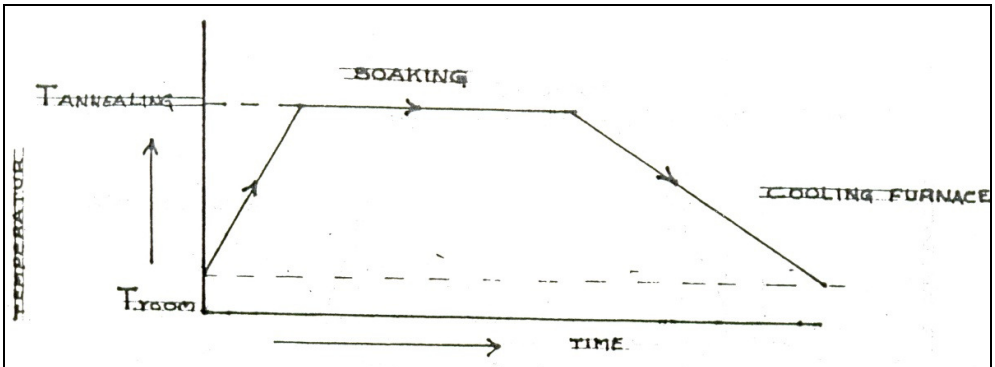


Fig. 3.4 Heat treatment cycle for Annealing on Time - Temperature diagrams for different types of steels

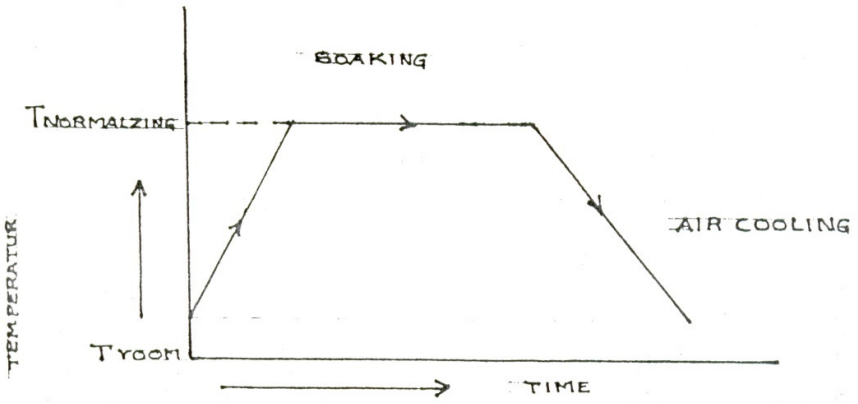


Fig. 3.5 Heat treatment cycle for Normalizing on Time - Temperature diagrams for different types of steels

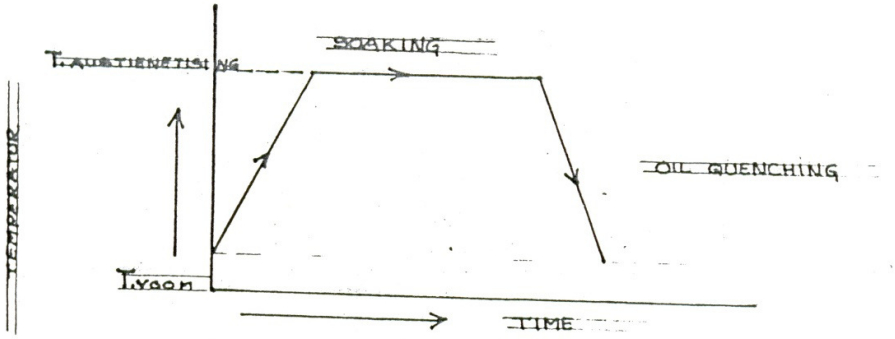


Fig. 3.6 Heat treatment cycle for Hardening on Time - Temperature diagrams for different types of steels

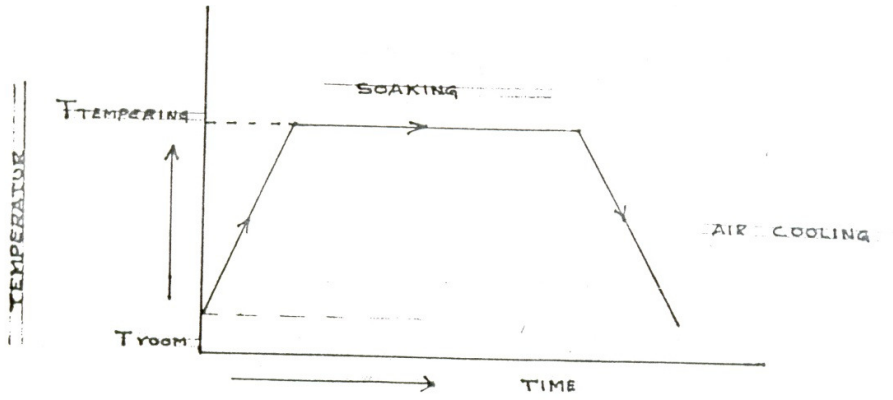


Fig. 3.7 Heat treatment cycle for tempering on Time - Temperature diagrams for different types of steels

MICRO STRUCTURE OF ALLOY STEELS

1. **AIM:**
   To identify the different phases and to draw the microstructure of alloy steels.
2. **APPARATUS AND SPECIMEN REQUIRED:**
   Metallurgical microscope, specimens of different Alloy Steels.
3. **THEORY:**
   Steels are to be alloyed for improving their mechanical properties. Common alloying are Al, Ni, Mn, Cr,, etc., However, the properties of alloy steels are not so much superior to plain carbon steels in untreated Cr, etc., However the properties of alloy steels are not so much supervisor to plain carbon steels in untreated condition. Different heat treatments are given to alloy steels to fully exploit their properties.
   a. **Effect of Alloying Elements:** Alloying elements may have one or more of the following effects.
      i. **Solid solution strengthening/Hardening:** Most of the alloying elements are soluble in ferrite to some extent and form solid solutions are harder and stronger than the pure metals and hence these elements increase strength and hardness of steels.
      Examples: Mn, Cr, W, Mo, V, Ti, Si, Al, Zr.....
      ii. **Formation of carbides:** Some of the alloying elements combine with carbon in steel and form respective carbides. These alloy carbides are hard and increase wear and abrasion resistance of steels.
      Examples: Mn, Cr, W, Mo, V, Ti, Si, Zr and Nb.....
      These phases increase the brittleness of steel and hence their presence in undesirable
      iii. **Formation of Intermediate Compounds:** Some of the elements from intermediate compounds with iron e.g. Fe, Cr(sigma phase in high chromium alloys) and Fe3W2 (in tool Steels).
      Examples: W, V, Ni, Si, Al, Zr, Cr, and Ti....
      iv. **Formation of inclusions**: They may combine with oxygen and form oxides when added to steel.
      Examples: Si, Al, Mn, Cr, V, and Ti...
      v. Shifting of critical temperature and eutectoid carbon: The alloying element may lower or raise the transformation temperature of steel. Elements, which are austenite stabilizers like Ni and Mn, lower the eutectoid temperature (A) while the elements, which are austenite stabilizers like Ni and Mn, lower the eutectoid temperature (A) while the elements, which are ferrite stabilizers, raise the above temperature.
      Most of the alloying elements shift the eutectoid carbon to lower values e.g. the carbon content of eutectoid in a 12% Cr steel is less than 0.4% as against to 0.8% in plain carbon steels.
      vi. Lowering of critical cooling rate: Most of the alloying elements (except Co) shift the T.T.T diagram to the right side, thus decreasing the critical cooling rate. This effect is very useful for increasing the hardenability of steel. Elements such as Mn, Mo, Cr and Ni are more effective in increasing the hardenability.
      vii. Changes in volume during transformation: Elements may be chosen in proper proportion so as to reduce in volume change to reduce distortions and the risk of quench cracking during hardening.

Other effects:

i. The transformation may become sluggish
ii. The corrosion and oxidation resistance may increase e.g. chromium increases corrosion resistance by forming a thin of chromium oxide on the surface. This is found in stainless steels.
iii. Creep strength may get increased due to the presence and dispersion of fine carbides.
iv. Fatigue strength may also get increased.

b. Classification of Alloying Elements:

With respect relation with Carbon, alloying elements can be classified into 3 groups.

a. Carbide forming elements: They form carbides when added to steels or cast irons.
Examples: Ti, Zr, V, nb, W, Mo, Cr, Mn.....

b. Neutral Elements: Cobalt is the only element in this category, which neither forms carbides nor causes graphitization.

c. Graphitizing elements: They try to decompose the carbides into graphite, in cast irons.
Examples: Ni, Si, Cu, Al

With respect to their effect on the temperatures intervals in which allotropic forms of iron exists alloying elements can be classified into 2 groups.

a. Austenite stabilizers: The elements from this group raise A_4, temperature and lower A_3, temperature, thus increasing the range of stability of austenite.
Example: Mn, Ni, Cu, C, N....

b. Ferrite Stabilizers: These elements lower A4 temperature and raised A3 temperature, thus increasing the range of stability of ferrite.
Examples: Cr, W, Mo, V, Ti, Ni, Si, Al, Zr, B ,Nb, P.....

c. Uses of Alloying Elements:

a. Sulphur: Sulphur combines with iron and forms iron sulphide and induces brittleness phase.

b. Phosphorus: Phosphorus dissolves in ferrite and increases its tensile strength and hardness.

c. Silicon: It is ferrite solid solution strengthener. It dissolves in ferrite increasing strength, hardness and toughness without loss of ductility. It is a strong graphitizer in cast irons.

d. Manganese: It dissolves in ferrite and increases yield strength tensile strength, toughness and hardness. It combines with sulphur and forms MnS reducing the detrimetal effect of FeS

e. Nickel: It is ferrite solid solution strengthener. It dissolves in ferrite and increases hardness, tensile strength and toughness without decreasing ductility. It increases impact resistances of steels at low temperatures i.e., it reduces ductile-brittle transition temperature.

f. Chromium:

Chromium has several functions as given below:

i. It forms carbides hardenability of steels.
ii. It forms carbides and increases hardness and wear resistance of steels.
iii. It increases corrosion and resistance when added in substantial amount.

Chromium has following disadvantages

i. It makes the steel susceptible to temper embrittlement.

ii. These steels are liable to form surface markings, generally referred to as chrome line.

g. Tungsten:

It has following functions:

i. It increases harndenability.
ii. It forms carbides and increases wear and abrasion resistance.
iii. It refines the gain size and the carbides inhibit the grain coarsening.
iv. It reduces the tendency of decarburization.

h. Molybdenum:

Molybdenum has similar functions as Tungsten. However, its resistance to grain coarsening and decarburization is less as compared to Tungsten.

i. **Vanadium:**

The Properties of vanadium containing steels are on similar lines as tungsten or/ and molybdenum containing steels. However, vanadium containing steels have improved distinct properties below:

i. The resistance to grain coarsening is excellent.
ii. The carbides of vanadium are extremely hard and hence, vanadium promotes secondary hardening during tempering.
iii. It effectively improves the fatigue and creep resistance.
iv. It is strong deoxidizer.

j. **Titanium:** It is strong carbide former it effectively inhibits grain coarsening and also acts as a grain refiner.

k. **Cobalt**: It is neither carbide former nor a graphitizer. It is the only element, which reduces hardenability of steels.

l. Aluminum: It is a powerful deoxidizer and hence is used for killing of steels. It is a grain refiner and also inhibitor.

m. **Boron**: small additions of boron (0.001 – 0.003%) sharply increase hardenability of medium carbon steels.

4. **The Microstructure of following Alloy steels are studied in this exercise.**

a. High Speed Tool Steel: The Important characteristics of Tool Steels are

i. High hardness at elevated temperatures ii) High wear resistance iii) High Hardenability iv) Good toughness

The steels maintain high hardness up to a temperature about 550^0C. These are designated by T-series.

Specimen	:	High speed steel
Composition Treatment	:	0.7%C, 18% W, 4% Cr, 1%V
Heat treatment	:	Heated to a temperature of 1250-1300^0C, soaked this temperature for every short period of time. The steel is then quenched in oil to room temperature. The steel is then multiple tempered at 550^0C at which it shows secondary hardening.
Etchant	:	Nital
Etching time	:	20 Seconds

The microstructure consists of tempered martensite, alloy carbides and low carbon retained austenite.

Application time	:	Cutting tools

b. Stainless steel: These steels have high corrosion resistance

Specimen	:	Stainless(Austenitic)
Composition	:	<0.15%C, 18% Cr, 10% Ni
Etchant	:	Nital
Etching time	:	20 seconds

The microstructure consists of Austenite grains. The dark regions are due to alloy carbide precipitation.

Applications: Utensils, Chemical plant equipment, Medical equipment Blades etc.,

c. High Carbon high Chromium steel: These steels have very high hardenability and very less distortion during hardening.

Specimen	:	High carbon high chromium steel
Composition	:	1.5%C, 12% Cr, 1% Mo
Heat treatment	:	Hardened and tempered
Etchant	:	Nital
Etching Time	:	20 seconds

The microstructure consists of tempered martensite. The dark areas are alloy carbides.

Applications: Drawing dies, Blanking dies etc

d. En36:

Specimen	:	En36
Composition	:	0.15%, 0.6%Mn, 3.35%Ni, 1.1%Cr, 0.35% Si
Heat treatment	:	Case Carburizing
Etching	:	Nital
Etching time	:	10 Seconds

The microstructures shows a while compound layer of few microns thick at the surface and Ferrite and pearlite at the core.

Applications: These are used where a hard case and a tough core is required. Boring bits etc.

5.REVIEW QUESTIONS:

i. Why alloying elements are added to steels?
ii. How negative effects of sulphur in steels will be neutralized?
iii. What is the composition of stain less steel?
iv. What are the important characteristic of Tool steels?
v. What is the composition of H.S.S?
vi. What makes High Carbon high chromium steel suitable for making dies>
vii. Show the heat treatment cycles, n Time-Temperature diagrams for different types of Steels?
viii. Compare the properties of alloy steels with and without heat treatment?

EXERCISE-5

STUDY OF MICROSTRUCTURES OF CAST IRONS

1. **AIM:**

   To Identify the different phases and to draw the microstructures of different cast Irons.

2. **APPARATUS AND SPECIMENS REQUIRED:**

   Metallurgical microscope, specimen of different cast irons

3. **THEORY**

4. Cast irons are Iron carbon alloys in which carbon content varies from 2 to 6.67%. cast-iron that contain carbon percentage between 2 to 4.3% are called Hypo eutectic cast irons. If carbon content of cast-iron is 4.3% it is called Eutectic cast iron. If the carbon content is above 4.3% it is called Hyper eutectic cast iron.

   3.1 Cooling of a Hypo eutectic cast iron (3% carbon):

   Alloy in fig.2.5(Iron-Iron carbide equilibrium diagram) represents Hypo eutectic cast iron with 3% carbon. Initially at point X_1, the alloy is in completely liquid state as shown in fig.5.1a. as it is slowly cooled no change is observed until it crosses 'BC' line (liquid line). After crossing 'BC' line austenite dendrites start forming from liquid iron. At X_2 the microstructure of alloy shows dendrites of protectoid austenite in liquid iron as showing in fig.5.1b. on further cooling of alloy when it crosses 'ECF' line(eutectic temperature line) liquid of alloy undergoes eutectic reaction at constant temperature (1130^0C) and transforms into lideburite (eutectic mixture of austenite and cementite)

Liquid eutectic cast Iron (Lideburite) $\xrightarrow{\text{Cooling}}$ (Austenite + Cementite)

The microstructure of alloy at X3 consists of dendrites of primary austenite, eutectic austenite and cementite as shown in fig.5.1c. on further cooling of alloy there is no considerable change in microstructure except increase of cementite (This cementite is separated from austenite because of decrease of solubility of carbon n austenite as temperature is reduces).

On further cooling of alloy when 'PSK' line (eutectoid temperature line) is crossed the austenite (primary as well as eutectic) undergoes eutectoid reaction at constant temperature (723^0C) and is converted to pearlite. At X_4 the microstructure of alloy consists of dendritic areas of transformed austenite (i.e. pearlite) in the matrix of transformed lideburite (pearlite + cemetite0 as shown in fig.5.1d

3.2 Cooling of Eutectic cast iron (4.3% carbon):

Alloy 5 in fig.2.5 represents eutectic cast iron with 4.3 % carbon. Initially at X1 the alloy is completely in liquid state as shown in fig.5.2a. on further cooling of the alloy no change is observed until it crosses 'ECF' (eutectic temperature line) at C. At 'C' liquid iron undergoes eutectic reaction at constant temperature (113^0C) and transforms into lideburite. At X2 the alloy consists of completely lideburite (Austenite + Cementite) as shown in fig. 5.2b. On further cooling of alloy no change is observed till it crosses 'PSK' line. When alloy crosses eutectoid temperature line('PSK') eutectic austenite undergoes eutectic reaction at 723^0C and transforms into pearlite. The microstructure of alloy at X3(Just below 'PSK' line) consists of transformed austenite

(pearlite and cementite as shown in fig.5.2c. On further cooling of alloy to room temperature there is no change in the microstructure.

3.3 Cooling of hyper eutectic cast Iron(4.5% Carbon)

Alloy 6 in fig.2.5 represents Hyper eutectic cast-iron with 4.5% carbon. Initially at X1 the alloy consists of only liquid iron as shown in fig.5.3(a). On cooling of alloy no change is observed till it crosses 'CD' line. After crossing 'CD' line cementite starts nucleating from liquid iron. The microstructure of alloy at X2 consists of proeutectic cementite dendrites in liquid iron shown in. .3b. on further cooling of alloy no change is observed till it crosses 'ECF' line (eutectic temperature line). When 'ECF' line is crossed liquid of the alloy undergoes eutectic reaction at constant temperature (1130^0C) and is transformed into lideburite (eutectic mixture of austenite and cementite). The microstructure of alloy at X3(just below 'ECF' line) consists of eutectic austenite, cementite and proeutectic cementite as shown in fig.5.3c. On further cooling of alloy no change is observed till it crosses 'PSK' line (eutectic temperature line). When it crosses 'PSK' line the austenite of alloy undergoes eutectoid reaction at constant temperature(723^0C) and transforms into pearlite. At X4(just below 'PSK' line) the microstructure consists of cementite and pearlite as shown in fig.5.3d. the alloy is further cooled to room temperature there is no change in the microstructure.

3.4 The useful properties of cast iron are

i) Good fluidity (ability to fill narrow cavities in casting in liquid steel ii) Low melting point iii) Good machinability iv) Less dimensional changes during solidification.

Cast irons are brittle and have low tensile strength than most of the steels. Specially in the case of Grey cast iron, the graphite present will act line cracks and reduce tensile strength, toughness etc.,

3.5a Types of cast irons:

Depending on the form of carbon, cast irons are divided into

a) white cast iron b) Gray cast iron c) Malleable cast iron d) Speheroidal cast iron e) Chilled cast iron

3.5a White cast iron: In white cast iron most of the carbon is present in combined form as cementite. This is obtained by rapidly cooling the cast iron from its molten state. These are hard and wear resistant. These are used only for hard and wear resistance applications and also used as raw material to produce malleable iron. At room temperature microstructure of Hypo eutectic C.I consists of dendritic areas of transformed austenite in a matrix of transformed lideburite. At room temperature microstructure of eutectic cast iron consists of cementite and pearlite. At room temperature microstructure Hyper eutectic C.I consists of dendrites of primary cementite in the matrix of transformed liderburite.

3.5b Grey cast iron:

In Grey cast iron carbon in present as free graphite flakes. They contain more carbon and silicon content than white cast irons. It is a low melting alloy having good cast ability and good damping capacity. The tendency of carbon to form graphite flakes is due to increase in carbon and silicon content and decreasing cooling rate. Grey cast iron receive its name from the color of a freshly made fracture. At room temperature the microstructure of Grey cast iron consists of graphite flakes and pearlite.

3.5.c Malleable cast iron:

Malleable cast iron is produced by heating white cast iron to 90 to 1000^0C for about 50 hours followed by slow cooling to room temperature. On heating white cast iron, cementite structure tend to decompose into ferrite and tempered carbon. The lubrication action of graphite imparts high machineability to malleable cast iron. Malleable castings are tough, strong and shock resistant. These are used for wide range of applications such as automobile parts, railroad equipment, manhole covers etc., At room temperature the microstructure of Malleable cast iron consists of rosettes of tempered carbon graphite in the matrix of pearlite.

3.5.d Spheroidal graphite cast iron (Nodular cast iron or Ductile cast iron):

Spheroidal graphite cast iron is an iron carbon alloy having a structure composed of nodules (spheroids) of graphite formed directly during the process of solidification and embedded in matrix of steel. The formation of spherical graphite is due to addition of Magnesium for hypo eutectic cast iron and cerium for hyper eutectic cast iron. This is used for hydraulic cylinder, valves cylinder heads for compressor and diesel engine etc., Due to spherodization tensile strength, ductility and toughness are improved. This cast iron combines the advantages of cast iron and steel. The graphite in spherical shape reduces stress concentration effect and hence higher strength and toughness results.

3.5e Chilled cast iron:

Chilled cast iron is produced by adjusting the composition of white cast iron and then cooling it rapidly to room temperature. Rapid cooling promotes hard, thin layer on the surface of a soft iron casting. It is used where surface hardness is important. It finds applications in making dies and rolls for crushing.

The Micro structures of following cast irons are studied in this exercise

4.a Grey cast iron:

Specimen	:	Grey cast iron
Composition	:	3.5% carbon 2%silicon 0.5% manganese 0.4% phosphorous 0.09% Sulphur
Heat treatment	:	Nil
Etchant	:	Nital
Etching time	:	20 seconds

The micro structure shows uniformly distributed and randomly oriented graphite flakes in the matrix of ferrite and pearlite.

Applications: These are widely used for machine bases, engine frames, cylinders and pistons of I.C engines etc.,

B.White cast Iron:

Specimen	:	White cast iron
Composition	:	4% carbon 0.5% silicon 0.4% manganese 0.05% phosphorous0.3% sulphur
Heat treatment	:	Nil
Etchant	:	Nital
Etching time	:	20 seconds

The micro structure shows dendrites of transformed austenite(pearlite) in the matrix of transformed Ledeberite(i.e. pearlite and cementite). Majority of these cast irons are Hypo eutectic cast irons.

Applications: Used for wearing plates, pump liners, dies, etc., and also for production of Malleable castings.

C. Malleable cast iron:

Specimen	:	Malleable
Composition	:	4%carbon 0.5% silicon 0.4% manganese 0.1% phosphorus 0.1% sulphur
Heat treatment	:	Nil
Etchant	:	Nital
Etching time	:	20 seconds

The micro structure shows irregular nodules of tempered carbon (graphite) in the matrix of white ferrite phase, (if cooling rate is low) or pearlite phase(if cooling rate is high).

Applications: Cam shafts, crank shafts, Axles, etc.,

d. Spheroidal graphite cast iron (Nodular cast iron or Ductile cast iron):

Specimen	:	Ductile cast iron/Nodular/Spheroidal cast iron
Composition	:	3.3% carbon, 2.4 silicon 0.05% manganese, small amount of Mn,Phosphorous & sulphur
Heat treatment	:	Nil
Etchant	:	Nital
Etching Time	:	20 Seconds

Time micro structure shows a typical structure. It contains nodules (spheroids) of graphite surrounded by ferrite in the matrix of pearlite.

Applications: Used for gears, punches, dies, metal working rolls, furnace doors, etc.

5.REVIEW QUESTIONS:

i. What are the different types of cast irons?
ii. What is the difference between white cast cast iron and Grey cast iron?
iii. What are the important properties of Grey cast iron?
iv. Why white cast iron has limited applications?
v. What is the structure of Malleable cast irons? Explain the heat treatment cycles used for black heart and white heart malleable iron?
vi. What is the additional metal added for spherodisation for Hypo and Hyper eutectic cast irons? How they act?
vii. What is chilled cat iron?
viii. What is the difference between Ferrite malleable, pearlitic malleable and Pearlitic-ferrite malleable cast irons?
ix. Why Gray cast irons has got that name?
x. Why Gray cast iron is o brittle?
xi. Explain important properties of different types of cast irons?

EXERCISE-6

STUDY OF MICROSTRUCTURES OF NON FERROUS METALS

1.AIM:

To determine the present and to draw the microstructures of copper, Aluminum & Magnesium.

2.APPARATUS AND SPECIMENS REQUIRED:

Metallurgical microscope, specimens of Aluminium ,copper and Magnesium.

3.THEORY:

3.INTRODUCTION TO NON METALS

Non ferrous metals don't contain as base . A wide range of Non metals are employed for various engineering applications. Most Non ferrous metals posses good corrosion resistance, formability, castablity and special electrical and magnetic properties. Important Non –ferrous metals their melting points and crystal structures are tabulated here under.

S.No	Name	Melting Point ^{0}c	Crystal Structure
1	Aluminum(Al)	660	FCC
2	Antimony(Sb)	630	Rhombohydral
3	Bismuth(Bi)	271	Rhombohydral
4	Cadmium(Cd)	321	CPH
5	Chromium(Cr)	1900	BCC
6	Copper(Cr)	1083	FCC
7	Gold(Au)	1064	FCC
8	Lead(Po)	327	FCC
9	Magnesium(Mg)	650	CPH
10	manganese(Mn)	1250	Complexcube
11	Nickle(Ni)	1453	FCC
12	Silver(Ag)	961	FCC
13	Tin(Sn)	232	Body centered tetragonal
14	Zinc(Zn)	419	CPH

4.**The microstructures of following specimens are in this experiment**

a. Copper:

Specimen	:	Pure Copper
Heat treatment	:	Nil
Etchant	:	Ferric chloride solution
Etching time	:	100 seconds

The micro structure shows equi axed grains of copper

b.Aluminium:

Specimen	:	Pure Aluminum
Heat treatment	:	Nil
Etchant	:	Ferric chloride solution
Etching time	:	60 seconds

The microstructure shows grains of Aluminum

c. Magnesium

specimen	:	Pure Aluminum
Heat treatment	:	Nil
Etchant	:	Ferric chloride solution
Etching time	:	60 seconds

The microprocessor shows grains of magnesium.

5.REVIWE QUESTIONS :

i. What are the important properties of Non-Ferrous metals and alloys?
ii. List out some important Non-Ferrous metals?
iii. What is melting point temperature of Aluminum?
iv. What is the crystal structure of Magnesium?
v. FCC metals are usually ductile and have high strain hardening tendency. Explain why?

EXERCISE-7

STUDY OF STRUCTURES OF NON FERROUS ALLOYS

1.AIM:

To determine the phases present and to draw the microstructures of some Non ferrous alloys.

2.APPARATUS AND SPECIMENS REUIRED:

Metallurgical microscope, specimens of alpha brass, alpha beta brass, Gunmetal and Tin based babbit.

3.THEORY:

3.1 Brasses: Brasses are the alloys of Copper and Zinc equilibrium diagram shown in fig observe that the region solid solution is quite extending from 0 to 38% of Zinc. If Zn percentage is more than 38% a second solid solution is formed. With zinc content more than 50% another solid solution called gamma is found .Useful Cu-Zn alloys are those that contain less 40% Zn.

Different brasses are Cap copper(contains 2 to 5% zinc),Gilding metals (contains 50% to 15% zinc)Cartridge brass(70% copper,30% zinc) Admiralty brass(69% copper ,30% zinc,1%tin), Muntz metal(605 copper,40% zinc),Naval brass(60% copper,39% zinc, 1% tin).

3.2 Copper-Tin Alloys:-

Alloys containing principally copper and tin are called Bronzes. Bronzes posses desirable properties of strength resistance and salt water corrosion resistance. From Copper-Tin equilibrium diagram shown in fig 7.2 one can observe that the solubility of Tin in Copper is 13.5% at 798% c, and it increases to 15.8% at 586c, and remains constant up to 520c,decreases to 11% at 350c and to about 1% at room temperature, With larger properties of Tin the hard compounds like Cu3Sn,epsilon phase, may appear in the structure .Useful engineering alloys in this system are those less than 20% Tin.

General range of composition of bronzes with respect to Copper and content may be divided into four groups as follows.

a. alloys containing up to 8% Tin which are used to sheets and wires.
b. Alloys containing Tin percentage between 8 to 12,which are used for gears and other machine parts.
c. Alloys containing between 12 and 20% Tin which are used for bearings.
d. Alloys containing between 20 and 25% Tin which are used for bells.

4.The microstructures of following specimens are observed in this exercise.

a. Cartridge Brass (Brass):

specimen	:	Cartridge brass
composition	:	70% Cu,30% Zn
Heat treatment	:	nil
Etchant	:	Ferric Chloride
Etching time	:	60 seconds

The micro structure shows single phase solid solution of zinc in copper ,grain of phase are polygonal and grain size is mixed. Application: Used cartridge cases, radiator fins, rivets etc.

b.Muntzmetal(α-β Brass):

specimen	:	Muntz metal
Composition	:	60% Cu ,40% Zn
Heat treatment	:	Nil
Etchant	:	Ferric Chloride
Etching time	:	60 seconds

The micro structures two phases. White α-Phases (α- solid solution of Zn in copper) is present in the matrix of dark β- phase (β- solid solution of Zinc in Copper)

Applications : Utensils, shafts, nuts, bolts and condenser tubes.

C. Gun metal:

specimen	:	Gun metal Bronze
Composition	:	10% Sn, 2%, Balance is Copper
Etchant	:	Ferric Chloride
Etching time	:	40 seconds

The micro structures shows heavily cored dendrites of and islands of (**α-δ)**eutectoid.

Applications: It is widely used for gun barrels, marine parts, valve bodies, bearing bushes etc.

d. White metal alloys(Babbits):

Babbits are either Lead based or Tin alloys. Both the types contain Antimony. These are mainly used as bearing materials. The microstructures of Babbits consist of hard cuboids of(sn-sb)in a soft matrix of eutectoid. In addition to above cuboids the microstructure may consists of hard needles of CuSn and hard star shaped crystals of Cu_3Sn.

Specimen	:	Tin Base Babbit
Composition	:	84% Sn,7%Cu,9%Sb
Heat treatment	:	Nil
Etchant	:	Ferric chloride solution
Etching Time	:	20 seconds

The microstructure shows star shaped Cu-Sn compound. Rectangular crystals of sn-sb compound are observed in ductile in matrix of Cu-Sn ternary eutectic.

Applications: Bearings

5.REVIEW QUESTIONS

i. What are the important alloys of Copper & Zinc?

ii. What is Composition of Muntz metal?

iii. What is the composition of Cartridge Brass?

EXERCISE-8

JOMINY END QUENCH TEST

1.AIM: To determine the harden ability of a given steel

2.APPARATUS: Jominy test apparatus, furnace, Rockwell hardness tester and a grinder.

3.THEORY:Jominy end quench test is used to determine harden ability of steels .The process of increasing the hardness of steel is known as Hardening .Specific specimen with standard dimensions, used for the test is given in fig.8.1.The hardness of hardened bar is measured along its length.

3.1. Harden ability: The depth up to which steel can be hardened is defined as harden ability. A steel having high hardness need not have high harden ability. Harden ability may be defined as susceptibility to hardening by quenching. A material that has high harden ability is said to be hardened more uniformly throughout the section than one that has lower harden ability.

M.A Gross man devised a method to decide harden ability.

3.1.1.Critical diameter: The size of the bar in which the zone of 50% martensite occurs at center is taken as critical diameter. This is a measure of harden ability of steel for a particular quenching medium employed.

3.1.2.Severity of Quench:

The severity of quench is indicated by heat transfer equivalent

H=f/k f = Heat transfer factor of quenching medium and the turbulence of the bath.

K=Thermal conductivity of bar material.

The most rapid cooling is possible with severity of as infinity

3.1.3.Ideal Critical Diameter:

The harden ability of steel can be expressed as the diameter of bar that will form structure composed of 50% marten site at the center when quenched with H=infinity. This diameter is defined as critical diameter.

4.Description of Apparatus:

Jominy end quench apparatus is shown in fig 8.2.

The apparatus consists of a cylindrical drum. At the top of the drum provision is made for fixing the test specimen. A pipe line is connected for water flow, which can be controlled by means of a stop cock.

5.PROCEDURE:

Out of the given steel bar, the standard sample is to be prepared as per the dimensions shown in the fig 8.1

a. The austenitising temperature and time for the given steel is to be determined depending on its chemical composition .
b. The furnace is setup on the required temperature and sample is kept in the furnace.
c. The sample is to be kept in the furnace for a predetermined time(based on chemical composition of steel) then it is taken out of the furnace and is kept fixed in the test apparatus.
d. The water flow is directed onto the bottom end of the sample. The water flow is adjusted such that it obtains shape of umbrella over bottom of sample.
e. The quenching is to be continued for approximately 15 minutes.
f. A flat near about 0.4 mm deep is grounded on the specimen.
g. The hardness of the sample can be determined at various points starting from the quenched end and the results are tabulated.
h. The graph is plotted with hardness versus distance from quenched end. From the results and graph plotted the depth of hardening of the given steel sample can be determined.

The harden ability of the specimen is foundry by observing the structure under the microscope. As detailed above the diameter at which the percentage of martensite is 50 indicates harden ability of material. More this diameter high will be the harden ability. Now the important factor is the relationship between size are diameter of a steel bar quenched in an ideal quenching medium which has the same cooling rate at it centre as a given position along the fact that if position on the jominy bar where the structures is 50% martensite is known then the shown fig 8.4 makes it possible to determined ideal critical diameter.

6.TABLE

S.NO.	Distance from quenched end (mm)	Hardness (BHN)

7. RESULTS:

8. CONCLUSION:

9. PRECAUTION: The specimen is to be handled carefully while transferring furnace to test apparatus

1. Proper water flow (at high pressure) over the bottom end of specimen is to be ensured.

10.REVIEW QUESTIONS:

1. What is the difference between Hardness & Harden ability?
2. What is severity of Quench?
3. What is critical diameter ?
4. What is the ideal critical diameter?
5. What is the quenching medium employed in the test?
6. What is the important precautions to be observed in the test?
7. why a flat is to be ground on the test specimen?
8. What is the equipment used to measure the hardness of specimen in the experiment?

EXERCISE -9

HARDENING OF STEELS

1. AIM:

To harden the given steel specimen.

2. APPARATUS:

Muffle furnace quenching medium(oil).

3. THEORY:

The purpose of hardening is to increase the hardness and wear resistance of steel .Steel specimens when heated to hardening temperature the structure will be transformed to austenite. When thin steel is cooled to room temperature at a cooling rate greater than the critical cooling rate. Austenite will undergo diffusion less transformation and gets converted in to Martensite. Is the hardest phase .Hence the hardness of steel specimen will be increased during hardening treatment. The improvement in hardness during hardening treatment depends on carbon content of austenite and also on type and amount of alloying elements present in the steel.

4. PROCEDURE:

i. Determine the hardness of given steel specimens
ii. Heat the steel specimens to hardening temperature and soak it for sufficient period of time.
iii. Quench the specimens in oil.
iv. Determine the hardness of the hardened specimens.

5. TABLE:

S.NO	MATERIAL	HARDNESS	HARDENING TEMPERATUR	SOAKING TIME	HARDNESS AFTER HARDENING

6. RESUL TS & DISCUSSION

7. CONCLUSION:

8. **PRECAUTIONS:**

i. The hot specimen is to be handled carefully

ii. The furnace should be carefully set to appropriate temperature.

9. REVIEW QUESTIONS:

i. Why specimen has to tempered after hardening?

ii. what is low temperature tempering?

iii. What is medium temperature tempering?

iv. what is high temperature tempering?

v. what is the micro structure of a hardened and tempered steel?

vi. What are the important precautions observed in the test?

vii. what is the type of furnace used and mention its specifications?

viii. What is the cooling medium employed during hardening &during tempering?

EXERCISE – 10

AGE HARDENING

1. **1.AIM:**
   To Age harden the A1-4.5% Cu alloy.

2. **APPARATUS:**
   Furnace, Quenching medium, Rock well hardness tester,clock,A1-4.5% Cu alloy**.**

3. **THEORY:**

Some of alloys show increase in hardness with time at room temperature or after heating to slightly higher temperature. This type of hardening is called Age or Precipitation hardening. Age hardening is observed in alloys such as

A1-4.5% Cu,

A1-6%Zn, 2.5% Mg,

Cu-2% Be,

T1-6% A1-4%v, etc.

Important applications of A1-4.5%Cu alloy(LM11) are aircraft castings and other highly stressed parts. The strength to weight ratio of LM11 is higher than steel.

3.1.1 The conditions for an alloy to undergo precipitation hardening are

i. The solubility in the solvent must decrease with decrease in temperature
ii. The precipitate that separates out from the matrix should be coherent.

Since the solute atoms are the different size from the solvent atoms, large amount of elastic distortion is observed around the precipitate particle. The coherent precipitate particles are powerful obstacles to the motion of dislocations. Hence dislocations will be piled up and material hardness will be increased.

The microstructures at different stages of a precipitation harden able alloy are shown fig 10.1

3.2.1 **A1- Cu Equilibrium Diagram:**

By observing A1- Cu equilibrium diagram showing in fig 10.2 it can be seen that solubility of Cu in A1 decreases from 5.65% at 48c to less than 0.25 % at room temperature An eutectic is formed at 33% copper .Useful A1 –Cu alloys are those which contain less than 10% Cu. The mechanical properties of A1-4.5%Cu) alloy can be improved by precipitation of phase(CuSl2) from solid solution .

3.3 **Steps in precipitation Hardening :** The general steps involved in precipitation hardening of an alloy (Al-C 4.5%%) are explained below

a. **Heating(Solutionising);** The alloy is heated to a temperature between the eutectic and a solves temperature, so that it forms a single phase solid solution i.e. ,α+θ → α. The alloy is kept at this temperature sufficient period of time for complete homogenization.

b. Quenching: The alloy is rapidly cooled to room temperature to obtain a super saturated solution α phase

c. Now the alloy is in solution treated condition. It's hardness is relatively low (but higher than annealed condition).

d. Aging:

i. Natural Aging: Some of the alloys show increase in hardness with time at room temperature. This is known as Natural Aging.

ii. Artificial Aging: For some alloys increase in hardness with time at room temperature is not appreciable. In such case they will be aged at a higher temperature(the temperature is roughly between 15 to 25% of the temperature difference of room temperature and solutionising temperature) to increase the kinetics of precipitation, this is known as Artificial aging. A decrease of aging temperature considerably increases aging time.

Note: Over aging decreases the hardness. Hence aging should be stopped as soon as the optimum hardness is obtained. In Al-4.5% Cu alloy precipitation hardening process Cu Al2 is precipitated.

During the aging the hardness of the specimen should be measured at different lengths of time and a graph is to be drawn between hardness and time.

4. PROCEDURE:

a. An (Al-4.5% Cu) alloy specimen is taken and cleaned.

b. Hardness of the specimen is determined.

c. The specimen should be treated to a temperature (600^0C).

d. The specimen is kept at that temperature for sufficient period of time.

e. The specimen is quenched to room temperature.

f. The specimen is again heated to a temperature (100^0C), and maintained at that temperature.

g. The hardness of the specimen is noted at different lengths of time.

h. Results are tabulated and graph is drawn between hardness and time.

5. TABLE

S.No	Time	Hardness

6. RESULTS & DISCUSSION:

7. CONSULSIONS:

8. REVIEW QUESTIONS:

i. What is Age hardening?

ii. What is difference between Natural aging and Artificial aging?

iii. What is the maximum solubility of Copper in Aluminum at room temperature?

iv. What is the name of (- phase observed in the age hardening of Aluminum Copper alloy?

v. What are the precautions to be observed in the experiment?

vi. What is the composition of age harden able Aluminum Copper alloy?

vii. Name different alloy that can be Age hardened?

viii. What is the problem with over aging?

PART –II

STRENGTH OF MATERIALS LAB

LIST OF EXPERIMENTS

S. No.	Name of the Experiment
1	To Study the various component parts of the Universal Testing Machine (U.T.M.) & test procedures of various practical's to be performed.
2	To study the Universal testing machine and perform the tensile test.
3	To study the Rockwell hardness testing machine & perform the Rockwell hardness test.
4	To study the Brinnel hardness testing machine & perform the Brinnel hardness test.
5	To perform compression & bending tests on UTM.
6	To perform shear test on UTM
7	To determine the stiffness of the spring and modulus of rigidity of the spring wire
8	To determine Bending test on UTM
9	IZOD Impact Test
10	Torsion Test

Note:

1. At least ten experiments are to be performed in the semester.
2. At least FOUR experiments should be performed from the above list. Remaining two experiments may either be performed from the above list or designed & set by the concerned institute as per the scope of the syllabus**.**

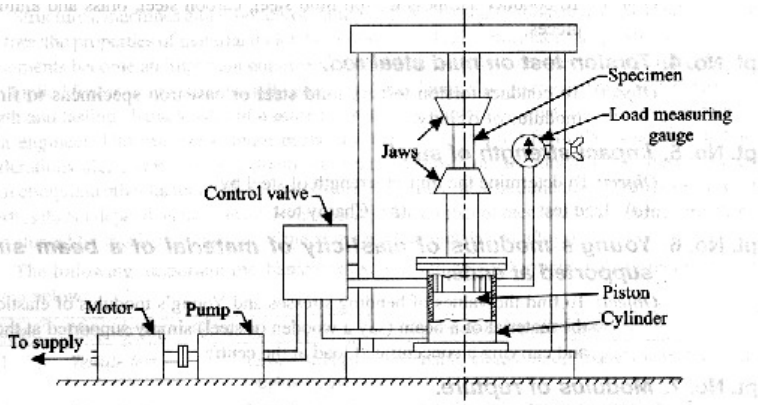
EXPERIMENT NO.: 01

AIM: Study of Universal Testing Machine (U.T.M.)

OBJECT: To Study the various component parts of the Universal Testing Machine (U.T.M.) & test procedures of various practical's to be performed.

APPARATUS: Universal Testing Machine with all attachment i.e. shears test attachment, bending attachment, tension grips, compression test attachment etc.

DIAGRAM:



• Fig. 1. Tenstile testing machine.

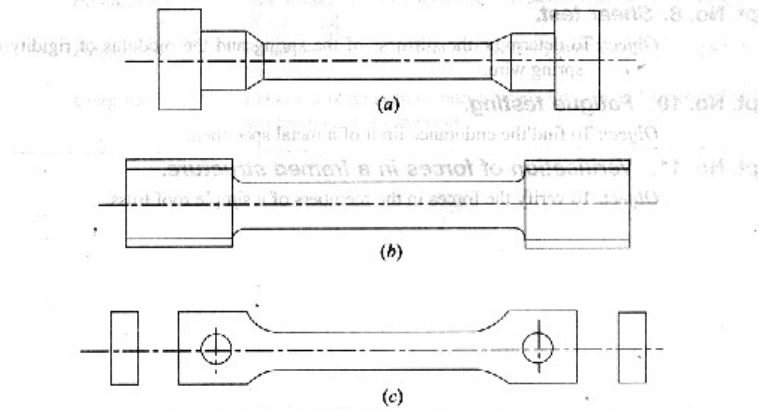


Fig. 2. Mild steel specimens.

THEORY: The Universal Testing Machine consists of two units. 1) Loading unit, 2) Control panel.

LOADING UNIT: It consists of main hydraulic cylinder with robust base inside. The piston which moves up and down. The chain driven by electric motor which is fitted on left hand side. The screw column maintained in the base can be rotated using above arrangement of chain. Each column passes through the main nut which is fitted in the lower cross head. The lower table connected to main piston through a ball & the ball seat is joined to ensure axial loading. There is a connection between lower table and upper head assembly that moves up and down with main piston. The measurement of this assembly is carried out by number of bearings which slides over the columns. The test specimen each fixed in the job is known as

'Jack Job'. To fix up the specimen tightly, the movement of jack job is achieved helically by handle.

CONTROL PANEL: It consists of oil tank having a hydraulic oil level sight glass for checking the oil level. The pump is displacement type piston pump having free plungers those ensure for continuation of high pressure. The pump is fixed to the tank from bottom. The suction & delivery valve are fitted to the pump near tank Electric motor driven the pump is mounted on four studs which is fitted on the right side of the tank. There is an arrangement for loosing or tightening of the valve. The four valves on control panel control the oil stroke in the hydraulic system. The loading system works as described below. The return valve is close, oil delivered by the pump through the flow control valves to the cylinder & the piston goes up. Pressure starts developing & either the specimen breaks or the load having maximum value is controlled with the base dynameters consisting in a cylinder in which the piston reciprocates. The switches have upper and lower push at the control panel for the downward & upward movement of the movable head. The on & off switch provided on the control panel & the pilot lamp shows the transmission of main supply.

METHOD OF TESTING: Initial Adjustment: - before testing adjust the pendulum with respect to capacity of the test i.e. 8 Tones; 10 Tones; 20 Tones; 40 Tones etc. For ex: - A specimen of 6 tones capacity gives more accurate result of 10 Tones capacity range instead of 20 Tones capacity range. These ranges of capacity are adjusted on the dial with the help of range selector knob. The control weights of the pendulum are adjusted correctly. The ink should be inserted in pen holder of recording paper around the drum & the testing process is started depending upon the types of test as mentioned below.

TENSION TEST: Select the proper job and complete upper and lower check adjustment. Apply some Greece to the tapered surface of specimen or groove. Then operate the upper cross head grip operation handle & grip the upper end of test specimen fully in to the groove. Keep the lower left valve in fully close position. Open the right valve & close it after lower table is slightly lifted. Adjust the lower points to zero with the help of adjusting knob. This is necessary to remove the dead weight of the lower table. Then lock the jobs in this position by operating job working handle. Then open the left control valve. The printer on dial gauge at which the specimen breaks slightly return back & corresponding load is known as breaking load & maximum load is known as the ultimate load.

COMPRESSION TEST: Fix upper and lower pressure plates to the upper stationary head & lower table respectively. Place the specimen on the lower plate in order to grip. Then adjust zero by lifting the lower table. Then perform the test in the same manner as described in tension test.

FLEXURAL OR BENDING TEST: Keep the bending table on the lower table in such a way that the central position of the bending table is fixed in the central location value of the lower table. The bending supports are adjusted to required distance. Stuffers at the back of the bending table at different positions. Then place the specimen on bending table & apply the load by bending attachment at the upper stationary head. Then perform the test in the same manner as described in tension test.

BRINELL HARDNESS TEST: Place the specimen on the lower table & lift it up slightly. Adjust the zero fixed value at the bottom side of the lower cross head. Increase the load slowly ultimate load value is obtained. Then release the load slowly with left control valve. Get the impression of a suitable value of five to ten millimeter on the specimen & measure the diameter of the impression correctly by microscope & calculate Brinell hardness.

SHEAR TEST: Place the shear test attachment on the lower table, this attachment consists of cutter. The specimen is inserted in roles of shear test attachment & lift the lower table so that the zero is adjusted, then apply the load such that the specimen breaks in two or three pieces. If the specimen breaks in two pieces then it will be in angle shear, & if it breaks in three pieces then it will be in double shear.

STUDY OF EXTENSOMETER: This instrument is an attachment to Universal / Tensile Testing Machines. This measures the elongation of a test place on load for the set gauge length. The least count of measurement being 0.01 mm, and maximum elongation measurement up to 3 mm. This elongation measurement helps in finding out the proof stress at the required percentage elongation.

WORKING OF THE INSTRUMENT: The required gauge length (between 30 to 120) is set by adjusting the upper knife edges (3) A scale (2) is provided for this purpose. Hold the specimen in the upper and lower jaws of Tensile / Universal Testing Machine. Position the extensometer on the specimen. Position upper clamp (4) To press upper knife edges on the specimen. The extensometer will be now fixed to the specimen by spring pressure. Set zero on both the dial gauges by zero adjusts screws (7). Start loading the specimen and take the reading of load on the machine at required elongation or the elongation at required load. Force setter accuracies mean of both the dial gauge (8) readings should be taken as elongation. It is very important to note & follow the practice of removing the extensometer from the specimen before the specimen breaks otherwise the instrument will be totally damaged. As a safety, while testing the instrument may be kept hanging from a fixed support by a slightly loose thread.

TECHNICAL DATA:

Measuring Range: 0 – 3 mm.

Least Count: 0. 01 mm.

Gauge Length adjustable from: 30 – 120 mm

Specimen Size: 1 to 20mm Round or Flats up to 20 x 20 mm.

A) Stress-strain graph of Mild Steel

Stress-strain Relationships

When a load is applied to a material, deformation will occur. The relationships between load and deformation of materials are usually determined by testing, in which the load and deformation are expressed in terms of stress and strain. Stress is the internal force per unit area experienced by the material while strain is the unit change in deformation of the

material. The stress-strain relationships can then be used to establish the compressive or tensile yielding strength, the modulus of elasticity and the ultimate strength.

Figure 3 presents a typical stress-strain curve for a structural mild steel specimen subjected to tensile test under normal conditions. The specimen elongation is plotted along the horizontal axis and the corresponding stresses are indicated by the ordinates of the curve 0ABCD. This diagram will be used to explain some of the following nomenclature.

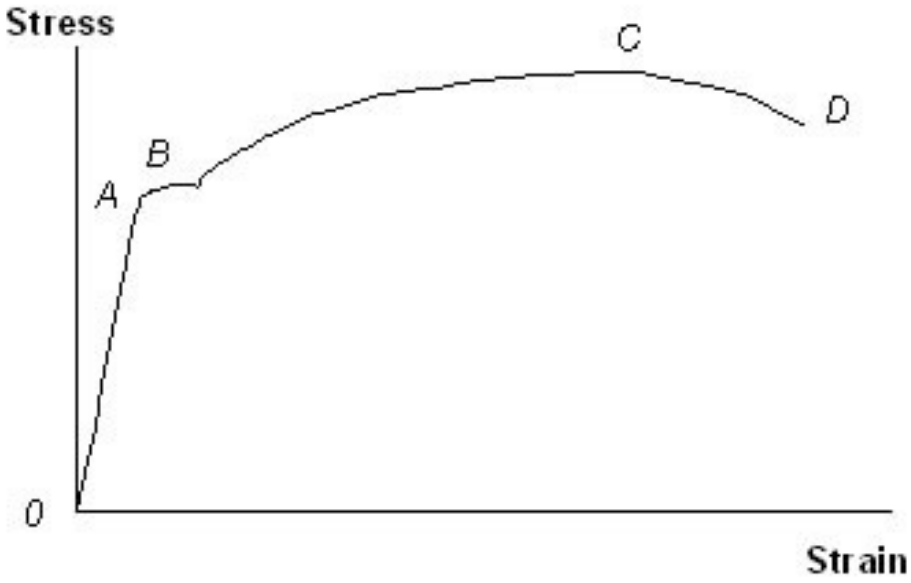


Figure 3. Stress –Strain graph of Mild Steel

Proportional Limit: In the region 0A, in Figure 3, the stress and the strain are proportional and the stress at A is the proportional limit. If upon removal of the stress (load), the strain in the specimen returns to zero as the stress goes to zero, the material is said to remain perfectly elastic.

Modulus of Elastic: The constant of proportionality in the straight-line region 0A is called the modulus of elastic or Young's modulus. Geometrically, it is equal to the slope of the stress-strain relationship in the region 0A**.**

Yield Strength: Upon loading beyond the proportional limit, the elongation increases more rapidly and the diagram becomes curved. At point B, a sudden elongation of the specimen takes place without significant increase in the applied load and the material has yielded. The value of stress at point B is called yield stress or yield strength. The deformation of the material prior to reaching the yield point creates only elastic strains, which are fully recovered if the applied load is removed. However, once the stress in the material exceeds the yield stress, permanent (plastic) deformation begins to occur. The strains associated with this permanent deformation are called plastic strains.

Ultimate Strength: ***When the material has passed through the yielding point, stress continues to increase with strain, but at a slower rate than in the elastic range, until a maximum value is reached which is termed the ultimate strength (point C in Figure 1). The***

increase in stress upon yield stress is due to material strain hardening. Beyond point C, the stress decreases until the specimen ruptures at point D.

B) Stress-strain graphs of different materials.

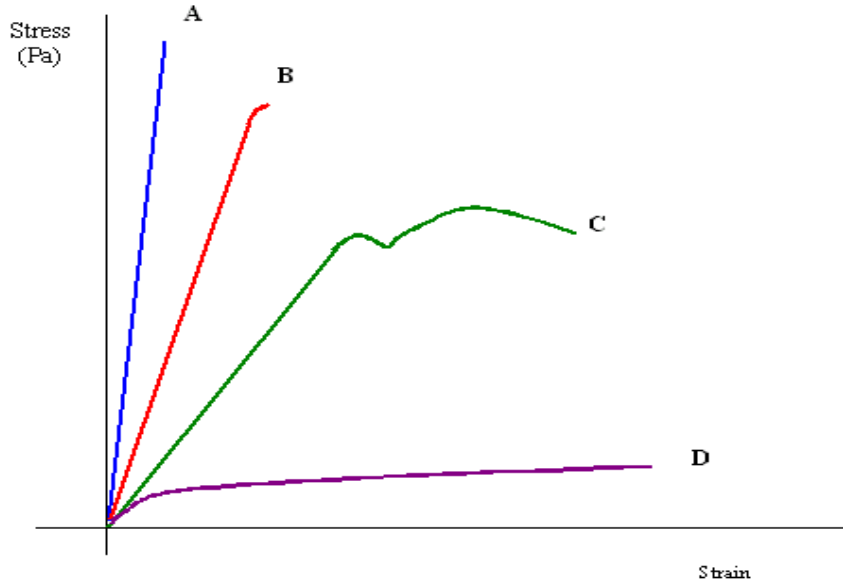


Figure 4: Stress-strain graphs of different materials

- Curve **A** shows a **brittle** material. This material is also strong because there is little strain for a high stress. The fracture of a brittle material is sudden and catastrophic, with little or no plastic deformation. Brittle materials crack under tension and the stress increases around the cracks. Cracks propagate less under compression.
- Curve **B** is a **strong** material which is not ductile. Steel wires stretch very little, and break suddenly. There can be a lot of elastic strain energy in a steel wire under tension and it will "whiplash" if it breaks. The ends are razor sharp and such a failure is very dangerous indeed.
- Curve **C** is a **ductile** material
- Curve **D** is a **plastic** material. Notice a very large strain for a small stress. The material will not go back to its original length.

EXPERIMENT NO.: 02

AIM: Determine tensile Strength of a given specimen using UTM.

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

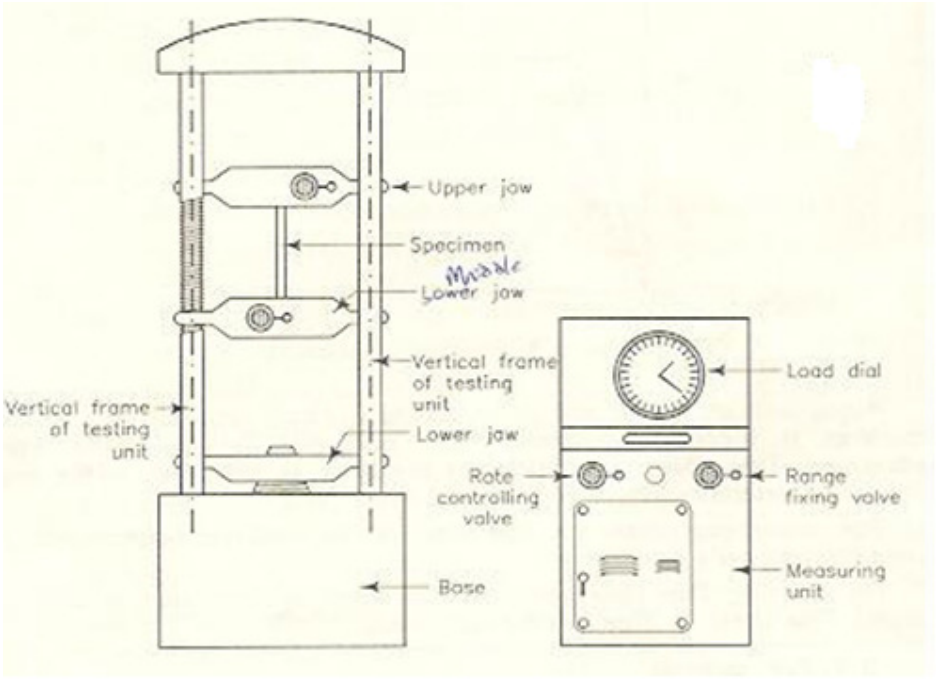
(i) Limit of proportionality (ii) Elastic limit (iii) Yield strength (iv) Ultimate strength

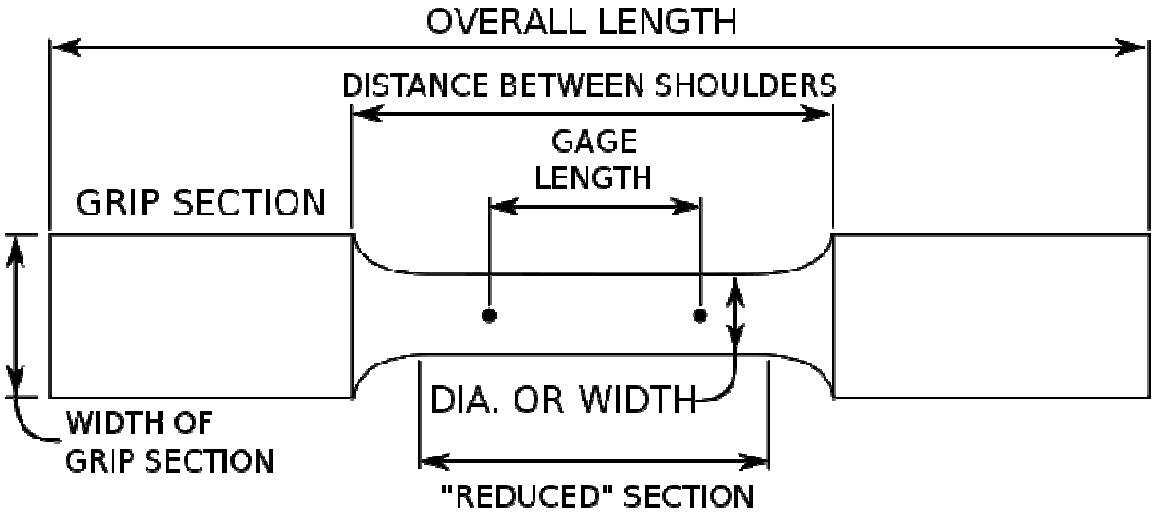
(v) Young's modulus of elasticity (vi) Percentage elongation (vii) Percentage reduction in area.

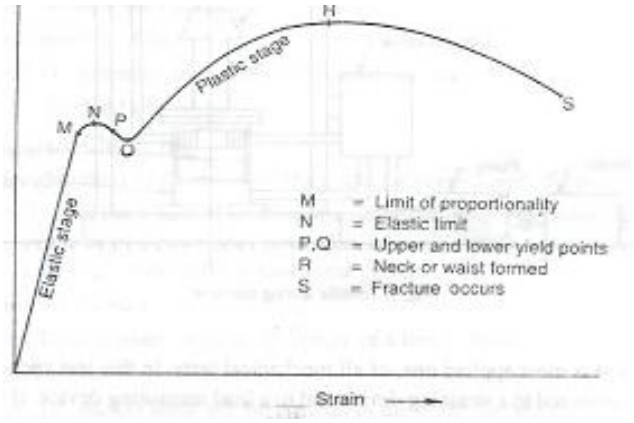
APPARATUS: (i) Universal Testing Machine (UTM) (ii) Mild steel specimens

(iii) Graph paper (iv) Scale (v) Vernier Caliper

DIAGRAM:-







THEORY: The tensile test is most applied one, of all mechanical tests. In this test ends of test piece are fixed into grips connected to a straining device and to a load measuring device. If the applied load is small enough, the deformation of any solid body is entirely elastic. An elastically deformed solid will return to its original from as soon as load is removed. However, if the load is too large, the material can be deformed permanently. The initial part of the tension curve which is recoverable immediately after unloading is termed. As elastic and the rest of the curve which represents the manner in which solid undergoes plastic deformation is termed plastic. The stress below which the deformations essentially entirely elastic is known as the yield strength of material. In some material the onset of plastic deformation is denoted by a sudden drop in load indicating both an upper and a lower yield point. However, some materials do not exhibit a sharp yield point. During plastic deformation, at larger extensions strain hardening cannot compensate for the decrease in section and thus the load passes through a maximum and then begins to decrease. This stage the “ultimate strength”’ which is defined as the ratio of the load on the specimen to original cross-sectional area, reaches a maximum value. Further loading will eventually cause ‘neck’ formation and rupture.

ABOUT OF UTM & ITS SPECIFICATIONS: The tensile test is conducted on UTM. It is hydraulically operates a pump, oil in oil sump, load dial indicator and central buttons. The left has upper, middle and lower cross heads i.e; specimen grips (or jaws). Idle cross head can be moved up and down for adjustment. The pipes connecting the lift and right parts are oil pipes through which the pumped oil under pressure flows on left parts to more the cross-heads.

SPECIFICATIONS:

1. Load capacity = 0-40 Tones.
2. Least count = 8 kgf.
3. Overall dimn. =
4. Power supply = 440 V

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.

OBSEVATION:

(a) Initial diameter of specimen d_1 =
(b) Initial gauge length of specimen L_1 =
(c) Initial cross-section area of specimen A_1 =
(d) Load of yield point Ft. =
(e) Ultimate load after specimen breaking F =
(f) Final length after specimen breaking L_2 =
(g) Diameter of specimen at breaking place d_2 =
(h) Cross section area at breaking place A_2 =

OBESERVATION TABLE:

S.No	Load (N)	Original Gauge Length	Extension (mm)	Stress = (N/mm^2)	Strain =
1					
2					
3					
4					
5					

CALCULATION:

(i) Ultimate tensile strength = = _____N/mm^2

(ii) Elastic Limit = $\frac{\text{Load at elastic limt}}{\text{Original area of cross section}}$ =_____ N/mm^2

(iii) Modulus of Elasticity (E) = $\frac{\text{Stree below Proportionality Limit}}{\text{Corresponding Strain}}$=_____ ___N/mm^2

(iv) Yield Strength= $\frac{\text{Yield Load}}{\text{Original area of cross section}}$=_____ N/mm^2

(v) % Reduction in Area = $\frac{\text{Orignal Area} - \text{Area at fracture}}{\text{Original area}}$

(vi) Percentage Elongation % =$\frac{\text{Final Length (at fracture)} - \text{Original Length}}{\text{Original Length}}$

(vii) Limit of Propagation =$\frac{\text{Load at limit of proportionality}}{\text{Original area of cross section}}$

PRECAUTIONS:

1. The specimen should be prepared in proper dimensions.
2. The specimen should be properly to get between the jaws.
3. Take reading carefully.
4. After breaking specimen stop to m/c.

RESULT: **(** i) Average Breaking Stress =

(ii) Ultimate Stress =

(iii) Average % Elongation =

VIVA-QUESTIONS:

1. Which steel have you tested? What is its carbon content?
2. What general information are obtained from tensile test regarding the properties of a material?
3. Which stress have you calculated: nominal stress or true stress?
4. What kind of fracture has occurred in the tensile specimen and why?
5. Which is the most ductile metal? How much is its elongation?

EXPERIMENT No.:03

AIM: Determine hardness of given specimen in Rockwell scale

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

APPARATUS: Rockwell hardness testing machine, soft and hard mild steel specimens, brass, aluminum etc., Black diamond cone indenter..

DIAGRAM:

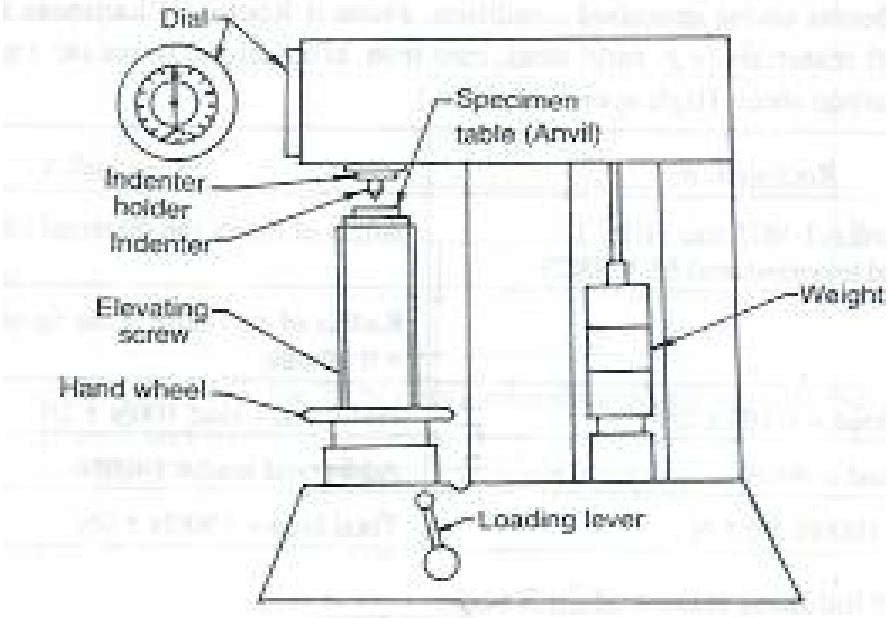


Figure 1: Rockwell hardness test equipment

THEORY:

Rockwell test is developed by the Wilson instrument co U.S.A in 1920. This test is an indentation test used for smaller specimens and harder materials. The test is subject of IS: 1586. The hardness of a material is resistance to penetration under a localized pressure or resistance to abrasion. Hardness tests provide an accurate, rapid and economical way of determining the resistance of materials to deformation. There are three general types of hardness measurements depending upon the manner in which the test is conducted:

a. Scratch hardness measurement,

b. Rebound hardness measurement

c. Indention hardness measurement.

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

indentation. The indenters usually a ball cone or pyramid of a material much harder than that being used. Hardened steel, sintered tungsten carbide or diamond indenters are generally used in indentation tests. The hardness of the material depends on the resistance which it exerts during a small amount of yielding or plastic. The resistance depends on friction, elasticity, viscosity and the intensity and distribution of plastic strain produced by a given tool during indentation In this test indenter is forced into the surface of a test piece in two operations, measuring the permanent increase in depth of an indentation from the depth increased from the depth reached under a datum load due to an additional load. Rockwell hardness tester presents direct reading of hardness number on a dial provided with the m/c. principally this testing is similar to Brinnel hardness testing. It differs only in diameter and material of the indenter and the applied force.

Although there are many scales having different combinations of load and size of indenter but commonly 'C' scale is used and hardness is presented as HRC. Here the indenter has a diamond cone at the tip and applied force is of 150 kgf. Soft materials are often tested in 'B' scale with a 1.6 mm diameter Steel indenter at 60kgf. Measurement of indentation is made after removing the additional load. Indenter used is the cone having an angle of 120 degrees made of black diamond.

PRECAUTIONS:

1. Thickness of the specimen should not be less than 8 times the depth of indentation to avoid the deformation to be extended to the opposite surface of a specimen.
2. Indentation should not be made nearer to the edge of a specimen to avoid unnecessary concentration of stresses. In such case distance from the edge to the center of indentation should be greater than 2.5 times diameter of indentation.
3. Rapid rate of applying load should be avoided. Load applied on the ball may rise a little because of its sudden action. Also rapidly applied load will restrict plastic flow of a material, which produces effect on size of indentation.

Various scales in Rockwell hardness test are given below

Scale	Type of indenter (Dimension)	Initial load (kgf)	Major load (kgf)	Pointer Position on dial	Kind of material
A	Cone, 120^{o}	10	50	0	Much harder such as carburized steel, cemented carbides
B	Ball, 1.58 mm	10	90	30	Soft steels, copper, aluminum, brass, grey cast iron.
C	Cone, 120^{o}	**10**	**140**	**0**	Hard steels, Ti, W, Va, etc

PROCEDURE:

1. Examine hardness testing machine (fig.1).
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 five times on the specimen selecting different points for indentation.

OBESERVATION TABLE:

S.No.	Specimens	Reading (HRC/)			Mean
		1	2	3	
1	Mild Steel				HRB =
2	High Carbon steel				HRC =
3	Brass				HRB =
4	Aluminum				HRB =

OBSERVATION:

1. The specimen should be clean properly
2. Take reading more carefully and
3. Take average of five values of indentation of each specimen. Obtain the hardness number from the dial of a machine.
4. Compare Brinnel and Rockwell hardness tests obtained.

Result: Rockwell hardness of given specimen is =

EXPERIMENT No.: 04

AIM: Determine hardness of given specimen in Brinnel scale.

OBJECT: To determine the hardness of the given specimen using Brinnel hardness test.

APPARATUS: Brinnel hardness testing machine, Aluminum specimen, Ball indenter.

DIAGRAM:

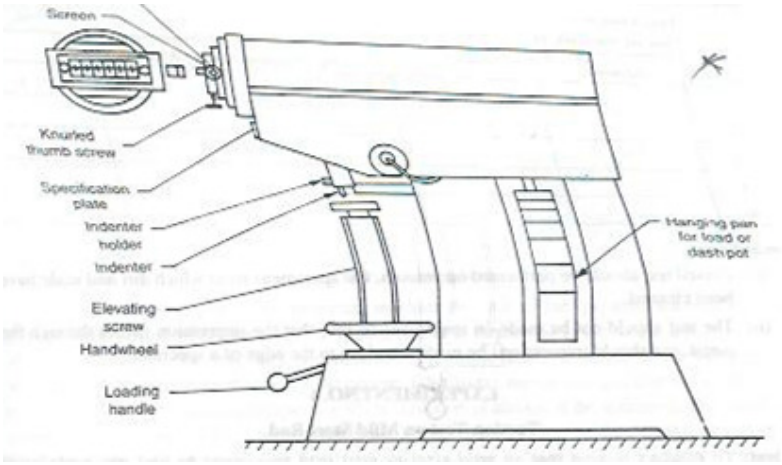


Figure: Brinnel hardness tester

THEORY:

Hardness of a material is generally defined as Resistance to the permanent indentation under static and dynamic load. When a material is required to use under direct static or dynamic loads, only indentation hardness test will be useful to find out resistance to indentation. In Brinnel 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). Hardness represents the resistance of material surface to abrasion, scratching and cutting, hardness after gives clear identification of strength. In all hardness testes, a define force is mechanically applied on the test piece for about 15 seconds. The indenter, which transmits the load to the test piece, varies in size and shape for different tests. Common indenters are made of hardened steel or diamond. In Brinnel hardness testing, steel balls are used as indenter. Diameter of the indenter and the applied force depend upon the thickness of the test specimen, because for accurate results, depth of indentation should be less than 1/8th of the thickness of the test pieces. According to the thickness of the test piece increase, the diameter of the indenter and force are changed.

SPECIFICATIONS: A hardness test can be conducted on Brinnel testing machine, Rockwell hardness machine or Vickers testing m/c. the specimen may be a cylinder, cube, think or thin metallic sheet. A Brinnel- cum-Rockwell hardness testing mmachine along with the specimen is shown in figure.

Its specification is as follows:

1. Ability to determine hardness up to 500BHN.
2. Diameter of ball (as indenter) used D = 2.5mm, 5mm, 10mm.
3. Maximum application load = 3000kgf.
4. Method of load application = Lever type
5. Capability of testing the lower hardness range = 1 BHN on application of 0.5D2 load.

PROCEDURE:

1. 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)

$F=30.D^2$

Where ball diameter, generally taken as 10 mm.

For guidelines hardness range for standard loads given below

Ball diameter	Load (kg)	Range of Brinnel hardness
10	3000	96 to 600
	1500	48 to 300
	500	16 to 100

2. 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]

3. Remove the load and measure the diameter of indentation nearest to 0.02 mm using microscope (projected image)

4. Calculate Brinnel hardness number (HB). As per IS: 1500.

5. Brinnel hardness number = 2F/ (π D [D-√D2-d2])

Where D is the diameter of ball indenter and d is the diameter of indentation. Hardness numbers normally obtained for different materials are given below (under 3000 kg and 10 mm diameter ball used)

Ordinary steels medium carbon	100 to 500
Structural steel	130 to 160
Very hard steel	800 to 900

Note: Brinnel test is not recommended for then materials having HB over 630. It is necessary to mention ball size and load with the hardness test when standard size of ball and load are not used. Because indentation done by different size of ball and load on different materials are not geometrically similar. Ball also undergoes deformation when load is applied. Material response to the load is not same all the time.

5. Brinnel hardness numbers can be obtained from tables 1 to 5 given in IS: 1500, knowing diameter of indentation, diameter of the ball and load applied.

OBSERVATIONS AND CALCULATIONS:

Following observation are recorded from a test on steel specimen using a hardened steel ball as indenter. Test piece material = ----------

S.No.	Ball Diameter 'D' in mm.	Load applied F in kgf.	Diameter of Indentation 'd' (mm)	P/D^2	BHN
1					
2					
3					
4					

BHN = Load Applied (kgf.)/ Spherical surface area indentation (in mm.) $= 2GP/\pi D(D-\sqrt{D^2 - d^2})$

PRECAUTIONS:

1. Thickness of the specimen should not be less than 8 times the depth of indentation to avoid the deformation to be extended to the opposite surface of a specimen.
2. Indentation should not be made nearer to the edge of a specimen to avoid unnecessary concentration of stresses. In such case distance from the edge to the center of indentation should be greater than 2.5 times diameter of indentation.
3. Rapid rate of applying load should be avoided. Load applied on the ball may rise a little because of its sudden action. Also rapidly applied load will restrict plastic flow of a material, which produces effect on size of indentation.
4. Surface of the specimen is well polished, free from oxide scale and any foreign material.

OBSERVATION:

1. The specimen should be clean properly.
2. Take reading more carefully and accurately.
3. Place the specimen properly.
4. Jack adjustment wheel move slowly.
5. Take average of five values of indentation of each specimen. Obtain the hardness number from equation.
6. Compare Brinnel and Rockwell hardness tests obtained.

RESULT:

The Brinnel hardness number of the specimen is

VIVA-QUESTIONS:

1. What is the limitation of Brinnel hardness test and why?
2. Which is the harness material and why?
3. Can we predict the tensile strength of a material if its hardness is known?
4. What is the unit of B.H.N?
5. Which ball size is recommended for Brinnel test?

EXPERIMENT No.: 05

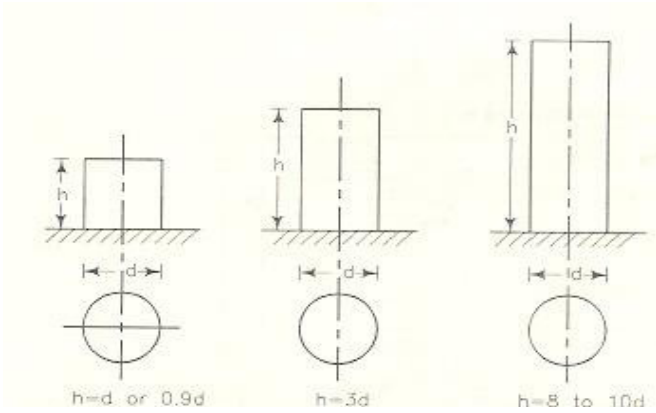
AIM: Find out the Compressive strength of a given specimen using UTM

OBJECT: To Perform compression test on UTM.

APPARATUS: A UTM or A compression testing machine, cylindrical or cube shaped specimen of cast iron, Aluminum or mild steel, vernier caliper, liner scale, dial gauge (or compressometer).

THEORY:

Several machine and 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. Contrary to this, many materials poor in tension but very strong in compression. Cast iron is one such example. That is why determine of ultimate compressive strength is essential before using a material. This strength is determined by conduct of a compression test. Compression test is just opposite in nature to tensile test. Nature of deformation and fracture is quite different from that in tensile test. Compressive load tends to squeeze the specimen. Brittle materials are generally weak in tension but strong in compression. Hence this test is normally performed on cast iron, cement concrete etc. But ductile materials like aluminum and mild steel which are strong in tension, are also tested in compression.



PROCEDURE:

1. Place the specimen in position between the compression pads.
2. Switch on the UTM
3. Bring the drag indicator in contact with the main indicator.
4. Select the suitable range of loads and space the corresponding weight in the pendulum and balance it if necessary with the help of small balancing weights
5. Operate (push) the button for driving the motor to drive the pump.
6. Gradually move the head control ever in left hand direction till the specimen fails.
7. Note down the load at which the specimen shears
8. Stop the machine and remove the specimen.

9. Repeat the experiment with other specimens.

OBSERVATION:

1. Cross sectional area of the specimen perpendicular to the load=A=……mm^2
2. Load taken by the specimen at the time of failure, W=. …… (N)
3. Strength of the pin against shearing (s) = [W/A] N/mm 2
4. Initial length or height of specimen h =———— mm.
5. Initial diameter of specimen do =———————— mm.

S.No.	Applied load (P) in Newton	Recorded change in length (mm)
1		
2		
3		
4		
5		

CALCULATIONS:

1. Original cross-section area A_o = -----
2. Final cross-section area A_f = --------
3. Stress = -------
4. Strain = -------

For compression test, we can

1. Draw stress-strain (σ-ε) curve in compression,
2. Determine Young's modulus in compression,
3. Determine ultimate (max.) compressive strength, and
4. Determine percentage reduction in length (or height) to the specimen.

PRECAUTIONS:

1. The specimen should be prepared in proper dimensions.
2. The specimen should be properly to get between the compression plates.
3. Take reading carefully.
4. After failed specimen stop to machine.

RESULT: The compressive strength of given specimen =———————- N/mm^2

CONCLUSION:

VIVA-QUESTIONS:

1. Compression tests are generally performed on brittles materials-why?
2. Which will have a higher strength: a small specimen or a full size member made of the same material?
3. What is column action? How does the h/d ratio of specimen affect the test result?
4. How do ductile and brittle materials in their behavior in compression test?
5. What are bi-modulus materials? Give examples.

EXPERIMENT No.: 06

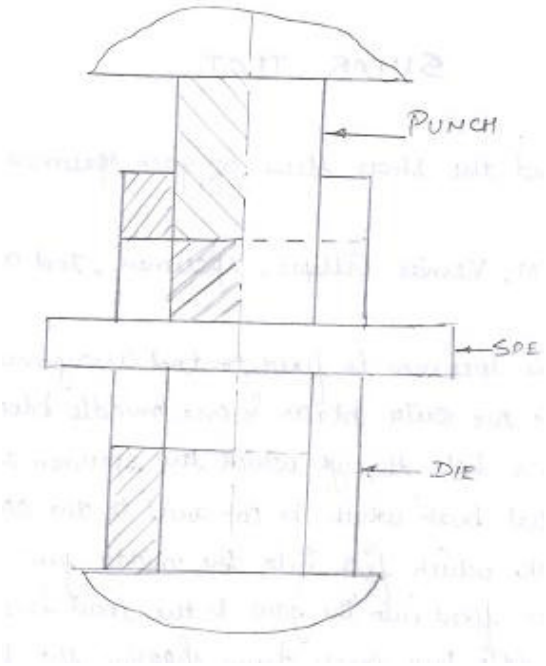
AIM: - Find out the Shear strength of a given specimen using UTM**.**

OBJECT: To find the shear strength of given specimen on UTM.

APPARATUS USED: A UTM, Specimen, shearing attachment, vernier caliper etc.

THEORY: A type of force which causes or tends to cause two contiguous parts of the body to slide relative to each other in a direction parallel to their plane of contact is called the shear force. The stress required to produce fracture in the plane of cross-section, acted on by the shear force is called shear strength.

DIAGRAM:



PROCEDURE:

1. Insert the specimen in position and grip one end of the attachment in the upper portion and one end in the lower position
2. Switch on the UTM
3. Bring the drag indicator in contact with the main indicator.
4. Select the suitable range of loads and space the corresponding weight in the pendulum and balance it if necessary with the help of small balancing weights
5. Operate (push) the button for driving the motor to drive the pump.
6. Gradually move the head control ever in left hand direction till the specimen shears.
7. Note down the load at which the specimen shears.
8. Stop the machine and remove the specimen.
9. Repeat the experiment with other specimens.

PRECAUTIONS:

1. The measuring range should not be changed at any stage during the test.
1. The inner diameter of the hole in the shear stress attachment should be slightly greater than the specimen.
2. Measure the diameter of the specimen accurately.
3. The method for determining the shear strength consists of subjecting a suitable length of steel specimen in full cross-section to double shear, using a suitable test rig, in a testing m/c under a compressive load or tensile pull and recording the maximum load 'F' to fracture.

OBSERVATION:

1. Applied compressive force (F) = ---------kgf.
2. Diameter of specimen = ---------mm.

Cross sectional area of the pin (in double shear) = $2 \times \pi/4 \times d^2$ =…. mm^2

Load taken by the specimen at the time of failure, W =. …… (N)

Strength of the pin against shearing (τ) = $4W/2\pi d^2$ _____N/mm^2

CONCLUSION:

Shear strength of specimen = --------

VIVA-QUESTIONS:-

1. Does the shear failure in wood occur along the 45° shear plane?
2. What is buldging? Why does it occur?
3. What is single & double shear?
4. What is finding in shear test?
5. What is unit of shear strength?

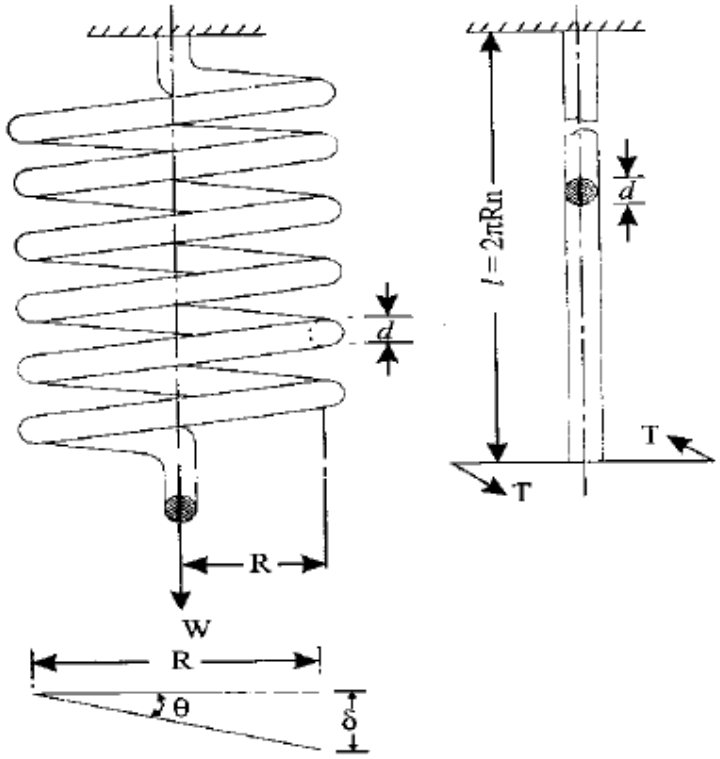
EXPERIMENT No: 07

AIM: Determine the stiffness of the spring and modulus of rigidity of the spring wire

OBJECT: To determine the stiffness of the spring and modulus of rigidity of the spring wire

APPARATUS: - i) Spring testing machine. ii) A spring iii) Vernier caliper, Scale.
iv) Micrometer.

DIAGRAM:-



Close-coiled helical spring.

THEORY:

Springs are elastic member which distort under load and regain their original shape when load is removed. They are used in railway carriages, motor cars, scooters, motorcycles, rickshaws, governors etc. According to their uses the springs perform the following Functions:

1) To absorb shock or impact loading as in carriage springs.
2) To store energy as in clock springs.
3) To apply forces to and to control motions as in brakes and clutches.
4) To measure forces as in spring balances.
5) To change the variations characteristic of a member as in flexible mounting of motors.

The spring is usually made of either high carbon steel (0.7 to 1.0%) or medium carbon alloy steels. Phosphor bronze, brass, 18/8 stainless steel and Monel and other metal alloys are used for corrosion resistance spring. Several types of spring are available for different

application. Springs may classified as helical springs, leaf springs and flat spring depending upon their shape. They are fabricated of high shear strength materials such as high carbon alloy steels spring form elements of not only mechanical system but also structural system. In several cases it is essential to idealize complex structural systems by suitable spring.

PROCEDURE:

1) Measure the diameter of the wire of the spring by using the micrometer.

2) Measure the diameter of spring coils by using the vernier caliper

3) Count the number of turns.

4) Insert the spring in the spring testing machine and load the spring by a suitable weight and note the corresponding axial deflection in tension or compression.

5) Increase the load and take the corresponding axial deflection readings.

6) Plot a curve between load and deflection. The shape of the curve gives the stiffness of the spring.

OBESERVATION

Least count of micrometer = ……mm

Diameter of the spring wire, d =……mm (Mean of three readings)

Least count of vernier caliper = ……mm

Diameter of the spring coil, D = ……mm (Mean of three readings)

Mean coil diameter, Dm = D - d……mm

Number of turns, n =

OBESERVATION TABLE:

S.No.	Load, W (N)	Deflection, (δ) (mm)	Stiffness K = W / δ, N
1			
2			
3			
4			
5			

Mean k = ……

Modulus of rigidity $C = 8W D^3 n/\delta d_m^4$

Spring Index = Dm/D

RESULT: The value of spring constant k of closely coiled helical spring is found to be_____ N/ mm

PRECAUTION:

1**)** The dimension of spring was measured accurately.

2) Deflection obtained in spring was measured accurately

EXPERIMENT No. 08

AIM: Determine the deflection and bending stress of simply supported subjected to concentrated load at the center .

OBJECT: To find the values of bending stresses and young's modulus of the material of a beam (say a wooden or steel) simply supported at the ends and carrying a concentrated load at the center.

APPARATUS USED:

UTM or Beam apparatus, Bending fixture, vernier caliper, meter rod, test piece & dial gauge.

THEORY:

Bending test is performing on beam by using the three point loading system. The bending fixture is supported on the platform of hydraulic cylinder of the UTM. The loading is held in the middle cross head. At a particular load the deflection at the center of the beam is determined by using a dial gauge. The deflection at the beam center is given by: $\delta = WL^3 / 48EI$

DIAGRAM:

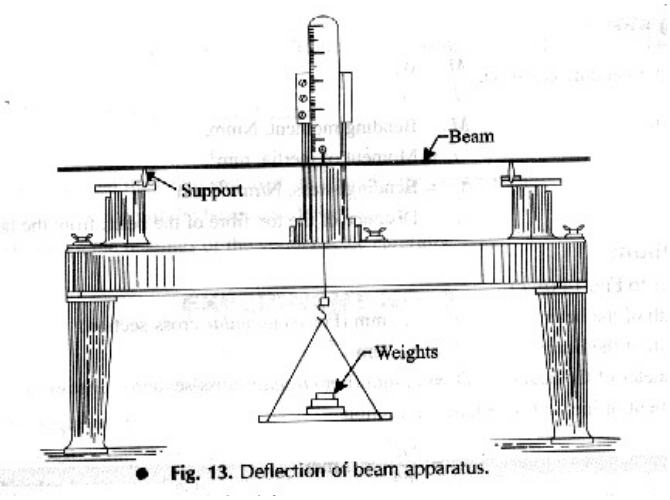


Fig. 13. Deflection of beam apparatus.

PROCEDURE:

1. Measure the length, width and thickness of test piece, by vernier caliper.
2. Place the bending fixture on the lower cross head of the testing machine.
3. Place the test piece on the rollers of the bending fixture.
4. By loading the dial gauge in a stand, make its spindle knob the test piece.
5. Start the m/c and note down the load and dial gauge readings.
6. Plot the graph between load and deflection.

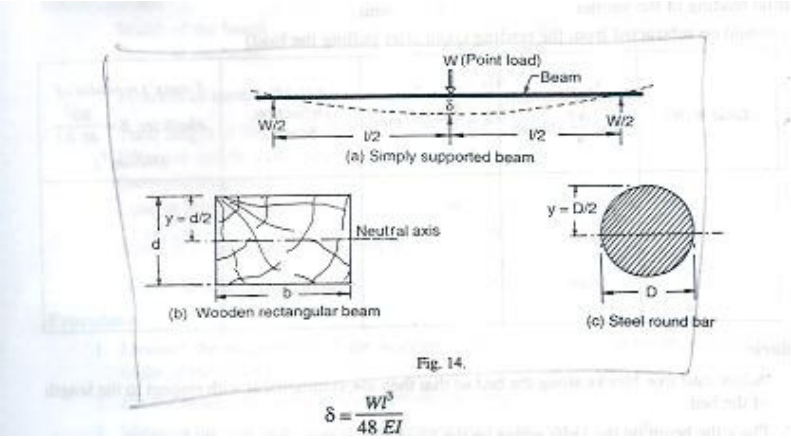


Fig. 14.

$$\delta = \frac{Wl^3}{48\,EI}$$

OBSERVATIONS:

1. Least count of vernier caliper = -----
2. Length of beam (L) = ------
3. Width of beam (b) = ------
4. Thickness of beam (t) = ------

S.No.	Load 'W' in Newton	Deflection 'δ' in mm.	Young's Modulus 'E' N/mm^2
1			
2			
3			
4			
5			

PRECAUTIONS:

1. Make sure that the beam and load is placed at the proper position.
2. Cross section of the beam should be large
3. Note down the readings of the vernier scale carefully.

CALCULATIONS:

1. $I = bt^3/12$
2. $\delta = WL^3/48EI$

CONCLUSION:

The Bending strength of given specimen = -------N/mm^2

EXPERIMENT No. 09

AIM: To perform the izod impact test on materials.

APPARATUS USED:

Izod impact test machine, test specimen, vernier calipers, steel rule

IMPACT STRENGTH: The resistance of a material to fracture under sudden load application.

MATERIALS: Two types of test pieces are used for this test as given.

1) Square cross-section
2) Round cross-section.

THEORY:

The type of test specimen used for this test is a Square Cross-section. The specimen may have single, two or three notches. The testing machine should have the following specifications.The angle between top face of grips and face holding the specimen vertical=90^0 The angle of tip of hammer =$75^0 \pm 1^0$ The angle between normal to the specimen and underside face of the hammer at striking point=$10^0 \pm 1^0$ Speed of hammer at impact=3.99m/sec Striking energy=168N-m or Joules Angle of drop of pendulum =90^0 Effective weight of pendulum=21.79kg

Minimum value of scale graduation=2 Joules.

Permissible total friction loss of corresponding energy=0.50%

Distance from the axis of rotation of distance between the base of specimen notch and the

point of specimen hit by the hammer=22mm±0.5mm

The longitudinal axes of the test piece shall lie in the plane of swing of the center of gravity of the hammer. The notch shall be positioned so that its in the plane of the hammer .the notch shall be positioned its plane of symmetry coincides with the top face of the grips .for setting the specimen the notch impact strength I is calculated according to the following relation.

Where I= impact strength in joules/m^2

PROCEDURE:

1. For conducting Izod test, a proper striker is to be fitted firmly to the bottom of the hammer with the help of the clamming piece.

2. The latching take for izod test is to be firmly fitted to the bearing housing at the side of the columns.

3. The frictional loss of the machine can be determined by free fall test, raise the hammer by hands and latch in release the hammer by operating lever 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. Otherwise frictional loss has to be added to the final reading.

4. The specimen for izod test is firmly fitted in the specimen support with the help of clamping screw and élan key. Care should be taken that the notch on the specimen should face to pendulum striker.

5. After ascertaining that there is no person in the range of swinging pendulum, release the pendulum to smash the specimen.

6. Carefully operate the pendulum brake when returning after one swing to stop the oscillations.

7. Read-off position of reading pointer on dial and note indicated value.

8. Remove the broken specimen by loosening the clamping screw.

The notch impact strength depends largely on the shape of the specimen and the notch. the values determined with other specimens therefore may not be compared with each other.

OBSERVATION TABLE:

S .No	A(Area of cross section of specimen)	K (Impact energy observed)	I (Impact Strength)
1			
2			
3			
4			

RESULT:

EXPERIMENT No. 10

AIM: To conduct torsion test on mild steel or cast iron specimen to find modulus of rigidity or to find angle of twist of the materials which are subjected to torsion?

APPARATUS:

1. A torsion test machine along with angle of twist measuring attachment.
2. Standard specimen of mild steel or cast iron.
3. Steel rule.
4. Vernnier caliper or a micrometer.

THEORY:

For transmitting power through a rotating shaft it is necessary to apply a turning force. The force is applied tangentially and in the plane of transverse cross section. The torque or twisting moment may be calculated by multiplying two opposite turning moments. It is said to be in pure torsion and it will exhibit the tendency of shearing off at every cross section which is perpendicular to the longitudinal axis.

Torsion equation:

Torsion equation is given by below

$$T / I_P = C\theta/L = \tau/R$$

T= maximum twisting torque (Nmm) I_P = polar moment of inertia (mm^4) τ =shear stress (N/mm^2)

C=modulus of rigidity ($N/mm^{2)}$

θ=angle of twist in radians

L=length of shaft under torsion (mm)

Assumptions made for getting torsion equation

1. The material of the shaft is uniform throughout.
2. The shaft, circular in section remain circular after loading.
3. Plane sections of shaft normal to its axis before loading remain plane after the torque have been applied.
4. The twist along the length of the shaft is uniform throughout.
5. The distance between any two normal-sections remains the same after the application of torque.
6. Maximum shear stress induced in the shaft due to application of torque does not exceed its elastic limit.

PROCEDURE:

1. Select the suitable grips to suit the size of the specimen and clamp it in the machine by adjusting sliding jaw.
2. Measure the diameter at about the three places and take average value.
3. Choose the appropriate loading range depending upon specimen.
4. Set the maximum load pointer to zero
5. Carry out straining by rotating the hand wheel or by switching on the motor.
6. Load the members in suitable increments, observe and record strain reading.
7. Continue till failure of the specimen.
8. Calculate the modulus of rigidity C by using the torsion equation.
9. Plot the torque –twist graph (T Vs θ)

OBSERVATIONS:

Gauge length **L** =

Polar moment of inertia **IP** =

Modulus of rigidity $\mathbf{C = TL / I_P \theta}$ =

S.No.	Twisting	(Moment)	Angle of Twist		Modulus of rigidity	Average 2
	(Kgf)	(Nm)	Degrees	Radians	C	C N/mm

RESULT: