MATERIALS ENGINEERING

LABORATORY MANUAL

B.TECH
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Department of Mechanical Engineering

MALLA REDDY COLLEGE OF ENGINEERING & TECHNOLOGY

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MATERIALS ENGINEERING LAB

LIST OF EXPERIMENTS

S. No.	Name of the Experiment
1	To Prepare the specimen by mounting powder.
2	To the study of Microstructure of Low, Medium & High carbon steels.
3	To the study of Microstructure Cast Irons. (Grey cast Iron & White cast Iron).
4	To the study of Microstructure Non – Ferrous pure metals. (Copper & Aluminum).
5	To the study of Microstructure Non-Ferrous alloys. (Brass & Bronze).
6	To the study of Microstructure Heat treated steels.
7	To find out the hardenability of steels by Jominy End Quench Test.
8	To find out the hardness of various treated and untreated steels.
9	Study of Microstructure of Composite Material subjected to tensile testing
10	Study of the Composite Material with the help of UTM.
11	Join the sheets using Ultrasonic Joining process

Exercise-1

To prepare the specimen by mounting powder

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:

1. Cut the specimen to the required size (small cylindrical pieces of 10 to 15mm diameter with 15mm height or 10mm cubes)
2. **Mounting of Specimens:**

   The primary purpose of mounting is to make it convincement to handle specimens of arbitrary shape and/or small sizes during various steps of metallographic sample preparation and examination. A secondary purpose is to protect and preserve extreme edges or surface defects during metallographic preparation. Specimens may also require mounting to accommodate various types of automatic devices used in metallographic laboratories or to facilitate placement on the microscope stage. An additional benefit of mounting is the identification of the sample (name, alloy number or laboratory code number) without damaging the specimen.

   Compression mounting:

   It is most common mounting method, which involves molding around the metallographic specimen by heat and pressure using the molding materials such as Bakelite, Diallyl Phthalate resins, and acrylic resins. Bakelite and Diallyl phthalate are thermosetting, and acrylic resins are thermoplastic. Not all materials or specimens can be mounted in thermosetting or thermoplastic mounting. The heating cycle may cause changes in the microstructure, or the pressure may cause delicate specimens to collapse or deform. The size of the selected specimen may be too large to be accepted by the available mold sizes. These difficulties are usually overcome by cold mounting.

   Cold Mounting requires no pressure and little heat, and is a mean of mounting large numbers of specimens more rapidly than possible by compression mounting. Epoxy resins are most widely used cold mounting materials. They are hard, and adhere tenaciously to most metallurgical, mineral and ceramic specimens.
3. **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.

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° so that new scratches shall be exactly perpendicular to previous scratches.

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.

1. The sample is then washed with water and dried.

Etching: the sample is then etched with a suitable etching reagent, detailed in article 5. After etching the specimen should be washed in running water and then with alcohol and then finally dried. The sample is now ready for studying its microstructure under the microscope.

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	
		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
		HCL(20ml) & H_2O (20ml)	

4.	Murakami’s reagent	Potassium ferry cyanide,	Stainless steels
		(10grms), KOH(10grms) and	
		Water(100ml)	
5.	Sodium hydroxide	Sodium hydroxide(10gm) and Water (90ml)	Aluminum & its alloys
6.	Keller’s reagent	Hydro fluoric acid(20ml)	Aluminum & its alloys
		Nitric acid(10ml) and	
		Glycerin (30ml)	
7.	Keller’s reagent	Hydro fluoric acid(1ml)	Duralumin
		Hydrochloric acid(1.5ml)	
		Nitric acid(2.5ml) and Water(95 ml)	
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.

i. a) MAGNIFICATION:

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

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

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.

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.

Optical compilation

Eye pieces and objectives of different magnifications are available. Huygens eyepieces: 5x, 10x Achromatic objectives 5x, 10x, 45x.

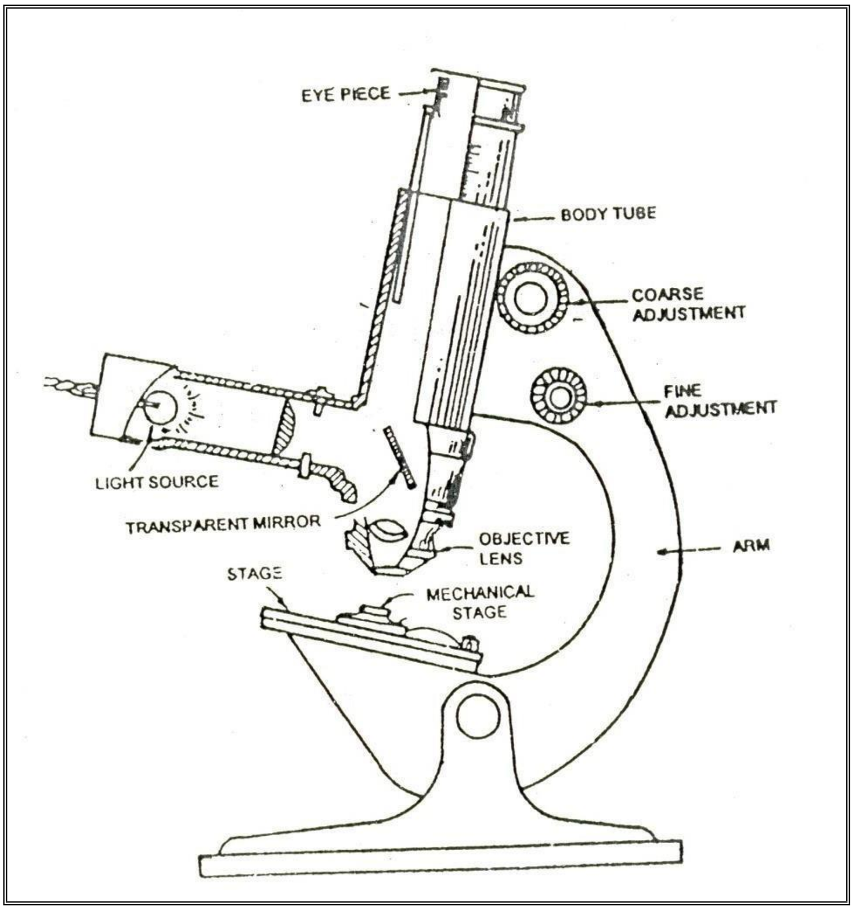
PRECAUTIONS:

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.

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

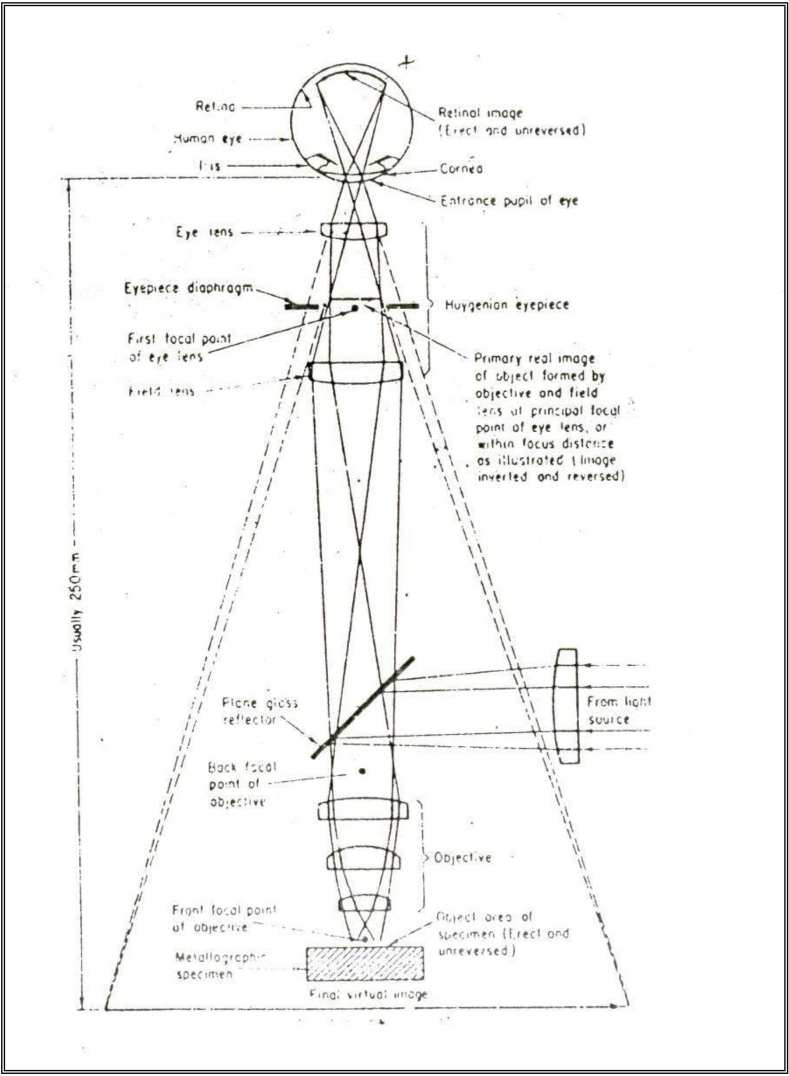


Illustration of Principle of Metallurgical Microscope

Exercise-2

To the study of Microstructure of Low, Medium & High carbon steels.

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**

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.

Phases

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

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.

c. 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.

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.

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).

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.

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. Ledeburite: 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.

Slow 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 X2 is shown in fig 2.6b. as alloy is further 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.

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

(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 X3 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.
Austenite $\xrightarrow{\delta \ \text{Cooling}}$ (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.

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).

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.

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.

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 %(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.

ow 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

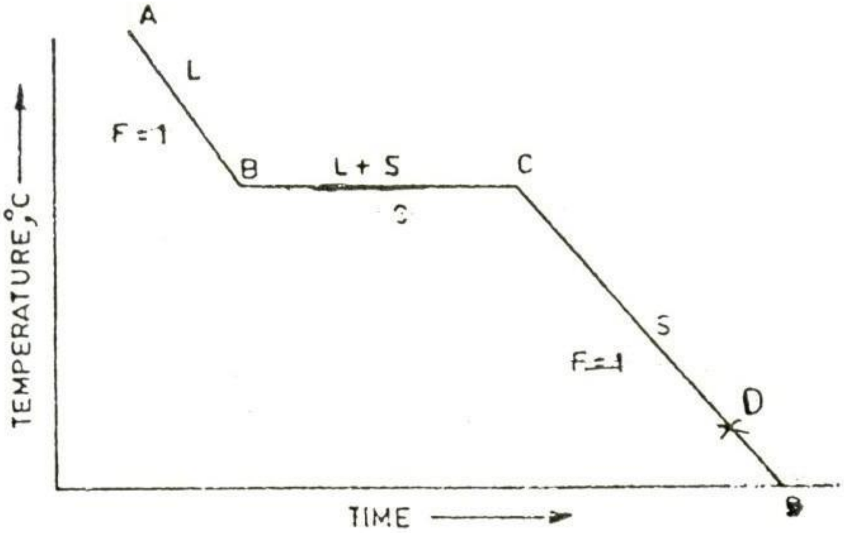
d. Hyper eutectoid steel

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

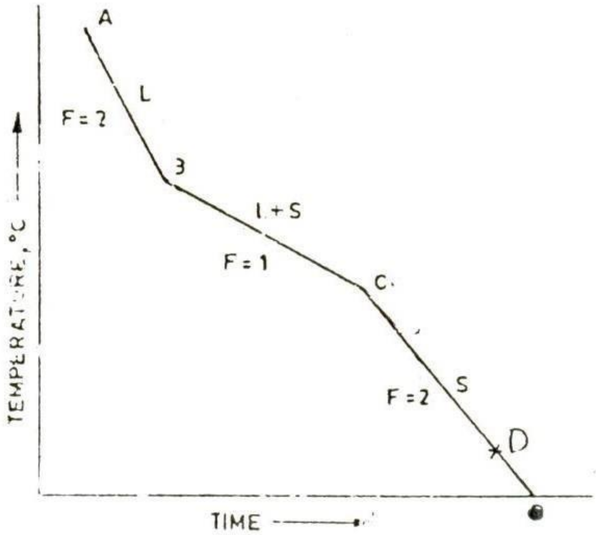
The microstructure shows continuous network of cementite along the grain boundaries of coarse pearlite.

5. REVIEW QUESTIONS:

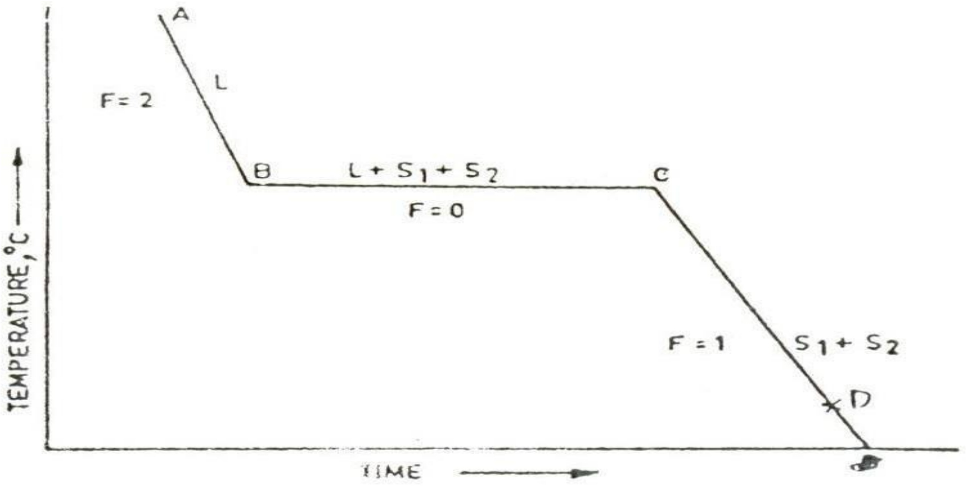
I. What is a cooling curve?
II. What is the use of equilibrium diagram?
III. What is curie temperature?
IV. What is the percentage of carbon in cementite?
V. What are the different phases in Fe-Fe3C equilibrium diagram?
VI. How Cast iron and steel are distinguished with respect to carbon percentage?
VII. What is eutectoid reaction?
VIII. What is peritectic reaction?
IX. Draw the microstructure of eutectoid steel?
X. Draw the microstructure of Hypo eutectoid steel?
XI. Draw the microstructure of Hyper eutectoid steel?
XII. What is the maximum solubility of carbon in ferrite?
XIII. What is the maximum solubility of carbon in Austenite?
XIV. What are the properties & applications of mild Steel?
XV. What are the properties & applications of medium carbon steel(hypo eutectoid steel)?
XVI. What is curie temperature?
XVII. What is the percentage of carbon in cementite?



Cooling curve of a pure metal.



Cooling curve of a solid solution alloy.



Cooling curve of an eutectic alloy.

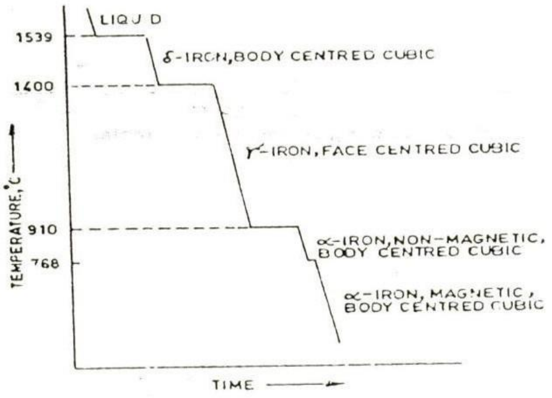


Fig. 2.4 Cooling curve of pure iron

Cooling curve of pure Iron

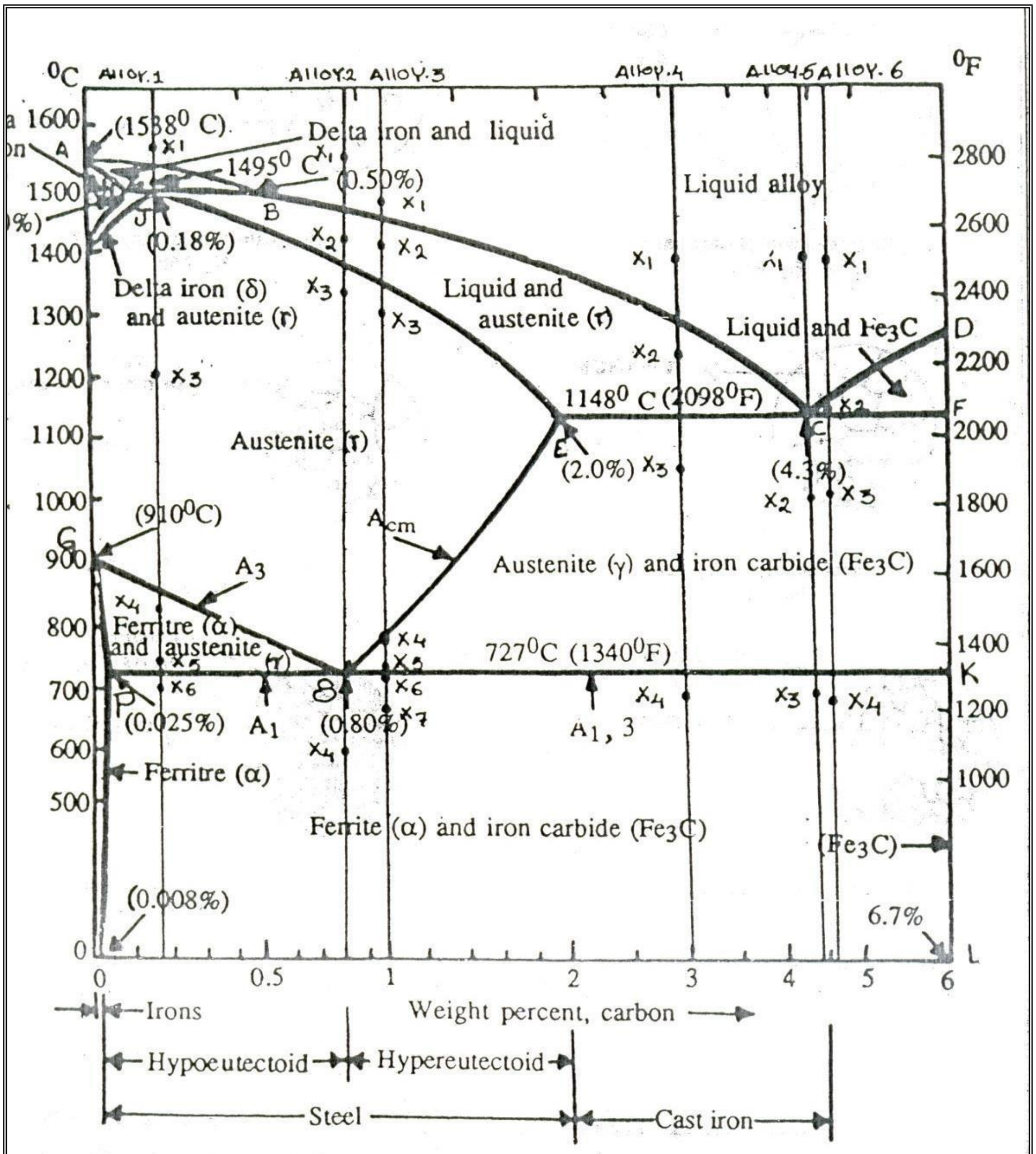


Fig. 2.5 Iron - Iron carbide equilibrium diagram.

Iron-Iron carbide equilibrium diagram

Exercise-3

To the study of Microstructure Cast Irons (Grey cast Iron & White cast Iron).

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

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.

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 X1, 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 X2 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^{0}C) and transforms into lideburite (eutectic mixture of austenite and 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^{0}C) and is converted to pearlite. At X4 the microstructure of alloy consists of dendritic areas of transformed austenite (i.e. pearlite) in the matrix of transformed lideburite (pearlite + cemetite).

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^{0}C) 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^{0}C 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.

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.

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.,

a 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) Spheroidal 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 lederburite.

b 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.

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.

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.

e 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.,

A. 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.

B. 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.,

4.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-4

To the study of Microstructure Non – Ferrous pure metals.
(Copper & Aluminum).

1. **AIM:** To determine the present and to draw the microstructures of copper, Aluminum & Magnesium.

2. **APPARATUS AND SPECIMENS REQUIRED:**

Metallurgical microscope, specimens of Aluminum, 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 of the Metal	Melting Temp. (®C)	Crystal Structure
4.	Aluminum(Al)	660	FCC
5.	Antimony(Sb)	630	Rhombohydral
6.	Bismuth(Bi)	271	Rhombohydral
7.	Cadmium(Cd)	321	CPH
8.	Chromium(Cr)	1900	BCC
9.	Copper(Cr)	1083	FCC
10.	Gold(Au)	1064	FCC
11.	Lead(Po)	327	FCC
12.	Magnesium(Mg)	650	CPH
13.	Manganese(Mn)	1250	Complex cube
14.	Nickle(Ni)	1453	FCC
15.	Silver(Ag)	961	FCC
16.	Tin(Sn)	232	BCT
17.	Zinc(Zn)	419	CPH

18. **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.

19. REVIEW 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-5

To the study of Microstructure Non-Ferrous alloys. (Brass & Bronze).

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:

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).

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 Cu_3Sn,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-6

To the study of Microstructure Heat treated steels.

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:

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. Temperinge. Surface hardening treatments

Time Temperature and Transformation Diagram(TTT diagram):

The TTT Diagram super imposed with different cooling austenitising temperature to room temperature is shown in fig.6.1

In fig. 6.1 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)

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.6.2

Annealing process cycle on Time-temperature diagram is show in fig.6.4 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.

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.6.2 Normalizing process cycle Time-Temperature diagram is shown in fig. Normalizing process consists of
- a. 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.)
- b. Holding the specimen at this temperature for a specified period of Time.
- c. Then cooling the specimen to the room temperature in air. Normalized Hypo eutectoid steel consists of Ferrite and fine Pearlite.

Hardening:Main purpose of hardening is to improve the hardness & wear resistance of steels. Temperature range of hardening of steels is shown in fig.6.3

Hardening process cycle on Time-Temperature diagram is shown in fig. 6.6. 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.

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.6.7 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.

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.

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.

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.

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.

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.

CarboNitriding: 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.

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

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.

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.

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.

REVIEW QUESTIONS

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 teels, before and after heat treatments?
vii. Show Time Temperature diagram for different types of plain carbon steels?

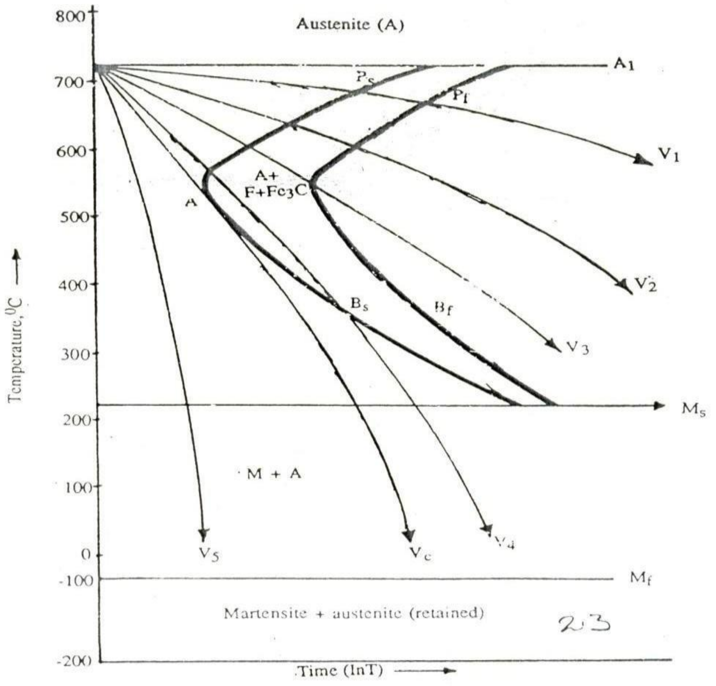


Fig. 3.1 TTT diagram (super imposed with different cooling rates)

TTT diagram(super imposed with different cooling rates)

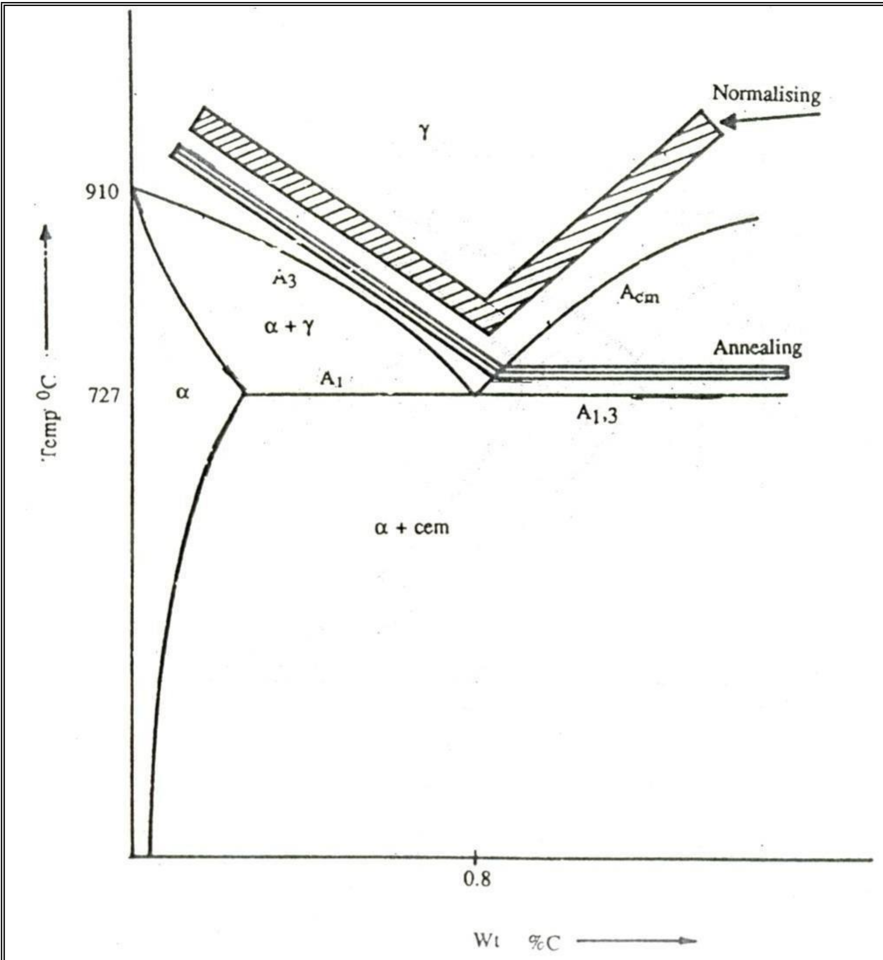


Fig. 3.2 Annealing and Normalising temperature ranges of steels

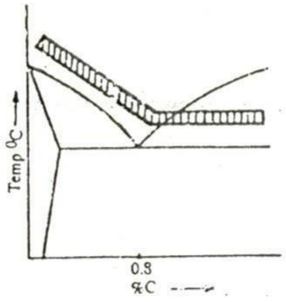


Fig. 3.3 Hardening temperature range of steels

Figure 4 Hardening temperature range of steels

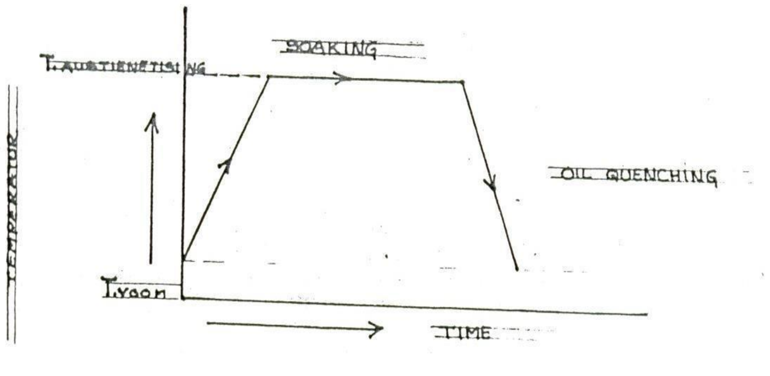


Fig. 3.6 Heat treatment cycle for Hardening on Time - Temperature diagrams for different types of steels

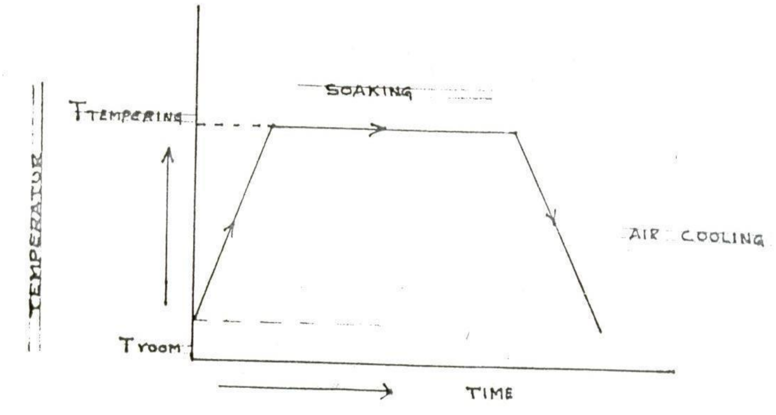


Fig. 3.7 Heat treatment cycle for tempering on Time - Temperature diagrams for different types of steels

Figure 5 Annealing and Normalising temperature ranges of steels

Exercise-7

To find out the hardenability of steels by 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 specimenwith standard dimensions, used for the test is given in fig.7.1.The hardness of hardened bar is measured along its length.

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.

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.

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

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 7.2.

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 7.1

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	Hardness

7. RESULTS:

8. CONCLUSION:

9. PRECAUTION:

1. The specimen is to be handled carefully while transferring furnace to test apparatus.
2. 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-8

To find out the hardness of various treated and untreated steels.

Aim: To compare the Brinell Hardness number of the specimen before and after heat treatment.

Apparatus:

Brinell hardness testing, Ball indenter, Brinell Microscope, Tongs, Muffle furnace.

Theory:

Hardness, BHN, indenter, Hardness test types.

Procedure:

1. Select the ball Indenter and fix the indenter into the indenter holder.
2. Place the specimen on the anvil. By rotating the hand wheel raise the anvil so that the testing specimen touches the indenter.
3. Press the specimen against indenter for the small movement of the needle, in this position the minor load is applied
4. Select the Load to be applied.
5. The major load is applied slowly by the movement of the lever.
6. Slowly move back the lever and rotate the anvil in opposite direction in order to lower the anvil in down ward direction.
7. Measure the diameter of the dent or impression on the specimen ‘d’ by Brinell Microscope.
8. Calculate the hardness number.
9. The procedure is repeated after Heat Treating the specimen.
10. Compare the Hardness number before and after heat treatment.

Observation and Tabular Column:

Type of heat treatment done:

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

Where, P = Load applied

D = Diameter of the ball

d = Diameter of the indentation or impression.

Before Heat Treatment:

S.NO	Load applied(kg.)	Dia of theBall(mm)	Dia of the indentation(mm)	BHN	Remarks
1					
2					
3					
4					
5					
6					

After Heat Treatment:

S.NO	Load applied(kg.)	Dia of theBall(mm)	Dia of the indentation(mm)	BHN	Remarks
1					
2					
3					
4					
5					
6					

Results:

BHN before heat treatment:………………………………….

BHN after heat treatment:…………………………………….

Conclusions:

Precautions:

1. Apply the minor load carefully.
2. Release the lever gently while applying the major load.
3. Observation should be made at a sufficient distance from previous indentation.
4. Handle the Brinnel microscope carefully.
5. Care must be taken to set the anvil and indenter firmly.

Viva Questions:

1. What is meant by heat treatment?
2. What are the different types of heat treatment?
3. Enumerate the need for heat treatment of steel?
4. List different types of hardness testing methods?
5. What is meant by BHN?
6. Differentiate between hardenability and hardness?
7. What are the different types of indenters used in hardness testing?
8. What are the factors which affect the hardness of steels?
9. Why is the minor load applied before applying the major load?
10. Derive the formula to calculate BHN.

Exercise-9

Study of Microstructure of Composite Material subjected to tensile test

1. **AIM:**

To identify the different phases and to draw the microstructures Composite materials.

2. **Apparatus and specimens required:**

Metallurgical microscope, Al6082 metal matrix composite.

3. **Theory:**

Aluminium (Al) is used as a key metal matrix constituent in the production of composite materials. There is an increased petition for a low cost, lightweight material with excellent mechanical and tribological properties in the aerospace and automobile industries. Composite materials of Al showed application in these industries. Most of the researchers tried to reinforce aluminium metals and their alloys with ceramic particles to improve their properties. These composite materials presented great applications in the area of commercial as well as industrial components.

Composite materials when compared to unreinforced alloy showed better mechanical and tribological properties; moreover, these improved properties can be modified for a particular requirement. The hardness of the aluminium matrix composites (AMCs) reinforced with Gr particles decreased with a linear increase in the graphite (Gr) content irrespective of the manufacturing process employed to manufacture the composite materials.

The wear resistance of the AMCs reinforced with Gr particles increased as compared to that of pure aluminium matrix due to formation of a thin lubricating film by Gr particles which prevented direct contact of sliding surfaces and reduced ploughing effects of Al chips which in turn reduced the wear and friction of the composite material resulting into easy machining of these composite materials manufactured by various techniques. The wear resistance of a single reinforced composite increased when Gr is used as a second reinforcement because Gr having self-lubricating properties enhanced the wear resistance of single reinforced composites by forming a thin lubricating film of Gr particles in case of hybrid composites irrespective of the manufacturing process employed for the manufacturing of hybrid composites.

It is revealed from studied literature that the main emphasis has been given on the wear and mechanical properties, especially hardness of AMCs reinforced with Gr particulates and a limited research work has been reported on microstructural characterization of AMCs containing wide range of reinforcements i.e. Gr.

Microstructure of Al:

The Al6082/Gr composites were fabricated by stir casting process. microstructure of cast Al6082, and the microstructure contains solid solution of aluminium and inter-dendritic network of aluminium silicon eutectic. The microstructure of cast Al6082 (Fig. 1(b)) reveals the formation of α-aluminium dendritic network structure which is formed due to super-cooling of casting during solidification, with less impurities present. The SEM image of manufactured composites is shown in Fig. 2(a)–(d). The microstructure of all composites reveals that there are large impurities with a non-uniform distribution of Gr particles along with clustering of Gr particles at some locations. The low density of Gr particles as compared to that of Al6082 causes the Gr particles to float in the aluminium melt resulting in non-uniform distribution. The microstructures of all composites contain solid solution of aluminium and inter-dendritic network of aluminium silicon eutectic. When the composites are solidifying, the Gr particles are prohibited in the direction of refined α-Al grains. Because of this, the further refinement of α-Al grains takes place and Gr particles act as nucleus on which the α-Al grains solidify and Gr particles offer confrontation against growing α-Al phase during the solidification process.

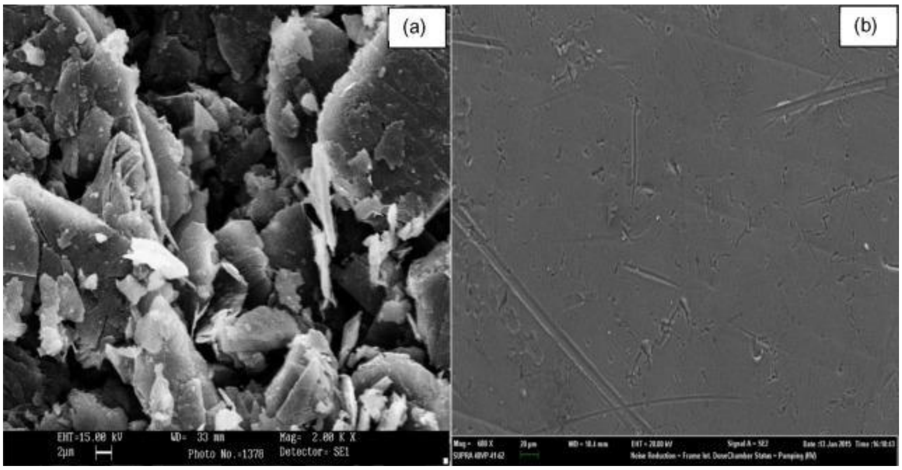


Fig. 1. (a) SEM image of pure Gr reinforcement. (b) SEM image of cast Al 6082.

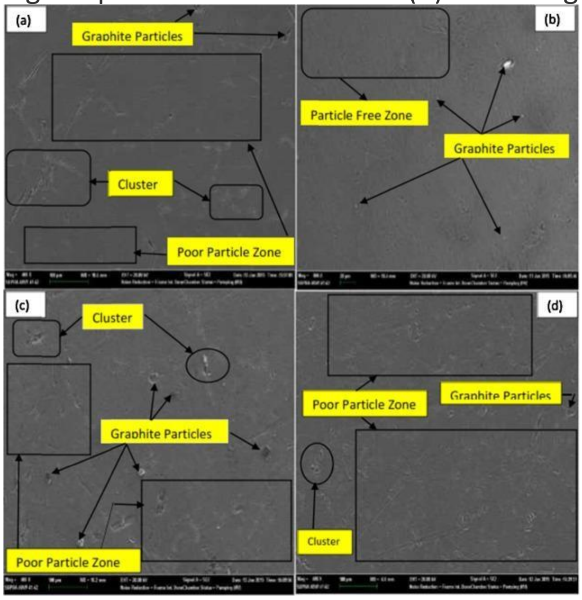


Fig. 2. SEM image of Al–Gr composites: (a) 3% Gr, (b) 6% Gr, (c) 9% Gr and (d) 12% Gr.

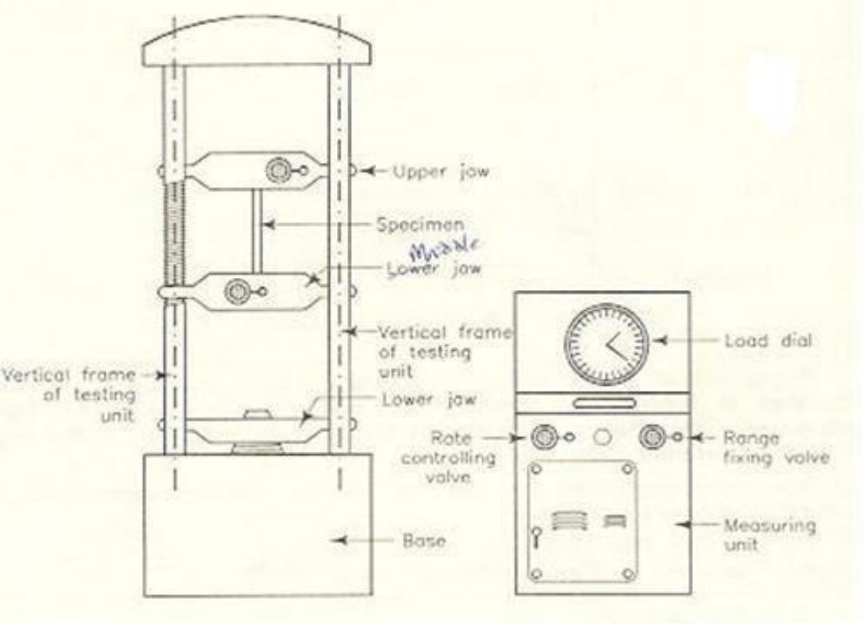
The scanning electron micrograph revealed a reasonably non-uniform distribution of Gr particles in the matrix.

Exercise-10

Study of the Composite Material with the help of UTM.

1. **AIM:** To Study of the Composite Material with the help of UTM.
2. **Objective:** To conduct a tensile test on a composite material 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.
3. **Apparatus:** (i) Universal Testing Machine (UTM) (ii) Mild steel specimens (iii) Graph paper (iv) Scale (v) Vernier Caliper, (vi) composite material of aluminium and polyethylene material.
4. **Theory:**

Automotive industry is on the verge of development. More and more comforts are being incorporated in a vehicle. On other hand customers have stringent demand of fuel economy, high performance at low cost. In order to have high fuel economy the auto-motive manufacturers are induced to reduce weight. In this research work flat plate is selected as a target weight reduction composite material. This can be achieved either using high strength low weight material or by using low weight composite sandwich panel. Aluminium composite (Aluminium skin, polyethylene core, resin binder material) material being light and strong, it is selected as an alternative material by considering peer reviewed papers and industrial guidance. By using this flat plate sandwich panel, tensile strength, bending strength, flexural limit have been carried out for optimization of composite material for sandwich panel construction. Tensile test, bending test is tested on Universal Testing Machine (UTM). One can use composite material to optimize mass and cost of various automobile, marine, aerospace and various structures.



Universal Testing Machine

5. **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.

6. Specifications:

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

6. Procedure:

1. Measure the original length and diameter of the specimen.
2. 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.
3. Insert the specimen into grips of the test machine and attach strain-measuring device to it.
4. Begin the load application and record load versus elongation data.
5. Take readings more frequently as yield point is approached.
6. Measure elongation values with the help of dividers and a ruler.
7. Continue the test till Fracture occurs.
8. By joining the two broken halves of the specimen together, measure the final length and diameter of specimen.

7. Observation:

(a) Initial diameter of specimen d1 =
(b) Initial gauge length of specimen L1 =
(c) Initial cross-section area of specimen A1 =
(d) Load of yield point Ft. =
(e) Ultimate load after specimen breaking F =
(f) Final length after specimen breaking L2 =
(g) Diameter of specimen at breaking place d2 =
(h) Cross section area at breaking place A2 =

8. Observation table:

S.No	Load (N)	Original Gauge Length	Extension (mm)	Stress = (N/mm2)	Strain
1					
2					
3					
4					
5					

9. Result:

(i) Ultimate tensile strength =_______________N/mm2