राज्य अभियांत्रिकी एवं प्रौद्योगिकी संस्थान, नीलोखेड़ी

State Institute of Engineering & Technology, Nilokheri

(Formerly Govt. Engineering College)

LABORATORY MANUAL

MATERIAL ENGINEERING LAB

ES-206LA

Department of Mechanical Engineering

STATE INSTITUTE OF ENGINEERING AND TECHNOLOGY

(Affiliated to K.U. University)

NILOKHERI – 132117, KARNAL

ME LAB

List of Experiments

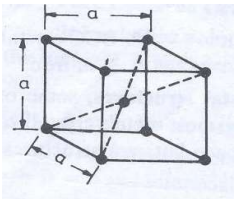
1. To Study various Crystal Structures through Ball Models.
2. To study the components and functions of Metallurgical Microscope.
3. To learn about the process of Specimen Preparation for metallographic examination.
4. To perform Standard test Methods for Estimation of Grain Size.
5. To perform Microstructural Analysis of Carbon Steels and low alloy steels.
6. To perform Microstructural Analysis of Cast Iron.
7. To perform Microstructural Analysis of Non-Ferrous Alloys: Brass & Bronze.
8. To perform Microstructural Analysis of Non-Ferrous Alloys: Aluminium Alloys.
9. To Perform annealing of a steel specimen and to analyze its microstructure.
10. To Perform Hardening of a steel specimen and to analyze its microstructure.
11. To Find out the Hardness of Various Treated and Untreated Steels.

Experiment-1

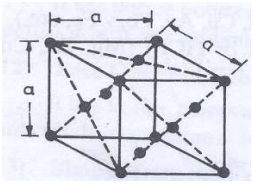
AIM:- TO STUDY VARIOUS CRYSTAL STRUCTURE THROUGH BALL MODELS

THEORY:- **BCC:-** In body centered cubic structure each one atom is placed at the corner of the cube and one atom is placed at the centre of the cube. Iron has BCC structure. At room temperature the unit cell of iron has an atom at each corner and another at the body centre of the cube. Each iron atom in BCC structure is surrounded by eight adjacent iron atoms. The unit cell of a cubic cell contains eight atoms at corners which are shared by the adjoining eight cubes.

Hence the share of each cube = ⅛ of each corner atoms
Total no of atoms = ⅛ × 8 = 1 atom
BCC crystal has one atom at center.
So, total no. of atoms in BCC = 2 atoms

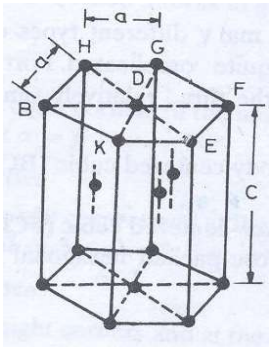


F.C.C.:- In this type of structure the unit cell contains one atom at center of each corner plus at each face. Examples of such type of crystal structure are copper, silver, gold etc.
In FCC crystal the atom on each face is surrounded or shared by two cubes. Son contribution of each towards crystal is ½, one atom at each corner. i.e. shared by eight other cubes so that its contribution towards crystal is ⅛.
So total no of atoms = ⅛ × 8 + ½ ×6 = 4 atoms



H.C.P.:- In case of hexagonal closed packing structure there are 12 atoms at corner. One atom at the center of two hexagonal faces and three atoms symmetrically arranged in the body of unit cell.

Total no of atoms per unit cell = 1/6 × 6 + 1/6 × 6 + ½ ×2 + 3 = 6 atoms



ATOMIC RADIUS:-
It is defined as half the distance between the nearest neighbors in the crystal structure of a pure element. It is expressed in terms of the cube edge element a and denoted by r.
BCC:- In this structure, the atoms touch each corner along the diagonal of the cube.

So, $AB^2 = a^2 + a^2$
$AB^2 = 2a^2$
$(AC^2) = (AB^2) + (BC^2)$
$(AC^2) = 2a^2 + a^2$
$4r = \sqrt{3}\, a^2$

$r = \sqrt{3}/4a$

FCC:- In this structure, one atom at each eight corners in addition to one atom at each face is present. From the geometry of the fig.

$BD = 4r = \sqrt{a^2 + a^2}$

$4r = \sqrt{2}\, a$

$R = \sqrt{2}/4 \times a$

ATOMIC PACKING FACTOR:- It may be defined as the fraction of volume occupied by spherical atoms as compared to the total available volume of the structure.

A.P.F. = volume of atoms in a crystal / volume of unit cell

=H/V

FOR BCC:-

Atoms per unit cell = 2

Volume $= 2 \times 4/3\ \pi\ r^3$

$V = 2 \times 4/3\ \pi \times (\sqrt{3}/4 \times a)^3$

$V = \pi\ \frac{\sqrt{3}}{8} a^3$

$APF = \frac{\Pi \sqrt{3} a^3}{a^3} = 0.68$

Atomic packing factor for BCC crystal is 0.68.

FOR FCC:-

total no of atoms = 4

Volume of 4 atoms $= \frac{4 \times 4 \times \Pi\, r^3}{3}$

$= \frac{\Pi}{6} \times \sqrt{2}\, a^3$

$APF = a^3 \frac{\Pi}{6} \frac{\sqrt{2}}{a^3} = 0.74$

Atomic packing factor for FCC crystal is 0.74.

FOR HCP:-

Area of ABCDEF = 6 × area of Δ FDE

$= 6 \times \frac{1}{2} \times a \times a \frac{\sqrt{3}}{2}$

$= 3\ a^2 \times \frac{\sqrt{3}}{2}$

$APF = \frac{no \times \frac{4}{3} \Pi\ r^3}{area\ of\ ABCDEF \times height}$

$= \frac{no \times \frac{4}{3} \Pi\ r^3}{3a^2 \times \sin 60° \times 1.633 \times a} = \frac{6 \times 4 \times \Pi}{3 \times 3 \times \sin 60° \times 1.633 \times 8 \times 3}$

$= 0.74$

So, APF for HCP is 0.74

Experiment -2

AIM: - TO STUDY THE COMPONENTS AND FUNCTION OF METALLURGICAL MICROSCOPE

OBJECTIVES:-

1. Familiarization with the different components of metallurgical components.
2. Familiarization with compound optical microscope and metallographic.
3. To study magnification system and how to increase in magnification.

INTRODUCTION: The metallurgical microscope is the most important tool of the metallurgist. It consists an objective and an eye-piece. Its primary function is to reveal the details of the object. The clarity and the extent to which the details are revealed depend on the degree to which these optical systems are created.

PRINCIPLE:A horizontal beam of light from the light source is reflected by means of a plane glass reflector downwards through the microscope objective on the surface of the specimen some of this incident light reflected from the specimen surface will be magnified and passing through the plane glass reflector and magnified again by upper lens system of the eye-piece.

CONSTRUCTIONAL DETAILS: The table type microscopes are consisting of

1. **Stage**: - A flat movable table supporting specimen. This can be moved up or down by knobs.
2. **Tubes**: - The vertically movable tube containing eyepiece, objective and plane reflector. The tube length varies from 160 mm to 250 mm.
3. **Rough & fine focus Adjustments** - The limbs of microscope carry the coarse & fine adjustments.
4. **Objective** – The body tube carries revolving nose piece carrying the three objectives. This enables quick change of the objective which helps for a quick resolving the structure of metal, the magnification of lenses is enlarged on focal length of the lens used.

The important properties of an objective are

1) Magnifying Power
2) Resolving Power

It is the property by which an objective shows distinctly represented two small adjacent bonds in the structure of the object. This is usually expressed as number of lines per mm that can be separated which depends on the numerical operator, the wavelength of the light used. Resolution is particularly important during the microscopy of the micro constituents of metals consisting of fine lamination with core resolution which appears as one uniform area, where as an objective with higher numerical appearance reveals deeper nature of the structure.
Total magnification of microscope may be calculated as

$M = L*E/F$

Where, L- The distance from back of objective to eyepiece, E- Magnification of Eye piece & F- The focal length of objective.

EYE PIECE- It is named, as it is near to the eye. It is made up of various Powers such as _ 5X, 10X, 15X etc.

Uses: -The metallurgical microscope is useful in quality control department in Industries to observe & study

1) Differential phases
2) Porosity or defects.

All these have a great effect on mechanical properties of material.

CONCLUSION:
Proper selection of magnification is very much essential because –

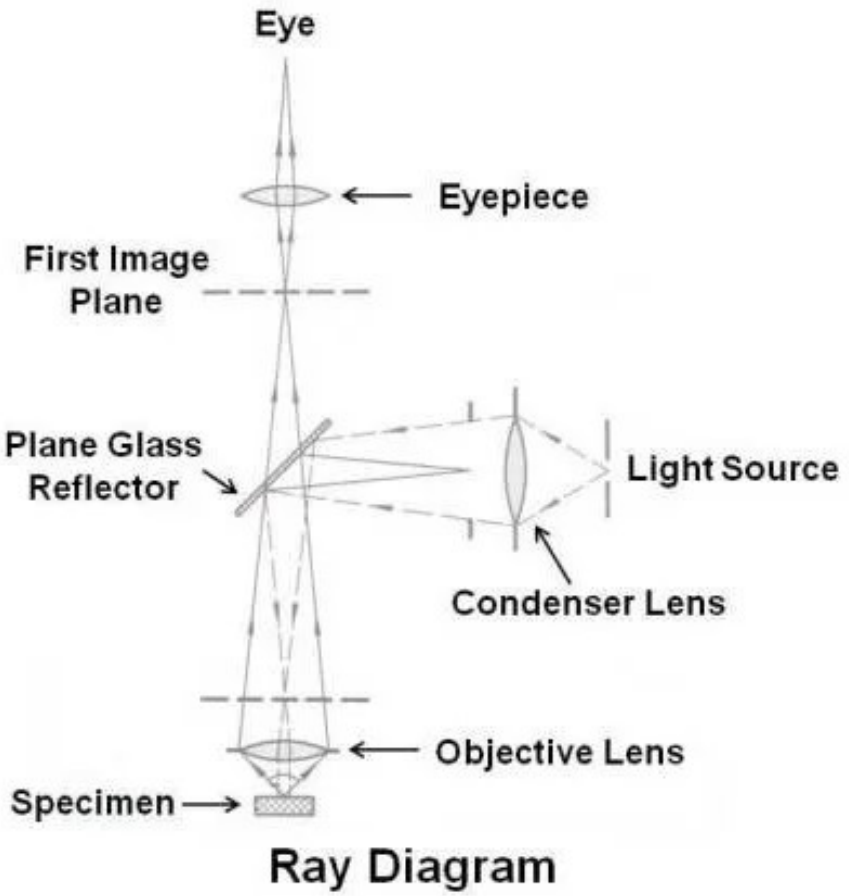
a. To travel inclusions in steel low magnification is used.

b. To travel grain size, grain structure, twin boundaries etc. medium magnification is used.

c. To travel particular e.g. coarse perlite, fine martensite, bainite, etc. high magnification is necessary.

Therefore, proper study of metallurgical microscope is necessary.

Metallurgical Microscope



Ray Diagram of Metallurgical Microscope

Experiment -3

AIM: TO LEARN ABOUT THE PROCESS OF SPECIMEN PREPARATION OF METALLURGICAL EXAMINATION

THEORY: The preparation of metallic or other materials for microscopic examination and microstructural characterization is in principal very simple. There are four basic processes that you will need to become familiar with: sample cutting and sectioning, metallographic mounting, Surface grinding and surface polishing.

PROCEDURE:

(a) Sample Cutting and Sectioning

Sectioning means removal of convenient size specimen from large sample with minimal damage to microstructure with the help of abrasive cut off machine. Abrasive cutting wheel/saw is attached to cutting machine and for work piece holding proper vice is provided on machine. The primary concern in this process is to minimize the heating of the sample due to the cutting. For this reason, the cut-off saws that is equipped with either water-cooling systems.

(b) Mounting

If sample is large enough (about 25 mm square or larger) than do not need to mount it, as itwill be able to control the sample during polishing without a mount. For smaller samples there are two basic mounting techniques used in this laboratory. Mounting facilitates handling during preparation and handling. It also avoids damage to polishing wheels during polishing. The most common uses a thermosetting plastic compound (Bakelite) to encapsulate the specimen known as hot-mounting process, and the second uses a room temperature curing epoxy known as cold mounting process. The Bakelite mounting is by far the most common and easiest. The room temperature curing epoxy mount should only be used for samples that are extremely sensitive to heat. The Bakelite process uses a sample mounting press that applies a pressure to the Bakelite/sample system during the cure to remove voids and gaps and to fully fill the sample spaces. Bakelite comes in a variety of colors, which can be combined to produce easy sample identification.

(i) The procedure for Hot mounting process.

The following process is used to encapsulate your specimen in Bakelite:

1) Place sample face down on the small piston inside the press, and lower the piston into the cylinder by opening slightly the valve on the front of the press.

2) Approximately three table spoons of Bakelite is poured over the sample, and the top of the press gently screwed into place. DO NOT TIGHTEN THE TOP OF THE PRESS. It is only necessary to engage all of the screw threads; you do not have to tightly secure the top.

3) The cylindrical heater is plugged in and turned on (the red light should turn on). Place the heater around the mold. The heater is thermostatically controlled and will heat the mold to about 135-150 °C. Close the valve, and pump up the cylinder using the hand lever. As the Bakelite heats, it will begin to flow to fill the void spaces, and the pressure will drop. Maintain the constant.

4) When the pressure stops rapidly dropping, the whole mold has reached 150°C. Begin timing for 5-7 minutes to fully cure the Bakelite. Maintain the pressure during the entire heating and cooling cycle.

5) At the end of the heating cycle, remove the heater and place the cooling collar on themold for an additional 6-8 minutes.
6) Crack the valve to release the pressure, and unscrew the top of the mold. When the mold top is fully unscrewed (it may not come out due to adhesion with the Bakelite), close the valve and slowly pump up the cylinder to push the sample fully out of the press. Mark the sample on the back.
7) Clean any residual Bakelite off of the mold surfaces.

(ii) The procedure for Cold Mounting process.
The following process is used to room temperature curing epoxy process:
1) Apply mold release agent to mold. Place specimen in the mold.
2) Mix epoxy powder and bonding liquid in 1:2 ration in a cup.
3) Pour into mold and wait for 10 minutes.
4) Eject the mold.

(c) Sample Surface Polishing
The goal of the surface polishing is to end up with a planar cross section of sample free from scratches or disturbed metal introduced by the cutting and sectioning. This process is a step-wise process that can be broken into three loosely separate parts: grinding, coarse polishing, and final polishing.

(i) Grinding
The first step in preparing your sample is to ensure that you have a flat surface to begin with. A water-cooled abrasive grinder is available to form a flat initial surface from which to begin. Start with the coarsest grit (240) and, using a firm and uniform pressure, slowly move the specimen forward and back across the abrasive. This will produce parallel scratches of uniform size. Continue this step until the entire surface of your sample is flat and contains only scratches of the size of 240 grit abrasive. When the sample is flat and the only scratches remaining are those due to the 240 grit abrasive, WASH your sample and your hands thoroughly, and move to the 320 grit abrasive. Repeat this procedure for the 400, 600, 800, 1200 and 1600 grit abrasive, checking after each step to be sure that only those scratches remain that are due to the smallest grit.

(ii) Final Polishing
1) Repeat steps 1-5 above on the right polishing wheel. This wheel uses a 0.05 micrometer Al_20_3 abrasive in a water suspension. At this point, the sample will be very smooth to the eye and even the oils and dirt on your fingers will scratch it with larger scratches than the abrasive.

(d) Etching
Grains cannot be seen without etching. Cracks, pores and defects are observed without etching. Etchant reacts with atoms and dissolves them. Atoms at grain boundaries dissolve quickly. Dissolved grain boundaries appear dark.
Steps: 1) Apply enchant to polished surface for some time
2) Rinse with distilled water

Enchants: 2% Nital: 2 ml concentrated HN03; 98 ml methyl alcohol.

Metallographic Observation

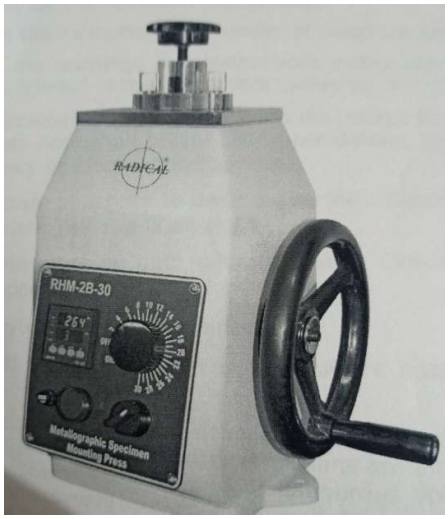
Observe microstructure, Place specimen on metallograph and adjust magnification, focus and position s adjust micro High magnification - to study phases and Low magnification -to study grain size.

.OBSERVATION:_____

PRECAUTIONS:

There are several general instructions to keep in mind during this part of the process.

1) CLEANLINESS!!! Keep the room and the work areas clean, especially the polishing area. Each step in the polishing process uses a finer grade of abrasive, so good results require that both your sample and your hands are free from abrasive at each stage before proceeding to the next stage of the process. Turn the power off and cover the wheelswhen you are through. Clean up any spilled water and wipe up the countertop.
2) Throw away the leftover etchants into the sink with a liberal amount of water. Swabs should be rinsed and thrown into the trash bin IMMEDIATELY AFTER USE. Wash your containers with water, rinse in methanol, and place them on the shelf above the sink.
3) Use goggles and gloves while handling chemicals. Contact the T.A. or the Instructor inthe case of an acid spill, or if new etchants are needed. Be extra careful when using hydrofluoric acids.
4) Do not eat or drink anything while working in the lab. Wash your hands thoroughly with soap before leaving the lab.



Metallographic Mounting press

Specimen Hot and Cold Mounted

Experiment 4

AIM: TO PERFORM STANDARD TEST METHODS FOR ESTIMATION OF GRAIN SIZE

THEORY: The Grain size is often determined when the properties of polycrystalline and single phase materials are under consideration. It is important to realize that for each material, the constituent grains have a variety of shapes and a distribution of sizes.
Grain size may be specified in terms of average or mean grain diameter and a number of Techniques have been developed to measure this parameters. Before the advent of the digital age, grain size determination was performed manually using photo micrographs. Today most technique are automated and use digital image and image analyses with the capacity to record, detect and measure accurately features of the grain structure (grain intercept counts, grain boundary length and grain area)

Two common steps for grain size determination:

1) **Linear Intercept**: Counting numbers of grain boundary intersections by straight test lines.
2) **Comparison**: Comparing grain structure with standardized charts which are based upon grain area (i.e. no of grain per unit area)

Discussion of these techniques is from the manual perspective (using photographs)

PROCEDURE:

For line intercept method, we should follow the following methods which are given below:

1) Lines are drawn randomly through several photomicrographs that shows in the grain structure (all taken at the same magnification).
2) Grain boundaries intersected by all the line segments are counted.
3) The mean intercept length $\bar{l}$, a measure of grain diameter may be determined by

$$\bar{l} = \frac{L_T}{PM}$$

Where L_T is total length of all lines.
P is sum of total number of intercepts and
M is magnification.

Line Number	Number of grain boundary intersection
1	
2	
3	
4	
5	
6	
7	
Total	Sum of grains (P)

To compute magnification from a scale bar:

1) Measure the length of the scale bar in millimeter using a ruler.
2) Convert this length into microns.
3) Magnification M can be calculated as:
4)

$$M = \frac{Measured\ scale\ length\ (converted\ into\ microns)}{The\ number\ appearing\ by\ the\ scale\ bar\ (in\ microns)}$$

Comparison method, we should follow the following instructions:

1) The comparison method of grain size determination was devised by the American Society for Testing and Materials (ASTM).
2) A specimen must be prepared properly to reveal the grain structure, which is then photographed.
3) Grain size is expressed as the grain size number of the chart that most nearly matches the grains in the micrograph. Grain size number is used extensively in the specification of steels
4) Let G represents the grain size number, and let n be the average number of grains per square inch at a Magnification of 100X.

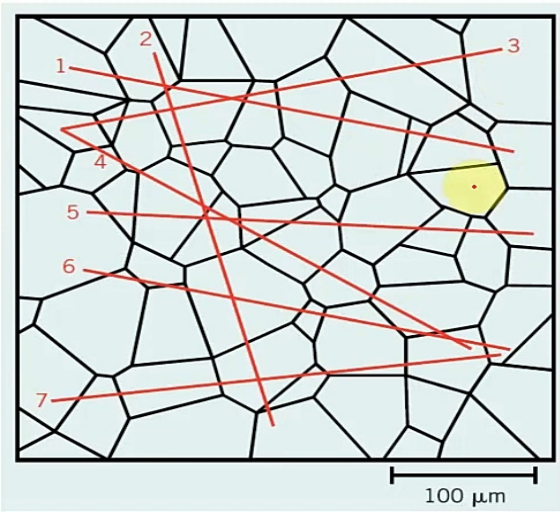
$$n = 2^{G-1}$$

5) For photomicrographs taken at magnifications other than 100X, the modified form of above equation is

$$n_M \left(\frac{100}{M}\right)^2 = 2^{G-1}$$

6) In this expression, n_M is the number of grains per square inch at magnification M.
7) Relationship has been developed that relate mean intercept length $\bar{l}$ (grain diameter) to ASTM grain size number 'G' as:

G = -6.6457 log $\bar{l}$ -3.298 (for $\bar{l}$ in mm)



Grain Structure

Experiment-5

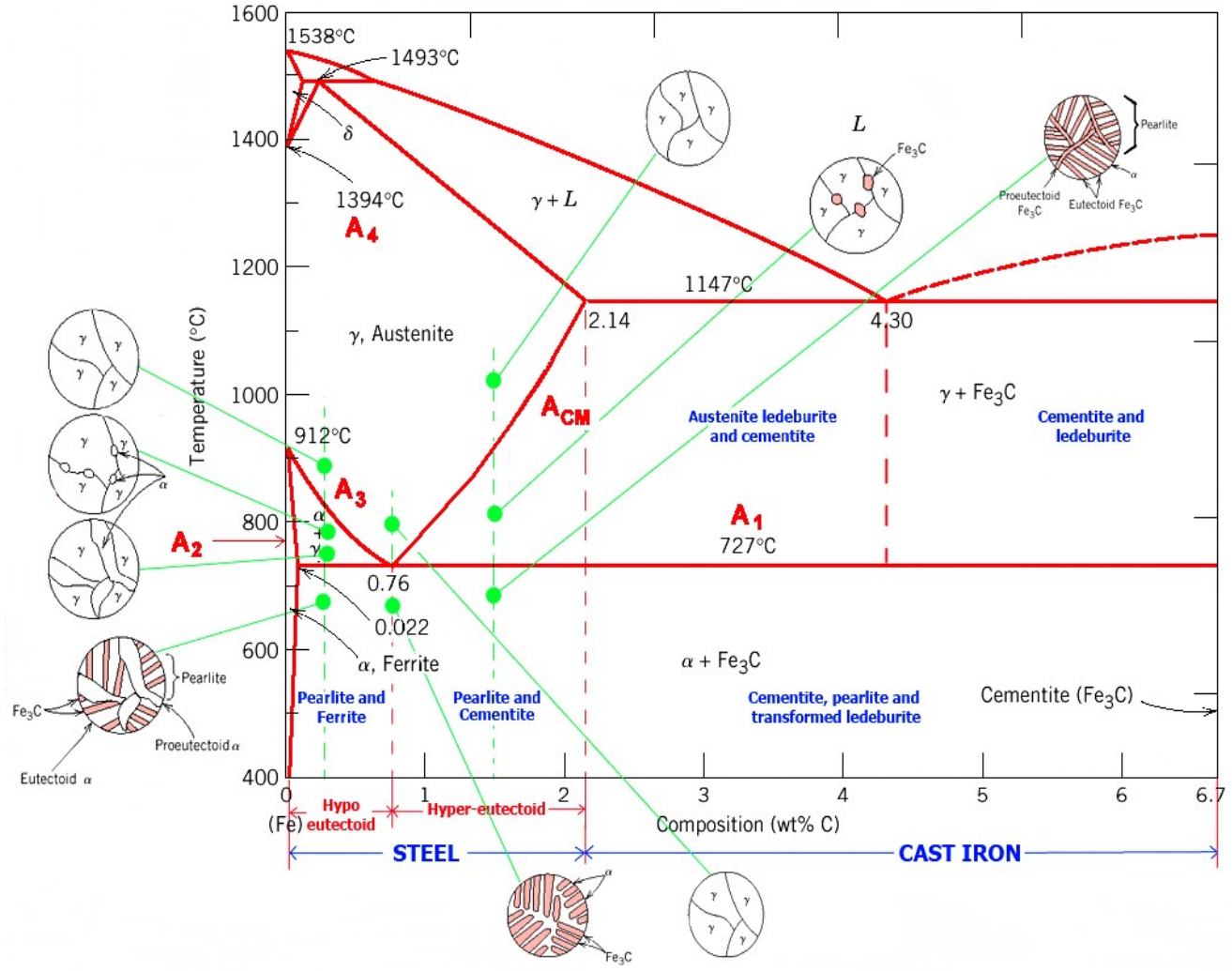
AIM: TO PERFORM MICROSTRUCTURAL ANALYSIS OF CARBON STEELS AND LOW ALLOY STEELS

APPARATUS : Cutting Machine, Mounting Press, Polishing Machine, Microscope

THEORY:

Mild Steel, Low Carbon steel and High Carbon Steel are types of ferrous materials and are most important to the engineering application because of their wide range of properties and verity of applications. Theoretically, steels are the alloys of iron and carbon in which the carbon content is between 0.008 to 2.0 per cent. The structures and properties can be discussed with the help of Fe-C equilibrium diagram.

Iron -Iron Carbide Equilibrium Diagram



Fe-Fe_3C Phase Diagram

Two very important phase changes take place at 0.83%C and at 4.3% C.

At 0.83%C, the transformation is eutectoid, called pearlite.

gamma (austenite) —> alpha + Fe3C (cementite)

At 4.3% C and 2066°F, the transformation is eutectic, called ledeburite.
L(liquid) --> gamma (austenite) + + Fe3C (cementite)

Definitions

Eutectoid: A eutectoid system occurs when a single-phase solid transforms directly to a two phase solid.

Hypereutectoid: Hypereutectoid systems exist below the eutectoid temperature.

Hypoeutectoid: Hypoeutectoid systems exist above the eutectoid temperature.

Ferrite: Body-centered cubic iron or an iron alloy based on this structure.

Austenite: Face-centered cubic iron or an iron alloy based on this structure.

Delta iron: The body-centered cubic phase which results when austenite is no longer the most Stable form of iron. Exists between 2802 and 2552°F has BCC lattice structure and is magnetic.

Body-centered: A structure in which every atom is surrounded by eight adjacent atoms, whether the atom is located at a corner or at the center of a unit cell.

Face-centered: A structure in which there is an atom at the corner of each unit cell and one in the center of each face, but no atom in the center of the cube.

Pearlite: A lamellar mixture of ferrite and carbide formed by decomposing austenite of

Eutectoid composition.

Cementite: The second phase formed when carbon is in excess of the solubility limit.

Ledeburite: Eutectic of cast iron. It exists when the carbon content is greater than 2 percent. It contains 4.3 percent carbon in combination with iron.

Classification of Steel: The steels are classified by various methods and each method is based on a definite criteria as follows,

i) Amount of carbon
- *Low carbon steels* (0.008 - 0.3%C)
- *Medium carbon steels* (0.30 - 0.60%C)
- High carbon steels (0.60 - 2.00%C)

ii) Amount of alloying elements and carbon
iii) Amount of deoxidation
iv) Method of manufacture
v) Form and use.

STRUCTURE EXAMINATION:

1. Ferrite:

Iron which contains little or no carbon is called ferrite. It is very soft and ductile and is known as alpha iron by the metallurgists. Ferrite is present to some extent in a great range of steels, particularly those low in carbon content, and it is also present, in soft cast iron. Ferrite does not harden when cooled rapidly. It forms smaller crystals when cooled from a bright red heat at a rapid rate.

2. Cementite:

This is a definite carbide of iron (Fe_3C) which is extremely hard, being harder than ordinary hardened steel or glass. Cementite increases generally with the proportion of carbon present, and the hardness and also the brittleness of cast iron is believed to be due to this substance.

It contains 6.6 percent carbon and occurs either in the form of a network or in globular or massive form, depending on the analysis of the steel and the heat treatment to which it is subjected. It is magnetic below 25°C. Its presence in iron or steel decreases the tensile strength but increases the hardness and cutting qualities.

3. Pearlite:

Pearlite is the name given to a mixture of about 87.5 percent ferrite and 12.5 percent cementite. It consists of alternate layers of ferrite and cementite in steel. Under high magnification the ferrite and cementite can be seen to be arranged in alternate laminations or plates.

When seen in the microscope the surface has appearance like mother of pearl, hence the name pearlite. The thickness of alternate plates and the distance between them is governed by the rate of cooling, slow cooling produces a coarser structure than rapid cooling. Pearlite is eutectoid of steel.

It has been found that the proportion of pearlite increases from nothing in the case of pure carbonless iron upto 100%, or saturation, for steel containing 0.90% of carbon thus a 0.3 percent carbon steel will consist of about 33 percent pearlite and rest ferrite. It is the characteristic of soft steels that they contain ferrite and pearlite, and the hardness increases with the proportion of pearlite. Hard steels are mixtures of pearlite and cementite.

Metallographic Observation

Observe microstructure, Place specimen on metallograph and adjust magnification, focus andposition s adjust micro High magnification - to study phases and Low magnification -to studygrain size.

.OBSERVATION:_____

Experiment-6

AIM: TO PERFORM MICROSTRUCTURE ANALYSIS OF CAST IRON

APPERATUS: Metallurgical Microscope, Standard Specimens of Cast Iron materials.

THEORY:

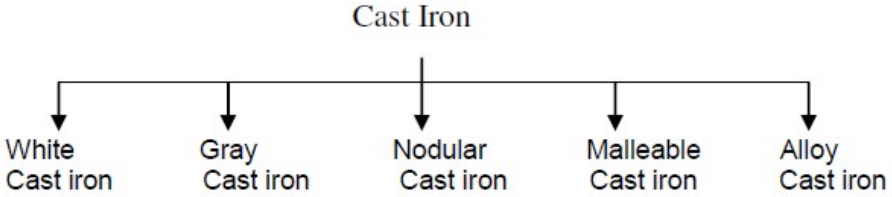
Cast Iron: Cast irons typically contain 2-4 wt% of carbon with a high silicon concentrations and **a** greater concentration of impurities than steels. The *carbon equivalent* (CE) of a cast iron helps to distinguish the grey irons which cool into a microstructure containing graphite and the white irons where the carbon is present mainly as cementite. The carbon equivalent is defined as:

$$CE(wt\%) = C + \frac{Si + P}{3}$$

The term cast iron, like the term steel, identifies a large family of ferrous alloys. Cast multi component ferrous alloys. They contain major (iron, carbon, silicon), minor (<0.01%), and often alloying (>0.01%) elements. Cast iron has higher carbon and silicon contents than steel. Because of the higher carbon content, the structure of cast iron, as opposed to that of steel, exhibits a rich carbon phase. Depending primarily on composition, cooling rate and melt treatment, cast iron can solidify according to the thermodynamically metastable Fe-Fe_3C system or the stable Fe- Gr system. When the metastable path is followed, the rich carbon phase in the eutectic is the iron carbide; when the stable solidification path is followed, the rich carbon phase is graphite. Referring only to the binary Fe-Fe_3C or Fe-Gr system, cast iron can be defined as an iron-carbon alloy with more than 2% C. Important notice is that silicon and other alloying elements may considerably change the maximum solubility of carbon in austenite (g). Therefore, in exceptional cases, alloys with less than 2% C can solidify with a eutectic structure and therefore still belong to the family of cast iron.

Types of Cast Iron

On the basis of Microstructure cast irons are classified as follows:



(a) White Cast iron

Composition of the iron is appropriate or the cooling rate of the metal is sufficiently rapid during solidification, the metal will solidify with the C combined with iron as iron carbide. This compound, also called cementite, is hard and brittle and dominates the microstructure of white iron. Thus, white iron is hard and brittle and has a white crystalline fracture because it is essentially free of graphite.

White iron has a high compressive strength and excellent wear resistance, and it retains its hardness for limited periods even up to a red heat. It can be produced in selected areas of a casting—such as. on the periphery of a cam—by causing localized rapid solidification of the iron. White iron at the surface of a casting is called chill. It is produced by making that portion of the mold—where the white iron is desired—of-a material that can extract heat very rapidly, such as iron or graphite. White iron does not have the easy castabiiity of other irons

because its solidification temperature is generally higher, and it solidifies with C in its combined form as iron carbide. Application includes rollers of rolling mills, Dies of metal extrusion and where high wear resistance is necessary.

(b) Gray Cast Iron

When the composition of the molten iron and its cooling rate are appropriate, the C in the iron separates during solidification and forms separate graphite flakes that are interconnected within each eutectic cell. The graphite grows edgewise into the liquid and forms the characteristic flake shape. When gray iron is broken, most of the fracture occurs along the graphite, thereby Cast Iron accounting for the characteristic gray color of the fractured surface. Because the large majority of the iron castings produced arc of gray iron, the generic term, cast iron, is often improperly used to mean gray iron specifically. The properties of gray iron are influenced by the size, amount and distribution of the graphite flakes, and by the relative hardness of the matrix metal around the graphite. These factors are controlled mainly by the C and Si contents of the metal and the cooling rate of the casting. Slower cooling and higher C and Si contents tend to produce more and larger graphite flakes, a softer matrix structure and lower strength. The flake graphite provides gray iron with unique properties such as excellent machinability at hardness levels that produce superior wear-resisting characteristics, the ability to resist galling and excellent vibration damping. The amount of graphite presents, as well as its size and distribution, is important to the properties of the iron. Whenever possible, it is preferable to specify the desired properties rather than the factors that influence them.

(c) Nodular cast Iron (Ductile iron, S. G Iron)

Ductile iron also referred to as nodular iron or spheroidal graphite iron, was patented in 1948. After a decade of intensive development work in the 1950s, ductile iron had a phenomenal ninefoldincrease in use as an engineering material during the 1960s, and the rapid increase in commercial application continue today. An unusual combination of properties is obtained in ductile iron because the graphite occurs as spheroids rather than as individual flakes as in gray iron. This mode of solidification is obtained by adding a very small, but specific, amount of Mg to molten iron of a proper composition. The base iron is severely restricted in the allowable contents of certain minor elements that can interfere with the graphite spheroid formation. The added Mg reacts with the sulfur and oxygen in the molten iron and changes the way the graphite is formed.

Control procedures have been developed to make the processing of ductile iron dependable. The high C and Si content of ductile iron provide the casting process advantages, but the graphite spheroids have only a nominal influence on the mechanical properties of the metal. Ductile iron, like malleable iron, exhibits a linear stress-strain relation, a considerable range of yield strengthsand, as its name implies, ductility. Castings are made in a wide range of sizes with sections that can be either very thin or very thick.

The different grades are produced by controlling the matrix structure around the graphite either as cast or by subsequent heat treatment. Only minor compositional differences exist among the regular grades, and these adjustments are made to promote the desired matrix microstructures. Alloy additions may be made to ductile iron to assist in controlling the matrix structure as-cast or to provide response to heat treatment. Special analysis ductile irons and high-alloy ductile irons provide unusual properties for special applications.

(d) Malleable Cast Iron

This type of iron is characterized by having the majority of its C content occur in the microstructure as irregularly shaped nodules of graphite. This form of graphite is called

temper carbon because it is formed in the solid state during heat treatment. The iron is cast as a white iron of a suitable chemical composition. After the castings are removed from the mold, they are given an extended heat treatment starting at a temperature above 1650°F (900°C). This causes the iron carbide to dissociate and the free carbon precipitates in the solid iron as graphite. The rapid solidification rate that is necessary to form the white iron limits the metal thickness in the casting that is practical for the malleable iron process.
A wide range of mechanical properties can be obtained in malleable iron by controlling the matrix structure around the graphite. Pearlitic and martensitic matrices are obtained both by rapid cooling through the critical temperature and with alloy additions. Malleable irons containing some combined carbon in the matrix often are referred to as pearlitic malleable, although the microstructure may be martensitic or a spheroidized pearlite.

PROCEDURE:

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An example of what is considered to be a good laboratory report sketch of the microstructures is included in the appendix. Your sketch MUST INCLUDE:
1) The sample name and composition,
2) The metallurgical history of the sample,
3) A simple sketch of the important microstructure indicating
a) The magnification used (i.e. “MAG= 100 X”),
b) Important phases and features noted,
4) Etchant used.

OBSERVATIONS:_____

PRECAUTIONS:
There are several general instructions to keep in mind during this part of the process.

1. CLEANLINESS!!! Keep the room and the work areas.
2. Don't touch etched and polished surface of the specimen.
3. Don't touch the lances of eyepiece with dirty hand.
4. Use clean clothes only to clean the lenses of eyepieces.
5. Handle the microscope with gently.
6. Return the standard specimen to the Lab Technician after observation.
7. Switch off the microscope after the observation.

Experiment-7

AIM: TO PERFORM MICROSTRUCTURE ANALYSIS OF NON-FERROUS ALLOYS: BRASS AND BRONZE

APPERATUS: Metallurgical Microscope, Specimens of Non Ferrous Metals.

THEORY: Copper and Copper Alloys
COPPER -: The properties of copper are high electrical and thermal conductivity, good corrosion resistance, machinability, strength and ease of fabrication.
Copper properties:-

- Its melting point is 1083ºC
- Specific gravity is 8.9.
- Has high electrical and thermal conductivity.
- Its good ductility and malleability due to its FCC structure.
- Cu containing 0.3% As is called as ARSENICAL Cu
- Cu containing 0.6% Al is called as FREE CUTTING Cu.

COPPER ALLOYS:
There are two types of Cu alloys popularly known as BRASS AND BRONZE.

(I) BRASS:-

Cu + Zn = Brass

• Brass are again divided as
(a) Alpha brass
(b) Alpha + beta brass

(a) Alpha Brass: Type of alpha brass is:

- **CAP Brass**consist of 2-5% Zn, very ductile alloy.Zn is used as deoxidiser for deoxidation of Cu and it is used for cap of detonation
- **Guilding Metal** consist of 5-15% Zn, has color of gold. It is used for making artificial jewellary, condenser tubes, coils, needles, etc.
- **Cartridge Brass** is known as (70-30) brass. It has maximum ductility and malleability of all brasses. Its applications are radiator fins, lamp fixtures, rivets, springs, etc.
- **Admirality Brass** consist of 1% Sn is added to cartridge brass to improve corrosion resistance. It's used in condenser tubes and heat exchangers. Containing 22%Zn,2%Al,0.04%Sn is used in marine applications.

(b) Alpha + beta brass:
It contains up to (32-40) % Zn. It is Hard, strong and less corrosion resistance compared to alpha brasses.

- **Muntz Metal:** It contains 40%Zn and becomes single phase at about 700ºC. It's also called (60-40) brass.It is used in utensils, shafts, nuts, bolts, condenser tubes, etc.
- **Naval Brass:** Adding l%Sn to muntz metal increase corrosion resistance to marine environment. It also called as TOBIN Bronze.
- **Leaded Brass:** Lead added in small amount (l-3)% to improve machinability and appears globules in microstructure.

(II) BRONZE (Cu-Sn alloy):

- **Al Bronze:** It is an alloy of Cu and Ni. Maximum solubility of Cu in Ni is 9.4%. It has good ductility, strength, toughness, corrosion resistance and fatigue resistance. It is also called as Imitation Gold. Applications of Al Bronze are valves components, pump castings, spark plug body.
- **Tin Bronze:** It is an alloy of Cu and Sn. Tin has affinity towards oxygen. The tin oxide reduces ductility and malleability. Zn or P are added as deoxidizer.
- **Coinage Bronze:** It contains 5%Sn and l% Zn. It is a ductile metal, having better formability and strength. It's used in manufacturing of coins.
- Gun Metal: It contains 10%Sn and 2% Zn and also known as (10-2) bronze.
- **Phosphorous Bronze**: It is an alloy of Cu and Zn with P. Phosphorous is a strong deoxidizer and helps in increase fluidity. Phosphorous content is max upto 1% depending on application,
  - (2.5-8)% Zn,(0.1 -0.35)%P known as Wrought Phosphorous Bronze.
  - (5-13)% Zn and (0.3-l)%P is known as Cast Phosphorous Bronze.
- **Monel Metal:** It is an alloy of Cu and Ni.Cupronickel metal alloy consists of 15-30%Ni. Cu and Ni are completely soluble into each other in both solid in liquid solution. It's applications are blades of turbine, coins, bullet envelops.

PROCEDURE:

In this laboratory, you will report the microstructures of prepared samples in specific formats. You will be expected to sketch the microstructure that you see under the microscope by hand. In sketching the microstructure there are several things to keep in mind. First, the magnification that you use depends upon the scale of the microstructure you are looking for. It is IMPORTANT to know in advance of the lab class what the expected microstructure for your samples are and at what scale they should appeal'. In sketching the microstructure, you should indicate only the important features of the structure that you observe-don't make a photographic reproduction of the microstructure. Simple sketches show that you know what the important structures are and have identified them in the cross section.

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3) A simple sketch of the important microstructure indicating
a) The magnification used (i.e. "MAG= 100 X"),
b) Important phases and features noted,
4) Etchant used.

OBSERVATION:

PRECAUTIONS:

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3. Don't touch the lances of eyepiece with dirty hand.
4. Use clean clothes only to clean the lenses of eyepieces.
5. Handle the microscope with gently.
6. Return the standard specimen to the Lab Technician after observation.
7. Switch off the microscope after the observation.

Experiment- 8

AIM: TO PERFORM MICROSTRUCTURE ANALYSIS OF NON-FERROUS ALLOYS: ALUMINIUM ALLOYS

APPERATUS: Metallurgical Microscope, Specimens of Non Ferrous Metals.

THEORY: Aluminium and its alloy

ALUMINIUM:

Al Properties:

- Light in wt.
- Castability and formability arc better.
- Corrosion resistance of Al is excellent.
- Powerful deoxidiser.
- Carries more electricity than Cu.
- Costlier metal in the family of light metal alloys.
- Has good electrical and thermal conductivity.
-

A1 ALLOYS:

- **Al-Si-Cu:**-Al alloy notation used are LM2,LM6, LM8, LM13. It is used for production of castings, due to their excellent fluidity nd casting characteristics. Higher Si content better are the mechanical properties.
- **Al-Mg (Magnalium Alloy):** Alloys notations areLM5 and LM10.It is used in marine environments because of high strength and resistant to corrosion. It has good surface finish.
- **Al-Cu (Duralium):** Alloys notations are LM11 (CU-4.5%). It is susceptible to hot tearing. Applications are casted components used in aircrafts.
- **Y Alloy (High strength Al Alloy):** Alloys notations are LM14. It contains 4%Cu, 2% Ni, and 1.5%Mg. It's used in heavy-duty petrol engine, piston block, etc.
- **RR350 (Hinduminium):** Itcontains 5%Cu, 1.5%Ni with small amounts of Mn, Ti, Sb, Co, Zr. It is used in aero engines and other continuous elevated temp service applications upto 300°C.

PROCEDURE:

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3) A simple sketch of the important microstructure indicating
a) The magnification used (i.e. "MAG= 100 X"),

b) Important phases and features noted,
4) Etchant used.

OBSERVATION:

PRECAUTIONS:
There are several general instructions to keep in mind during this part of the process.

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5. Handle the microscope with gently.
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7. Switch off the microscope after the observation.

Experiment-9

AIM: - TO PERFORM ANNEALING OF A STEEL SPECIMEN AND TO ANALYSE ITS MICROSTRUCTURE.

THEORY: Heat Treatment is the controlled heating and cooling of metals to alter their physical and mechanical properties without changing the product shape. Heat treatment is sometimes done inadvertently due to manufacturing processes that either heat or cool the metal such as welding or forming.

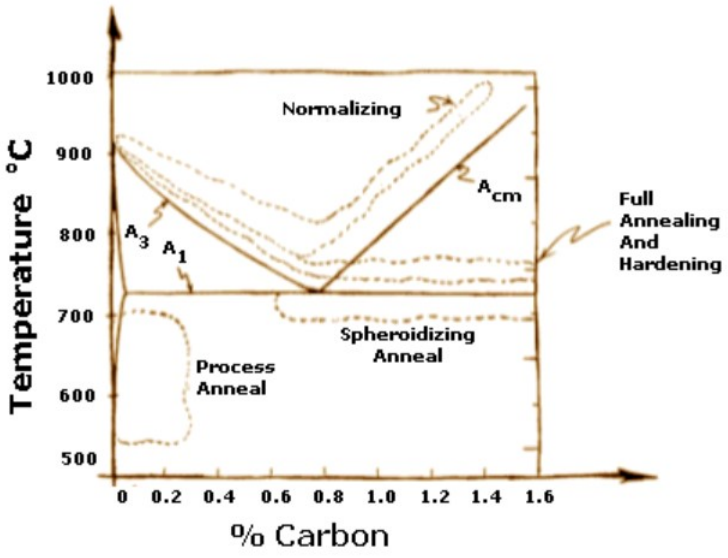
Heat Treatment is often associated with increasing the strength of material, but it can also be used to alter certain manufacturability objectives such as improve machining, improve formability, and restore ductility after a cold working operation. Thus it is a very enabling manufacturing process that can not only help other manufacturing process, but can also improve product performance by increasing strength or other desirable characteristics.

Steels are particularly suitable for heat treatment, since they respond well to heat treatment and the commercial use of steels exceeds that of any other material. Steels are heat treated for one of the following reasons: Softening, Hardening, Material Modification.

Annealing: The process consists of heating the steel to above A3 temperature for hypo-eutectoid steels and above Al temperature for hypereutectoid steels by 30-50°C, holding at this temperature for a definite period and slow cooling to below Al or to room temperature in the furnace. Due to slow cooling, eutectoid phase transformation occurs very nearly in accordance with conditions represented by Fe-C phase diagram.

Purpose of Annealing -:

1. To relive the internal stresses induced due to cold working, welding.
2. To reduce hardness and to increase ductility.
3. To refine the grain size.
4. To make the material homogeneous in respect of chemical composition.
5. To increase machinability
6. To increase the uniformity of phase distribution and to make the material isotropic in respect to mechanical properties.



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3) A simple sketch of the important microstructure indicating a) The magnification used, b) Important phases and features noted,
4) Etchant used.

Experiment- 10

AIM: - **TO PERFORM HARDENING OF A STEEL SPECIMEN AND TO ANALYSE ITS MICROSTRUCTURE.**

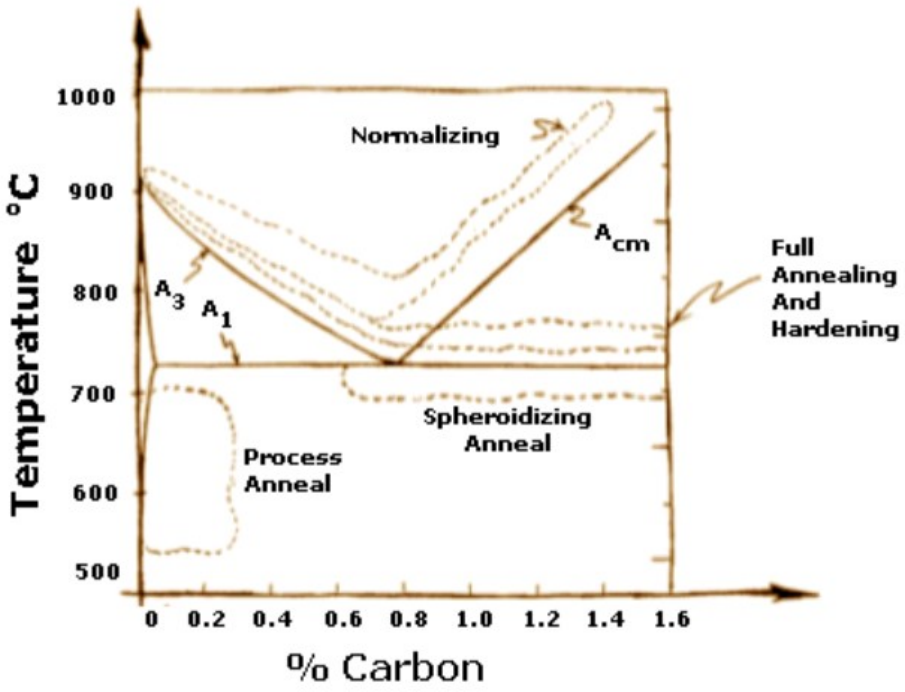
THEORY:

Heat Treatment is the controlled heating and cooling of metals to alter their physical and mechanical properties without changing the product shape. Heat treatment is sometimes done inadvertently due to manufacturing processes that either heat or cool the metal such as welding or forming.

Heat Treatment is often associated with increasing the strength of material, but it can also be used to alter certain manufacturability objectives such as improve machining, improve formability, and restore ductility after a cold working operation. Thus it is a very enabling manufacturing process that can not only help other manufacturing process, but can also improve product performance by increasing strength or other desirable characteristics.

Steels are particularly suitable for heat treatment, since they respond well to heat treatment and the commercial use of steels exceeds that of any other material. Steels are heat treated for one of the following reasons: Softening, Hardening, Material Modification.

Hardening: The hardening process consists of heating the steel to above A3 temperature for hypoeutectoid steels and above Al temperature**.**



PROCEDURE: In this laboratory, you will report the microstructures of prepared samples in specific formats. You will be expected to sketch the microstructure that you see under the microscope by hand, in sketching the microstructure, there are several things to keep in mind. First, the magnification that you use depends upon the scale of the microstructure you are looking for. It is IMPORTANT to know in advance of the lab class what the expected microstructure for your samples are and at what scale they should appear. In sketching the

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4) Etchant used.

Experiment-11

AIM: TO FIND OUT THE HARDNESS OF VARIOUS TREATED AND UNTREATED STEELS.

OBJECTIVES:

1. To understand what hardness is, and how it can be used to indicate some properties of materials.
2. To conduct typical engineering hardness tests and be able to recognize commonly used hardness scales and numbers.
3. To learn the advantages and limitations of the common hardness test methods.

THEORY:

A commonly accepted engineering definition of hardness is the resistance to indentation. Resistance to indentation is a function of the mechanical properties of the material, primarily its elastic limit and to a lesser extent, its work-hardening tendency, and the modulus of elasticity. For a given composition with a known history it is possible to relate the elastic limit (for practical purposes, the yield strength) to the tensile strength, ductility, and toughness. Hence, the hardness tests can provide information from which many important mechanical properties can be derived. Since the hardness test can be conducted easily and quickly, they are very popular and are used to control processing and for inspection and acceptance of materials and components.

(1) ROCKWELL TESTS: The Rockwell tests depend upon the measurement of the differential depth of a permanent deformation caused by the application and removal of differential loads. Various penetrator and load combinations are used to adapt different Rockwell tests to materials of varying hardness and thickness. The penetrators include a cone-shaped diamond, known as a Brale, and hard steel balls from 1/16-inch to 1/2 -inch in diameter.

(2) BRINELL TEST: The Brinell test relies on mechanical or hydraulic loads as large as 3000 Kg. acting through a 10 mm hard steel or carbide ball. In order to compensate for variations in the response of materials to the application of the load, the time for which the load is applied is specified. For hard materials such as steel, a 30-second loading period is adequate. Softer metals and alloys such as brass or aluminum require about 60 seconds. After the load is removed, the diameter of the impression made by the ball is measured in millimeters. The Brinell hardness number, abbreviated as BHN, is the quotient of the load, P (kg), divided by the area, A, of the impression:

Where D is the diameter of the ball penetrator (mm) and d is the diameter of the impression (mm). In practice, the BHN is read directly from a table listing different values of d for various values of load, P. The Brinell test makes a large impression on the surface of the piece tested. Unless such a large impression can be tolerated, and often it cannot, the test is destructive. However, the large impression is advantageous because it gives a more representative result than would a smaller impression, which would be more sensitive to local soft or hard inhomogeneties. The size of the impression also renders the test less sensitive to the presence of rough surface finish and mill scale than is the case when tests are used which rely on small indentations.

PROCEDURE:

For carrying out test the following procedure should be adopted very carefully, any negligence may lead damage to the Indentor.

1. Adjust the weights on plunger (3) or dashpot according to the Rockwell scale required as shown in chart on machine by load selection disc (13).
2. Keep the lever (9) at position 'A'.
3. Place specimen securely on testing table.
4. Turn the hand wheel (10) clockwise so that specimen will push the Indentor and show a reading on dial gauge (6) as small pointer at set (red spot) and long pointer close to 'O' of outer scale (i.e. 'B' 30 inner scale).
5. Turn the lever (9) from position A to B slowly so that the total load is brought into action without any jerks.
6. The long pointer of dial gauge retches a steady position when indentations complete. Then take- back the lever (9) to 'A' position slowly (sudden return of lever (9) from 'B' to 'A' may show erratic readings). The weights (4) are thereby lifted off, only the initial load remaining active.
7. Read the figure against the long pointer. This is the direct reading of the Rockwell Hardness of specimen. Use black or red scale as per the selection of Rockwell scale. Black scale for 40 “C” scale and red for 'B' scale.
8. Turn back the hand wheel (10) and remove the specimen piece. Carry on the same procedure for further tests.
9. The first hardness value so obtained may not be correct. All standards recommended neglecting first two readings to ensure that specimen. The Indentor and the anvil are seating correctly, further reading will be correct.

Standard Calibration:

1. Understand thoroughly the operation of each machine, and check its operation before proceeding. 2. Check the calibration of the Rockwell Machines with Standard Calibration Test Blocks for the scale selected.

3. Using the appropriate scale
(a) Check the hardness of each test specimen on a Rockwell Test Machine. (b) Tabulate the results. (c) Convert all readings to either RB or Re values.
4. Using the hardness conversion chart, find the Tensile Strength of the steel samples.

OBSERVATION: The following is a sample hardness data as presented in a laboratory report. Use the same format in your report