COLLEGE OF ENGINEERING & TECHNOLOGY

LABORATORY MANUAL

Material Science and Metallurgy

SUBJECT CODE: 3131904

B.E. 3rd SEMESTER

NAME: ______________________________

ENROLLMENT NO: ______________________________

BATCH NO: ______________________________

YEAR: ______________________________

Amiraj College of Engineering and Technology,

Nr.Tata Nano Plant, Khoraj, Sanand, Ahmedabad.

AMIRAJ
COLLEGE OF ENGINEERING & TECHNOLOGY

Amiraj College of Engineering and Technology,

Nr.Tata Nano Plant, Khoraj, Sanand, Ahmedabad.

CERTIFICATE

This is to certify that Mr. / Ms. ____

Of class___________________ Enrolment No __________________________has

Satisfactorily completed the course in __________________________________as by the Gujarat Technological University for ____ Year (B.E.) semester___ of Mechanical Engineering in the Academic year_______.

Date of Submission

Faculty Name and Signature (Subject Teacher) **Head of Department (Mechanical)**

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Experiment No 1
Specimen Preparation and Its Microscopic Examination

AIM:
Study of Metallurgical Microscope and to prepare specimen for the examination of its microstructure.

OBJECTIVES:
1. To study different parts as well as optics of a Metallurgical Microscope.
2. To provide initial training for the use of Metallurgical Microscope.
3. To became familiar with the techniques used for specimen preparation.
4. To develop the skill of preparation and examination of specimen.

APPARATUS:
1. Metallurgical Microscope.
2. Metallurgical mounting press.
3. Specimen for observation.
4. Sample cutting equipment.
5. Abrasive papers of grade 1/0, 2/0, 3/0 and 4/0.
6. Polishing machine, grinding machine and fine abrasive slurry.
7. Etching chemicals example 2 % ‘Nital’ etchant.

THEORY:
Metallurgical Microscope is used for the examination of the microstructures of various specimens. It uses artificial light source such as lamp that gets reflected from the specimen surface and depending upon the various magnification power of the objective and eyepiece lens the magnified image of the microstructure is obtained. There are two-adjustment screws coarse screw for adjustment of the specimen-mounting stand to the approximate setting for viewing the microstructure and fine screw for clear view of the microstructure. We can also set the position of the specimen by giving vertical and horizontal movement to the specimen-mounting slide on the stand.

Experience has indicated that success in microscopic study depends largely upon the care taken in preparation of specimen. Even the most expensive microscope will not reveal the structure of a specimen that has been poorly prepared. The study of microstructure offers the details of grain size, shape and distribution of various phases and inclusions, which have a great effect on the mechanical properties of metals. The techniques of specimen preparation should produce flat scratch free mirror like surface

PRECAUTION:
1. Careful handling of the specimen such that the surface of it is not contaminated.
2. Careful handling of the eyepiece lens.

3. Ensure to switch off the power supply in case of power failure to prevent the lamp damage.
4. Proper and safer handling of the specimen during various machining and preparation stages.
5. Timely and repeatedly cooling of the specimen when it gets heated to control its temperature.
6. Ensuring that specimen preparation is done in the one specific direction as per the different stages used for preparation.
7. Careful handling of the chemicals used as etchant as they are mostly highly reactive acids.
8. Effective utilization of the costly abrasive slurry.
9. The mirror like surface obtained should not be contaminated.

PROCEDURE:

1. Draw the neat sketch explaining the working principle of metallurgical microscope, which is available in our laboratory.
2. Examine the metallurgical microscope. Locate each component and understand the function of each component.
3. Note down the total magnification available on the M/M.
4. Try to develop the skill for operating the microscope and examining the specimen.

1. Sampling: Select longitudinal or transverse section from the parent metal as a sample. Sample should be representative of parent metal in all respect .For example for failure analysis the sample should be selected from the failure area or as close to it as possible. Sample should be cut off with the hacksaw or abrasive cut off wheel depending upon the hardness of the parent metal. Care should be taken to control the temperature of the sample by using some cooling medium so as to avoid any structural changes during cutting or grinding stage.

2. Rough Grinding: This can be carried out by flat/belt-sander depending upon the type of material, using suitable cooling medium. Move the specimen perpendicular to existing scratches with uniform applied force in every new stroke on the grinding surface. Grind/polish only either in forward or backward direction not in both and lift during remaining half stroke. Try to maintain constant angle between axes perpendicular to surface to be prepared and the grinder surface. This procedure should be continued until the surface is flat and free of burrs all the scratches due to cutting. The turning of specimen about its vertical axis is offered shallower scratches characteristics of finer abrasive instead of deeper. This method also helps in faster material removal rate. The grains that are in same plane will facilitate better and accurate micro structural view.

3. Mounting: Place the specimen and powder of bakelite in cylinder of mounting press and apply pressure up to 4000 psi (27.579Mpa) at 15^{o}C simultaneously. Remove the specimen from the molding die while it is still hot. Unmounted specimen is small and awkward in shape. Because of this mounting is required so that the handling/holding becomes easier. The bakelite is a thermosetting resin and available in powder form in different colors.

Lucite can also be used for specific reasons, which offers transparency when properly molded. Apart from this some clamping devices are also used.

4. Abrasive Paper Polishing: Polish the specimen on series of abrasive papers successively on finer grades (1/0, 2/0, 3/0, and 4/0) to get mirror like finish with the help of above discussed techniques. Silicon carbides may be used for soft metals, which give greater metal removal rate.

5. Fine Polishing: In this stage the specimen is polished on "DISC POLISHING" machine in which wet rotating wheel covered with special velvet cloth is used. The choice of cloth depends on type of specimen and study of objective. The completion of this operation results in the clean shiny surface with small dots if it is observed in microscope.

6. Etching: Now apply the appropriate reagent on a prepared surface and keep for very short time period, and then follow further procedure.

Each and every metal or alloy has different chemical composition with different phases. Apart from this grains are also arranged at different angle. Because of all these the chemical reaction will be different with the reagent. After completion of all above stages transfer the specimen on the microscope and precede the goal. The whole procedure is consisting of all above stages right from sampling to microscope setting and including the drawing of structural sketches/photographing is known as "METALLOGRAPHY".

CONCLUSION:

QUESTIONS:

1. Define Metallography.
2. Draw the diagram of metallurgical microscope and explain its working principle with the functions of each accessory.
3. Refer to optics of a Metallurgical Microscope. Explain the purpose of the transparent reflector (Mirror).
4. Differentiate between Biological & Metallurgical Microscope.
5. Write your comments regarding the practice of micro specimen preparation and examination.
6. Why the preparation is required for the microscopic examination?
7. Why it is important to follow the rules of cleanliness in preparation of micro specimen?
8. "Etching will reveal the grain boundaries." Explain.
9. Draw the microstructure of the specimen as viewed in microscope before etching and after etching.

Signature of faculty: **Date:**

Experiment No 2
Iron Carbon Thermal Equilibrium Diagram

AIM:

Study of Iron Carbon Thermal Equilibrium Diagram.

OBJECTIVES:

1. To study the Iron Carbon Thermal Equilibrium diagram.
2. To know its practical utility in engineering field.
3. To get idea regarding existence of various phases, its proportions, curves and reactions.

APPARATUS:

1. Iron Carbon Equilibrium diagram.

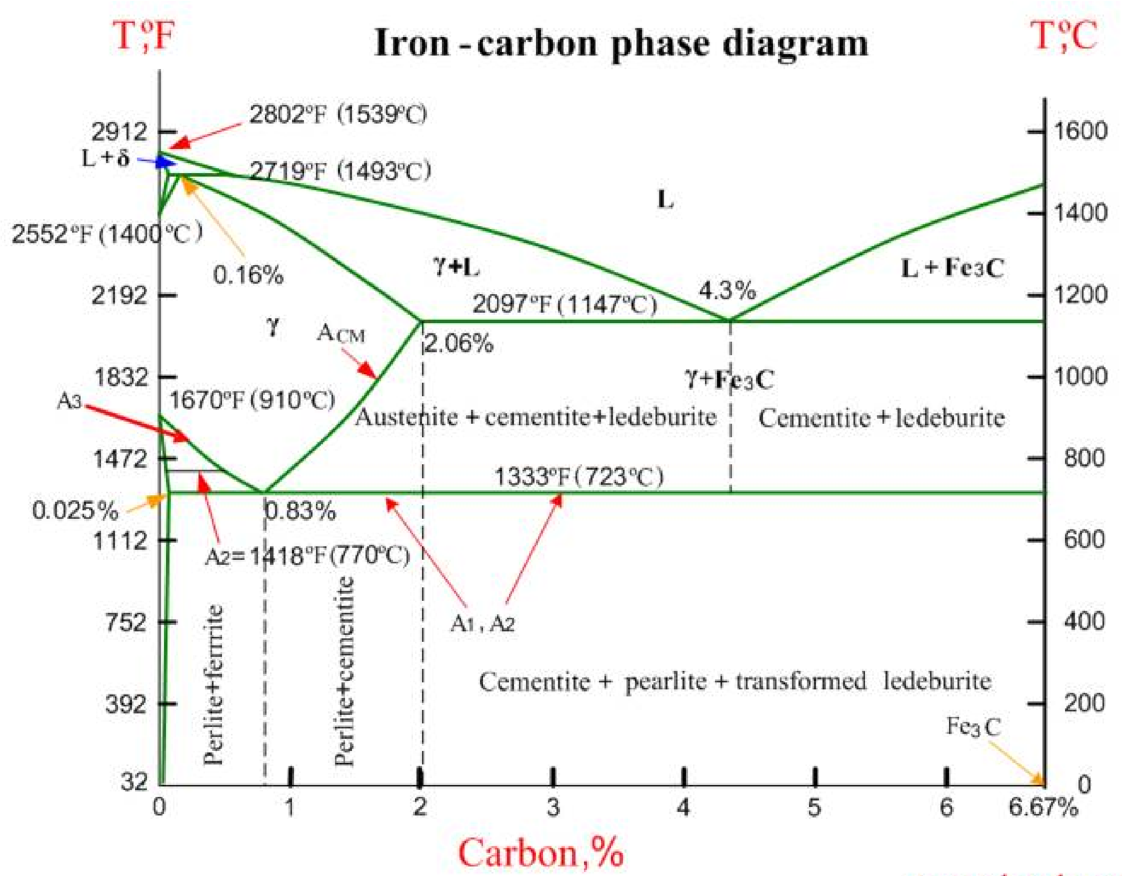
THEORY:

In today's modern industries the applications of ferrous metallurgy are very extensive which covers wide range of steel and cast iron. Their main constituents are iron and carbon. So it becomes necessary for us to study the iron carbon system. Strictly speaking it should be named "Iron-Iron carbide Equilibrium diagram" since this is the part between pure iron and interstitial compound called iron carbide (Fe_3C), which contains 6.67 %carbon by weight. Therefore this portion is called as iron -iron carbide. Apart from this diagram is not a true equilibrium diagram because iron carbide is a metastable phase and will decompose in to iron and graphite (carbon). But it takes a long time period at room temperature and even at $700^{O}C$ it takes several years. Hence it could be consider as representing equilibrium under condition of relatively slow heating and cooling. This diagram can be understood by knowing the various phases in different regions, their relative properties and various temperature and compositions at which phase transformation takes place.

PROCEDURE:

1. On a single large page draw the iron – iron carbide diagram from any reference book and label it in general terms in all respect i.e. phases, phase region, points different reactions and their respective temperature lines.
2. Define and understand all the names, which for descriptive or commemorative reasons, have been assigned to the phase (structure) appearing on this diagram. Also know their constitutions atomic arrangement and respective properties.
3. Define and understand the importance of different curves (lines) in respect of phase change, carbon solubility and temperature changes.
4. In respect of above two steps understand the importance of phase region different reactions and their locations with temperature changes.
5. Take the case of 0.2 % carbon steel (Hypo eutectoid) to know its various changes with respect to change in temperature and phase details at room temperature.

6. Draw vertical X-X line from the point which indicate 0.2% C on X axis and right from the austenite range come downward to the X axis on the same line.(During this exercise we have presumed that steel is in austenizing range.)
7. During the journey note down the phase changes with respect to the decreasing temperature which is shown on Y-axis. Identify the reasons for these changes their effects on properties of respective steel and other effects. This exercise should be continued up to the room temperature, which is shown on Y-axis. To know the relative amounts of the structural constituents apply the "Lever rule"
8. Make the brief note of above exercise.



QUESTIONS:

1. What are the limitations on the use of the iron – iron carbide diagram?
2. What is the difference between Pearlite and Ledeburite?
3. What do you understand by critical points and critical range how are they related to heating and cooling of steel? Write eutectic, eutectoid & peritectic reactions with reference to iron carbon diagram.
4. Explain allotropy of iron with figure.
5. Draw iron carbon equilibrium diagram and explain ferrite, pearlite, austenite, cementite, martensite, ledeburite, banite & torsite.

Signature of faculty: **Date:**

Experiment No 3
Electron Microscopy

AIM:
Study of Electron Microscopy.

OBJECTIVES:
1. To know the principle and working of Transmission Electron Microscope (TEM).
2. To know the principle and working of Scanning Electron Microscope (SEM).

APPARATUS:
1. Flow diagrams of TEM & SEM.

THEORY:
Source of illumination in optical microscope is ordinary visible light of wavelength of about 5000 A^0. In electron microscope source of illumination is beam of electrons of = $0.05A^0$. Resolving power of a microscope is inversely, proportional to the wavelength of illumination; the EM has much better resolving power & details as small as $10A^0$ can be seen. In addition EM provides facilities for selected area diffraction i.e. diffraction can be obtained from a very small particle. The illuminating system is electron gun consisting of heated filament of W at very high potential of 100-200 KV.

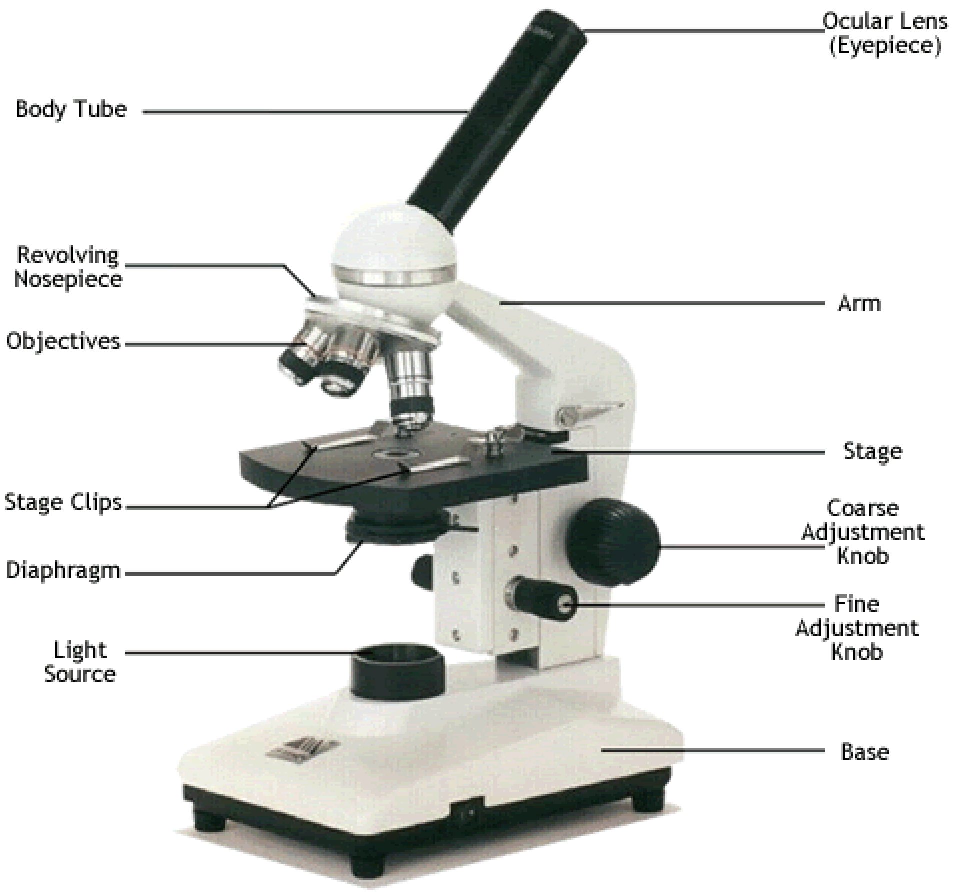
Magnetic lenses are used in electron microscope. The condenser lens focuses the electron beam on specimen. The objective lens produces first magnifies image, which is further magnified by intermediate lens. The final magnification is by projector lens, which produces the image on fluorescent screen. For recording photographic film is put on place of screen. A dark field image is formed from one or more of diffracted beam by moving the objective aperture to transmit only diffracted beam & block the main beam. By this precipitate particles can be seen more easily. A tilting stage is also provided for metallurgical look.
Metals are examined by two ways:

1. Replicas: A replica is a thin film having exact reproduction of contour of specimen surface. For replica a thin layer of Lacquer, carbon, quartz is applied to surface (formwar)
2. Thin metal foils: Thin metal foils of less than $2500A^0$ thickness, which can be seen directly under microscope by following techniques.
a) Deposition method: Vacuum deposition, electro deposition. b) Deformation method: By mechanical working
c) Dissolution method- Chemical etching, Ion bombardment, Electro polishing, Electrolytic jet machining.In SEM beam is moved over specimen surface. The electrons interact with the surface atoms & output depends upon composition & topography. The depth of focus

of SEM is so high that a fractured surface can be directly examined without any polishing. (Fractrogrpahy).

The various applications of electron microscopy are as below:

1. Examination & measurement of Nano grains.
2. Examination of fractured surface.
3. Examination of fine structure of metallic surfaces.
4. Detailed structure of metals & alloys.
5. Examination of slip lines, dislocations.
6. Examination of electronic circuits.
7. Thin film studies.



Optical Microscope

CONCLUSIONS:

QUESTIONS:

1. Differentiate between Transmission Electron Microscopy (TEM) and Scanning Electron Microscopy (SEM).
2. Explain working principle of TEM.
3. Explain working principle of SEM.
4. What are the drawbacks of TEM?
5. Draw the diagrams of SEM & TEM.
6. What are the advantages of TEM over metallurgical microscope?

Signature of faculty: **Date**

Experiment No 4
Jominy End-Quench Hardenability Test

AIM:
Study of Jominy end-quench hardenability test.

OBJECTIVES:
1. To conduct the Jominy hardenability test and obtain hardenability curve on high carbon steel.
2. To utilize the Jominy test results to determine the hardenability of the steel.
3. To convert hardenability data into hardness distribution curves.

APPARATUS:
1. Furnace capable of attaining the required hardenability temperatures.
2. Jominy end quenched apparatus & scale for measuring the water jet height.
3. Rockwell hardness testing machine.
4. Cast iron chips or graphite.
5. Proper tongs & hand gloves for handling hot specimen.
6. Standard specimen of high carbon steel of 25 mm diameter and 100 mm length.

THEORY:

When steel is hardened by quenching from a temperature above its critical temperature, its maximum resulting hardness is on the surface because that is the location where the cooling rate fastest. Since the cooling rate is slower further inside the steel there is a tendency for the resulting hardness to decrease progressively between the surface & the center of a section.
The amount & rate of this decrease varies widely & is dependent on:
1. Composition of the steel.
2. Cooling rate of the quenching medium.
3. Section size.

The degree of ability which steel possesses to resist having this fall of in hardness is called its hardenability. In other words hardenability is the steel's ability to develop hardness below its surface when it is quenched.

Steel with high hardenability is hardnable far below its surface & is called a deep hardening steel. If the distance below the surface is short then it is called shallow hardening steel.

When the hardness decreases from the surface towards the center of a piece of quenched steel it does so because the percentage of martensite decrease towards the center while that of softer constituents (bainite, pearlite etc.) increases.In industry 50 % martensitre is considered the minimum percentage that should exist even at the center of a section. This is necessary if consistently for the manufacturing of high quality industrial product.

The Jominy test is the standard one for measuring the hardenability of steel. This test uses a standard specimen of high carbon steel of 25 mm diameter and 100 mm length.The Jominy test is performed by directing a jet of water against a one end of the red-hot specimen. In this way the quenched end is cooled vary rapidly while the rest of the piece is cooled more slowly the further away it is from the wetted end. Thus different cooling rates exist throughout the length of the specimen.

Hardness measurements made after cooling show the decline in hardness as a function of the distance from the water quenched end.
A curve plotted from this test is called a Jominy curve or hardenability curve.

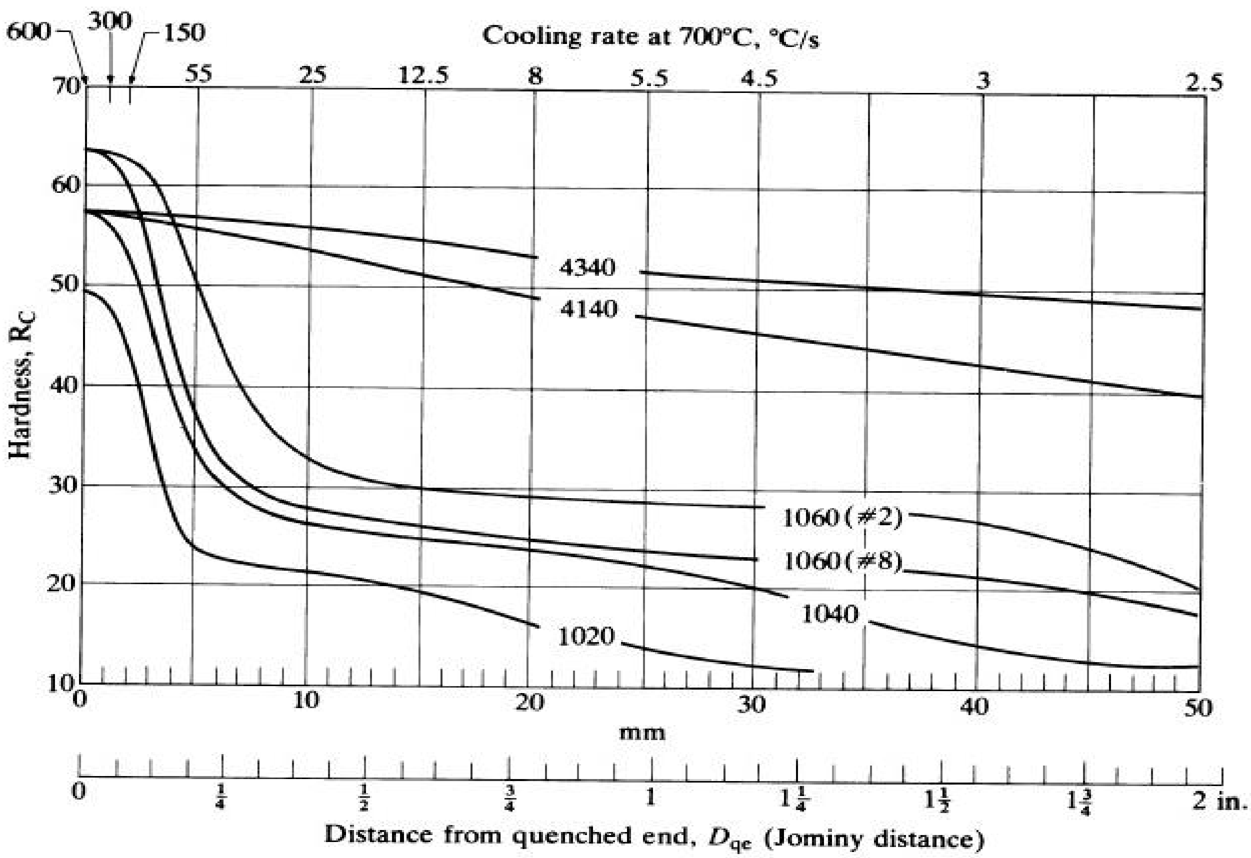


Figure 1 - Hardenability curves for steels of various composition and grain sizes.

A pure iron containing no carbon cannot be hardened by heat treatment. With increasing carbon content the martensite obtained by adequate quenching increases in hardness. Therefore, the hardness at the quenched end (Dqe 0) is determined by thecarbon content of the steel as shown in Figure 2. With alloying, alloy steels (4340 and 4140) generally have improved hardenability and maintain rather flat hardenability curves. Plain carbon steels (1060, 1040 and 1020) have curves that drop off quickly. Grain size refinement in general causes decrease in hardenability

PRECAUTION:

1. Ensure that the required temperature is set in furnace; oxidation of the carbon from specimen doesn't take place by covering with cast iron or graphite flakes.
2. The handling of the hot specimen should be with toungs and hand gloves.
3. The location of jominy test equipment should be nearby the furnace as the transfer of specimen can be done in few seconds.
4. Ensure the proper flow of water through jet in jominy set up to cool the specimen so that rapid water-cooling takes place at one end & slow air-cooling at the other end.
5. Try to take the accurate readings as much as possible at the exact distance mentioned in the procedure.

PROCEDURE:

1. Determine the temperature required to heat the standard specimen.
2. Switch ON the furnace & set temperature.
3. Place small amount of C.I. or graphite chips in furnace & cover the specimen with it to prevent oxidation of carbon.
4. Heat-treat the specimen to the required temperature as per the composition of the specimen.
5. After heating the specimen transfer it on Jominy fixture and cool through the water jet at the end of specimen. The transfer time from furnace to fixture should not exceed than few second.
6. After the 10-minute period of quenching is completed stop the water jet & remove specimen from the fixture allow it to cool to room temperature.
7. Measure the hardness at an interval of 1.5 mm for first 3mm, at 2mm for next 12mm & for the rest up to a total length of 5 mm interval from the water quenched end.
8. Plot the graph showing variation in hardness v/s distance from water quench end.

QUESTIONS:

1. What is the difference between Hardness & Hardenability?
2. Write the Utility of this test with suitable example.
3. What are the factors affecting Hardenability?
4. List various quenching media used to cool a specimen and what are the effects of water, air & oil when used as a quenching media?
5. Draw the figure of the standard jominy specimen and plot the graph of distance from water quench end v/s hardness for this specimen.

Signature of faculty: **Date**

Experiment No 5
Examination of microstructure of Carbon Steel Specimens

AIM:
To study and examination of microstructures of carbon steel specimens.

OBJECTIVES:
1. To study the microstructures of low, medium and high carbon steels.
2. To study the effect of carbon content on mechanical properties & microstructure of steel.
3. To study the effect of alloying elements on carbon steel.

APPARATUS:
1. Metallurgical microscope.
2. Specimens of carbon steels: 0.1 %, 0.2%, 0.4%, 0.6% carbon

THEORY:

Metals/alloys used in engineering may be classified into categories: (i) Ferrous (ii) Non-ferrous. The ferrous metals/alloys are carbon based which include varieties of irons & steels.

In addition to iron, they contain carbon, sulphur, phosphorus & manganese in varying amounts. Most of the tools, machines &equipments generally used up are made up of these metals/alloys.

Any iron carbon alloy containing less than 2% carbon is called **STEEL**& more than 2% is called **CAST IRON**.

In plain carbon steel the three distinct constituents are ferrite, pearlite & cementite. They vary in amount in different steels, according to the carbon content.

Carbon steel owes its distinctive properties chiefly to the carbon it contains. Alloy steel owes its distinctive properties chiefly due to presence of some elements other than carbon such as chromium, nickel, molybdenum, vanadium, cobalt, etc.

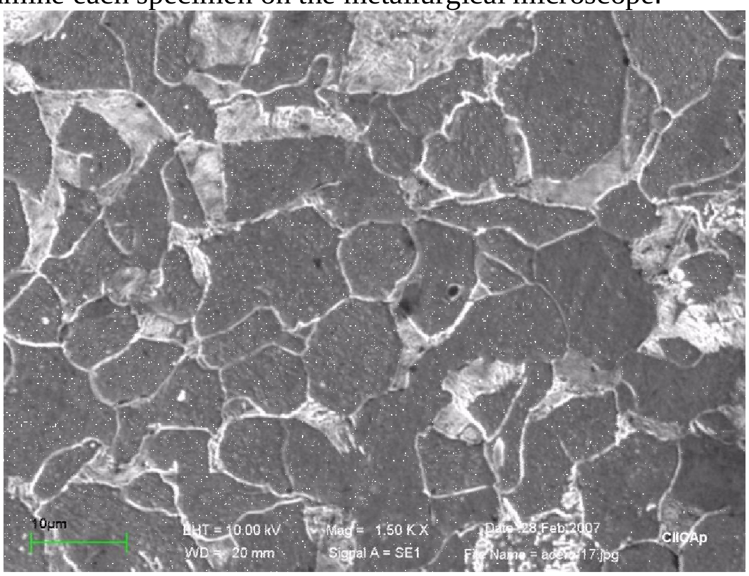
Carbon steel is classified as low carbon steel if it has max 0.25% carbon, medium carbon steel if it has 0.25-0.65% carbon and high carbon steel if has 0.65-1.5% carbon. **FERRITE** is a soft & ductile phase while **CEMENTITE** is hard & brittle. As the carbon content & the proportion of cementite increases the steel becomes harder & less ductile. **PEARLITE** is a strong constituent & the steel will have maximum strength when its structure is wholly pearlitic at 0.8% carbon.

PRECAUTION:

1. Careful handling of the specimens such that the surface of it is not contaminated.
2. Careful handling of the eyepiece lens.
3. Ensure to switch off the power supply in case of power failure to prevent the lamp damage.

PROCEDURE:

1. Obtain the specimens to be examined for microstructures.
2. Adjust the specimen mounting stand of microscope by coarse & fine adjustment screw so that microstructure of the specimen is visible..
3. Examine each specimen on the metallurgical microscope.



(Carbon steel Microstructure)

CONCLUSION:

QUESTIONS:

1. Draw the figure showing the effect of increasing carbon % on micro constituents as well as mechanical properties of plain carbon steel.
2. How will the properties of mild steel be affected by the presence of sulphur & phosphorous in steel?
3. What important properties of mild steel make it one of the widely used metal?
4. What are some important applications of medium carbon steel?

Signature of faculty: **Date:**

Experiment No 6
Examination of Microstructure of Stainless Steels & High-Speed Steel Specimens

AIM:
To study and Examination of microstructures of stainless steels & high-speed steel.

OBJECTIVES:
1. To study the microstructure of stainless steel & high speed steel.
2. To study the effect of various phases on the properties of these steels.

APPARATUS:
1. Metallurgical microscope.
2. Specimens: Austenitic S.S, Ferritic S.S, Martensitic S.S & H.S.S

THEORY:
Steels are the alloy of iron & carbon. Steels may be classified as plain carbon steel or alloy steel depending on absence or presence of alloying element in the steel. Alloying elements are added to the steel in order to obtain certain desirable properties. Stainless steel contains minimum 11.5% of chromium present in it forming a stainless, passive and corrosion resistant chromium oxide film that is "stainless".
1. Stainless steel: Stainless steel is the term that is generally applied to corrosion resistant alloy of varying carbon content. The properties of which mainly depend on the presence of a high chromium content. A certain amount of chromium must be present in solid solution in order to impart corrosion resistant to the alloys. Stainless steel may be divided into 3 groups depending upon the presence of a specific phase as under:
(i) Ferritic SS (ii) Martensitic SS & (iii) Austenitic SS

If the amount of carbon is negligible the alloy will be ferritic under all conditions. This alloy will not respond to heat treatment except it may affect the grain size. With an increase in carbon content the alloy may become partly or wholly austenitic on heating to the proper temperature.

A martensitic structure is readily obtainable by heating the alloy to the austenitic region & quenching. Quenching in oil from above 1000^0C produces such a structure. The austenitic alloys are most readily obtained at room temperature in the presence of nickel. A well-known alloy of this type is so called "18-8" containing 18 % chromium with 8% nickel. If a significant amount of chromium precipitate as chromium carbide the particular regions were this occurs will be depleted of their chromium content & will no longer possess proper corrosion resistance.

2. High speed steel: High-speed steel are high alloy tool steels with W, Mo, V, Cr & often Co as their main alloying elements. In addition to red hardness, high wear resistance & resistance to cheeping are the important properties of high-speed steel. High-speed steels are mainly categorized into two broad groups as under

a. Tungsten type-high speed steel (W-HSS)
b. Molybdenum type HSS (Mo-HSS)

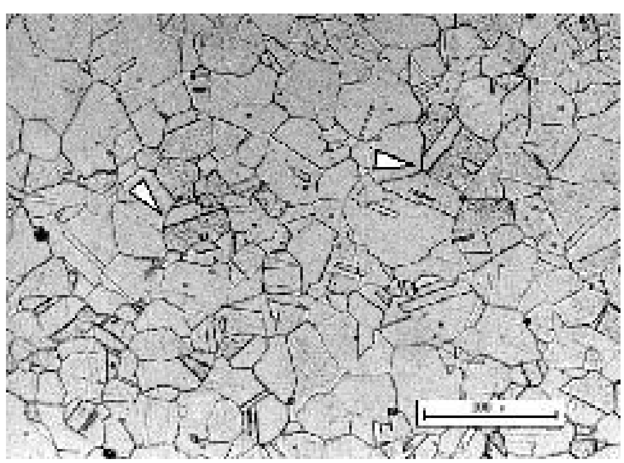
Tungsten type high speed steel contains 18%W along with Cr, V and carbon. As such W becomes the major alloying element in this class of HSS, the well-known example is of 18-4-1 HSS that consist of 18% W, 4%Cr. & 1%V.By replacing large amount of W by Mo and this class of HSS in which tungsten have been partly replaced by Mo is known as Mo HSS.

PRECAUTION:

1. Careful handling of the specimens such that the surface of it is not contaminated.
2. Careful handling of the eyepiece lens.
3. Ensure to switch off the power supply in case of power failure to prevent the lamp damage.

PROCEDURE:

1. Obtain the specimens to be examined for microstructures.
2. Adjust the specimen-mounting stand of microscope by coarse & fine adjustment screw so that microstructure of the specimen is visible.
3. Examine each specimen on the metallurgical microscope.



(Stainless Microstructure)

(HSS Microstructure)

CONCLUSION:

QUESTIONS:

1. What is stainless steel? How does it derive its corrosion resistance?
2. How would you differentiate between martensitic, Ferrite & austenitic SS?
3. What is the factor responsible for lower corrosion resistance in SS even though it has sufficient Cr for corrosion resistance? What remedial measure would you suggest to take care of it?
4. List the factors that you would take into account while selecting the tool steel.
5. How does the composition & structures of high strengths constructional steel differ from that of tool steel?
6. What is hydrogen embrittlement?
7. Draw figures of the microstructures and mention the type of steel specimen, magnification, etchant & phases present in the structures, which are observed by you.

Signature of faculty: **Date:**

Experiment No 7
Examination of Microstructure of Cast Iron Specimens

AIM:

To study and examination of microstructures of cast irons.

OBJECTIVES:

1. To study the microstructure of cast irons.
2. To correlate the properties with microstructure for each type of cast iron.

APPARATUS:

1. Metallurgical microscope.
2. Specimens: White cast iron, grey cast iron, malleable cast iron, & spheroidal cast iron.

THEORY:

Cast iron is a general term applied to a wide range of iron-carbon-silicon alloys in combination with smaller % of several other elements. Cast irons possess carbon either in combined form as cementite or free form as graphite. The various types of cast irons are:

1. White cast iron
2. Grey cast iron
3. Malleable cast iron
4. Spheroidal cast iron (Nodular or Ductile cast iron)
5. Alloyed cast iron
6. Chilled cast iron

White cast iron: It contains the greater part of carbon in combined form as cementite. It is called white cast iron because it shows a white fractured surface. Microstructure of such a cast iron consists of pearlite, cementite & transformed ledeburite. Due to the presence of cementite, white cast iron is hard and brittle. A large tonnage of white cast iron is used for the manufacture of malleable iron.

Grey cast iron: It contains the greater part of carbon in the form of graphite flakes. It is called grey cast iron because it shows a grey surface on fracture. Graphite flakes are sharp at their tips & act like internal cracks or stress raisers, for this reason, grey cast iron is brittle. As the cracks do not propagate under compressive loads the strength of grey iron is 3-5 times more in compression than in tension.

Malleable cast iron: It is produced by heat-treating white cast iron. Heat treatment removes brittleness of white cast iron & produce castings, which are malleable or bendable. Microstructure of this iron consists of graphite nodules called tempered carbon, uniformly distributed in a ferritic or pearlitic matrix.

Nodular (Spheroidal or ductile) iron: It is improved version of grey cast iron with higher toughness. Its microstructure consists of nodules or spheroids of graphite in a pearlitic or ferritic matrix hence this iron is known as S.G. iron or nodular iron. Due to its nodular graphite it has higher ductility as compared to grey iron, which has graphite flakes. Therefore it is also known as ductile cast iron.

Alloyed cast iron: Alloy cast irons are made by addition of alloying elements such as nickel & chromium in cast irons. Addition of alloying elements improves shock & impact resistance as well as corrosion & heat resistance of cast irons.

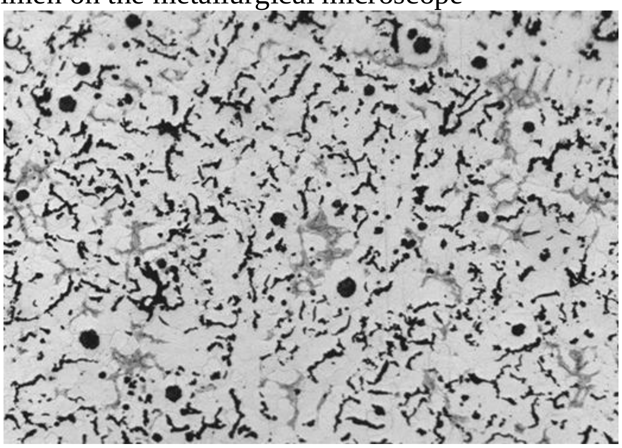
Chilled cast iron: It possess structure of grey cast iron in the innermost core & white cast iron to the outermost surface. It is formed when differential cooling is done rapid cooling of the outermost surface & slow cooling of the innermost core.

PRECAUTION:

1. Careful handling of the specimens such that the surface of it is not contaminated.
2. Careful handling of the eyepiece lens.
3. Ensure to switch off the power supply in case of power failure to prevent the lamp damage.

PROCEDURE:

1. Obtain the specimens to be examined for microstructures.
2. Adjust the specimen mounting stand of microscope by coarse & fine adjustment screw so that microstructure of the specimen is visible.
3. Examine each specimen on the metallurgical microscope



(Cast Iron Microstructure)

CONCLUSION:

QUESTIONS:

1. Draw only the cast iron related portion of Iron Carbon equilibrium diagram indicating important phases compositions & temperatures.
2. Discuss the change that takes place in the structure of the cast iron with following cooling conditions from their liquid state to room temperature.
   i. Rapid cooling ii. Slow cooling iii. Very slow cooling.
3. Prepare table showing properties characteristics & uses of different cast irons.
4. “Grey cast iron is widely used for machine tool beds even though it has low tensile strength & ductility.” Evaluate the statement.
5. “Effect of graphite flake size shape & orientation on properties of G. C. I.” Explain.

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Experiment No 8
Ultrasonic Testing Method

AIM:
Study of Ultrasonic testing method.

OBJECTIVES:
1. To know the basic principle of ultrasonic testing.
2. To understand its applications.

THEORY:

Defects, flaws, imperfection or whatever one cares to call them can be introduced into a product at any stage of its manufacture or life. Therefore we may be required to test the component by some type of NDT if the quality of such component is important.

The term NDT means testing or inspection of materials or product without impairing its future usefulness. From an industrial view point the purpose of NDT is to determine whether the material or part will satisfactory perform its indented function. The primary purpose of NDT is to find the existing state or quality of material with a view to acceptance or rejection.

Ultrasonic testing: Ultrasonic testing method is one of the main NDT method in which a piezoelectric crystal is one to which the application of an alternating voltage results in the generation of an alternating strain & vice versa. This piezoelectric crystal is used to transmit ultrasonic sound waves into a material under examination. These waves travel through the material as stress wave, which are reflected back either by the far boundaries of the material or by the flaws within it. The reflected pulses received either by the transmitting crystal during a period when it is not driven or by separate receiving crystal. The stress pulses are converted into electrical signals, which are displayed on the screen of a CRT from which the position of the flaw can be determined.

Sound is produced by vibrating body & itself a mechanical vibration of particle about equilibrium position. The actual particle does not travel through the material away from the sound source. It is the energy produced which causes the particles to vibrate that are moving through the medium. The human ears can hear sound waves up to 20000 Hz. Beyond this sound is referred as ultrasonic. Since we cannot hear this frequency by ear it is transformed electrically & observed with an electronic device usually a visual display.
There are 3 types of waves. Longitudinal, transverse & surface waves.

In commercial market following methods are mostly used.

Resonance method: This system uses the reflection between two parallel limiting faces of the specimen resonance occurs. Wave frequency is varied until standing waves are set up causing the item to resonate at greater amplitude. A difference in vibration resonance is then sensed by the generator indicator instrument & this information are shown on CRT.

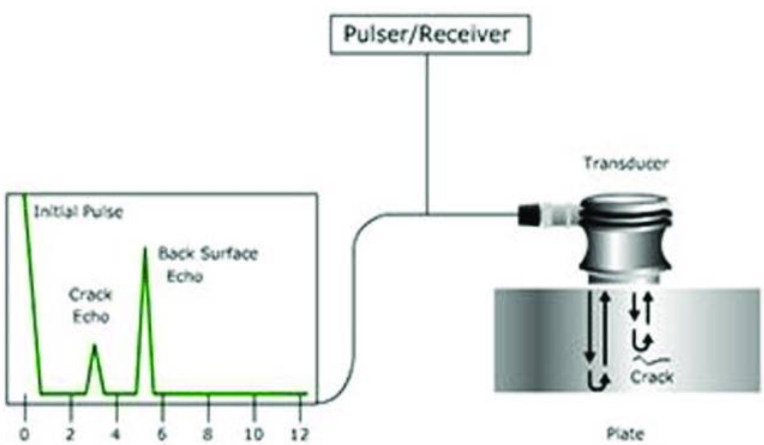
Transmission method: This system makes use of two transducers one for transmitting another for receiving the sound waves. Transducer is a device which changes electrical energy into sound energy \ waves or vice versa. By utilizing piezo electric effect the short pulses are transmitted into & through the material by transmitting transducer & the aligned receiving transducer convey it in the form electrical energy to the CRT. The soundness or quality of material is measure in term of energy lost by sound beam. This method is applicable to those items whose sides are parallel to each other.

Pulse Echo Method: It is the most widely used method. In this only one transducer is used which playing the role of both transducer which are mentioned in previous method. As the wave passes through the top surface of the material being tested there will be a pip on the CRT, which indicate the beginning of the test specimen. If specimen has the flow the wave will bounce off indicating the distance from the surface of this flaw.

Couplant (oil glycerin base substance) is used to help make contact between the transducer & the surface of material. It performs the function of removing air from in-between of a medium for proper transfer of sound vibrations.

It major applications are:

Mill components	Rolls, shafts & drive press columns
Power equipment	Turbine, forging generator rotor
Jet engine parts	Turbine & compressor forging
Casting components	Aircraft components



(Ultrasonic testing method.)

CONCLUSION:

QUESTIONS:

1. Define ultrasonic waves.
2. Explain briefly the principle & function of piezoelectric crystal.
3. Name different piezoelectric crystals used with its merits & demerits.
4. Why couplant is necessary in ultrasonic testing? Which are the materials used as couplant?
5. List the advantages & limitations of ultrasonic test.

Signature of faculty: **Date:**

Material Science and Metallurgy **Date:**

Experiment No. 9
Introduction of Composite Materials and Its Application

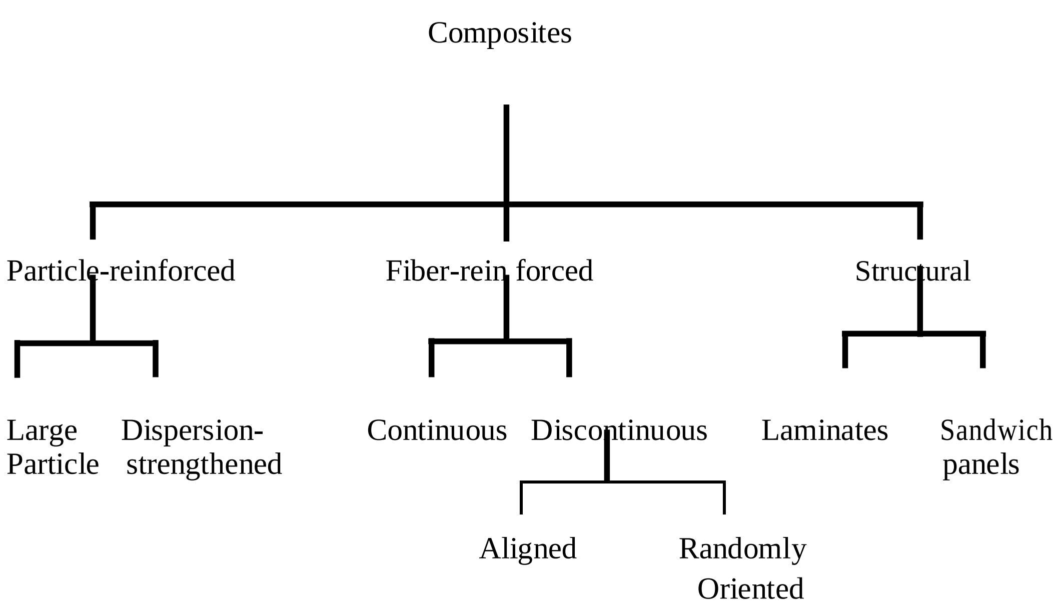
AIM:
To study different composite materials

OBJECTIVE:
To study classification of composite materials and its properties

INTRODUCTION:

A composite material is a combination of two or more material having compositional variation and depicting properties distinctively from those of the individual material of the composite. The composite material is generally better than any of the individual components as regards their strength heat resistance or stiffness.

CLASSIFICATION



1) Plastic -reinforced composites:

(a) Large particle composites: These composite are utilized with all these types of material, viz. metal, polymers, and ceramics.

(1)Automobile tyres: containing 15 to 30% volume of spherical partical of car ban with 20-50 µm diameter in vulcanized rubber which improves the tensile strength toughness and resistance against corrosion.

(2) **Concrete-** consisting of cement and sand and gravel.

(3) **Cement:** e.g. cemented carbide- consisting of extremely hard particle of a refractory carbide ceramic embedded in a matrix of a metal such as cobalt's or nickel These composites are widely used for cutting tools for hardened steel, drills, electrical contacts, magnets and rocket nozzles etc. Other application of cemented carbides are burner nozzle, gauges and plugs used for inspection of material, grinding ball and liners in grinding balls and lines in grinding mills. The cement are prepared by powder metallurgy techniques.

(b) Dispersion-Strengthened Composites: The metals and metal alloys may be strengthened by the uniform dispersion of several volume percent of fine partials of a very hard and inert material. The dispersed phase may be metallic or non-metallic, oxide material are often used.

The Strength of nickel alloys at elevated temperature may be enhanced considerably by the addition of about 3 volume percent of thoria as finely dispersed particles this material is known as thoria dispersed nickel.

2) Fiber-reinforced Composites:

The most important composites, technologically, are those in which the disperse phase is in the form of the fiber. Fiber-reinforced composites with high specific strengths and moduli have been produced that utilize low-density fiber and matrix materials.

The strength and other properties of these composites are influenced by the following. (1)The arrangement or orientation of the fiber relative to one another.
(2)The fiber concentration.
(3)The fiber distribution.

Important fiber-reinforced composites are:

Polymer-matrix composites

-Glass fiber-reinforced polymer Composites -
Carbon fiber-reinforced polymer Composites -
Aramid fiber-reinforced polymer Composites

Metal-matrix composites

Ceramic- matrix composites
Carbon-Carbon composites
Hybrid composites.

3) Structural Composites:

(a) Laminar Composites:

The layers are sacked and subsequently cemented together such that the orientation of the high strength direction varies with each successive layer. These composites are made from the two dimensional sheets or panels that have a preferred high strength direction.

(b)Sandwich panels:

These composites are composed of two strong outer sheets or faces (typical face materials include aluminums alloys, fiber-reinforced plastics, titanium steel and plywood)separated by a layer of less-dense material or “core”(typical core materials include foamed polymer, synthetic rubber, inorganic cements and wood)which has lower stiffness and lower strength The core, structurally perform the following two function:

1. It separates the face and resists deformation perpendicular to the face Plane.
2. It provides a certain degree of shear rigidity along planes which arePerpendicular to the faces.

Sandwich panels find wide application in the following:

1. Roof, floors and walls of bulding;
2. In aircraft for wings, fuselage and tailplane skins.

CONCLUSION:

QUESTIONS:

1) What is composite material? Give three examples of composites.
2) What is the distinction between matrix and dispersed phase in a composite material?
3) What is the difference between cement and concrete?
4) Why glass fibers are most commonly used for reinforcement?
5) How are composites classified?

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