Metallic Materials lab manual

MME 2292

Department of Mechanical Engineering

University of Global Village (UGV),

Barishal

COURSE OBJECTIVES

The objectives of this course are to:

1.	Acquire basic knowledge by understanding iron-carbide diagram and its application in engineering
2.	Expose to Metallographic study and analysis of various metals.
3.	Acquires knowledge in determining the hardness of metals before and after various Heat treatment operations.
4.	Understand differences between different heat treatment methods.
5.	Understand the relation between micro structure and properties

COURSE OUTCOMES

CO No.	Course Outcomes
CO 1	Apply the procedure for preparing the sample for metallographic observation.
CO 2	Identify different materials by examining the phases in their micro structure.
CO 3	Analyze the effects of various heat treatment by studying the grain structure
CO 4	Determine the tensile, compressive and impact strength for various materials
CO 5	Measure hardness, shear strength and check their suitability for a given design requirement.
CO 6	Determine the Shear force, bending moment and Young's modulus of different beams under various loading conditions.

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EXPERIMENT –01
STUDY OF METALLURGICAL MICROSCOPE, IRON-IRON CARBIDE DIAGRAM, SPECIMEN PREPARATION

AIM: - To study the working principle of a Metallurgical Microscope, Procedure for mounting and preparation of a Specimen for metallographic examination and Iron-Iron carbide diagram

METALLURGICAL MICROSCOPE: -

***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.

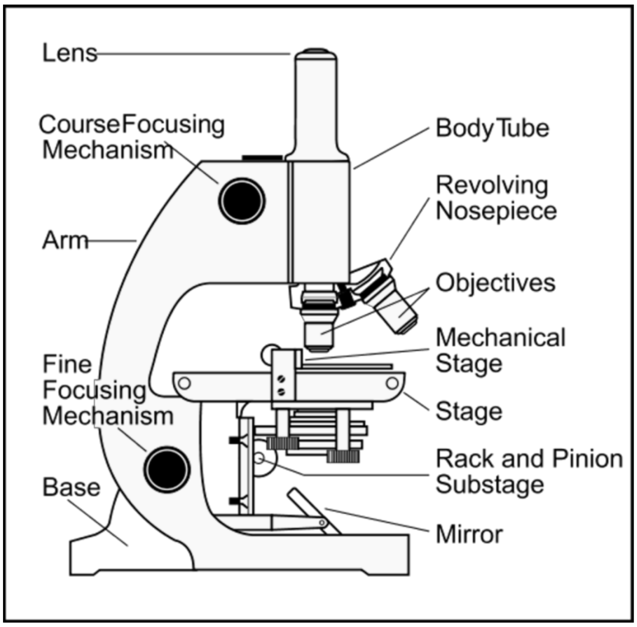


Fig: - Metallurgical Microscope

THEORY: - The science of metallography is essentially the study of the structural characteristic of a constitution of a metal/alloy in relation to the physical and mechanical properties.

Metallography consists of macroscopy and microscopy. Macroscopic examination involves study of metal either by naked eye or with the aid of low magnification (<10X). This type of examination reveals some of the important details such as uniformity of structure and presence of defects.

Construction and Working of Metallurgical Microscope: -

A metallurgical microscope consists of a stand, to which a movable tube is attached containing the optical parts of the microscope, and a device for illuminating the specimen. Light from an electrical bulb falls on a glass reflector kept at 45^0 to the vertical axis in the movable tube. These light rays get reflected vertically downwards, travel through the objective, and fall on the specimen. The light reflected by flat and polished specimen surface travel through the objective and transparent portion of glass plate and come to the eye piece. The image can be observed through the eye piece, or these rays can be focused on a screen and image can be observed.

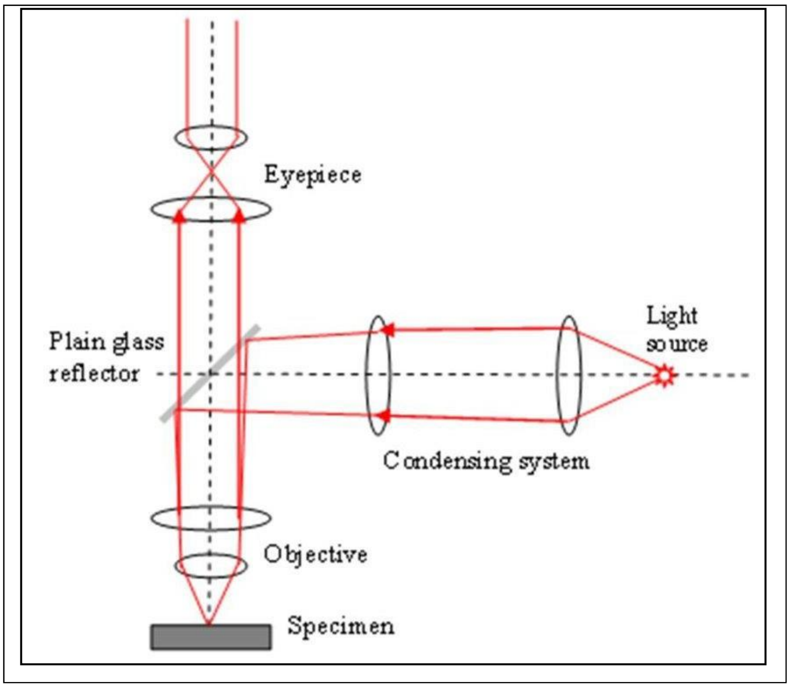


Fig: - Optical features of metallurgical microscope

Some important terms related to all optical metallurgical microscopes are –

a) Magnifying power of objective: -

It is the ability of an objective to magnify the real object by definite number of times without the aid of an eye-piece. The is engraved on the objective mount objective are available with magnifying powers of 5X, 10X, 40X, 50X, 90X or 100X (X sign denotes linear magnification)

b) Magnifying power of eye-piece: -

It is the ability of an eye-piece to magnifying the real object by definite number of turns. This is engraved on the eye-piece mount. Eye-pieces are available with magnifying powers 5X, 10X, 15X, 20X, or 25X.

The total magnification obtained by the combination of given eye-piece and objective depends not only on initial magnifying power but also on the distance by which these two are separated in the microscope. Almost all the objectives are designed for use at a definite tube length, which is about 250mm. When a given combination of objective and eye-piece is used at appropriate tube length. The total magnification is the product of their initial magnification. When the image is projected onto a screen, total magnification is given by $M= D^* (M_1M_2)/250x$.

M = Magnification on screen,

M_1 = Magnification of objective

M_2= Magnification of eye piece and

D = Projection distance i.e., the distance from the eye lens of eye piece to the screen in mm.

c) Numerical aperture of the objects:

It is the light collection or light gathering capacity of an objective. It is constant for a given objective and is a function of a design.

Numerical Aperture = n sinμ

n= refractive index of the immersion medium between objective and specimen

μ= one-half of the objective's opening angle

d) Resolving Power (or) Resolving of an objective: -

It is the ability of an objective to produce sharply defined separate images of closely spaced details in the object. Fineness of details or limit of resolution is the minimum clearance distance that can be seen clearly by that objective at some suitable magnification for a narrow beam of light

Fitness details or resolution limit = λ/NA

Where λ➔ wave length of illumination
NA ➔ numerical aperture of the objective

Resolving power or resolution is inversely proportional to the fineness detail.

Resolving power of a given microscope can be increased by using visible light beam of smaller wave length and by oil immersion objective. Desired light can be obtained by inserting an appropriate filter in the illumination screen.

***Uses*:** The metallurgical microscope is useful in quality control department in Industries to observe & study 1) Differential phases 2) Porosity or defects.

MOUNTING OF SPECIMEN: -

Specimens that are very small or awkwardly shaped should be mounted to favourite, intermediate & final polishing wires small rods steel, sheet metal specimens, thin sections etc. must be approximately mounted in a suitable material or rigidly damped in a mechanical mount Synthetic plastic materials applied in a special mounting press will yield amount of uniform convenient size (usually 1 inch or 1.25 inch or 1.5 inch. in diameter) for handling in subsequent polishing operation. This mounts when properly made are very resistant to attack by etching reagent ordinarily used. The most common thermosetting resin for mounting is ‘Bakelite’. Bakelite molding powders are available in variety of colors which simplifies the identification of mounted specimen. The specimen & the correct amount of Bakelite powder is available in variety of cloves which simplifies the identification of mounted specimen. The specimen & the correct amount of Bakelite powder is placed in the cylinder of the mounting press. The temperature is gradually 150ºC & a molding pressure of about 4000 PSI is applied simultaneously. Since Bakelite is set & curved when this temperature is reached, the specimen mount may be ejected from the molding die which is still hot.

Lucite is the most common thermosetting plastic resin for mounting. It is completely transparent when properly mounted. This transparency is useful when it is polished or when it is desirable for any other reason to see the entire specimen in the mould mount unlike the thermosetting plastic, the thermosetting resin don’t undergo curing at the molding temperature, rather they set on cooling. The specimen & a proper amount of Lucite powder are placed in the mounting press & are subjected to the same temperature & pressure as for Bakelite (150⁰ C, 4000PSI). After this has been reached, the heating coil is removed & cooling fins are placed around the cylinder to cool the mount to about 75ºC in about 7 minutes while the molding pressure is maintained. Then the mount be ejected from the mould. Ejecting the mount while still hot, or allowing it to cool slowly in the molding cylinder to ordinary temperature before ejection will cause mount to remain opaque. Small specimens may be continently mounted for metallographic preparation in a laboratory made damping device. Thin sheet specimens when mounted in a damping device, are usually alternated with metal. 'Filler' sheet which have approximately the same hardness as these specimens. The use of filler sheet will preserve surface irregularities of the specimen & will prevent to some extent the edges of the specimen from becoming rounded during polishing.

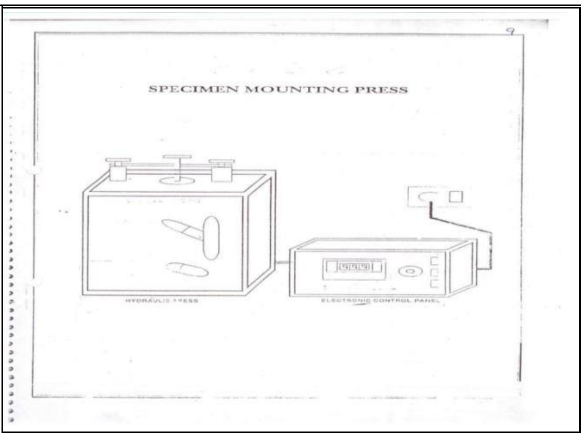


Fig: Specimen Mounting Press

PROCEDURE FOR SPECIMEN PREPARATION: -

***Introduction*: -**

Metallographic study consists of the microscopic study of the structural characteristics of material or an alloy. The microscope is thus the most important tool of a ***metallurgist*** from both, scientific & technical study point view. It is possible to determine grain size & the size, shape & distribution of various phases & inclusions which have a great effect on the mechanical properties of metal. The microstructure will reveal the mechanical & thermal treatment of the metal & it may be possible to predict its behaviour under a given set of conditions.

Experience had indicated the success in microscopic study depends upon the care taken in the preparation of specimen. The most expensive microscope will not reveal the structure of a specimen that has been poorly revealed. The procedure to be followed in the preparation of a specimen is comparatively similar and simple & involves a technique which is developed only after constant practice. The ultimate objective is to produce a flat, scratch free, mirror like surface. The steps required to prepare a metallographic specimen properly are covered in the coming section explained below.

Sampling: -

The choice of sample for microscopic study may be very important. If a failure is to be investigated the sampling should be chosen as close as possible to the area of the failure & should be compared with one taken from the normal section. If the material is soft, such as non-ferrous metals or alloy & non heat treated steels, the section is obtained by manual hack sawing
/power saw. If the material is hard, the section may be obtained by use of an abrasive cut off wheels. This wheel is thin disk of suitable cutting abrasive rotating at high speed. The specimen should be kept cool during the cutting operation.

Rough Polishing: -

Whenever possible the specimen should be of a size & shape that is convenient to handle. A soft sample may be made flat by slowly moving it up to & back across the surface of a flat smooth file. The surface to be examined is made plane using motor-driven emery belt and specimen kept cool by frequent dipping in water during the grinding operation. In all grinding and polishing operation the specimen should be moved perpendicular to the existing scratches this will facilitate, recognition of stage when the deeper scratches are replaced by shallower one characteristic of the finer abrasives. The rough grinding is continued until the surface is flat & free from wire brushes & all scratches due to hacksaw or cut-off wheel are no longer visible.

Intermediate Polishing: -

After the previous processes the specimen is polished on a series of emery paper containing successively finer abrasive (Si-C). The first paper is usually no. 1 than 1/0, 2/0, 3/0, & finally 4/0. The intermediate polishing operation using emery paper is usually done dry. However, in certain cases such as preparation of soft material, Silicon Carbide has greater removal rate & as it is resin bonded, can be used with a lubricant, which prevents overshooting of the sample, minimizes shearing of soft metals & also provides a rising action to flush away surface removal product so the paper won't be clogged.

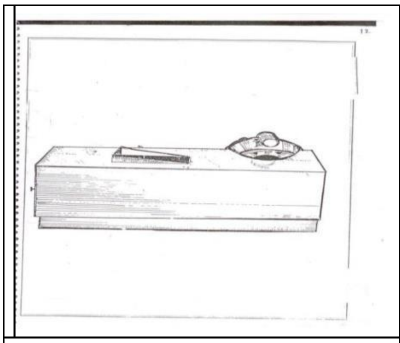
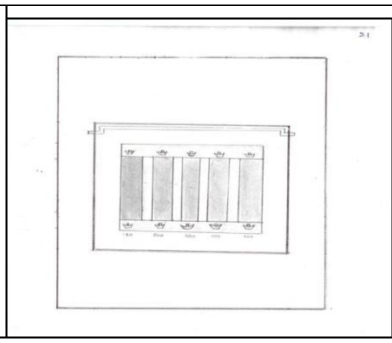
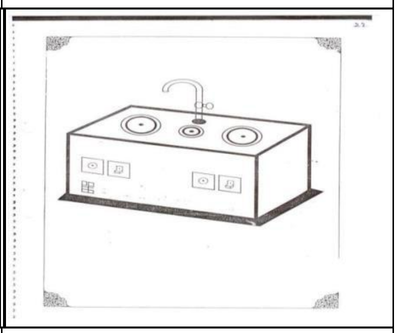
Fine polishing: -

The time consumed & the success of fine polishing depends largely on the case that we exercised during the previous polishing processes. The final approximation to the flat, scratch free surface is obtained by the use of a wet rotating wheel covered with a special cloth that is charged by carefully sized abrasive particles. A wide range of abrasive is available for final polishing, while many will do a satisfying job, these appear to be presence of gamma form of Aluminium-oxides (Al_2O_3), for ferrous & copper based materials & Cerium oxide for Aluminium, Magnesium & their alloys, other final polishing abrasives often used are diamond dust, chromium oxide & magnesium oxide etc. A choice of proper polishing cloth depends upon the particular material being polished & the purpose of metallographic study. The cloth may be Selvyt, Velvyt, Microcloth or Miracloth. A cloth to be used for the first time is soaked in water and in wet condition, it is stretched tightly over the lapping wheel and firmly clamped.

Etching: -

The purpose of etching is to make the many structural characteristics of the metal or alloy visible. The process should be such that the various parts of the microstructure may be clearly differentiated. This is to subject the polished surface to chemical action. In the alloys composed of two or more shapes. The components are revealed during etching by a preferential attack of one or more of the constituents by the reagent because of difference in chemical composition of the phases. In uniform single phase alloy contact is obtained and the grain boundaries are made visible because of difference in the rate at which various grains are attacked by the reagent.

This difference in the rate of attack by reagent which is mainly associated with angle of the different grain structure section to the plane of the polished surface. Because of chemical attack of the chemical reagent the grain boundary appears as valleys in the polished surface light from the microscope hitting the side of these valleys will be reflected but of the microscope making the grain boundaries appears dark lines. The selection of the appropriate etching reagent is determined by metal or alloys & the specific structure desired for viewing.

		
Belt Grinding Machine	**Plate Polishing Machine**	**Disc Polishing Machine**

Etching reagents are applied to the polished surface of a specimen by means of either immersion or swabbing technique. In immersion technique, the specimen is dipped into the etchant by means of tongs and agitated moderately without touching the bottom surface of the container. In swabbing, the polished surface is swabbed with a soft cotton saturated with etchant. After etching, sample is quickly washed in running water, rinsed in ethyl alcohol and dried in a blast of warm air. The etched specimen is now observed under the microscope at the desired magnification. The following are the some of the commonly used etchants.

Etchant	Composition	Concentration	Conditions	Comments
Nital	Ethanol Nitric acid	100 ml 1-10 ml	Immersion from a few seconds to minutes	Most common etchant for Fe, carbon and alloy steels and cast iron
Keller's Reagent	Distilled water Nitric acid Hydrochloric acid Hydrofluoric acid	190 ml 5 ml 3 ml 2 ml	10-30 second immersion. Use only fresh etchant	Excellent for Aluminium and Titanium alloys
Copper No.1	Nitric acid Distilled water	125 ml 125 ml	1 second to several minutes by immersion or swabbing	Common etchant for copper and copper alloys such as brass, bronze

IRON-IRON CARBIDE DIAGRAM: -

Iron can exist in three different crystalline forms each having limited solubility of carbon. The stability of these depends on temperature and composition. The two high temperature forms of iron are δ ferrite which is BCC (stable above 1394°C) and austenite (γ: stable above 910°C) which is FCC. The room temperature form of iron is α ferrite which is BCC. The solubility of carbon in ferrite is limited. The maximum solubility is around 0.025wt% as against this the solubility of carbon in austenite is a little more. It is about 2wt%. Apart from this iron carbon system may have iron carbide (Fe_3C) called cementite. It has 6.67 wt%. carbon. It is considered as an inter-metallic compound having relatively more complex crystal structure than those of ferrite and austenite. It is a meta-stable phase. It may exist for indefinite periods of time at room temperature. However, on prolonged thermal exposure at 600°C or beyond it transforms into ferrite and graphite. Therefore, iron carbon alloys of commercial importance may be considered as a binary alloy of iron and cementite. Let us first look at its phase diagram. It is also known as iron cementite meta-stable phase diagram. Although it is a binary system there are 5 different phases including the liquid. This is likely to have more than one invariant reaction involving 3 phases.

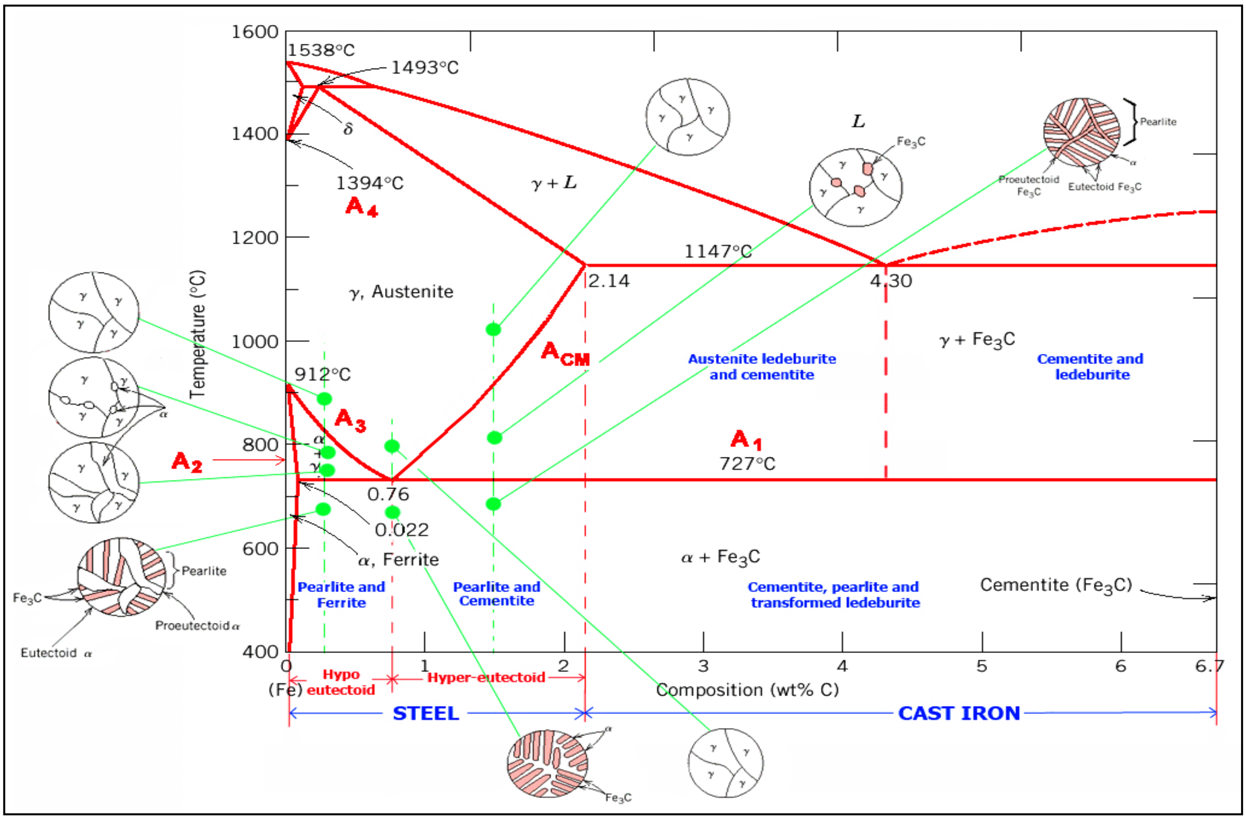


Figure shows a Fe-Fe3C phase diagram. It has 3 invariant reactions (transformation). The one occurring at 1495°C is the peritectic reaction. The delta ferrite reacts with liquid to form austenite. The one at 1147°C is known as the eutectic reaction where the liquid transforms into a mixture of austenite and cementite. The eutectic mixture of austenite and cementite is known as Ledeburite. The one at 727°C is known as eutectoid transformation where austenite decomposes into a mixture of ferrite and cementite. This is known as Pearlite. On the basis of this diagram iron – carbon alloys having less than 2.0% carbon are known as steel, whereas those having more than 2.0% carbon are known as cast iron. This classification is based on their ability to undergo large plastic deformation. Steel is ductile but cast iron is brittle.

RESULT & CONCLUSIONS: - Thus the Metallurgical Microscope, Procedure for Specimen preparation & mounting and iron-iron carbide diagram has been studied.

VIVA QUESTIONS

1. What is the use of micro study?
2. What is the difference among 1/0, 2/0, 3/0 and 4/0 emery papers?
3. What is lapping?
4. Why does the specimen have to be etched before lapping?
5. What are the different abrasives used in lapping?
6. Why does the specimen have to be etched before micro structural study?
7. What is the etchant used for mild steel? viii. In a microstructure how the grain boundary area appears?
8. Why specimen to be rotated through 90(between. Polishing on 1/0 and 2/0 emery papers?
9. What is etching reagent used for duralumin?
10. Why should a specimen be prepared following the set procedure before its observation under a microscope?

EXPERIMENT – 02

MICRO STRUCTURE OF LOW AND MEDIUM CARBON STEEL

AIM: - To prepare and study the Micro Structure of Low Carbon steel and Medium Carbon Steel.

APPARATUS / EQUIPMENT: -

- Abrasive Cut-Off Wheel Machine,
- Specimen Mounting Press
- Belt Grinding Machine.
- Double disc Polishing Machine.
- Metallurgical Microscope

Consumables/ Raw material: -

Rod or Sample pieces of Mild steel, Low carbon and Medium carbon steel, set of emery papers (220, 320, 400, 600, 1/0, 2/0, 3/0, and 4/0) Bakelite powder, lapping cloth, Alumina powder of different grades.

***Etchant*:** Nital (100 ml ethanol, 1-10 ml Nitric acid)

THEORY: -

Mild Steel, Low Carbon steel, Medium 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 variety 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 properties and characteristics of steel are according to the carbon content present in it and there is a minor influence on this type of carbon due to the alloying and residual materials.

Plain carbon steel is subdivided into three groups

1. Low carbon steel
2. Medium carbon steel
3. High carbon steel

***Low carbon steel*: -**

In low carbon steel the carbon content is less than 0.30 percent and is the most commonly used grades. They can be machined and welded nicely and their ductility is greater than high carbon steel. They are also called as Structural steels.

Medium carbon steel: -

In medium carbon steel the carbon content is from 0.30 to 0.60 percent carbon. Due to increased carbon content there is an increase in hardness and tensile strength and decrease in ductility and its machining and welding is difficult than low carbon steel due to increased content of carbon. They are also called as Machinery steels.

***High carbon steel*: -**

In high carbon steel the carbon content is in between 0.6 to 1.5 percent. They are hard, wear resistant brittle, difficult to machine and weld. They are also called as Tool steels. The structures and properties can be discussed with the help of Fe-Fe_3C equilibrium diagram.

PROCEDURE: -

- **Selection of the Specimen**: It is essential that the specimen would be selected from the metal which can be representative of the whole mass.
- **Cutting of the Specimen**: The cutting of the selected metal is made with the help of a Saw of trepanning tool and an abrasive wheel for fine sizing**.**
- **Belt grinding:** One of the faces of the specimen is pressed against the emery belt of the belt grinder so that all scratches on the specimen surface are unidirectional.
- **Intermediate polishing**: The sample is to be polished on 220, 320, 400, 600, 800, 1/0, 2/0, 3/0, and 4/0 emery papers with increasing fineness of the paper. While changing the polish paper, the sample is to be turned by 90^0 so that new scratches shall be exactly perpendicular to previous scratches.
- **Disc polishing (Fine polishing)**: After polishing on 4/0 paper the specimen is to be polished on disc polishing machine. In the disc-polishing machine a disc is rotated by a vertical shaft. The disc is covered by a velvet cloth. Alumina

solution is used as an abrasive. Alumina solution is sprinkled continuously over the disc and specimen is gently pressed against it. In case of Non-Ferrous metal such as Brass, Brasso is used instead of Alumina and water. The polishing should be continued till a mirror polished surface is obtained.

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

***Precautions*: -**

- Grinding should be done on the emery papers only in one direction.
- While polishing the specimen uniform pressure should be exerted on the specimen.
- While going to the next grade of emery papers, the specimen has to be rotated through 90^0.
- While switching over to new emery paper, specimen should be thoroughly washed with water to remove all loose particles.
- After etching the specimen should be washed away with in a few seconds.
- Operate the Microscope Knobs gently (without jerks)

RESULT & CONCLUSIONS: - Thus the microstructure of the given specimen has been studied.

VIVA QUESTIONS

1. What is Microscopy?
2. Why is it necessary to mount the specimen before grinding and polishing?
3. Which different etching agents are used for specimen preparations?
4. What is the principle of metallurgical Microscope?
5. How is the microstructure of pure Iron?
6. How is the microstructure of pure Copper?
7. How is the microstructure of pure aluminium?
8. How is the microstructure of low carbon steel?
9. How is the microstructure of medium carbon steel?
10. What is the purpose of Etching?
11. How will you identify cast iron, mild steel and high carbon steel?
12. What is High carbon steel?
13. What are the different alloying elements and their effects on the properties of the steel?

EXPERIMENT -03

MICRO STRUCTURE OF EUTECTOID STEEL AND HYPER EUTECTOID STEEL

AIM: - To prepare and study the Micro Structure of Eutectoid Steel and Hyper Eutectoid Steel.

APPARATUS / EQUIPMENT:

- Abrasive Cut-Off Wheel Machine,
- Specimen Mounting Press
- Belt Grinding Machine.
- Double disc Polishing Machine.
- Metallurgical Microscope

Consumables/ Raw material:

Rod or Sample pieces of Eutectoid Steel and Hyper Eutectoid Steel, set of emery papers (220, 320, 400, 600, 1/0, 2/0, 3/0, and 4/0) Bakelite powder, lapping cloth, Alumina powder of different grades.

***Etchant*:** Nital (100 ml ethanol, 1-10 ml Nitric acid)

THEORY: -

Iron carbon alloy containing less than 2% carbon is called steel. Steels with 0.8% C are called eutectoid steels. Steels containing less than 0.8% carbon (eutectoid composition) are called hypo eutectoid steels and those containing between 0.8% and 2% are called hyper eutectoid steels.

PROCEDURE: -

- **Selection of the Specimen**: It is essential that the specimen would be selected from the metal which can be representative of the whole mass.
- **Cutting of the Specimen**: The cutting of the selected metal is made with the help of a Saw of trepanning tool and an abrasive wheel for fine sizing.

- **Belt grinding:** One of the faces of the specimen is pressed against the emery belt of the belt grinder so that all scratches on the specimen surface are unidirectional.
- **Intermediate polishing**: The sample is to be polished on 220, 320, 400, 600, 800, 1/0, 2/0, 3/0, and 4/0 emery papers with increasing fineness of the paper. While changing the polish paper, the sample is to be turned by 90^0 so that new scratches shall be exactly perpendicular to previous scratches.
- **Disc polishing (Fine polishing)**: After polishing on 4/0 paper the specimen is to be polished on disc polishing machine. In the disc-polishing machine a disc is rotated by a vertical shaft. The disc is covered by a velvet cloth. Alumina solution is used as a abrasive. Alumina solution is sprinkled continuously over the disc and specimen is gently pressed against it. In case of Non-Ferrous metal such as Brass, Brasso is used instead of Alumina and water. The polishing should be continued till a mirror polished surface is obtained.
- The sample is then washed with water and dried.
- **Etching**: The sample is then etched with a suitable etching reagent. After etching the specimen should be washed in running water and then with alcohol and finally dried.
- The sample is now ready for studying its microstructure under the microscope.

***Precautions*: -**

- Grinding should be done on the emery papers only in one direction.
- While polishing the specimen uniform pressure should be exerted on the specimen.
- While going to the next grade of emery papers, the specimen has to be rotated through 90^0.
- While switching over to new emery paper, specimen should be thoroughly washed with water to remove all loose particles.
- After etching the specimen should be washed away with in a few seconds.
- Operate the Microscope Knobs gently (without jerks)

RESULT & CONCLUSIONS: - Thus the microstructure of the given specimen has been studied

VIVA QUESTIONS

1. What is the microstructure of hypo eutectoid steel?
2. What is the microstructure of hyper eutectoid steel?
3. How does carbon affect the properties of steel?
4. How is steel classified?
5. How will you identify cast iron, mild steel and high carbon steel?
6. What is High carbon steel?
7. What are the different alloying elements and their effects on the properties of the steel?
8. Which type of grains formed after hardening the steel?
9. What is the difference between Wrought iron, Cast iron and Pig iron?
10. Why is heat treatment of steel necessary?

EXPERIMENT- 04

MICROSTRUCTURES OF TYPES OF IRON

AIM: - To identify the different phases and to draw the microstructures of White Cast-iron, Grey Cast-iron and Malleable cast-iron.

APPARATUS / EQUIPMENT: -

- Abrasive Cut-Off Wheel Machine,
- Specimen Mounting Press
- Belt Grinding Machine.
- Double disc Polishing Machine.
- Metallurgical Microscope

Consumables/ Raw material: -

Rod or Sample pieces of white cast iron, set of emery papers (220, 320, 400, 600, 1/0, 2/0, 3/0, and 4/0) Bakelite powder, lapping cloth, Alumina powder of different grades.

***Etchant*: -** Nital (100 ml ethanol, 1-10 ml Nitric acid)

THEORY: -

Cast irons are Iron carbon alloys in which carbon content varies from 2 to 6.67%. Cast irons that contain carbon percentage between 2 to 4.3% it is called hypo eutectic cast iron. If carbon content of cast iron is 4.3% it is called as eutectic cast iron. If the carbon content is above 4.3% it is called hyper eutectic cast iron. In white cast iron most of the carbon is present in combined form as cementite. This is obtained by rapidly cooling the cast iron from its molten state. These are hard and wear resistant. These are used only for hard and wear resistance applications and also used as raw material to produce malleable iron. At room temperature microstructure of Hypo Eutectic C.I consist of dendritic areas of transformed austenite in a matrix of transformed Ledeburite. At room temperature microstructure of eutectic cast iron consists of cementite and pearlite. At room temperature microstructure Hyper eutectic cast iron consists of cementite and pearlite. At room temperature microstructure Hypereutectic C.I consists of dendrites of primary cementite in the matrix of transformed Ledeburite.

Specimen	White cast iron
Composition	2.3 to 3% carbon, 0.5% silicon, 0.4% manganese, 0.05% sulphur, 0.3% phosphorous
Specimen	Grey cast iron
Composition	3.5% carbon, 2% silicon, 0.5% manganese, 0.4% phosphorous, 0.09%Sulphur
Specimen	Grey cast iron
Composition	3.5% carbon, 2% silicon, 0.5% manganese, 0.4% phosphorous, 0.09%Sulphur
Heat treatment	Nil
Etchant	Nital
Etching time	20 seconds

PROCEDURE: -

- **Selection of the Specimen**: It is essential that the specimen would be selected from the metal which can be representative of the whole mass
- **Cutting of the Specimen**: The cutting of the selected metal is made with the help of a Saw of trepanning tool and an abrasive wheel for fine sizing
- **Belt grinding:** One of the faces of the specimen is pressed against the emery belt of the belt grinder so that all scratches on the specimen surface are unidirectional.
- **Intermediate polishing**: The sample is to be polished on 220, 320, 400, 600, 800, 1/0, 2/0, 3/0, and 4/0 emery papers with increasing fineness of the paper. While changing the polish paper, the sample is to be turned by 90^0 so that new scratches shall be exactly perpendicular to previous scratches.
- **Disc polishing (Fine polishing)**: After polishing on 4/0 paper the specimen is to be polished on disc polishing machine. In the disc-polishing machine a disc is rotated by a vertical shaft. The disc is covered by a velvet cloth. Alumina solution is used as a abrasive. Alumina solution is sprinkled continuously over the disc and specimen is gently pressed against it. In case of Non-Ferrous metal such as Brass, Brasso is used instead of Alumina and water. The polishing should be continued till a mirror polished surface is obtained.
- The sample is then washed with water and dried.
- **Etching**: The sample is then etched with a suitable etching reagent. After etching the specimen should be washed in running water and then with alcohol and finally dried.
- The sample is now ready for studying its microstructure under the microscope.

***Precautions*: -**

- Grinding should be done on the emery papers only in one direction.
- While polishing the specimen uniform pressure should be exerted on the specimen.
- While going to the next grade of emery papers, the specimen has to be rotated through 90^0.
- While switching over to new emery paper, specimen should be thoroughly washed with water to remove all loose particles.
- After etching the specimen should be washed away within a few seconds.
- Operate the Microscope Knobs gently (without jerks)

RESULT & CONCLUSIONS: - Thus the microstructure of the given specimen has been studied.

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VIVA QUESTIONS

1. What are the different types of cast irons?
2. What is the difference between white cast iron and Grey cast iron?
3. What are the important properties of Grey cast iron?
4. Why white cast iron has limited applications?
5. What is the structure of Malleable cast irons?
6. Explain the heat treatment cycles used for black heart and white heart malleable iron?
7. What is the additional metal added for spheroidisation for Hypo and Hyper eutectic cast irons? How do they act?
8. What is chilled cast iron?
9. What is the difference between Ferrite malleable, pearlitic malleable and Pearlitic Ferritic malleable cast irons?
10. Why has Gray cast iron got that name?

EXPERIMENT – 05

MICRO STRUCTURE OF ALUMINIUM, BRASS AND BRONZE

AIM: -To prepare and study the Micro Structure of Aluminium, Brass and Bronze.

APPARATUS / EQUIPMENT: -

- Abrasive Cut-Off Wheel Machine.
- Specimen Mounting Press.
- Belt Grinding Machine.
- Double disc Polishing Machine.
- Metallurgical Microscope.

Consumables/ Raw material:

Rod or Sample pieces of Aluminium, set of emery papers (220, 320, 400, 600, 1/0, 2/0, 3/0, and 4/0) Bakelite powder, lapping cloth, Alumina powder of different grades.

***Etchant*:** Keller's reagent (190 ml distilled water, 5 ml Nitric acid, 5 ml Hydrochloric acid, 2 ml Hydrofluoric acid)

THEORY: -

The best known characteristic of aluminium is its light weight; Aluminium has good malleability and formability, high corrosion resistance and high electrical and thermal conductivity. Pure aluminium has a tensile strength of about 13,000psi. One of the important characteristic of aluminium is its machinability and workability.

Brasses are alloys of copper; contain zinc as a principal alloying element. The equilibrium solubility of Zn in Cu is around 38% and is sharply influenced by cooling rate. Under the conditions of usual cooling rates encountered in industrial practice, the solubility limit may go down to 30%. With Zn additions exceeding the solubility limit, a second phase β is formed. Beta intermediate phase exhibits order-disorder transformation between 453^0C and 470^0C. Below this temperature, the structure of β is ordered and above this is disordered. With more than 50 % Zn another phase γ (intermediate phase) is formed.

Bronzes are the alloys of copper containing elements other than zinc. In these alloys, zinc may be present in small amount. Originally the name bronze was used to denote copper-tin alloys.

Commercially important bronzes are aluminium bronzes, phosphor bronzes, tin bronzes, beryllium bronzes and silicon bronzes. Phosphor bronzes, or tin bronzes, are alloys containing copper, tin and phosphorous. The phosphor bronzes contain 0.5 and 11% tin and 0.01 to 0.35% phosphorous

PROCEDURE: -

- **Selection of the Specimen**: It is essential that the specimen would be selected from the metal which can be representative of the whole mass
- **Cutting of the Specimen**: The cutting of the selected metal is made with the help of a Saw of trepanning tool and an abrasive wheel for fine sizing
- **Belt grinding:** One of the faces of the specimen is pressed against the emery belt of the belt grinder so that all scratches on the specimen surface are unidirectional.
- **Intermediate polishing**: The sample is to be polished on 220, 320, 400, 600, 800, 1/0, 2/0, 3/0, and 4/0 emery papers with increasing fineness of the paper. While changing the polish paper, the sample is to be turned by 90^0 so that new scratches shall be exactly perpendicular to previous scratches.
- **Disc polishing (Fine polishing)**: After polishing on 4/0 paper the specimen is to be polished on disc polishing machine. In the disc-polishing machine a disc is rotated by a vertical shaft. The disc is covered by a velvet cloth. Alumina solution is used as an abrasive. Alumina solution is sprinkled continuously over the disc and specimen is gently pressed against it. The polishing should be continued till a mirror polished surface is obtained.

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

***Precautions*: -**

- Grinding should be done on the emery papers only in one direction.
- While polishing the specimen uniform pressure should be exerted on the specimen.
- While going to the next grade of emery papers, the specimen has to be rotated through 90^0.
- While switching over to new emery paper, specimen should be thoroughly washed with water to remove all loose particles.
- After etching the specimen should be washed away with in a few seconds.

RESULT & CONCLUSIONS: - Thus the microstructure of the given specimen has been studied.

VIVA QUESTIONS

1. What are the differences between Brass and Bronze?
2. Brass is an alloy of what?
3. What is the appearance of copper?
4. What is the melting point of Copper?
5. Which bronze alloy is commonly used as bearing alloy?
6. How much tin is contained in a Babbitt metal?
7. Babbitt metals are also known as?
8. What is the melting point of magnesium?
9. What is the melting point of titanium?
10. Which nickel alloy is used as a substitute in tableware and jewellery?

EXPERIMENT – 06

JOMINY QUENCH TEST

AIM: - To study hardness as a function of quench rate and investigate the hardenability of steels.

EQUIPMENT AND MATERIAL REQUIRED: -

1. Furnace that attains required hardening temperature.
2. Jominy end quench apparatus.
3. Brinell's hardness testing machine.
4. Proper tongs and hand gloves.
5. Specimen.

Specimen of Furnace Used: -

Power- 2KW, Voltage-250V

Max temperature- 850^o C

Hardness of a material is defined as the ability of a material to resist plastic deformation. Whereas ***Hardenability*** of materials is its ability to get hardened as a result of hardening heat treatment.

A steel that has highest hardenability is one that has martensite, not only at the surface but throughout the entire interior or core of the steel.

The Hardenability of steels depends on

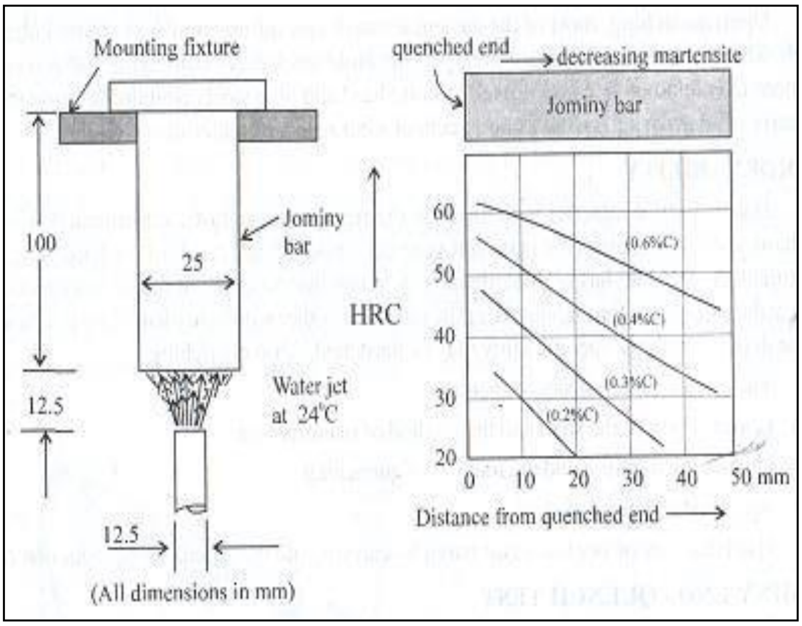
a. Composition of the steel and method of manufacture
b. Quenching medium and the method of quenching
c. Section (thickness) of steel

THEORY: - The test consists of heating a standard steel specimen to a given quenching temperature for a specific period of time follower by a water, quenching at one end under specified conditions. The specimen must be a BS4437 (or) IS: 3848-1966. The quenched specimen is subjected to hardness test of various parts from the quenched end along the length of the piece from the quenched end.

Specimen standards: - BS 3337 (or) IS 3848 - 1966

Process parameters: -

- Water inlet orifice diameter 12.5mm
- Free jet height 62.5mm
- Distance between orifice & bottom
- End of steel bar 12.5mm
- Temp of water 21-25° C
- Quenching time 10 min



***Tabular Column*: -**

S No.	Distance from Quenched End (mm)	BHN
1	5	
2	10	
3	15	
4	20	
5	25	
6	30	
7	35	
8	40	
9	45	
10	50	

*** Plot the graph of Distance Vs Hardness**

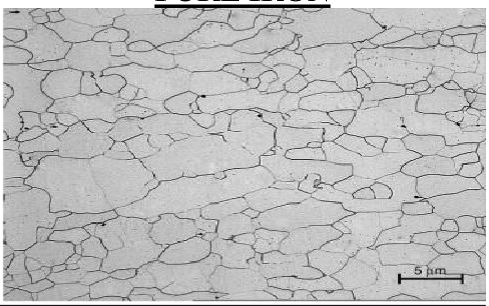
RESULT & CONCLUSIONS: - From Jominy test the hardening curve for specimen is obtained for different steel, kinds, and shapes of the curve varies.

VIVA QUESTIONS

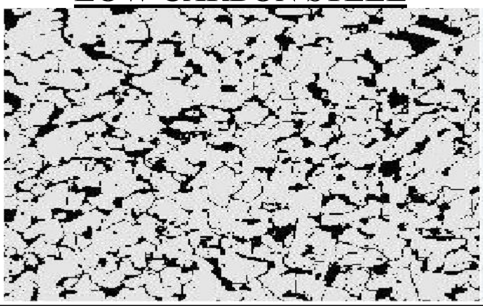
1. What is the difference between Hardness & Hardenability?
2. What is the severity of quench?
3. What is the critical diameter?
4. What is the ideal critical diameter?
5. What is the quenching medium employed in the test?
6. What are the important precautions to be observed in the test?
7. Why is a flat ground on the test specimen?
8. What is the equipment used to measure the hardness of specimens in the experiment?
9. Why does the hardness of steel increase after quench hardening?
10. What are the common heat treatment processes used in industries?

MICROSTRUCTURE IMAGES OF VARIOUS MATERIALS

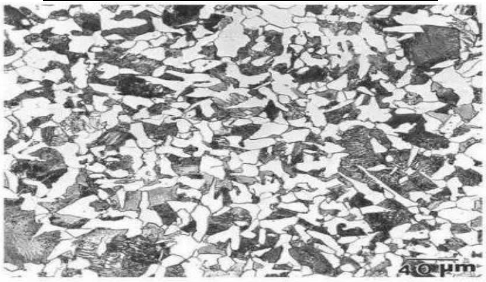
PURE IRON



LOW CARBON STEEL

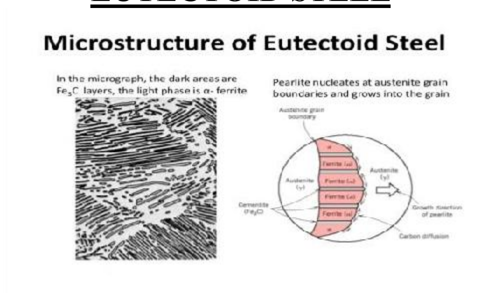


MEDIUM CARBON STEEL

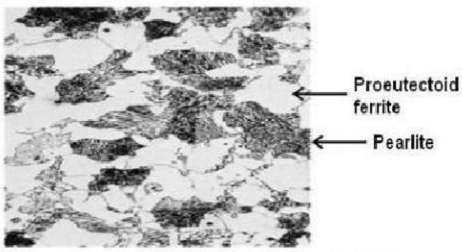


Medium-carbon AISI/SAE 1040 Steel

EUTECTOID STEEL

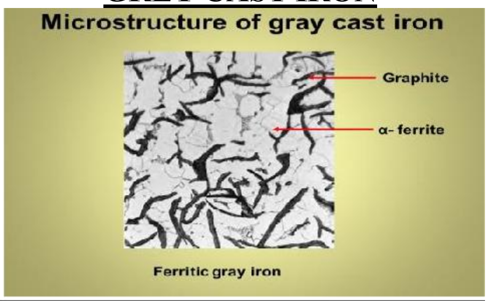


HYPO ETECTOID STEEL

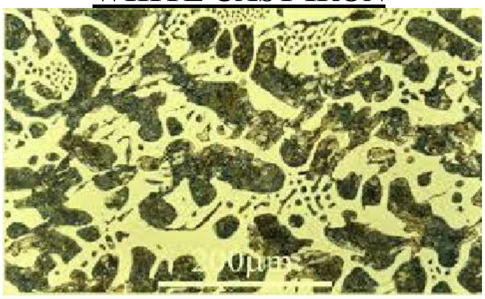


Microstructure of Hypoeutectoid Steel

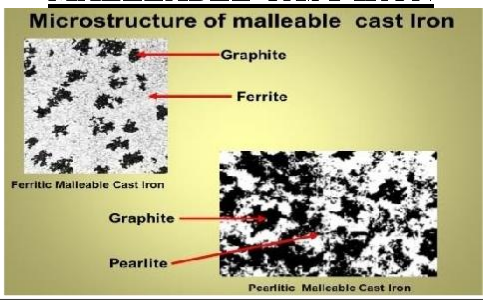
GREY CAST IRON



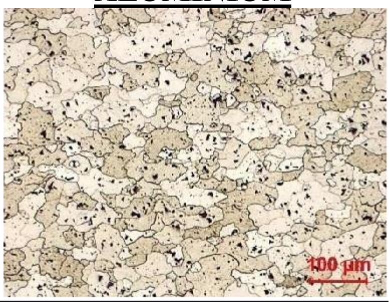
WHITE CAST IRON



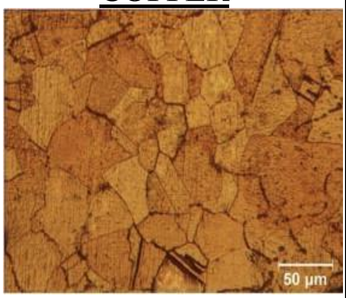
MALLEABLE CAST IRON



ALUMINIUM



COPPER



BRASS