DEPARTMENT OF MECHANICAL ENGINEERING

34421C03 – MECHANICAL BEHAVIOUR OF MATERIALS AND METALLURGY LAB (UG)

LAB MANUAL

Prepared by

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METALLURGY LABORATORY

SAFETY RULES

Do's:

- ✓ Laboratory is not a place to play. Avoid distractions while working with machines.
- ✓ Always wear tight fitting clothes and thick leather shoes.
- ✓ Report immediately about the injury caused; if necessary use the first aid box available in the laboratory.
- ✓ Report immediately about the damage caused to the machines to the Instructor.
- ✓ Before operating a machine, learn completely the working procedure of it.
- ✓ Handle your materials and loads ergonomically.
- ✓ Handle the Etchants carefully as they are hazardous Chemicals.
- ✓ Take care of your fingers while polishing the specimen.

Don'ts:

- ✗ Don't touch the polished and etched surface. Avoid scratches after etching.
- ✗ Don't wipe the etched surface.
- ✗ Don't interchange the specimen positions. Store the specimen in their respective place.
- ✗ Don't keep bare hand into the furnace. Use tongs and wear gloves.
- ✗ Don't wear watches or bracelets while working in machines.
- ✗ Don't carry tools in pockets.
- ✗ Don't touch the lens of Microscopes.
- ✗ Don't remove any guards or parts of any machine.

1. INTRODUCTION TO METALLOGRAPHY

AIM:

To know about metallography and to study the various tools used in the relevant field.

METALLURGY/METALLOGRAPHY:

Metallurgy is the science and technology of metals. As an art it has been practiced since ancient times. The art of smelting, refining and shaping metals was highly developed by both the Egyptians and the Chinese. Knowledge of dealing with metals was generally passed directly from master to apprentice in the middle ages, leading to an aura of superstitions surrounding many of the processes.

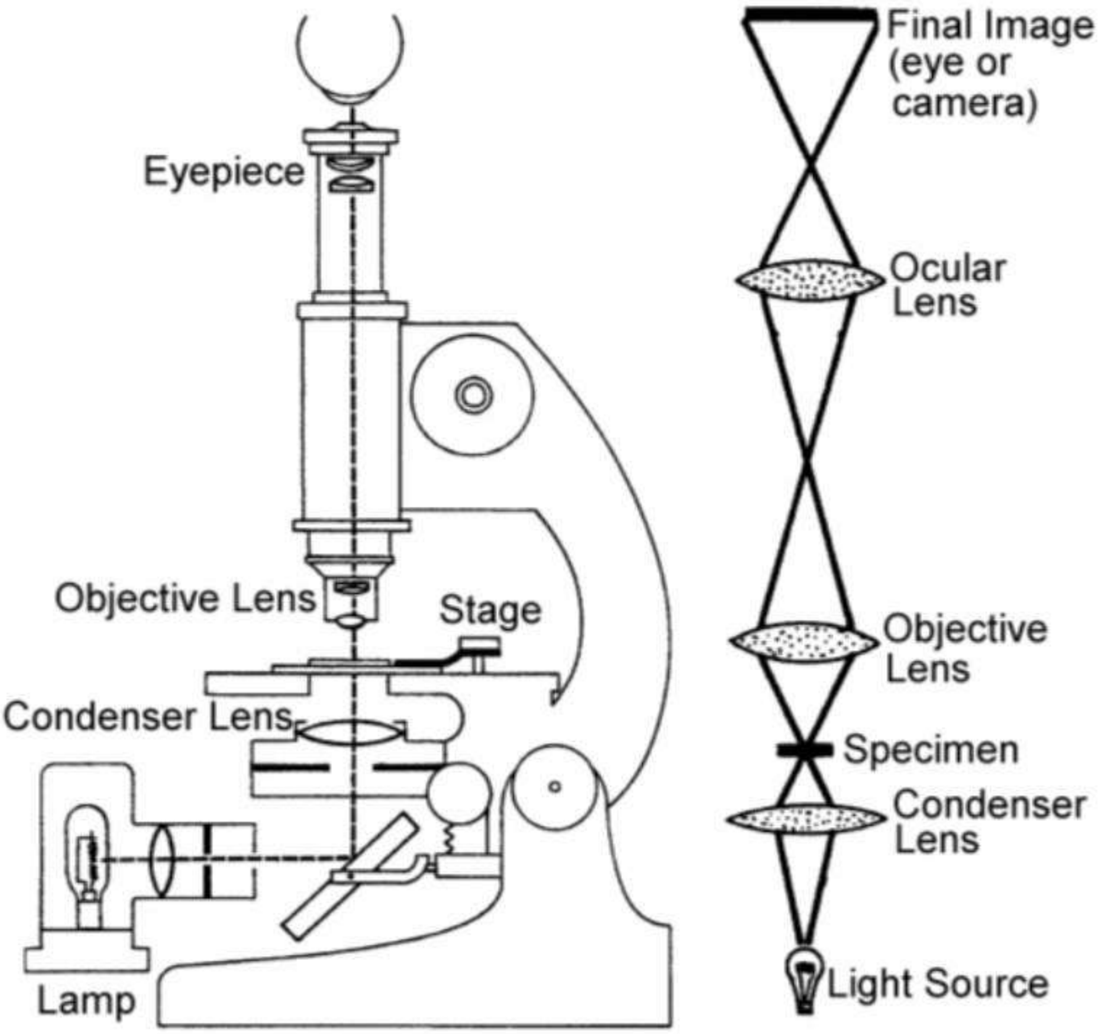
Metallurgy has become an important subject in the modern technology. Years ago, the great majority of steel parts were made of cheap low carbon steel that would machine and fabricate easily. Heat treatment was reserved largely for tools. Designers were unable to account for structural inhomogenity, surface defects etc. and it was considered good practice to use large factors of safety. Consequently, machines were much heavier than they should have been and the weight was considered a mark of quality. This attitude has persisted to some extent to the present time but has been discouraged under the leadership of the aircraft and automotive industries. They have strongly emphasized the importance of strength - weight ratio in good design and this has led to the development of new high strength, light weight alloys.

New technical applications and operating requirements pushed to higher levels have created a continued need for the development of new alloys. Metallurgy is really not an independent science since many of its fundamental concepts are derived from physics, chemistry, and crystallography. The metallurgical field may be divided into two large groups such as Extractive metallurgy and Physical metallurgy.

The science of obtaining metals from their ores, including mining, concentration, extraction and refining metals & alloys is Extractive Metallurgy.

The science concerned with the physical and mechanical characteristics of metals and alloys is termed as Physical Metallurgy. This field studies the properties of metals and alloys as affected by their chemical compositions, mechanical and heat treatments.

PRINCIPLE OF METALLURGICAL MICROSCOPE



TOOLS OF METALLURGIST:

Highly sophisticated and calibrated tools are available in the field of metallurgy. Metal expansion thermometers, liquid expansion thermometers, vapour expansion thermometers, resistance thermometer, thermo electric pyrometer, optical pyrometer, thermo electric materials, radiation pyrometer, metallurgical microscopes are some among them.

Let us study the construction and working principle of ***Metallurgical Microscope*** in detail. The microscope is by far the most important tool of the metallurgist from both the scientific and technical stand points. It is possible to determine grain size, shape and distribution of various phases and inclusions which have a great effect on the mechanical properties of the metal. The microstructure will reveal the mechanical and thermal treatment of the metal and it may be possible to predict its expected behavior under a given set of conditions. A microscope is employed to study the microstructure of material since the object is opaque it is viewed under reflected light.

In comparison with the biological type, the metallurgical microscope differs in manner by which the specimen is illuminated. Since the object is opaque, the sample must be illuminated by reflected light. As shown in figure, a horizontal beam of light from some light source is reflected, by means of a plane-glass reflector, downward through the microscope objective onto the surface of the specimen. Some of this incident light reflected from the specimen surface will be magnified in passing through the lower lens system, the objective and will continue upward through the plane-glass reflector and be magnified again by the upper lens system, the eye piece. The initial magnifying power of the objective and the eye piece is usually engraved on the lens mount. When a particular combination of objective and eyepiece is used at the proper tube length, the total magnification is equal to the product of magnifications of objective and eyepiece. It is possible to mount a camera bellows above the eye piece and use the table type microscope for photomicrography.

The maximum magnification obtained with the optical microscope is about 2000x. The principle illumination is the wave length of visible light, which limits the resolution of fine detail in the metallographic specimen. The magnification may be extended somewhat by the use of shorter wave length radiation, such as ultraviolet radiation, but the sample preparation would include more techniques. The greatest advance in resolving power was obtained by the electron microscope. Under certain circumstances, high velocity electrons behave like light of very short wave length. The electron beam has associated with it a wavelength nearly 100000 times smaller than the wave length of visible light, thus increasing the resolving power tremendously.

The lenses of the electron microscope are the powerful magnetic fields of the coils and the image is brought into focus by changing the field strength of the coils while the coils remain in a fixed position. In optical microscope the image is brought into focus by changing the lens spacing. Although the principle of electron and optical microscopes are same, the former is large. The electron microscope is much larger because of the highly regulated power supplies that are needed to produce and control the electron beam. The entire system must be kept pumped to a high vacuum since air would interfere with the motion of the electrons.

RESULT:

Thus the metallography and the various tools used in the relevant field were studied.

2. PREPARATION OF METALLOGRAPHIC SPECIMEN

AIM:

To prepare a specimen for microscopic examination.

TOOLS REQUIRED:

Linisher- Polisher, Different grades of emery sheets (Rough & Fine), Disc Polisher, Metallurgical Microscopes.

PROCEDURE:

The specimen preparation consists of following stages:

i) Rough grinding
ii) Intermediate Polishing
iii) Fine Polishing
iv) Etching

(i) Rough grinding:

It is first necessary for specimen to obtain a reasonable flat surface. This is achieved by using a motor driven energy belt called Linisher-Polisher. The specimen should be kept over the moving belt which will abrade the specimen and make the surface flat. In all grinding and polishing operations, the specimen should be moved perpendicular the existing scratches, so that the deeper scratches will be replaced to a shallower one. This operation is done until the specimen is smooth, free from rust, burs, troughs and deep scratches.

(ii) Intermediate Polishing:

It is carried out using emery paper of cogressively fine grades. The emery paper should be of good quality. The different grades of emery paper used are 120,240,320,400 and 1/0, 2/0, 3/0, 4/0 (Grain size from coarse to fine). The emery paper should be kept against the specimen and moved gently until a fine matrix of uniformly spaced scratches appears on the object. Final grade is then chosen and the specimen is turned perpendicular to the previous direction. This operation is usually done dry.

(iii) Fine Polishing:

An approximate flat scratch free surface is obtained by the use of wet rotary wheel covered with abrasive of alumina powder of 0.05 microns. In this operation, water is used as lubricant and carrier of the abrasive so that it comes in contact to specimen to be polished. Fine polishing removes fine scratches and very thin layer produced due to previous operations.

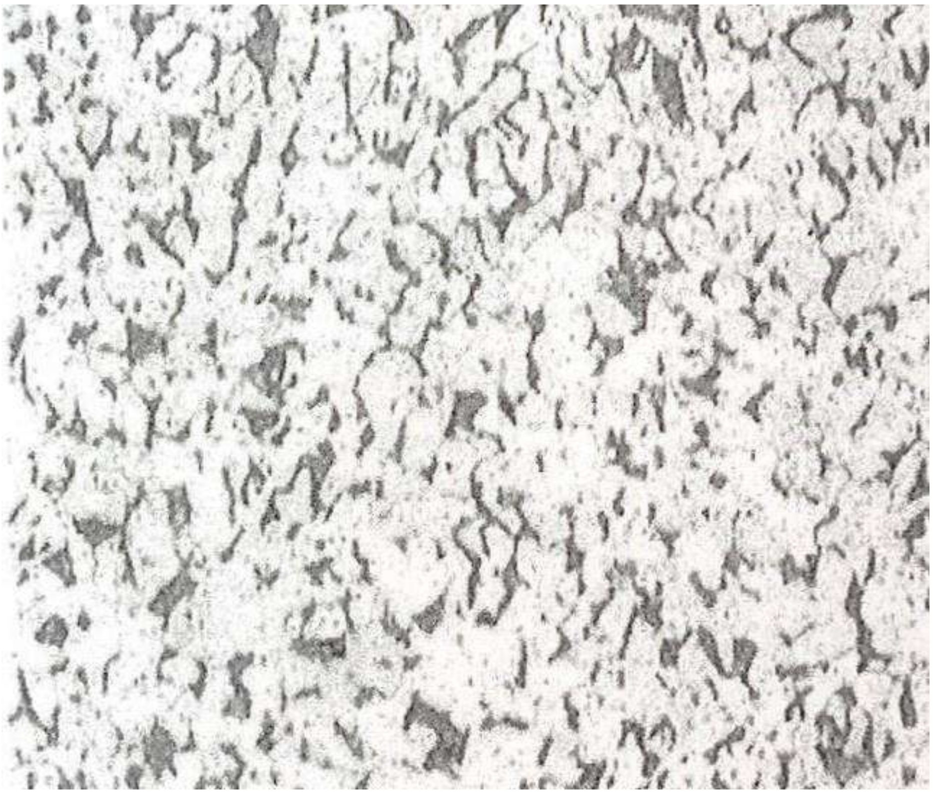
(iv) Etching:

The polished surface is washed with water and etching is done by rubbing the polished surface gently with cotton wetted with etching reagent. After etching the specimen is again washed and then dried. It is then placed under the metallurgical microscope to view the microstructure of it. Thus the specimen is identified.

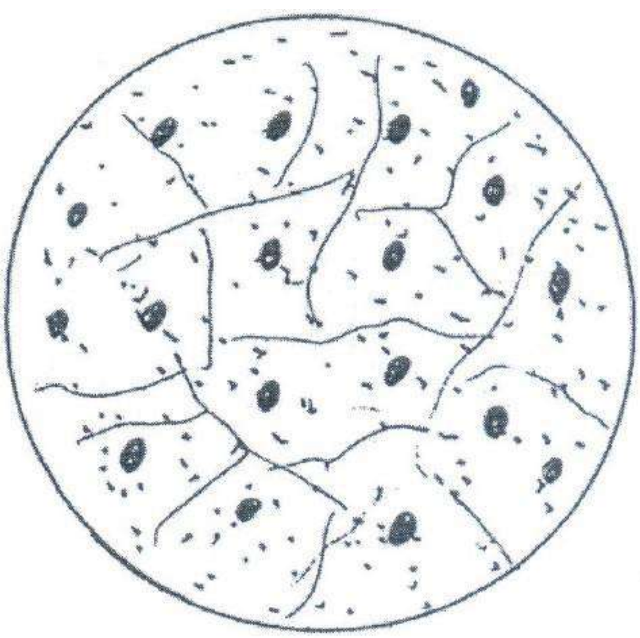
RESULT:

Thus the specimen was prepared for microscope observation for its identification.

LOW CARBON STEEL



Magnification: 100x ETCHANT: Nital Solution



3. IDENTIFICATION OF LOW CARBON STEEL

AIM:

To identify the given specimen and to study the microstructure, characteristics and applications of it.

TOOLS REQUIRED:

- Linisher - polisher,
- Emery sheets,
- Disc polisher,
- Alumina powder,
- Etchant and
- Metallurgical microscope.

PROCEDURE:

1. The specimen is abraded against the linisher polisher to remove burs.
2. Then it is polished using the various grades of emery paper.
3. The specimen is fine polished in disc polishing machine using alumina powder as lubricant.
4. Then the specimen is washed thoroughly in water and then etched with nital solution.
5. After etching the specimen is washed and dried for some seconds.
6. Now view the structure under microscope.

IDENTIFICATION:

The structure is pearlite and the specimen is identified as **Low Carbon Steel.** The pearlite is a lamellar structure of cementite in ferrite matrix.

CHARACTERISTICS OF LOW CARBON STEEL:

- High ductility and toughness
- Possesses good formability and weldability
- Least expensive
- Low tensile strength

APPLICATIONS OF LOW CARBON STEEL:

- It is used for manufacturing products like screws, nails, nut, bolt, washers, wire fences etc.
- Automobile body components
- Structural steels, bars, grills, angles etc.

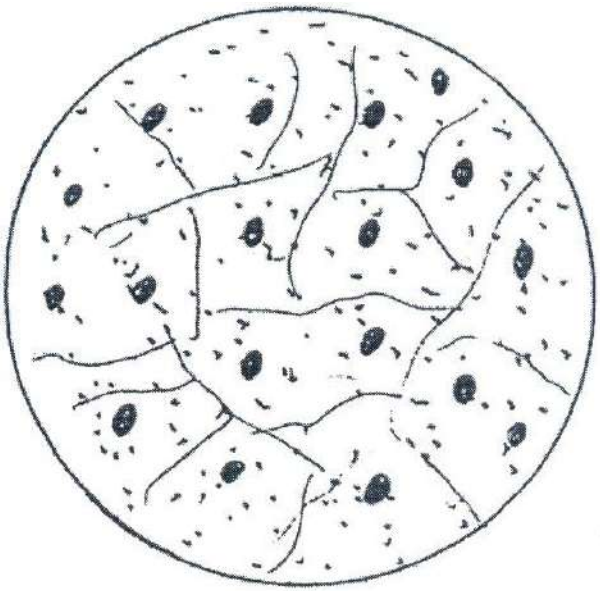
OBSERVATION:

RESULT:

Thus the given specimen is identified as **Low Carbon Steel** and its characteristics and applications were studied.

MEDIUM CARBON STEEL

Magnification: 100x ETCHANT: Nital Solution



4. IDENTIFICATION OF MEDIUM CARBON STEEL

AIM:

To identify the given specimen and to study the microstructure, characteristics and applications of it.

TOOLS REQUIRED:

- Linisher - polisher,
- Emery sheets,
- Disc polisher,
- Alumina powder,
- Etchant and
- Metallurgical microscope.

PROCEDURE:

1. The specimen is abraded against the linisher polisher to remove burs.
2. Then it is polished using the various grades of emery paper.
3. The specimen is fine polished in disc polishing machine using alumina powder as lubricant.
4. Then the specimen is washed thoroughly in water and then etched with nital solution.
5. After etching the specimen is washed and dried for some seconds.
6. Now view the structure under microscope.

IDENTIFICATION:

The structure is pearlite and cementite then the specimen is identified as **Medium Carbon Steel.** The pearlite is a lamellar structure of cementite matrix.

CHARACTERISTICS OF LOW CARBON STEEL:

- Ductility and toughness
- Possesses good formability and weldability
- Least expensive
- Considerable hardness

APPLICATIONS OF MEDIUM CARBON STEEL:

- It is used for manufacturing products like screws, nails, nut, bolt, washers, wire fences etc.
- Automobile body components
- Structural steels, bars, grills, angles etc.

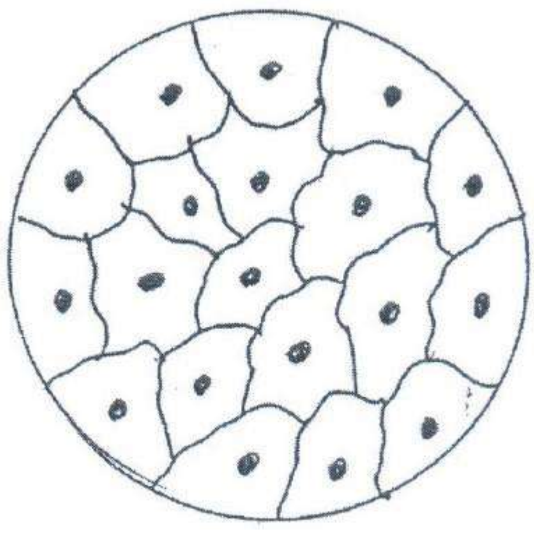
OBSERVATION:

RESULT:

Thus the given specimen is identified as **Medium Carbon Steel** and its characteristics and applications were studied.

AUSTENITIC STAINLESS STEEL

Magnification: 100x ETCHANT: Aqua Solution



5. IDENTIFICATION OF AUSTENITIC STAINLESS STEEL

AIM:

To identify the given specimen and to study the microstructure, characteristics and applications of it.

TOOLS REQUIRED:

- Linisher - polisher,
- Emery sheets,
- Disc polisher,
- Alumina powder,
- Etchant and
- Metallurgical microscope.

PROCEDURE:

1. The specimen is abraded against the linisher polisher to remove burs.
2. Then it is polished using the various grades of emery paper.
3. The specimen is fine polished in disc polishing machine using alumina powder as lubricant.
4. Then the specimen is washed thoroughly in water and then etched with aqua regia.
5. After etching the specimen is washed and dried for some seconds.
6. Now view the structure under microscope.

IDENTIFICATION:

The structure is austenite and the specimen is identified as **Austenitic Stainless Steel.**

CHARACTERISTICS OF AUSTENITIC STAINLESS STEEL:

- Highest corrosion resistance
- Good ductility at cryogenic temperature i.e. below 0°C Non- magnetic

APPLICATIONS OF AUSTENITIC STAINLESS STEEL:

- Engine parts

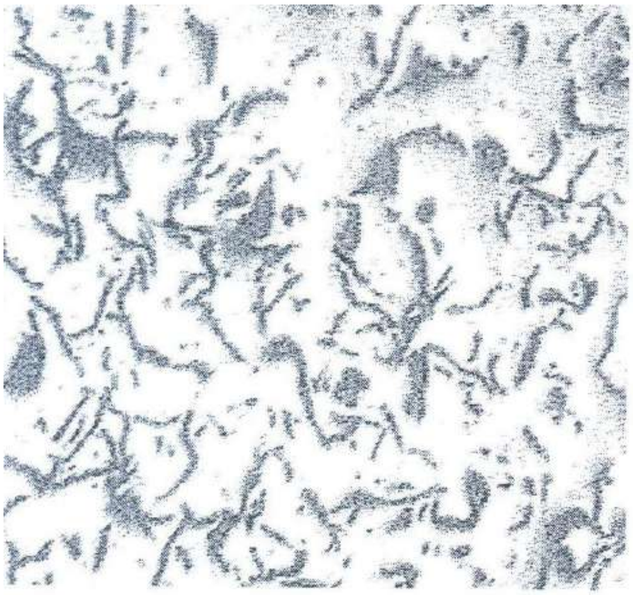
- Heat exchangers
- Food processing and house hold items
- Dairy industry

OBSERVATION:

RESULT:

Thus the given specimen is identified as **Austenitic Stainless Steel** and its characteristics and applications were studied.

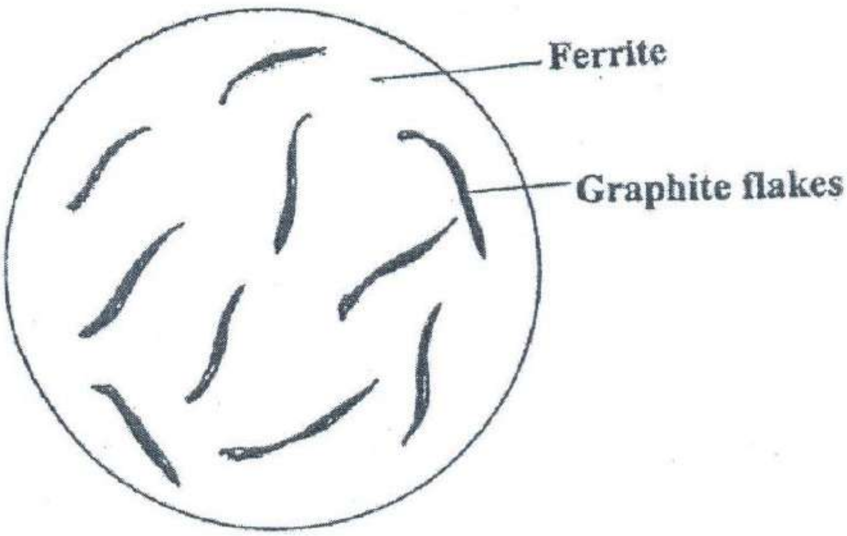
GREY CAST IRON



As Polished - Magnification: 100x

As Etched - Magnification: 250x

ETCHANT: Nital Solution



6. IDENTIFICATION OF GREY CAST IRON

AIM:

To identify the given specimen and to study the microstructure, characteristics and applications of it.

TOOLS REQUIRED:

- Linisher - polisher,
- Emery sheets,
- Disc polisher with Alumina powder,
- Etchant and
- Metallurgical microscope.

PROCEDURE:

1. The specimen is abraded against the linisher polisher to remove burs.
2. Then it is polished using the various grades of emery paper.
3. The specimen is fine polished in disc polishing machine using alumina powder as lubricant.
4. Then the specimen is washed thoroughly in water and then etched with nital solution.
5. After etching the specimen is washed and dried for some seconds.
6. Now view the structure under microscope.

IDENTIFICATION:

The structure is graphite flakes in ferrite matrix and the specimen is identified as Grey Cast Iron.

CHARACTERISTICS OF GREY CAST IRON:

- ➢ Excellent compressive strength
- ➢ Good torsional and shear strength
- ➢ Good corrosion resistance
- ➢ High damping capacity

APPLICATIONS OF GREY CAST IRON:

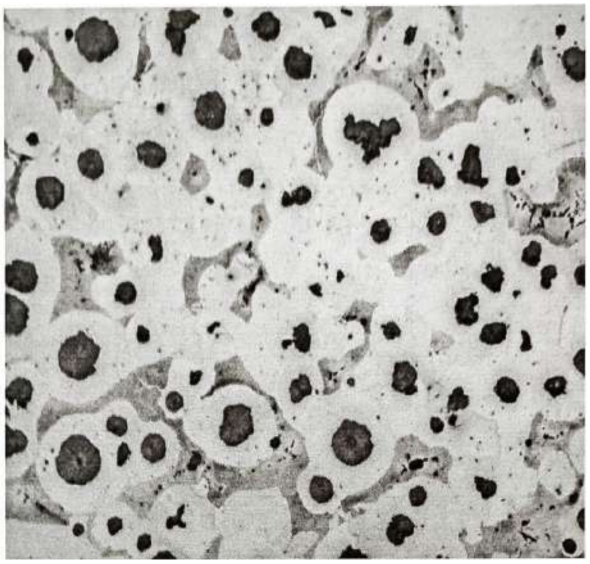
- Machine tool bodies
- Engine blocks
- Cam shafts
- Rolling mills, agricultural machineries etc.

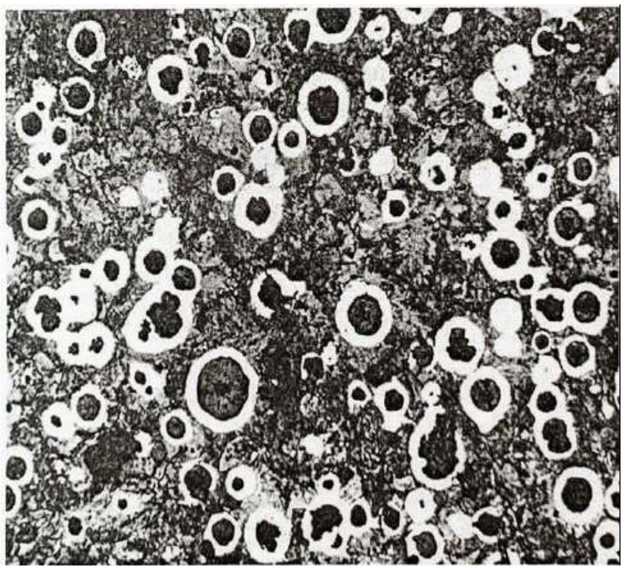
OBSERVATION:

RESULT:

Thus the given specimen is identified as **Grey Cast Iron** and its characteristics and applications were studied.

NODULAR CAST IRON

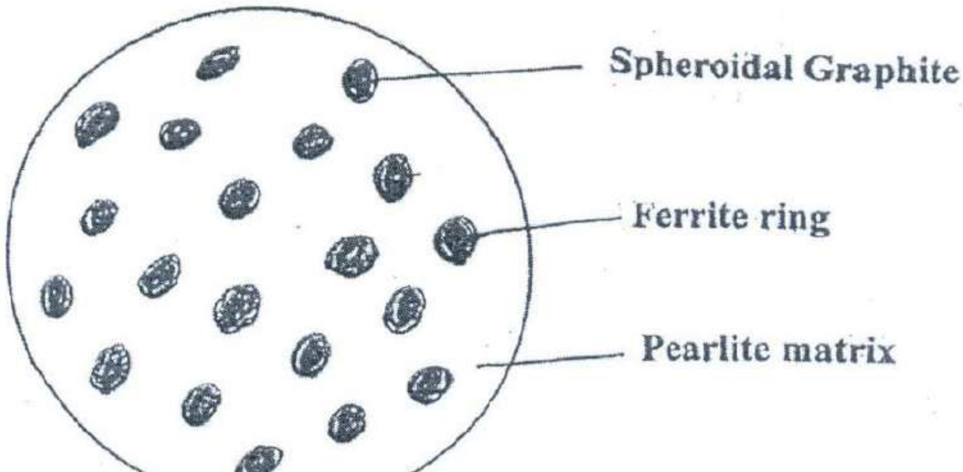




As Polished - Magnification: 100x

As Etched - Magnification: 250x

ETCHANT: Nital Solution



7. IDENTIFICATION OF NODULAR CAST IRON

AIM:

To identify the given specimen and to study the microstructure, characteristics and applications of it.

TOOLS REQUIRED:

- Linisher - polisher,
- Emery sheets,
- Disc polisher with Alumina powder,
- Etchant and
- Metallurgical microscope.

PROCEDURE:

1. The specimen is abraded against the linisher polisher to remove burs.
2. Then it is polished using the various grades of emery paper.
3. The specimen is fine polished in disc polishing machine using alumina powder as lubricant.
4. Then the specimen is washed thoroughly in water and then etched with nital solution.
5. After etching the specimen is washed and dried for some seconds.
6. Now view the structure under microscope.

IDENTIFICATION:

The structure is graphite nodules in a matrix of ferrite and pearlite with a majority of ferrite content and the specimen is identified as **Nodular Cast Iron.**

CHARACTERISTICS OF NODULAR CAST IRON:

- ➢ Good ductility and malleability
- ➢ High yield strength and tensile strength
- ➢ Excellent impact and fatigue strength
- ➢ Excellent machinability
- ➢ Ability to resist oxidation at high temperatures

APPLICATIONS OF NODULAR CAST IRON:

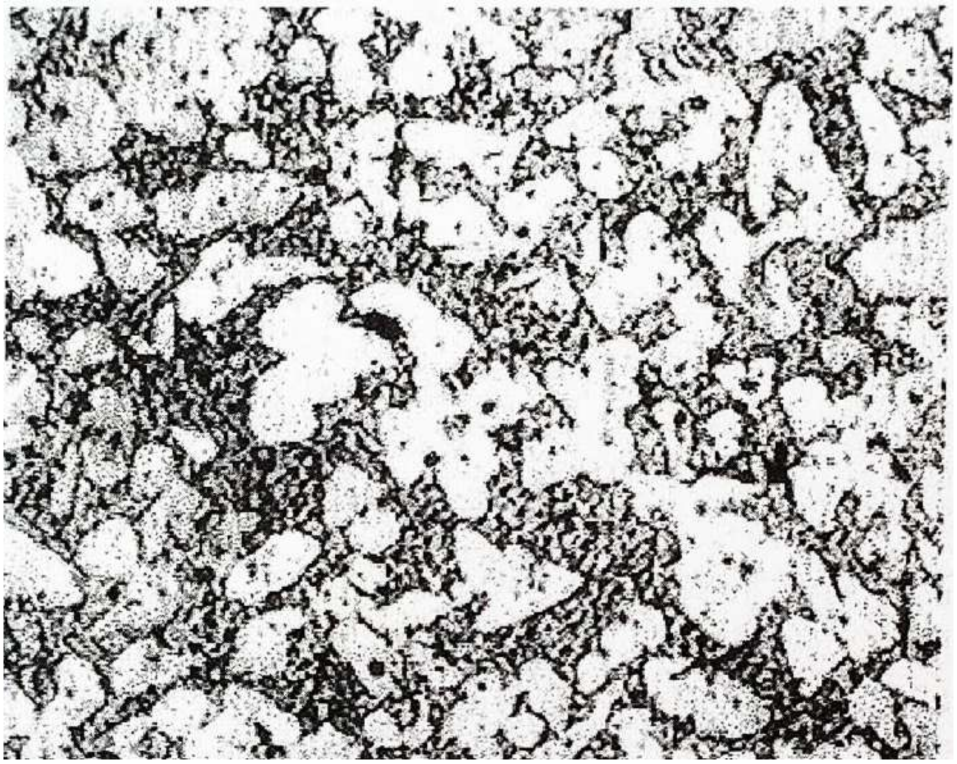
- Valves, pumps
- Gears, pinions
- Crank shafts,
- Power transmission equipments

OBSERVATION:

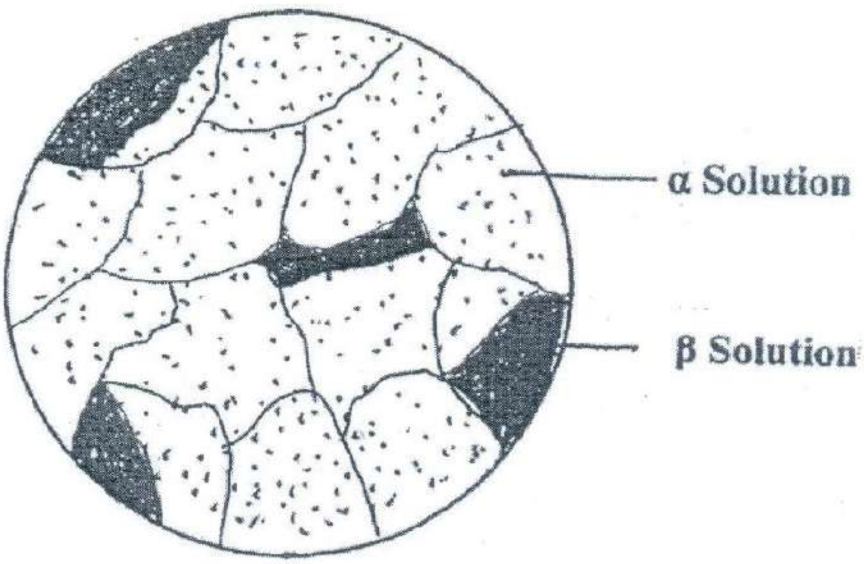
RESULT:

Thus the given specimen is identified as **Nodular Cast Iron** and its characteristics and applications were studied.

BRASS (COPPER ALLOY)



Magnification: 200x ETCHANT: Ammonia & H_2O_2 Solution



8. IDENTIFICATION OF BRASS (COPPER ALLOY)

AIM:

To identify the given specimen and to study the microstructure, characteristics and applications of it.

TOOLS REQUIRED:

- Linisher - polisher,
- Emery sheets,
- Disc polisher with Alumina powder,
- Etchant and
- Metallurgical microscope.

PROCEDURE:

1. The specimen is abraded against the linisher polisher to remove burs.
2. Then it is polished using the various grades of emery paper.
3. The specimen is fine polished in disc polisher using alumina powder as lubricant.
4. Then the specimen is washed thoroughly in water and then etched with ammonia and hydrogen oxide solution.
5. After etching the specimen is washed and dried for some seconds.
6. Now view the structure under microscope.

IDENTIFICATION:

The structure is equiaxed grains of alpha in a matrix of beta solid solution and the specimen is identified as **Brass (Copper alloy).** The black spots are due to shrinkage cavity formed during casting.

CHARACTERISTICS OF BRASS:

- Cast into moulds, into wires into sheets etc.
- Colour of brass changes from red to white, depending on the amount of zinc present.

APPLICATIONS OF BRASS:

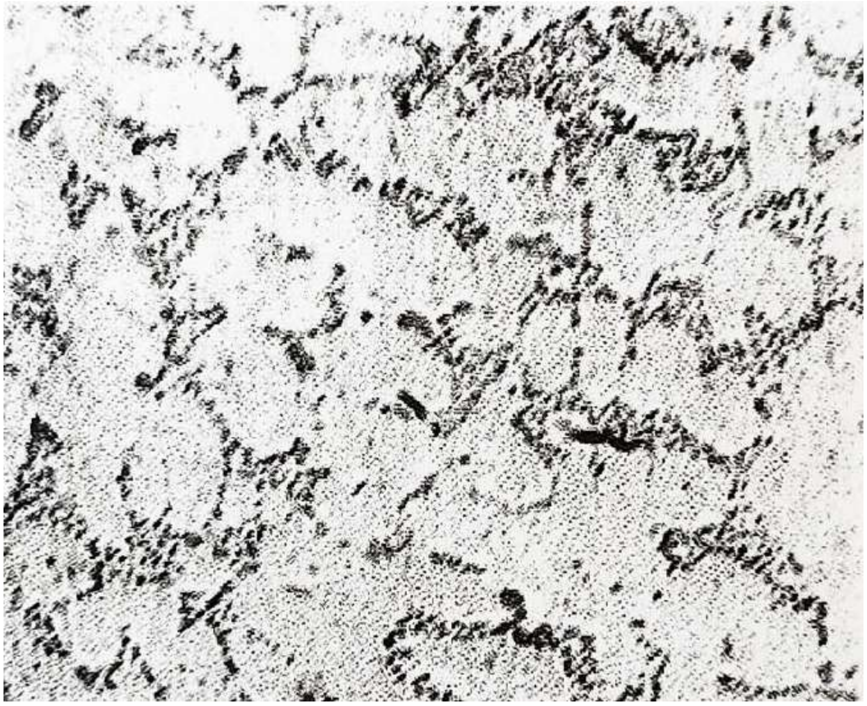
- Jewelleries
- Pumps, tubes Springs Screws

OBSERVATION:

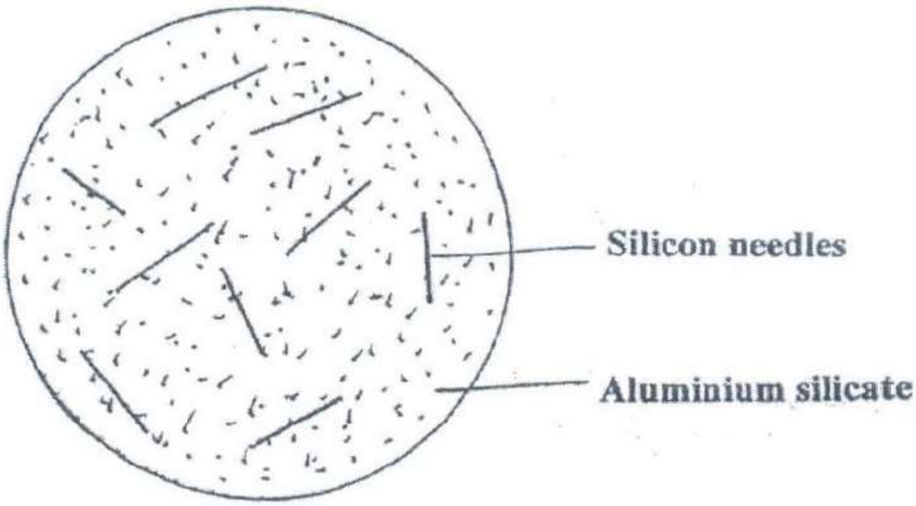
RESULT:

Thus the given specimen is identified as **Brass (Copper alloy)** and its characteristics and applications were studied.

ALUMINIUM ALLOY



Magnification: 100x ETCHANT: Hydrofluoric Acid



9. IDENTIFICATION OF ALUMINIUM ALLOY

AIM:

To identify the given specimen and to study the microstructure, characteristics and applications of it.

TOOLS REQUIRED:

- Linisher - polisher,
- Emery sheets,
- Disc polisher,
- Alumina powder,
- Etchant and
- Metallurgical microscope.

PROCEDURE:

1. The specimen is abraded against the linisher polisher to remove burs.
2. Then it is polished using the various grades of emery paper.
3. The specimen is fine polished in disc polishing machine using alumina powder as lubricant.
4. Then specimen is washed thoroughly in water and etched with hydrofluoric acid.
5. After etching the specimen is washed and dried for some seconds.
6. Now view the structure under microscope.

IDENTIFICATION:

The structure shows very fine grains of aluminium-silicon in a matrix of aluminium solid solution and the specimen is identified as **Aluminium alloy.**

CHARACTERISTICS OF ALUMINIUM ALLOY:

- Light weight
- High strength to weight ratio
- High reflectivity
- Non toxicity

APPLICATIONS OF ALUMINIUM ALLOY:

- Aeroplane parts
- Precision instruments
- Furnitures, electrical conductors
- Corrugated sheets, windows etc.

OBSERVATION:

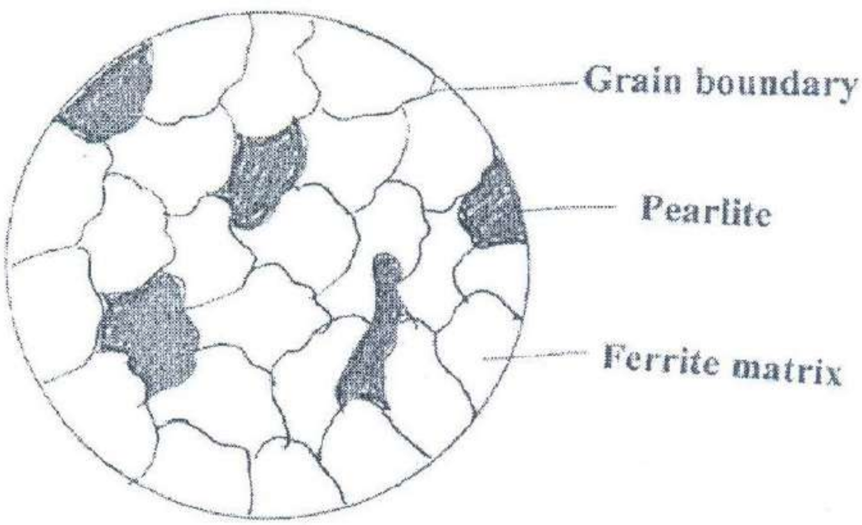
RESULT:

Thus the given specimen is identified as **Aluminium alloy** and its characteristics and applications were studied.

INDENTOR USED: ..……………..

SL. NO.	**HARDNESS VALUE (SCALE: ……...)**	
	BEFORE NORMALISING	**AFTER NORMALISING**
1		
2		
3		

NORMALISED PLAIN CARBON STEEL



Magnification: 675x

ETCHANT: Nital Solution

10. HEAT TREATMENT - NORMALISING

AIM:

To normalise the given plain carbon steel specimen.

TOOLS REQUIRED:

- Muffle furnace
- Hardness testing machine- Rockwell Hardness Machine
- Microscope

THEORY:

Normalising is one of the heat treatment processes in which the steel is heated above 800"C,holding the specimen at this temperature for a specified period of time followed by cooling it in still air to room temperature. The cooling rate is 30-50°C per minute. The resultant microstructure is Pearlite. Normalising refines the grains, improves sub-structure, hardness, strength, toughness and machinability with the release of residual stresses.

PROCEDURE:

1. Measure the hardness of given specimen in Rockwell hardness testing machine.
2. Put on the temperature controllable furnace.
3. When the temperature in furnace is 800°C keep the specimen inside it.
4. Allow the specimen to be in furnace for 15 - 20 minutes at 800°C temperature.
5. Put off the furnace and take the specimen out.
6. Cool the specimen for 30 - 60 minutes in air.
7. Measure the hardness again in Rockwell hardness testing machine.
8. Confirm the presence of Pearlite under microscopic view.

OBSERVATION:- BEFORE NORMALISING:

AFTER NORMALISING:

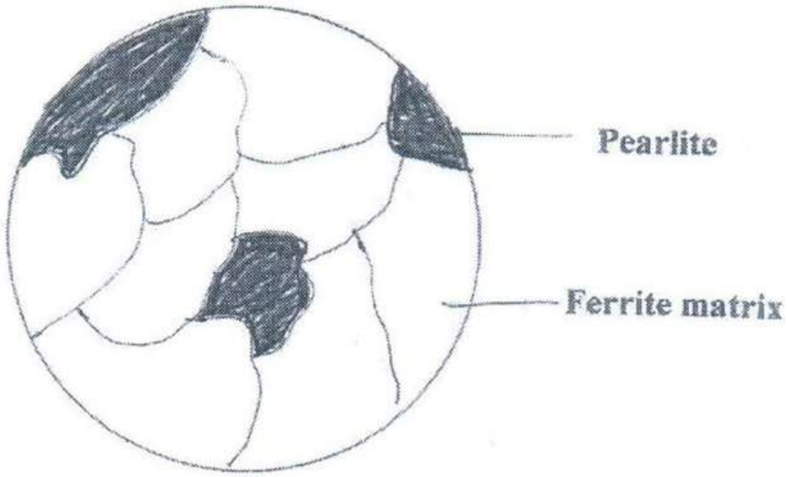
RESULT:

Thus the Normalizing- heat treatment process is carried out.

INDENTOR USED: ..……………..

SL. NO.	HARDNESS VALUE (SCALE: ……...)	
	BEFORE ANNEALING	AFTER ANNEALING
1		
2		
3		

ANNEALED PLAIN CARBON STEEL



Magnification: 675x ETCHANT: Nital Solution

11. HEAT TREATMENT - ANNEALING

AIM:

To anneal the given plain carbon steel specimen.

TOOLS REQUIRED:

- Muffle furnace
- Hardness testing machine- Rockwell Hardness Machine
- Microscope

THEORY:

Annealing is one of the heat treatment processes in which the steel is heated above 800°C, holding the specimen at this temperature for a specified period ohime followed by cooling it inside the furnace. The cooling rate is 20-30°C per minute. The resultant microstructure is Ferrite. As this transformation takes place inside the furnace, the cooling rate is very slow and hence it improves softness and ductility, relieves internal stresses, refines the grains and redistributes the dispersed phases i.e. uniformity of phase distribution is increased. It also improves machinability, electrical and magnetic properties. The annealing temperature depends on the percentage of carbon in steel.

PROCEDURE:

1. Measure the hardness of given specimen in Rockwell hardness testing machine.
2. Put on the temperature controllable furnace.
3. When the temperature in furnace is 800°C keep the specimen inside it.
4. Allow the specimen to be in furnace for 15 - 20 minutes at 800°C temperature.
5. Put off the furnace and Cool the specimen inside the furnace for 1- 2 hours.
6. Measure the hardness again in Rockwell hardness testing machine.
7. Confirm the presence of Ferrite under microscopic view.

OBSERVATION:- BEFORE ANNEALING:

AFTER ANNEALING:

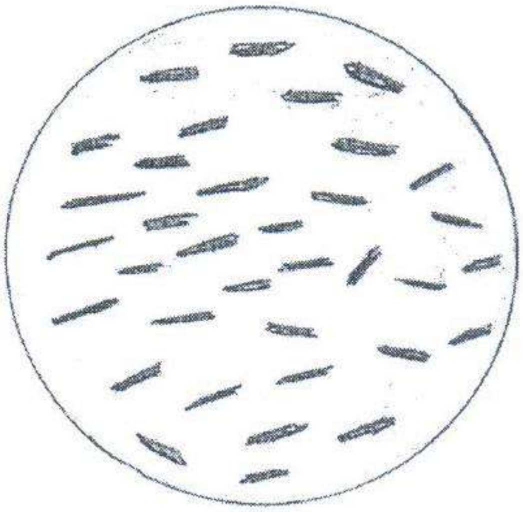
RESULT:

Thus the Annealing - heat treatment process is carried out.

INDENTOR USED: ..……………..

SL. NO.	HARDNESS VALUE (SCALE: ……...)	
	BEFORE HARDENING	AFTER HARDENING
1		
2		
3		

HARDENED PLAIN CARBON STEEL



Magnification: 675x ETCHANT: Nital Solution

12. HEAT TREATMENT - HARDENING

AIM:

To harden the given plain carbon steel specimen.

TOOLS REQUIRED:

- Muffle furnace
- Hardness testing machine- Rockwell Hardness Machine
- Microscope

THEORY:

Hardening is one of the heat treatment processes in which the steel is heated above 850°C, holding the specimen at this temperature for a specified period of time followed by cooling it by quenching the specimen in water. The cooling rate is 80-100°C per minute. The resultant microstructure is Martensite. The hardening is done to improve mechanical properties like strength, elasticity, ductility and toughness, to improve wear resistance and to develop high hardness.

PROCEDURE:

1. Measure the hardness of given specimen in Rockwell hardness testing machine.
2. Put on the temperature controllable furnace.
3. When the temperature in furnace is 850°C keep the specimen inside it.
4. Allow the specimen to be in furnace for 10- 15 minutes at 850°C temperature.
5. Put off the furnace.
6. Take the specimen and quench it by dipping in water.
7. Measure the hardness again in Rockwell hardness testing machine.
8. Confirm the presence of Martensite under microscopic view.

OBSERVATION:- BEFORE HARDENING:

AFTER HARDENING:

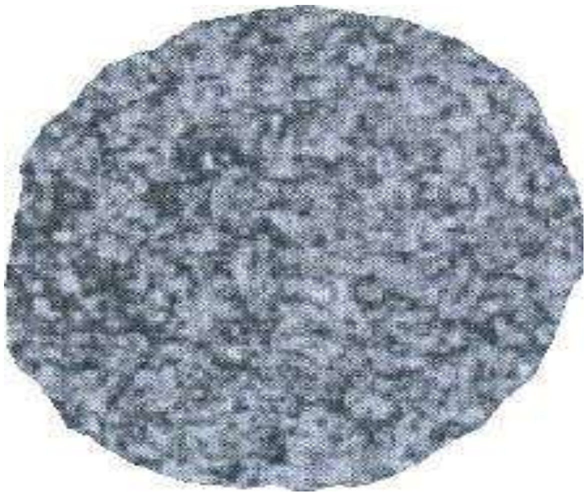
RESULT:

Thus the Hardening - heat treatment process is carried out.

INDENTOR USED: ..……………..

SL. NO.	HARDNESS VALUE (SCALE: ……...)	
	BEFORE TEMPERING	AFTER TEMPERING
1		
2		
3		

<u>TEMPERED MARTENSITE</u>



Magnification: 100x ETCHANT: Nital Solution

13. HEAT TREATMENT -TEMPERING

AIM:

To study the effects of Heat Treatment-Tempering process in the given hardened steel specimen.

TOOLS REQUIRED:

- Muffle furnace
- Hardness testing machine- Rockwell Hardness Machine
- Microscope

THEORY:

Steels that have undergone hardening by quenching are usually mixture of austenite and martensite, with later constituent predominating. Both of these structures are unstable and slowly decompose in to stable phases. Tempering of steel is a process in which previously hardened or normalized steel is usually heated to a temperature below the lower critical temperature (723°C) and cooled to room temperature at slow cooling rate. Tempering is done, primarily to increase ductility and toughness, to increase the grain size of the matrix, to relieve quenching stresses and to ensure dimensional stability. Tempering process would end in the conversion of martensite structure to cementite in the ferrite matrix.

PROCEDURE:

1. Measure the hardness of given specimen in Rockwell hardness testing machine.
2. Put on the temperature controllable furnace.
3. When the temperature in furnace is 550°C keep the specimen inside it.
4. Allow the specimen to be in furnace for 30 minutes at 550°C temperature.
5. Put off the furnace.
6. Take the specimen and quench it by dipping in water.
7. Measure the hardness again in Rockwell hardness testing machine.
8. Confirm the presence of cementite in the ferrite matrix under microscopic view.

OBSERVATION:- BEFORE TEMPERING:

AFTER TEMPERING:

RESULT:

Thus the effect of Heat Treatment-Tempering process in the given hardened steel specimen was studied.

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