3

Metallic Materials

Contents

3.1 Types of Metals

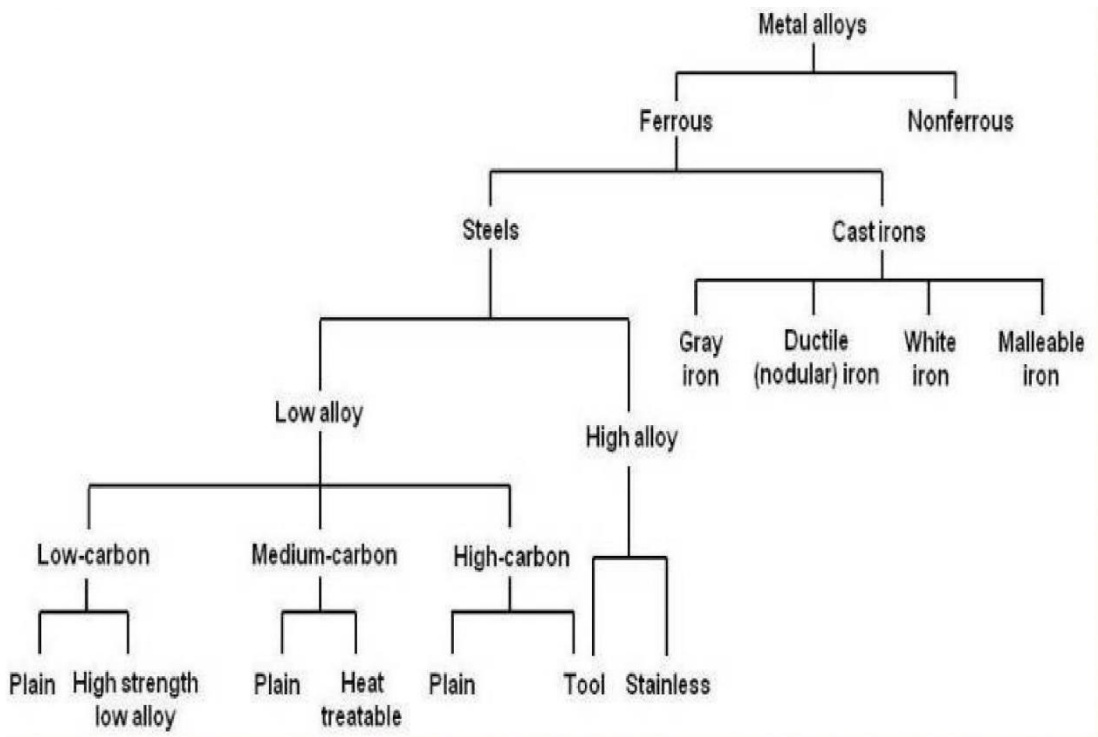


Fig.3.1 – Types of Metal

*Table **3.1** - Difference Between Ferrous and Non-ferrous Material*

Ferrous Material	Non Ferrous Material
Contain any amount of iron in its basic form	Does not contain any amount of iron in its basic form
Posses Magnetic property and make them prone to corrosion	They do not possess magnetic Property but resist corrosion much better than ferrous material
They have high tensile strength since they can carry a high amount of strain.	They have very low tensile strength.
They have the ability for oxidation, known as corrosion.oxidation of ferrous metals form as a reddish-brown deposit on the surface and is an oxide of iron.	They have typically lightweight higher melting point & are basically resistant to corrosion.
E.g. Pig iron, Cast iron, steel etc.	E.g. Cobalt, Aluminum, Zinc etc.

Non Ferrous Material

- Ferrous materials are those which contains iron as their main constituent whereas, non-ferrous materials are those which contains metals other than iron as their main constituent.
- Non-ferrous materials are most costly as compared to ferrous materials but they are widely used due to the following properties:
  - Good electrical and thermal conductivity
  - High corrosion resistance
  - Low-density o High ductility

- Ease of fabrication
- Non-magnetic in nature,

The important non-ferrous materials included

- Copper and its alloys
- Aluminium and its alloys
- Nickel and its alloys
- Bearing materials
- Titanium and its alloys
- Soldering and brazing alloys

3.2 Copper and its Alloys

- The alloys of copper are classified as brass and bronzes.
- Brasses are alloys of copper and zinc with small amount of other alloying elements. Bronzes are alloys of copper and any other alloying element but not zinc.

3.2.1 Brasses

Brasses are alloys of Copper and Zinc with small amount of other alloying elements.

3.2.1.1 Cartridge Brass (70 : 30 brass)

Composition

Zn - 30 % balance is Cu.

Properties

- It has high ductility and malleability.
- The microstructure in the cast form is dendritic.
- After cold working and subsequent annealing, its microstructure is observed to be equiaxed grains.

Applications

- Cartridge cases, radiator fins, headlight reflectors, lamp fixtures, rivets, springs, plumbing accessories, etc.

3.2.1.2 Admiralty Brass. (71:28:1 Brass)

Composition

Zn - 28 %; Sn - 1 %; balance is Cu.

Properties

- It has properties similar to cartridge brass.
- Addition of Sn improves corrosion resistance.

3.2.1.3 Muntz Metal (60 : 40 brass)

Composition

Zn - 40 %; balance is Cu.

Properties

- It becomes a single phase above 700 °C.

- They are hard and strong as compared to α -brasses.
- At high temperature, β has more ductility and malleability.
- Hence, it is usually hot worked, rolled and extruded.
- It has a tensile strength in the range of 35 to 40 kg/mm and hardness of 100 to 120 VPN.

Applications

- Pump parts such as valves, condenser tubes, shafts, nuts, bolts, utensils, brazing rods, etc.

3.2.1.4 Naval brass (60:39:1 brass)

Composition

Zn - 39 %; Sn - 1 %; balance is Cu.

Properties

- It has properties similar to Muntz metal.
- Addition of Sn improves corrosion resistance.
- It 1s used m marine environment, hence called Naval Brass.

Applications

- Marine hardware, propeller, piston rods,
- welding rod, nuts and bolts, water taps, etc.

3.2.2 Bronze

- Bronzes are alloys of Copper and any other major alloying element but not Zinc (such as Al, Be, Sn, etc.).
- Bronzes sometimes also contain zinc but in small proportion to take advantage of its properties.

The major bronzes that are

1. Al-Bronze
2. Sn-Bronze
3. Be-Bronze
4. Si-Bronze

3.2.2.1 Aluminium - Bronze (AI - Bronze)

- Aluminium bronzes are alloys wherein, Copper is the base metal and Aluminium is the major alloying element.
- The solubility of Aluminium in Copper increases with decrease in temperature.
- The solubility of Aluminium in Copper is 7.4 % at 1040 ˚Cand it increases to 9.4 % at 565 °C.
- Commercial Al-Bronzes contain Aluminium in the range of 4 to 11 %.
- In addition alloying elements such as Fe, Ni, Si, Zn, Mn, etc. are added for improvement of certain properties.
- Al-Bonzes are also referred to as imitation gold due to their lustrous finish, golden colour and fine polishing.

Properties of Aluminium

- Its specific weight is only 2.7 gm/cm3 compared to 7.8 gm/cm3 for steel and 8.8 gm/cm3 for copper.
- Its electrical conductivity is about 60 % of that of copper.
- It has high thermal conductivity.

- It has high corrosion resistance because of oxidation and formation of protective Al203 layer.
- It has a great affinity for oxygen.
- It is non-magnetic.

3.2.2.2 Tin – Bronze

- Tin bronzes are alloys wherein, Copper is the base metal and Tin is the major alloying element.
- The solubility of tin in copper varies with the temperature and is higher in the temperature region of 350 °C to 798 °C.

Some of the important Tin-Bronzes alloys

1. Gunmetal

Composition

Cu - 88 %; Sn - 10 %; Zn - 2 %

Properties

- Zinc is used as a de-oxidizer.
- Zinc also improves fluidity.
- It has excellent corrosion resistance.

Applications

- Gun barrels and gears, bearings, valve bodies, etc.

2. Silicon - Bronze

- Silicon bronzes are alloys wherein, Copper is the base metal and Silicon is the major alloying element.
- The maximum solubility of Silicon in Copper is 5.3 % at 845 and decreases to less than 4 % at room temperature.
- The composition of typical Silicon-Bronze is :

  Cu - 94.5 to 99 %; Si - 1 to 5.5 %.
- These bronzes have high corrosion resistance, tensile strength and toughness.
- They can be further cold worked to improve mechanical properties.
- They can also be hot worked and even be used for casting.
- They are cheaper than Sn-Bronzes.
- Other alloying elements that are added to Si-Bronzes include Mn, Zn, Sn, Pb and Fe.
- These alloying elements improve mechanical properties.

Applications

- High strength bolts, rivets, springs, pressure vessels, marine containers, propeller shafts, bells, etc.

3. Beryllium - Bronze (Be - Bronze)

- The solubility of beryllium in copper is 2.1 % at 864 °C and decreases further to 0.25 % at room temperature.
- This drastic change in solubility gives rise to precipitation hardening.
- The precipitation cycle consists of heating the alloy at around 800°C and quenching in water.
- This is followed by further heating from 300 to 320°C for a couple of hours to accelerate ageing treatment.

- Be-Bronzes have good corrosion and fatigue resistance.
- They have high resilience and good bearing properties.
- They have low hysteresis and non-sparking characteristics.

Applications

- Springs, diaphragms, flexible bellows, gears, bearings, non-sparking tools, etc.

3.3 Aluminium and its Alloys

- Aluminium is one of the most widely used non-ferrous metals.

The important properties of Aluminium are

- It is ductile and malleable due to its F.C.C. structure.
- Its specific gravity is only 2.7 gm/cm3 compared to 7.8 gm/cm3 of steel and 8.8 gm/cm3 of copper.
- Its electrical conductivity is about 60 % of that of copper.
- It has high thermal conductivity.
- It has a tendency to form non-toxic aluminium oxide AL203, which provides high corrosion resistance.
- It is non-magnetic and non-sparking in character.
- It is a powerful de-oxidizer and used for de-oxidation of steel forming killed steel.

Some important Aluminium alloys

- Aluminium can be easily alloyed with elements such as Si, Mg, Cu, Ni, Zn, Mn, Fe and Ti. Aluminium alloys are designated by LM series.

3.3.1 Aluminium - Copper Alloys (AI-Cu)

Duralumin

Composition

Al - 94.5 %; Cu - 4.5 %; Mg - 0.5 %; Mn-0.5%

Properties

- It produces good strength after precipitation hardening.
- It has good mechanical and shock resisting properties.
- It also has good corrosion resistance.

Applications

- Aircraft industry.

3.4 Nickel and its Alloys

The important properties of Nickel are

- It has an F.C.C. structure.
- It has good ductility and malleability.
- It exhibits good resistance to corrosion and oxidation.
- It has fairly good electrical conductivity.
- It has better formability.

- It is chemically inert hence used for electroplating.
- It is highly used in the production of stainless steel, nickel alloys, magnets, etc.

3.4.1 Monel Metal

Composition

Ni - 64 %; Cu - 30 %; Si - 2 %; small amount of other elements.

Properties

- It has good casting properties.
- It has high corrosion resistance.

Applications

- Marine casting parts, valve seats, pump liners, etc.

3.4.2 Invar

Composition

Ni - 36 %; Fe - 64 %

Properties

- Invar means invariable.
- It has the lowest coefficient of thermal expansion.
- It has good resistance to corrosion.

Applications

- Length standards, measuring tapes and instruments such as scales, verniers, etc.
- Variable condensers, special springs, etc.

3.4.3 Inconel

Composition

Ni- 77 %; Cr- 15 % ; Fe - 8 %

Properties

- It has good corrosion and oxidation resistance.
- It maintains good strength at elevated temperatures.
- It can withstand repeated heating and cooling cycles.

Applications

- Heaters, furnace parts, carburizing containers, thermocouple covering tubes, exhaust manifolds of aero engines, mufflers, etc.

3.5 Bearing Materials

- Bearing materials are anti-friction materials used as rotating shaft holders or supporters.
- These shaft holders or supporters transmit loads to a shaft rotating relative to the bearing.
- Bearings are required in various applications such as machinery, engines, reciprocating parts, etc.

Bearings are classified as

1. Sliding contact bearings
2. Rolling contact bearings
3. thrust bearings

Requirements of Bearings

- A properly lubricated bearing should ensure a film of oil in between the moving parts, under all working conditions.
- However, during starting, stopping and severe running conditions, it is difficult to maintain the oil film.
- This results in metal-to-metal contact causing wear and subsequent seizure of the bearing.
- To avoid such a seizure, the following properties are essential for a good bearing:
    1. The bearing and rotating parts should have the least friction to reduce power loss in transmission.
    2. The bearing material should be hard and wear-resistant for longer life.
- It should have adequate mechanical properties and load-bearing ability at ambient and elevated temperatures.
- It should have enough plasticity and deformability to sustain large deflection and misalignment of the shaft.
- It should possess high fatigue strength.
- It should have good resistance to corrosion, galling and seizing.
- It should possess better thermal conductivity to dissipate the frictional heat generated during working.
- It should be able to retain oil on the bearing surface.
- It should have good machinability.
- It should be cheap and easy to service.

3.5.1 White Metal Alloys (Babbitt Material)

Composition

Lead-based Babbitts

Pb - 80 %; Sb - 10 %; Sn - 10 %; small amount of Cu, Cd and As.

Tin - based Babbitts

Sn - 90 %; Sb - 5 %; Cu - 5 %; small amount of Pb and As.

Properties

- During solidification, Sn-Sb combines early and forms hard cuboids.
- These hard cuboids float on the surface of the material, while the internal microstructure consists of a soft matrix of eutectic.
- This makes the bearing hard at the surface and soft from within.

Applications

- Bearings of I.C. engines, lathe machine, milling machine, electric motors, etc.

3.6 Fracture of Materials

- Fracture is considered as the end result of the plastic deformation process
- Fracture is the separation or fragmentation of a solid body under stress into two or more parts/pieces. Separation of the body (i.e. fracture) is caused either by physical-mechanical or chemical force

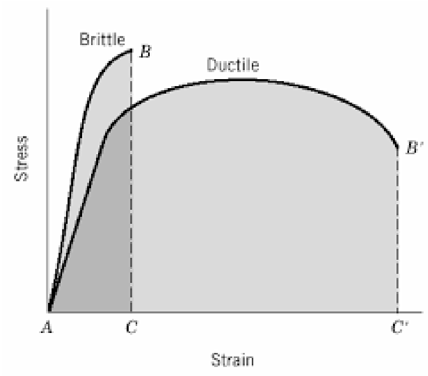


Fig.3.2 – Ductile and Brittle fracture

- Fracture results in the creation of new surfaces
- A fracture can occur under all service conditions
- Study of characteristics of various fractures is useful for preventing failure during service which is the most important problem faced by the engineers in their Field.

Process of Fracture consists of two-phase/ components

1. Crack initiation &
2. Crack propagation.

- The mode of fracture is very much dependent on the mechanism of crack Propagation. Sub-Microscopic crack develops preferably along slip plane of grain or at a sharp edge, inclusion, blowholes, porosities, etc.
- All these are the potential sites for stress concentration under the dynamic condition of loading, and allow the crack ti propagate once initiated in the alloy.

Types of Fracture

1. Brittle fracture,
2. Shearing fracture.
3. Completely ductile fracture &
4. Ductile fracture.

   there are different modes of fracture of materials but the actual mode of fracture is determined by a number of factors, such as

   - crystal structure of the material,
   - it's purity,
   - its mechanical, metallurgical & thermal properties,
   - temperature
   - design of the component,
   - the state of stress,
   - the rale of loading, and
   - by the environmental conditions under which it is loaded.

   Various fracture mechanisms are:

   1. Ductile fracture 2. Brittle fracture 3. Fatigue fracture and 4. Creep fracture

1. Ductile Fracture

- When a metal is subjected to load above the yield point and the process of deformation continues, fracture eventually occurs.
- Ductile fracture is characterized by appreciable plastic deformation prior to and during the propagation of the crack. A sufficient amount of gross deformation is usually present at the fractured surface.

- Another important feature of ductile fracture is that it occurs by a slow tearing of the metal with the expenditure of considerable energy.
- Many varieties of ductile fractures can occur during the processing of metals and their use in different services.

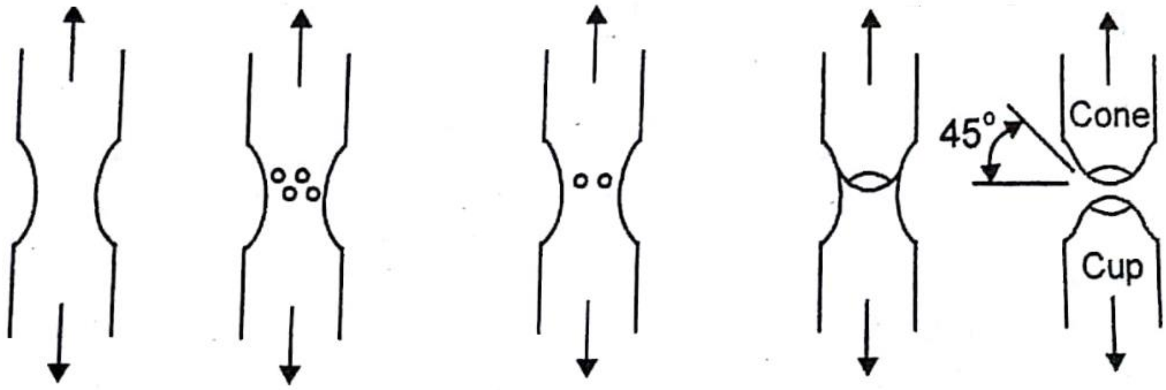


Fig.3.3 – Ductile Fracture Mechanism

- Ductile fracture in tension is usually preceded diameter called necking.
- Highly ductile metals may actually draw down separation.
- Under tensile load, the neck termination takes place after crossing ultimate strength some fine cavities are formed in the necked region as the metal is pulled away from the weak interface. This occurs at the maximum load.
- As necking (reduction in area) proceeds, many small cavities form of at the centre the necked region and under continued straining, they grow or expand by, plastic deformation and coalesce into a centre crack.
- This crack grows in a direction perpendicular to the axis of the specimen, then r: propagates along localized shear pra.nes at approximately 45° to the axis to form the cone part (the other part being called as a cup)of, the fracture and lastly leads to a fracture.
- Ductile fracture normally occurs through the grains. The failure of most ductile materials in the polycrystalline form occurs with a cup-&-cone fracture.
- Ductile fractures are very important in metalworking processes, such as deep drawing, forging, etc. These can easily be observed in metals with FCC crystal structure.

2. Brittle Fracture (Cleavage Fracture)

- Brittle fracture is characterized by a rapid rate of crack propagation with minimum energy absorption and no gross deformation or having little micro deformation.
- The brittle fracture occurs by separation normal to tensile stress
- In this case, there is no gross deformation and very little mass deformation Here, the movement of crack involves very little plastic deformation of the metal adjacent to the crack.
- It may occur at stresses well below the yield strength, in the case of materials. subjected to impact or shock loads and .usuaily without warning.
- Brittle fractures are most likely to take place in large_size components, structures as a result of shock loading.
- Brittle fracture in crystalline materials occurs usually along characteristic crystallographic planes called cleavage planes. It shows a granular appearance which is called cleavage fracture.
- This happens when bonds are broken perpendicular to the fracture plane/cleavage plane.

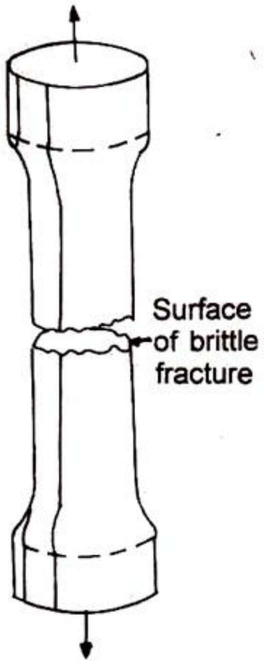


Fig.3.4 – Brittle Fracture

3. Shearing Fracture

- A shearing fracture occurs as the result of extensive slip on the active slip plane. It is promoted by shear stresses.
- single crystal of HCP. metals may slip on successive basal planes finally the crystal (0001) until separate by shear.
- such a slip determination takes place as a result of the movement of dislocations on the basal planes of HCP crystals.

4. Fatigue Fracture

- when metal parts are subjected to a repetitive or fluctuating stresses they fail ar much lower stress than required to cause fracture on a single application of load.
- Fatigue failure is particularly dangerous as it occurs suddenly without any prior warning; i.e it refers to premature failure under action of repeated stresses or dynamic loading.
- It appears to be inherent in most engineering materials and often leads to catastrophic failure.
- Thus, fatigue is a general term used to describe the behaviour of metals under repeated cycles of stress or load which spoils the strength & ductility properties of them resulting in a progressive structure.
- All rotating parts, e.g axles and crankshafts subjected to alternating stresses; aircraft wings subjected to repeated gust load; Ship hulls & floor beams of bridges are subjected to fatigue, and piping, etc. are also subjected to fatigue through temperature variations and consequent cyclic thermal stresses.
- The increased use of plastics for machine parts such as gears & bearings creates a new problem in fatigue.

3.7 Micro- and Macro-Examination

Sr. No.	Micro-Examination	Macro-Examination
1.	Micro-examination or micrography involves the study of the structures of metals and their alloys under a microscope at magnifications from X20 to X2000. The observed structure is called the microstructure.	Macro-examination involves the study of the structure of metals and their alloys by the naked eye or by low power magnification up to X15. The observed structure is called the Macrostructure
2.	Micro-examination involves much smaller areas and brings out information which can never be revealed by low magnification.	Macro-examination gives a broad picture of the interior of metal by studying relatively large sectioned areas.
3.	The aim of micro-examination is – To determine the size and shape of the crystallites which constitute an alloy. – To reveal structures characteristic of certain types of mechanical working operations. – To discover micro defects – To determine the chemical content of alloys – To indicate the quality of heat treatment, mechanical properties.	The aim of macro-examination is – To reveal the size, form and arrangement of crystallites. – To reveal fibres in deformed metals. – To reveal shrinkage porosity and gas cavities – To reveal cracks appearing during certain fabrication processes. – To show chemical no homogeneity in the distribution of certain constituents appearing in alloys upon their solidification from the liquid state.
4.	Micro-examination requires proper surface preparation of the specimen before studying it under the microscope.	Surface preparation for macro examination follows similar lines to those for micro examination but need not be taken to such a high degree of surface finish and so the final stages of polishing can be omitted.
5.	Micro-examination requires that the polished specimen surface should be etched with a suitable reagent.	Macro-examination is also carried out on an etched surface. Various Etching Reagents For Steel Nitric acid 25 CC Water 75 CC

3.8 Specimen Preparation

- Specimen preparation or polishing is necessary to study its microstructure because the metallurgical microscope discussed earlier makes use of the principle of reflection of light (from the specimen) to obtain the final image of the metal structure.
- Satisfactory metallographic results can be obtained only when the specimen has been carefully prepared. Even the most costly microscope will not reveal the metal structure if the specimen has been poorly prepared.
- The procedures for preparing the specimen both macro and micro-examination is the same, except that in the latter the final surface finish is more important than in the former.

1. Selection of specimen. When investigating the properties of a metal or alloy, it is essential that the specimen should be selected from that area (of the alloy plate or casting) which can be taken as representative of the whole mass.
2. Cutting of the specimen. After selecting a particular area in the file mass, the specimen may be removed with the help of a saw, a. panning tool, an abrasive wheel, etc.
3. Mounting the Specimen. If the specimen is too small to be held in hand for further processing, it should be mounted in thermoplastic resin or some other low melting point alloy.

4. Obtaining Flat Specimen Surface. It is first necessary to obtain a reasonably flat surface on the specimen. This is achieved by using a fairly coarse file or machining or grinding, by using a motor-driven emery belt.
5. Intermediate and Fine Grinding. Intermediate and fine grinding is carried out using emery papers of a progressively finer grade.

   - The emery papers should be of very good quality in respect of uniformity of particle size. Four grades of abrasives used are 220 grit, 320 grit, 400 grit and 600 grit (from coarse to fine); the 320 grit has particle sizes (of the silicon carbide) as about 33 microns and 600 grit that of 17 microns (1 micron = 10-4 cm).
   - The specimen is first ground on 220 grit paper so that scratches are produced roughly at the right angle to those initially existing on the specimen and produced through preliminary grinding or coarse filing operation. Having removed the primary grinding marks, the specimen is wash free of No. 220 grit. Grinding is then continued on the No. 320 paper, again turning the specimen through 900 and polishing until the previous scratches marks are removed. The process is repeated with the No. 400 and No. 600 papers. Grinding with the No. 200, No. 320, etc., papers could be done in the following ways:

a. The specimen may be hand-rubbed against the abrasive paper which is laid over a flat surface such as a piece of the glass plate.
b. The abrasive paper may be mounted on the surface of a flat, horizontally rotating wheel and the specimen held, in the hand, against it. In either case, the surface of the abrasive paper (with a waterproof base) shall be lubricated with water so as to provide a flushing action to carry away the particles cut from the surface.

6. Rough Polishing. A very small quantity of diamond powder (particle size about 6 microns) carried in a paste that is oil-soluble is placed on the nylon cloth-covered surface of a rotating polishing wheel. The lubricant used during the polishing operation is specially prepared oil. The specimen is pressed against the cloth of the rotating wheel with considerable pressure and is moved around the wheel in the direction opposite to the rotation of the wheel to ensure a more uniform polishing action.
7. Fine Polishing. The polishing compound used is alumina (Al2O3) power (with a particle of 0.05 microns) placed on a cloth-covered rotating wheel. Distilled water is used as a lubricant. Fine polishing removes fine scratches and very thin distorted layer remaining from the rough polishing stage.
8. Etching. Even after fine polishing, the granular structure in a specimen usually cannot be seen under the microscope; because grain boundaries in metal have a thickness of the order of a few atom diameters at best, and resolving power of a microscope is much too low to reveal their presence. In order to make the grain boundaries visible, after fine polishing the, metal specimens are usually etched. Etching imparts unlike appearances to the metal constituents and thus makes metal structure apparent under the microscope.

Before Etching, the polished specimen is thoroughly washed in running water. Then, the etching is done either by

- Immersing the polished surface (of the specimen) in the etching Reagent or by
- Rubbing the polished surface gently with a cotton swab wetted with the Etching Reagent.

After etching, the specimen is again washed thoroughly and dried.

3.9 Macro Etching

The macro etching is the procedure in which a specimen is etched and evaluated macro structurally at low magnifications. It is a frequently used technique for evaluating steel products such as billets, bars, blooms, and forgings. There are several procedures for rating a steel specimen by a graded series of photographs showing the incidence of certain conditions and is applicable to carbon and low alloy steels. A number of different etching reagents may be used depending upon the type of examination to be made. Steels react differently to etching reagents because of variations in chemical composition, method of manufacturing.

Etching Reagents for Microscopic Examination

*Table **3.2** - Etching Reagents for Microscopic Examination*

Sr. No.	Type of Etchant	Composition		Uses
1.	Nital	i. Cone, Nitric acid ii. Absolute methyl alcohol	2 CC 98 CC	For etching steels, grey cast
2.	Aci ammonium persulphate	i. Hydrochloric acid ii. Ammonium persulphate iii. Water	10 CC 10 gms 80 CC	For etching stainless steels
3.	Ammonia hydrogen peroxide	i. Ammonium hydroxide (0.880) ii. Hydrogen peroxide(3% solution) iii. Water	50 CC 20-50 CC 50 CC	The best general etchant for copper, brasses and bronzes.
4.	Dilute hydro- fluoric acid	i. Hydrofluoric acid ii. Water	0.5 CC 99.5 CC	A good general etch-ant for Al and its alloys
5.	Keller's reagent	i. Hydrofluoric acid ii. HCI iii. HNO3 iv. Water	1 CC 1.5 CC 2.5 CC 95 CC	For etching of Duralumin type alloys
6.	Mixed nitric and Acetic acids	i. Nitric acid ii. Glacial acetic acid	50 CC 50 CC	A good general etchant for Al and its alloys

3.10 Sulphur Print

- Sulphur present in steel is in the form of FeS, which has a low melting point. Presence of FeS makes steel 'hot short' segregation of Fe S is detrimental to the properties of steel.
- The distribution of sulphides, in the cross-section prepared, can be found out by sulphur print however estimation of sulphur content is not possible by sulphur print. Sulphur print provides a permanent record of sulphide distribution.

The procedure of sulphur print

- The surface under consideration is polished by 0 and 00 emery papers and then washed under tap water.

- Photographic bromide paper is soaked in 2Vo aqueous solution of sulphuric acid for the duration of 5 to 10 minutes.
- The emulsion side of photographic paper soaked with sulphuric acid is brought in close contact with the polished steel surface to be studied.
- The contact time maybe 3 to 4 minutes. A roller is used to make close contact between paper and surface.
- Sulphur printing involves following reactions.

i) $FeS + H_2SO_4 \rightarrow FeSO_4 + H_2S$

(From Steel) (On Photographic paper)

or

$MnS + H_2S \rightarrow MnSO_4 + H_2S$

(From Steel) (On Photographic paper)

ii) $H_2S + 2AgBr \rightarrow Ag_2S + 2HBr$

(Emulsion on Photographic Paper) (Create Dark Brown Spot on Photographic Paper)

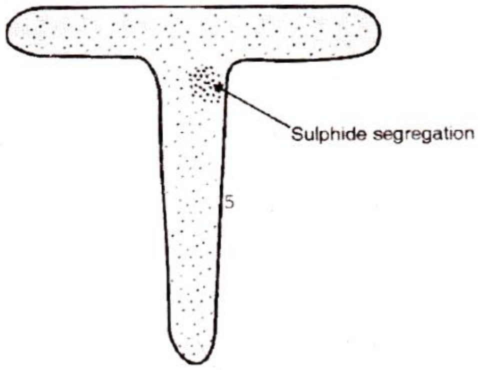


Fig.3.5 - Sulphur Print

- The photographic paper is then removed from the polished surface and washed thoroughly under tap water.
- The photographic paper is then fixed by dipping it in sodium thiosulphate for 15 minutes to create the permanent record
- The entire process of sulphur print is carried out in daylight

3.11 Spark Test

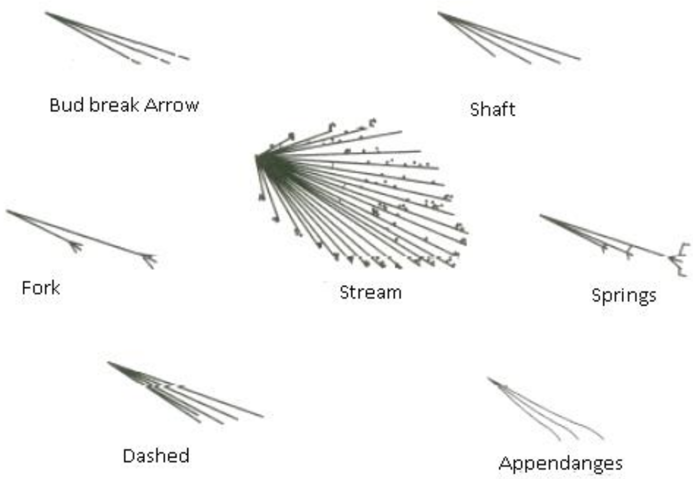
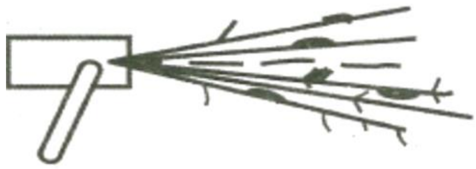
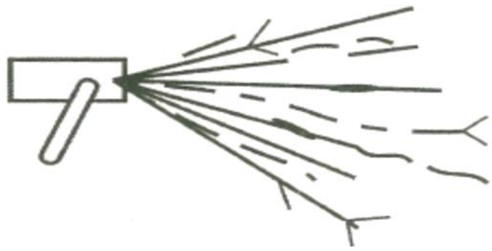
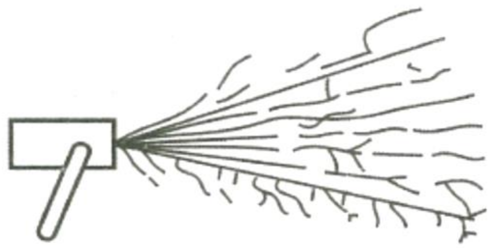
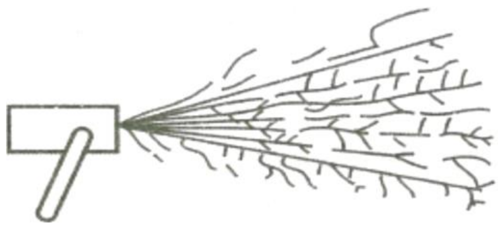


Fig.3.6 - Types of Sparks

- Spark test can be considered as macro examination as the inspection is carried out by unaided eyes.
- This test is useful in sorting the steels according to their chemical composition by observing the spark struck by the steel when brought in contact with rotating abrasive wheel such as a grinder. Estimation of contents of constituent elements is not possible by spark test.

Table 3.3 - Result of Spark Tests

Sr.No.	**Grade of Steel or Cast iron**	**Types of Spark**	**Spark**
1.	Pure iron or wrought iron	It shows only forked rays with yellow colour.	
2.	Plain carbon steel	Yellow forked rays with white stars	
3.	Medium carbon steel	Yellow sparks, finer and more feathery Shorter than plain carbon steel	
4.	High carbon steel	Less bright sparks. More feathery and have secondary branches.	
5.	Cast iron	Faint red spark ends with bushy yellow sparks.	
6.	Grey cast iron	Red to straw yellow colour. Many springs are small and repeated.	

- When steel is brought in contact with rotating abrasive wheel, due to friction between both steer particles become loose. These hot particles (due to generated heat) move away in from the wheel in a trajectory called 'carrier lines'.
- Hot steel particles following carrier lines contain carbon. Carbon in particles reacts with oxygen in the air to form CO2. This reaction develops the internal pressure within the particles and makes them explode. An explosion is expressed as burst or spurt.
- The following fig.3.6 shows various types of sparks.
  The sorting of steel from another is possible because
    a. Carrier lines for different steels vary in number, length, breadth and colour.
    b. Bursts for different steels have a difference in number shape and intensity.

3.12 Chemical Analysis of Iron for Carbon, Sulphur & Phosphorous

- Carbon is the principal alloying element of steels and largely influences the properties of steels. carbon in steels is in combined form.
- Following are widely used methods of carbon estimation of steels chemical analysis.
  a. Carbon by combustion: suitable for carbon content determination in all types of steels.
  b. Eggert Method: suitable for carbon content determination in plain carbon and low alloy steels.
  c. Carbon by combustion

a. Carbon by Combustion

- Principle: oxidation of carbon is effected by combustion at high temperature in a regulated oxygen stream that converts carbon into carbon dioxide. Carbon dioxide is made free of sulphur gases and moisture' carbon dioxide, then, is absorbed in solid absorbent. Difference between the final weight of absorbant (after co2 is absorbed) and initial weight of solid absorbent (before co2 is absorbed) is a measure of the carbon content of the steel. Reagents used:
    i. Soda asbestos-Absorbant (L2 to30 mesh grade)
    ii. Anhydrous - i.e. Magnesium perchlorate
    iii. Chromic - Sulphuric acid solution

Procedure

- Maintain the furnace temperature of the furnace at 1080°C for carbon steel samples and around 1150°C for high/alloy steels.
- Regulate the flow of oxygen B2E ml/min and note manometer level Keeping Nesbitt bulb in assembly.
- Detach Nesbitt bulb and weigh it.
- By attaching the bulb again continue for 10 minutes and again take the weight. Continue weighing at every 10-minute interval until a constant weight is obtained.
- Measure 2.729 gms of clean steel trimmings or drillings and transfer to previously ignited combustion boat.
- Place pure assay grade lead foil on the top of the sample (lead accelerates the combustion of carbon). To make lead foil carbon-free it is washed ln ether and then dried.
- Allow the oxygen stream to pass through the safety valve, E, weighed Nesbitt bulb at', place the boat containing steel into the hot zone of combustion tube and readmit the oxygen supply to the combustion tube.
- Combustion starts after one minute and is indicated by reduced oxygen flow through sulphuric acid tubes. Continue combustion for 5 more minutes, detach Nesbitt bulb and weigh it.
- The increase in weight of Nesbitt bulb is a measure of coz absorbed.
- If factor weight i.e. 2.72 Gms of steel is taken, the weight of coz is multiplied by 10 to get a percentage of carbon.

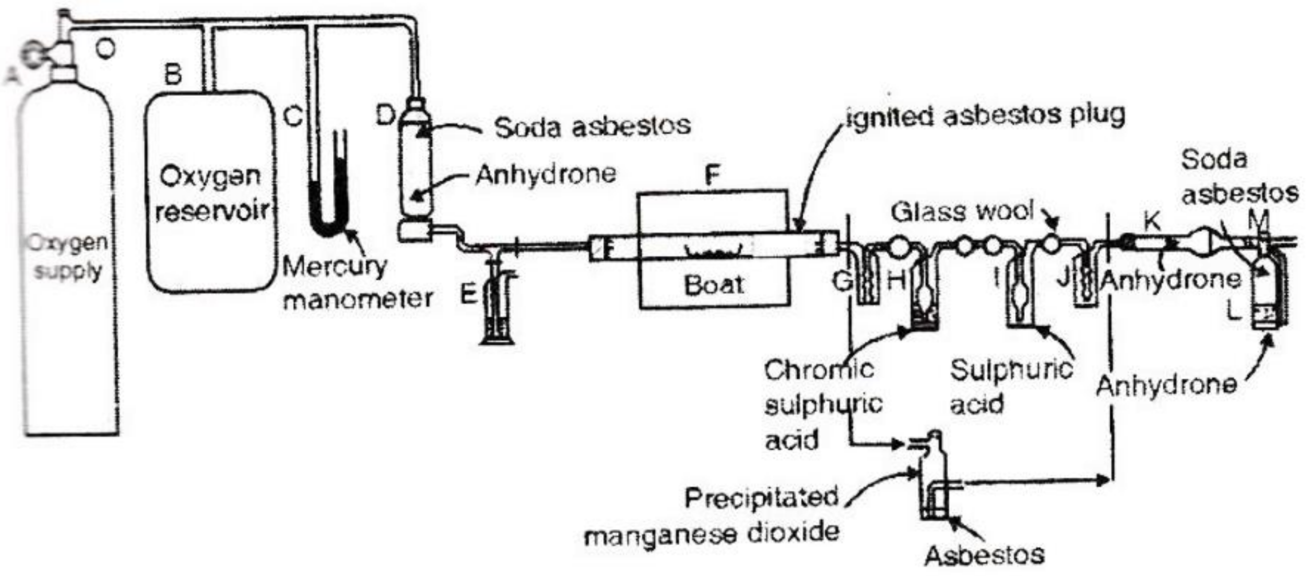


Fig.3.7 - Apparatus for Carbon by Combustion

b. Eggert Method For Carbon Estimation In Steel

- Principle: When steels are treated with dilute Nitric acid, combined carbon from steel forms a nitrated compound, brown in colour. The intensity of the brown colour of this compound is proportional to the carbon content of the steel. The intensity of brown colour formed by steel sample is then compared with that of standard specimen and conclusion is arrived at.
- 3 to 5 ml of dilute HNO3 with sp. gravity 1.2 is slowly added to 0'1 gm. of steel samples.
- Slow addition is recommended at earlier stages of HNO3 additions in order to avoid a violent reaction.
- Heat in a water bath and occasionally shake if bubbling is observed.
- Stop heating when steel is completely dissolved.
- Remove from the water bath and allow the solution to cool.
- Take 0.1 gm. of standard steel of similar carbon content and treat similarly to obtain the solution. (It generally takes 20 to 30 min)
- Compare the colours of both solution by taking them in Eggertz tubes after necessary dilution with water.
- Quantities recommended for different steels.
- 0.2 gm. for low carbon steels
- 0.1 gm. for medium carbon steels
- 0.05 gm. for high carbon steels

3.13 References

O. P. Khanna “Material Science and Metallurgy” Dhanpat Rai Publications.