3. FERROUS AND NON FERROUS ALLOYS

STEELS:

The iron–carbon alloys that contain between 0.008 and 2.14 wt% C are classified as steels. The mechanical properties are sensitive to the content of carbon. Some of the more common steels are classified according to carbon concentration as low carbon steels, medium carbon steels and high carbon steels.

Classification of Steels:

By Method of Manufacture:

- Crucible Steel,
- Bessemer steel,
- Open-hearth Steel,
- Basic Oxygen Steel and Electric-furnace Steel.

By Use:

- Machine Steel,
- Spring Steel,
- Boiler steel,
- Structural Steel or Tool Steel.

By Chemical Composition:

A numbering system is used in classification by chemical composition method (AISI, SAE etc.)

By the Carbon Content:

- Low-carbon steels: up to 0.30 percent carbon
- Medium-carbon steels: 0.30 to 0.60 percent carbon
- High-carbon steels: above 0.60 percent carbon

Classification of Steels

Low carbon steels:

Of all the different steels, those produced in the greatest quantities fall within the low-carbon classification. These generally contain less than about 0.25 wt% C and are unresponsive to heat treatments intended to form martensite; strengthening is accomplished by cold work. Microstructures consist of ferrite and pearlite constituents. As a consequence, these alloys are relatively soft and weak but have outstanding ductility and toughness; in addition, they are machinable, weldable, and, of all steels, are the least expensive to produce. Typical applications include automobile body components, structural shapes (I-beams, channel and angle iron (L-shaped)), and sheets that are used in pipelines, buildings, bridges, and tin cans. They typically have a yield strength of 275 N/mm^2, tensile strengths between 415 and 550 N/mm^2.

Medium carbon steels:

The medium-carbon steels have carbon concentrations between about 0.25 and 0.60 wt%. These alloys may be heat treated by austenitizing, quenching, and then tempering to improve their mechanical properties. They are most often utilized in the tempered condition, having microstructures of tempered martensite. The plain medium-carbon steels have low hardenabilities and can be successfully heat treated only in very thin sections and with very rapid quenching rates. Additions of chromium, nickel, and molybdenum improve the capacity of these alloys to be heat treated, giving rise to a variety of strength–ductility combinations. These heat-treated alloys are stronger than the low-carbon steels, but at a sacrifice of ductility and toughness. Applications include railway wheels and tracks, gears, crankshafts, and other machine parts and high-strength structural components calling for a combination of high strength, wear resistance, and toughness.

High carbon steels:

The high-carbon steels, normally having carbon contents between 0.60 and 1.4 wt%, are the hardest, strongest, and yet least ductile of the carbon steels. They are almost always used in a hardened and tempered condition and, as such, are especially wear resistant and capable of holding a sharp cutting edge. The tool and die steels are high-carbon alloys, usually containing chromium, vanadium, tungsten, and molybdenum. These alloying elements combine with carbon to form very hard and wear-resistant carbide compounds (e.g., $Cr_{23}C_6$ – chromium carbide, V_4C_3 – Vanadium carbide, and WC- tungsten carbide).

<u>Effect of minor constituents on the properties of steel</u>

Manganese:

- Deoxidizer- Reacts with oxygen in ferrous oxide and joins in slag
- Removes harmful FeS
- Improves strength by forming solid solution in ferrite

•Reduces red-shortness- brittleness at high temperatures

•Ranges from 0.5 -0.8%

Silicon:

•Deoxidizer

•Forms solid solution with ferrite – increases yield point

•Ranges from 0.35-0.5%

Sulphur

•Comes from raw material and furnace gases

•Harmful impurity- forms low melting point FeS at grain boundaries

Phosphorus:

•Comes from raw material

•Content should be kept low (0.02-0.5%)

•Forms Fe3P which is brittle

•Increases the tensile strength and yield point but reduces ductility and toughness

CAST IRONS:

- Cast irons are a class of ferrous alloys with carbon contents above 2.14 wt%;
- The range of Cast iron melting temperatures range is between 1150 and 1300^{o}C, which is considerably lower than for steels. Thus, they are easily melted and amenable to casting.
- Different types of cast iron are explained below.

Gray Cast Iron:

- In these cast irons, the graphite exists in the form of flakes (similar to corn flakes), which are normally surrounded by an α-ferrite or pearlite matrix;
- The microstructure of a typical gray iron is shown in Figure 5.1a.
- Because of these graphite flakes, a fractured surface takes on a gray appearance
- gray iron is comparatively weak and brittle in tension as a consequence of its microstructure; the tips of the graphite flakes are sharp and pointed, and may serve as points of stress concentration when an external tensile stress is applied.
- Strength and ductility are much higher under compressive loads.
- They are having good damping capacity.

- Base structures for machines and heavy equipment that are exposed to vibrations are frequently constructed of this material.
- gray irons exhibit a high resistance to wear.
- gray cast irons are among the least expensive of all metallic materials.
- The presence of graphite flakes provides lubricating effect to sliding bodies.

Ductile (or Nodular) Iron:

- Adding a small amount of magnesium and/or cerium to the gray iron , graphite is in the form of nodules or sphere-like particles instead of flakes. The resulting alloy is called nodular or ductile iron,
- a typical microstructure is shown in Figure 5.1b.
- Castings are stronger and much more ductile than gray iron.
- Typical applications for this material include valves, pump bodies, crankshafts, gears, and other automotive and machine components.

White Iron and Malleable Iron:

- For low-silicon cast irons (containing less than 1.0 wt% Si) and rapid cooling rates, most of the carbon exists as cementite instead of graphite.
- A fracture surface of this alloy has a white appearance, and thus it is termed white cast iron.
- the microstructure of white iron is presented in Figure 5.1c.
- As a consequence of large amounts of the cementite phase, white iron is extremely hard but also very brittle.
- Its use is limited to applications that necessitate a very hard and wear-resistant surface, without a high degree of ductility—for example, as rollers in rolling mills.
- Generally, white iron is used as a raw material for production malleable iron.

Malleable iron:

- Heating white iron at temperatures between 800 and 900^{o}C for a prolonged time period and in a neutral atmosphere (to prevent oxidation) causes a decomposition of the cementite, forming graphite, which exists in the form of clusters or rosettes surrounded by a ferrite or pearlite matrix, depending on cooling rate.

- Malleable iron is presented in Figure 5.1d.
- Applications include connecting rods, transmission gears, and differential cases for the automotive industry, and also flanges, pipe fittings, and valve parts for railroad, marine, and other heavy-duty services.

Compacted Graphite Iron (CGI):

- the graphite in CGI alloys has a worm-like (or vermicular) shape;
- a typical CGI microstructure is shown in the optical micrograph of Figure 5.1e.
- Compared to the other cast iron types, desirable characteristics of CGIs include the following:
  - ✓ Higher thermal conductivity
  - ✓ Better resistance to thermal shock (i.e., fracture resulting from rapid temperature changes)
  - ✓ Lower oxidation at elevated temperatures

Compacted graphite irons are now being used in a number of important applications—these include: diesel engine blocks, exhaust manifolds, gearbox housings, brake discs for high-speed trains, and flywheels.

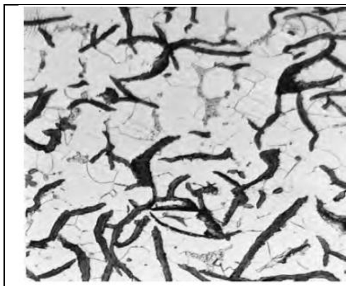
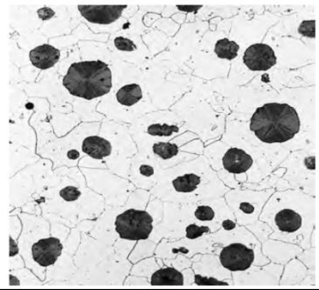
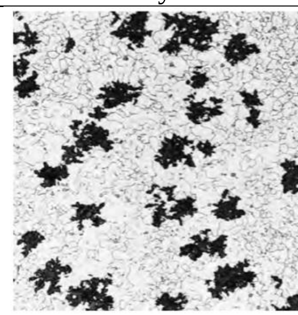
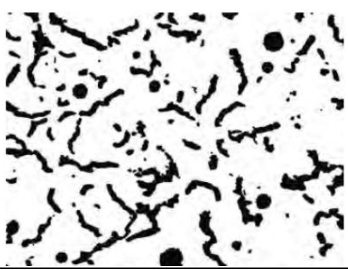
	
(a)Gray iron: the dark graphite flakes are embedded in an -ferrite matrix.	**(b)Nodular (ductile) iron:** the dark graphite nodules are surrounded by an -ferrite matrix.
	
(c)White iron: the light cementite regions are surrounded by pearlite, which has the ferrite–cementite layered structure.	**(d)Malleable iron:** dark graphite rosettes (temper carbon) in an – ferritematrix.
	**(e) Compacted graphite iron:** dark graphite worm-like particles areembedded within an -ferrite matrix.

Figure No. 5.1: Optical photomicrographs of various cast irons.

NON-FERROUS ALLOYS:

List out the properties of copper. Explain alloys of copper.

Copper has the following notable properties:

- It has good ductility and malleability because of its FCC structure.
- It has high electrical and thermal conductivity.
- It is non magnetic and has a pleasing reddish color.
- It has an ability of getting alloyed with many other metals which helps in improving properties.
- It has fairly good corrosion resistance to general atmospheric conditions.

Due to these properties, it is widely used for electrical conductors, automobile radiators, roofing, pressure vessels, utensils, kettles, coins etc. the most copper alloys are brasses and bronzes.

Alloys of copper:

Brasses:

Brasses are the alloys of copper and zinc. Brasses are classified on the basis of structure as α-brasses and α-β brasses. On the basis of colour, brasses are classified as red brasses and yellow brasses.

α- Brasses:

α- brasses containing upto 36% zinc possess relatively good corrosion resistance and good cold working properties. The color of α- brasses varies according to copper content from red for high copper alloys to yellow at about 62% copper. The α- brasses may bedivided into two groups, yellow α- brasses and red brasses.

Yellow α- brasses:

These contain 20 to 36% zinc have good strength with high ductility. The most widely used yellow α- brasses are cartridge brass, admiralty brass etc.

Cartridge brass:

It contains 70% copper and 30% zinc. It is very ductile and have excellent cold working properties. It can be easily drawn into wires, rods and tubes. It is used for cartridge cases, locomotive and condenser tubes.

Admiralty brass:

It is an alloy of copper, zinc and tin (copper 70%, zinc 29%, tin 1%). It has good resistance to corrosion and is used for condenser tubes and marine parts.

Red brasses:

These contain between 5 and 20% zinc. Theses generally have better corrosion resistance than yellow brasses and are not susceptible to seasonal cracking.

α- β Brasses:

Commercial α- β brasses contain zinc between 32 to 42 %. These are hard and strong as compared to α- brasses and fabricated by hot working process. The most widely used α- β brasses is muntz metal (60Cu – 40Zn) which has high strength and excellent hot working properties. Muntz metal is used in architectural work, utensils, condenser tubes, etc.

Bronzes:

Bronzes are the alloys of copper containing elements other than zinc. Originally bronze is an alloy of copper and tin. These are stronger than brasses but corrosion resistance is less than brasses. The main types of bronzes are phosphorous bronze, aluminum bronze, gun metal etc.

Phosphorous bronze:

It contains 6% tin, 0.3% phosphorus, the remainder is copper (93.7%). The phosphorous increases strength and wear resistance of alloy. It can be obtained in the form of wires, bars and sheets. This alloy is used for springs, turbine blades etc.

Aluminum bronze:

It is an alloy of copper and aluminum. It contains 90 – 95% copper and 5 – 10% aluminum. It is a ductile alloy with high strength and has good resistance to corrosion. It retains strength and wear resistance at elevated temperatures. It is used for condenser tubes and parts used in chemical plant.

Gun metal:

It is an alloy containing 88% copper, 10% tin and 2% zinc. This small addition of zinc improves the castability and intricate shapes may be cast with fine details. It has high strength and corrosion resistance. It is used for marine and boiler fittings.

List out properties of an Aluminum. Explain aluminum alloys.

Aluminum:

Aluminum has several excellent properties:

- It is ductile and malleable due to FCC structure.
- It is light in weight.
- It has very good thermal and electrical conductivity.
- It has excellent ability of getting alloyed with other elements like Cu, Si, Mg, Mn, Zn, etc.
- It has excellent corrosion and oxidation resistance. This is due to the formation of Al_2O_3 film on the metal surface.
- Corrosion product of aluminum, i.e. Al_2O_3 is non toxic which makes the metal suitable for food packaging purpose.
- It is non magnetic.
- Aluminum is used for cooking utensils, mixers, toasters, food containers, coins etc.

Various aluminum alloys are designated by LM series. Properties and applications of some of the aluminum alloys are explained below.

Aluminum – silicon and aluminum – silicon – copper alloys:

The aluminum silicon alloys are widely used for the production of castings due to their excellent fluidity and casting characteristics. The properties of aluminum – silicon alloys depend on the amount of silicon. Higher the silicon content better are the mechanical properties, better is the corrosion and oxidation resistance. If we increase the silicon to very high, eutectic will increase, then the mechanical properties decreases.

Aluminum – magnesium alloys (Magnalium):

LM5 (5% Mg – 0.5% Mn) is highly resistance to corrosion, machines well and takes a high polish. It has good strength and particularly suitable in marine environments.

Aluminum – Lithium alloys:

It is developed recently for the use of aircraft and aerospace industries. They have low densities, excellent fatigue strength etc. its composition is 2.7 Cu, 0.25 Hg, 2.25Li, 0.12Zr.