

ENGINEERING MATERIALS



Lecture No. 6

Ferrous Materials and Non-Ferrous Metals and Alloys

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INTRODUCTION

Ferrous materials/metals may be defined as those metals whose main constituent is iron such as, cast iron, steel and their alloys. The principal raw materials for ferrous metals is pig iron. Ferrous materials are usually stronger and harder and are used in daily life products. Ferrous material possess a special property that their characteristics can be altered by heat treatment processes or by addition of small quantity of alloying elements. Ferrous metals possess different physical properties according to their carbon content.

IRON AND STEEL

The ferrous metals are iron base metals which include all varieties of iron and steel. Most common engineering materials are ferrous materials which are alloys of iron. Ferrous means iron. Iron is the name given to pure ferrite Fe, as well as to fused mixtures of this ferrite with large amount of carbon (may be 1.8%), these mixtures are known as pig iron and cast iron. Primarily pig iron is produced from the iron ore in the **blast furnace** from which cast iron, wrought iron and steel can be produced.

CLASSIFICATION OF CARBON STEELS

Plain carbon steel is that steel in which alloying element is carbon. Practically besides iron and carbon four other alloying elements are always present but their content is very small that they do not affect physical properties. These are **sulphur, phosphorus, silicon and manganese**. Although the effect of sulphur and phosphorus on properties of steel is detrimental, but their percentage is very small. Sulphur exists in steel as iron sulphide which produces **red shortness** or manganese sulphide which does affect its properties.

CAST IRON

It is primarily an alloy of iron and carbon. The carbon content in cast iron varies from 1.5 to 4 per cent. Small amounts of silicon, manganese, sulphur and phosphorus are also present in it. Carbon in cast iron is present either in free state like graphite or in combined state as cementite. Cast iron contains so much carbon or its equivalent that it is not malleable. One characteristic (except white cast iron) is that much of carbon content is present in free form as graphite. Largely the properties of cast iron are determined by this fact.

Melting point of cast iron is much lower than that of steel. Most of the castings produced in a cast iron foundry are of grey cast iron. These are cheap and widely used. The characteristics of cast iron which make it a valuable material for engineering applications are:

(1) *Very good casting characteristics.*

(2) *Low cost*

(3) *High compressive strength*

(4) *Good wear resistance*

(5) *Excellent machinability*

The main limitation of this metal is brittleness and low tensile strength and thus cannot be used in those components subjected to shocks.

The varieties of cast iron in common use are:

(1) *Grey cast iron*

(2) *White cast iron*

(3) *Malleable cast iron*

(4) *Nodular cast iron*

(5) *Chilled cast iron*

(6) *Alloy cast iron*

Grey Cast Iron

It is the iron which is most commonly used in foundry work. If this iron is machined or broken, its fractured section shows the greyish colour, hence the name “grey” cast iron. The grey colour is due to the fact that carbon is present in the form of free graphite. A very good characteristic of grey cast iron is that the free graphite in its structure acts as a lubricant. This is suitable for those components/products where sliding action is desired. The other properties are good machinability, high compressive strength, low tensile strength and no ductility.

White Cast Iron

It is so called due to the whitish colour shown by its fracture. White cast iron contains carbon exclusively in the form of iron carbide Fe_3C (cementite). From engineering point of view, white cast iron has limited applications. This is because of poor machinability and possessing, in general, relatively poor mechanical properties. It is used for inferior castings and places where hard coating is required as in outer surface of car wheels. Only crushing rolls are made of white cast iron. But it is used as raw material for production of malleable cast iron.

STAINLESS STEELS

The only material known to engineers which possesses a combination of various properties such as: wide range of strength and hardness, high ductility and formability, high corrosion resistance, good creep resistance, good thermal conductivity, good machinability, high hot & cold workability and excellent surface finish is stainless steel. Alloy steels have been developed for a specific purpose. We shall study them as follows:

They are known as stainless since they do not corrode or rust easily in most of environment and media. Stainless steels can be further divided into the following three categories:



- **Austenitic stainless steel**

There are two main characteristics of this type of stainless steel. First, there is a lot of chromium included during the production of austenitic stainless steel. Items produced with this material are more corrosion-resistant. Second, these items tend to be non-magnetic, although they can become magnetic with a cold forming process. These are the most common types of stainless steel alloys.

- **Ferritic Stainless Steel**

This type of stainless steel is the second most common type of alloy and is also magnetic. Items produced with this alloy can be hardened through cold forming and also tend to be less expensive than other types due to the lower nickel content.

- **Martensitic Stainless Steel**

This material is the least common type of stainless steel alloy. Martensitic stainless steel is used in applications where high tensile strength is needed or a lot of impact resistance. In many cases, this material is also combined with a protective polymer coating to improve corrosion-resistance

Copper

The crude form of copper extracted from its ores through series of processes contains 68% purity known as Blister copper. By electrolytic refining process, highly pure (99.9%) copper which is remelted and casted into suitable shapes. Copper is a corrosion resistant metal of an attractive reddish brown colour.

Properties and Uses

- (1) High Thermal Conductivity:** *Used in heat exchangers, heating vessels and appliances, etc.*
- (2) High Electrical Conductivity:** *Used as electrical conductor in various shapes and forms for various applications.*
- (3) Good Corrosion Resistance:** *Used for providing coating on steel prior to nickel and chromium plating*
- (4) High Ductility:** *Can be easily cold worked, folded and spun. Requires annealing after cold working as it loses its ductility.*

Aluminium

Aluminium is white metal which is produced by electrical processes from clayey mineral known as bauxite. However, this aluminium ore bauxite is available in India in plenty and we have a thriving aluminium industry.

Properties and Uses

- (1) Like copper it is also corrosion resistant.*
- (2) It is very good conductor of heat and electricity although not as good as copper.*
- (3) Possesses high ductility and light weight so widely utilized in aircraft industry.*
- (4) Needs frequent annealing if cold worked since it becomes hard after cold working.*
- (5) In view of its ductility and malleability it has replaced copper in electrical transmission and appliances to some extent.*
- (6) It is used in manufacturing of household utensils including pressure cookers.*

Lead

*Lead is the heaviest of the common metal. Lead is extracted from its ore known as **galena**. It is bluish grey in colour and dull lusture which goes very dull on exposure to air.*

Properties and Uses

- (1) Its specific gravity is 7.1 and melting point is 360°C.*
- (2) It is resistant to corrosion and many chemicals do not react with it (even acids).*
- (3) It is soft, heavy and malleable, can be easily worked and shaped.*
- (4) Lead is utilized as alloying element in producing solders and plumber's solders.*
- (5) It is alloyed with brass as well as steel to improve their machinability.*
- (6) It is utilized in manufacturing of water pipes, coating for electrical cables, acid tanks and roof covering etc.*

Tin

It is a brilliant white metal with yellowish tinge. Melting point of tin is 240°C

Properties and Uses

- (1) Tin is malleable and ductile, it can be rolled into very thin sheets.*
- (2) It is used for tinning of copper and brass utensils and copper wire before its conversion into cables.*
- (3) It is useful as a protective coating for iron and steel since it does not corrode in dry or wet atmosphere.*
- (4) It is utilized for making important alloys such as fine solder and moisture proof packing with thin tin sheets.*

Zinc

*The chief ores of zinc are **blende** (ZnS) and **calamine** ($ZnCO_3$). Zinc is a fairly heavy, bluish-white metal principally utilized in view of its low cost, corrosion resistance and alloying characteristics. Melting point of zinc is $420^\circ C$ and it boils at $940^\circ C$.*

Properties and Uses

- (1) High corrosion resistance:** *Widely used as protective coating on iron and steel. Coating may be provided by dip galvanizing or electroplating.*
- (2) High fluidity and low melting point:** *Most suitable metal for pressure die casting generally in the form of alloy.*
- (3) When rolled into sheets,** *zinc is utilized for roof covering and for providing a damp proof non-corrosive lining to containers.*
- (4) The galvanized wires, nails, etc.** *are produced by galvanizing technique and zinc is also used in manufacture of brasses.*

ALLOYS OF COPPER

Copper alloys are among the best conductors of heat and electricity and they have good corrosion resistance. The common types of copper alloys are brasses and bronzes. The various alloys of copper are discussed as follows:

Brass is a metal alloy primarily composed of copper and zinc. However, other metals—such as iron, aluminum, silicon, and manganese—are also mixed in to produce different properties and color variations. For instance, a high zinc content leads to increased strength and ductility, while the inclusion of manganese results in enhanced corrosion resistance.

Properties of Brass

Compared to bronze, brass is more malleable, making it ideal for applications that require a high level of formability. On the other hand, it also demonstrates a significantly lower melting point (900 degrees Celsius).

Other properties of brass include the following:

- Muted yellow/gold color (depending on the amount of zinc)
- High corrosion resistance (especially if it contains an above-average amount of manganese)
- Susceptibility to cracking from excessive stress
- Highly castable
- Above-average thermal conductivity
- Non-ferromagnetic (making it easier to separate for recycling)

Applications of Brass

Brass finds application across a wide range of industries, such as:

- The brighter, gold-looking appearance of brass makes it an excellent choice for decorative applications.
- Musical instruments.** Its workability and durability make it a highly suitable source material for musical instruments (e.g., guitar strings)
- Plumbing pipes and tubing.** The high corrosion resistance demonstrated by brass makes it suitable for plumbing applications.
- Similar to bronze, brass is used in electronic applications, due to its excellent electrical conductivity.

What Is Bronze?

[Bronze](#) is a metal alloy that primarily contains copper and 12% tin. Other elements—such as aluminum, arsenic, manganese, phosphorus, and silicon—are also added to yield different properties. These mixtures form some of the common bronze alloys, including:

- Leaded bronze
- Phosphor bronze
- [Aluminum bronze](#)
- Silicon bronze
- Manganese bronze



Properties of Bronze

Bronze contains several unique properties that make it highly suitable for applications ranging from works of art to computer electronics. Characteristics of bronze include:

- Reddish-brown color
- Hardness and brittleness (although typically it is less brittle than cast iron)
- Melting point of 950 degrees Celsius
- High resistance to corrosion from saltwater
- Exhibits low metal-to-metal friction

Applications of Bronze

Bronze's characteristics make it suitable for use in functional and aesthetic applications, such as:

- **Marine and fishing.** Many boats and ships employ bronze fittings and propellers due to the material's high corrosion resistance.
- **Sculptures and musical instruments.** Bronze's dull-gold tone makes it a popular source material for sculptures and other artistic endeavors, such as bells and cymbals.
- **Electrical connectors and springs.** Some bronze alloys are particularly suitable for electrical applications due to their excellent electrical conductivity.
- **Bushings and bearings.** The material's low metal-to-metal friction makes it suitable for high-stress environments, such as those experienced by bushings and bearings.

NON FERROUS METALS



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Thank you for listening