Lecture 03: Ferrous Metal Production

1. Classification of Engineering Materials

Some commonly used engineering materials are broadly classified as shown in Fig. 2.1. Engineering materials may also be categorized into metals and alloys, ceramic materials, organic polymers, composites and semiconductors. The metal and alloys have tremendous applications for manufacturing the products required by the customers.

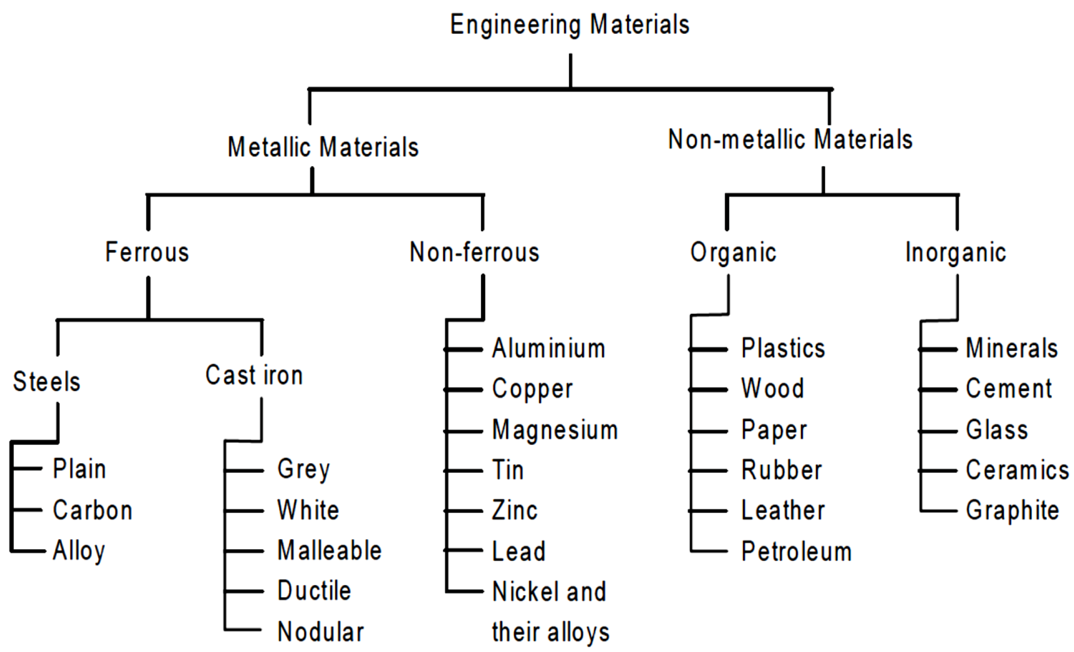

Fig. 2.1 Classification of engineering materials

Metals and Alloys

Pure metals possess low strength and do not have the required properties.

Alloys are produced by melting or sintering two or more metals or metals and a non-metal, together. Alloys may consist of two more components.

a. **Ferrous metals** are those which have the iron as their main constituent, such as crude (pig) iron, cast iron, wrought iron and steels.
b. **Non-ferrous metals** are those which have a metal other than iron as their main constituent, such as copper, aluminium, brass, bronze, tin, silver zinc, invar etc.

2. Ferrous Metals

The ferrous metals are those which have iron as their main constituents. The ferrous metals commonly used in engineering practice are *cast iron, wrought iron, steel and alloy steels*. The basic principal raw material for all ferrous metals is crude (pig iron) which is obtained by smelting ***iron ore***, coke and limestone, in the ***blast furnace***. The principal iron ores with their metallic contents are shown in Table 2.1.

S.No.	Iron ore	Color	Iron %
1.	Haematite (Fe_3O_4)	Red	70%
2.	Magnetite (Fe_2O_3)	Black	72%
3.	Limonite	Brown	62.5%
4.	Siderite	Brown	48%

2.1. Main Types of Iron

1. **Cast iron:** Cast iron is basically an alloy of iron and carbon and is obtained by re-melting pig iron with coke, limestone and steel scrap in a furnace known as cupola. The carbon content in cast iron varies from 1.7% to 6.67%. It also contains small amounts of silicon, manganese, phosphorus and sulphur in form of impurities elements.
    a. White cast iron
    b. Gray cast iron
    c. Malleable cast iron
    d. Ductile cast iron
    e. Meehanite cast iron
    f. Alloy cast iron

2. **Wrought iron**: Wrought iron is the assumed approximately as purest iron which possesses at least 99.5% iron. It contains a large number of minute threads of slag lying parallel to each other, thereby giving the metal a fibrous appearance when broken. It is said as a mechanical mixture of very pure iron and a silicate slag.

3. **Steel:** Steel is an alloy of iron and carbon with carbon content maximum up to 1.7%. The carbon occurs in the form of iron carbide, because of its ability to increase the hardness and strength of the steel
    a. Plain carbon steels
        i. *Dead Carbon steels*
        ii. *Low Carbon steels*
        iii. *Medium Carbon steels*
        iv. *High Carbon steels*
    b. Alloy steels
        i. *High speed steel*
        ii. *Stainless steel*

2.2. Cast Iron Production (Blast furnace)

Blast furnace was invented in 14th century. A typical blast furnace along with its various parts is shown in Fig. 2.2. Modern blast furnaces range in size from 20 to 35 m diameter. It is set on the top of brick foundation. There are four major parts of blast furnace from bottom to top:

1. hearth,
2. bosh,
3. stack and
4. top.

The hearth acts as a storage region for molten metal and molten slag. The charge of blast furnace possesses successive layers of iron ore, scrap, coke, and limestone and some steel scrap which is fed from the top of the furnace.

Iron ore exists as an aggregate of iron-bearing minerals. These mineral aggregates are oxides of iron called hematite, limonite, and magnetite. They all contribute to the smelting process. *It takes about 1.6 tons of iron ore, 0.65 ton of coke, 0.2 ton of lime-stone and about 0.05 ton of scrap iron and steel to produce 1 ton of crude (pig) iron. For burning this charge, about 4 tons of air is required*.

The impurities or other minerals are present in the ore. These impurities may be silicon, sulfur, phosphorus, manganese, calcium, titanium, aluminum, and magnesium. *The amounts of silicon, phosphorus, and sulfur present will determine the purification process used in the manufacture of the steel.*

The output from the furnace in form of crude (pig) iron is collected in large ladles from the tap hole existing at lower portion of furnace. As the coke burns, aided by the air forced into the furnace, the ore melts and collects in the hearth. As the melting process proceeds, the entire mass settles and thus makes room for the addition of charges at the top. While the melting is going on, the limestone forms a slag with the impurities.

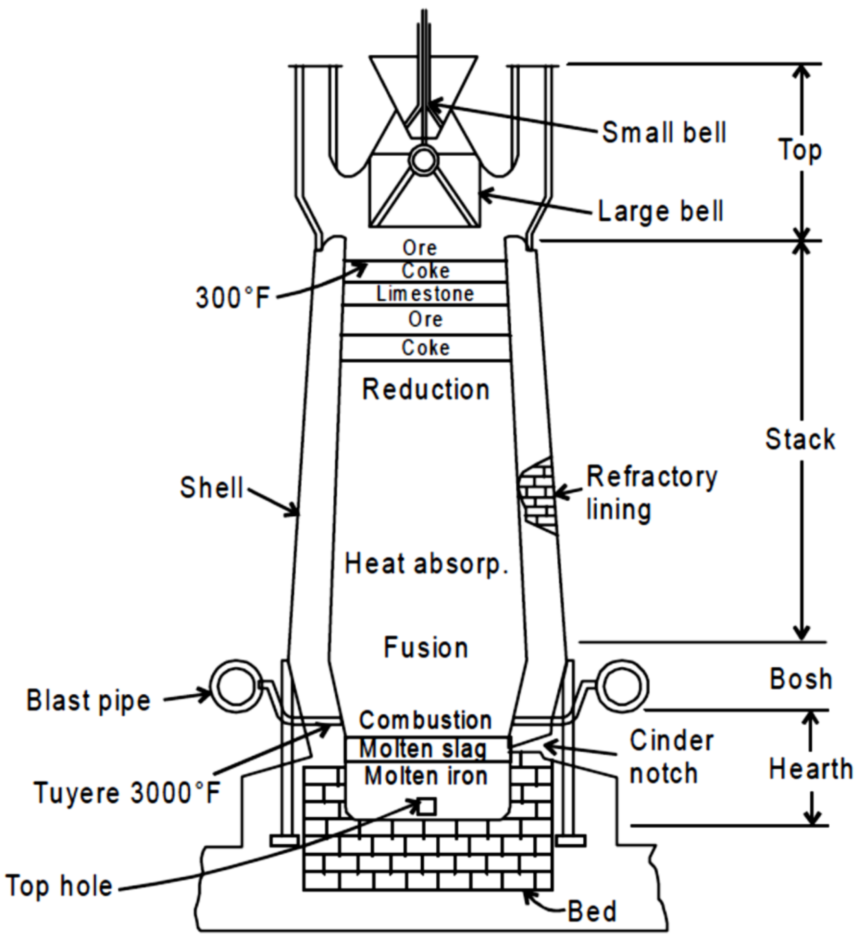

Fig. 2.2 Typical blast furnace

2.3. Steel Production Furnaces

The iron picks up carbon from the coke and impurities from the ore. The amount of carbon picked up by the iron is more than is needed in the production of steel. The carbon becomes part of the pig iron used in the making of steel. *The control of this carbon during the subsequent processes determines the properties of the steel*.

The crude (pig) iron is then processed for purification work for production of various kinds of iron and steel in form of ingots (large sections) using different furnaces. The steel ingots can be further processed in rolling mill or blooming mill to produce different structural shapes and sections of steel.

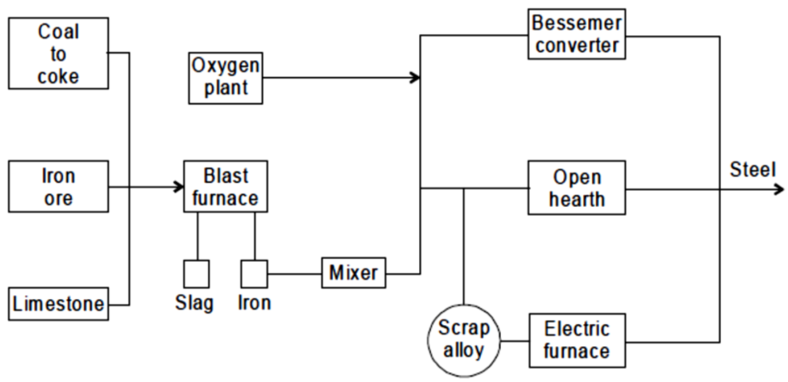

Fig. 2.3 Flow chart for converting pig iron into useful iron and steel

2.3.1. Bessemer Convertor

The Bessemer process was the first inexpensive industrial process for the mass-production of steel from molten pig iron. The process is named after its inventor, Henry Bessemer, who took out a patent on the process in 1855. The key principle is removal of impurities from the iron by oxidation with air being blown through the molten iron. The oxidation also raises the temperature of the iron mass and keeps it molten. The process is carried on in a large ovoid steel container lined with clay or dolomite called the Bessemer converter. The capacity of a converter was from 8 to 30 tons of molten iron.

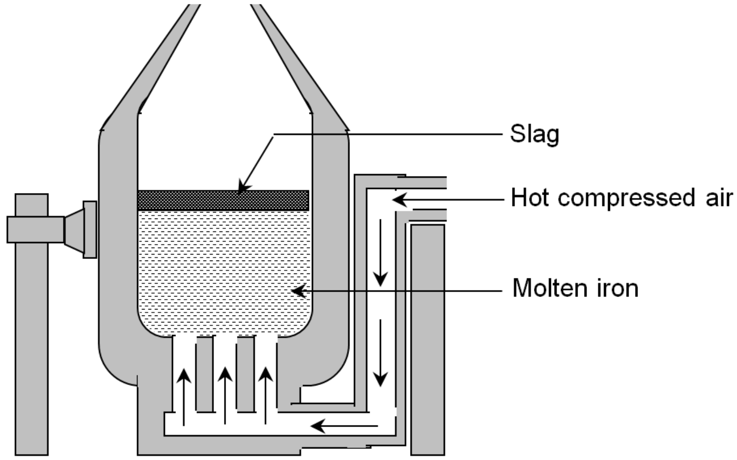

Fig. 2.4 Bessemer Convertor

2.3.2. Open Hearth Furnace

In open hearth furnace, pig iron, steel scrap etc. are melted to obtain steel. The hearth is surrounded by roof and walls of refractory bricks as shown in Fig. 2.5. The charge is fed through a charging door and is heated to 1650°C mainly by radiation of heat from the burning of gaseous fuels above it. The products of combustion at the same time pass through the checkers at the other end of the furnace, then process then reverses itself.

Oxygen is one of the most important elements used in the reduction of the molten metal. Twice the oxygen input quantity will double the carbon reduction and increases the steel production of the furnace.

For magnesite lined furnace, the charge consists of pig iron, limestone, and scrap iron. The slag reacts with the sulfur and the phosphorus in the metal, while the bubbling air causes oxidation of the carbon and silicon. For acid lining furnace, the charge should be scrap iron and low-phosphorus pig iron.

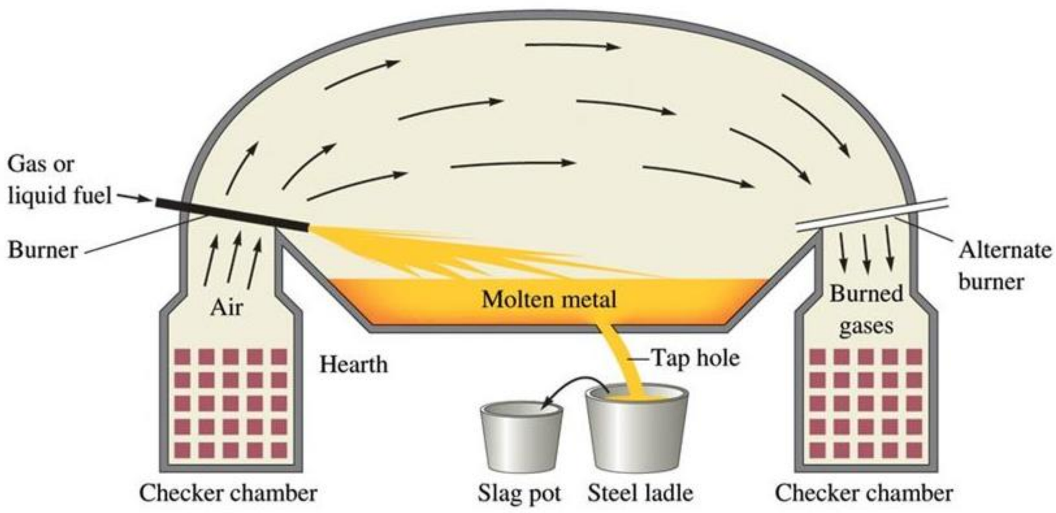

Fig 2.6 open hearth furnace

2.3.3. Electric-arc steelmaking Furnace

About one-quarter of the world's steel is produced by the electric-arc method, which uses high-current electric arcs to melt steel scrap and convert it into liquid steel of a specified chemical composition and temperature. External arc heating permits better thermal control than does the basic oxygen process, in which heating is accomplished by the exothermic oxidation of elements contained in the charge.

The electric-arc furnace (EAF) is a squat, cylindrical vessel made of heavy steel plates. It has a dish-shaped refractory hearth and three vertical electrodes that reach down through a dome-shaped, removable roof (see figure). The shell diameter can be reached to 9m and can produce about 300-ton.

The roof is also made of water-cooled panels and has three circular openings, equally spaced, for insertion of the cylindrical electrodes. Another large roof opening, the so-called fourth hole, is used for off-gas removal. Additional openings in the furnace wall, with water-cooled doors, are used for lance injection, sampling, testing, inspection, and repair.

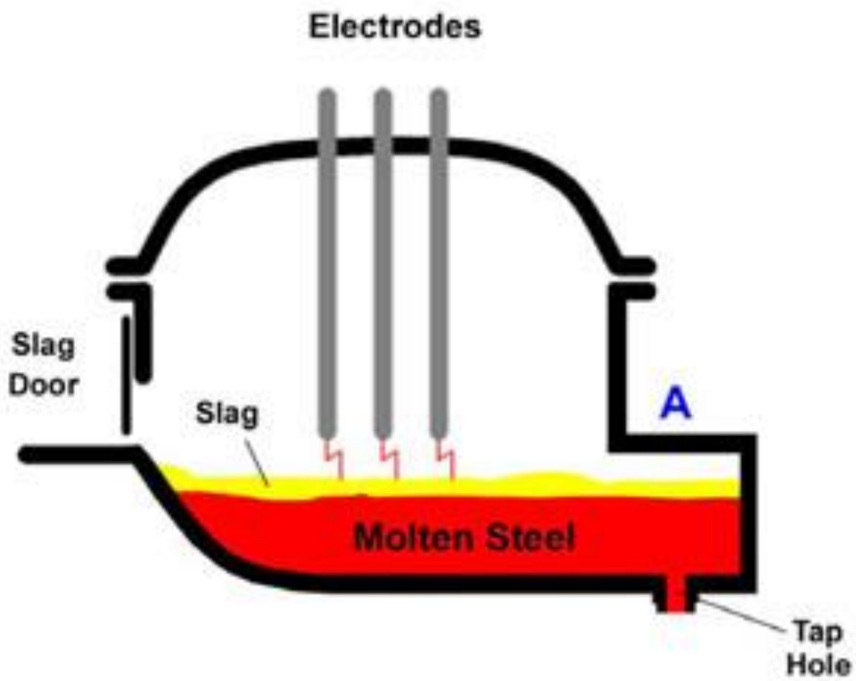

Fig 2.6 Electric-arc steelmaking furnace

YouTube: https://youtu.be/JrH9m5wfIBs