STEEL

Lecture - 1

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Content

Introduction

Metals are aiming the most useful building materials. They exist in nature as compounds like oxides, carbonates, sulphides and phosphates and are known as ores. *Metals are derived from ores by removing the impurities*. Those used for engineering purposes are classified as **ferrous metals**, with iron as the main constituent, e.g. **cast iron**, **wrought iron** and **steel** and others like aluminium, copper, zinc, lead and tin in which the main constituent is not iron as non ferrous metals.

Iron

Iron is by for the most important of the metals used in engineering construction. It is available in abundance, but does not occur freely in nature. The ores of iron are classed according to the iron mineral which is predominant. The iron content of the main ores are as follows:

Megnetite (Fe_3O_4) = 70 – 75%

Haematite (Fe_2O_3) = 70%

Limonite ($2Fe_2O_3.3H_2O$) = 60%, it is hydrated haematite,

Iron pyrite (FeS_3) = 47%

Siderite ($FeCO_3$) = 40%

Iron

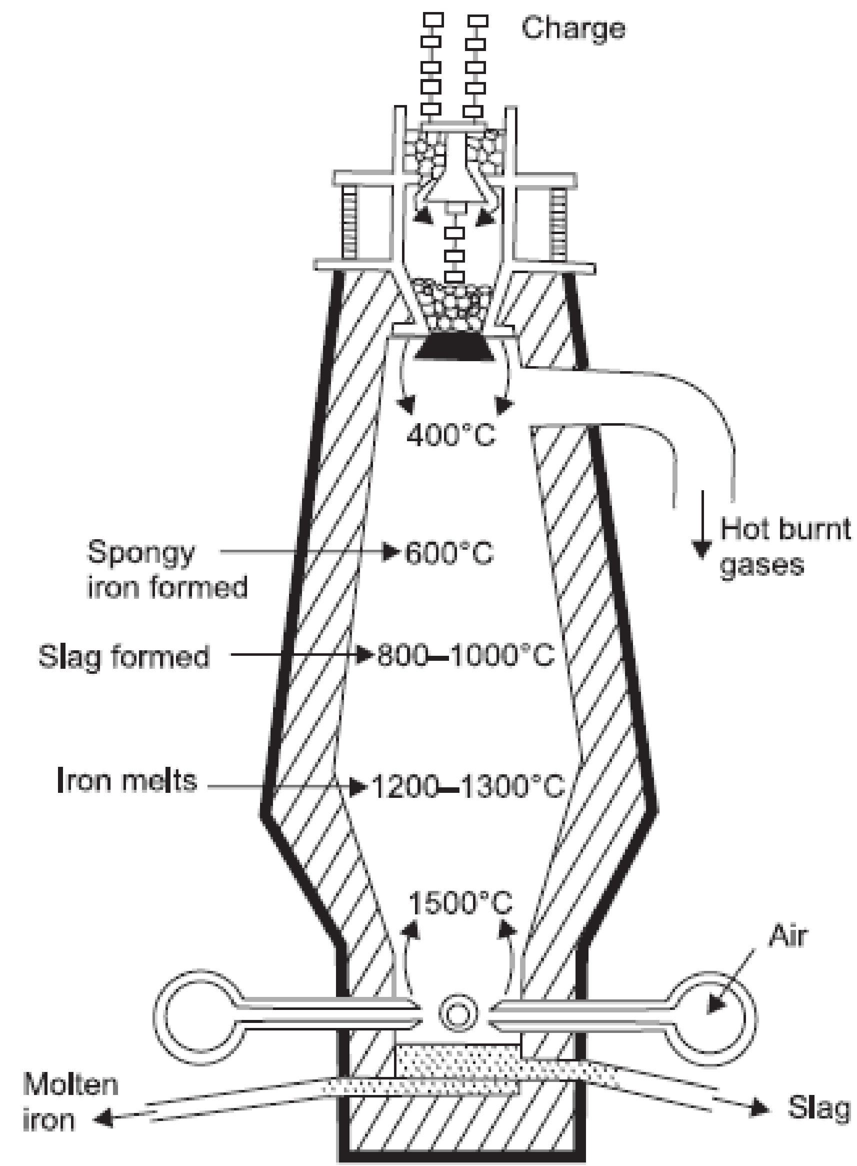
The fundamental chemical principles in the extraction of iron from the ores is very simple. *Heating the ores* in the presence of a reducing agent will result in the formation of **CO or CO_2**, liberated as a gas, and metallic iron.

Iron owes its greatest utility to the fact that it alloys freely with other elements, and its inherent properties are markedly altered and improved for varying conditions of service.

Pig Iron

The iron ore is dressed by crushing it to about 50 mm cubes. The impurities are knocked off and the ore is then calcined to drive off moisture. The calcined ore is smelted in blast furnace as shown in Fig.. The iron is deoxidised and a part of sulphur is also removed. Then limestone, which acts as flux*, is added to finally remove the sulphur. The molten metal is tapped from the furnace and is cast in the form of pigs.

**Flux is a mineral substance charged into blast furnace to lower the melting point of the ore and to remove impurities such as ash, sulphur, etc. It combines with the ashes of the fuel and the impurities of the ore to form fusible products which separate from the metal as slag*



Blast Furnace for the Manufacture of Pig Iron

Pig Iron

Pig iron Contain;

Carbon – 3-4%

Silicon – 0.5-3.5%

Manganese – 0.5 – 2%

Sulphur – 0.02% - 0.1%

Phosphorous – 0.03% - 1%

Properties

Pig iron is hard and brittle with fusion temperature of 1200°C and melts easily. It can be hardened but cannot be tempered and magnetised. Its compressive strength is high but is weak in tension and shear. Pig iron does not rust and cannot be riveted or welded.

Uses

Pig iron is most suitable for making columns, base plates, door brackets, etc.

Cast Iron

Pig iron is remelted with limestone (flux) and coke and refined in Cupola furnace. It is then poured into moulds of desired size and shape. The product is known as cast iron containing about 2–4% of carbon in two forms, i.e., as the compound cementite—in a state of chemical combination; and as free carbon—in a state of mechanical mixture.

Cast Iron

Carbon in the first form is called combined carbon, and graphite in the latter form. The quality of cast iron thus depends upon the state in which carbon exists in it. The word cast iron is a misnomer as steel with carbon content less than 2% can also be cast. The striking difference between steel and cast iron is that the form or is plastic and forgeable while the latter is not. However, some of the modern cast iron develop a fair degree or plasticity and toughness.

Cast Iron

Properties of Cast Iron

Cast iron is hard and brittle. It can neither be riveted nor welded. It is strong in compression (600 N/mm^2) but weak in tension (150 N/mm2) and shear. Its specific gravity is 7.50. It has low melting point (1200°C) and is affected by sea water. It cannot be magnetized and is not suitable for forging. Iron containing large amounts of manganese and chromium are likely to be permanently white, while those having a high silicon content are grey. With proper adjustment in composition, cast iron may be rendered white by cooling rapidly or grey by cooling slowly from the molten state.

Effect of Impurities

Carbon

The proportion of carbon and its form more or less influence most of the physical and mechanical properties of cast iron. The melting temperature of cast iron is reduced as the carbon content or the percentage of combined carbon is increased. Consequently white cast iron has a lower melting point than grey cast iron. Shrinkage varies inversely as the carbon content.

Silicon

In small percentages (0.5–3%) silicon increases the fluidity of the molten iron, decreases blow holes and increases the density of castings. It also reduces the solubility of carbon in iron and shrinkage. When silicon is increased up to 6 per cent the iron becomes hard and has a mirror-like fracture.

Effect of Impurities

Sulphur

Sulphur is an undesirable element in cast iron and is limited to less than 0.1 per cent. It combines with manganese to form the sulphide (MnS) or, if the manganese is very low and not sufficient to satisfy the sulphur, iron sulphide (FeS) may be formed. Since these sulphides solidify at considerably lower temperatures, than cast iron, they tend to make castings brittle and weak at higher temperatures. High sulphur content also increases shrinkage and causes hard, brittle iron. These may be neutralized by proper additions of silicon.

Phosphorus

When phosphorus is less than 0.5 per cent, it has no marked effect on cast iron. Usually it is present to the extent of 0.1 to 1.5 per cent. If more than 2 per cent, the iron is embrittled and strength diminished. High phosphorus irons are much more fluid and shrink less, which make them suitable for ornamental castings.

Effect of Impurities

Manganese

When present in range of 0.4–1.2%, manganese combines with sulphur, and having satisfied sulphur with carbon to form manganese carbide. It increases the tensile strength and hardness of iron. Manganese increases the solubility of carbon in iron and opposes the liberation of graphite, which is a cementite stabilizer. High percentage of manganese increases shrinkage and hardness. Thus in grey iron which is to be machined manganese should be kept low.

Uses of Cast Iron

more common uses of cost iron are making ornamental castings such as wall brackets, lamp posts; bathroom fittings such as cisterns, water pipes, sewers, manhole covers, sanitary fittings and; rail chairs, carriage wheels and machine parts subjected to shocks. It is used as basic material for manufacturing wrought iron and mild steel.

Wrought Iron

Wrought iron considered to be pure iron, is produced by removing the impurities of cast iron. The total impurities are limited to 0.5% with a maximum percentage of carbon as 0. 15, silicon 0.15 – 0.2%, Phosphorus 0.12 – 0.16%, sulphur 0.02–0.03% and manganese 0.03 – 0.1%.

The molten iron is first refined by blasting air in the furnance. The metal is cooled and poured into moulds. The metal becomes brittle. It is then melted in reverberatory furnace where iron melts due to burning of gas. After melting, puddle balls are produced which are sent for shingling. Here the balls are formed as bloom. The bloom is sent to grooved rollers to form flat bars. The process is repeated several times to remove the impurities.

Properties

Wrought iron is ductile, malleable, tough and moderately elastic. Its ultimate crushing strength is 200 N/mm^2 and ultimate tensile strength is 40 N/mm^2. The modulus of elasticity of wrought iron is 1.86 × 105 N/mm^2. The melting point of wrought iron is 1500°C and sp. gr. about 7.80. It can be forged and welded. Wrought iron effectively resists corrosion. It is tough and withstands shocks. At about 900°C wrought iron becomes so soft that its two pieces can be jointed by hammering. Alloying elements used in wrought iron include nickel, copper and molybdenum. Addition of nickel from 1.5 - 3.5% produce substantial increases in the elastic limit and tensile strength.. Copper may be added to increase corrosion resistance properties.

Steel

Steel is the most suitable building material among metallic materials. This is due to a wide range and combination of physical and mechanical properties that steels can have. By suitably controlling the carbon content, alloying elements and heat treatment, a desired combination of hardness, ductility and strength can be obtained in steel. On the basis of carbon content steel may be classified as under:

S.NO.	Type of Steel	Carbon Content (%)
1	Dead Mild Steel	< 0.15
2	Mild Steel	0.15 – 0.3
3	Medium Carbon Steel	0.3 – 0.8
4	High Carbon Steel	0.8 – 1.5
5	Hard Steel	> 1 is also called cast steel or tool steel

Manufacturing of Steel

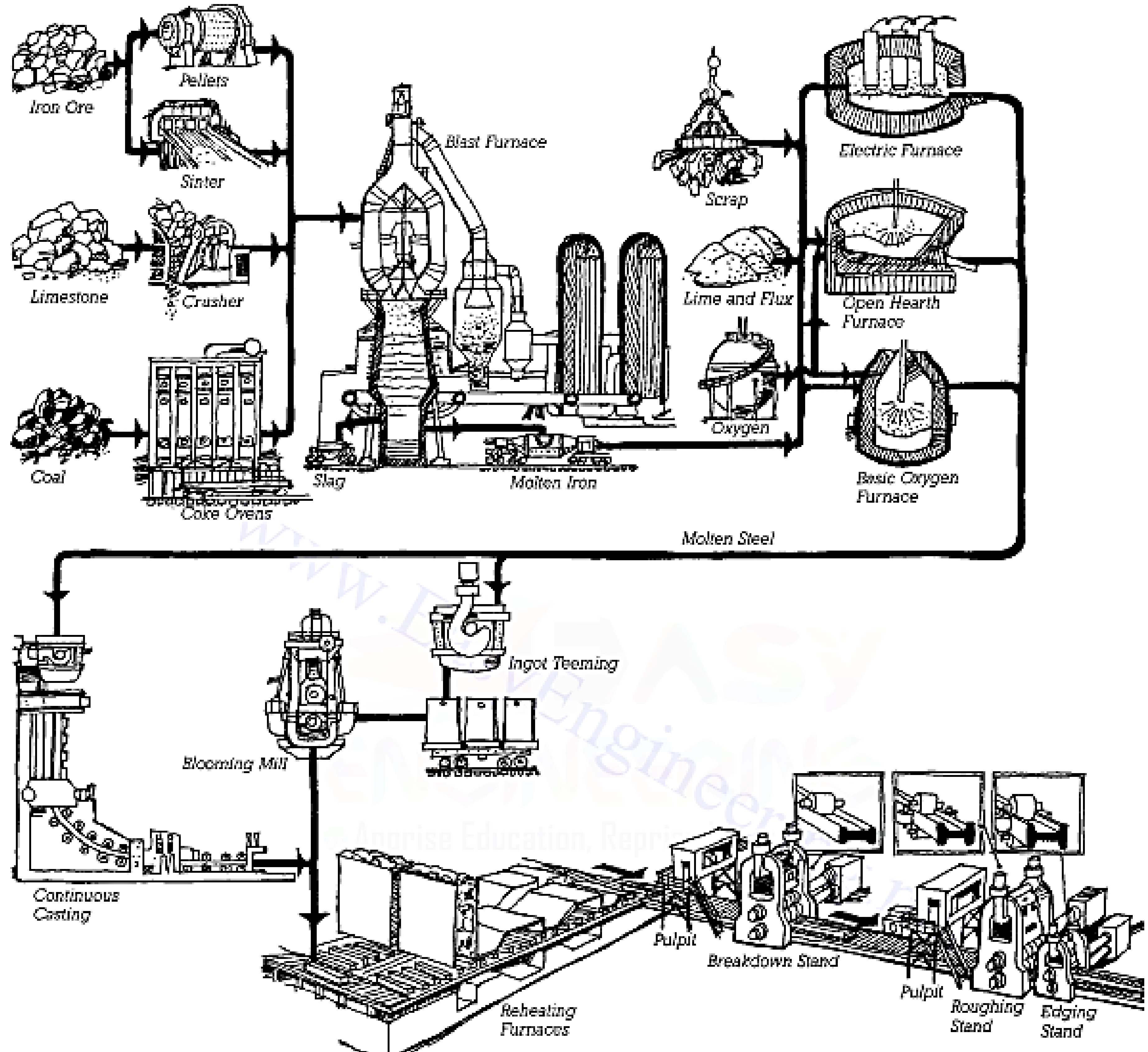
- Bassemer process
- Cementation process
- Crucible process
- Open Hearth process
- Electric Smelting process
- Dupulex process
- Lintz and Donawitz (L.D.) process

Manufacturing of Steel

- The most prominent present-day steel-making process is the Bessemer process was introduced in 1856. The pig iron is first melted in Cupola furnace and sent to Bessemer converter Blast of hot air is given to oxidize the carbon.
- Depending upon the requirement, some carbon and manganese is added to the converter and hot air is blasted once again.
- Then the molten material is poured into moulds to form ingots. L.D. process is modification of the Bessemer process in which there in no control over temperature. By this method steel can be made in hardly 25 minutes.

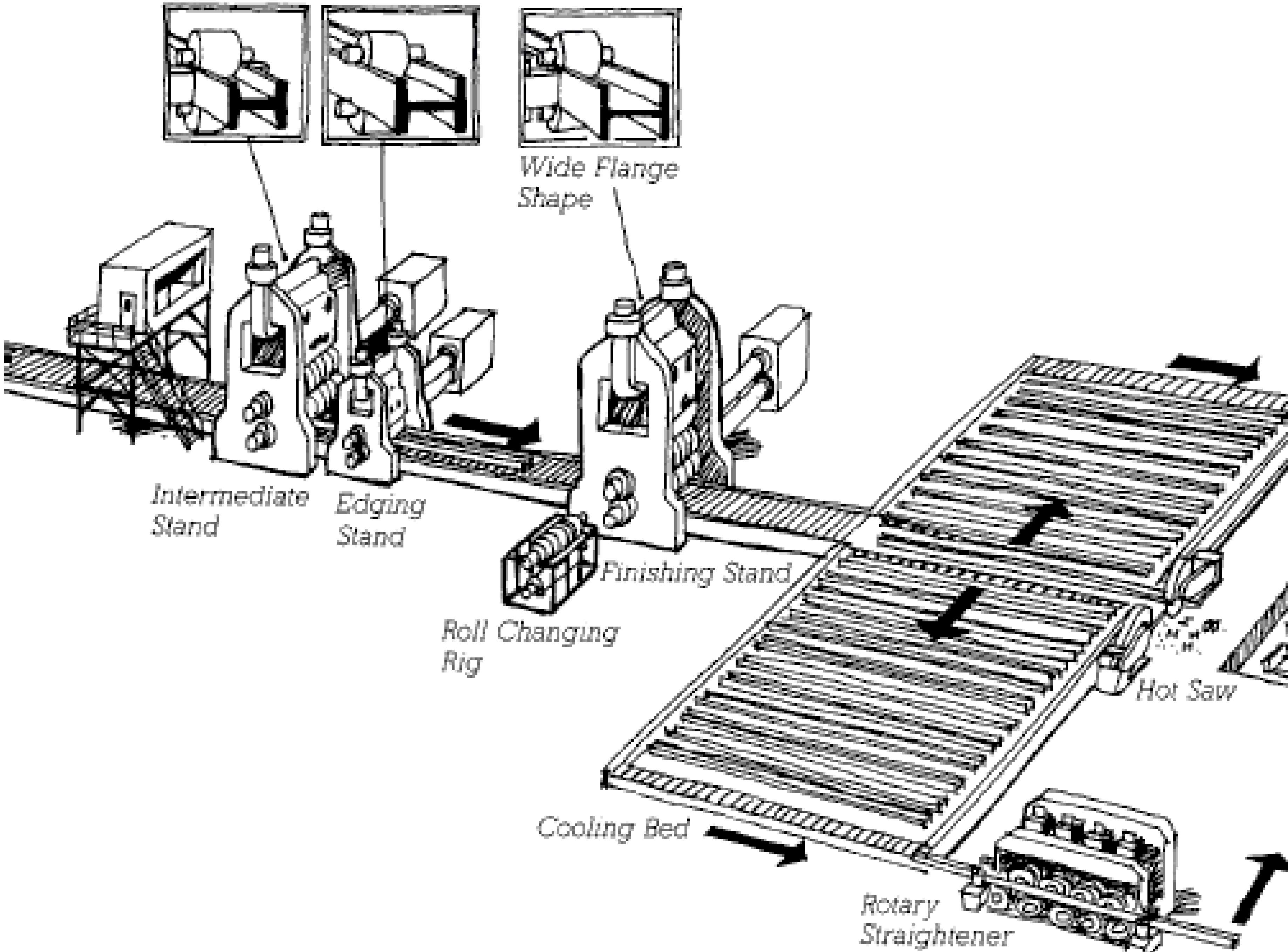
Manufacturing of Steel

- In Open-hearth process also known as Siemen's-Martin process, the steel produced is more homogeneous than by Bessemer's.
- The electric process is costly but no ash or smoke is produced.
- The Crucible process involves melting of blister steel or bars of wrought iron in fire clay crucibles. Cast steel so obtained is very hard and is used for making surgical equipments.
- The Duplex process is a combination of Acid Bessemer process and Basic Open Hearth process.



The steelmaking process, from iron ore to structural shapes. Notice particularly the steps in the evolution of a wide-flange shape as it progresses through the various stands in the rolling mill.

Allen, E., Iano J., Fundamentals of Building Construction Materials & Methods



Wide flange shapes are inspected for quality on the cooling bed

The steelmaking process, from iron ore to structural shapes. Notice particularly the steps in the evolution of a wide-flange shape as it progresses through the various stands in the rolling mill.

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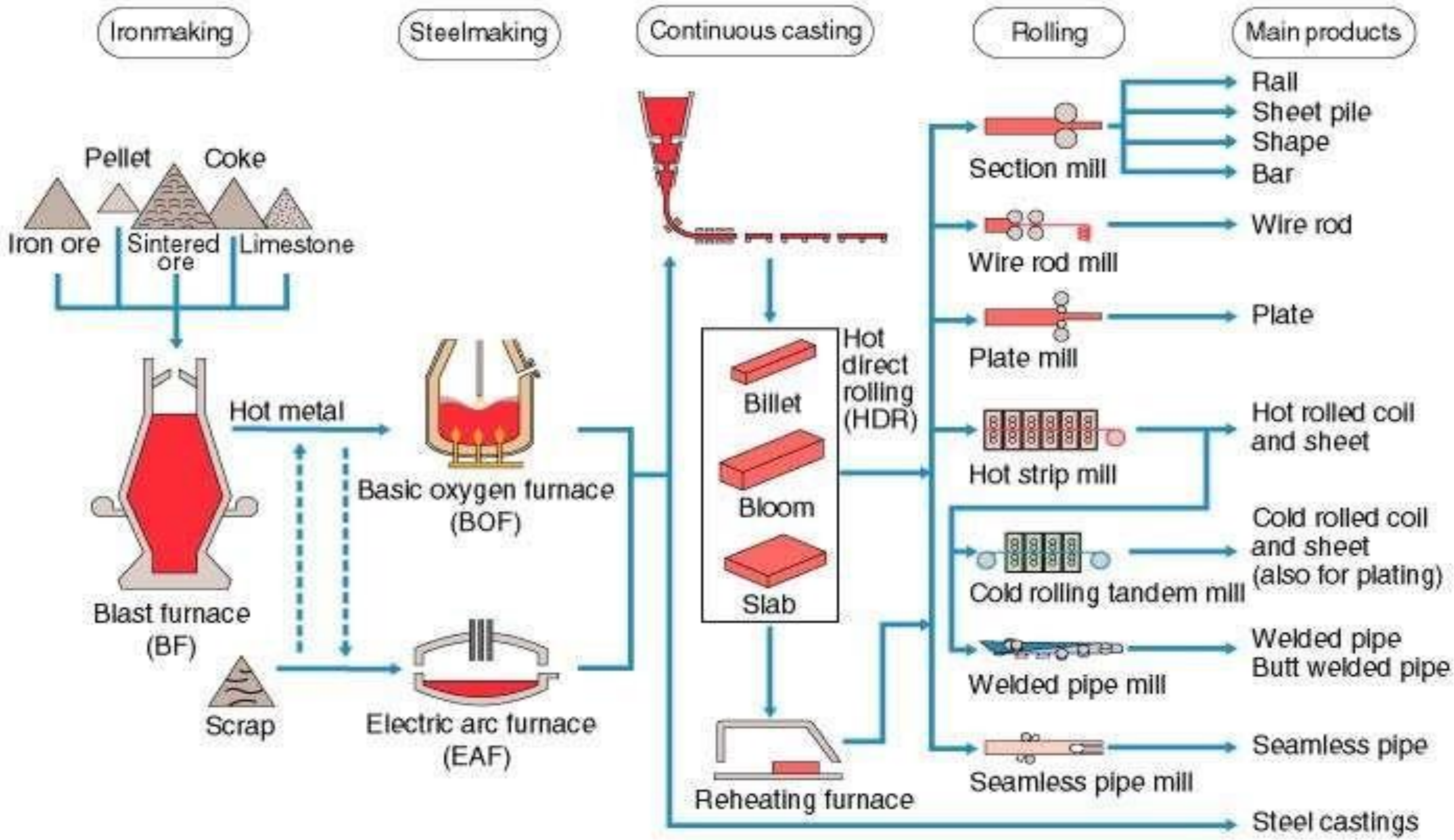


Ironmaking
Steelmaking
Continuous casting
Rolling
Main products
Pellet
Coke
Iron ore
Sintered ore
Limestone
Blast furnace (BF)
Hot metal
Basic oxygen furnace (BOF)
Scrap
Electric arc furnace (EAF)
Billet
Bloom
Slab
Hot direct rolling (HDR)
Reheating furnace
Section mill
Wire rod mill
Plate mill
Hot strip mill
Cold rolling tandem mill
Welded pipe mill
Seamless pipe mill
Rail
Sheet pile
Shape
Bar
Wire rod
Plate
Hot rolled coil and sheet
Cold rolled coil and sheet (also for plating)
Welded pipe
Butt welded pipe
Seamless pipe
Steel castings

Properties and Use

Mild Steel

Also known as **low carbon or soft steel**. It is ductile, malleable; tougher and more elastic than wrought iron. Mild steel can be forged and welded, difficult to temper and harden. It rusts quickly and can be permanently magnetised. The properties are: Sp. gr. = 7.30, ultimate compressive and tensile strengths 800–1200N/mm^2 and 600–800N/mm^2. Mild steel is used in the form of rolled sections, reinforcing bars, roof coverings and sheet piles and in railway tracks.

High Carbon Steel

The carbon content in high carbon steel varies from 0.55 to 1.50%. It is also known as hard steel. It is tougher and more elastic than mild steel. It can be forged and welded with difficulty. Its ultimate compressive and tensile strengths are 1350 N/mm^2 and 1400–2000 N/mm^2, respectively. Its Sp. gr. is 7.90.

High carbon steel is used for reinforcing cement concrete and prestressed concrete members. It can take shocks and vibrations and is used for making tools and machine parts.

Properties and Use

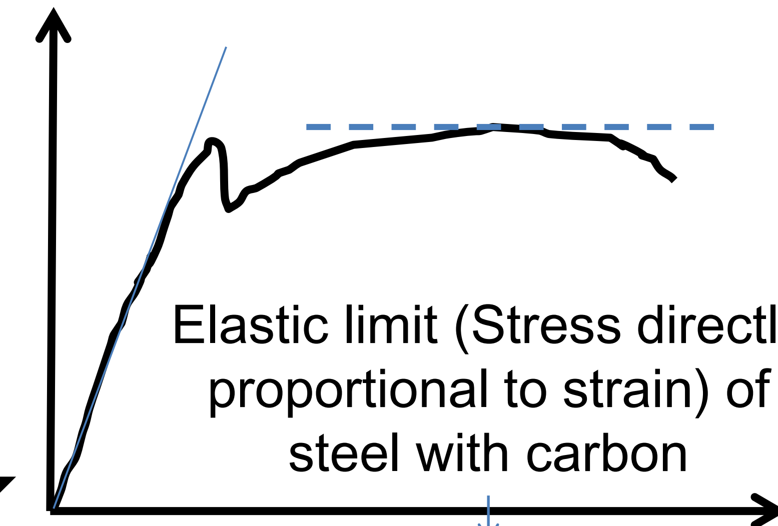
High Tensile Steel

The carbon content in high tensile steel is 0.6–0.8%, manganese 0.6%, silicon 0.2%, sulphur 0.05% and phosphorus 0.05%. It is also known as high strength steel and is essentially a medium carbon steel. The ultimate tensile strength is of the order of 2000 N/mm^2 and a minimum elongation of 10 per cent.
High Tensile steel is used in prestressed concrete construction.

Chemical Composition

Presence of Carbon in Steel → high degree of hardness and strength

Carbon + Iron → Malleability and Ductility ↓



Increases but at a lower rate

The compressive strength of steel increases directly with carbon content up to 1.0 per cent. The shear strength of steel also increases with the carbon content. The ratio of shear strength to the tensile strength is 0.80 for medium and low carbon steels and 0.60 for high carbon steels. The modulus of elasticity is nearly same for tension and compression and is practically independent of the carbon content. The ductility of steel decreases markedly as the carbon content increases. The resistance of steel to heavy shocks or blows decreases with increase of carbon content./

Thank You