# METALS

All metals used for engineering works are classified into

- Ferrous metals : Wherein iron is the main constituent (Cast iron, wrought iron and different forms of steels)
- Non-Ferrous metals: Wherein iron is not the main constituent (Copper, Aluminum, Zinc and lead etc)

**a) <u>Ferrous Metals</u>:**
**<u>Occurrence of iron</u>**:-

Iron is not available in pure form. It is extracted in the form of pig iron from the iron ores. Pig iron is the crudest form of iron and wrought iron is purest one. All the ferrous metals are obtained by suitably purifying and by varying composition of pig iron.

The ores from which iron is extracted are:

i) Magnetite ($Fe_3O_4$). 70-75% iron
ii) Haematite ($Fe_2O_3$). 70% iron
iii) Iron pyrite ($FeS_2$). 47% iron
iv) Siderite ($Fe\ Co_3$). 40% iron
v) Limonite ($Fe_2O_3.nH_2O$)

**i. <u>Pig Iron</u>**

To remove the impurities from the iron ores coke and flux are added while melting it. The refined product so obtained is the crudest form of iron and is called pig iron. It is casted into rough bars called pigs. BASIC PIG IRON contains 3.5-**4.5%** carbon. It has the following properties:

i) It is difficult to bend
ii) Its melting point is 1200 $^{o}$ C
iii) It cannot be magnetized
iv) It is very strong in compression and week in tension and shear
v) It does not rust
vi) It cannot be welded or riveted
vii) It is not malleable (Material that can be shaped and stretched is malleable)

Uses: cast iron, wrought iron and mild steel are obtained by refining the pig iron. Because of its high compressive strength it is used in columns, base plate, door brackets and pipe work.

ii. **<u>Cast Iron</u>**

Pig iron is re-melted with limestone and coke and poured into molds of desired shapes and sizes to get purer product known as cast iron. Carbon content in cast iron varies from 2 to 5%. During re melting of pig iron, scrap iron may also be added for economy

**Properties of Cast Iron**

i) Its structure is coarse, crystalline and fibrous

ii) It is brittle, non-ductile, non-malleable and cracks when subjected to shocks
iii) It cannot be magnetized
iv) It does not rust
v) It cannot be welded and riveted
vi) It is strong in compression but weak in tension and shear
vii) Its melting point is 1200 $^{o}$ C
viii) Its specific gravity is 7.5

**USES**

It is used for casting rain water pipes, gutters, gratings, railing, cisterns, man hole covers and balustrades. Because of high compressive strength it is used to make columns, support for machinery, carriage wheels and bed plates etc.

### iii. WROUGHT IRON

When pig iron is melted in such a way as to remove all of the carbon and other impurities, the result is wrought iron. Good quality wrought iron contains 99.5 % iron, less than 0.1 % of Silicon, 0.01 % of Sulfur, 0.07 % of phosphorus, 0.03 % of manganese and 0.25% of carbon.

**Properties of Wrought Iron**

i) Its structure is fibrous and has silky luster
ii) Wrought iron is very malleable and ductile
iii) Its tensile strength is 20-26 tons /in$^2$
iv) It is strong in compression but not so strong as steel
v) It can be easily worked, welded and is tough
vi) Its melting point is 1500$^{o}$C
vii) Wrought iron became pasty and very plastic at red heat and could be easily forged at about 1650F
viii) It form temporary magnet and cannot be permanently magnetized
ix) It rust easily
x) It is nearly equally strong in compression, tension and shear
xi) Its specific gravity is 7.25

**USES:** Since mild steel has replaced the wrought iron, therefore it is no longer produced in large extent. Still in use for roof sheets, wires and metal ornaments such as grills, gate and railings etc.

## iv. Steel

Steel is an alloy of iron and carbon. Pure iron’s strength remarkably increases when alloyed with carbon. The tensile strength decreases with increasing carbon content and also the ductility reduces (becomes tough and hard). Steel having its properties because of the presence of carbon alone is called “Plain carbon steel

1. **Low carbon steel or mild steel:**

Steel wherein the carbon content is from 0.15 to 0.3 % is called mild steel or soft steel.

**Properties:**

i) Its structure is fibrous and with dark bluish color
ii) It is ductile and malleable
iii) It can be permanently magnetized
iv) It is more tough and more elastic than cast iron and wrought iron
v) It corrodes quickly
vi) It can be easily forged, welded and riveted
vii) It can with stand shocks and impacts well
viii) It is not much affected by saline water
ix) It is equally strong in compression, tension and shear
x) Its specific gravity is 7.8

Uses: in construction it is chiefly used as rolled structural sections like I section, T section, angle section and channel section etc. mild steel round bars are extensively used as reinforcement in reinforced cement concrete. Plan and corrugated sheets of mild steel are used as roof covering. It is extensively used in manufacturing tools and equipment, machine parts, rail track, transmission tower and industrial buildings.

2. **Medium-carbon steel :**

Steel wherein the carbon content is 0.3 to 0.8% is called as medium carbon steel. It is stronger than the mild steel but slightly less ductile used for shafts, connecting rods and rails etc.

3. **High- carbon steel :**

Carbon content is 0.8 to 1.5 %. Harder and stronger than mild steel and medium carbon steel

Uses ► Keys, knifes, drills etc.

**Properties of High-carbon Steel**

1. Its structure is granular
2. It is more tough and elastic than mild steel
3. It is more difficult to forge and then to weld
4. It can be permanently magnetized
5. Comparatively it is stronger in compression than in tension or in shear
6. It withstands vibration and shocks better

IF carbon content In steel increases 1.5% then it will behave like cast iron.

**MANUFACTURE OF STEEL**

**Blast Furnace**

Three basic raw materials are needed in large quantities for the production of steel

1. Iron Ore

2. Coal
3. Lime stone

The first step in the steel manufacture begins at the blast furnace. To separate iron from iron ore coke (substance when gas is taken out of coal), limestone and dolomite are charged into the blast furnace Temperature is raised to 1600$^{o}$C-1800 $^{o}$C.

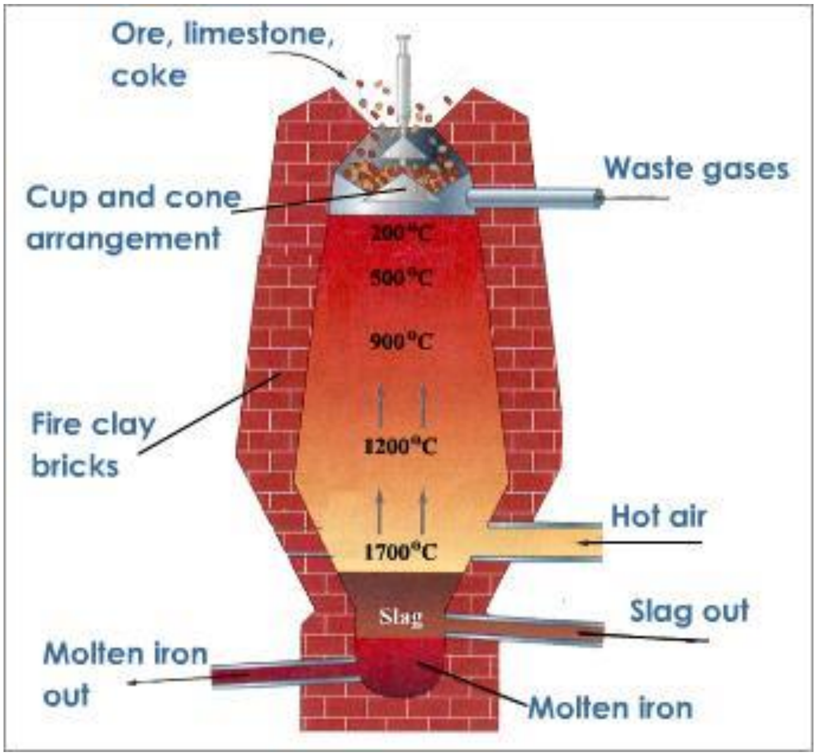


Fig Blast Furnace

This high temp causes the coke to burn and melt the iron. This red hot iron drained at an opening at the base of the furnace. Natural gas is often injected to reduce the amount of coke consumed. The dolomite and limestone combine with the non-ferrous elements of the ore to form a slag, which floats on the top of the molten iron and is removed separately. The product of the blast furnace is known as "Pig Iron" the basic ingredient of steel. It takes 2 tons of iron ore, 2/3 ton of coke, ½ ton of limestone, 4 tons of air to make 1 ton of Pig iron. Some of the pig iron goes to the foundries to make iron castings, but the vast majority is re melted and used in the production of steel in steel furnace. Several types of furnaces are used for the production of steel including

- Open Hearth Furnace
- Bessemer Furnace
- Electric Furnace
- New Oxygen Furnace

**OPEN-HEARTH FURNACE**

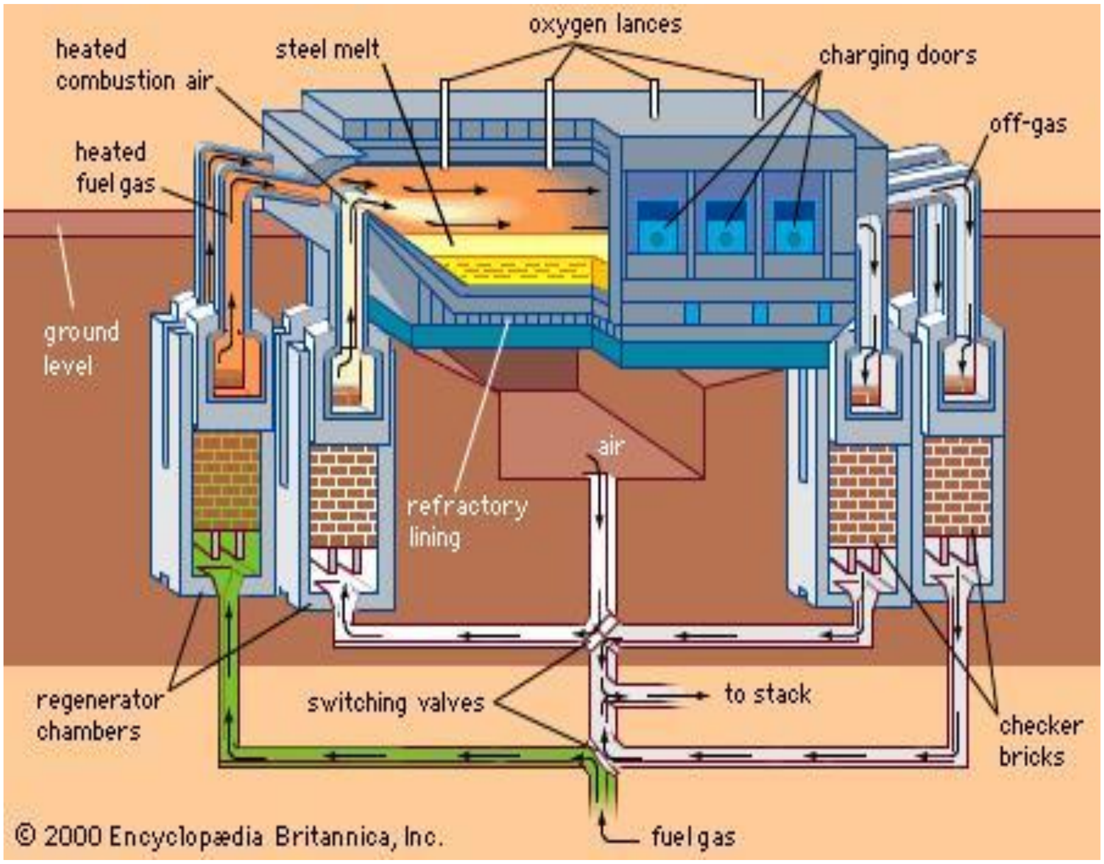


Fig Open Hearth Furnace

The open hearth furnace is called “open” because the charge is exposed to the sweep of flames over the surface. Molten pig iron, scrap iron and steel, limestone and high grade iron ore are charged into an open-hearth furnace. Limestone is put in first to act as a flux, then the scrap and iron ore are introduced. When they have began to melt, molten pig iron is added. The ingredients are heated using natural gas a fuel. Refining takes from 3½ to 7 hours at a temperature up to 30000F. During this period samples are taken and checked. Impurities are removed by limestone. Burnt lime may be added to hasten(fasten) the absorption of sulfur and phosphorus. When the molten steel is ready, it is drawn from the furnace in giant ladles, from which it is poured into “ingot moulds”. The moulds containing the ingots are then transported for cooling. The moulds are then removed, and the ingots placed in pits, where they are reheated to a uniform temperature high enough for rolling. Hot ingots goes into a blooming mill, where variety of products are made from these ingots, including sheets, rods, plates, pipes, wires, nails etc.

## Bessemer Furnace

The Bessemer process was the first inexpensive industrial process for the mass-production of steel from molten pig iron before the development of the open hearth furnace. 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.

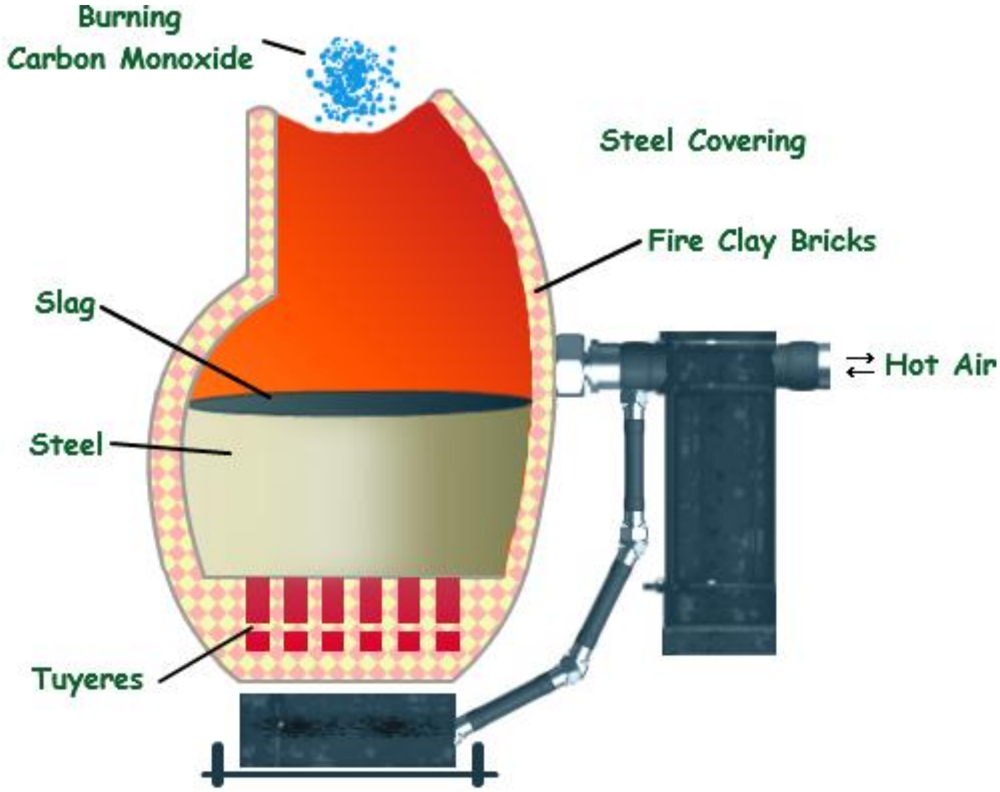


Fig Bessemer Furnace

Related decarburizing with air processes had been used outside Europe for hundreds of years, but not on an industrial scale. One such process has existed since the 11th century in East Asia, where the scholar Shen Kuo describes its use in the Chinese iron and steel industry. In the 17th century, accounts by European travelers detailed its possible use by the Japanese. The modern process is named after its inventor, the Englishman Henry Bessemer, who took out a patent on the process in 1856. The process was said to be independently discovered in 1851 by the American inventor William Kelly, though there is little to back up this claim. The process using a basic refractory lining is known as the "basic Bessemer process" or "Gilchrist–Thomas process" after the English discoverers Percy Gilchrist and Sidney Gilchrist Thomas.

**What is Rolling of Steel**

In metalworking, rolling is a metal forming process in which metal stock is passed through one or more pairs of rolls to reduce the thickness and to make the thickness uniform. The concept is similar to the rolling of dough. Rolling is classified according to the temperature of the metal rolled. If the temperature of the metal is above its recrystallization temperature, then the process is known as hot rolling.

**Hot Rolled**

Hot rolling is a mill process which involves rolling the steel at a high temperature (typically at a temperature over 1700° F), which is above the steel's recrystallization temperature. When steel is above the recrystallization temperature, it can be shaped and formed easily, and the steel can be made in much larger sizes. Hot rolled steel is typically cheaper than cold rolled steel due to the fact that it is often manufactured without any delays in the process, and therefore the reheating of the steel is not required (as it is with cold rolled). When the steel cools off it will shrink slightly thus giving less control on the size and shape of the finished product when compared to cold rolled.

**Uses:** Hot rolled products like hot rolled steel bars are used in the welding and construction trades to make railroad tracks and I-beams, for example. Hot rolled steel is used in situations where precise shapes and tolerances are not required.

### Cold Rolled

Cold rolled steel is essentially hot rolled steel that has had further processing. The steel is processed further in cold reduction mills, where the material is cooled (at room temperature) followed by annealing and/or tempers rolling. This process will produce steel with closer dimensional tolerances and a wider range of surface finishes. The term Cold Rolled is mistakenly used on all products, when actually the product name refers to the rolling of flat rolled sheet and coil products.

When referring to bar products, the term used is “cold finishing”, which usually consists of cold drawing and/or turning, grinding and polishing. This process results in higher yield points and has four main advantages:

- Cold drawing increases the yield and tensile strengths, often eliminating further costly thermal treatments.
- Turning gets rid of surface imperfections.
- Grinding narrows the original size tolerance range.
- Polishing improves surface finish.

All cold products provide a superior surface finish, and are superior in tolerance, concentricity, and straightness when compared to hot rolled.

Cold finished bars are typically harder to work with than hot rolled due to the increased carbon content. However, this cannot be said about cold rolled sheet and hot rolled sheet. With these two products, the cold rolled product has low carbon content and it is typically annealed, making it softer than hot rolled sheet.

Uses: Any project where tolerances, surface condition, concentricity, and straightness are the major factors

### Methods of Corrosion Prevention

In virtually all situations, metal corrosion can be managed, slowed, or even stopped by using the proper techniques. Corrosion prevention can take a number of forms depending on the circumstances of the metal being corroded.Corrosion prevention techniques can be generally classified into 6 groups:

1. Environmental Modifications

2. Metal Selection and Surface Conditions

3. Cathodic Protection

4. Corrosion Inhibitors

1. Coating

2. Plating

**Environmental Modification**:

Corrosion is caused by chemical interactions between metal and gasses in the surrounding environment. By removing the metal from, or changing, the type of environment, metal deterioration can be immediately reduced.

This may be as simple as limiting contact with rain or seawater by storing metal materials indoors or could be in the form of direct manipulation of the environmental affecting the metal.

Methods to reduce the sulfur, chloride or oxygen content in the surrounding environment can limit the speed of metal corrosion.

For example, feed water for water boilers can be treated with softeners or other chemical media to adjust the hardness, alkalinity or oxygen content in order to reduce corrosion on the interior of the unit.

**Metal Selection and Surface Conditions:**

No metal is immune to corrosion in all environments, but through monitoring and understanding the environmental conditions that are the cause of corrosion, changes to the type of metal being used can also lead to significant reductions in corrosion.

Metal corrosion resistance data can be used in combination with information on the environmental conditions to make decisions regarding the suitability of each metal.

The development of new alloys, designed to protect against corrosion in specific environments are constantly under production. Hastelloy nickel alloys, Nirosta steels and Timetal titanium alloys are all examples of alloys designed for corrosion prevention.

Monitoring of surface conditions is also critical in protecting against metal deterioration from corrosion. Cracks, crevices or asperous surfaces, whether a result of operational requirements, wear and tear, or manufacturing flaws, all can result in greater rates of corrosion.

Proper monitoring and the elimination of unnecessarily vulnerable surface conditions, along with taking steps to ensure that systems are designed to avoid reactive metal combinations and that corrosive agents are not used in the cleaning or maintenance of metal parts are all also part of effective corrosion reduction program.

**Cathodic Protection:**

Galvanic corrosion occurs when two different metals are situated together in a corrosive electrolyte. This is a common problem for metals submerged together in seawater, but can also occur when two dissimilar metals are immersed in close proximity in moist soils. For these reasons, galvanic corrosion often attacks ship hulls, offshore rigs and oil and gas pipelines. Cathodic protection works by converting unwanted anodic (active) sites on a metal's surface to cathodic (passive) sites through the application of an opposing current. This opposing current supplies free electrons and forces local anodes to be polarized to the potential of the local cathodes. Cathodic protection can take two forms. The first is the introduction of galvanic anodes.

This method, known as a *sacrificial system*, uses metal anodes, introduced to the electrolytic environment, to sacrifice themselves (corrode) in order to protect the cathode.

While the metal needing protection can vary, sacrificial anodes are generally made of zinc, aluminum, or magnesium, metals that have the most negative electro-potential. The galvanic series provides a comparison of the different electro-potential - or nobility - of metals and alloys. In a sacrificial system, metallic ions move from the anode to the cathode, which leads the anode to corrode more quickly than it otherwise would. As a result, the anode must regularly be replaced.

A second method of cathodic protection is referred to as *impressed current protection*.

This method, which is often used to protect buried pipelines and ship hulls, requires an alternative source of direct electrical current to be supplied to the electrolyte. The negative terminal of the current source is connected to the metal, while the positive terminal is attached to an auxiliary anode, which is added to complete the electrical circuit. Unlike a galvanic (sacrificial) anode system, in an impressed current protection system, the auxiliary anode is not sacrificed.

**Corrosion Inhibitors:**

Corrosion inhibitors are chemicals that react with the metal's surface or the environmental gasses causing corrosion, thereby, interrupting the chemical reaction that causes corrosion.

Inhibitors can work by adsorbing themselves on the metal's surface and forming a protective film. These chemicals can be applied as a solution or as a protective coating via dispersion techniques.

The inhibitors process of slowing corrosion depends upon:

- Changing the anodic or cathodic polarization behavior
- Decreasing the diffusion of ions to the metal's surface
- Increasing the electrical resistance of the metal's surface

Major end-use industries for corrosion inhibitors are petroleum refining, oil and gas exploration, chemical production and water treatment facilities.

The benefit of corrosion inhibitors is that they can be applied in-situ to metals as a corrective action to counter unexpected corrosion.

**Coatings:**

Paints and other organic coatings are used to protect metals from the degradative effect of environmental gasses.

Coatings are grouped by the type of polymer employed. Common organic coatings include:

- Alkyd and epoxy ester coatings that, when air dried, promote cross-link oxidation
- Two-part urethane coatings
- Both acrylic and epoxy polymer radiation curable coatings
- Vinyl, acrylic or styrene polymer combination latex coatings
- Water-soluble coatings
- High-solid coatings
- Powder coatings

**Plating:**

Metallic coatings, or plating, can be applied to inhibit corrosion as well as provide aesthetic, decorative finishes.

There are four common types of metallic coatings:

1. Electroplating: A thin layer of metal - often nickel, tin, or chromium - is deposited on the substrate metal (generally steel) in an electrolytic bath. The electrolyte usually consists of a water solution containing salts of the metal to be deposited.
2. Mechanical plating: Metal powder can be cold welded to a substrate metal by tumbling the part, along with the powder and glass beads, in a treated aqueous solution. Mechanical plating is often used to apply zinc or cadmium to small metal parts
3. Electroless: A coating metal, such as cobalt or nickel, is deposited on the substrate metal using a chemical reaction in this non-electric plating method.
4. Hot dipping: When immersed in a molten bath of the protective, coating metal a thin layer adheres to the substrate metal.