Non-Ferrous Metals and Alloys

1. Aluminum

Aluminum ore is found as a hydrated aluminum oxide, called bauxite. The impurities present in it are oxides of iron, silicon, and titanium. The process therefore, is to separate aluminum oxide from these impurities. For this purpose, bauxite is fused in electric furnace and carbon is added to reduce the impurities, which form sludge and can be removed. As a result of this refining pure aluminum oxide is separated from the impurities. Then an electrolytic bath is used to reduce aluminum from its oxide. As the electrolytic process proceeds the oxygen escapes through the bath and molten aluminum collects at the bottom, from where it is periodically tapped off.

Properties:
1. High electrical conductivity
2. High heat conductivity
3. Good resistance to corrosion
4. Highly ductile
5. Light in weight

Application
1. Used for heavy conductor and bus bar work.
2. In domestic utensils and other heat conductive appliances.
3. Used in manufacture of containers for chemical industries.
4. It can be easily worked, extruded, rolled, drawn, and forged.

2. Copper

It is not available in pure form under the earth. It is extracted from its ores through a series of processes. Copper pyrites are the main ores used for extracting copper. The copper ore is first roasted to drive out the water, CO2 and sulphur. It is followed by melting in a reverberatory furnace of the type used for wrought iron. Silica is added to the charge to form slag with impurities like iron and alumina, etc. The molten metal is tapped and transferred to a convertor where air is blown through it to burn the impurities. This result in the production of crude form of copper, known as blister copper, containing 68% purity. Final refining is done by an
electrolytic process, pure copper depositing on the cathode. This gives a highly pure (99.9\%) copper which is re melted and cast into suitable shapes.

**Properties:**

1. High electrical conductivity.
2. High heat conductivity
3. Good corrosion resistance
4. High ductility
5. Light in weight

**Application:**

1. Used as electrical conductor in various shapes and forms viz., sheet and contacts.
2. Used in heat exchanger and heating vessel and appliances.
3. Used for providing base coating on steel prior to nickel and chromium plating.
4. Can be easily cold worked, rolled, and drawn.
5. Used in various appliances where light weight is desired.

### 3. Magnesium

Principle sources for obtaining magnesium are natural salt brines, sea water, and water liquors obtained from potash industry and ores. The principle ores are magnesite, dolomite and carnallite. Various processes have been developed for its extraction, but the most popular and widely used one is electrolytic process.

**Properties**

1. Lightest of all metals, weighing about two-third of aluminum.
2. It may be sand, gravity and pressure die-cast.
3. Its casting is pressure tight and obtains good surface finish.
4. It may be easily formed, drawn, forged and machined with high accuracy.
5. Addition of 10\% aluminum and small amount of zinc and manganese improve its strength and casting characteristic.
6. Addition of 2\% Mn helps in its easy forming into plates and sheets and extrusion works.
4. Zinc

The zinc ore is first concentrated through suitable process. This concentrate is fed into a retort with suitable amount of carbonaceous material (say coal). Several retorts are housed in one furnace and their temperature raised to 1100°C. Zinc emerges as a vapour and is passed through a condenser. By rapid cooling the zinc vapour may be quickly converted into powdered zinc.

Properties

1. High corrosion resistance
2. Low melting point
3. High fluidity

Application: Widely used as a protective coating on iron and steel. Low melting point and high fluidity make it the most suitable metal for pressure die-casting.

5. Lead

Lead ores are generally found as oxides or sulphides. Other impurities present in the ores are iron, copper and zinc etc. The prepared ore concentrate, together with the flux (lime and silica), is fed into a small blast furnace, where the temperature is raised to about 1010°C. The lead is melted and a liquid slag formed of the impurities. Both slag and molten lead are tapped at intervals. Further refining is carried out in a reverberatory furnace where an oxidizing atmosphere is maintained to burn out the impurities.

Properties:

1. Good corrosion resistance
2. Good resistance to chemical action.
3. It is soft heavy and malleable
4. It is alloyed with brass and steel to impart them free cutting properties.
Application
1. Used for water pipe and roof protection
2. Used for acid bath and containers in chemical industry.
3. Can be easily worked and shaped.
4. Used as an alloying element in making soft solders and plumber’s solders.

6. Tin
The most prominent tin ore is cassiterites. It also carried compounds of copper, iron, lead antimony, bismuth and zinc etc. As usual an ore concentrate is prepared. This concentrate is roasted to drive off excess arsenic and sulphur. The roasted or is transferred to a reverberatory furnace, where it is heated. Anthracite is added to the charge which reacts chemically to separate tin, the latter sinking to the bottom of the furnace. From there it is tapped at intervals. This crude tin is re melted and re find further.

Properties
1. Good resistance to acid corrosion
2. It is soft, has good plasticity and can be easily worked.
3. It can be easily rolled in thin foils, but cannot be drawn due to low strength.

Application
It is used as an alloying element in soft solders, bronzes bearing metals.

7. Nickel
Its extraction process consists of first roasting the ore, followed by melting in a small blast furnace. Lime stone and quartz are added as flux. They form slag with impurities. Coke is used as fuel. Crude molten nickel tapped off periodically from the bottom of the furnace. This crude metal is further refined in a Bessemer convertor followed by treating with sulphuric acid to extract pure nickel. Copper is separated as a copper sulphate.

Properties
1. It has good resistance to both acid and alkali corrosion
2. It has high tensile strength and can be easily worked cold and hot.

Application
1. It is widely used in food processing.
2. It is plated on steel to provide a corrosion resistant surface
3. It is important alloying element with steel.

Non-ferrous alloys

Due to poor physical and mechanical properties and high costs the non-ferrous metals are seldom used in their in pure state. But their alloys carry very good physical and mechanical properties and are widely used. In general they have lower strength, hardness, and modulus of elasticity than irons and steels. However they carry their own importance due some exceptional properties possess, like lightness, ease in fabrication, good machinability, high resistance to corrosion, attractive appearance and good cast ability etc. Some commonly used non-ferrous alloys are described in the following articles:

1. Brasses

All brasses are basically alloys of copper and zinc. There are two main varieties of brasses:
  1. Alpha brass (Zn up to 37%) - for cold working.
  2. Alpha beta brass (Zn 33% to 46%) – for hot working.

Alpha brasses are very ductile and can be readily cold worked without any chances of fracture. They can be cold rolled into sheet, drawn into wire, deep drawn and drawn into tubes. In these brasses, as the proportion of zinc increases, their strength increases but ductility decreases. They are worked hardened when subjected to intensive cold working, but ductility can be regained by annealing them at $600^0$ C. Slow cooling provides maximum ductility, but for common uses they may be water quenched. Deep drawing of this brass requires periodical annealing during the process.

Alpha beta brasses lose strength at high temperature but become very plastic. It, therefore respond very well to hot rolling, hot extrusion, hot stamping and casting, etc. when cold worked, fracture are likely to develop.

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Common types of brasses in engineering use are the following:

a) **Cartridge brass**: - It has 70% Cu and 30% Zn. It is very strong and ductile. It is used for wide range of drawn components like cartridge cases, head lamp reflector, radiator shells and drawn tubes.

b) **Muntz metals**: - It contains 60% Cu and 40% Zn and can be cast, rolled, extruded and stamped. It is a sort of general purpose alloy having good resistance to corrosion. It is used for casting pump parts, valve, taps and other similar items.

c) **Naval brass**: - It contains 60% Cu, 39% Zn and 1% tin. It is more or less similar in composition to Muntz metals except that 1% Zn is replace by 1% tin. As a result of this change the resistance to sea water corrosion is vastly improved. This alloy is therefore, widely used for cast and forged fittings for ships.

d) **Admiralty brass**: - It contains 70% Cu, 29% Zn and 1% tin. It is similar to cartridge brass in composition except that 1% Zn is replaced by 1% tin. It can be cold worked and has good resistance to sea water corrosion. It is cold drawn into tubes and rolled into sheets and bars. It is widely used in ship fitting, bolts, nuts, washer and other items subjected to sea water corrosion.

e) **Gilding brass**: - It contain up to 15% zinc and the rest Cu. It is very cold working alloy and is used for jewelry, decorative and ornamental work. It is commercially available as cold rolled strip, wire or sheet. Its color according to the percentage of Zn varies from red to bright yellow. It is also called Gilding metal.

f) **Delta brass**: - It is also known as delta metal, it consists of 60% of Cu, 37% Zn and 3% iron. It can be easily hot worked, forged, rolled, extruded and cast. It has fairly good tensile strength after hot working and casting. It also has a good corrosion resistance. It can suitably replace steel castings.

g) **Free cutting brass**: - It contains 60% Cu, 37%Zn and 3% Pb. It is specially used in machining work, such as producing components from bar stock on turret and automatic lathe. It is also used for making cast, forged, or stamped, blanks to be used for further machining. With this metal very high speeds and feeds can be employed in machining.

h) **Beta brass**: - It contains 50% Cu, and 50% Zn. Higher percentage of zinc render it hard and brittle, but it softens quickly when heated and melts at 870°C. Its main application is brazing solder.

i) **Silicon brass**: - It contains 80% Cu, 16% Zn and 4% Si. It responds well to welding and is widely used for refrigerators and fire extinguisher shells. It can also be easily sand or
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gravity die cast, hot stamped and extruded. It can be used as a cheaper substitute for phosphor bronze.

2. Bronzes

Bronze is basically an alloy of copper and tin. In general, it possesses superior mechanical properties and corrosion resistance than brass. Those containing up to 8% tin are called working bronze. They can be easily cold worked, rolled, formed and drawn. They are available in various forms, as strip, wire and sheet etc.

With the increase in tin content, its strength and corrosion resistance increase. It is then known as hot working bronzes. Small addition of phosphorous further improves its strength, ductility and bearing properties. The amount of phosphorous added is 0.5%. This is then known as phosphorous bronze.

a. Phosphorous bronze: - Widely used in the several manufacturing units, we present an array of phosphor bronze alloys rods, phosphor bronze bars, phosphor bronze squares and many more. These phosphor bronze alloys offer resistance towards fatigue and chemical corrosion, so they are used for varied application in various industries such as in heavy engineering, defense, aviation, electrical and more.

b. Gun metal: - The term 'gunmetal' is applied to a family of copper-based casting alloys containing between 2-11% tin and 1-10% zinc. Modified forms may contain, in addition, such elements as lead (up to 7%) and nickel (up to 6%) when the alloys are classified as 'leaded gunmetal' and 'nickel gunmetal'. Gunmetal is noted for the manufacture of intricate castings required to be pressure tight such as valves, pipe fittings and pumps.

c. Aluminum bronze: - Aluminum bronzes are used for their combination of high strength, excellent corrosion and wear resistance. Aluminum bronze alloys typically contain 9-12% aluminum and up to 6% iron and nickel. Alloys in these composition limits are hardened by a combination of solid solution strengthening, cold work, and precipitation of an iron rich phase. High aluminum alloys are quenched and tempered. Aluminum bronzes are used in marine hardware, shafts and pump and valve components for handling seawater, sour mine waters, and industrial process fluids. They are also used in applications such as heavy duty sleeve bearings, and machine tool ways.

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d. **Silicon bronze:** - it contains 1 to 4% Si, 0.25% to 1.25% Mn, 0.5% to 1% iron (if added) and the rest copper. Small addition of up to 0.5% Pb will improve machinability. It has high strength, toughness, and corrosion resistance. It can be readily hot worked. With low silicon content it can be safely cold worked also. It is widely used for boiler parts, tanks marine hardware and similar other items.

e. **Manganese bronze:** - It contains 55% to 60% copper, 38% to 42% Zn, up to 1.5% tin, up to 2% iron, up to 1.5% Al and up to 3.5% Mn. It has superior mechanical properties and high corrosion resistance. It has poor response to cold working but can be readily hot worked. It is used for such parts where high strength and corrosion resistance are desired, such as in ship propellers and rudders, etc.

### Aluminum alloys

a. **Duralumin:** - It contains 4% Cu, 0.5% Mg, 0.5% Mn and the rest aluminum. Duralumin alloys are relatively soft, ductile, and workable in the normal state; they may be rolled, forged, extruded, or drawn into a variety of shapes and products. Their light weight and consequent high strength per unit weight compared to steel suit them for aircraft construction. Because duralumin loses strength in welding, a special laminated sheet form called alclad is used for aircraft construction; it has thin surface layers of pure aluminum or a corrosion-resistant aluminum alloy covering the strong duralumin core.

b. **Aluminum casting alloy:** - It contains 90% Al, 8% Cu, 1% iron and 1% Si. It has good strength, hardness and machinability. It may be sand, pressure or gravity die cast.

c. **Y-alloy:** - It contains 93% Al, 4% Cu, 2% Ni, and 1% Mg. Its principle use is as a casting alloy. It maintains its strength at elevated temperatures, and is used for pistons of I.C. engines. A treatment of Y-alloy castings, consisting of quenching in boiling water from a temperature of 510\(^{0}\) C and then aging for 5 days, develops very good mechanical properties in them. It is also used in strip and sheet forms.

### Nickel alloys

a. **German silver:** - The name German silver or nickel silver is misleading since it has no silver content, but is an alloy of 60% Cu, 20% Ni and 20% Zn. It resembles silver but instead of the soft white color it has a yellow-grey tinge. German silver is used extensively in the hollow-ware and flatware industries as E.P.N.S. (electro-plated nickel silver), which is a nickel silver item with a plating of silver. Nickel silver is slightly more difficult to work for jewelry purpose, than copper and other metals, since it is a harder alloy. Again it is prone to tarnish on exposure to air and will turn the skin green with prolonged contact.
b. **Constantant**: - It contains 45% Ni, 55% Cu. It has high specific resistance, which is unaffected by temperature variation. It is used for accurate resistors, thermocouples, Wheatstone bridge, low temperature heater and resistances.

c. **Monel metal**: - It contains 68% Ni, 30% Cu, 1% iron and small additions of Mn and other elements. It is a nickel-copper alloy with high strength and excellent corrosion resistance in a range of media including sea water, hydrofluoric acid, sulfuric acid, and alkalis. Used for marine engineering, chemical and hydrocarbon processing equipment, valves, pumps, shafts, fittings, fasteners, and heat exchangers.

d. **Inconel**: - It contains 80% Ni, 14% Cr and 6% iron. Inconel Alloys Are Generally Known For Their Resistance To Oxidation And Their Ability To Maintain Their Structural Integrity In High Temperature Atmospheres. There Are Several Inconel Alloys That Are Used In Applications That Require A Material That Does Not Easily Succumb To Caustic Corrosion, Corrosion Caused Purity Water, And Stress-Corrosion Cracking. While Each Variation Of Inconel Has Unique Traits that make it effective in different circumstances, the majority of the alloys are used frequently in the chemical industry.

e. **Nichrome**: - Like Inconel it is also a nickel chromium alloy which is extensively used in electrical appliances as resistance wire.

f. **Incoloy**: - It is also a Ni based alloy which is widely used as a high temperature alloy. It consists of 42% Ni, 13% Cr, 6% Mo, 2.4% Ti, 0.04% C and rest iron.

g. **K-Monel**: - It possesses similar composition as monel, but about 3 to 4% Al is added to it. It carries similar application as monel, but has better mechanical properties than that.

h. **Nimonic alloy**: - It contains 80% Ni and 20% Cr. It has high strength and ability to operate under intermittent heating and cooling conditions. It is widely used in gas turbine engines.

**Bearing metals**

Bearing metal should posses the following important characteristics:

1. It should have enough compressive strength to posses adequate load carrying capacity.
2. It should have good plasticity to allow for small variation in alignment and fitting.
3. It should have low co-efficient of friction to avoid excessive heating.
Some important bearing metals are the following:

a. **Babbit metal**: It is white metal containing 85% tin, 10% Sb and 5%Cu. It is used for heavy duty vehicles.

b. **Lead alloy**: It contains 40% lead and 60% Cu. It may be cast in position or fused as a thin shell to a bronze or steel reinforcing shell outside.

c. **Phosphor bronze**: With 10% tin is used for light load low speed bearings. It can be sand and centrifugal cast.