14

Non-Ferrous Metals

14.1 INTRODUCTION

Athough the production of individual non-ferrous metals is small in comparison to the iron, the former play an important part in many engineering structure and industrial processes. The non-ferrous metals and their alloys are used despite their high cost because they provide a wide variety of properties. Some of the more commonly used non-ferrous metals are aluminium, copper, tin, zinc, lead and manganese.

14.2 ALUMINIUM

The principal constituents of bauxite ($Al_2O_32H_2O$) which yield aluminium on a commercial scale are hydrated oxides of aluminium and iron with some silica. Some of the other aluminium ores are corundum, kaolin or china clay, and kryolite. The ore is purifed by Bayer's process and is reduced to aluminium by Hall Hiroult's process in two stages. In the first stage bauxite is converted into alumina by roasting, grinding, heating (with sodium hydrate) and filtering. Then it is agitated for several hours to precipitate the hydrate, which is separated, washed and calcined at 1000° C. In the next stage aluminium is extracted by electrolysis of alumina in a molten bath (Fig. 14.1) of crystolite (a fluoride of alumina and sodium). A flow diagram for extraction of aluminium is shown in Fig. 14.2.

Aluminium is silver white in colour with a brittle metallic lustre on freshly broken surface. It is malleable, less ductile than copper but excels zinc, tin, and lead. Aluminium is harder than tin. Aluminium is very light, soft, strong and durable, has low thermal conductivity but is a good conductor of electricity. Aluminium can be riveted and welded, but cannot be soldered. It can be tempered at 350° C. The melting point is 657° C, tensile strength is 117.2 N/mm^2 in the cast form and 241.3 N/mm^2 when drawn into wires. Aluminium is found to be resistant

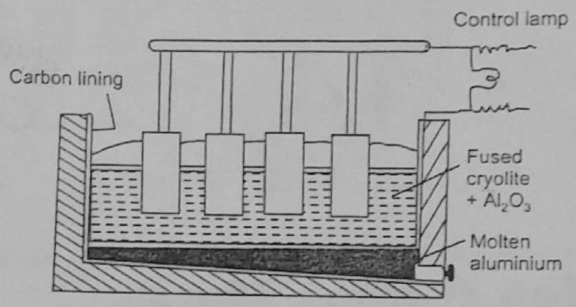

Fig. 14.1 (a) Extraction of Aluminium by Electrolysis

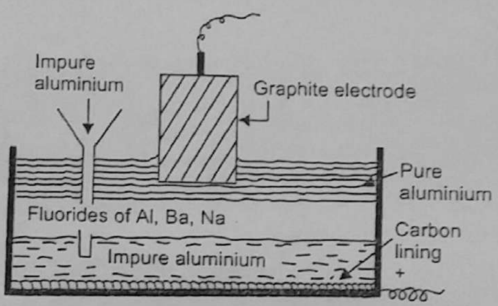

Fig. 14.1 (b) Hoope's Cell for Refining Aluminium

to the attack of nitric acid, dissolves slowly in concentrated sulphuic acid and is soluble in hydrochloric acid. At normal temperature it is not affected by sulphur, carbonic acid, carbonic oxide, vinegar, sea water, etc., but is rapidly corroded by caustic alkalis.

Uses Pure aluminium is very soft and is unsuitable for structural purposes. Satisfactory properties are derived by alloying copper, manganese, zinc, silicon, nickel with aluminium. It is most suitable for making door and window frames, railings of shops and corrugated sheets for roofing system. Aluminium sheets are used over doors in bathrooms to protect them from getting rot and for stamping into a variety of shapes. Aluminium powder is used for making paint. Aluminium is extensively used in making parts of internal combustion engine, airplanes, utensils and packings for medicines, chocolates, etc. Alluminium alloys are widely used for the manufacture of rolled sections, such as angles, channels, I-sections, round and rectangular pipes, rivets and bolts.

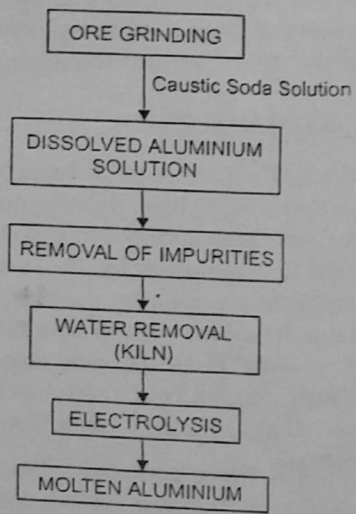

Fig. 14.2 Flow Diagram for Extraction of Aluminium

Alloys

Aluminium is commonly alloyed with copper silicon, magnesium or zinc to improve its mechanincal propeties. Some aluminium alloys also contain one or more of the metals manganese, lead, nickel, chromium, titanium, beryllium. A large part of the aluminium production is utilized in making light, stiff, corrosion-resistant alloys with these metals. Aluminium alloys may be classed as the *cast alloys*, which are shaped by casting and *wrought alloys*, which are worked into different shapes by mechanical operations. Cast alloys are generally binary alloys containing copper or silicon, and sometimes magnesium. Wrought alloys contain copper, magnesium, silicon and manganese that form precipetation hardening alloys with aluminium. Following are some of the aluminium alloys.

Duralumin contains 3–5% copper, 0.51–1% magnesium and 0–0.07% manganese. 0.3–0.6% iron and 0.3%–0.6% silica are present as impurities. The relative density is 2.80, which is quite low as compared to that of mild steel. However, when rolled and heat treated tensile strength equals that of mild steel. Its yield point is 206.85 N/mm^2. It is highly resistant to corrosion. Wire and sheets are drawn from duralumin. Duralumin may be fabricated into different structural shapes to be used for construction.

Magnalium is an alloy of aluminium and magnesium (6 per cent). It has got very good mechanical properties and is a little lighter than pure aluminium. It is easy to work, exceptionally strong, and ductile and is widely used as deoxidizers in copper smelting operations.

Aldural When a coating of aluminium is given to duralumin it is known as aldural and has better corrosion resisting properties.

Y-alloy invented during World War II contains 4 per cent copper, 20 per cent nickel and 1.5 per cent magnesium. Toughness and hardness are achieved by heating it to 500° C for six hours and then cooling it down in boiled water. Its relative density is 2.80 and resists corrosion better than duralumin. Y-alloy has good thermal conductivity and can sustain high temperature. It is used for making pistions of I.C. engines, cylinder head, connecting rod and propeller blades.

Aluminium Bronze contains less than 11 per cent of aluminium and is rather inappropriately named. It is highly ductile when aluminium is less than 7.3 per cent. As the aluminium increases, ductility decreases and at 12 per cent the alloy is very brittle. Bronzes containing less than 7.3 per cent aluminium are highly resistant to torsional stress, readily rolled, forged, cold drawn, exhibit toughness under impact and resistance to alternate bending stress.

An input of 1 per cent of maganese into 10 per cent aluminum bronze increases the yield point and ductility without change in strength or endurance under reversal of stress. The modulus of elasticity of aluminium bronze is about 1.03425 × 10^5 N/mm^2. These are almost incorrodible in sea water and in this respect are superior to Muntz metal or naval brass.

Aluminium bronze is used for pump lines, tubes, springs, screws, rivets, ornamental works, marine engineering castings, motor boat shafting, musical instruments, and as a substitute of mild steel to resist corrosion, grill works, etc.

Light Alloy contains 3 per cent copper and 12 per cent zinc. It is used for castings such as crank and gear housings.

Aluminium-Copper Alloy contains copper up to 4 per cent. Less liable to burning the alloy produces light castings that are stronger and tougher than that made from aluminium. It is mainly used in automobile industry for casting.

Aluminium-Zince Alloy contains zince up to 15 per cent and is used for light casting which can be easily machined or forged into desired form. These are very sensitive to high temperatures in melting and in solid form exhibit low strength and brittleness when heated above 50° C. Alloys containing 15 to 25 per cent zinc are harder, stronger, but less ductile and more difficult to roll or draw. If percentage of zinc is increased above 25 the alloy suffers decrease in strength when excessively worked, either hot or cold. Aluminium zinc alloys have well defined yield points.

Aluminium-Silicon Alloy Aluminium alloys containing 5 to 15 per cent silicon are important because their excellent casting qualities, including excellent fluidity and freedom from hot-shortness, permit the pouring of thin intricate sections. They also have high resistance to corrosion, are good conductors of heat, and have low thermal expansion.

14.3 COPPER

Copper is extracted form ores, e.g., copper pyrite, such as, chalcopyrite ($CuFeS_2$, 34.5 per cent copper), malachite ($CuCO_3 + Cu(OH)_2$, 57.3 per cent copper) and copper glance (Cu_2S, 79.8 per cent copper). Nearly all the copper is extracted by smelting. After calcining the ore it is mixed with silica and coke. Then it is oxidized in Bessemer converter where removal of major portion of iron and sulphur compounds is effected. The crude copper thus produced is known as *blister copper* which is cast into small pigs. The blister copper contains many impurities and is refined in the reverberatory finance (Fig. 14.3) or by electrolysis.

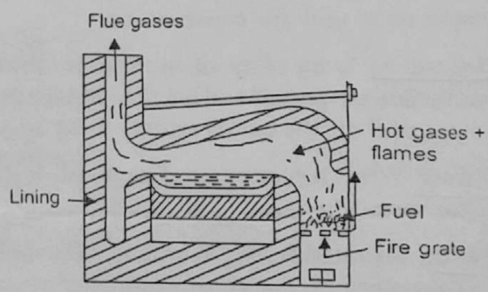

Fig. 14.3 Roasting of Copper-Pyrite Ore in Reverberatory Furnance

In reverberatory furnance the sulphides are oxidized and the cuprous oxide exerts cleansing action on the base metals in the crude copper. A larger excess or a deficiency of cuprous oxide in the copper makes it weak and brittle which make it necessary to remove any excess which remains after the impurities have been skimmed off. This is achieved by the addition of charcoal and green wood to the bath. Fire refining imparts malleability, toughness and ductility. Electrolytic refining is used when pure grade copper is required for electrical purposes, and where there is a considerable quantity of gold or silver associated with the crude copper.

Properties Copper is a bright shining metal of reddish colour which turns greenish on exposure to weather. Copper is malleable and ductile and can be worked in hot and cold conditions. It is not weldable, except on red heat. It is soft and good conductor of heat and electricity. The electrical resistivity of copper having less than 0.1 per cent non-metallic impurities lies between 0.155–0.159 ohm per metre gram at 20° C. The resistivity increases with the content of impurities and with amount of wire drawing. Its tensile strength is high.

Uses Copper is extensively used for electrical purposes, tubes for condensers and for other conductors which must withstand corrosion. In buildings copper is used for roofing, sheeting and damp proofing. Its use is restricted in the appliances and connections used for water supplies in houses.

Alloys

The alloying elements most frequently used with copper are zinc, tin, and lead. Some of the important alloys made with copper are brass and bronze.

Brass is an alloy 60–90% copper and 10–40% zinc. The colour is silvery-white for low content of copper and copper-red for higher copper content.

Brass may be either cast or wrought. Brass for castings usually contains 30–40% zinc. Tin (2–3%) when added increases hardness but decreases ductility. An addition of about 2 per cent lead renders brass easy to turn, file and polish but ductility and strength are reduced. Aluminium (1–6%) when added raises the strength but decreases the ductillity. Cast brasses are stronger and more ductile than either of their components, copper and zinc. Compared to copper its electrical conductivity is quite low.

The zinc content is 37–45% for brasses suitable for forging, rolling or extruding and hot working. Brasses used for extruding contain 2–4% lead to make them flow easily through dies. Lead, however, lessens the amount of reduction in working, which these alloys will withstand without cracking, makes the metal more susceptible to bruning during melting. The brasses brought into shape by cold working have copper to zinc ratio 2:1 and 3:1, the former being used for making sheets, wires and stamped and drawn articles.

Brasses with copper to zinc ratio 1:1 are used for brazing brass goods. They have a very high crushing strength but are too brittle for mechanincal working.

Alloys containing 57–63% copper are called Muntz metals also known as *yellow metals*. These are used for making bolts, rods, tubes and extruded shapes. Alloys having 70–75% copper are used for making cartridge cases, condenser tubes and spinning operations. With 80–85% copper the brasses take a good polish resembling gold and are used for making medals and artificial jewellry.

Manganese Bronze contains small percentage of tin (0.5–1.5%), iron (0.51.0%), manganese (< 0.5 per cent) and lead (< 0.2 per cent). On account of its high strength (551.1.6 N/mm^2 in tension), the facility with which it can be rolled or forged, and its resistance to salt water, manganese bronze is extensively used in marine engine, propeller blades and condenser tubes.

Naval Brass has same coposition as that of manganese bronze except it does not contain manganese and iron. It is slightly weaker but more ductile than manganese bronze.

Sterro Metal is brass containing 38 per cent zinc and 1.5–2.0% iron and copper. It is used for hydraulic cylinders working under heavy pressure.

Delta Metal contains 50–65% copper, 50–30% zinc, 0.1–5% iron and 0.1–1% tin and is as strong as mild steel having a tensile strength of 413.7–551.6 N/mm^2.

Bronze

Bronze is an alloy of copper and tin with one or more additional metal. When copper (95 per cent) is alloyed with tin (5 per cent) the bronze is known as *coinage bronze* used for making coins. Copper (88 per cent), tin (10 per cent) and zinc (2 per cent) results in *Gun metal* used for making valves and bearings. *Bell metal* is produced by alloying copper (65–45%) to zinc (35–20%) and nickel (5–35%). It is used for making utensils, fittings and electric goods.

Zinc Bronze It contains 59 per cent copper, 39 per cent zince and 2 per cent tin. The tensile strength of such a casting is 413.7 N/mm^2. It is too brittle, however, to be of much value.

Phosphor Bronze is an alloy of copper and tin with phosphorus as a deoxidizer. For malleability tin and phosphorous should not exceed 4 per cent and 0.1 per cent, respectively. Phosphorous up to 4 per cent increases hardness and brittleness. If added in excess the product becomes useless.

Lead Bronze contain copper, tin, phosphorous (<1.0 per cent) and lead (< 3.0 per cent). It is most suitable for making bearings. When lead is more than 4 per cent, bronze segregates forming soft spots in the hard matrix which rapidly wears and forms cavities for the lubricant.

Copper-Beryllium Alloys These alloys posses exceptional strength, good resistance to corrosion, fair electrical activity, and high wear resistance. They are used for springs, gears, electric contacts, bearings, and for, tools such as chisels and wrenches. These alloys contain about 2 per cent beryllium, and in some alloys addition of 0.35 per cent nickel or cobalt may be made to refine the grain structure.

14.4 ZINC

The main source of zinc is the sulphide ore zinc blende or black jack (ZnS, 67 per cent zinc). The other ores for extraction of zinc are zinc carbonate, calamine ($ZnCO_3$, 52 per cent zinc) and zinc silicates-hemimorphite and willemite. The sulphide ore is finely ground and calcined in reverberatory furnace until nearly all the sulphur is expelled. Carbonate ores and silicate ores are often calcined in shaft furnace before being distilled. Ore containing impurities of iron is broken to small pieces and calcined to powder and iron is removed by electromagnet. Zinc is extracted either by distillation or by electrolysis. The ore is mixed with coal or coke and kept in retort (Fig. 14.4). By carefully controlling the temperature of the retort to white heat, carbon monoxide is produced and the zinc is relieved of its oxygen. Zinc is collected and cooled to liquid form in condensers. From time to time molten zinc is tapped from condensers, skimmed and poured into moulds. The zinc so cast is known as *spelter.*

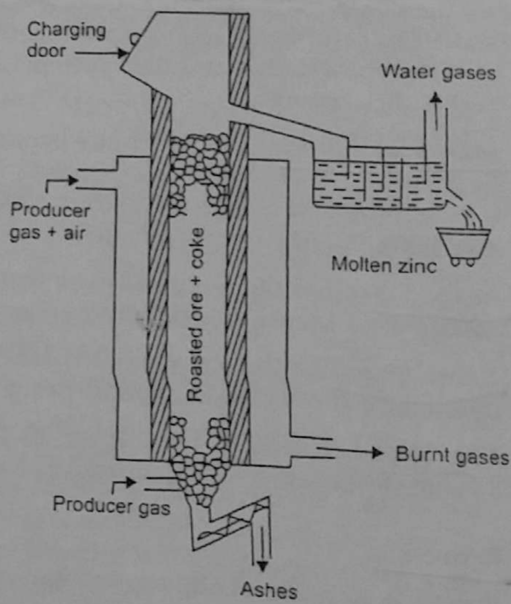

Fig 14.4 Vertical Retort Furnace for Extraction of Zinc

Properties The most important property of zinc is its resistance to atmospheric corrosion. Ductility is good and it can be deformed into desired shapes. Lead (< 0.1 per cent) makes the spelter roll easier, however, it softens, weakens and ductility is reduced. Iron and cadmium embrittle and harden zinc and are, therefore, a detriment in spelter which is to be rolled or used for galvanising. They should not exceed 0.02 per cent. Zinc, either rolled or cast, shows no well defined yield point.

Uses It is used to produce brass, German silver, some of the bronzes, as a protective coating on iron and steel, boiler tubes, fruit jar covers and cans for resisting corrosion and for negative pole pieces of batteries.

14.5 LEAD

Mainly used in its pure form, lead is the densest, softest and the weakest metal. The principal ore is lead sulphide, galena (PbS, 86.6 per cent lead). Lead is extracted by reducing the sulphur content by roasting the raw ore in pots or sintering it in shallow pallets (Fig. 14.5). It is then smelt in a blast furnace (Fig. 14.6) along with flux and coke. Lead, zinc, copper, arsenic, etc., are taken out of the blast furnace and seperated atrernately on the basis of their different melting points.

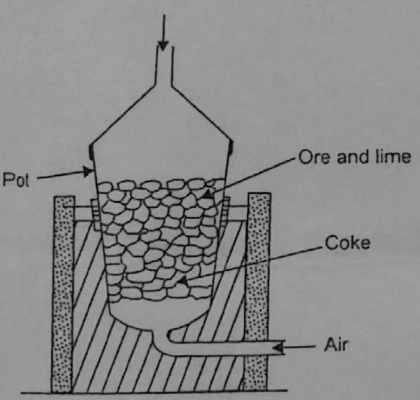

Fig. 14.5 Roasting of Lead Ore in Sinterer

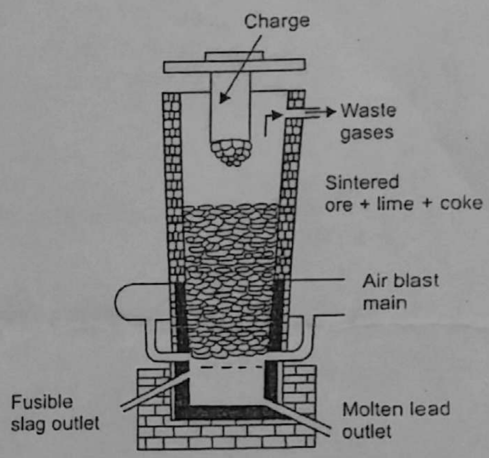

Fig. 14.6 Smelting of Galena in Blast Furnace

Properties Pure lead can be scratched even with finger nail, highly malleable and can be rolled, into thin foils. It has a blue grey colour and dull metallic lusture when freshly fractured. When exposed to moist air it loses lusture due to oxidation. Its relative density is 11.34 and melting temperature is 327° C. The softness and specific gravity of lead are reduced because of the impurities such as antimony, arsenic, zinc and copper. Magnesia (2 per cent) raises the hardness abruptly.

Uses It finds its principal use in paints as base, lead pipes and joints in sanitary fittings and in batteries.

Alloys

Some of the important lead alloys are as follows:

Lead Antimony Alloy also known as high lead alloy is made by alloying 15–20% antimony with lead. The antimony serves as hardener and the alloy so produced is used for making bearings. Lead antimony tin alloys containing 10–20% antimony, 5–20% tin and the remainder lead are used for bearings subjected to moderate loads. *Mangolia metal* is one of the common bearing metal of this class. Theses are also used for type metal.

Lead Tin Alloys are used in making solder and toys. By adding tin to lead the strength and hardness are considerably increased. The alloy carrying more than 50 per cent lead remains pasty over a considerable range of temperature before solidifying. It is suitable for plumbers solder. Additions of tin to lead increase the strength and hardness.

Fusible Alloy A wide variety of compositions are used to obtain alloys that melt at specific low temperatures. These are frequently binary or ternany alloys of lead, tin, bismuth, cadmium. Considerable use of these alloys is made in automatic sprinkles systems, fire alarms and safety devices to prevent overheating.

14.6 TIN

It is extracted from black oxide of tin, casseterite (SnO_2.78.6 per cent tin). Tin is extracted from the ore by crushing, roasting and melting to a temperature of about 1000° C in a way similar to that of coppers.

Properties Tin is a silvery-white, lustrous, and extremely malleable metal. It is so soft that it can be cut by a knife. Its specific gravity is 7.3 and it melts at 232° C. It is harder, more ductile and stronger than lead. Tin is as ductile as soft steel. It is highly resistant to corrosion and has low tensile strength.

Uses Sheets coated with tin are used to make cans, utensils and furnace pipes. Sheets coated with lead-tin alloy are used for roofing. Tin is also used for making bronze and other alloys.

Alloys

The important tin alloys are solder, babbitt metal, white metal, and pewter.

Solder It is obtained by alloying tin with antimony (0.5–3%), lead (5–40%) and tin (40–95%). These have low melting points. Solder is used for joining copper, lead, tin, iron, zinc, etc.

Babbitt Metals These are alloys with tin base containing small proportions of copper and antimony. These are used for making bearings.

White Metal It is an alloy of tin, lead and antiomoy with copper in varying proportions. It is used for making bearings. This bearing metal accommodates itself for any defect in the alignment of bearings.

Pewter It is an alloy of tin 75 per cont and lead 20–25%. It has high corrosion resistance.

14.7 NICKEL

Nickel is generally extracted from pyrite or silicate ores.

Properties A brittle metal approaching sliver in colour nickel takes good polish and at ordinary temperatures does not tarnish or corrode in dry air. It has specific gravity 8.30, when cast and 8.70, when rolled. Its melting point is 1500° C. It is almost as hard as soft steel far more malleable, and when rolled and annealed, is somewhat stronger and almost as ductile. Nickel