GENERAL INFORMATION FOR MANUFACTURE OF ALUMINIUM

HISTORY:

The basic process technology for production of aluminum is the same for the entire plants world over. Substantial technological improvements, however, have taken place in the developed countries in the areas of alumina, primary aluminum and the semis production.

Details of Basic raw material for manufacture of Aluminium:

Alumina is the basic raw material for production of aluminum and is obtained from bauxite, a mineral containing upto 60% in the form of mono/trihydrate. The conventional **Bayer process** invented in 1888 has been found to be the most economical route for production of alumina even today. Though the basic process has remained unchanged, considerable advancement in technology has taken place for improvement in respect of efficiency of the various operations, energy savings, and optimization in production cost, pollution control, etc.

Alumina is the main input for the production of aluminium through electrolytic process. The production of alumina from bauxite is carried out through the Bayer route, an extractive hydro-metallurgical process which belongs to the alkaline group of processes. This process was invented in 1888 by Kari Joseph Bayer of Austria and is still the most economical process for extraction of alumina from bauxite. In 100 years of its existence although the Bayer process has remained basically the same considerable improvements have taken place keeping pace with the developing technology, with respect to efficiency of the various operations, savings in energy, pollution abatement and optimization of production cost.

All the plants under private sector and Korba Alumina Plant under Public Sector were designed and engineered by foreign collaborators. In India, all the alumina plants are captive to the aluminium smelters and therefore any impact on aluminium production due to power constraints, demand pattern or any other reason is directly reflected on capacity utilization of alumina plants.

Alumina production process consists of crushing and grinding of *bauxite* with caustic liquor in ball/rod mills. The slurry after desilication is pumped to large tanks/autoclaves/tubes for digestion at 110^{o} C to 300^{o} C depending upon the mineralogy of bauxite. The digested slurry is diluted and classified in thickeners. The overflow (aluminate liquor) is pumped for control filtration and underflow containing red mud is washed / filtered and disposed to red mud pond. The filtered aluminate liquor is cooled to 50-85^{o} C in plate heat exchanger/flash tanks and pumped to precipitation tanks with addition of seed hydrate and retained for 30-75 hours with finishing temperature of 40-55^{o} C depending on the type of alumina to be produced. The precipitated hydrate slurry is classified and the coarser part (under flow) is filtered and washed to obtain the product hydrate and the fine part is recycled as seed hydrate. The hydrate containing 10-20% moisture is calcined in rotary kilns/stationary calciners at 1000^{o} to 1200^{o} C to obtain calcined alumina.

The aluminum metal is produced through electrolytic reduction of calcined alumina, based on process invented by C.M. Hall in USA and P.L.T. Heroult in France in 1886.

In the electrolysis process, alumina is dissolved in fused electrolyte bath of cryolite at operating temperature ranging from 920^{o} C to 970^{o} C. Under the influence of high intensity direct current, alumina gets dissociated to aluminum and oxygen ions in the electrolytic cells. Aluminum ions go to anode where they react with carbon of anode and form CO_2 and CO. Gases evolved are cleaned to recover the valuable fluorides and reduce the concentration of noxious contaminants before discharge to the atmosphere. Molten aluminums is tapped from the bottom of electrolytic cells and cast into ingots, billets, etc. for conversion to semis.

Aluminum semis covering flat the non-flat products are produced utilizing the processes of DC casting, continuous casting, extrusion, hot and cold rolling.

Alumina Process / Production:

Production of alumina basically involves elimination of impurities like iron oxide, titanium dioxide, silica and other from various alumina bearing raw materials so as to extract product of high purity for its subsequent reduction to aluminium metal. Although the research on alumina production from various raw materials and different process routes has continued for many years, World's major production of electrolytic grade alumina is through the conventional Bayer Process.

The basic principle of the process is based on the fact that the alumina present in the bauxite in the trihydrate from (Gibbsite) is readily attacked at low temperature ranging from 100 to 140^o C by liquor of low caustic concentration (about 110 g/1 of Na_2O) while monohydrate (Boehmite and Diaspore) is economically extracted at higher temperature ranging from 240 to 300^o C using high caustic concentration of about 140 to 170 g/1 of Na_2O. Alumina solubility in caustic lye depends on temperature and concentration of caustic soda. The basic reactions involved are dissolution of alumina present in bauxite by caustic soda lye with formation of sodium aluminate solution leaving the gangue materials as insoluble red mud.

The above reaction is endothermic and reversible in nature. On suitable selection of temperature and concentration, the alumina hydrate is precipitated out at temperatures ranging from 50 to 80^o C and caustic soda is regenerated at the later part of the process. The hydrate is calcined generally at 1000 to 1200^o C to produce the electrolytic grade alumina. Usually the bauxite having silica module (we Al_2O_3/wt Sio_2) greater than 8 is considered suitable for treatment by the Bayer process. Dealing with the trihydratic bauxite with low caustic concentration and temperature is termed as 'American Process' for production of coarse alumina while the other variant requiring high temperature and caustic concentration in case of monohydratic bauxite as 'European Process' for production of fine alumina. The exact parameters are determined based on the optimization of the results obtained by bench scale/pilot plant tests taking into consideration the extraction efficiency, quality of raw materials, energy consumption, capital and operating costs and mainly the nature of bauxite.

Bauxite suitable for alumina production is mined and transported to Alumina Plant after primary crushing generally upto (-) 100 mm to (-) 200 mm. At alumina plant, bauxite is crushed (secondary crushing) and ground with caustic liquor in ball/rod mills, slurried and sent for desilication, where the slurry is retained for about 8-10 hours at about 95^o C in large tanks. The desilicated slurry is pumped to digestion unit. Digestion of bauxite can either be carried out at low or high temperature ranging from 110^o C to 300^o C depending upon the mineralogy of the bauxite.

The digested slurry is diluted and classified in thickeners. The overflow (aluminate liquor) from the thickener is pumped for control filtration. The underflow containing red mud is counter currently washed and/ or filtered in washers/drum filters and disposed to red mud pond.

Control filtration is carried out in Kelly/ pressure plate filters to reduce the suspended red mud solids below 20 mg/1 in aluminate liquor. The liquor is cooled to 50-85^o C in plate heat exchangers/flash tanks and is pumped to precipitation tanks with addition of seed hydrate and retained for 30-75 hours with finishing temperature of 40-55^o C depending on the type of alumina to be produced. The precipitated hydrate slurry is classified in hydroseparators/thickeners. The coarser part (under flow) is filtered and washed in pan/drum/disc filters to obtain the product hydrate and the fine portion is recycled as seed hydrate. The product hydrate containing 10-12% moisture is calcined in rotary kilns/fluid bed calciners at 1000 to 1200^o C to obtain calcined alumina.

The liquor obtained after filtering and washing of hydrate is partly used for grinding, partly for dilution and remaining is concentrated by evaporation in multiple effect evaporators. The major raw materials used in the process are bauxite, caustic soda, lime, flocculants, fuel oil/natural gas, etc.

- **Bauxite**

  Bauxite is a complex multi-component ore containing oxide of Al, Fe, Si, Ti, P, V, Ca, Mg, etc, having variable chemical and mineralogical composition and physical characteristics. Most of the alumina plants are designed to handle only a narrow range of bauxites.

  The two most important variable which influence plant design are alumina and silica content and the mineralogical from in which they are present in bauxite. Hardness and particle size distribution are foremost among the physical properties of bauxite influencing process design and economics. Harder bauxites require intensive grinding while fine-grained softer bauxites grind easily and result in faster reaction rate. However, fine bauxites pose settling and filtration problems.

  Under Indian context, about 80% of the bauxite reserves are predominantly gibbsitic in nature, while other bauxites are mixed ore containing trihydrate as well as monohydrate. The bauxite from captive mines of Bihar, Madhya Pradesh, Tamilnadu and Maharashtra, being used by HINDALCO, BALCO, NALCO and INDAL, contains appreciable amount of monohydratic alumina (from 15 to 30% of total alumina) and calls for high/medium pressure digestion as adopted by the above plants. On the other hand, the East Coast bauxite of Panchpatmali – Orissa (Gbbsite more than 90% of total alumina) is degested at atmospheric pressure.

- **Caustic soda**

  Caustic soda is used for digestion of bauxite. Presence of impurities in bauxite such as silicates, phosphates organics, vanadates and gallates which are partly soluble in caustic, leads to the losses in caustic soda. Caustic soda is usually supplied in the form of lye of 50% concentration. This is one of the most expensive raw materials used in alumina production in India.

- **Lime**

  Burnt lime is used in the process for:

  - Causticisation
  - Filter aid for control filtration.
  - Transformation of iron mineral.
  - Enchancing monohydrate dissolution of alumina.

  Usually its consumption varies from 30 kg to 250 kg/t of alumina depending on its use.

- **Flocculants**

  Flocculants are used to enhance the settling rate of the red mud in thickeners. The natural flocculants are wheat, maize or rye flour. Synthetic flocculants are also in use. Specific consumption is usually about 2 to 3 kg/t of alumina.

- **Energy source**

  Fuel oil, coal or natural gas are used as primary source of energy. These are used for generating electrical power, steam and calcinations of hydrate.

- **Major technological facilities**

  Unit operations of the Bayer process can be classified under following two broad heads:

  - Red Section
  - White section

  -Units of red section cover:

  (i) Bauxite storage, crushing and grinding.
  (ii) Desilication.
  (iii) Digestion.

(iv) Red mud separation, washing and disposal.

-While units of white section cover:

(i) Control filtration.

(ii) Precipitation.

(iii) Hydrate classification.

(iv) Calcination.

RED SECTION

(i) Bauxite storage crushing and grinding.

To ensure smooth and continuous operation, is necessary to have bauxite storage stockpiles from 15 to 90 days stock. Size of the bauxite received from the mines is usually 100 to 200 mm and is required to be crushed before grinding. Bauxite is ground and slurried in spent liquor to produce slurry of desired concentration and particle size distribution. Rod/ball mills in combination with various types of screens are used. Type of mill depends on the hardness of bauxite to be ground.

(ii) Desilication

The bauxite slurry is pumped to large desilication tanks where the slurry is heated to around 95^{o} C with a retention time of 8 to 10 hours. This process reduces scale formation in digestion equipment. It is some times possible to eliminate the desilication process entirely. The slurry after desilication is pumped to digesters. If required lime is added in desilication tanks to control phosphorus in the liquor/slurry.

(iii) Digestion

During digestion aluminium hydroxide is extracted from bauxite at optimum efficiency. The conditions type of equipment and mode of operation are different depending on type of bauxite.

Performance Norms:

The major pollutants under environmental norms are caustic present in red mud, dust in flue gases from steam plant and calcinations unit. Performance norms have been found to vary considerably from plant to plant. It has been seen that in India the consumption of bauxite varies from 2.66 to 3.08 t/t of alumina while that of caustic soda from 78 to 131 kg/t of alumina.

All the aluminum smelters in India have been installed with different design parameters depending on technological know-how adopted. It has been observed that performance norms are varying from plant to plant depending on the status of technology adopted. Consumption of DC power per tonne of aluminum from 1.91 to 1.97 t/t of aluminum. The power consumption in technologically advanced international smelters is presently about 13,000 KWh with average alumina consumption of 1.90 to 1.98 t/t of aluminum.

Performance norms for aluminum semis have been considered for consumption of energy and services, operating consumables and supplies, man-hour requirement per tonne of production and percentage yield. It has been observed that the performance norms are widely varying from plant to plant depending upon the process technology, design of equipment, product-mix, etc.

Improvements / upgradation / new Technologies for production of Aluminium:

Considerable developments have taken place in the process for production of alumina, aluminum and semis in the developed countries.

a) Alumina Plants

- Use of rod mills with classifiers for wet grinding of bauxite.
- Adoption of tube digestion system in order to achieve improved digestion yield.
- Adoption of Alcoa combination process for digestion and extraction of trihydrate as well as monohydrate alumina.

- Adoption of hydro garnet technology to treat gothetic bauxites.
- Adoption of direct filtration technology to separate the red mud directly downstream the digestion under the same conditions of pressure and temperature.
- Adoption of red mud separation system for improvement in the clarity of liquor.
- Liquor purification system for removal of carbonates and organic matters.
- Improved mechanical agitation system for precipitators.
- Adoption of modified hydrate classification system.
- Adoption of special disc filters for filtration of seed and product hydrate.
- Adoption of multistage falling film evaporation systems in place of conventional single stage system.
- Installation of stationary calciners in place of conventional rotary kilns.
- Adoption of dry disposal system of red mud.
- Automation and computerized process control systems for better operation of the plants.
- Recovery of vanadium and gallium as valuable by-products of Bayer alumina.

b) Aluminum Smelters

- Improvement in electrolyte bath chemistry to minimize re oxidation of metal.
- Improvement in alumina feeding system by adopting point feeding for proper distribution of alumina in the electrolyte.
- Improvement on magnetic field characteristics through bus bar network redesign for stable metal pad.
- Improvement in heat balance of cell to reduce the heat dissipation.
- Increase the current efficiency by accurate control of process parameters.
- Possibility of lowering anode current density by increasing the anode size.

- Replacement of monolithic cathode lining with prebaked cathode blocks for better cell life.
- Improvement in the technique of anode manufacturing and anode baking devices.

c) Semis Production

- Hot top casting for billets combined with air-slip process, for smooth outer surface and better internal grain structure.
- Electro-magnetic casting for extrusion billets and rolling slabs for smooth and glossy cast surface.
- Adoption of FDC process in place of DC casting process for large production runs.
- Adoption of horizontal casting (HDC) process for rolling billets/slabs of long length.
- Inline metal treatment for removal of hydrogen, non-metallics and undesirable trace elements before casting.
- Spray casting and rolling process adopting spraying of liquid metal on a moving substrate.
- Many developments as incorporated in the modern extrusion presses.
- New processes like CONFORM extrusion and hydro-static extrusion for improved extruded products.

Source:
The above report has been extracted from the book
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