LECTURE 15 Electric Furnace Steelmaking

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Key words: Electric arc furnace, Melt-down period, Transformer power

Introduction:

Steelmaking in electric arc furnace has emerged as an important steelmaking process in recent years. The flexibility and easy adoptability of EAF steelmaking to accommodate the fluctuating market demand have evolved into the concept of mini steel plants to produce different grades of finished products (long or flat or mixed) of plain carbon or alloy steels from scrap and other metallic charge materials. Although scrap is the preferred raw material but sponge iron and iron carbide are being used regularly in most plants because of shortage of steel scrap and to dilute the concentration of tramp elements. Several developments in the design and operation have made EAF steelmaking to contribute significantly to the overall total production of steel in the world. According to an estimate, the proportion of electric steel is around 40 to 45% in the total world steel production. It must be noted that EAF consumes lot of electric energy and hence the cost and availability of electrical power are important issues in electric steel development.

Type of Electric furnaces:

In principle an electric arc is formed between the electrode and the metallic charge and charge is heated from the arc radiation. Electric arc furnaces are of two type (a) alternating current and (b) direct current. In alternating current, furnace operates by means of electric current flowing from one electrode of three to another through the metallic charge. In direct current, the current flows from carbon electrode, which acts as cathode, to an anode embedded in the bottom of the furnace.

Construction of AC Electric Arc Furnace

The furnace consists of a steel shell, lined with suitable refractory materials and is mounted on the tilting mechanism. The shell thickness is around 0.005 times the shell diameter. Three electrodes enter through the roof. The hood may be swung away for charging. Heat is generated by the hot area formed between the electrodes and the charge.

Hearth

The hearth contains metal and slag. The hearth lining consists of backing lining and working lining. The backing lining is few layers of high fired magnesite bricks on which working lining is rammed with either dolomite or magnesite mass. Permeable blocks or porous refractory elements are introduced through the bottom to inject inert gas for stirring. The EAF steel bath is shallow; the aspect ratio of the bath is around 0.2 to 0.22.

Roof

The roof is exposed to more heat than other furnace elements. Its lining is also subjected to radiant heat reflected from the walls and slag. High alumina bricks and magnesite – chromite bricks are used for roof lining. The roof lining is water cooled which increases the life of refractory lining to at least 10-20 times more than without water cooling.

The roof has three holes to allow insertion of the electrodes.

Electrode

A typical alternating current operated EAF has three electrodes. Electrodes are round in section, and typically in segments with threaded coupling, so that as the electrodes wear, new segments can be added. Graphite electrodes are preferred over carbon electrodes because of better electrical conductivity. The electrodes are automatically raised and lowered by a positioning system.

Electrode consumption depends on

- Oxidation of the surface of the electrode
- Mechanical losses due to fracture
- Dissolution in slag during carbon boil

The diameter of the electrode should correspond to the current supplied; if current density is excessively high, electrodes will be heated and oxidized vigorously. The electrode current could vary from 12 to $16\,\mathrm{A/cm^2}$ for 400 to 600 m electrode diameter. Larger electrode diameter increases electric energy consumption.

The electrodes are positioned at apexes of an equilateral triangle. The diameter of the circle passing through the centers of electrodes is called the diameter of the electrode spacing. If the electrodes are placed close to each other and far from furnace walls, the charge at the furnace banks will be heated belatedly. With large spacing diameter, electric arcs will burn near the walls, which will result in rapid wear of the lining.

The electrode spacing diameter for the bath diameter could be 0.45 for small furnaces, 0.35 for medium- sized and large furnaces, and still lower for super- powerful furnaces. For a bath diameter of 5560 mm of a 100 ton furnace the electrode spacing diameter would be $0.35 \times 5560 = 1900\mathrm{mm}$.

Side walls

The side walls refractory materials should be able to withstand thermal shock and corrosive action of slag. Hot spot is formed on the side walls due to the radiation from arc flames, reflected from bath surface during power input. The side wall is lined with magnesite, dolomite or chrome magnesite bricks up to the slag line. The side wall thickness is usually 450 to 500mm for 10 to 50 ton furnaces and 550 to 650mm for 100 to 200 ton furnaces.

Transformer power: Electric furnaces are powerful consumers of electric energy. The operating voltage of a furnace is 100-800V and the current may reach several thousand amperes. The furnace transformer transforms high voltage energy into low voltage. The melting process consists of two periods: melt-down and refining period. In melt down period higher electric energy is required as compared with the refining period.

In small furnaces, the power consumption for melting is about $600\mathrm{k\,Wh/ton}$ and it falls to $450\mathrm{k\,Wh/ton}$ in big furnaces. Additional 150 to 400 $\mathrm{k\ \ Wh/ton}$ power is required during refining depending on the practice.

Large transformers are required to run electric arc furnaces. During melting more power is required than during refining. The transformer capacity is designed to suit melting requirements. The capacity of the transformer is usually 470- 650 KVA per tonne of furnace capacity. In terms of hearth area, the transformer capacity is in the range of 750-900 KVA per square meter

Charging materials:

Steel scrap is the principle raw material. It may constitute 60 to 80% of the charge. In some practices sponge iron and or pig iron is also used for chemical balance. In basic furnaces slag formers like limestone, fluorspar, sand, and quartzite are used to form a slag to refine the metal. For decarburization oxygen lancing is used. Iron ore is also added. Ferro-manganese, ferrosilicon or aluminium are used for deoxidation. To produce alloy steels, alloying elements are added.

Plant layout

Layout of an electric arc furnace steelmaking shop varies from plant to plant due to difference in the quality of the product and the scale of production. Some plants have just one EAF while others have two. The variation is also due to whether the shop is provided with oxygen lancing and carbon injection facilities, gas cleaning equipments and finished castings or ingots. Broadly electric furnace steelmaking shop comprises of the following:

a) Electric furnace
b) Transport facilities for ladle
c) Scrap charging
d) Auxiliary injection facilities
e) Electrode movement mechanism
f) Charging of raw materials and weighing system
g) Slag disposal.

In an ideal layout, all the above facilities should be arranged so as to ensure smooth input and output of materials.

Arc Furnaces Operation

It consists of charging, melt down period and refining. The large baskets containing heavy and light scrap are preheated through the exit gas. Burnt lime and spar are added to help early slag formation. Iron one or mill scale may also be added if refining is required during melt- down period.

The roof is swung off the furnace, and the furnace is charged. Some furnaces are equipped with continuous charging. Hot metal is also charged as per the requirement.

In the meltdown period, electrodes are lowered and bored into the scrap. Lower voltages are selected in order to protect the roof and walls from excessive heat and damage from the arcs. Once the arc is shielded by scrap, voltage is increased to form molten metal pool to reduce the meltdown period. During meltdown period, silicon, manganese and carbon oxidizes. Also oxidizing and limy slag is produces which promotes dephosphorization as well. Melt- down time depends on

- Arc conditions: larger arc requires lower current and lower heat losses
- Deep or shallow bath: deep bath shortens the meltdown period.

Refining continues even during melting. Removal of phosphorus must be complete before the rise in temperature and carbon boil.

The single oxidizing slag practice is employed when removal of sulphur is not required. When both P and S are required to be removed double slag practice is used. In double slag practice, oxidizing slag is removed and reducing slag is formed after deoxidation with ferrosilicon or ferromanganese or aluminum. Reducing slag helps to avoid loss of alloying elements.

Once the bath chemistry and its temperature are attained, heat is deoxidized and finished for tapping.

Comparison with oxygen steelmaking

	EAF	Oxygen steelmaking
Source of energy	Electric + chemical energy	Chemical energy; Autogeneous process
Iron containing raw material	Hot metal + directly reduced iron + scrap in the suitable proportion as per practice	Hot metal + 20 – 30% scrap
Operating procedure	Oxygen lancing is to promote decarburization, scrap melting and post combustion.	Oxygen supply is continuously done to refine hot metal to steel. A three phase dispersion of slag/metal/gas forms to accelerate the refining rates.
	Slag foaming is induced to shield refractory lining from the heat of arc.	
	Carbon injection is done to induce foamy slag practice	

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