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Study of Steel from Sponge Iron- At a Glance

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Abstract:
A certain proportion of DRI produced in India is consumed for the steel production through the induction furnace route which provides for slag metal separation actuated by a mere melting of the DRI without any purification reactions. Government of India, owing to the poor quality of steel produced from DRI through the induction furnace route has stipulated that, steel to be marketed must contain less than 0.085% of combined sulphur and phosphorous. Therefore the DRI producing companies are initiating a method of dephosphorizing the steel produced from the induction furnace route. The present work is an attempt at dephosphorizing the steel produced in the induction furnace route from DRI which is high in phosphorous (upto 0.096% are common). A neutral lining is provided in the induction furnace and double slagging by the addition of Calcium Aluminate, Calcium Barium Aluminate and Barium Aluminate is adopted. It is observed that double slagging by the addition of Barium Aluminate yielded the best result so far as the dephosphorization is concern.

Keywords: Dephosphorization, Doubleslagging, Induction furnace route, Neutral lining, Synthetic slag.

I. INTRODUCTION:

Steel making in India is branched into two sections specifically primary route and secondary route. In the primary route of steel making iron ore is used as raw material. In the first stage iron ore is melted in a blast furnace to produce hot metal, and in second stage this hot metal is moved to a steel making shop to produce steel in a basic oxygen furnace. In the secondary route of steel making steel is produced using sponge iron, scrap etc. In this route steel is produced in electric furnaces. The main electric furnaces that are used in secondary steelmaking to produce steel are induction furnace and electric arc furnace. As per the information presented by ministry of steel, total manufacturing of crude steel in India is around 74MT in the last year. Out of this 35 percent steel was produced using induction furnace. The prime raw material for induction furnace is steel scrap, sponge iron and cast iron. The percentage of directly reduced iron in the burden differs from 10 to 95 percent, depending on its inventory and monetary value of manufacturing. Large scale of steel formed through secondary route is alloy steel and plain carbon steel. [2] In the present work, our objective is to set up preliminary info for dephosphorization of steel in 150 kg induction furnace. As for the expulsion of phosphorous basic environment is desirable, the basicity is controlled by the addition of Barium Aluminate, Calcium Aluminate and Calcium Barium Aluminate in the form of slag. The FeO present in DRI is responsible for providing oxidation potential to the added slag.

Three heats had been carried out for each slag and, slag and metal samples were collected to determine the degree of dephosphorization. Phosphorous comes to induction furnace from DRI and pig iron and the quality of pig iron depends on the quality of hematite. The range of phosphorous varies from 0.05 to 0.09 % with the variation in the quality of raw materials. Steel containing phosphorous has some adverse effect on the quality of steel, hence the amount of phosphorous should be beneath a suitable amount. The elimination of phosphorous from steel is conducted by oxidation. The compound which is produced after oxidation reaction is in the form of P_2O_5, which is a component of the dross. Dephosphorization is very much sensitive towards the operating temperature of the furnace. Because at very high temperature phosphorous in the dross may get back to the steel.

On the primary route of steel making oxidation potential for removal of phosphorous is obtained by direct lancing of the oxygen jet into the bath. But in induction furnace route it is difficult to remove phosphorous by oxygen lancing because, here the height of metal level is equal to the depth of furnace. The second constraint that suppresses dephosphorization is the acidic refractory lining which is used in induction furnaces. The removal of phosphorous and sulfur is difficult with acidic lining as they form basic slag. In the present work we had used Magnesia based basic lining for the removal of phosphorous.

- **Induction furnace steelmaking:**

A melting furnace in which electric current is applied to melt metal is called induction furnace. Melting and alloying a wide variety of metals with minimum melt loss are the features of induction furnace. Induction furnace is also used for refining of metal. [6] Straight off a day's induction furnace making has come forth as a major steel producing operation. In India induction furnace plants are termed as mini steel plants, because the maximum production capacity of these plants is less than 1MT of steel per year. In induction furnace, steel scrap is used as charge material, only due to less availability of steel scrap directly reduced iron (DRI) is likewise utilized in induction furnace. Now a day's induction furnace in integrated with mini blast furnace, and in such type of plants the metallic charge, usually consists of hot metal, steel scrap and DRI in varying proportions to get different properties of steel. Improvement of induction furnace design goes on day by day, which permits enhancement of electrical efficiency in modern furnaces, and metallurgical efficiency has also been greatly improved by oxygen lancing.

II.TYPES OF INDUCTION FURNACE:

There are basically two designs of induction furnaces are available, namely, the core type or channel furnace and the coreless type. Both types have advantages which make one or the other suitable to a particular operation. As compared to coreless induction furnace, core type furnace is a more efficient type of induction furnace. In case of core type construction maximum power transfer into the metal is possible. This design has a distinct advantage of providing a large capacity of molten metal with low holding power level. Core type induction furnace is an excellent furnace for small foundries with special requirements for large castings. Because of the requirement to keep the channel molten, core type furnaces are energized 24 hours a day. Hence the application of core type furnace is limited to one alloy or similar base alloy. Hence the power supplies are of line frequencies of 60 or 50 Hz. If quick melting of one alloy is desirable**,** then coreless induction furnace is used. The coreless furnace can be used for one shift operation because it is easy to stop and restart the furnace. [6] Coreless induction furnace process has some advantages over other types of arc furnace.

i. Since there are no electrodes, it is possible to melt steels very low in carbon.
ii. The metal produced is really low in gases because of the absence of arc.
iii. Temperature control of the process can be managed easily.

The disadvantages of induction furnace are:

i. Life of basic lining is low.
ii.Low temperature of slag, which is heated from the metal.

2.9. Devices for Electric heating:

Any material through which an electric current flows is heated thereby. The rate at which heat is generated depends on current density and the specific resistance of the material which is called as a 'resistor'. [11]

Electric energy can be utilized for industrial heating in several ways.

a) The material to be heated serves as a resistor.
b) Separate resistors transfer heat to the work load by radiation and convection and in a few cases by conduction.
c) The work load is heated by induced current.

2.10. Principle of induction furnace:

The principle of induction furnace is the induction heating.

2.10.1. Induction Heating:

A change in the electric current that flows in a wire causes a change in the magnetic conditions around the wire. The change in magnetism can be used to produce an electric current in a properly placed object, which is heated by the current. The general equipment required for induction heating consists of a coil of wire in which alternating current flows. The object to be heated is placed inside the coil of wire. Factor affecting distribution of temperature in the heated object is the frequency of alternation (cycles per second).

At a high frequency, temperature at the skin of the work piece is highest. The rate of heating decreases exponentially and rapidly towards the center. At low frequency also distribution of temperature from skin to the center is exponential, but temperature decreases more gradually than it drops with high frequency. This is the facts; bars of large cross section are heated with low frequency. [11] Induction coils are not expensive, but additional equipment required for induction heating is expensive. Low frequency (60cps) heating requires more capacitors for correction of the power factor.

. Advantages of induction furnace over electric arc furnace:

Induction furnace consumes less power compared to EAF due to faster melting, lower taping temperature and higher power density. Melting of FeCr is difficult in an arc furnace due to the absence of stirring. Also, heat losses in EAF are high as lime and fluxes added to protect the lining take away substantial amount of heat. In induction furnace no electrodes are used as in EAF thus reducing cost of production. Again it uses lesser quantity of refractory. Initial investment of plant and equipment is less. Acidic ramming mass used in induction furnace is much cheaper when compared to basic ramming mass and bricks used in EAF.
Induction furnace has lower tapping temperature compared to EAF to recover the oxidized chromium. Also there is no need to add reductants like carbon or FeSi in induction melting unlike in the EAF. Recovery of chromium is higher in induction furnace compared to EAF as negligible amount of chromium is oxidized in induction furnace. [5]

2.14. Manufacturing of steel from DRI:

2.14.1. Introduction

Direct reduction, an alternative route of iron making, overcomes some of the conventional blast furnace. Direct reduced iron (DRI) which is also known as sponge iron is manufactured through either natural gas or coal based technology. Oxygen from the iron ore escapes during the solid state reduction and leaves pores. When observed under the microscope, this looks similar to sponge, hence the name sponge iron. Iron ore is reduced in solid state at 700°C to 1050°C either by reducing gas (H+CO) or coal. The investment and operating costs of direct reduction plant are low compared to blast furnace which requires coking coal for producing coke. Demand for use of DRI in steel making is increasing due to shortage of steel scrap and power. The principal constituents of sponge iron are metallic iron, residual iron oxides, carbon and impurities such as phosphorous, Sulphur, Silica, Aluminum etc.

2.14.2. Characteristics of DRI

DRI can be produced in different forms, namely pellet, lump and hot briquette. The secondary product form from fine DRI is called cold briquetted iron. Hot briquette is also known as hot briquetted iron (HBI). Hot briquetted iron is a mixed solid form of pellet and lump which is pressed as 800 to 7000C immediately after reduction. Quality of hot briquetted iron can be varied by mixing lumps and pellets in different ratios. Due to high density and low surface area of hot briquetted iron, there is a low chance of. Oxygen present in the DRI is in the form of FeO, which reacts eagerly with carbon in the molten bath and improves heat transfer, slag metal contact and homogeneity of the bath. DRI having higher Carbon content is desirable. Hence, gas based DRI (which content 1.0 to 2.5% C) is more desirable than coal based DRI (0.2% C). Depending on the process used for DRI production, the degree of metallization varies from 80 to 95%. Low degree of metallization leads to higher dross volume, more power consumption, increased heat time and low yield during steel making. [3, 16]

2.14.3. Types of sponge iron making:

A. Coal based processes using rotary kiln.

B. Coal based processes using shaft furnace.

C. Retort processes using gas or coal as the reluctant.

III. ROTARY KILN:

Rotary kiln is reactor for sponge iron making, but it is also used for calcinations of lime stone, production of cement and manufacturing of refractory material. Because of its versatile usage in processing materials, it is used for drying, heating, calcining, sintering and reduction. Normally the coal based rotary kiln method of making sponge iron is followed by the plants. Rotary kiln is like a closed vessel. The vessel body is container of uniform cylindrical shape. Its charging end is open for discharging gas and feeding raw materials. The other end is used for discharging of product and gangue material. The vessel body (shell) is made of boiler quality steel. The shell is protected by an inside layer of high alumina refractory, which takes care of the high operating temperature of 1000-1100°C. The kiln rotates at a constant speed with the help of gears and motors arrangement supported by rollers. Each kiln has seven zones, and each zone having blowers for supplying atmospheric air inside the kiln for burning of coal. Thermocouples are arranged in different zones to measure the operation temperature. [5]

IV. RESULTS:

In primary steel making, oxygen is used as an agent for oxidation of dissolved impurities like C, Si, Mn and P. To some extent, iron itself is also oxidized during the process. The process is also known as oxygen steelmaking. On the other hand, in induction furnace steel making, no direct oxygen is introduced in the bath. The impurities are oxidized by introducing FeO in the bath. The requirement of FeO for slag formation and oxidation of various elements is fulfilled by addition of sponge iron. Thus, presence of FeO is important as it corresponds to oxygen potential of the slag. Removal of phosphorous takes place by oxidation. The product, phosphorous pentoxide is being held by basic constituents, like CaO, present in the slag. In steel making processes basicity of the slag is maintained by addition of calcined lime. The reaction may be given by,

$$[P] + 5/2[O_2] + 3/2(O^{-2}) = (PO4^{-3}) \quad (1)$$

The oxidation reactions for other elements may be written as,

$$[Si] + 2(FeO) \rightarrow (SiO_2) + 2[Fe] \quad (2)$$

Mn- + (FeO) → (MnO) + ,Fe- (3)

,C- + (FeO) → *CO+ + ,Fe- (4)

In the present work, dephosphorization experiments have been carried out as discussed in previous section. Total four heats were processed using, scrap and sponge iron. During each individual heat, the samples of slag and liquid metal have been collected. The results for metal and slag samples are given in Table 4.6 and 5.1 respectively. The results show chemical analysis of metal and slag samples. From the data it can be observed that degree of dephosphorization varies from 21.74% to as high as 55.55 % for various heats. Borovsky [10] showed that phosphorous distribution ratio i.e. (P2O5) / [P] or Up required higher basicity's and FeO content, lower SiO2 and Al2O3, and very low P2O5. However, FeO content in the slag is needed to be 15–35 % for effective dephosphorization. Another very important condition for dephosphorization is lowest possible temperature [11]. In IMF operation, slag is removed from furnace top. Many a times it is a manual process. Increase in basicity leads to increase in slag volume. Large slag volume makes IMF operation difficult. Moreover, upper surface of the slag remains in contact with atmosphere which decreases slag temperature. Hence the slag is continuously churned by rod from the top.

V. CONCLUSIONS:

Though primary steelmaking is more popular than induction furnace steelmaking, the metallurgical aspects of the process are needed to be studied. Removal of Sulphur and phosphorous from steel in induction furnace route of steelmaking can be possible with neutral or basic lining. The stirring of the molten bath in induction furnace is also important. The project establishes beyond doubt that it is possible to dephosphorizing steel produced from induction furnace route by,

- Closely monitoring the temperature.
- Double slagging has to be adopted.
- Changing the acidic lining of the furnace in to a more costly basic lining or at least to a neutral lining.
- Deslagging with the Barium Aluminate gives the best result concerning dephosphorization.
- Removal of phosphorous can be achieved by maintaining basicity and FeO in the slag.
- In the present work maximum 55.55% dephosphorization has been achieved.
- However before making a farm decision more number of experiment has to be conducted.

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