Usage of oxygen as chemical energy input in electric arc furnace

B.V.R.RAJA, N.PAL, P.L.TALWAR, N.P.JAYASWAL
Alloy Steels Plant,
STEEL AUTHORITY OF INDIA LTD.,
DURGAPUR 713 208

Introduction

Electric Arc Furnace was invented by Pichon of France in 1853. However, the availability of electric power was limited during that period of time. The first man to successfully melt steel with electric current was Sir William Von Siemens in 1879 by indirect arc struck between two horizontal electrodes over a crucible containing scrap. It was in 1899 that the first direct arc furnace for making steel was commissioned by Dr. Paul Heroult. The earlier furnaces were of single phase type. Three phase furnaces were soon developed which are the fundamental feature of the large Electric Arc Furnace that is in use today. Later on, many parallel developments of the erstwhile "Heroult" design took place to improve upon capacity, productivity and quality leading to the reduction in cost of energy, electrode and refractories.

Electric Arc Furnace (EAF) utilization for steel making has shown a tremendous growth with rise from a level of 20 Million Tons in 1960 to a whooping 319 Million Tons in 2003 in the world. This equates to an improvement in the ratio of Electric Arc Furnace steel making to total steel making from 7% to 33.10%. The reasons for such a trend have been mainly due to lower investment cost combined with better flexibility regarding product mix.

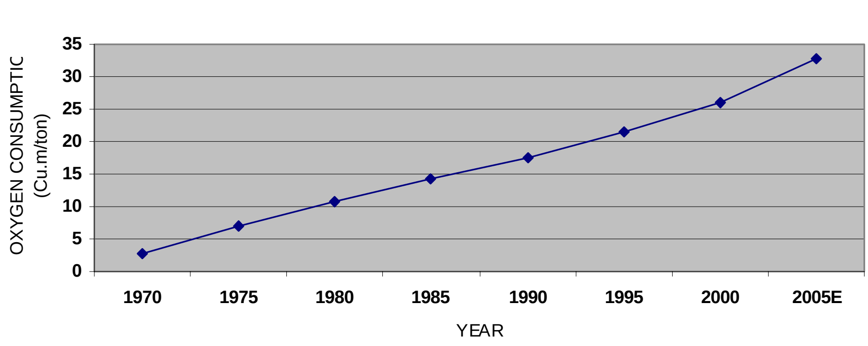
In spite of the growth in EAF steel making, there is a constant pressure on the steel makers to reduce the cost of production as many lean alloy steels are shifting towards the Basic Oxygen Furnace Steel Making route. The major contributors for the cost are raw materials and energy.

Evolution of Oxygen as chemical input

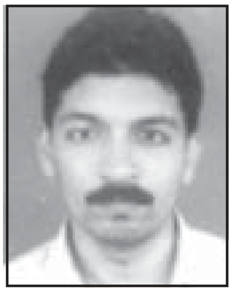
Energy accounts for as high as 12% of the total steel production cost in EAF. The high electrical energy costs pushed the EAF steel makers to intensify chemical energy application through use of oxygen during scrap preheating and melting. Sooner, EAF steel production started moving towards increased usage of oxygen. This has been mainly due to the advantage of oxygen supplementing electric energy resulting in reduction of power on time and improving productivity leading to reduced cost. Also, oxygen allows recovery of energy through CO post combustion which otherwise would be lost to the fume extraction system.

The amount of oxygen that is used in electric arc furnace is limited by the amount of oxygen that the process is capable of accepting. The oxygen consumption that would maximize the profit of each individual electric arc furnace is different and is based on inputs and specifics of operation. The increasing trend of oxygen usage in EAF is shown in Fig.1.

FIG.1. TREND IN INCREASING USE OF OXYGEN IN EAF



The optimum amount of oxygen to be used is where the marginal gain of increased oxygen is equal to the marginal cost. Here, the gains include improved productivity and reduced energy while the costs include oxygen, increased electrode consumption, high refractory wear and down time.



B.V.R.Raja
Manager (Quality)

He has worked in the areas of Alloy Steel making, Continuous casting (bloom/slab), Bloom/Billet & Plate rolling, Forging and Heat treatment in Alloy Steels Plant, SAIL, Durgapur and made significant contributions in the field of work. Has presented papers in national and international conferences and has to his credit many publications and presently working as Manager (Quality)

Methods of Oxygen introduction in EAF

The best oxygen introduction method as chemical energy system in Electric Arc Furnace is the one which effectively uses oxygen for de-carburization, assures high jet velocity at slag/metal boundary for aggressive mixing, minimizes negative effects to the furnace environment and helps in the post combustion of CO.

The various methods of oxygen introduction can be broadly classified as Moveable System and Fixed System.

Moveable System

This system has the capability to introduce chemical energy close to the molten bath during the last phase of melting. Being moveable in nature and presence outside the furnace, the equipment maintenance can be performed with furnace in operation and chances of mechanical and heat damages are minimized.

The equipment used can be either Submersible Hand Lances (oxygen to the tune of max. 15 Nm3/ton can be used), Consumable Pipe Manipulators (oxygen more than 15 Nm3/ton with carbon injection facility for foamy slag generation), Water Cooled Lances or Retractable Burners installed along the slag door. These devices introduce chemical energy through the slag door.

The major problems encountered through this system include need of large opening in EAF shell leading to cold air infiltration resulting in high energy input requirement, slag and metal splashing restricts the device movement necessitating cleaning of the openings, late start of foamy slag as heat input cannot be delivered with scrap covering the device insertion into the furnace coupled with excessive repairs and down time. Also, frequent involvement of the operator makes automation difficult and complicated.

Fixed System

The system requires lesser operator intervention, no openings with slag door closed to result in minimizing

N. Pal
Deputy General Manager (RCL)

He worked in different capacities as and headed departments like Heat Treatment & Finishing Shop, Forge Shop, Continuous casting & Steel Melting Shop of Alloy Steels plant, SAIL, Durgapur and contributed to the developments in the area of work and presently heading R & C Laboratory as Dy. General Manager (RCL)

heat losses and capable of greater degree of automation with increased consistency in practice. Also, it allows early start of oxygen and carbon injection leading to foamy slag generation with drastic reduction in electric energy coupled with less space occupied by fixed burner and lance systems both inside and outside the furnace.

The various devices in the fixed system include Oxy-Fuel Burners along the side walls in the region of the cold spots with ratings of 3 MW – 5 MW per burner and roof with 5 MW rating, Supersonic Jet Oxygen Burners to deliver oxygen early in the melting process for preheating scrap followed by introducing extra oxygen for CO post combustion and introduction of supersonic stream of oxygen for de-carburization cum refining with conventional function of oxy-fuel burner, side wall mounted Virtual Lance Burner with water cooled design to support scrap melting and lancing with oxygen and Carbon Injection Lance installed in a copper case water cooled from outside the EAF shell mounted with certain horizontal angle 150 mm – 200 mm above the liquid steel level to create and generate the foamy slag close to each oxygen source or directly into the hot spot for distribution in furnace areas where conventional foamy slag generation is not feasible. However, safety is highly important and hence, a reliably designed water cooling system is critical for achieving uninterrupted operation of EAF.

Selection of oxygen introduction method in EAF

The selection of oxygen introduction method depends on the type of metallic inputs used as charge and the design of the furnace itself.

Based on the type of metallic inputs

- **Hot Metal or Direct Reduced Iron**

When using these inputs, the bath level fluctuates significantly which necessitates location of burners and lances close to the bath for efficient use of oxygen through out the entire heat cycle. Here, slag door manipulator/side wall lances if used need to be constantly monitored and if the lance is not positioned close to

the molten steel bath, oxygen would not penetrate with splash formation from steel & slag interrupting EAF operation and decreasing productivity. In addition to the fluctuating bath levels, the process operates on flat bath condition for most of the time which would require positioning of the carbon injection port closer to the bath at an optimum angle for effective foamy slag on low bath conditions.

The location of the supersonic jet lances must be concentrated towards the Direct Reduced Iron feeding point

P.L.TALWAR
General Manager & I/C (Works)

He worked and headed the areas of Plate & Sheet Mill, Forge Shop, Blooming & Billet mill and Marketing. He made significant contributions in the field of Alloy Steel making, Shaping & Treatment and presently heading works as General Manager I/C (Works),Alloy steels plant,SAIL, Durgapur.

to guarantee faster melting of the material and an increase in the feeding rate. In case of hot metal, multi-point oxygen injection is preferred which uses oxygen in a lancing mode for de-carburization of the melt with the virtual pipe as well as the burner function to support the scrap melting in the cold spots. These methods lead to faster reactions for the de-carburization process and an improvement of the degassing effect due to CO bubbles in the steel resulting in achievement of low levels of hydrogen & nitrogen in the steels.

N.P.JAYASWAL
Executive Director

He has worked in various areas in Rourkela Steel Plant & Bokaro Steel Plant before joining Alloy Steels Plant, SAIL, Durgapur as Executive Director. He has made significantly high contributions in the field of Iron & Steel.

- **100% Scrap Input**

The best choice would be the fixed system of using oxy-fuel burners along the cold spots and carbon injection lance for better foamy slag practice

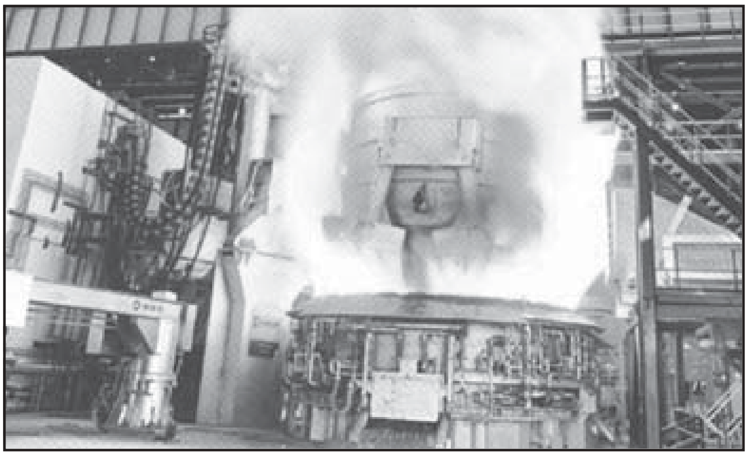
Based on the type of furnace design

- **DC – EAF**

The best location for installation of oxygen system with carbon injection would be the area opposite to the area of arc deflection to avoid refractory wear and result in early generation of foamy slag.

- **Low to Medium Powered EAF**

Various furnace sizes exceeding 20 M/t and low to medium transformer capacities fall under this category. Due to longer scrap melting time in low powered EAF, burners along the cold spots would be an appropriate option. However, the burner operations are limited to small capacity furnaces because of their lesser hearth diameter. Excessive



oxygen introduction through slag door manipulators affect the operational efficiency with loss of chemical energy to exhaust system, increased refractory wear and excessive electrode consumption.

For efficient operation, the oxygen injection system would be a fixed wall device with the design allowing burners and supersonic nozzles to be placed on the furnace shell just above the molten steel bath level. Such a design would not require opening in EAF and several burners/injectors can be placed around the furnace circumference to eliminate overheating.

- **High Powered Large EAF**

Slag door manipulator and a set of fixed side wall burners would serve the purpose of efficient oxygen injection system. Further modifications in the form of carbon injectors at various positions located circumferentially around EAF can help in early start of foamy slag generation and improve the productivity in the large EAFs having capacities exceeding 80 M/t.

Conclusions

Oxygen has emerged as a potential substitute to electric energy in EAF. Savings of energy about 3 KWh/Nm3 oxygen per ton of liquid steel are obtained when one kg of coke is added to the furnace. Installation of oxy-fuel burners revolutionized the electric steel making process with capability to deliver about 10% of the total power required in EAF. The fixed systems of oxygen injection evolved has brought in productivity improvement by 6% - 8% with 70% - 90% oxygen efficiency and carbon utilization cutting energy costs by 6% - 10%.

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