Lecture 20: Process Control BOF Steelmaking

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Key words: Dynamic modeling, static modeling, Process controll

Introduction

Steelmaking in BOF is very fast. It takes approximately 15 to 20 minutes for oxygen blowing and 50 to 60 minutes to tap molten steel. Liquid steel at turndown results from several non linear interconnected complex processes like gas/ liquid metal reaction as dependent on oxygen availability, slag/metal reaction as dependent on physic-chemical properties of slag and faster reaction rate induced by three phase dispersion (CO+ slag +metal droplets).

Control of the above processes is needed so that for a given input of hot metal, scrap, flux and oxygen flow rate, steel of the desired chemistry is produced with minimum loss of iron in slag

How are the above processes controlled?

Rates of gas/metal, slag/metal and gas/slag/metal droplet reaction are controlled by lance profile, oxygen flow rate and bottom stirring rate, it is required to raise or lower the lance distance for a given oxygen flow rate and bottom stirring rate so that steel of desired composition and tapping temperature can be obtained within the stipulated blowing time. For this purpose we need to develop process models which can describe the process quantitatively. These models must be supported by the data for accurate predictions for the future requirements.

Process Control Models

One of the objectives of the process control models is to predict turndown composition and temperature of steel so that unnecessary blowing of oxygen is not required. For a long time human expertise was the control tool. The operator used to deliver instructions to exercise the process control. These controls were human specific.

Developments in computer has resulted into development of sophisticated models, like

a. Static model
b. Semi-dynamic model
c. Dynamic model

Static Model

Static models are based on materials and heat balance by considering initial and final states of reactants. In the material balance, mass of all input and output elements is considered. Once mass balance is done then heat balance is done.

Sensible heat of all inputs+ Heat produced or absorbed by oxidation reaction= Heat taken out by steel, slag and exit gases and fumes+ heat losses from the converter mouth and through the lining of the converter+ any other heat losses

In making materials and heat balance some assumptions may be required for example

- iron loss in slag,
- carbon removal in the form of CO,
- complete dissolution of CaO in slag
- basicity of slag
- thermo-physical and thermo-chemical properties of slag and metal

The above are some of the assumptions, further may be added.

By coupling of mass and balance one can predict

i) Quantity of hot metal and scrap
ii) Amount of flux
iii) Total quantity of oxygen required to be blown.
iv) Amount of slag produced
v) Volume of exit gases

It is very much important that the prediction based upon the model is verified by the actual plant data. Tuning of the model is necessary because the predictions are based on equilibrium considerations and uncertainties due to simplified assumptions.

Reliability of predictions increases when the predictions of the model are compared with the plant data for large number of heats. Statistical correlations can be developed and used to fine tune the model. For this purpose it is of utmost necessary to collect the reliable data from the reliable instruments

BOF steelmaking is a stochastic process. Oxygen blowing produces lot of turbulent in the phases during hot metal refining. The amount of droplets emulsified in the slag, amount of lime dissolution, carbon removal rate, intensity of oxygen jet impinging the bath, lance distance, bottom stirring rate due to plugging of tuyeres etc. may vary from one heat to the other. The error in predictions may be due to

i) Error in weighing
ii) Differences in lime dissolution from one heat to the other
iii) Effect of size of scrap on its dissolution. Large size will take more time to dissolve as compared with smaller ones.
iv) State of foaming of slag and entrained metal droplets in slag. This may vary from one heat to other due to behavior of oxygen jet in a dynamic surrounding as discussed in lecture 13. Surrounding of oxygen jet changes during the blow. As a result extent and magnitude of slag/metal reactions might change.
v) Converter lining profile due to wear.
vi) Extent of mixing within the phases and between the phases.

Semi – dynamic model

The above features make static control models inadequate. Hence improvements are required. Static model predictions can be improved by measurements on temperature and composition of slag and metal by a sub lance during the blow.

Immersion type sensors can also be used to measure carbon and oxygen concentration during the blow. All these data are collected and fed into the computer which compares the model predictions to suggest the action to be taken by the operator. These are semi-dynamic model. It must be noted that error in carbon measurement may need to over blow the heat when end carbon measured is greater than specified carbon. Also if end point carbon measured is lower than the specified, carburization has to be done in the ladle for carbon adjustment.

Determination of carbon by a sub lance is indirectly done by measuring the temperature of steel through a sample collected by the sub lance during the flow.

Dynamic Models

Static models do not calculate the variation of blowing parameters as a function of time. For this purpose continuous measurement of some representative parameter is required during the blow. In a preprogrammed model, these values are fed continuously and corrections can be done during the blow. Dynamic models contain all features of static model; in addition it includes reaction kinetics and process dynamics. In steelmaking major reactions are oxidation of carbon and iron. In a dynamic model rate of decarburization and O_2 consumed are determined from exit analysis. Computation of Fe is then done.

Dynamic control requires measurements continuously. Exit gas temperature and its composition can be measured continuously and the data can be fed to computer. From the exit gas composition and temperature carbon, oxygen in bath can be determined as a function of time. From carbon balance, decarburization rate can be determined. Oxygen balance provides the following information:

- Total rate of oxidation
- Relative fraction of oxygen reacting with carbon and iron and other elements

Enthalpy balance based on exit gas temperature and composition and amount gives information on energy leaving the system.

Slag height can also be determined by measuring the acoustic sound produced by the slag during the blow. Sonic meter measures the intensity of sound. Intensity of sound is fed to computer which in turn adjusts the lance height, oxygen flow rate and bottom stirring rate to control the slag/metal height.

It must be mentioned that large number of literature is available on the process control models in steelmaking. It is not possible to cover in one lecture. The interested reader may go through the references given at the end of the lecture. Some references are given. You may find more.

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