Development of Dynamic Process Models for Oxygen Steelmaking

Geoffrey Brooks
FEIS, Swinburne University of Technology, Hawthorn, Victoria 3122, Australia

Oxygen steelmaking is a mature technology with over fifty years of continuous process development. Over the last twenty years, there have been significant advances in lance technology (e.g. coherent jets), refractories (e.g. C-MgO linings) and process control (e.g. use of cameras to monitor slopping). However, two inter-related challenges have only been partially addressed, namely:

a) how to minimise flux additions whilst still providing adequate protection to the refractory lining and meeting the required grade of steel (particularly, in regard to phosphorus).

b) how to lower blowing times without excessive slopping whilst still meeting the required grade of steel and ensuring process stability.

These problems are not easily addressed through the traditional static models because by they reflect interrelated issues of a dynamic nature, for example, lowering the lance close to the bath may accelerate decarburisation, lowering the potential blowing time, but this may result in slopping under certain circumstances. Similarly, changing the sequence of flux additions to a furnace may reduce the risk of slopping but maybe also expose the refractory to attack early during the blow. “Black box” modelling techniques (i.e. neural networks, fuzzy logic and multi-variate statistics) have been used to address the issues such as these and there is some evidence that these techniques can help in optimising the operation. These types of approaches tend to be quite specific to the operation being modelled and also rarely provide insight into the underlying physics and chemistry of the process.

Several groups around the world have recently attempted to address this shortfall in understanding of Oxygen Steelmaking through the development of “Grey box” process models i.e. models based on underlying scientific principles but with semi-empirical corrections. At Swinburne University of Technology, we have previously developed a two zone model of Oxygen Steelmaking that is focused on understanding how decarburisation is affected by lance height, blowing rate, flux dissolution and scrap melting. A schematic diagram outlining the basic components of the model are provided in Figure 1. The model has been successfully validated against the industrial results of Cicutti et al. but is limited in its wider application because it doesn’t include slag generation, slopping behaviour and dephosphorisation. More recent work at Swinburne has made significant progress in developing models for predicting slag foaming behaviour and droplet generation, with the ultimate goal that these models are incorporated into a general process model of Oxygen Steelmaking.

Guo et al. from Arrcelor Mitall have recently published a paper in which they outline some of the features of a model that calculates slag chemistry with time, as a function of lance height and flux additions. This model has been used to form strategies to limit slopping and minimise flux additions. Guo et al. claims to limit lime addition through accurate determination of lime saturation and phosphorus content from equilibrium relationships. They also provide evidence that slopping incidents have been greatly reduced since applying these strategies and linking their models to practice.

High Temperature Processing Symposium 2013
Swinburne University of Technology
Recent work at JFE Steel has focused on optimising phosphorus removal through dynamic modelling of the slag chemistry.\textsuperscript{9} In particular, they focused on predicting the FeO content (critical to understanding the phosphorus behaviour) of the slag by means of a dynamic Oxygen balance and relatively simple semi-empirical kinetic expressions to predict chemistry changes. It is not clear how they incorporate lance position into their model but they provide some evidence that their FeO estimations correlate reasonably well to plant data. This work and other related projects around the world point toward the eventual development of full dynamic kinetic models of Oxygen steelmaking that should allow optimisation of the process through a fuller understanding of the dynamics of the process.

References