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Original Article

Thermo-chemical model for blast furnace process control with the prediction of carbon consumption

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ABSTRACT

The operational stability of a complex process such as the blast furnace is under constant threat owing to variation in the quality of raw materials as well as other operating conditions. Significant cost reductions can be achieved with adequate control of this process. Hence, mathematical models have proven to be useful in the thermal control of blast furnaces with regards to the fuel consumption and operational stability of these reactors. The thermo-chemical model calculates the hourly carbon consumption, which allows the operator to adjust for the aiming quantity of carbon. A strong correlation is observed between the results of the model and the actual results from the process. Thus, the model provides conditions for the operator to anticipate carbon behavior, and thus prevent large variation in the thermal properties of the blast furnace and provide high levels of operational safety.

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1. Introduction

The aim of the ironmaking area in the steel industry is to safely produce hot metal at the lowest cost and within the specifications of the steel mill. To achieve this objective, many efforts have been made in the past few years such as improving the quality of the raw materials, equipment, facilities, and theoretically investigating the process phenomena.

Various phenomena that take place inside a blast furnace are still not clearly explained. Therefore, blast furnace operation models have been developed with the aim of predicting operational deviations and perfecting the process to guarantee the stability of the blast furnace and to reduce fuel consumption [1–3].

The blast furnace operation is usually investigated with two objectives: predicting the process indicators and understanding the internal blast furnace phenomena. These two

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objectives can be studied by different methods, including industrial-scale investigations, pilot experiments (in laboratory), and mathematical models. Industrial-scale investigations contributed to the understanding of the internal aspects of the blast furnace by dissecting it. These investigations could also be conducted by sampling the material of the tuyeres; however, such techniques are difficult to use since they require stopping the blast furnace and are costly. Pilot experiments are also conducted to understand the internal phenomena of blast furnaces, but they are not able to completely represent the phenomena of a real blast furnace and are also associated with high costs. Hence, mathematical models have played an important role in predicting process indicators and investigating the internal phenomena of blast furnaces [4].

The thermal control for most blast furnaces is still corrective; a measure is only taken after the observation of a deviation in the range of composition or temperature of the hot metal. Therefore, the thermal control often depends on the operator's experience and the response to the problem could be slow, i.e., a large variation is introduced in the quality and temperature of the hot metal and in the fuel consumption.

To improve the stability of the blast furnace, a thermo-chemical model was developed for process control. The purpose of the thermo-chemical model is to assist in operator decision-making regarding fuel consumption in blast furnaces. This model calculates the amount of carbon consumed at a given moment and establishes that the loaded quantity should equate to the consumption value in order to maintain a constant thermal level in the blast furnace.

Thermal control of the process is critical for the hot metal production in blast furnaces, since greater thermal control improves product (hot metal) quality and increases process efficiency, such as the reduction of the total energy (fuel) consumption [5–7].

In addition to thermodynamics, the thermo-chemical model applies the concept of dividing the blast furnace into the preparation and elaboration zones, and considers the incoming gases in the preparation zone to be at thermodynamic equilibrium with iron and wüstite. The thermo-chemical model is based on the degree of reduction in metallic burden within the preparation zone [8].

The gas yield (usage of CO gas) or CO/CO_2 ratio, cited by Spence and Pritchard [9] and also discussed by Harvey and Gheribi [10], has a large influence on the fuel consumption. It can be observed that smaller CO/CO_2 ratios or better use of carbon monoxide results in the lower consumption of coke. Top gas analysis is the main sensor of the thermo-chemical model.

Hence, the control provided by the thermo-chemical model allows for corrections in the process as soon as the deviation occurs, decreasing the risk of abrupt cooling, improving the quality of hot metal and reducing fuel consumption [11].

The following are some of the advantages of applying an operational (thermo-chemical) model:

- Higher operational safety;
- Higher operational stability with lower production costs;
- Preventive detection of process phenomena.

2. Methodology

The thermo-chemical control proposed in the present study will be based on five different types of information: data from the top gases, burden, blow, hot metal, slag and heat loss. The information from the top gases is the most important (main sensor) in this type of control, because any alteration in the process causes instantaneous changes in the temperature and composition of these gases.

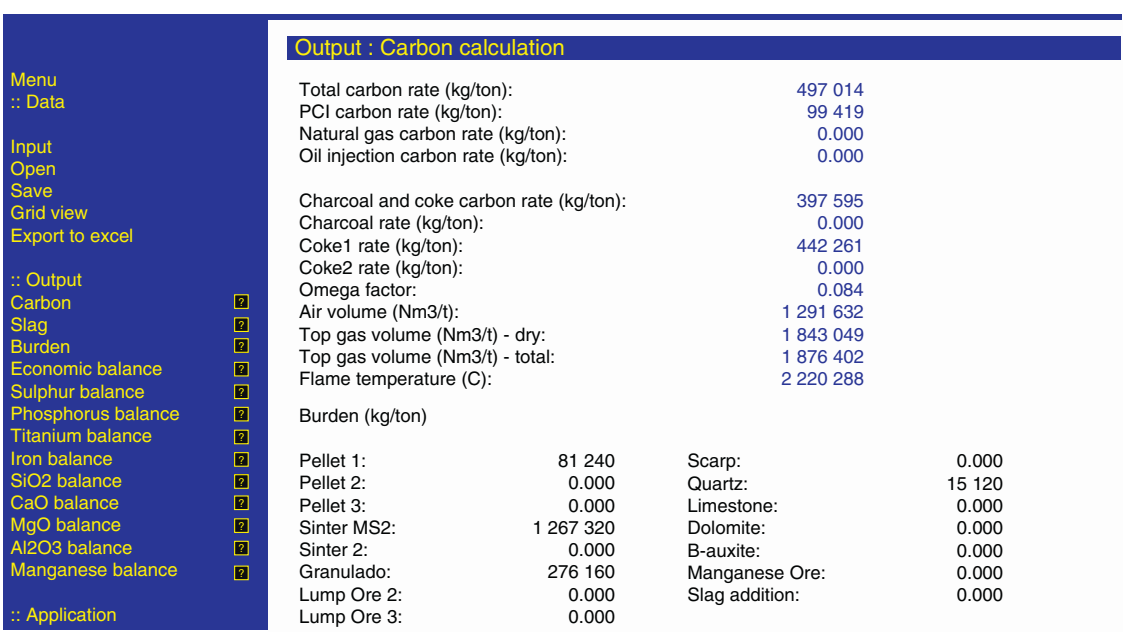

Fig. 1 – Screen with the results of the thermo-chemical model.

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