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PARAMETRIZATION OF THE STEEL SMELTING PROCESS IN THE BASIC OXYGEN FURNACE

Abstract. The article is devoted to the actual problem of analyzing the features of the mathematical description of the steelmaking process in basic oxygen furnace (BOF). It presents the concept of a two-level algorithm for the process of steelmaking in BOF. Parametrization of the main technological operations for steel smelting according to the proposed algorithm model was carried out.

Keywords: BOF, steel, two-level algorithm, static model, dynamic model.

Formulation of the problem

At the present stage of development of metallurgy a special place is given to the automation of technological processes. This task is successfully being solved in the field of engineering and material processing, but in the technological processes of iron and steel production has not been completely solved yet at a level that would satisfy the requirements of production. First of all the reason is the complex character of the above-mentioned technological operations, as well as high rates of the physical and chemical transformations.

Analysis of publications on the research topic

Initially, the management of the progress of the steelmaking process in BOF was carried out directly by the distributor of the converter. In this case, the steelmaking process depended on the qualification of technical personnel, and the production itself was distinguished by a significant number of melts that should be corrected to target carbon content and temperature [1, 2]. During expanding the theoretical ideas about the regularities of metal refining in BOF, a number of static models were created. They allow predicting with a high accuracy the consumption of whole materials for smelting [3]. The basis for creating a static model of BOF smelting is material and thermal balances, and the accuracy of prediction is determined by the correct definition of additional parameters (heat loss of the vessel, contamination of scrap, etc.) [4]. At the same time, an essential shortcoming of this forecasting is the impossibility of determining the dynamics of the main technological parameters of melting. As the methods of monitoring and measuring the basic parameters of BOF melting have been improved, dynamic forecasting models have appeared. Their

introduction allows determining the main technological parameters of melting at any time. At the same time, it is necessary to install a significant amount of auxiliary expensive equipment for monitoring of technological parameters [5-7].

Purpose and objectives of research

Modern conditions of metallurgical production are characterized by a shortage of high-quality charge materials. That leads to the need of using the materials with a significant fluctuation of the chemical and fractional composition and non-traditional materials in the BOF process. That leads to a significant complication of the steelmaking process in BOF, a decrease of its efficiency and an increase of the cost of crude steel. The only effective way to overcome the current situation is to develop improved methods for forecasting the results of BOF melting, which would take into account both static and dynamic models.

Main part

To effectively forecast the process and results of steelmaking in BOF, it is necessary to take into account both static and dynamic algorithms and the proposed model will be two-level (Fig. 1).

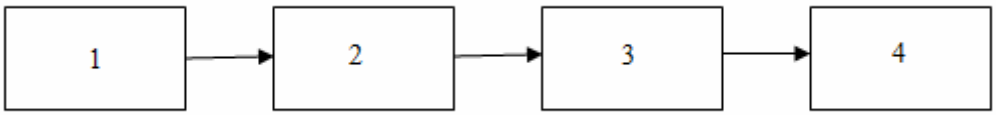

Figure 1 – Scheme of a two-level algorithm for modeling of BOF steelmaking: 1 – input parameters; 2 – forecasting taking into account static models; 3 – elaboration of technological operations using dynamic models; 4 – results of melting

At the first level, a preliminary assessment of the BOF steelmaking processes is carried out, which allows to determine the necessary consumption of oxygen, flux materials, metal scrap and other coolants, and also pig iron for melting. The next step in the calculation is the elaboration of certain material consumptions and the order of their additives in the vessel. That is solved by the use of dynamic models.

For successful implementation of the planned two-level algorithm, it is necessary to make an adequate parametrization of the BOF steelmaking process. A feature of this operation is the choosing of the most significant factors for each of the levels of the algorithm. The differentiation of technological factors in accordance with the main blocks of the developed algorithm is presented in Table 1.

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During the research, the normative documents [8, 9], that regulate the technological features of BOF steelmaking, were analyzed, it was determined that the main factors determining the characteristics of smelting include: a variety of used technology; chemical composition, final temperature and weight of the finished steel.

The statistical models used in the algorithm are based on the law of conservation of energy and mass, which is realized in the basic equations of thermal and material balances of BOF melting [10]. Therefore, when performing calculations on their basis, it is necessary to specify the following specifying parameters: the amount, chemical and fractional composition of the used materials; heat losses of the converter. As a result of calculation using static models, a decision is made about the necessary amount of materials spent on melting as a whole.

Given that the process of steelmaking is characterized by high rates of refining processes, the mandatory operation in the algorithm of its description is the elaboration of the main technological parameters accordance to the dynamic models. These models are based on the basic kinetic equations of physical and chemical reactions in the BOF [11, 12]. Thus, in accordance with the developed algorithm, it is determined that the results of calculations based on static models are used as initial parameters. In addition, the calculation of dynamic parameters involves the use of the following parameters: the features of the blowing regime (dynamics of the lance position and the flow of oxygen during the melting process); slag regime (dynamics of flux additives and slag forming); the need for additional technological operations during smelting (discharging of foamed slag, carrying out correction blowing). To efficiently calculate dynamic models, it is necessary to provide for the placement of additional equipment to record the dynamics of changes in the chemical composition of the waste gases, the bath temperature and the lance position. The mentioned above equipment should be included in the system of the APCS of the BOF.

Table 1

Parametrization of the technological operation for smelting steel in oxygen converters

№	Type of parameters	Types of parameters
1.	Input parameters	- a variant of the applied technology; - temperature and chemical composition of steel; - target weight of crude steel.
2.	Specifying parameters for calculation by static models (1st level of the algorithm)	- weight, dimensions and chemical composition of metal scrap; - heat loses of the BOF; - chemical composition and temperature of

		the pig iron; - purity of oxygen.
3.	Input parameters for calculations by dynamic models (determined by the results of a static calculation)	- weight of pig iron for melting; - weight of flux materials for melting; - weight of auxiliary materials for melting; - oxygen consumption.
4.	Specifying parameters for calculation by dynamic models (2^{nd} level of algorithm)	- blowing regime (oxygen consumption, lance position); - slag regime (use of additional flux materials, additive regime); - additional technological operations (slag discharging, correction blowing).
5.	Results of melting	- target duration of blowing; - target temperature of steel; - target chemical composition of steel; - target weight of steel.

Forecasting of steelmaking in BOF must ensure the achievement of the most significant parameters for the smelting of steel in BOF: the target duration of melting, target chemical composition, temperature and weight of the steel.

The use of two levels of calculation in the algorithm allows preliminary, before carrying out the melting, to determine the necessary consumption of charge materials and specify their amount and regime of addition into the metal bath directly during the blowing. Thus, the implementation of the proposed scheme of the algorithm for predicting the results of melting in an oxygen converter should significantly simplify this process and significantly reduce the share of smelting with correction blowing.

Conclusions and prospects for further research

1. On the basis of the studies carried out, the most characteristic features of forecasting the results of oxygen-converter steel with the use of static and dynamic models have been determined.

2. A scheme of a two-level algorithm for predicting oxygen-converter melting with the combination of both static and dynamic models was proposed.

3. Parametrization of the steelmaking process taking into account the features of the developed two-level algorithm was carried out.

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Бойченко Б.М., Нізяєв К.Г., Стоянов О.М., Молчанов Л.С., Синегін Є.В. **Параметризація процесу виплавки сталі в кисневому конвертері** // Системні технології. Регіональний міжвузівський збірник наукових праць. – Випуск ? (??). – Дніпропетровськ, 2013. – С. ?? - ??.

Стаття присвячена актуальній проблемі аналізу особливостей математичного опису процесу виплавки сталі в кисневих конвертерах. У ній представлено концепцію дворівневого алгоритму процесу виплавки сталі в кисневому конвертері. Проведена параметризація основних технологічних операцій по виплавці сталі відповідно до запропонованої моделі алгоритму.

Бібл. 12, іл. 1, табл. 1.

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Бойченко Б.М., Низяев К.Г., Стоянов А.Н., Молчанов Л.С., Синегин Е.В. **Параметризация процесса выплавки стали в кислородном конверторе** // Системные технологии. Региональный межвузовский сборник научных трудов. – Выпуск ? (??). – Днепр, 2017. – С. ?? - ??.

Статья посвящена актуальной проблеме анализу особенностей математического описания процесса выплавки стали в кислородных конвертерах. В ней представлена концепция двухуровневого алгоритма процесса выплавки стали в кислородном конвертере. Проведена параметризация основных технологических операций по выплавке стали в соответствии с предложенной моделью алгоритма.

Библ. 12, ил. 1, табл. 1.

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Bojchenko B.M., Nizjaev K.G., Stoyanov A.N., Molchanov L.S., Sinegin E.V. **Parametrization of the steelmaking process in basic oxygen furnace** // System technologies. Regional Interuniversity collection of scientific papers. – Issue ? (??). – Dnipro, 2013. – P. ?? - ??.

The article is devoted to the actual problem of analyzing the features of the mathematical description of the process of steel smelting in BOF. It presents the concept of a two-level algorithm for the process of steelmaking in BOF. Parametrization of the main technological operations for steel smelting according to the proposed algorithm model was carried out.

Ref. 12, fig. 1. tab. 1