УДК 669.162.262:669.13:669.162.144

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PHYSICAL AND CHEMICAL CRITERIA AND MODELS FOR IMPACT ASSESSMENT CHARGE AND TECHNOLOGICAL CONDITIONS ON THE DISTRIBUTED ELEMENTS CHARGE BETWEEN IRON AND SLAG

Abstract. The new approach to construction of a complex indicator domain charge and temperaturno-dutevogo a mode with use of the generalised Harringtons function of desirability Harington for concrete working conditions of a blast furnace is stated. Models are developed for calculation of factors of distribution of elements charge between products of fusion for the purpose of their further use at forecasting of structure of products of domain fusion and optimisation of quality of pig-iron.

Keywords: physical and chemical criteria, predictive models, the distribution of elements, blast charge, melt, iron, slag.

Relevance. In modern conditions of blast furnace the instability supplies enterprises by iron ore materials and coke, changes of pricing policy lead to the need for frequent formation workable charge involving unconventional raw materials. The successful solution of these problems associated with the in-depth study and an adequate description of the formation and interaction of melts, the development of physical and chemical models and generalized criteria to evaluate the composition and properties of melting products in relation to the raw material and process parameters and product quality control in unstable conditions blast furnace

The Institute of Ferrous Metallurgy NASU developed and constantly evolving new approach to the choice of rational composition of blast furnace charge by optimizing slag regime, based on the prediction of the composition and properties of the products of blast furnace and processes of interaction between them [1].

Formulation of the problem. Objective of this work is the selection and justification of physical and chemical criteria and the development of models to predict the distribution coefficients of the elements of charge between the iron and slag in concrete charge and technological conditions.

The presentation of material. For solving problems predicting the composition and properties of the final products of blast furnace process we use method of physical and chemical modeling of metallurgical melts and processes, including the idea of modeling smelting reduction by scheme "Charge" + "Technology" = "Melting products".

In this case, the composition of melting products is calculated depending on the composition of the initial charge and the parameters of the technological regime on the basis of predictive models for the distribution coefficients of elements between the products of melting, depending on the specific charge and technological conditions: L_E=f (F_C; F_T), where F_C and F_T is integrated indicators loaded charge and technological regime.

Previously, as parameters of charge we used the indicators: content Fe_2O_3 (richness of charge) and parameters of the slagging charge ρ and Δe, determine its properties, and as process parameters is the blow mode indicators, such as: theoretical combustion temperature $T_т$ and the length of the tuyere zone L_{TZ}, which takes into account the use of the thermal state of the furnace hearth [2].

To improve the predictive power of the models L_E=f (F_C; F_T) and more fully account of influence of charge and technological conditions on the formation of the final melting products developed integral index of blast furnace charge K_C, and also provides a comprehensive indicator of the blow-temperature regime K_{BT}.

Generation of structure generalized indicators K_C and K_{BT} was performed using a generalized desirability function of Harrington [3], allowing different size indexes converted into a dimensionless scale of desirability and "roll" them into a single composite index. Such approach makes it possible to perform a comprehensive assessment of a multidimensional object and enhance information capacity of integral indicator. At the same time composite index includes several criteria, which is the basis for a comprehensive process optimization.

The mathematical apparatus of recalculation of specific parameters in abstract numerical values reduced to the following. The basis is one of the logistics functions E.K Harrington is called "desirability curve", which was derived empirically from observations for the real objects of experimental research. Its formula: $d = \exp(-(\exp(-y))$ (fig.1) determines the function with two sections of saturation (in d → 0 and d → 1) and a linear section (from d = 0,2 to d = 0,63). Y coordinate axis is called the scale of particular indicators. Axis d is called a desirability scale. Period of effective values on the scale of particular indicators is [-2; +5].

Each indicator is broken down into categories of quality: very good, good, satisfactory, bad and very bad (Fig. 1) in accordance with standard estimates on the scale of desirability. Importance of the private response translated into a dimensionless desirability scale, is denoted by di called private desirability. Value d_i = 0 corresponds to an absolutely unacceptable level of the i-th parameter optimization, the value of d_i = 1 is the best value of the i-th parameter. The standard mark on the desirability scale presented in table. Selection markers on the desirability scale 0.63 and 0.37 is explained by convenience computing: 0,63 ≈ 1 — (1/e), 0,37 ≈ (1/e). The value d_i = 0,37 usually corresponds to the boundary of acceptable values. This function has the useful properties such as continuity, monotonicity and smoothness. Also in a desirable area, close to 0 and 1, "sensitivity" it is significantly lower than in the middle zone.

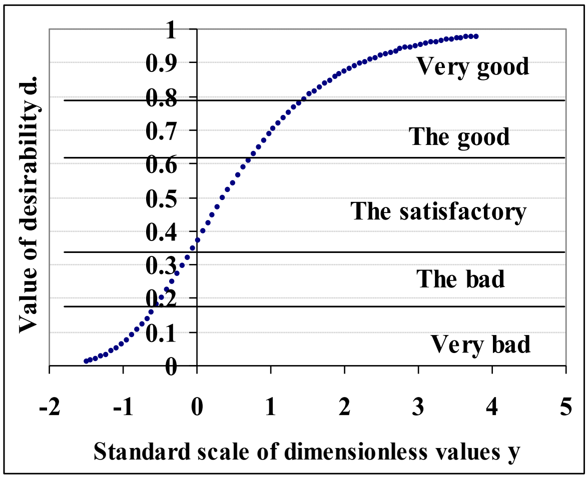

Figure 1 - Graph of desirability function $d = \exp(-(\exp(-y))$

Таблица

Standard marks for the desirability scale

Desirability	Graduations private desirability d_i	Coded value indicators y_i
Very good	1,00 – 0,80	1,5 –3,0
Good	0,80 – 0,63	0,85 – 1,5
Satisfactory	0,63 – 0,37	0,0 – 0,85
Bad	0,37 – 0,20	-0,5 – 0,0
Very bad	0,20 – 0,00	-1,5– - 0,5

Appointment desirability scale is the establishment of correspondence between the obtained values indicators of properties and ratings of the experimenter relative desirability of an indicator. To obtain a single, generalized assessments need to ask the most desirable value of the individual taken to the analysis of indicators that can be installed on the recommendations of experts, from the relevant standards or dependency.

Using a scale of desirability for each particular indicator x_i calculated default values on the ordinate axis y_i, which are determined by particular indicators of quality in dimensionless units d_i and calculated composite index D as the geometric mean of private functions of the desirability, considering the importance of each property: $D = \underset{i=1}{\overset{n}{P}} d_i^{\beta}$, where P is the product private desirability functions, d_i is individual performance, n is number of indicators, β is indicator of the significance properties.

In developing the generalized index of charge were used actual data performance of blast furnaces in Ukraine and Russia. To the array of production data formed by scheme "Charge" + "Technology" = "Melting products", in order to reduce measurement errors of the chemical composition of charge components and products melting was applied procedure of minimize the deviations of the material balance [4], which allows to improve the relationship of parameters and increase accuracy of forecast models.

The analysis of balanced data sets on the work of blast furnaces on the basis of statistical and factor analysis revealed a complex oxides charge ratios and parameters of primary melts characterizing aggregate conversion and restoration materials in the furnace [5]: Fe_{COM}/SiO_2, CaO/SiO_2, MgO/SiO_2, Al_2O_3/SiO_2, R_2O/CaO, T_{df}/T_{lf}, $FeO_{PS}/(-\Delta e/\rho)$. Index Fe_{COM}/SiO_2 is the ratio of iron content to the content of silica in the charge, CaO/SiO_2 is the basicity, MgO/SiO_2, Al_2O_3/SiO_2, R_2O/CaO is magnesia, alumina and alkaline modules, T_{lf} is filtration temperature liquid phases through coke nozzle, T_{df} is temperature of melt flow drip, FeO_{PS} is content in the primary slag, Δe and ρ is chemical equivalent of charge composition and stoichiometry index.

Analytic dependence of generalized index blast furnace charge conditions for BF number 9 PLC "ArcelorMittal Krivoy Rog" is as follows:

$$K_C = \left(\frac{Fe_{COM}}{SiO_2}\right)^{0,2} \cdot \left(\frac{CaO}{SiO_2}\right)^{0,2} \left(\frac{Al_2O_3}{SiO_2}\right)^{0,2} \cdot \left(\frac{MgO}{SiO_2}\right)^{0,1} \cdot \left(\frac{T_{df}}{T_{lf}}\right)^{0,15} \cdot \left(\frac{FeO_{PS}}{-\Delta e/\rho}\right)^{0,15}. \qquad (1)$$

Similarly, using the generalized desirability function developed a comprehensive indicator of temperature-blow mode K_{TB}, comprising the indicators blow melting mode and waste gases. So, the analysis of actual data production of pig iron in the working conditions BF number 9, which compares indicators loaded charge and technological conditions, a connection was established distribution coefficients of sulfur and silicon with the degree of utilization of gas η_{CO}, with indicator of the thermal state of the hearth deep tuyere zone Ltz, and also with a temperature index furnace TIF, which "connects" the top of the blast furnace with its bottom and is calculated by the formula: $TIF^* = \frac{2500 - Tt}{T_{FG}} \bullet \frac{1550 - T_{PI}}{1250 - T_B}$, where Tt is theoretical combustion temperature of coke at tuyeres, T_{fg}, T_{pi}, T_B is temperature furnace gas, pig iron and blowing.

For the working conditions of BF number 9 to calculate the dependence of the complex index of temperature-blow mode:

$$K_{TB} = TIF^{0,4} \cdot \eta_{CO}{}^{0,3} \cdot L_{tz}{}^{0,3}, \quad (2)$$

Based on the complex charge indicators and temperature-blow mode developed analytical relationships to predict the distribution coefficients of the elements charge between the iron and slag:

$$Ls = (O/C\ )^{0.19} \cdot K_C{}^{0,43} \cdot K_{TB}{}^{0,38}, \qquad R=0,85 \quad (3)$$

$$Lsi = (O/C)^{0.37} \cdot K_C{}^{0,1} \cdot K_{TB}{}^{0,53}, \qquad R=0,87 \quad (4)$$

$$Lmn = (O/C)^{0.3} \cdot K_C{}^{0,27} \cdot K_{TB}{}^{043}, \qquad R=0,86 \quad (5)$$

where O/C is ore load characterizing the download materials.

Exponents in the expressions (1-5) indicate the proportion of the effect of each index on the distribution of the elements of the charge.

Comparative evaluation of actual and calculated by the model (3) - (4) the values of distribution coefficients of elements sulfur and silicon is shown in Fig. 2. Adequacy of models (3) - (5) is estimated by correlation coefficients R and shows higher accuracy than previously used dependencies forecasted of distribution coefficients of silicon and sulfur in the form: $L_Y = f(Fe_{COM}, \rho, \Delta e, O/C, \eta_{CO}, L_{TZ})$, for which R^2=0,51.

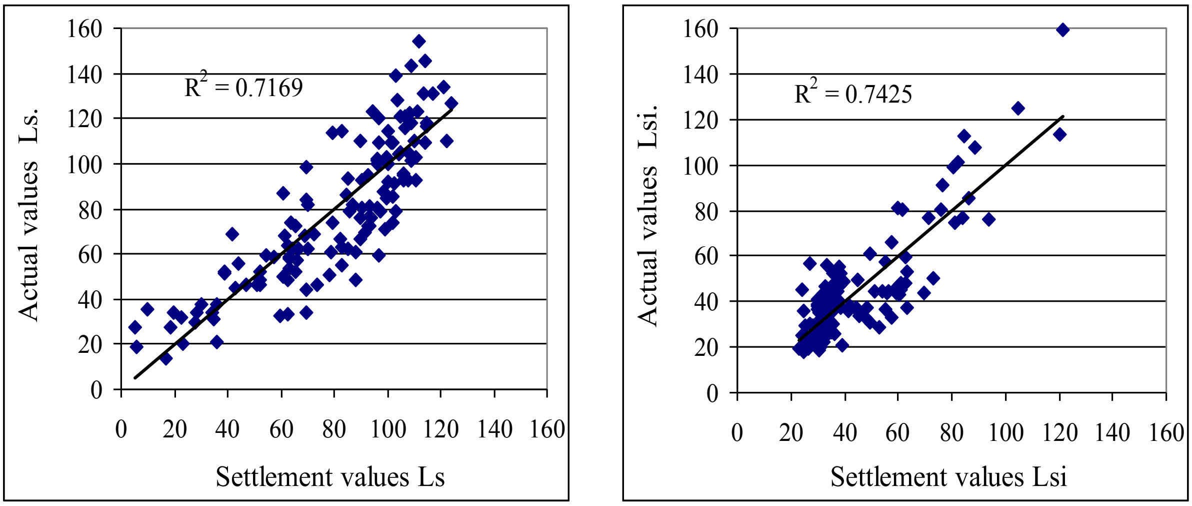

Figure 2 - Actual and calculated values of distribution coefficients of sulfur and silicon models (3) - (4) for working conditions BF number 9 PLC "ArcelorMittal Krivoy Rog"

Conclusions. Using a generalized function of desirability to assess the charge and technological conditions blast furnace developed integral index of blast furnace charge K_C. Also provides a comprehensive indicator of the temperature-blow regime K_{TB}.

Developed the analytical dependence for the prediction of the coefficients distribution of elements of the charge between iron and slag based on complex criteria of charge and temperature-blow mode.

Submitted physical and chemical criteria and models are designed for use for solving informed choice of charge, providing the required quality of smelting iron by optimizing and management slag mode in concrete of charging and technological conditions of smelting.

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Рефераты

УДК 669.162.262:669.13:669.162.144

Тогобицкая Д.Н., Белькова А.И., Степаненко Д.А., Скачко А.С. **Физико-химические критерии и модели для оценки влияния шихтовых и технологических условий на распределение элементов шихты между чугуном и шлаком**.

Изложен новый подход к построению комплексного показателя доменной шихты и температурно-дутьевого режима с использованием обобщенной функции желательности Харрингтона для конкретных условий работы доменной печи. Разработаны модели для расчета коэффициентов распределения элементов шихты между продуктами плавки с целью их дальнейшего использования при прогнозировании состава продуктов доменной плавки и оптимизации качества чугуна.

Библ. 5, ил. 2.

Тогобицька Д.М., Бєлькова А.І., Степаненко Д.О., Скачко О.С. **Фізико-хімічні критерії та моделі для оцінки впливу шихтових і технологічних умов на розподіл елементів шихти між чавуном і шлаком.**

Викладено новий підхід до побудови комплексного показника доменної шихти і температурно-дуттєвого режиму з використанням узагальненої функції бажаності Харрингтона для конкретних умов роботи доменної печі. Розроблено моделі для розрахунку коефіцієнтів розподілу елементів шихти між продуктами плавки з метою їхнього подальшого використання при прогнозуванні складу продуктів доменної плавки та оптимізації якості чавуну.

Бібл. 5, іл. 2.

Togobitskay D. N., Bel’kova A.I., Stepanenko D.A., Skachko A.S. **Physical and chemical criteria and models for an influence estimation charge and technological conditions on distribution of elements charge between pig-iron and slag.**

The new approach to construction of a complex indicator domain charge and temperaturno-dutevogo a mode with use of the generalised Harringtons function of desirability Harington for concrete working conditions of a blast furnace is stated. Models are developed for calculation of factors of distribution of elements charge between products of fusion for the purpose of their further use at forecasting of structure of products of domain fusion and optimisation of quality of pig-iron.

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