

Intelligent Support System of Steel Technical Preparation in an Arc Furnace: Functional Scheme of Interactive Builder of the Multi Objective Optimization Problem

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Abstract: The purpose of the study is to increase the efficiency of the steelmaking process in large capacity arc furnace on the basis of implementation a new decision-making system about the composition of charge materials. The authors proposed an interactive builder for the formation of the optimization problem, taking into account the requirements of the customer, normative documents and stocks of charge materials in the warehouse. To implement the interactive builder, the sets of deterministic and stochastic model components are developed, as well as a list of preferences of criteria and constraints.

1. Introduction

Modern metallurgical production is highly technological and science-intensive, both in terms of technology and management. In spite of this, there are processes, where intellectual support tools are not used to make a decisions [1–8]. Decision-making is carried out on the basis of expert assessments, the significance of which is determined by the human experience. One such process is the decision-making about the using of stock of charge materials for the technical preparation of steel production in an arc furnace. When building the system, there is a need for the organization and maintenance of specialized software for an automated system of technical preparation of production, including the formation of a database with a ready-made solutions [9]. Compliance with the requirements for the chemical composition of steel, the cost of finished products, the saving of energy resources leads to the formulation of disparate tasks of multi-criteria optimization that do not have a relationship between the obtained solutions [10–13]. That is why, there is a need to create a system of continuous monitoring and process management [5], which requires automation of management processes and decision-making in the automated mode at all stages of metallurgical operations. In accordance with the above, the authors identified one of the problem in the synthesis of special mathematical software and a package of standard modules for the functioning of the intellectual support system for the technical preparation of steel production in an arc furnace.

2. Simulation

An analysis of the methods for preparation a technological letter on the structure of charge materials made it possible to develop new requirements to a system for collecting and preparing information.



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The fundamental principles of the new system are: empiricalness, apriorism, adaptability, intellectuality.

The structure of the new system for collecting and preparing information for forming decisions about the structure of charge materials includes modules: interactive selection of attributes from the data warehouse; transformation and data generation; formation of a multicriteria optimization problem; intellectual decision-making support and the accumulation of a solutions for their subsequent adaptation and use [9]. The disadvantages of the previously known mathematical models are: the model restriction by the steelmaking conditions for one type of units DSP-180; the limited number of constituents of charge materials with the main types of charge materials (scrap metal, liquid and solid cast iron, hot briquetted iron); no restrictions on the reserves of charge materials.

To eliminate these shortcomings, an extended deterministic and statistical model is proposed to predict the results of arc melting.

The mathematical model includes two components: deterministic and statistical.

The set of deterministic components of model D includes known dependencies, assumptions, conditions and constraints. Such components are:

D_1 : dependence $R = f(t_1, t_2)$, where R is specific electricity consumption per ton of finished steel, kW; t_1 is arc time under the current, minutes; t_2 is duration of melting, minutes;

D_2 : system of constraints $[E_i^{\min}] \leq [E_i] \leq [E_i^{\max}]$, $i = \overline{1; k}$, where k is the number of chemical elements requiring strict limitations on their content for obtaining the designated steel grade; $[E_i]$ is proportion of the i -th chemical element in finished steel, %; $[E_i^{\min}]$, $[E_i^{\max}]$ is allowable proportion of the i -th chemical element in the finished steel according to the technological handbook, %;

D_3 : system of constraints $[P_j^{\min}] \leq [P_j] \leq [P_j^{\max}]$, $j = \overline{1; m}$, where m is the number of components of the charge materials, %; $[P_j]$ is proportion of the j -th component of the charge materials in electric arc furnace, %; $[P_j^{\min}]$ and $[P_j^{\max}]$ is allowable proportion of the j -th component of the charge materials in electric arc furnace according to normative documents, %;

D_4 : dependence $R_0 = f(\{[P_j]\})$, $j = \overline{1; m}$, where R_0 is bulk density of charge materials in the working area of an electric arc furnace, kg/m³;

D_5 : dependence $C = f(\{c_j\}, \{[P_j]\}, R(t_1, t_2), c_e)$, $j = \overline{1; m}$, where C is prime cost of one ton of finished steel, RUB, in thousands; c_e is cost of 1 kW of electric energy consumed by EAF, RUB;

D_6 : system of constraints $0 \leq [M_j] \leq [M_j^{\max}]$, $j = \overline{1; m}$, where $[M_j]$ is mass of the j -th component of the charge materials, t; $[M_j^{\max}]$ is mass of j -th component of charge materials in production reserves, t.

The set of stochastic components of the model S assumes a description of the regularities for which analytical forms of recording based on the fundamental laws of physics, chemistry, and mathematics have not been known so far.

It is impossible to study such processes on operating aggregates and it is connected with the absence of methods for direct measurement of values, studied quantities, in real time, the presence of many known and unknown factors that influence the course of the process, the presence of high temperatures and enclosed space that restricts access to the object. The set of stochastic components of the mathematical model contains empirical dependences of the linear and nonlinear forms, which are constructed from the results of passive observation of the smelting process and are recorded in the melting report. The set of stochastic components includes empirical dependencies (1)–(5):

$$S_1 : t_1 = f(\{[P_j]\}), j = \overline{1; m}; \quad (1)$$

$$S_2 : t_2 = f(\{[P_j]\}), j = \overline{1; m}; \quad (2)$$

$$S_3 : [E_i] = f(\{[P_j]\}), j = \overline{1;m}; i = \overline{1;k}; \quad (3)$$

$$S_4 : [E_i] = f(\{[P_j]\}), j = \overline{1;m}; i = \overline{1;k}; \quad (4)$$

$$S_5 : T_s = f(\{[P_j]\}), j = \overline{1;m}. \quad (5)$$

The sets of deterministic and stochastic components expand depending on the requirements of the customer for the quality of the finished product, taking into account the technological conditions of the subsequent redistribution.

3. Result and analysis

The model forms the basis of the intellectual support system in the system of management of the technical preparation of production for the electric arc furnace. Paper [14] propose one of the classification of the of decision-making tasks, according to the available information on the variety of alternatives X and the optimality principle opt , the tasks are divided as follows:

- common decision-making problem – X and opt are unknown;
- the choice problem – X is known, opt is unknown;
- the problem of optimization or the problem of ordering the alternatives – X and opt are known.

The presence of a deterministic and stochastic model makes it possible to determine the structure of an interactive builder for setting the problem of making decisions in the system for managing the technical preparation of production for an electric arc furnace, in particular, the choice of the structure of charge materials. In Figure 1 the structure of the interactive constructor is shown.

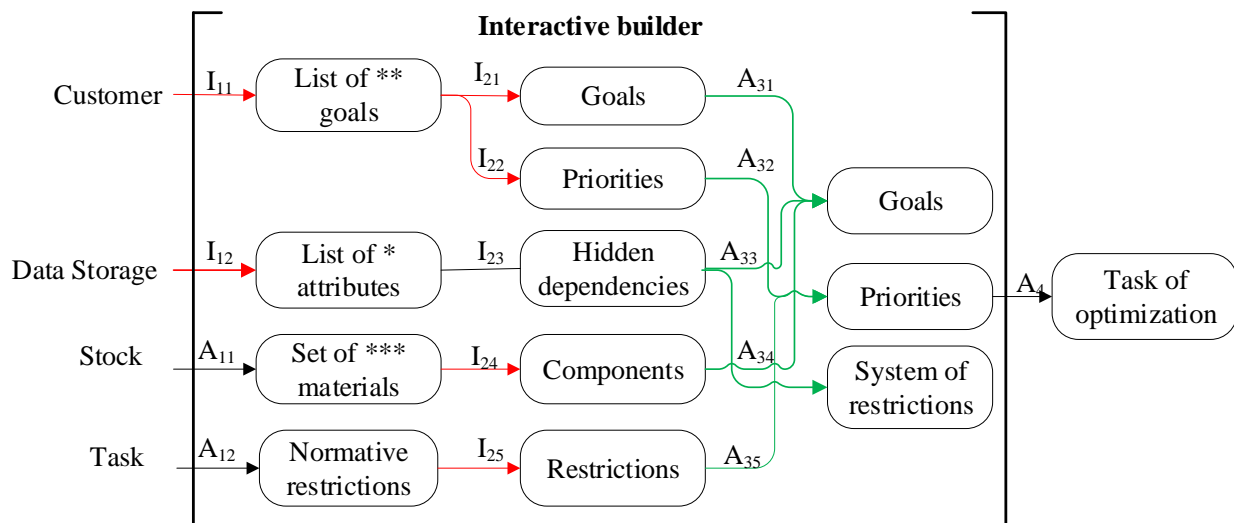


Figure 1. Scheme of functioning of the interactive builder of the multicriteria optimization problem for selecting components for steelmaking in EAF

The notations in Figure 1 are: I_{kl} – interactive mechanism for transferring data from sets S and D ; A_{kl} – automatic data transfer mechanism from the sets S and D . Distinctive features of the interactive builder are: * – consolidation of empirical, normative and deterministic information in the formation of the model; ** – the possibility of forming a multiple goal; *** – the possibility of integration with the tasks of planning stocks in production warehouses.

4. Conclusion

Thus, the authors carried out:

1) rationale the need to set the task of multicriteria optimization in an interactive mode in the intellectual decision support system for the process of technical preparation of steel production in an arc furnace;

2) the construction of mathematical support in the form of a deterministic and stochastic model for its use in the module for the formation of a multicriteria optimization problem;

3) the development of a functional design of the interactive designer for the task of multi-criteria optimization for a new system of intellectual support for the technological preparation of steel production in an arc furnace.

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