Development of methodology for controlling the parameters of TP

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Abstract. This article describes TP control step of the intelligent system for predicting the properties of CGI, which includes three parts: the selection of parameters for comparison, the comparison with the simulation results, the change of the current TP. The list of parameters under which control in the production is carried out has been determined, the adjustment algorithm of TP is designed.

1. Introduction
TP control phase is needed in case of a mismatch of intermediate values obtained during the modeling operations TP and control results in the production, in this case TP and chemical composition adjustment is performed by introducing additional elements (elementwise) or modifiers. If adjustment is required only for one element, the rule base is used [1]. If there is a mismatching of several elements, the simulation is carried out by predicting using a cascade neural network. The TP adjustment is necessary because there is currently a large percentage of deviations in technology - alloy overmodification, non-observance of temperature indicators and incorrect choice of modifiers to adjust the composition.

Intelligent system [2] should provide a preparation of the optimal process, depending on the data entered by the operator. To compile TP we should have all the necessary data on the chemical composition of the product, its mass and wall thickness, and the allowable ranges of technical and economic indicators. If the chemical composition or ranges of technical and economic parameters are not known, it is necessary to predict them and only after that start the TP compiling.

2. Basic part
TP control phase is divided into three blocks: selecting parameters for comparison, a comparison with the results of modeling, the change of the current TP. First, the list of parameters by which a production control is carried out has been defined. After determining the parameters pairs for comparison are formed, consisting of TP parameters values in the manufacture and the values of the simulated TP.

Comparison of these pairs allows you to clarify whether the process has been deviated from the simulated TP, and if it is so - by how much. If you deviate from the planned process it will change. Changing of the TP is carried out by means of the rule base, the genetic algorithm and the neural networks [3]. With the help of the rule base the possible actions by which the TP parameters in the production will match the simulated TP are identified. Genetic algorithm based on abovementioned rules, allows you to choose the best way to solve this problem, taking into account the possible combinations of TP parameters.
Compilation of TP involves selection of the base cast iron or its spectral and thermal analysis to obtain the necessary data to select and calculate the number of modifiers. Rules for selecting base cast iron must have the following logical chain: "Basic cast iron products for producing the products with compacted graphite cast iron should have: a coefficient of carbon equivalent in the range of 4-4.7, 3.5-3.9% carbon content, oxygen content - 500-100 ppm and etc."

Next, using the rule base, processing method, a casting method and the choice of heat treatment are selected. Such rules should have the following logical chain: "When modifying the base cast iron modifier FSMg6PZM1.5 with magnesium content of 6.3%, 1.5% REM and calcium - to 0.4% was used. Since this modifier refers to the comprising a high amount of magnesium in its composition there should be applied an intra-form ladle inoculation. The maximum length of the article is 700 mm, the minimum wall thickness of 5 mm, weight 42kg - so chill casting is the most appropriate way of casting."

It may be several possible TP, the most optimal solution is selected among them, depending on the quality, cost, availability of equipment and raw materials, etc.

To ensure the process it is carried out: preparation of charge and ladles, melting and refinement of the initial cast iron melt according to the required chemical composition, equalizing of the initial cast iron melt, the calculation of the required amount of active nodularizing, vermiculating (magnesium, REM), alloying (tin, copper, molybdenum, nickel) and graphitizing (silicon, aluminum, alkaline earth metals) elements based on the content of the initial melt cast iron the core elements (carbon, silicon, etc.), oxygen and sulfur, weighing of ligatures, modifier, metal processing, chemical analysis, the temperature and the time count, transportation of cast iron, deslagging, sampling on the physico-mechanical properties, casting [4].

Analysis of the sources [5], [6], [7] showed that quality control of raw materials, intermediate products of various degrees of readiness and finished product includes (Figure 1):
- Incoming inspection of materials for compliance with regulatory documentation;
- Express control of the chemical composition of the melt on a certain set of elements;
- Control of the melt temperature;
- Control of the propensity of iron to whiten;
- Visual inspection of casting.

Also in the sources [8], [9] is mentioned that in the development of TP of manufacturing castings sometimes additionally are carried out:
- Thermal analysis of the melt behavior during cooling and crystallization;
- Manufacturing and analysis of technological samples for the determination of the casting properties of the melt;
- Production and analysis of samples for determining the mechanical and special consumer properties of the alloy;
- Non-destructive testing of bulk and surface defects in castings.

The production process is based on monitoring of the whole TP operation by operation, according to the modeled TP. The function of the intellectual system is as follows: if a mismatch of intermediate values obtained in the simulation operations of TP and testing results in the production, in this case an adjustment of TP and chemical composition by introducing additional elements or modifiers is carried out.

Adjustment of the chemical composition is made:
- Using a rule base;
- Using a cascaded neural network [10];
- Using predictive models.

TP adjustment is performed according to the algorithm shown in Figure 2.

Changing of the current process is carried out by means of rules, a cascade of neural network and a genetic algorithm. With the help of the rule base volumes of TP parameters application of which will allow to achieve the compliance with modeled TP are defined. Simulation is performed after correcting using cascaded neural network. Genetic algorithm can find the optimal solution, taking into
**Figure 1.** Controlled parameters in determining the quality of the CGI products on the TP stages

**Figure 2.** Algorithm of TP adjustment process
consideration the alternatives.

Since at certain stages of the TP as a result of control measurements is formed different amounts of data, we must use more appropriate ways of forecasting. With a small amount of data it is appropriate to use a neural network for forecasting.

If increasing the amount of data more adequate results will be obtained by using predictive models.

3. **Conclusion**

In this paper we propose the following solution for the implementation of TP control:

1. **TP control stage** is divided into three parts: the selection of parameters for comparison, the comparison with the simulation results, the change in the current process. First, we define the list of parameters with which the control in the production is carried out. After determining the parameters the pairs are formed for comparison, consisting of values of TP parameters in the production and the values of the simulated TP.

2. **TP and chemical composition adjustment** is produced by introducing additional elements (elementwise) or modifiers. If adjustment is required only for one element it is used rule base. If it is a mismatching of several elements, modeling will be conducted by forecasting using cascade neural network.

3. **TP changing** is carried out by means of the rule base, the genetic algorithm and the neural network. With the help of the rule base possible actions by which the TP parameters in the production will match the simulated process are identified. Genetic algorithm based on abovementioned rules, allows you to choose the best way to solve this problem, taking into account the possible combinations of TP parameters.

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