Development of the intellectual system for predicting the properties of compacted graphite iron

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Abstract. The paper considers the ways of reduction of the metal consumption and the cost of castings and improving their physical and mechanical properties and operational characteristics in iron foundries.

1. Introduction

Technical progress in iron foundries aims to reduce the metal consumption and the cost of castings and to improve their physical and mechanical properties and operational characteristics. In this context, a perspective kind of compacted graphite iron with the so-called vermicular (worm-like) shape of graphite is of a particular interest. Currently it is the most popular and promising material in the manufacturing of parts in mechanical engineering (clutch housing, clutch divider transmission, cylinder block, transmission housing). The perspectives of application of compacted graphite iron (CGI) in mechanical engineering are caused by some economic, technological and operational advantages in comparison with conventional casting alloys. Currently in foundry manufacture, particularly in the production of cast iron, the properties of the final products are determined by the control samples obtained from the relevant series of the batch of parts. There are no methods that allow to predict the properties of the final articles based on the information about the components. As compacted graphite iron is modified iron, the selection of the optimal composition and characterization of CGI requires a large number of experimental studies, which causes high costs in production. In this connection, there was a need to create the systems using the elements of artificial intelligence to predict the properties of CGI on the basis of information about the components with the possibility of adaption and self-learning of the system, if we change the input parameters and evaluation criteria. As a result, it will allow to achieve the reduction of laboriousness and the number of experimental studies. It will, undoubtedly, impact on improving the quality and reducing the cost of manufactured products.

2. Shortcomings of existing CAD

In the analysis of existing CAD systems a number of shortcomings is revealed:
1. high cost of CAD;
2. high costs of CAD data maintenance;
3. highly qualified staff;
4. the need to purchase additional modules for modeling different kinds of casting;
5. complexity of modernization;
6. impossibility (in many of them) of optimization of the composition for a given value of the parameter;
7. high demands on the machine resources.

The proposed solution is in the use of elements of artificial intelligence, self-learning neural networks and combination of mathematical analysis methods that will increase the speed of system response on the change of the initial data. Application of the popular software will reduce the cost and simplify the requirements for machine resources.

3. The stages of intellectual system

The system design is divided into two stages: the training stage and the designing stage. The main aim of the training stage is to train the neural network using genetic algorithm. Then, the obtained results are compared with the results contained in the knowledge base. If such data are not available, the experiments are conducted. The results obtained in the experiments are compared with the results obtained by using the neural network. If the results match, they are recorded in the knowledge base. If the results are not confirmed, the initial data are corrected by the expert and the whole cycle repeats.

The process of conducting experiments is divided into several stages. Preliminarily the planning of the experiments by the method of the combinational squares is carried out, that will reduce their number in $n^{m-n}$ times (m - number of factors, n - number of combinations of factors). After the experiment, statistical processing of the experimental data is conducted by the method of combinational squares, to determine the impact degree of each factor on the final properties of the material, and correlation and regression analysis is carried out to find out the dependency of elements from each other. The data obtained are recorded in the knowledge base.

After the neural network is trained, you can start to work with the system. Chemical elements and final product are going to be the input parameters. Based upon the data about the final form of the product it is possible to determine the wall thickness of the article, as the speed and time of solidification of cast iron strictly depends on it.

The stage of work is divided into several blocks.

The first block is the block of initial data formation. Then the program accesses the knowledge base, which includes a database, a base of precedents, rules bases, a block of the image-making formation and a block of searching the similar images with the help of the base of precedent. The data of the base of precedents are used to search for data options with similar characteristics. Precedent is an array of data that describe existing facilities and processes. To make the base of precedents work, it is necessary to work out the rules that help to search the precedent. If the precise values that are specified by the user are not found, then the values in the range are ±3% from specified are searched. If the precedent is not found, there is a search of the rules for the corresponding values of the chemical elements. The method of fuzzy logic is taken as a basis. The database structure is determined by the structure of the precedent and information used in the process of work.

The second block is a prediction of the optimum quantitative ratio of the chemical elements of CGI, based on the information inputted by a user without taking into consideration the influence of factors such as: the amount and the input order of modifiers, casting method, the methods of feeding of metal into the mold, kind of heat treatment, the rate and conditions of solidification of cast iron. We should consider not only the chemical composition of cast iron, but also the composition of inoculants. The matter is that having the same chemical composition of the basic elements you can significantly affect the final result adding different kinds of modifiers. At the output from the block we’ll obtain a quantitative content of the chemical elements to get the optimum properties of cast iron.

The fourth block is the definition of casting method, a method of feeding metal into a mold and heat treatment. The matrix of CGI directly depends on the casting method. Selection of the casting method depends on the following parameters: material, weight, complexity of construction and overall dimensions. Overall dimensions and casting weight often play a decisive role in choosing the method of manufacturing.
The fifth block is the definition of speed and conditions of solidification of cast iron. These criteria were chosen because the shape and quantity of graphite depend not only on the additives of modifiers, but also on the crystallization time. The nature of solidification of cast iron is determined by its composition and cooling rate. Slow cooling promotes graphite, accelerated cooling partially or completely suppresses graphite precipitation and contributes to the formation of cementite. The cooling rate depends on the wall thickness of the article; therefore, the mechanical properties of CGI depend on it either.

4. Conclusion
As the intelligent system consists of the stages (modules), it is possible to add or exclude certain modules according to the complexity of the problem; as a result, it expands the range of application of this intelligent system.

5. References
[1] V I Bolshakov Y I Dubrov, A N Tkachenko 2010 The task of identifying the qualitative characteristics of materials on the basis of expert systems. // Vestnik of Dnieper State Academy of Construction and Architecture : scientific and theoretical journal. - D.: PDACA - № 1. - P. 46-49
[2] V I Bolshakov Y I Dubrov, E J Zhevtilo 2009 The research of efficiency and effectiveness of empirical empirical prediction of the quality characteristics of steel at the pre- stage of its creation. // Reports of the National Academy of Sciences of Ukraine: Scientific and theoretical journal. - N 9. - S. 103-107: Fig., Tab. - Ref. (8). - ISSN 1025-6415.
[3] V V Kurban Improving the quality of the mechanical properties of hot-rolled sheet steel pipe using neural network modeling. Materials and abstract of the author's dissertation (HAC) 05.02.23
[4] A D Chertov 2003 Application of artificial intelligence systems in the metallurgical industry. TsNIIchermet "Metallurge" : N 7
[5] I H Tukhvatulin, Y P Lankin Forecast of properties of metallic alloys by means of neural networks
[6] www.aiportal.ru/articles/neural-networks/
[7] Osovsky S 2004 Neural networks for information processing
[8] Kruglov V V Borisov V.V. 2002 Artificial Neural Networks. Theory and Practice
[9] Rutkovskaya D Pilinsky M., L. Rutkovski, 2006 Neural networks, genetic algorithms and fuzzy systems
[10]. Alekseeva L G The influence of chemical composition of cast iron on its mechanical properties. Section 15, "Instrumentation, control and diagnostics in technological processes, standardization"
[11] Bolshakov A E Lovushkin M Y 2011 Prediction of compositions of aluminum alloys by their properties Mechanical engineering and life safety,№ 2, p. 37-43 ISSN 2222-5285
[12] F Sh Sharifyanov R F Mamleyev 2002 Designing of castings: Textbook / ; Ufimsk. gov. aviation. tehn. University -Ufa
[13] V T. Senchenko A A Yatsenko Y A Siniev 2001 The production of castings from cast iron. Part 1: Writing lectures. - SPb.: NWTU
[14] M O Matveeva B V Klimovich V V Klimovich E A Dvornikova 2013 Simplex method of optimization of the cast iron with a given set of properties during the casting / "System Technology" 2 (85) p.124 -131
[15] A A Radchenko A V Gal'chenko 2011 Improving the quality of steel and cast iron castings. Casting-2011: Materials of the VII International scientific and practical conference. p.154 -155