Stages of vermicular cast iron properties modeling in the intelligent design system

K V Klochkova, S V Petrovich, L A Simonova, L R Yusupov
Kazan Federal University, Naberezhnye Chelny Institute
423810, Naberezhnye Chelny, Mira av., 68/19, Russia.

E-mail: kvsimonova@mail.ru

Abstract. This article presents the structure of intelligent system of the cast iron with vermicular graphite iron (CGI) design under the conditions of current production, the technique of the optimal process TP parameters of the production of CGI parts in the preparatory phase of production based on mental models is designed.

1. Introduction

The object of the study is compacted graphite iron (CGI), because at the moment it is the most popular and promising material in the manufacture of parts in mechanical engineering (clutch housing, splitter gear crankcase, cylinder block, transmission housing).

Analysing the source [1] and [2] it can be concluded that in the production of compacted graphite iron is very important to control accurately the chemical composition of the modified cast iron, processes of cooling, casting, primary and secondary modifications.

Intelligent system for predicting the properties of cast iron with vermicular graphite will reduce the complexity of experimental studies, improve a prediction of physical-mechanical and technological properties of materials, which ultimately affect the quality and cost of manufactured products.

Despite the existing designs an urgent problem remains: the development of software modules to predict the chemical composition and properties of cast iron in the existing production. Operative forecast is designed to detect unwanted trends and developing of corrective actions aimed at their prevention.

Today, there are a number of functional and popular systems for forecasting: MedeA, Ansys, ProCAST, SIMULIAAbaqus, and PoligonSoft. However, these systems have high demands to the machine resources and for the prediction a highly qualified staff is required, since it is necessary to interpret the results [3].

The proposed solution is to apply the elements of artificial intelligence, self-organizing neural networks and a combination of methods of mathematical analysis, which will increase the rate of reaction of the system to change the source data. The use of popular software system will reduce the cost and simplify the requirements for the machine resources. As a model of knowledge representation are chosen production rules in the form of the structure of fuzzy sets, as this view helps to solve problems where knowledge meets ambiguity of knowledge (interpretations) [4]. Intelligent system design is based on a unified knowledge base, which consists of the precedent base, rule base and the database [5]. The knowledge base is formed during the technological process at the stages of system functioning. The need to train the system, ie updating the knowledge base, as well as in some cases the lack of ready-made solution creates the need for new experimental studies. To do this, you must make rational planning of experiments with their subsequent statistical processing to design the predictive

models. The need for using a mathematical model with a combination of methods of rational experiment planning and statistical processing methods of experimental data is due to the fact that the application of these methods separately in the tasks with a large number of variables does not give adequate results, and if they give, the computation is very time-consuming.

The analysis revealed that the neural network is a flexible and powerful tool for forecasting, due to its ability to educate themselves and complete their education. [6] With their help it is possible to solve both direct and inverse problems, and describe any mathematical model. Selecting a genetic algorithm as a tool for optimization is due to the fact that for the solution of the given task is required a systematic approach, effective methods and criteria for assessing the adequacy of the models, which are aimed not only (not so much) for the maximization of the criteria, but also to optimize the relationship.

The TP adjustment is necessary because there is currently a large percentage of deviations, in technology – alloy overmodification, unacceptable temperature indicators and incorrect choice of modifiers to adjust the composition.

At the moment, to formulate the task of obtaining a certain qualitative composition precisely or diagnose a specified quality with modern production methods is not possible.

2. Basic part

In the result of analysis of TP operations of products manufacturing from CGI by sources [7], [8], [9] and identifying the main dependencies, the structure of intelligent system of CGI design is developed (Figure 1), as well as the technique of the optimal TP parameters formation of CGI parts production in the preparatory phase of production based on mental models.

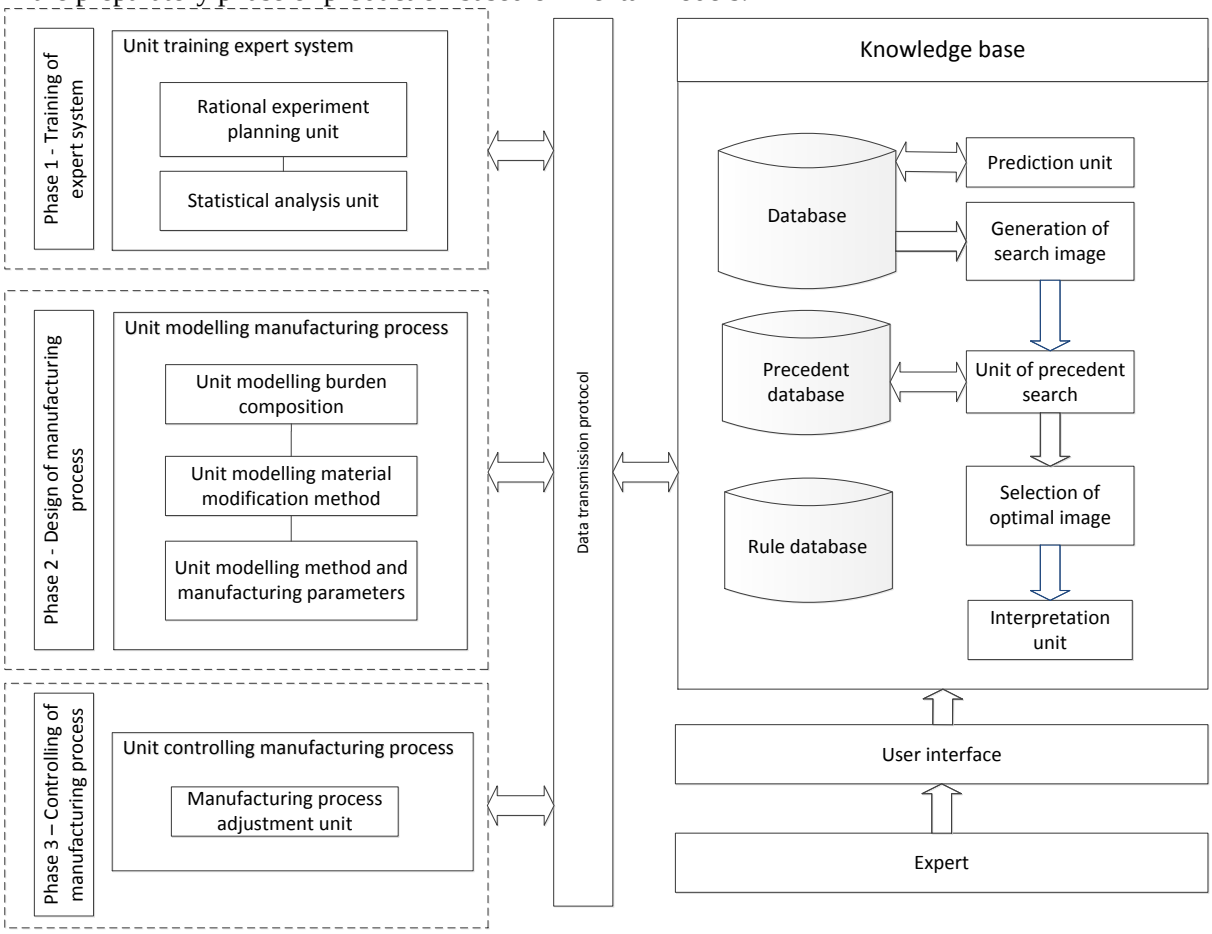

Figure 1 - Structure of the intelligent system of CGI design

Intellectual system functioning of CGI design is divided into three stages: learning stage, the stage of TP modeling, the stage of TP controlling.

The training phase. It is intended to supplement the knowledge base. The training phase consists of the following blocks: block of rational planning of the experiment, block of statistical processing . The need for applying of a mathematical model using a combination of methods of rational experiment planning (by the method of combinational squares) and methods of experimental data statistical processing (using regression analysis and statistical processing block of combinational squares method) is due to the fact that the application of these methods separately in the tasks with a large number of variables does not give adequate results, and if they give, the computation is very time-consuming.

Block of rational experiment planning is for pre-planning of experiments by the combinational squares method, which will reduce their number in the n^{m-2} times (*m* - number of factors, *n*- number of factor combinations), while retaining the ability to predict results for the full amount of experiments.

Statistical processing block is designed for experimental data processing with a combinational squares method, and using regression analysis for the predictive models obtaining.

After the experiments the obtained data are recorded in the database, and the parameters of the experiments are recorded as precedents.

TP modeling stage. At this stage, TP operational parameters modeling is carried out, the raw materials (stock) and the finished castings properties. It consists of a stock composition simulation block, modeling block of modifying method, modeling block of method and processing parameters.

Block of stock composition modeling. Prediction of the optimal quantitative chemical elements correlation of the stock on the assumption of the information entered by the user without the influence of factors such as the number and sequence of modifiers input, methods and heat treatment parameters. Simulation is performed using a cascade neural network [10]. To do this, apply a genetic algorithm.Прогнозирование оптимального количественного соотношения химических элементов шихты исходя из информации введенной пользователем без учета влияния таких факторов, как: количество и очередность ввода модификаторов, способ и параметров термической обработки. Моделирование выполняется с помощью каскадной нейронной сети[10]. Depending on the concentration of chemical elements there can be various embodiments of the materials properties, whereby there is a need to optimize the task. To do this, we apply a genetic algorithm.

Block of method of modifying modeling. Depending on the initial chemical composition it is necessary to determine how and in what order to add modifiers to obtain the desired intermediate properties of the alloy, so as with the same chemical composition of the main elements the type of added modifiers can significantly affect the final result. Determination of the composition of modifiers and their percent concentration are determined by searching in the precedents database and by prediction based on a cascaded neural network if no precedent has been found.

Block of modeling of method and processing parameters. Methods and processing parameters at various stages (melting process, exposure process, a pouring into ladle and a mold, cooling and crystallization, defining a casting method, a method of supplying the metal in the mold, and heat treatment) are simulated. Is performed by applying a cascade neural network.

Stage of technological process control (TP). Necessary in case of a mismatch of intermediate values obtained in the simulation operations TP and testing results in the production, in this case of an adjustment TP and chemical composition by introducing additional elements (elementwise) or modifiers. If adjustment is required only for one element is used a rule base. If there is a mismatching of several elements, modeling is conducted by forecasting using cascade neural network.

Exchange of information with intelligent system modules is done through data transfer protocol.

Since the intelligent system consists of stages (modules), it is possible to add or exclude certain modules, depending on the complexity of the problem, which extends the range of application of the intelligent system.

The knowledge base is to create a single data space required for the exchange of information throughout the intelligent system. Knowledge base contains not only a factual information, but also the rules of inference, allowing automatic conclusions of newly introduced facts and, as a result, meaningful information processing.

The knowledge base includes a database, precedents database, rule base. The functional part of the knowledge base is represented by the forming image block to search for a precedent, the search precedents block, the optimum selection block, interpretation block and the prediction block.

At the request of the operator database management system generates the required input data of the local task.

These databases are used to search for options of data with similar characteristics. If the case is not found, the original data transferred to the prediction module. The structure of the precedents base is determined by the structure of precedent and information used in the process. Precedent is an array of data that describes the existing facilities and processes.

Precedent is formed as follows:

$$П_i=S_j,M,V,L,G,I_м,Q,T_п,T_о,HB,\ \sigma_в,D$$

Wherein $П_i$– precedent, with the number of elements I; S_j – chemical composition, with the number of elements; M – mass; V– type of molding; L – walls thickness; G – modification method; $I_м$ – modifier; Q – casting method; $T_п$ – melting temperature; $T_о$ – cooling temperature; HB – hardness; $\sigma_в$ – long-term strength; D – mark of the obtained cast iron.

Precedent example:

П1=S1(3.84); S2(0.012); S3(2.44); S4(0.36); S5(0.06); M(12,2); M(74); V (interaxle differential crankcase); L(50); G(Inmold); Iм(CompactMag); Q (in sand molds); Tп(1600); To(1125); HB(180); σв(400);D(ЧВГ45).

Operation of prediction module is based on a usage of the cascade (hybrid) of a neural network.

In the basis of the rules are stored the rules necessary for the functioning and connection of all elements of the intellectual system. As the basis for the creation of the rules is taken the method of fuzzy logic.

Rule example for finding the optimal way of solving on the found similar precedents:

Rule 1

IF «Pi» ≤ «Pmax» and «Pi» = «Pmin» And "Pc" = "High" SHOULD BE "Send to the interpretation block»

Forming the image for search Depending on the entering data and the task under consideration (finding the optimal composition, predicting the properties. TP formation, etc.) there is a request to the database for the necessary information.

The appropriate image of solution is formed, which is an search object in precedent database.

Search of a similar image in the precedents base. If a search of the identical images with a composed solution manner in the precedents base returned no results, it is necessary to search for similar precedents.

Selection of the optimal image. If the system managed to find a few images to solve this task, you need to select the most optimal one. Optimality criteria can be indicators of quality, cost, and the degree of similarity of the found solution.

In case of not finding identical or similar images in the precedents database it is provided a system application to *the prediction block.*

Interpretation block. It is intended to explain the solution found in the form of a precedent for subsequent output to an expert interface.

3. Conclusion

The paper presents an intelligent system of design based on a common knowledge base, which consists of the precedent base, rule base and the database. The functional part of the knowledge base is represented by the image forming block, search precedents block, optimum image selection block, interpretation block and the prediction block. As a model of knowledge representation are chosen

production rules in the form of the structure of fuzzy sets. Functioning of the intelligent system of CGI design is divided into three stages: learning stage modeling process, the stage of controlling the process. Determination of the composition of modifiers and their percent concentration is carried out by searching in the precedents database and by prediction based on a cascaded neural network if no precedent has been found. Module operation is based on a prediction of the cascade (hybrid) neural network.

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