

# Possibilities of information technologies application to production problems solving by math modeling methods

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**Abstract.** Nowadays there exist a great number of program packages, allowing solution of common tasks of automation of the math modeling. Industries with their specific features may demand particular approaches to solving their problems. Modern information technologies allow development of a special application software for processing a specific task in such cases. The article suggests a description of a general architecture concept of the application software, which can automate tasks of the math modeling to solve different issues related to the industrial production. It describes a detailed algorithm of data processing in such a product using the capabilities of the information technologies. The capabilities of such an application software are shown in the example of preliminary draft model design of large pouring ladle stopper durability. The results that have been achieved with the help of the extemporized model allow making a conclusion that a model that has been built by the same techniques based on an annual scope of collected information will make it possible to get reliable answers for the tasks of production management.

## 1. Introduction

Nowadays the whole world is widely using systems engaging employees in active participation in improvement of technologies and equipment utilized at an enterprise. Such a system known as ‘Think Tank’ successfully operates at the Nizhny Tagil Iron and Steel Works. Nevertheless, not only the used real production processes need to be improved, but also do methods for making decisions on their replacement with more advanced processes. These days they are usually solved by formal hourly discussions of drawings in a narrow circle of supervisors, and sometimes individually.

At the Nizhny Tagil Technological Institute (branch) of Ural Federal University, a method for making decisions on purchase of new technologies and equipment using the modeling as a management tool has been developed. The use of modeling (both mathematical and physical) allows engaging workers and foremen in this procedure. For instance, when the production qualities of proposed equipment are under discussion, the developer must present its acting physical model. This factor makes it possible for workers and foremen to actively participate in the discussion and make appropriate adjustments.

Various computer modeling programs are increasingly used in the practice of plants. The basis for functioning of all these programs are the math models. There is a variety of models: the ones executed using a relatively complex mathematical apparatus and the ones executed using a relatively simple mathematical apparatus. But each of them contains three structural elements: variables, a relation



between the variables and a model parameter [1–4]. For this specific enterprise, input and output variables and relation between variables used in models of other enterprises may be quite adequate, but a model parameter shall be inherent and distinct. The most inherent parameter appertains to models, built on the basis of technical and economic variables of this specific enterprise, accumulated in its information dump [5]. Obviously, that kind of model will be a more reliable tool of production management due to sufficiently large scope of information dumps in series and large-scale production. Moreover, a large scope of information makes it possible for metallurgic engineers to build a preliminary draft version of a model without applying a complex mathematical apparatus. It will significantly increase the likelihood of success during cosynthesis of a run-time version of a model with professional mathematicians.

With successful purchase of a new technology, a problem of its modernization arises over the course of time. The idealized technology will certainly be followed by appearance of heavy shortcomings in it. As a rule, when technological optimization is required, one resorts to metallurgical engineering theoreticians in big cities. This resort is formed by a small group of engineering technologists. Before sending such a resort, the new method makes a provision for creation of a draft math model of a process, which will allow specifying a task for the theoreticians to the utmost, and most importantly, it allows taking the necessary part in solving this problem.

## 2. Materials and method

In the age of advanced technologies and fast-growing scopes of information, a huge role is given to software solutions allowing processing of information quickly, easily and conveniently, as well as presenting visualized and tangible result in the end.

Nowadays there are many software packages giving a possibility to a person (even the one, who does not have any programming skills) to solve complex tasks, including the tasks of math modeling. Among them one can find such solutions as MathCad, MATLAB, Excel and other popular software packages.

However, ready-made solutions in the field of information technologies do not always make it possible to solve a specific range of industry-related problems. In these cases, it's possible to opt for creating an inherent decision software package for processing of any specific problem [6–8]. This approach allows flexibly elaborating a specific problem solution.

Currently, the popular and effective means for development of software solutions are Microsoft Visual Studio and QtCreator. The first one will allow writing and debugging a code in a variety of languages, among which are C++, C# Python. QtCreator makes it possible to develop solutions in languages C++, Python and other.

The approach to development of a software package lies in the analysis of a task with its further division into logical blocks, their establishment in the form of algorithms and implementation of a sequence of actions in a code. Algorithms for solving subtasks, into which the target task has been divided, are taken from sources in the Data Science field or from the mathematical apparatus. Then it is necessary to connect the algorithms to each other by interfaces. Afterwards, the algorithm is presented in a code of a chosen programming language. The source code can be composed in the form of a single file, but when writing user-defined classes, the project source code is usually presented by several files: one of them is main, and the rest are devoted to the description of other user-defined classes. They implement auxiliary fields and methods solving the subtasks and storing intermediate data. Initializing of classes instances and call for their methods are performed in the main file. If a program has a user interface, then a source code file accounting for an active window often serves as the main file. Input data is put into fields of the classes by means of setters and/or constructors and is processed when the methods are called for. The calculation results are output to a console or to a form by means of a language. But before that they are requested from fields of classes instances by calling methods-getters.

The compilation and linkage editing are carried out through a special software suit which is usually included in development environments. After these procedures, the source code becomes a software.

Then its testing and debugging is performed. A certain data set is supplied to the input of the software. A result is compared with an expected one according to the test.

The software receives the input data set from the file. The user indicates on a field form which columns refer to input ( $x$ ) system parameters and which refer to output ( $y$ ) ones. The data is parsed and is put into a container, which is transferred for a further analysis by auxiliary methods of class of tools. The correlation analysis is made by columns of input parameters. The following calculations are made according to the mathematical apparatus of design of experiment. Based on the input data, an experiment design matrix and extremum seeking of a response function by a steepest ascent method are executed. If the response function is inadequate at this point, then it is an optimum point. Additionally, an analysis of coefficients significance is carried out by the Fisher's ratio test in the process of calculation. Non-significant coefficients are suppressed and relevant input factors are not taken into account in the future. The calculations are carried out by calling the methods of a class of tools, each of which is in charge of its subtask and its part of calculation. Results and main points of calculations are entered into the form in a user-friendly style.

An example of a possible preliminary draft model design of large pouring ladle stopper durability with the participation of all employees related to a real site of production (direct and indirect workers, foremen) is given below: Having a monthly scope of accumulated information available, the methods presented in the paper [5] are used. The number of melts poured without replacement of the stopper ( $Y$ ) has been taken as the output variable of a modeling object. By interviewing all the employees involved in preparation and operation of the stopper, all the factors that possibly affect the stopper durability have been listed. 8 of them are defined as the input variables ( $X$ ):

1. Content of MnO in slag ( $x_1$ ).
2. Melt temperature ( $x_2$ ).
3. Pouring rate ( $x_3$ ).
4. Content of  $Al_2O_3$  in the chemical composition of the stopper body ( $x_4$ ).
5. Content of MgO in the chemical composition of the stopper head end ( $x_5$ ).
6. Heating-up temperature of the stopper before pouring ( $x_6$ ).
7. Melt level in the ladle ( $x_7$ ).
8. Diameter of the ladle nozzle ( $x_8$ ).

The opinions of the participants in model synthesis on the power of influence of each factor on the stopper durability have been mathematically processed. The processing has showed the strongest influence of the MnO content in the slag, of the  $Al_2O_3$  content in the stopper body and of the pouring rate on the durability, which has not contradicted the experience of using the stoppers at this enterprise.

The second ( $x_4$ ) and the third ( $x_3$ ) factors by the strength have been selected from the three most powerful input values according to the capabilities of production variation. Taking into account the small scope of technological information, a linear dependency between the variables of a future model has been taken. In spite of a small scope of available information, the dependency of stopper durability on pouring rate ( $x_3$ ) and  $Al_2O_3$  ( $x_4$ ) content in coded variables has been obtained.

$$Y = 11 - 3x_3 + 2x_4 \quad (1)$$

From expression (1) it follows that the pouring rate has a stronger influence on the stopper durability than  $Al_2O_3$  by the value and sign of the coefficient under the factor, and as the rate increases, the durability decreases, and  $Al_2O_3$  increases the durability. This information is consistent with the peculiarities of the real process of melt pouring. Theoretically, the resulting model can be used for operational control of the technological process. For this, expression (1) has been transformed into an equation with natural variables (2).

$$Y = -0.7 - 12x_3 + 0.33x_4 \quad (2)$$

The transition to the natural variables is necessary for the operational solution of the production tasks. Suppose, for example, that there is a need to purchase stoppers with a lower  $Al_2O_3$  content due

to financial difficulties. The average-weighted  $\text{Al}_2\text{O}_3$  content in the monthly technological information (Table 1) is 70.7 %. If stoppers with the content of 76 % are rejected, the average value will decrease to 66.1 %. The average durability of stoppers per month is 14 full melts. In order to maintain this level of durability when using cheap stoppers with a lower  $\text{Al}_2\text{O}_3$  content according to expression (2), it is necessary to reduce the pouring rate to 0.59, which is at disposal of the plant's technological management.

**Table 1.** Distribution of  $\text{Al}_2\text{O}_3$  content in stoppers.

$\text{Al}_2\text{O}_3$ %	Frequency
64	7
66	1
68	8
76	14

### 3. Conclusion

Of course, the technological parameters that have been obtained with the help of the presented extemporized model cannot be applied in production, but the model that has been built by the same techniques based on the annual scope of collected information will make it possible to get reliable answers for the tasks of production management.

### References

- [1] Chaykin A V, Volnov I N and Chaykin V A 2009 Study of cast iron modification process using methods of mathematical statistics and modeling *Vestnik of Nosov magnitogorsk state technical university* **1** pp 41–5
- [2] Bigeev V A, Chernyaev A A and Panteleev A V 2014 Mathematical modeling of the two-stage method for sludge and dust recycling *Vestnik of Nosov magnitogorsk state technical university* **3** pp 48–52
- [3] Yanishevskaya A G 2009 The mathematical models of the industrial system in foundries *Bulletin of Voronezh state technical university* **11** pp 230–4
- [4] Leushin I O and Reshetov V A 2014 The use of mathematical modeling in technological preparation of foundry *J. of Siberian Federal university engineering & technologies* **4** pp 430–5
- [5] Gruzman V M 2013 *Development of Information Dumps of Casting Production: Monograph* (Nizhny Tagil: NTI (branch) UrFU) p 108 [In Russian]
- [6] Kosenko D V, Voronova L I and Voronov V I 2014 Developing software for processing complex structured data of scientific experiment *Vestnik of Nizhnevartovsk state university* **3** pp 45–52
- [7] Safonov D S and Logunova O S 2015 Automation of the design of secondary cooling sections of the continuous casting machine *Vestnik of Nosov magnitogorsk state technical university* **1** pp 111–27
- [8] Baydyuk A P and Kovalev M I 2013 Quality management system on the example of foundry *Izvestiya Tula state university. Technical sciences* **4** pp 252–60
- [9] Kosach A A and Kovshov E E 2018 Automation of non-destructive testing data processing based on artificial neural network *Cloud of Science* **5** **3** pp 524–31
- [10] Kosach A A and Kovshov E E 2017 Software and hardware for industrial automation in the management of remote leakage detection control *Cloud of Science* **4** **2** pp 264–73