The effectiveness of the use of information technologies in the manufacture of parts by molding methods

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Abstract. The choice of the gating feeding system of castings is made by trial and inevitable errors, which are the less, the more experience of the casting engineer who develops the type of system for different types of casting. The design of the gating system and the modeling of the casting process, the formation of casting, and the analysis of emerging defects can be made more efficiently due to the great possibilities of the computer simulation program "Polygon". Considering the investment casting, the automated design program greatly simplifies the process of finding the best solution, as the investment casting is a complicated and a multiphase process, which requires taking many steps such as designing a press mold, building a cluster, et cetera. The factory design of the casting model is a stock of unified exemplary segments, which are interconnected and characterized by an unproductive usage of a top part. It is proposed to improve the model casting unit “Flange” of the current production, without changing the design of the model units, and increasing the number of models of the casting from one to four, which can lead to an increase in the yield of fit. In preparation for the calculation, the three-dimensional model was divided into a finite element mesh. The computer program calculates the process of solidification and formation of shrinkage defects for metal. The conducted computer experiment showed that this technology of casting arrangement, developed with the aid of the automated design program, can be used in production, which will significantly accelerate the implementation of the annual program, ensuring the production of high-quality castings, which is confirmed by the experimental fills. Programming processing in SprutCAM allowed to reduce processing time by minimizing idling and to obtain a trouble-free control program for the CNC machine.

Key words: information technology, computer modeling system, casting, defect.

1 Introduction

Foundry production is an important link in ensuring the quality of engineering products. Enterprises today rely mainly on the practical experience of qualified technologists who achieve positive results when working out complex technologies by trial and error [1, 2]. The use of specialists mainly heuristic techniques in solving technological problems is accompanied by significant expenditures of time and material resources [3, 4].

To obtain defect-free castings intuitively have to take into account the role of many factors in casting process such as foundry alloy and its properties, the geometry of the casting and its location in the shape, geometry of the Gating system, the melt temperature and fill rate of the melt shape, the material form and its pre-heating, speed control of heat transfer through inner and outer surfaces by
means of refrigerators, coatings, insulation, etc. [5, 6]. Experienced engineers keep in mind a huge amount of empirical information about successful and unsuccessful attempts to obtain castings.

Currently, there is an alternative to factory tests [7], which will certainly interest everyone [8, 9]. Computer modeling of casting technologies has developed so much in recent years that today we can talk about real savings in time [10, 11] and material resources at the stage of designing tooling and casting geometry using virtual casting simulators [12, 13].

It is quite obvious that modern science and engineering depend on informational technologies considerably. Unfortunately, it is not always that simple to employ IT to casting engineering. Indeed, there are a number of reasons for that. Firstly, it is rather complicated to represent all of the technological processes of casting engineering and apply mathematical approach at the same time. Secondly, there is a certain lack of suitable software that allows creating optimal technological models for pre-set qualitative casting. Additionally, there are numerous factors that influence the process of forming a required structure of a casting model, which again must contain certain features. Thus, most of the crucial technological qualities are carried out in the casting center directly and of course through trial and errors that help to gain work and empiric experience. Consequently, it takes more time, effort and material maintenance to validate the technique.

Nonetheless, there is a possible solution to decrease these inputs and expenses, which is both promising and progressive – computer-based system [14, 15]. Indeed, this technological approach can be decidedly useful and help to do the following: solve specific casting tasks, shape the process of solidification with the aid of functionally combined modules, solve all of the tasks of the targeted casting foundry [16, 17].

2 Materials and methods
The data acquired by the means of calculations became a primary method to solve the “B” type task, which is a computerized modeling of the casting formation process. As a result, the transient temperature fields of the solidifying metal were determined. Furthermore, the obtained data indicated the phases of metal at every instant and the dynamics of shrinkage defects such as porosity and microporosity, which are acknowledged as the most dangerous according to the theory of casting formation. Consequently, the acquired data was thoroughly analyzed and evaluated for technical compliance. The task was considered solved if the solidified metal contained an acceptable quantity of shrinkage defects or did not contain any of them.

The resulting exemplary material was carefully examined for adequate work performance under factory conditions [18, 19]. If the computer and full-scale experiments were approved as adequate, the exemplary material was considered as optimal and recommended for manufacturing mass production [20, 21].

The manufacturing technology of workpiece production by the means of casting was considered the development subject. It is not necessary to know programming languages or comprehend the concept of operating systems to use technological subsystem software [22]. Indeed, the whole process functions in a dialogue mode, which decreases an extensive software check and allows solving a specific technological task by the means of a man-machine operating mode [23, 24].

The modeling process of casting with the use of computer modeling simulation “Polygon” was performed in 3D. In order to execute the operation, a geometrical image of casting was created with the aid of SolidWorks hardware. Thereafter, the image was divided into finite elements through the use of HyperMesh and finally, it was converted into the Polygon’s format. After that, the 3D finite element mesh of the cast model with a mold was undergoing a correction procedure and finally, became a reference for automated numerical calculations. The task’s numerical solution is based on the differential equations of transitory solidification processes, as well as the distribution of transient temperature fields and defects. Consequently, all of the results are displayed on a computer screen and stored in its memory.

The process of modeling the machining of the casting was carried out using SprutCAM. Processing programming in SprutCAM allows you to get a high-quality control program, eliminating accidents
associated with working movements of the machine's executive bodies, tools and auxiliary equipment involved in the processing of the part.

The composition and structure of project procedures when working with SCM LP is shown in figure 1.

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**Figure 1.** Composition and structure of project procedures.

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### 3 Results

Gating and feeding system of a “Flange” unit was optimized with the aid of the computer simulation program “Polygon”. The aim of this optimization was to determine the possibility of acquiring four quality castings instead of just one as it happens under factory conditions. Furthermore, the whole process was to be operated with no readjustments of press molds but with stationary gating and feeding system configuration. The results were to increase the output factor of good products. Plant presents the following key figures for the casting process (figure 2a):

- casting accuracy – 9-0-0-9 GOST R 53 464-2009;
- working material – steel 10X18H11БЛ GOST R 977-88;
- weight of a die-cast part – 4.9 kg;
- weight of a casting – 5.3 kg;
- weight of a gating and feeding system – 21.6 kg.

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**Figure 2.** Model casting unit "Flange":

a) initial; b) horizontal position in the block; c) vertical position in the block.
Considering the investment casting, an automated constructional design can simplify the search for a better solution essentially, as the gating and feeding system is a complicated and a multiphase process, which requires taking many steps such as designing a press mold, building a cluster, et cetera.

A default construction of the gating and feeding system is a stock of unified exemplary segments, which are connected to each other (fig. 2b). Unfortunately, this type of construction is characterized by an unproductive usage of a top part. The casting unit “Flange” could be improved without remodeling any of the segments, which is a crucial point when it comes to production of the press molds. The improvement could be accomplished by increasing the amount of casting models from one to four. Additionally, it would enhance the output factor of good products (figure 3).

![Figure 3. Finite element mesh.](image)

However, it is necessary to maintain the highest quality even with decreased metal consumption. At this point, the computer simulation program “Polygon” can help with that. A 3D-model was laid out into a finite element mesh during the preparation to the calculations (figure 3). After that, a 11 mm sized shell was modeled. In order to design a casting technology, the thermophysical properties of steel were chosen to serve as reference data. The boundary conditions, which are needed to carry out the calculation, are given in the following table 1.

| Parameter          | Value     |
|--------------------|-----------|
| Liquidus temperature | 1570 ° C  |
| Solidus temperature   | 1490 ° C  |
| Poring temperature    | 1620 ° C  |
| Shell material        | ceramic   |
| Shell thickness       | 11 mm     |

The process of solidification, as well as the formation of shrinkage cavities, were calculated regarding three temperature points: 450 ° C and 100 ° C respectively. It can be seen in figures 4, 5.

![Figure 4. 450 °C, 100 °C.](image)
4 Discussions
Using "Polygon" we solved the following problems:
- thermal (solidification of the casting) and received information in the form of temperature-time fields in the metal and shape and the phase state of the casting for various moments of time;
- the problem of power: the distribution of defects – shrink holes, shrinkage porosity, rychlosti section of the casting.

In this paper, we assume that the formation of the casting begins immediately after filling the mold, so the calculation of hydrodynamic casting processes was not performed.

As seen in figure 5, the shrinkage cavities are formed in the top part in a way that prevents any possible defects from occurring, which is the most crucial and desired technological result.

From the experimental results it is obvious that the technology of production of castings in way of LVM extends the weight, size, configuration and other parameters, allows to reduce the cost of casting and to improve performance by increasing strength and permeability of the calcined forms, elimination or sharp reduction of losses forms and scrap castings caused cracks forms during calcination and pouring the metal, reducing time and energy consumption for calcination.

Using the SprutCAM program, visualization of the machining of the casting was obtained (figure 6) and a control program for CNC equipment was developed.

Figure 6. Machining visualization in SprutCAM.

Thus, the conducted computer experiment showed that this technology of casting arrangement, developed with the aid of the automated design program, can be used in production, which will significantly accelerate the implementation of the annual program, ensuring the production of high-quality castings, which is confirmed by the experimental fills.
The system of casting solidification and its technological modes, which can be used for oil and gas equipment, aircraft, etc., were prompted by the executed work. Programming processing in SprutCAM allowed to reduce processing time by minimizing idling and to obtain a trouble-free control program for the CNC machine.

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