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Article

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IMPROVING THE TECHNOLOGY OF MANUFACTURING CAST BRAKE DRUMS IN PINK SAND MOLDS

The object of research in the paper is the production technology of casting «brake drum» from cast iron of the basic grade SCh20 according to GOST 1412-85 (DSTU EN 1561, EN-GJL-200). The existing problem is that due to the imperfection of the technological processes of manufacturing castings, final internal defects of a shrinking nature are possible. This can lead to a decrease in the strength and operational reliability of the drums, regardless of the chemical composition, which may meet the technical conditions and should provide the specified strength indicators according to the grade of cast iron.

Based on the results of 3D modeling, it has been found that with the existing technology of manufacturing brake drum castings in one-time sand molds, final shrinkage defects are formed in the upper part of the casting. To eliminate this problem, a decision is proposed to increase the allowance for mechanical processing on the upper surface of the casting. The possible excess of the mass of the casting and excess consumption of the alloy that will occur when implementing this solution can be compensated by reducing the allowance on other surfaces based on their optimization by the method of dimensional chains and reducing the thickness of the casting wall. For this, a reduction in the carbon content in the alloy is proposed as a factor in increasing the tensile strength of cast iron. On the basis of 90 serial meltings in industrial conditions, the possibility of increasing the strength limit of cast iron by approximately 11 % by reducing the average carbon content in cast iron from 3.45 % to 3.4 % has been proven.

The proposed solutions are the essence of improving the production technology of cast brake drums, which are produced by casting in one-time sand molds.

The presented study will be useful for machine-building enterprises that have foundries in their structure, where iron is melted for the production of castings.

Keywords: *brake drum, chemical composition of cast iron, allowances for mechanical processing, serial melting of cast iron, charge materials, strength limit of cast iron.*

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1. Introduction

Modern views on the development of technologies for the production of castings are based on the fact that the processes of filling casting molds and crystallization of the alloy can be modeled [1–3], the result of which is the detection of internal defects [4]. The results obtained by such modeling can be related to decisions made at the stage of design and technological preparation of production. If such decisions are taken for implementation, then based on the monitoring of the obtained quality indicators, it is possible to check the correctness of the modeling process and the correctness of the assignment of all initial data [5]. As a rule, dimensional and geometric accuracy of castings are quality indicators. Modeling makes it possible to identify possible deviations from the specified values of these indicators [6–8] and to solve additional issues related to the development and improvement of the technological process [9]. The idea of such improvement at the stage of development or improvement of the technological process of casting in disposable sand molds, and, accordingly, the development or improvement of model casting equipment is presented in [10]. Its essence is that, by changing the design parameters of the elements of the sprue system or the variants of its arrangement on the basis of experimental planning methods, it is possible to obtain a mathematical description of the influence of the design parameters of the equipment on the formation of one or another indicator of the quality of finished castings. On the basis of such a description, it is possible to purposefully regulate the properties of castings, choosing rational design and technological solutions.

However, all the above solutions revealed in works [1–10] refer only to issues of design and technological preparation of production without taking into account the influence on the quality of castings of the composition and properties of the alloy. Such characteristics of the alloy are very important, because with a low-quality alloy, all other quality indicators will not be so important, because the necessary functional properties of castings will not be provided.

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The specified properties can be obtained by technological processes of modification of the melt when it is issued from the furnace [11] and by combining modification with alloying [12, 13]. On the other hand, the imperfection of the selected design and technological solutions and, as a result, of the casting equipment, or the technology of compaction of the molding mixture during the production of half-forms [14], leads to the formation of defects [15]. This, in turn, does not provide the required mechanical or special functional properties, even if the quality of the alloy meets all the requirements. Therefore, the question of forming the quality of castings and developing or improving the technology of their production requires a comprehensive approach.

The object of research in the work is the production technology of casting «brake drum» from cast iron of the basic grade SCh20 according to GOST 1412-85 (DSTU EN 1561, EN-GJL-200). *The aim of research* is to improve the technological process of manufacturing the casting.

2. Materials and Methods

Melting was carried out by the duplex process «cupola furnace – electric arc furnace». Alloying was carried out with chromium and nickel, introduced with the charge into the cupola furnace in the composition of chromium-nickel cast iron with the ratio of elements Cr/Ni=2.2:1–2.4:1. In addition, Cu=(0.1–0.58) %, Ti=(0.041–0.095) % were added to the cast iron with titanium-copper cast iron in the composition of the charge, with an average ratio of Cu/Ti=4.264.

The operation of proving the chemical composition of chromium was carried out in an electric arc furnace by introducing FeCr100. The modification was carried out on the chute of the electric arc furnace during the discharge of the melt with ferrosilicon (FeSi75) at a temperature of about 1400 °C. The modifier was introduced in the amount of 0.3 % of the mass of liquid metal in fractions of 1–10 mm. Testing of tensile strength (σ_b, MPa) was carried out in accordance with DSTU EN 10002-1 (DSTU EN 10002-5). A detailed description of the technological process can be found in [16].

Single-use sand molds were made using molding shaking machines: the top half-forms – on a machine with additional pressing without shock absorption without turning the half-form (model 703M), the bottom half-forms – on a machine with additional pressing without shock absorption with turning the half-form (model 254M).

3D modeling was used to determine the final defects of filling the forms. The data of chemical analysis and determination of ultimate strength were processed by the methods of mathematical statistics by calculating sampling functions – the mathematical expectation of the content of the element (1) and the value of the mean square deviation (2):

$$\overline{X} = \frac{1}{N}\sum_{i=1}^{N} X_i, \quad (1)$$

$$S_X = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}\left(X_i - \overline{X}\right)^2}, \quad (2)$$

where X_i – the content of the element of the chemical composition, %, or σ_b, S_x – the mean square deviation of the content of the element of the chemical composition, or σ_b, N – the number of experimental points.

3. Research results and discussion

The brake drum with sprue system elements is presented in Fig. 1, the form technology is given in [17].

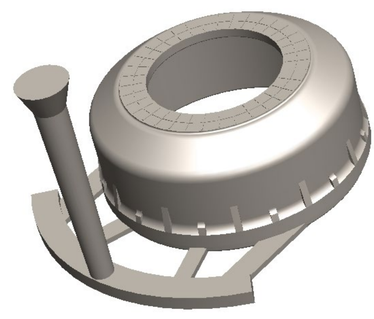

Fig. 1. Brake drum with sprue system elements

Fig. 2 presents the results of computer modeling demonstrating the formation of final shrinkage defects.

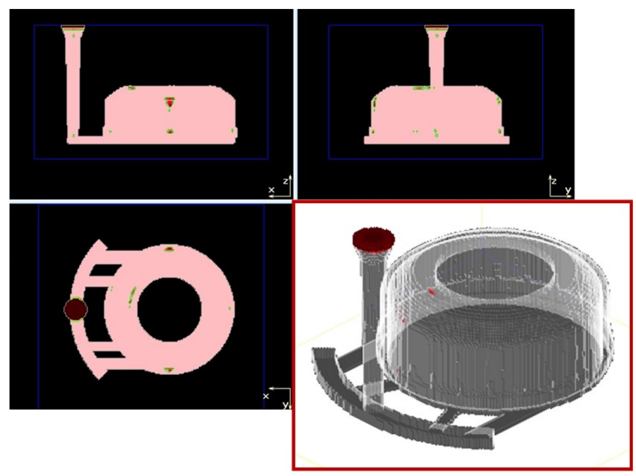

Fig. 2. Results of computer modeling of the formation of shrinkage defects

Fig. 2 shows that the final defects of the shrinkage character are localized in the upper part of the casting. To reduce the probability of the formation of a surface defect in the form of an open shell after removing the allowance, it is necessary to increase the size of the allowance. However, this will lead to an increase in the weight of the casting and an overrun of the alloy. To compensate for this deficiency, it is possible to reduce the amount of allowance on the remaining walls of the casting. This requires optimization of the assumption by the well-known method of dimensional chain analysis. The second version of the solution may be to make changes to the design of the casting by reducing the thickness of the remaining walls of the castings. But a decrease in the thickness of the casting wall will cause a decrease in strength characteristics. To prevent this, it is necessary to increase the strength limit of the alloy, striving to obtain a higher grade of cast iron. For this, it is necessary to correct the chemical composition of the alloy. For this, in particular, it is possible to use the well-known qualitative effect of the carbon content on the tensile strength of cast iron – with an increase in the amount of carbon in the alloy, the strength limit decreases. The possibility of such a solution follows directly from the condition [18]:

$$[\sigma_{b1}]S_1 = n[\sigma_{b1}]S_2 \to S_2 = \frac{S_1}{n}, \quad (3)$$

where n – the ratio of the strength limit of cast iron optimized by chemical composition ($[\sigma_{b2}]$, MPa) to the strength limit of typical cast iron by chemical composition ($[\sigma_{b1}]$, MPa), $n=[\sigma_{b2}]/[\sigma_{b1}]$, S_1, S_2 – working area cross sections of the wall of the base casting and the optimized design, respectively, m^2.

To check the possibility of such an effect on the alloy in order to increase the strength limit, 90 serial meltings were carried out, the results of which after statistical processing are shown in Fig. 3–5.

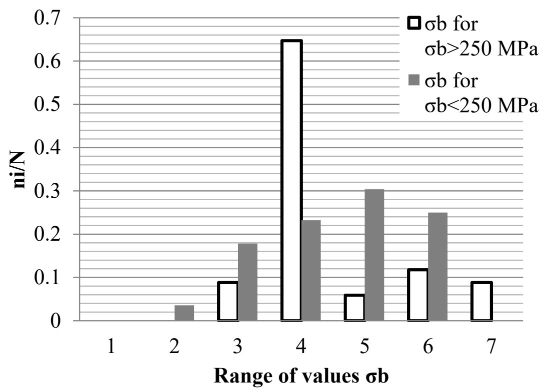

Fig. 3. σ_b distribution (values of sampling functions for $\sigma_b>250$ MPa: $N=34$, $\overline{X}=255$ MPa, $S_X=7.23$ MPa, values of sampling functions for $\sigma_b<250$ MPa: $N=56$, $\overline{X}=226$ MPa, $S_X=12.76$ MPa)

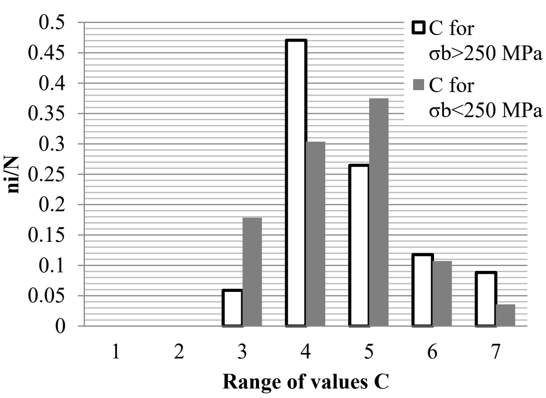

Fig. 4. Distribution of C, % (values of sampling functions for $\sigma_b>250$ MPa: $N=34$, $\overline{X}=3.398$ %, $S_X=0.08$ %, values of sampling functions for $\sigma_b<250$ MPa: $N=56$, $\overline{X}=3.448$ %, $S_X=0.096$ %)

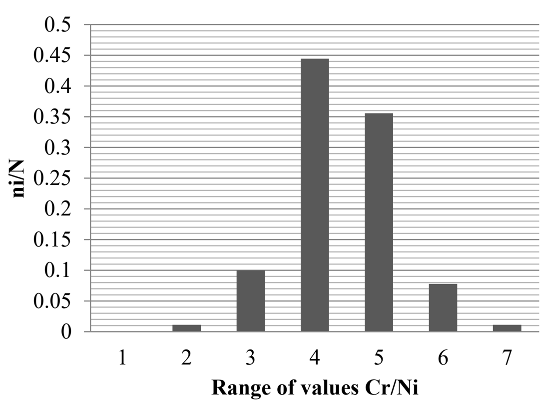

Fig. 5. Distribution of Cr/Ni ratio (values of sampling functions for $N=90$: $\overline{X}=2.034$, $S_X=0.337$)

From the obtained results shown in Fig. 3, 4, it follows that with a decrease in the average carbon content from 3.448 % to 3.398 %, the average value of σ_b increases from 226 MPa to 255 MPa, i. e. by approximately 11 %.

At the same time, the results of the distribution of the Cr/Ni ratio, based on a complete sample of data, testify to the distribution law of this value, which is close to normal (Fig. 5). That is, the obtained conclusions regarding the increase in the strength limit with a decrease in the carbon content apply to the case when the average ratio Cr/Ni$\approx$2, or with the greatest probability is in the range Cr/Ni$\approx$(1.7–2.7).

The result obtained in this way makes it possible to recommend, as an improvement in the technology of manufacturing cast brake drums, an increase in the allowance on the upper surface of the casting while simultaneously reducing the thickness of the remaining walls and adjusting the composition of the charge. The latter should be calculated in such a way as to ensure the average carbon content of C$\approx$3.4 % in cast iron.

The proposed solution, from the point of view of practical implementation, is limited to the fact that making changes to the design will lead to an increase in costs for the development of an improved technological process. In addition, certain difficulties may arise at the stage of changing the charge flow rates, with the additional difficulty of accurately obtaining the specified carbon content in the alloy for pouring. This will require switching to induction melting and using a clean charge.

The further development of the research may be the clarification of the influence of the chemical composition on the mechanical properties, taking into account the random nature of its production, as well as the modeling of the process of filling and crystallization of the melt in the mold based on the planning of the experiment. This will make it possible to obtain a mathematical model that connects structural and technological factors with the formation of final defects of a shrinking nature, and subsequent optimization of the tooling design or technological modes of casting production.

4. Conclusions

Computer modeling established that the final shrinkage defects in the casting of the brake drum, made by casting in disposable sand molds, are localized in the upper part of the casting. The elimination of this defect is possible by making changes to the design of the casting, which may include:
- increase in the allowance for mechanical processing on the corresponding surface of the casting;
- optimization of the assumption on the remaining surfaces of the casting;
- reduction of the thickness of the remaining walls of the casting;
- reduction of the carbon content in the alloy.

These recommendations are based on the obtained results, which showed the possibility of increasing the strength limit of cast iron by approximately 11 % due to the reduction of the average content of carbon in cast iron from 3.45 % to 3.4 %. Increasing the strength limit will make it possible to reduce the thickness of the casting walls, compensating for the increase in the allowance on the upper surface. This prevents an increase in the mass of the casting and an overrun of the alloy.

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The proposed solutions are the essence of the improvement of the technology of manufacturing cast brake drums, produced by casting in disposable sand molds.

Conflict of interest

The author declares that he has no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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Data availability

The manuscript has no associated data.

Use of artificial intelligence

The author confirms that he did not use artificial intelligence technologies when creating the current work.

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