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STUDYING THE PROPERTIES AND MICROSTRUCTURE OF PARTS OBTAINED BY DIFFERENT CASTING TECHNOLOGIES

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The paper presents some data of studying the microstructure, properties and surface quality of parts obtained in different modes. It is shown that in the case of quenching and tempering (QT) in the process of primary crystallization by vibration, in the future it becomes possible to replace QT with a simpler and cheaper method: normalization with accelerated air-water cooling. After this treatment, the steel structure is characterized by almost the same parameters as after QT. Tensile strength, hardness, average grain size are comparable with the performance of QT steels.

Keywords: casting, 30HGSNM steel, heat treating, mechanical properties, structure

INTRODUCTION

A significant part of mining equipment in the Republic of Kazakhstan is produced by casting. One of the most common casting methods remains the method in sand-clay molds (SCM). Despite serious disadvantages, this method is widely used, as it is affordable and cheap. However, if the use of SCM is justified when casting simple castings of carbon steels, then the use of SCM becomes unprofitable in manufacturing shaped castings of alloyed steels as it leads to a high percentage of scrap and metal waste.

To obtain high-quality shaped castings of alloyed steels, the investment casting method is often used [1, 2].

This method is quite expensive but it provides production of parts with high surface finish and degree of compliance with geometric dimensions. To obtain a high-quality structure of the part, various techniques are used, such as treatment by vibration, magnetic field, introduction of inoculants, and others [3-6].

Based on previous studies, the technology of producing shaped castings with a better structure was improved [7]. For the basic production method, the IC method was used, and to improve the quality of the structure and properties, the vibration treatment stage was introduced in the process of primary crystallization. After such treatment the microstructure of the part is characterized by a finer grain, a high degree of homogeneity, and, accordingly, higher mechanical properties.

In order to confirm the laboratory results, production tests of the proposed technology were carried out. Shaped castings were smelted of 30HGSNM steel using the IC method, the mass was 1,2 kg/pc. Shell molds with the melt were subjected to vibration at the frequency of 110 Hz within 5 minutes. After cooling, the castings were knocked out of the shells and subjected to normalization at the temperature of 920 °C with accelerated water-air cooling (sample No. 2). Microstructures, surface quality, some mechanical properties, and stress level were measured on the samples from experimental parts. As reference samples there were used castings obtained by the usual technology by the SCM method with subsequent quenching at 920 °C and high tempering at 500 °C (No. 1), and samples that were not subjected to vibration, normalized at 920 °C with accelerated air-water cooling (No. 3).

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EXPERIMENTAL STUDIES
Equipment and tools

The sections for metallographic analysis were made at the Struers sample preparation complex; etching was performed using A3 electrolyte within 25 sec. The analysis was performed on an Altami MET microscope at various magnifications using Thixomet Pro software. This software allows determining the average grain size, the integral and differential distribution of grain sizes, the grain area and other quantitative indicators of the structure. The analysis was carried out in no less than 10 fields of view. Based on the data obtained, the degree of the structure homogeneity was calculated by the formula:

$$g = \frac{d_{\min} \cdot S_1}{d_{\max} \cdot S_2}$$

where: d_{min} is the grain minimum diameter, mm; d_{max} id the grain maximum diameter, mm; S_1 is the share of the grain area with the minimum diameter; S_2 is the share of the grain area with the maximum diameter.

Table 1 **The results of metallographic analysis and testing mechanical properties**

Sample No.	Reference sample No. 1	Experimen-tal sample No. 2	Sample No. 3
Grain average diameter /mm	0,073	0,081	0,112
Rough-ness, Rz / µm	0,98	0,56	0,61
Deviati-on from the external size / mm	1,81	0,65	0,68
Tensile strength / MPa	436	423	285
Contamination index	1,7	1,2	1,82
Homoge-neity degree	0,44	0,7	0,78
Hardness / HV	362	355	230

Figure 1 shows the diagrams built according to the data of Table 1. For convenience, the indicators are reflected on one scale, which does not reduce the visibility of changing the indicators.

From the data in Table 1 and Figure 1 it is seen that the reference sample (No. 1) is inferior to the prototype (No. 2) in almost all the analyzed parameters. In the reference sample a greater deviation from the given size is almost 3 times; the contamination index is 30 % higher; the degree of roughness is 2 times higher, while the average grain size after heat treatment is almost the same (Figure 1a). As to mechanical properties, such as tensile strength and hardness, samples No. 1 and No. 2 differ slightly (Figure 1b).

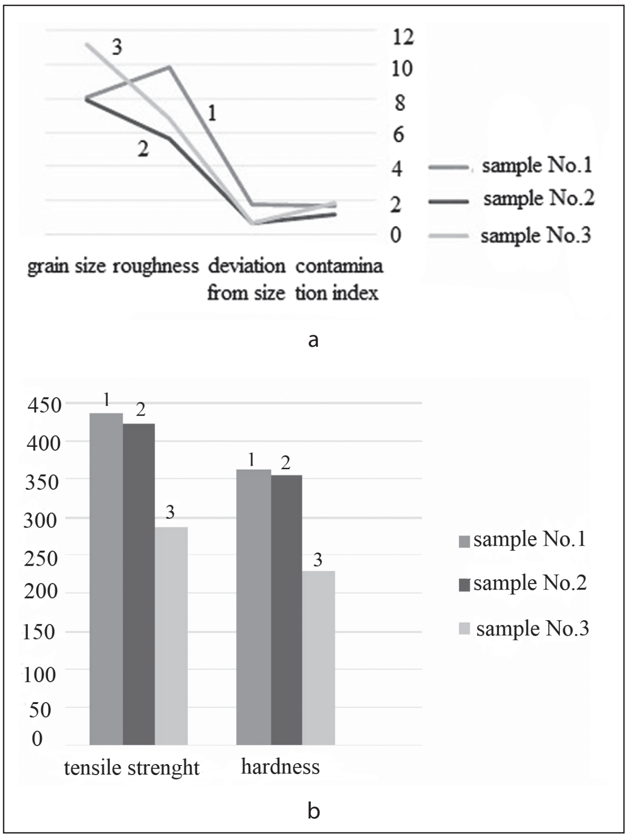

Figure 1 The results of testing the casting properties: a – surface quality and the data of metallographic analysis; b – mechanical properties

The results obtained suggest that the final structures of the samples under study, despite different heat treatments, have similarities, which explains a small difference in the mechanical properties. It is seen from Figure 2 that the microstructure of sample No. 1 and prototype No. 2 practically do not differ. In Figure 2a, the structure is represented by tempering sorbitol, and in Figure 2b a quasi-eutectoid-type ferrite-pearlite mixture.

In both cases, the structure is represented by a sorbitol-like mixture; the average grain size practically coincides [8]. The data obtained allow making the conclu-

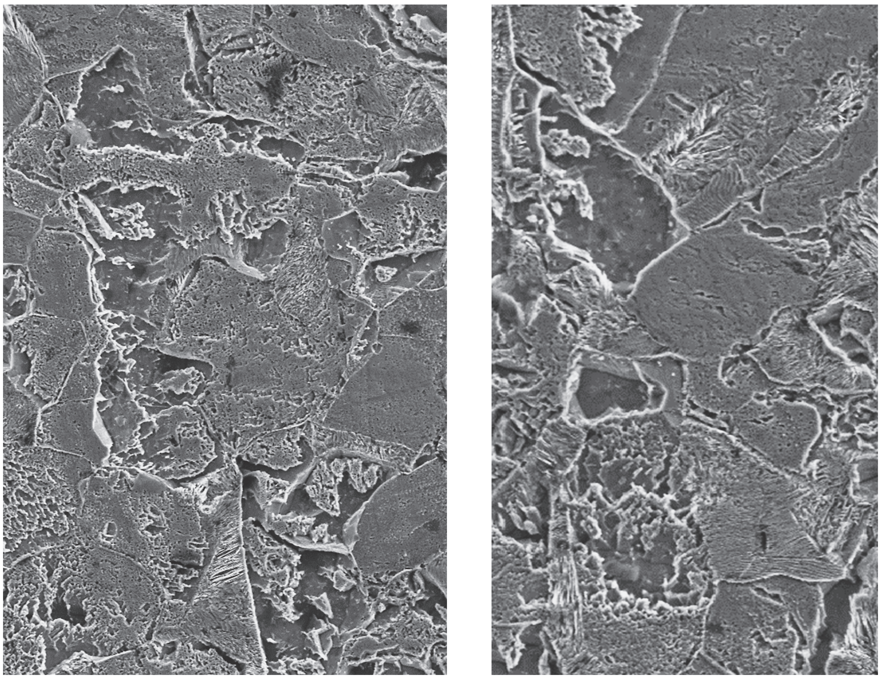

Figure 2 The microstructure of the samples made at the industrial site: a – sample No. 1; b – sample No. 2 (magnification × 1 500)

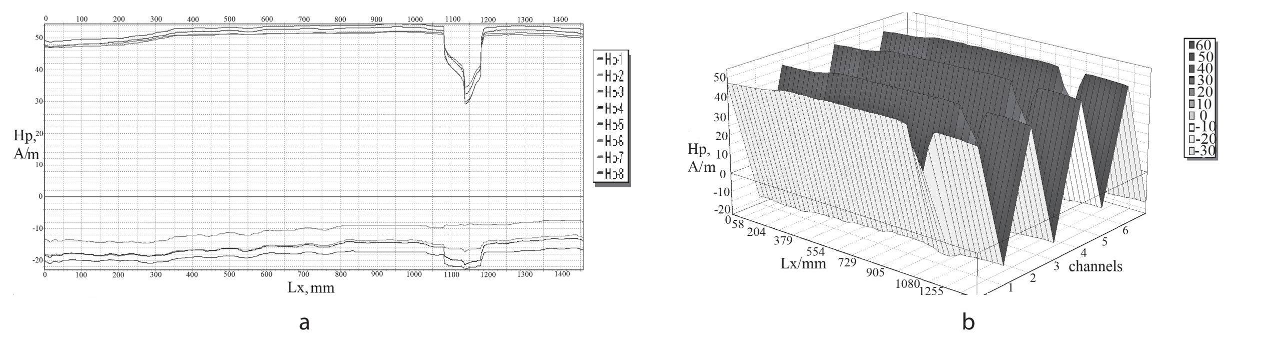

Figure 3 Magnetograms of the experimental sample (prototype): a – linear dependence of magnetization on the distance; b – magnetization dependence on the distance in 3D

sion that the use of normalization with accelerated cooling for a homogenized structure allows achieving almost the same level of mechanical properties as after double heat treatment, consisting of quenching and high tempering. It should be noted that despite a slightly higher level of mechanical properties of the reference sample (approximately 5 %), double heat treatment is required to achieve them, while a one-stage inexpensive normalization was used for the prototype.

A significant difference in other indicators is conditioned by the casting method. It is obvious that the IC method provides higher surface cleanliness and compliance with specified sizes.

In randomly selected samples from the batch of experimental castings (25 % of the total), the stress level in the casting was measured in order to detect hidden casting defects. For measurements, the IKN-7M-16 device was used. It allows judging by the shape of curves and surfaces of changes in magnetograms about the presence of internal defects [9]. Figure 3 shows a typical magnetogram of the prototype. The uniform nature of changing the dependence of magnetization on the edge of the surface (Figure 3a) indicates the absence of obvious casting defects (shells, porosity) in the body of the casting. The presence of a small extremum (at the depth of 130 mm from the surface) does not indicate the presence of a casting defect but rather changing the nature of the material under study, for example, the presence of a non-metallic inclusion. The uniform character of changing the magnetogram in 3D (Figure 3b) confirms this assumption, otherwise, the 3D image would also have a sharp response along the plane.

CONCLUSION

The results of studying the properties and microstructure of the samples show that the use of normalization with accelerated air-water cooling provides the same structure and level of tensile strength and hardness of 30HGSM steel as after heat treatment.

However, replacement of heat treatment with normalization is possible only if the structure is treated in the process of primary crystallization by vibration, otherwise such results are unattainable. Using the proposed technology allows for high accuracy and surface finish of the casting, which leads to significant metal savings.

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Note: Responsible for the English language is Natalya Drak, Karaganda, Kazakhstan