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STUDYING STRUCTURE AND PROPERTIES OF SHAPED INGOTS OBTAINED IN VARIOUS CONDITIONS OF CRYSTALLIZATION

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One way to produce shaped ingots with the minimum percentage of rejects is casting into sandy-resin (shell) molds (SRM). Various technologies are used to obtain SRM: the temperature impact, pressing, using various binders, etc. The factors listed lead to the improvement of some performance indicators, in particular, tensile strength and surface roughness, i.e. contribute to the quality of the ingot. This allows recommending to produce shaped ingots of white cast iron using sand and resin molds, while the quality and life time of the ingot compensates for some increase in the cost of the product.

Keywords: ingots, crystallization, sandy-clayey mold, microstructure, mechanical properties

INTRODUCTION

One of the main factors that affect obtaining a quality ingot is the conditions of crystallization and heat exchange. The quality of the ingot is understood as homogeneity of the composition and structure, provision of the required mechanical properties, absence of segregation, gas shells and porosity throughout the ingot body, a low index of nonmetallic inclusions pollution.

In the production of shaped ingots (castings), the achievement of specified requirements for ingots is largely determined by the composition of the mold and the way of its manufacturing, in this case it is the mold that determines the conditions for crystallization and heat exchange [1, 2].

In production practice the most common form of the mold is a sandy-clayey mold (SCM). it is easy to manufacture and cheap, which determines its wide use. However, forming the ingot in the SCM does not provide high metallurgical quality. The disadvantages of the ingots obtained in the SCM are presence of shells, high porosity, zonal and chemical liquation, a large number of nonmetallic inclusions [3-6].

One way to produce shaped ingots with the minimum percentage of rejects is casting into sandy-resin (shell) molds (SRM) [7-8]. Various technologies are used to obtain SRM: the temperature impact, pressing, using various binders, etc. The undoubted advantage of casting in the SRM for obtaining shaped ingots is improving heat exchange conditions, which leads to a positive structural change.

The purpose of this work is to carry out a comparative analysis of the properties and structure of shaped ingots obtained by pouring in the SCM and SRM.

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EXPERIMENTAL PART AND DISCUSSING THE RESULTS

Sand-clayey mold has been obtained on the press machine PF-4. Manufacturing a shell mold has been carried out on a modernized bunker-type molder at the temperature of 240 °C, pressure of 0.3 MPa, and pulverbakelite as the binder. As the material for ingots there has been used white cast iron IChH28, its chemical composition is given in Table 1. Cast iron IChH 28 is widely used for manufacturing parts of mining equipment operating under conditions of high abrasive wear.

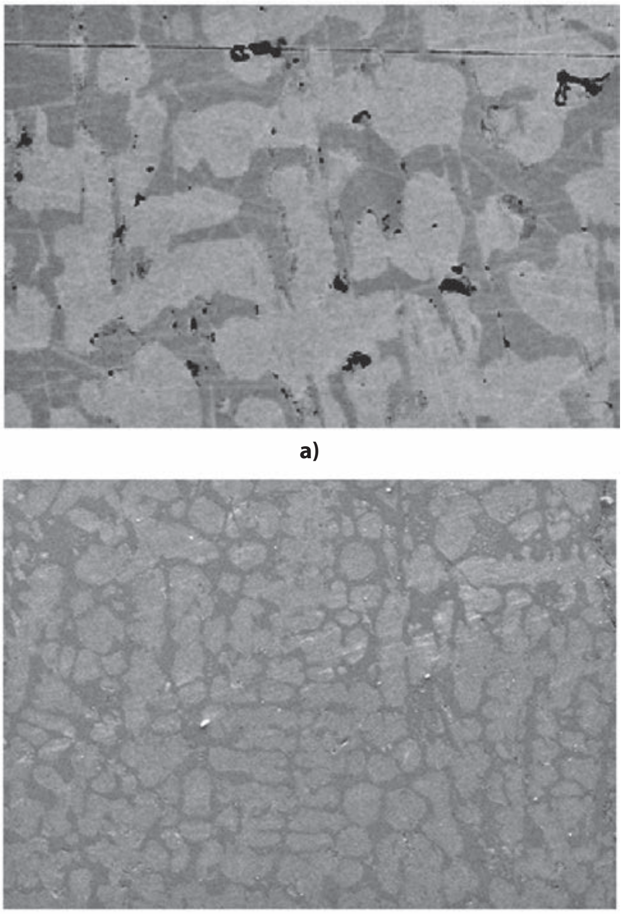
At 1 380 ^{0}C cast iron has been poured into two kinds of molds: the SCM and SRM. After complete cooling samples have been cut out from the resulting ingots for structural and property studies. Metallographic sections have been made on the Struers sample preparation complex, etching has been carried out using electrolyte A3 within 25 seconds. The analysis of the structure has been carried out in at least 10 fields of vision.

Table 1 **Chemical composition of cast iron of IChH28 grade / wt. %**

C	Mn	Si	Cr	S	P	Fe
2,5	0,7	1,2	26	No more than 0,1	No more than 0,5	rest

The microstructural analysis of the samples has shown (Figure 1) that in the ingot crystallized in the SCM the structure is represented by coarse colonies of alloyedledeburite and perlite, in addition, large pores and large nonmetallic inclusions are present in the structure of the SCM ingot (Figure 2). The presence of such large non-metallic inclusions (Figure 2b) in the SCM ingots is an expected factor because when pouring, there takes place a partial destruction of the mold.

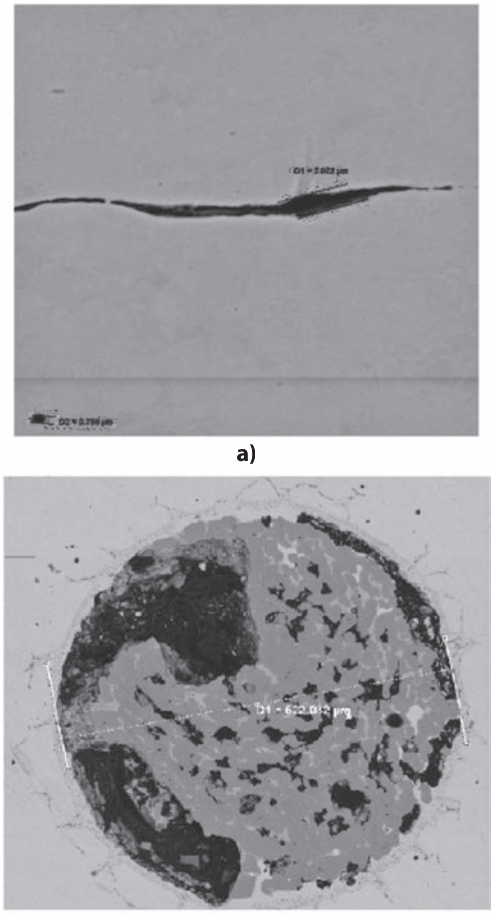
Comparison of the microstructures of the ingots obtained under different conditions of crystallization



a)

b)

Figure 1 Ingot microstructure: obtained in the SCM (a); obtained in the SRM (b) -500%



a)

b)

Figure 2 Ingot microstructure in the SCM: Pore sizes (a); nonmetallic inclusion sizes (b)

shows that with a similar structural composition in the SRM ingots there is formed a finer structure. Colonies of alloyed ledeburite and perlite are more dispersed, in addition there are no visible pores and nonmetallic inclusions.

More detailed metallographic studies have not been carried out at this stage, but it is obvious that even the initial analysis of the structure allows making a forecast regarding the higher properties of the SRM ingot. This is firstly associated with increasing strength characteristics due to increasing dispersion of the structure. But the main expected advantage of the SRM ingots is absence of fine porosity and segregation both in composition and in properties along the ingot body.

To determine fine porosity (pores with the radius less than 100 nm), the mercury porosimetry method has been used. Samples of ingots have been studied on the mercury porosimeter of the PASCAL 400 system, which allows detecting pores with the radius up to 2 nm. The results of the analysis are shown in Figure 3.

The program presented in Figure 3 shows that in the SRM ingot most of the pores are represented by pores in the range of 10,000 nm. In the ingot obtained in the SRM there are pores with the size from 0.759 μm to 2.02 μm (Figure 2a). It is obvious that presence of such large pores already determines the nature of the porous structure and it is not expedient to investigate fine porosity.

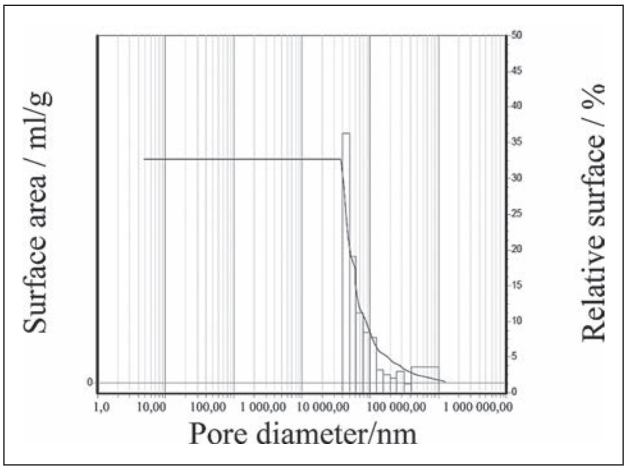


Figure 3 Pores distribution in the SRM ingot

Then the experimental samples have been subjected to tempering at 550 ^{0}C in water. Such heat treatment is very common for ingots of this grade because it allows reducing excessive hardness and removing internal stresses. After heat treatment some mechanical properties of the samples have been studied. Hardness has been determined on the WillsonVH1150 hardness tester, tensile strength has been determined at the Instron100 set.

Hardness has been studied at several points of the ingots. Studies have shown that hardness of the ingots crystallized in the SRM is practically unchanged throughout the ingot body, which indicates absence of dendritic and chemical segregation. Absence of segregation and more dispersed and homogeneous structure confirm the flow of laminar circulation of the liquid metal and zonal heat removal under the SRM conditions, which forms favorable conditions for crystallization. The results of hardness tests at different points of ingots are given in Table 2.

Table 2 **Ingots hardness / HB**

Ingot crystallization conditions	Hardnessmeasurementpoint			
	Surfaced periphery	Surface center	Periphery in the ingot depth	Center in the ingot depth
SRM	412	409	406	403
SCM	429	405	388	368

Comparison of the tensile strength (R_m) results has also shown a slight increase in strength of the ingots obtained in the SRM (Figure 4) compared to the same index of the SCM ingot. This fact is quite easy to explain if to compare the ingots microstructures: the greater dispersity of the ledeburite and perlite colonies uniquely leads to increasing hardness and strength.

When obtaining shaped ingots, the roughness of the surface is of great importance. For this purpose there have been made measurements of the surface roughness of both the mold and the ingot itself. The measurements have been carried out using the roughness measuring instrument TR 100. The data obtained are shown in Table 3.

Studies at various points have shown that the difference between the roughness of the mold and casting surfaces is 40 - 60 μm (Table 3), with a clear correlation: the higher the degree of roughness of the mold, the higher the degree of roughness of the ingot (Figure 5). Large roughness in the cavity of the gating system is due to the presence of slags in it.

Table 3 **Determining roughness at various points of the mold and the ingot**

Place of measurement	Mold roughness R_z / μm	Ingot roughness, R_z / μm
Along the ingot height on the lateral surface: 0 mm		
50 mm	73	125
100 mm	70	121
150 mm	68	116
200 mm	66	110
In the ingot center	65	97
In the casting cavity periphery	73	115
In the gating system cavity	71	136

CONCLUSION

The studies carried out have shown that different conditions of ingot crystallization in the SRM and SCM have a great impact on forming the structure and properties of shaped ingots made of white cast iron. A higher cooling rate under the conditions of the SRM leads to

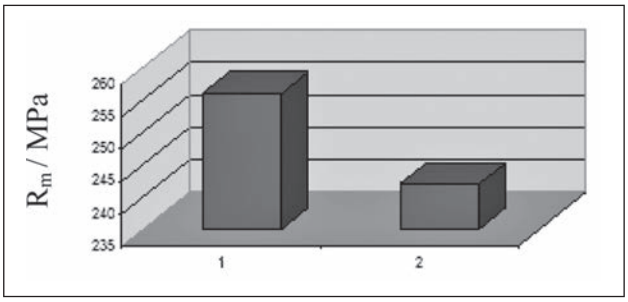


Figure 4 Histogram of tensile strength of the ingots obtained in different conditions: 1 – SRM, 2 – SCM

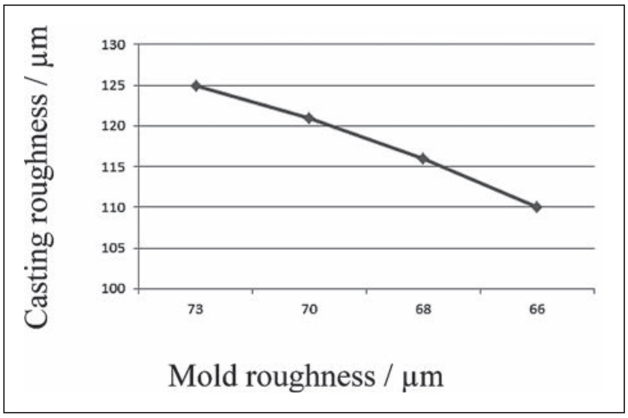


Figure 5 Dependence between the mold and the ingot surface roughness

forming finely dispersed colonies of alloyed ledeburite and perlite, to the absence of zonal and dendritic segregation. In addition, due to the peculiarities of the technology of obtaining the SRM, less nonmetallic inclusions are present in the liquid metal during the crystallization process and lower porosity is formed in comparison with the ingot obtained in the SCM.

The factors listed lead to the improvement of some performance indicators, in particular, tensile strength and surface roughness, i.e. contribute to the quality of the ingot. This allows recommending to produce shaped ingots of white cast iron using sand and resin molds, while the quality and life time of the ingot compensates for some increase in the cost of the product.

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REFERENCES

[1] L.Yu; W.Xudong; S.Yi Research on a new detection method of slab surface crack in mould during continuouscasting // Metallurgical Research &Technology 1 (2018) 108, 321-329

[2] B. Hiba; A. Farida; T. Delphine Thermomechanical behavior of resin bonded foundry sand cores during casting // Journal of Materials Processing Technology 246 (2017) 8, 30-41

[3] R. Lei; Z. Lifeng; W. Qiangqiang Measurements of surface velocity and level fluctuation in an actual continuous wide slabcastingmold // Metallurgical Research &Technology 1 (2018) 102, 282-287

[4] Kmita, A.; Fischer, C.;Hodor, K. Thermal decomposition of foundry resins: A determination of organic products by thermogravimetry-gas chromatography-mass spectrometry (TG-GC-MS) // Arabian Journal of Chemistry 11(2018) 3, 380-387.

[5] Kvon, Sv.S.; Kulikov, V.Yu.; Filippova, T.S.; Omarova, A.E. Using high-chromium iron as material for production of the equipping components of mine shafts // Metalurgija 55 (2016) 2, 206-208

[6] Kovalyov, P.V.; Ryaboshuk, S.V.; Issagulov, A.Z.; Kulikov, V.Yu.; Kvon, Sv.S.; Chsherbakova, Y.P.; Sultamurat G.I.; Jironkin, M.V. Improving production technology of tube steel grades in converter process // Metalurgija 55 (2016) 4, 715-718.

[7] Volkov, D., Volkov, A.D., Efimenko A.V. Casting into shell molds and its universality in small-scale and serial production//Foundryman of Russia (2016) 4, 26-30.

[8] Vertsyukh, S.S., Znamensky, L.G., Ivochkina, O.V. Technology of casting into shell ceramic fmolds with the use of aluminoborophosphate concentrate// Bulletin of South Ural State University. Series: Metallurgy 253 (2011) 36, 45-47

Note: The responsible for England language is Natalya Drak, Karaganda Kazakhstan