

STUDYING THE PROPERTIES OF SHELL MOLDS MANUFACTURED UNDER INDUSTRIAL CONDITIONS USING UNSTEADY-STATE PRESSURE

Received – Priljeno: 2020-03-12

Accepted – Prihvačeno: 2020-07-05

Preliminary Note – Prethodno priopćenje

The article deals with studying the properties of shell molds. A series of tests was carried out using ground broken chamotte bricks. The tests show that the most durable mold is obtained using the ratio of quartz sand and fireclay chips in approximately the same proportions. There were used different base pressures during shaping, the most rational was recognized 0,2 MPa. A field study showed an exponential dependence of density on base pressure. The pressure of 0,25 MPa allows obtaining dense molds that withstand transportation between workshops. The dependences of the sand density on forging pressure, bending strength on the applied static pressure, gas permeability of the sand-resin shell depending on the duration of the shaping, gas permeability of the mold on the sintering time and gas permeability of the mold on the sintering temperature are considered.

Keywords: casting, shell mold, sand-resin mixture, pressure, quality.

INTRODUCTION

One of the most important technological processes that determine the quality of castings is manufacturing a mold.

Sand-resin molds make it possible to produce high-quality castings with the minimum percentage of casting defects [1-4]. The disadvantage of such molds is a high cost of the binder: thermosetting resin of pulverbakelite [5-6]. The ongoing research is aimed at developing technological modes that reduce the amount of the binder used in the mixture due to using static pressure. This leads to decreasing the cost of the mold, and, consequently, the casting as a whole.

Using the proposed regulation of pressure and temperature will help to obtain the most optimal mold structure. This will subsequently make it possible to obtain high-precision castings with a homogeneous structure and low roughness due to equalization of the temperature fields over the entire volume of the hardened metal and outgassing through the shell [6-8].

However, the use of unsteady-state pressure will reduce the binder percentage, which will reduce the cost of the obtained castings.

This will improve the culture of producing castings in sand-resin molds, increase profitability of the foundries re-equipment.

RESEARCH METHODOLOGY

Earlier [7-9], the main technological parameters were determined during the shaping of sand-resin mixtures. After that, the hopper with the mixture was tipped over onto the match board heated to 230 °C with radiator models. At this, pressure of 0,25 MPa was supplied through the board. After 10 - 12 seconds, pressure was increased to 0,35 MPa. 10 - 12 seconds later, pressure was reduced to 0,2 MPa. At this there was shaped a shell mold 12 - 15 mm thick. After this, the molds were sintered within 2 minutes at the temperature of 320 - 340 °C. There was selected the composition of the mixture, defined the main and auxiliary components of the mixture and their concentration.

The optimal composition of the sand - resin mixture is as follows: 1K0315 quartz sand 70 %; 1K02 quartz sand 30 %; pulverbakelite SF - 011A 4,5 (over 100 %); kerosene 0,2 - 0,4 (over 100 %); white spirit 2 - 3 % (over 100 %); boric acid 0 - 0,2 % (over 100 %).

In the conditions of the Parkhomenko KMZ LLP foundry (Karaganda, Kazakhstan) a batch of shell molds was made according to the developed technology, 35L steel was poured into the molds obtained to produce castings. The resulting molds and castings were studied to evaluate their properties and differences in performance from the molds and castings obtained in laboratory conditions.

A series of tests was also carried out using ground broken fireclay bricks (Table 1). In practice in production conditions, a significant amount of used fireclay bricks is often formed that is used for lining furnaces and ladles. Fireclay bricks were ground in a mill to the

V. Yu. Kulikov, Sv. S. Kvon, M. K. Ibatov, Ye. P. Chsherbakova, D. A. Issagulova, A. M. Dostayeva (e-mail: sherbakova_1984@mail.ru, KSTU), Karaganda State Technical University, Karaganda, Kazakhstan

Table 1 Results of testing shell molds samples with chamotte additive

| Composition | Puverbakelite / % | Chamotte / % | Grade 1K315A sand / % | Pressure / MPa | Gas permeability / (hole diameter) | | Compressive strength / MPa |
|-------------|-------------------|--------------|-----------------------|----------------|------------------------------------|-----|----------------------------|
| | | | | | 1,5 | 0,5 | |
| | 5 | 95 | 0 | 0 | 200 | 34 | 0,36 |
| | 5 | 95 | 0 | 0,2 | 145 | 36 | 2,2 |
| | 5 | 95 | 0 | 0,3 | 54 | 69 | 2,8 |
| | 5 | 45 | 50 | 0 | 75 | 62 | 5,36 |
| | 5 | 45 | 50 | 0,2 | 81 | 50 | 12,99 |
| | 5 | 45 | 50 | 0,3 | 80 | 45 | 7,06 |
| | 5 | 0 | 95 | 0 | 166 | 62 | 1,14 |
| | 5 | 0 | 95 | 0,2 | 81 | 57 | 7,45 |
| | 5 | 0 | 95 | 0,3 | 69 | 37 | 6,27 |

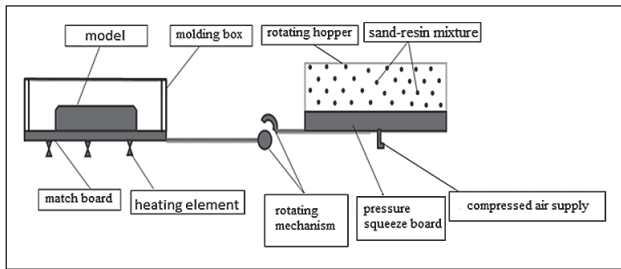


Figure 1 Diagram of the 51713 model molding machine

fraction of 0,1 - 0,2 mm. The tests show that the most durable mold is obtained using the ratio of quartz sand and fireclay chips in approximately the same proportions. It is obvious that it is caused by the most dense packing of the filler particles. There were also used different base pressures during shaping, the most rational was recognized 0,2 MPa. It should be noted that the use of only fireclay without pressure does not allow obtaining the mold strength. The use of pressure in the process of shaping the mold increases its strength several times, which indicates good compactibility of fireclay chips.

Tests in service at the Parkhomenko KMZ LLP were carried out using a semi-automatic molding machine of the 51713 model. The diagram of the molding machine of the 51713 model is presented in Figure 1.

EXPERIMENTAL STUDIES

Equipment and tools

Figure 2 shows the dependence of the molding sand density on pressure. A field study showed an exponential dependence of density on base pressure. Pressure of 0,25 MPa allows obtaining dense molds that can withstand transportation between workshops (for example, when moving from the molding section to the mold pouring section).

Figure 3 shows the dependence of bending strength on the applied static pressure on the mixture. The experiments show that in industrial conditions, as well as in laboratory conditions, at 0,25 - 0,3 MPa the greatest bending strength is obtained, further pressure increase does not give a significant intensity increase in strength.

Figures 4 - 5 show the studies of various factors effect on gas permeability. It was determined that the tem-

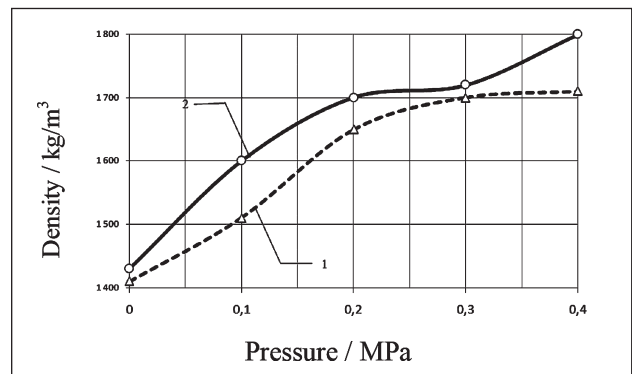


Figure 2 Molding sand density dependence on forging pressure: 1 – in laboratory conditions, 2 – in industrial conditions

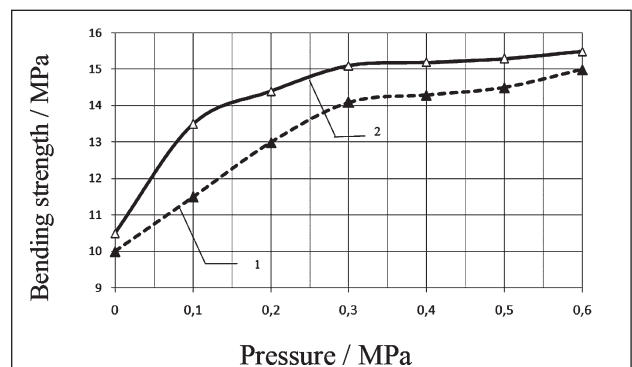


Figure 3 Bending strength dependence on applied static pressure on the mixture: 1 – in laboratory conditions, 2 – in industrial conditions

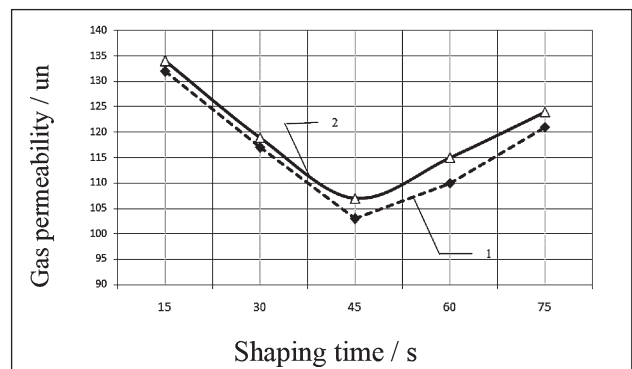


Figure 4 Sand-resin shell gas permeability depending on the shaping duration: 1 – in laboratory conditions, 2 – in industrial conditions

Table 2 Results of testing friability of a shell mold

| Pressure, MPa | Temperature, °C | | Friability / % |
|---|-----------------|-----------|----------------|
| | Shaping | Sintering | |
| $P_1 = 0,25,$ $P_2 = 0,$ $P_3 = 0$ | 250 | 350 | 4,9 |
| $P_1 = 0,25,$ $P_2 = 0,35,$ $P_3 = 0$ | 250 | 350 | 3,8 |
| $P_1 = 0,25,$ $P_2 = 0,35,$ $P_3 = 0,2$ | 250 | 350 | 1,2 |
| $P_1 = 0,25,$ $P_2 = 0,35,$ $P_3 = 0,2$ | 200 | 350 | 3,7 |
| $P_1 = 0,25,$ $P_2 = 0,35,$ $P_3 = 0,2$ | 300 | 350 | 4,1 |
| $P_1 = 0,25,$ $P_2 = 0,35,$ $P_3 = 0,2$ | 250 | 250 | 3,7 |
| $P_1 = 0,25,$ $P_2 = 0,35,$ $P_3 = 0,2$ | 250 | 450 | 4,2 |

perature of 330 - 350 °C with the sintering duration of 85 - 100 s allows obtaining shells with the best gas permeability.

An important indicator for the mold is friability. It was determined on the model 02212 (GOST 23409,9 - 78) device for determining friability of molding and core mixtures. The samples were pre-weighed, then loaded into the center of the drum of the machine, which was rotated within 60 seconds. The sample was recovered and weighed again. The test results of the samples obtained under various technological conditions are presented in Table 2.

Another important technological parameter of manufacturing castings is the pouring temperature. It is known that it should be in a strict range, since a low temperature leads to underfilling, junctions and increased porosity due to the fact that gases do not have time to leave the metal, and a high temperature also leads to casting defects and causes increased gas formation when interacting with the mold. In addition, there can occur clogging of the casting body by the mold components when these *particles* are washed away by the liquid metal stream. It was necessary to consider these factors in terms of the mold quality in practice. Measuring the metal temperature in the Parkhomenko KMZ LLP foundry was carried out using a Tn - A 212nT - 12 - 1250 Thermoconverter. Smelting of grade Sch20 cast iron was carried out in the ASF - 0,5. Pore processing was carried out using microstructural images of castings samples using the Thixomet Pro software (Russia). The results are presented in Table 3.

It is obvious that the temperature of pouring the given alloy into shell molds obtained using unsteady - state pressure is 1320 - 1340 °C. Figure 6 shows the com-

Table 3 «Cover» casting samples porosity obtained at different pouring temperatures

| No. | Pouring temperature / °C | Pores presence / % | Pores nature |
|-----|--------------------------|--------------------|--------------|
| 1 | 1300 | 7 | Fine |
| 2 | 1320 | 3 | Fine |
| 3 | 1340 | 4 | Fine |
| 4 | 1360 | 7 | Medium |
| 5 | 1380 | 11 | Large |

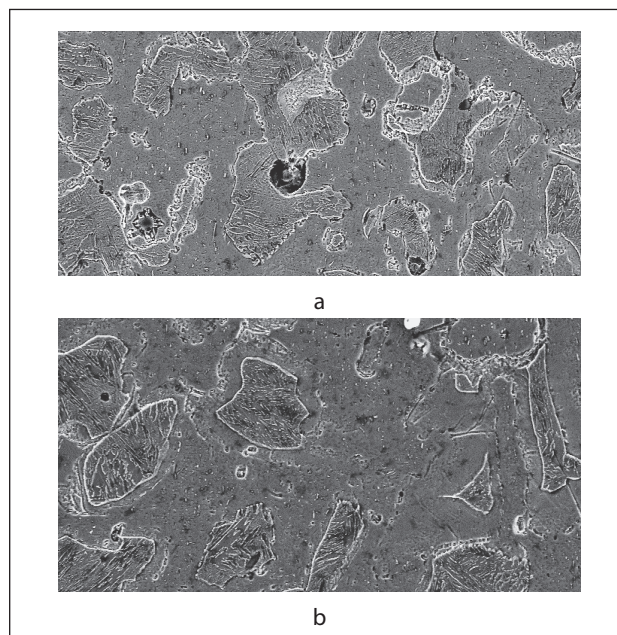


Figure 5 Casting samples structure obtained at different pouring temperatures: a - 1380 °C; b - 1320 °C

parison of the castings structure shaped at different pouring temperatures.

In Figure 5, a few pores are visible, including large ones, in Figure 5, b only a few micropores are visible in the area. At this, the area of the compared samples is the same.

CONCLUSION

The tests carried out confirm the effectiveness of the proposed method of manufacturing shell molds and indicate the feasibility of using a profile board.

It is shown that under industrial conditions, the best mechanical (strength) and technological (gas permeability) properties of the shell form are achieved using a base pressure of 0,2 MPa with a subsequent increase to 0,35 MPa. In this case, the formation time is 45 s. The sintering temperature of the shell is advisable in the range of 330 - 340 °C for 90 s.

The smallest porosity of castings from cast iron of the Sch 20 brand when casting into shell molds takes place when casting at a temperature of 1 320 - 1 340 °C. Porosity with this technological mode is 3 - 4 %.

The proposed method of using two - stage unsteady - state pressing increases the shell molds strength.

Acknowledgments

These studies were carried out in the framework of the Science Committee of the Ministry of Education and Science of the Republic of Kazakhstan grant AR05130026 «Development and implementation of producing sand-resin molds under unsteady -state pressure in order to improve the finished products quality».

REFERENCES

- [1] 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
- [2] 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
- [3] Ren, Lei; Zhang, Lifeng; Wang, Qiangqiang Measurements of surface velocity and level fluctuation in an actual continuous wide slab casting mold // *Metallurgical research & technology* 1(2018)102, 132-135
- [4] Liu, Yu; Wang, Xudong; Sun, Yi Research on a new detection method of slab surface crack in mold during continuous casting // *Metallurgical research & technology* 1(2018)108, 100-103
- [5] Bargaoui, Hiba; Azzouz, Farida; Thibault, Delphine Thermomechanical behavior of resin bonded foundry sand cores during casting // *Journal of materials processing technology* 246(2017)8, 30-41
- [6] Volkov D., Volkov A., Efimenko V. Contradictiones conprimis, testa sua mobilitate, et est in figura commercialis productio et parva-scale // *aliquet pretium Russian* 4(2016), 26-30
- [7] 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
- [8] Usenko R. V., Mazorchuk V. F. Repyakh S. I. In robore supporting sintering filler testam pertusura cribri remanebit // *Liteynoye proizvodstvo* // 12(2016), 16-18
- [9] R. Lei; Z. Lifeng; W. Qiangqiang Measurements of surface velocity and level fluctuation in an actual continuous wide slabcasting mold // *Metallurgical Research & Technology* 1 (2018) 102, 282-287
- [10] Zymankowska-Kumon, S. Determination of Content of Phenol in Foundry Resins by Pyrolysis Gas Chromatography-Mass Spectrometry Method // *Archives of foundry engineering*, 18 (2018)4, 83-86
- [11] Diaz Pace, D. M.; Miguel, R. E.; Di Rocco, H. O. Quantitative analysis of metals in waste foundry sands by calibration free-laser induced breakdown spectroscopy // *Spectrochimica acta part B-atomic spectroscopy*, 131 (2017)5, 58-65
- [12] L. Yu; W. Xudong; S. Yi Research on a new detection method of slab surface crack in mold during continuous casting // *Metallurgical Research & Technology*, 1 (2018) 108, 321-329
- [13] Kvon S. S., Kulikov V.Y., Issagulov A. Z., Dostayeva A. M., Kovalyova T. V. Studying structure and properties of shaped ingots obtained in various conditions of crystallization // *Metalurgija* 57(2018)4, 313-316
- [14] Kulikov V. Y., Issagulov A. Z., Ibatov M. K., Kvon S. S., Kovalyova T.V. Shell forming mode effect on casting quality // *Metalurgija* 58(2019)3-4, 295-298

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