V. YU. KULIKOV, A. Z. ISSAGULOV, M. K. IBATOV, YE. P. SHCHERBAKOVA, T. V.KOVALEVA ISSN 0543-5846
METABK 58(3-4) 295-298 (2019)
UDC – UDK 621.74:621.744.74.04:620.179.6:620.16: 66.063=111

SHELL FORMING MODE EFFECT ON CASTING QUALITY

Received – Primljeno: 2019-01-14
Accepted – Prihvaćeno: 2019-03-30
Preliminary Note – Prethodno priopćenje

The paper deals with the influence of shell forming modes on some parameters of castings: the surface and internal defects. The degree of roughness and stress concentration were determined on the castings obtained under production conditions. According to the result, it was found that the use of variable pressure in the formation of the shell ensures the purity of the casting and the reduction of the stress level in the casting.

Key words: casting, sand-resin mold, roughness, concentration of stresses, homogeneity.

INTRODUCTION

One of the most promising methods of manufacturing precision castings is sand-resin mold (SRM) casting. This method allows obtaining very accurate in geometric dimensions castings with a low degree of roughness. When the sand-resin mixture is heated, the resin (pulverbakelite) at the temperature of about 130 °C graduates into the liquid state; as the temperature rises above 200 °C, the resin becomes irreversible, i.e. it changes its aggregation state. This property of resin allows forming a thin, sufficiently strong and at the same time pliable shell that ultimately ensures a high quality of the casting surface and the absence of internal defects.

One of the potentials for the development of the SRM method is a simultaneous effect of two external factors: temperature and pressure.

A number of studies have been carried out to study the effect of variable pressure in the molding process on the casting quality [1-8]. It should be noted that the range of the proposed pressure changes, as well as the base one, varies widely: from vacuum to several atmospheres.

This work deals with studying the effect of the base and variable pressure on the quality of the casting surface and the presence of internal defects. The technological process of shell formation (SRM) is as follows. The base pressure is applied to the model plate with the prepared sand-resin mixture. In work [2] it is noted that the optimal range of the base pressure during shell formation is the range of 0,15 - 0,35 MPa. This helps to remove the excess air from the mixture and to increase the number of contacts between particles of sand and resin, which leads to increasing heat transfer. During the formation of a layer with the liquid resin directly at the surface of the model, it is advisable to increase pressure. In work [3] it is shown that in this case a closer contact between the grains of sand occurs, resin is distributed more evenly throughout the forming shell, it completely envelops sand particles (cladding). After the layer of crust hardens near the surface of the model, the pressure should be reduced again in order to avoid squeezing the sand out of the already formed shell and its destruction.

EXPERIMENTAL STUDIES

Equipment and tools

Shell molds were made on the set for manufacturing shell molds at the Parkhomenko KMZ LLP (Karaganda). The composition of the mixture for manufacturing the shell was as follows, wt.%: pulverbakelite 4,5% (in excess of 100 %); sand fraction 1K02A 70 %; fraction 1K016A 30%; kerosene 0,2 % (in excess of 100 %), white spirit 2 % (in excess of 100 %). The shells were manufactured in different modes: at the first stage only the base pressure was varied from 0,15 to 0,35 MPa according to the recommendations of work [2]. Steel 35L was poured into the resulting shells. As an indicator of the casting quality at that stage only the degree of the casting roughness was determined. The degree of roughness was determined using a TR-220 instrument (Figure 1). It is known [9 - 10] that the accuracy of castings made into shell molds corresponds to the accuracy of 11-16 qualifications (CMEA ST 144-75). Such a high degree of purity of the casting surface is achieved primarily due to a high surface quality of the shell and a correct temperature mode of the casting [11 - 15].

Figure 2 shows the dependence of the casting roughness degree on the base pressure at which the shell was formed.

From the above dependence it can be seen that the most optimal is the base pressure of 0,25 MPa. A lower value of the pressure reduces the mold strength, which

V. Yu. Kulikov, A. Z. Issagulov, M. K. Ibatov, Ye. P. Shcherbakova, T. V. Kovaleva (e-mail: sanya_kazah@mail.ru, KSTU), Karaganda State Technical University, Karaganda, Kazakhstan.

Figure 1 Instrument TR-220 for measuring roughness

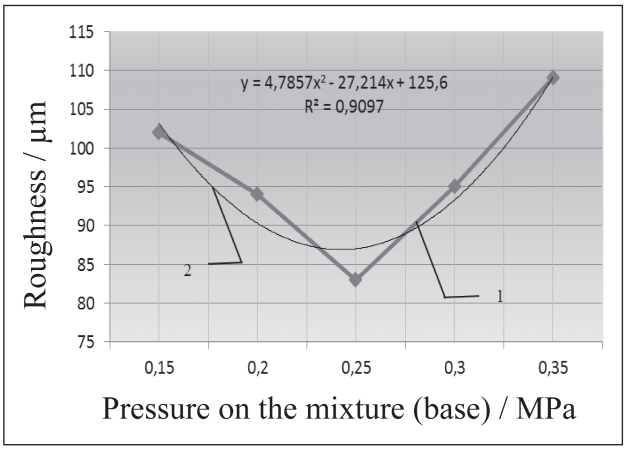

Figure 2 Dependence of the casting roughness on the base pressure of shell mold forming (1 – theory; 2 – experiment)

leads to its partial "shedding" and, thereby, increases the surface roughness. Large values of the base pressure lead to the extrusion of individual particles of sand, which also leads to deterioration of the surface quality.

At the second stage of the experiment, the effect of the pressure variability during shell formation on the casting roughness was considered. In this case, the base pressure was 0,25 MPa according to the results obtained (Figure 2). The change in pressure occurred 10 - 12 seconds after the start of the forming process, the total time of forming was 35 seconds. Steel 35L was poured into the casings produced in different modes; in the castings obtained in different shells the degree of surface roughness was also determined (Table 1).

It can be seen from the Table that the highest surface roughness is observed in casting No. 2. The shell of this casting was formed under the following mode: base pressure was 0,25 MPa, after 10 seconds the pressure was increased by 0,1 MPa, then the pressure dropped to 0,2 MPa with the total molding time 35 sec. The use of variable pressure in the process of shell formation in any case contributes to increasing the surface roughness of the shell itself and the casting crystallizing in it. The resulting shell surface is the most even, since the immersion of the surface layer of sand reaches the edge of the molten resin, thereby forming smooth surface areas.

Table 1 **Roughness of the castings obtained in shells with different forming modes (base pressure = 0,25 MPa)**

Specimen number	Pressure on the mixture (relative to the base one) / MPa	Casting roughness / µm
0	Base pressure = 0,25 + 0;- 0;	125
1	*+ 0,20; - 0,05*	99
2	*+ 0,10; - 0,15*	86
3	- 0,20; + 0,05	115
4	- 0,10; + 0,15	110

In addition to the degree of roughness of the casting surface, the stress level of the casting was also controlled. It is known [9] that stresses represent a great danger in the initial period of crystallization. The nature of the resulting stresses can be caused by several reasons. Firstly, it is the difference in the volumes of the melt and the crystallizing solid phase; secondly, it is the difference in the volumes of various phases formed in the process of crystallization as a result of phase transformations (for example, austenite - ferrite); thirdly, it is the presence of formed defects: porosity, gas inclusions, segregation of impurities, etc. Total stresses can lead to hot cracks in castings. The first two factors are objective and, if the process of filling and cooling is properly carried out, they form the background stress mode; the third factor leads to abnormal deviations from the background mode. Thus, the level of stress indirectly suggests the presence of these defects in the body of the casting.

Stresses in the castings were determined using stress concentration meter TSC-3M-12 (Figure 3). The meter allows determining, recording and processing the diagnostic data of the stress-strain state of metals and alloys using the metal magnetic memory method (MMM). Determining the stress concentration zones in samples was carried out using a specialized fluxgate magnetometer TSC-3M-12 with 12 measurement channels and a 1-8M type scanning device using magnetometric diagnostics based on measuring the magnitude of the intrinsic magnetic field of a metal sample and identifying abnormal magnetic field zones associated with defective metal sites. By the method of magnetic metal memory (MMM) stress concentration zones, the structural changes in the metal, surface and subsurface defects are determined by the magnitude and nature of changing the magnetic scattering field Hp measured by the device above the surface of the monitored objects.

The data processing was performed using MMM-System, version 3.0.

The common signs of the stress concentration (SC) zones are:

- alternating distribution of the magnetic field in all the channels simultaneously;
- multiple changing the sign of the magnetic scattering field H in all the channels simultaneously at the distance of less than two wall thicknesses;
- a sharp heteropolar distribution of the Hp field across the channels or a sharp surge in one of the channels;
- spasmodic (possibly without a sign change) distribution of the Hp field with the maximum gradient dH / dx *

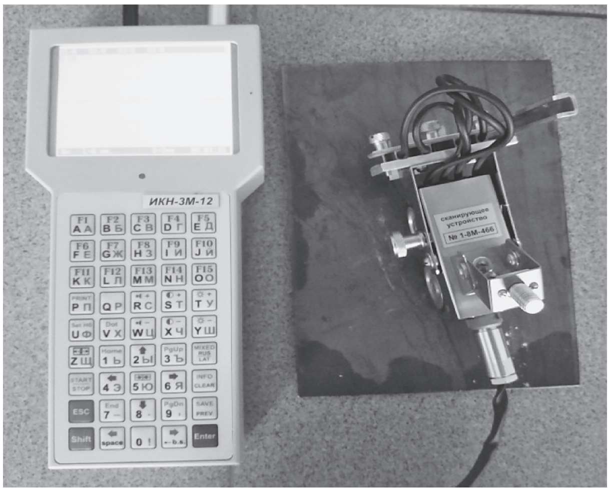

Figure 3 Instrument IKN-3M-12 for measuring stress concentrations

The stress level was determined in the “Coupling” castings (35L steel) made in shell molds obtained only with the use of thermal impact (Figure 4) and with the simultaneous thermal and static impact (Figure 5).

To estimate the intensity, we used the *H*p field measurement simultaneously over 8 channels, the values of which, as well as the gradients, are shown on the magnetic record in different colors:

H_p is the intensity of the magnetic scattering field, A/m

dH / dx is the magnetic field gradient, (A / m) / mm

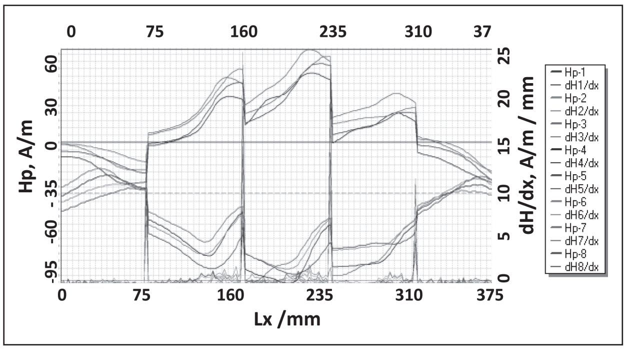

Figure 4 Stress distribution on the “Coupling” casting surface from the periphery to the center (the shell mold was obtained with the use of only thermal impact)

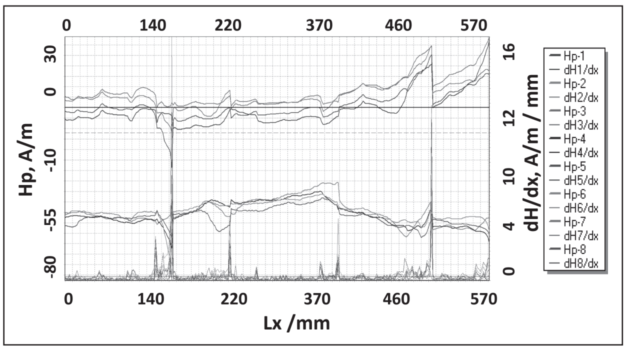

Figure 5 Stress distribution on the “Coupling” casting surface from the periphery to the center (the shell mold was obtained with the simultaneous use of thermal and static impact)

Lx is the length of the registered sensor displacement / mm

It can be seen from diagrams that the concentration of stresses in the second case is more uniform and does not have such a pronounced growth towards the center of the casting. This is obviously due to the greater compliance of the mold made with unsteady pressure. As it was noted above, when using increased pressure at the moment of the resin liquid state, the sand particles are uniformly covered with resin. At the same time, the entire mold becomes more pliable, which ultimately gives the metal free shrinkage. In the first case tensile stresses reach 65 A/m. In the second specimen the maximum stress is 30 A/m.

A three-dimensional magnetic record of the specimen was also examined (Figure 6). The distribution of the magnetic field H_p of the specimen is mainly uniform, there are small negative anomalies with the amplitude of up to 60 A/m. The absence of obvious anomalies from the background mode indicates the absence of internal defects in the casting body.

The maximum indicator of the magnetic field strength H_p is about 45 A/m, the intensity of the field change along the length *dH/dx* is within 10 (A/m)/mm.

The structure of the ingot obtained by casting in a shell mold made according to the proposed technology

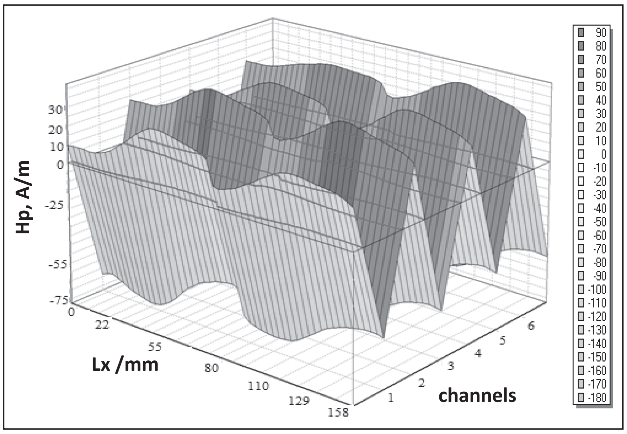

Figure 6 Three-dimensional plot of distribution of the normal component of the magnetic field strength H_p

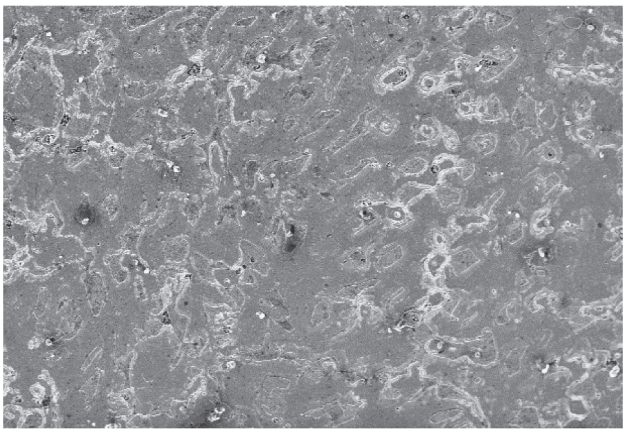

Figure 7 The structure of the ingot obtained by casting into a shell mold, × 500

is characterized with homogeneity and fine grain, so, mechanical and operational properties of the casting increase (figure 7).

CONCLUSION

The studies carried out have shown that the use of variable pressure in forming of a sand-resin shell mold allows obtaining a shell that provides a high degree of the casting purity and reducing the level of stress in the casting due to the greater flexibility of the mold. That provides free shrinkage of the metal during crystallization and, thereby, helps to avoid internal defects. The recommended mode of manufacturing shell molds is as follows: the base pressure is 0, 25 MPa; the pressure increase within 10 - 12 seconds to 0, 35 MPa, then the pressure decrease to 0,2 MPa; the total shell formation time is 35 sec. The holding temperature of the model plate is 230 °C, the sintering temperature is 320 - 340 °C within 2 minutes. As a result of the proposed technological regime there is formed a 10 - 12 mm thick shell providing the degree of the casting roughness of 86 microns, which corresponds to 14 quality class.

The studies were carried out within the framework of implementing the grant of the Committee of Science of the RK MES AP05130026 «Developing and implementing production of sand-resin molds under unsteady pressure with the aim of improving the quality of the finished product»

REFERENCES

[1] Issagulov, A., Kulikov, V., Issagulova, D. Developing technological process of obtaining giality casts, Metalurgija 53 (2014)4, 601-604.

[2] Issagulov, A.Z.; Kulikov, V.Yu.; Chsherbakova, Y.P. Kovaleva, T.V.; Kvon, Sv.S. The corrosion resistant coating with halloysite nanoparticles, Metalurgija 55 (2016)3, 426-428.

[3] Issagulov, A.Z.; Kvon, Sv.S.; Kulikov, V.Y. Studying microstructure of heat resistant steel deoxidized by barium ferrosilicon, Metalurgija 55(2016)3, 388-390.

[4] Illarionov, I.E., Pestrikov, V.F., Strelnikov, I.A., Gartfelder, V.A., Korolev, A.V. Special types of casting, Cheboksary, 2015, 120.

[5] Volkov D., Volkov A.D., Efimenko A.V. Shell casting and its versatility in small-scale and serial production, Liteisch Rossii (201)4, 26-30.

[6] Melnikov A.P., Kukui D.M. Modern trends in the development of technology in the foundry industry, Casting and metallurgy. 47(2008)3, 65-80.

[7] Ozerova E.S., Savokhina OM, Morozov V.V., Kutsyy O.Ya. Features of the design of synthesized furan forms, Foundry production (2015)11, 8-10.

[8] Smolko V.A., Antoshkina EG, Smolko V.V. Exergy of casting molds and cores from synthetic mixtures, Uchenye zapiski Komsomolsk-on-Amur State Technical University 20(2014), 70-73.

[9] Issagulov, A.Z., Kulikov, V.Yu., Yeremin, E.N., Kovalyova, T.V., Shcherbakova, Ye.P. Pressure effect on the strength of shell molds, Foundry (2017) 5, 23-25.

[10] Kulikov, V.Yu., Kvon, S.S., Kovaleva, T.V., Yeremin, E.N. Studies of the influence of pressing modes on the parameters of the porous structure of the form, Russian Founder (2018) 8, 9-14.

[11] 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.

[12] 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 5 (2017) 131, 58-65.

[13] Liu, Hong; Gao, Yang; Ding, Shaohu Research on the effect of the waveform on the droplet injection behavior of a piezoelectric printhead and the forming accuracy of casting sand molds, International journal of advanced manufacturing technology 100(2019)1-251-261.

[14] Wang, Guangjun; Wan, Shibin; Chen, Hong Fuzzy Identification of the Time- and Space-Dependent Internal Surface Heat Flux of Slab Continuous Casting Mold, Journal of heat transfer-transactions of the ASME 140 (2018)12.

[15] Elamami, Hamid Ali; Incesu, Alper; Korgiopoulos, Konstantinos Phase selection and mechanical properties of permanent-mold cast Mg-Al-Ca-Mn alloys and the role of Ca / Al ratio, Journal of alloys and compounds 764 (2018), 16-225.

Note: The responsible for England language is Nataliya Drag, Karaganda Kazakhstan