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STUDYING THE PROPERTIES OF SAND-RESIN MOLDS MADE USING A VARIABLE LOAD

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Preliminary Note – Prethodno priopćenje

The article investigated both shell mold samples and casting samples. The castings were made of 35L steel. A scheme of the formation of a sand-tar shell form using variable pressure was presented. As can be seen from the graphs, the application of the load during the formation of the shell form significantly affects the size of the burn in the direction of its decrease. The pressure of 0,18 ... 0,25 MPa, which is defined as optimal for obtaining the forms of castings «Link», can be considered very satisfactory for the value of the burnout. As pressure increases, the rate of decline of the burn on the castings decreases. Obtained in semi-industrial conditions, the samples were investigated in the laboratory of KSTU. The strength, hardness and gas permeability of the forms were determined.

Keywords: casting of steel, mold, sand-resin mixture, pressure, properties

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 [1-5]. The disadvantage of such molds is a high cost of the binder, thermosetting pulverbakelite resin [6-10]. The ongoing studies are aimed at developing technological modes that reduce the amount of using the binder in the mixture due to applying static pressure. This leads to decreasing the cost of the mold, and, consequently, of the casting as a whole.

Earlier [11-14], the main technological parameters were determined during formation of sand-resin mixtures. After that, the hopper with the mixture was tipped over onto a plate pattern heated to 230 °C with radiator models. At this, pressure of 0,25 MPa was supplied through the plate. After 10-12 seconds, the pressure was increased to 0,35 MPa. Still after 10-12 seconds pressure was reduced to 0,2 MPa. At this, a shell mold with the thickness of 12-15 mm was obtained. After this, the molds were sintered within 2 minutes at the temperature of 320-340 °C.

Selecting the composition of the mixture was also carried out, the main and auxiliary components of the mixture and their concentration were determined. The optimal composition of the sand-resin mixture is as follows: quartz sand of the 1K0315 grade – 70 %; quartz sand of the 1K02 grade – 30 %; pulverbakelite SF-011A – 4,5 (in excess of 100 %); kerosene – 0,2-0,4 % (in excess of 100 %); white spirit - 2-3 % (in excess of 100 %); boric acid - 0-0,2 % (in excess of 100 %).

Industrial tests of the technology were carried out on the basis of the Parkhomenko KMZ.

Both shell mold and casting samples were studied. The castings were made of 35L steel.

The curing mechanism of the shell mold under conditions of unsteady pressure was previously considered.

The sand-resin mixture under conditions of simultaneous heat action from a heated plate pattern and applied static pressure by means of a press plate experiences tripartite deformation. This leads to irreversible compaction of the mixture. In addition, as it was previously determined, unsteady pressure improves the mold inner cavity quality and consequently reduces roughness and the burn on amount on the outer part of the castings. Since the studied mixture has inherent elastic, viscous and plastic properties, it can be considered a rheological body.

First of all, it is necessary to evaluate the behavior of the mixture components under the conditions of pressing and thermal heating.

Under the conditions of deformation at the beginning of the shell molding, the bonds between sand and resin inside the mixture are destroyed. Subsequently, upon reaching a certain stage of compaction, the mixture becomes elastic. Then, with increasing pressure, when the ultimate shear stress is reached, the mixture begins to deform plastically.

It is obvious that the compaction process significantly affects the interstitial air, which is enclosed in the mixture. Under the conditions of volumetric compression, a significant amount of air is removed from the mixture, while air that is not removed is trapped in the closed cavities between the particles and held in them

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due to the presence of shells on the binder particles, which contribute to the formation of closed cavities.

In the course of compaction, in the closed pores of the mixture a normal stress appears; besides, there is an additional stress, which is caused by the presence of internal friction.

Let's also consider the transformations in the mixture that occur under the conditions of shear strain. It is known that at the beginning of deformation the mixture experiences elastic deformation, and with increasing shear stresses a certain limit is reached, in excess of which the viscous flow of the mixture takes place. Its speed increases with increasing the applied shear stress. Increasing the temperature changes the resin dry state to the liquid (viscous) state. With increasing the temperature, viscosity of the mixture should change smoothly, which will enable resin to be evenly distributed not only between the grains of sand, but also on the sand surface, that is, there is a kind of cladding the mixture.

EXPERIMENTAL STUDIES

Equipment and tools

In the process of pressing the mixture, three main stages can be distinguished. The first stage of compaction is determined by the external force and leads to structural compaction of the mixture layer as a result of the sand and resin particles movement, squeezing air and filling the voids with these particles in the volume of the layer. At the second stage of pressing, the layer is densified as a result of deformation of the particles themselves. The second stage takes place after laying the particles of the mixture components. As the load increases, deformations occur at the particle contact points, propagating throughout the entire volume of sand and resin particles. The corresponding stresses are initially lower than the elastic limit, and with increasing the force the yield strength is achieved. At this, there is observed relative sliding of particles along each other and along the flask wall. As a result, a part of the pressing energy is spent for overcoming internal and external friction. At this stage of pressing, the elastic-plastic deformation of particles determines the main energy costs of the process. Therefore, at the second pressing stage a strong porous shell is obtained. The third stage of the process is volumetric compression of the porous body.

The pattern of the formation of a sand-resin shell mold using variable pressure can be represented as follows:

1 Filling the molding sand onto the plate pattern (Figure 1)

$T=T_1$, $P=0$.

Figure 1 shows that the particles of sand and resin are mixed randomly, and resin is in the dry powder state.

2 Applying pressure to the mixture (Figure 2)

$T=T_1$, $P=P_1$.

Where:

T – total temperature, °C,

T_1 – model plate temperature 230 °C,

P – total pressure on the mixture, MPa,

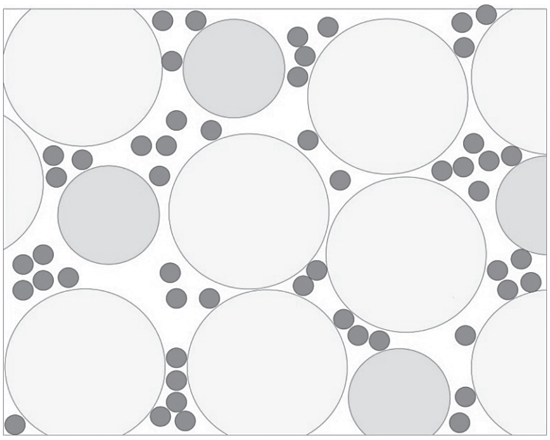


Figure 1 Sand-resin mixture at the moment of filling onto the plate pattern

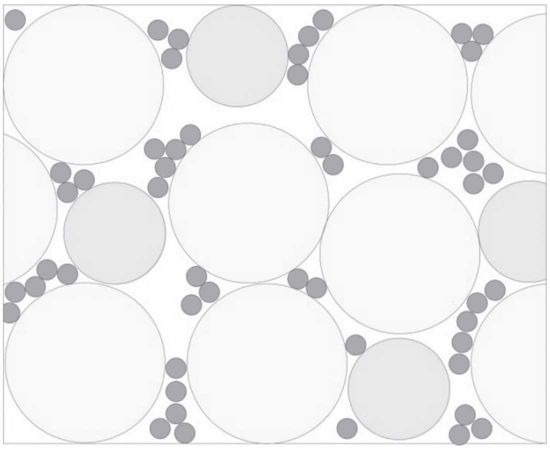


Figure 2 The mixture at the moment of applying pressure

Figure 2 shows that after applying pressure, the mixture porosity decreases due to denser packing of sand and resin particles, and resin is in the dry powder state.

3 The effect of heat on the molding mixture (Figure 3)

$T=T_1$, $P=P_1$.

Where:

P_1 – 0,25 PMa

Figure 3 shows that under the action of heat the resin particles melt and the sand particles combine with it.

4 Increasing pressure

$T=T_1$, $P=P_2$.

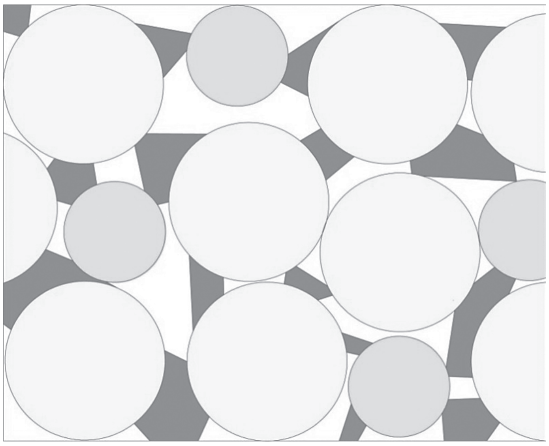


Figure 3 The molding mixture at the moment of resin melting

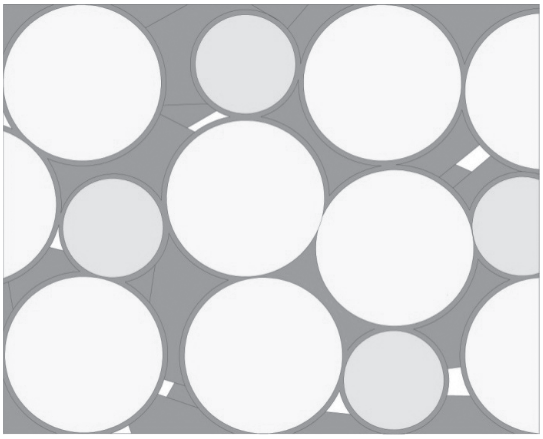


Figure 4 The mixture at the moment of increasing pressure

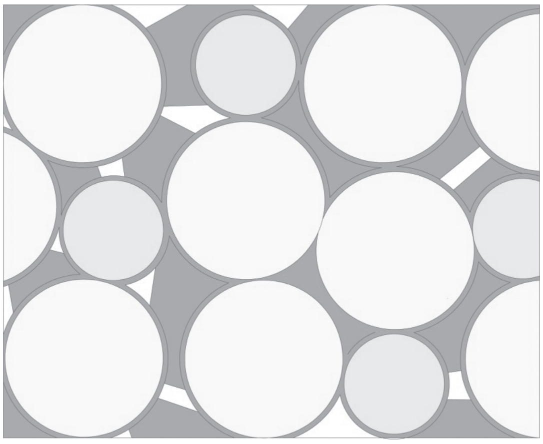


Figure 5 The mixture after reducing pressure

Where:

P_2 – 0,35 PMa

With increasing pressure, the sand particles are enveloped by resin due to the movement of particles and distribution of the resin particles (Figure 4).

5 Reducing pressure (Figure 5)

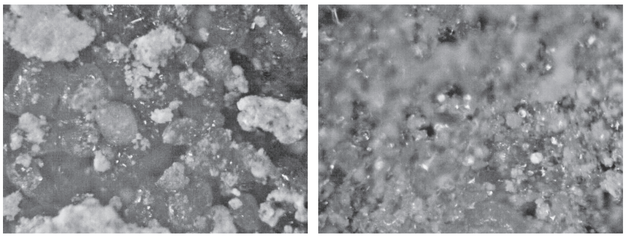
$T=T_1$, $P=P_3$

Where:

P_3 – 0,20 PMa

Figure 5 shows that after pressure is reduced, relaxation occurs in the mixture, which leads to increasing the number of pores inside the mixture components.

Therefore, there is confirmed the idea that under conditions of unsteady pressure there takes place the process leading to cladding of the mixture (fairly even enveloping sand particles with the binder).



a b

Figure 6 The shell mold structure obtained in different conditions: a – with steady pressure, b – with unsteady pressure, ×200

Figure 6 shows the structure of the shell mold with 200 times magnification. It can be seen in the Figure that the use of unsteady pressure significantly increases the mixture components density.

Discussion of the results

The results of experimental data of the dependence of the burn-on value on pressure applied to the mixture are shown in the graph (Figure 7). It can be seen from the graph that applying the load during formation of the shell mold significantly affects the magnitude of the burn on in the aspect of its decreasing. Pressure of 0,18...0,25 MPa that is defined as optimal for obtaining the «Link» castings can be considered very satisfactory for the value of the burn on. As pressure increases, the rate of reducing the casting burn on decreases.

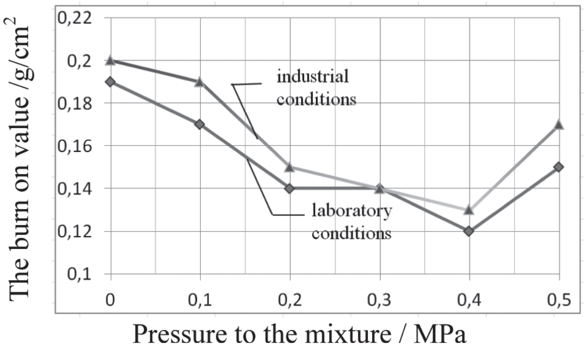


Figure 7 The burn on dependence on pressure to the mixture in the course of molding

An important indicator of the casting quality is the surface roughness. The additional expenses for cleaning the casting surface invoke its increased cost. In order to assess the casting quality, the surface roughness measurements of both the internal mold cavity and the surface of the castings themselves were made. The measurements were carried out using a TR 220 roughness measuring device. The studies in various areas show that the difference between the surface roughness of the mold and the casting is 45-60 μm (Figure 8). It is obvious that increasing the roughness of the mold cavity leads to decreasing the surface finish of the casting.

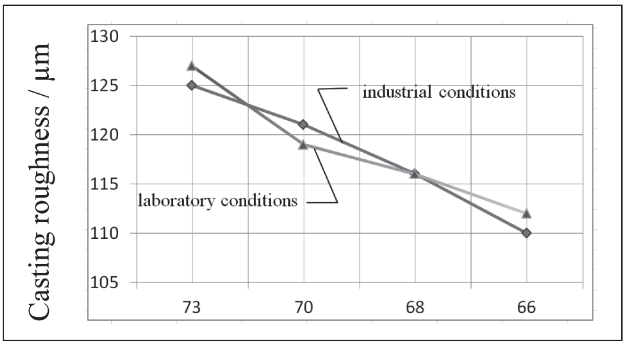


Figure 8 Dependence between the mold and the ingot surface roughness

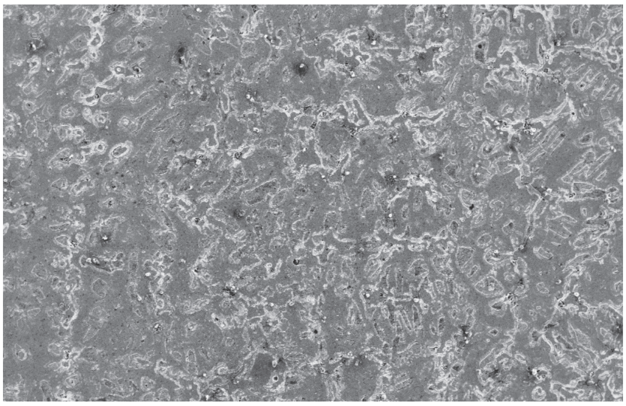


Figure 9 The microstructure of castings made in pilot industrial casting molds, × 500

Large roughness in the cavity of the gate system is caused by the presence of slag in it.

The microstructure of castings obtained in the studied shell molds was investigated. As the studies have shown (Figure 9), the structure of the casting is fine-grained, dense and homogeneous, there are no gas and slag shells.

The samples obtained in semi-industrial conditions, were studied in the laboratory of KSTU. There was determined strength, hardness (hardness gage for dry forms and cores model 04421) and gas permeability of the molds. The methodology of determining these properties is given above. The results are presented in Table 1.

Table 1 **The properties of shell molds obtained in semi-industrial**

Mold sample	Laboratory	Semi-industrial
Strength / MPa	12,4	11,9
Hardness / H	105	103
Gas permeability / un.	119	108

Comparing the data in Table 1 shows that the developed technological mode of obtaining sand-resin molds allows obtaining products with desired properties.

CONCLUSION

Thus, it has been determined that the proposed method of obtaining a casting shell is feasible in the production environment. There is no need in additional costs for the process of molding a shell, since at the plant pressure is supplied from the compressor compartment through the pneumatic pipe. For this technology, there is used pressure that is lower than the main pressure (the main pressure at the plant is 7 atmospheres).

The use of pressure in the molding a shell allows obtaining a strong and solid mold, which subsequently positively affects the castings obtained in them. Such castings have lower surface roughness, a lower amount of burn on and a more dense defect-free structure.

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