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The use of SHS-process slag for the preparation of foundry sand

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Abstract. The article presents the construction of a linear approximation of the response function (strength of molding sand on tensile strength and air permeability) in a given area by changing the investigated factors for which charge makeup of SHS-cast iron obtaining process and content of the slag product of this process in the molding mixture were used. The analysis of regression coefficients significance of the objective function was done to identify the most important input parameters.

1. Introduction

Plastic and liquid sand on cement binders have high technological properties, due to which they found quite widely usage in manufacturing steel and iron castings with particularly large mass [1]. Various structures of discussed molding compounds have been developed [1-5], which provide them with sufficient survivability and mobility, required strength and gas permeability, low crumbling, good knocking out ability, the optimal duration of curing. An integral and important component of the cement forming mixtures is the binder, for which special construction cement with high-coy specific surface area and the addition of gypsum are used. Construction cement from Pikalev plant and Vorovskoj plant is well proven [2]. Aluminous cement is widely used as a binding agent.

2. Basic part

In the present study the properties of the cement moulding mixture were investigated, in which process slag of obtaining SHS-cast iron was used as a binder [6,7]. This slag is similar to the aluminous cement and has binding properties as aluminous cement of grade 400, 500. The cost of used binding material is lower than of standard analogue, which is confirmed by other researchers [8], who also used the SHS process and received a floating fused alloy spinel.

Cement sand was made of the following components: quartz sand, slag process of obtaining SHS-cast iron, water, foaming agent (DS-RAS) in mass ratio 100:(13-16):8: 0,1. In the mixture there are no accelerators from adoption. This is due to the fact that the studied cement molding mixture has sufficient speed of binding material bondability [9]. The quality of the moulding mixture was evaluated on the strength parameters of its tensile strength and gas permeability.

To determine the strength of the molding mixture on tensile parameter samples in the core box were made by filling it with a mixture of easy seal by its hand. The excess mixture was cut off. The cured samples were assayed within 24 hours in normal conditions. The samples had the form of figure “8” with height 75 mm, thickness 25 mm, width of the head and neck 40 mm and 25 mm accordingly. Then the samples were subjected to stretching at a car company "Dietert" type 405.

To determine the gas permeability of sand, its right hand weighing 165±15 g was taken and placed in a one-piece steel polished liner with an inner diameter of 50±0.025 mm and height of 120 mm. In the appropriate seals samples were received with a height of 50±0.5 mm, which were dried in natural conditions within 24 hours. Next, the liner sample was mounted on the test apparatus for gas permeability. For this 2000 ml of air was poured through the sample under pressure 980,7 PA (10 cm water.ct.) and fixed the value of gas permeability on the readings. A machine Permmeter of "Dietert" firm was used as a setting for defining gas permeability of mixture.

The aim of the study was to determine a linear approximation of the response function (y1 – sand stretching strength, 105 PA; y2 – gas permeability, unit) in a given area by changing the investigated factors for which charge makeup of SHS-cast iron obtaining process (x1, x2, x3) and content of the slag product of this process in the molding mixture were used.

The charge of this process consisted of forge scale, siluminum and graphite shavings, powdered lime and ammonium nitrate. The composition of the SHS process charge – input controllable factors was formed in relation to the forge scale of the Foundry plant of OJSC KAMAZ. Moreover, in all variants of the charge amount of siluminum shavings AK18 was maintained at the level of 40%. The impact of the following factors characterizing features of the charge composition was investigated:

x_1 is a quantity of the mixture of aluminum shavings and ammonium nitrate in a relative mass ratio 1:3,5;

x_2 is an amount of graphite shavings;

x_3 is an amount of powdered lime.

The influence of an input controlled factors on the magnitude of the output parameters implemented using the method of proposed experiment [10]. For the structure of the linear mathematical model fractional factorial experiment 2^{4-1} was used for four input factors and three parallel observations when generating the ratio $x_4 = x_1 \cdot x_2 \cdot x_3$.

Mathematical model is the following:

$$y_1 = 16{,}07 + 2{,}69x_1 + 0{,}13x_2 - 0{,}93x_3 + 1{,}32x_4 \quad (1)$$

and is justified due to the fact that the difference between the maximum and minimum average values of the output parameter y_1 is significant. This follows from the comparison of the experimental values of Student criterion ($t_{эк}$) with table (t_α) for the number of degrees of freedom f =4 and reliability α = 0,95. The calculation of the experimental values of Student criterion showed that $t_{эк}$ = 11,42. This value significantly exceeds t_α = 2,78. This fact allows us to conclude that the mathematical model (1) is justified.

The calculation of the total variance of the output parameter, called dispersion reproducibility, showed that $S^2_{y_1} = 0{,}337$.

After checking the significance of equation regression coefficients (1), we come to the conclusion that the a_2 coefficient is not significant, as $t_{2эк} < t_\alpha$. Hence, the equation of the regression, which describes the relationship between the strength of the moulding mixture in tension and the controlled factors, takes the following form:

$$y_1 = 16{,}07 + 2{,}69x_1 - 0{,}93x_3 + 1{,}32x_4. \quad (2)$$

Using Fisher's test the model was tested for the hypothesis of adequacy (suitability). The regression equation (2) is converted into the following form, if you use the values of the factors named in (natural) units:

$$y_1 = -1{,}65 + 0{,}11x_1 - 0{,}06x_3 + 0{,}88x_4. \quad (3)$$

We will hold a similar statistical study regarding the output parameter y_2 gas permeability of sand.

$$y_2 = 291{,}4 - 0{,}35x_1 + 0{,}41x_3 - 12{,}56x_4. \quad (4)$$

Analysis of the regression equation (4) establishing the influence of input parameters on the strength of sand under tension shows that the most significant parameters is x_1 – a quantity of the mixture of aluminum shavings and ammonium nitrate. The influence of other parameters (x_3 – number of powdered lime and x_4 – content of the slag product of the SHS process in sand) is equivalent. The difference in qualitative result of the influence of the parameters x_1 and x_3 on the strength of the moulding mixture should be noted. It is connected, obviously, with the level of binding properties of the slag product of SHS process. Previous studies showed that the cementing properties of the specified product grow with growth of parameter *x1* and fall with the growth of parameter x_3. As the increase in both parameters contribute to the saturation of the slag phase Al_2O_3 in the first case and CaO in the second one, the conditions of their variation in the composition of the charge of SHS process are the best prerequisites for the relevant formation of monocalcium aluminate $CaO{\cdot}Al_2O_3$ (CA), which defines the binding properties of the slag product. Indicated mineral in reaction with water eventually leads to the formation of compounds such as dicalcium of hydroalumination ($2CaO{\cdot}Al_2O_3{\cdot}8H_2O$ (C_2AH_8)) and aluminum hydroxide ($Al(OH)_3$), crystallization of which leads to the formation of cement with high strength. The experimental results allow to conclude that, under the influence of increasing the parameter x_1 and decreasing the parameter x_2 the above-described processes are initiated that causes the increase of the binding properties of the slag product of SHS process and accordingly the strength of the investigated cement sand. The increase of the parameter x_4, i.e. the amount of slag product of the SHS process in the molding mixture, also contributes to the last fact. It should also be noted the negative impact of excess lime in the slag product to the level of the knit of existing properties and, accordingly, the strength of the sand due to the fact that the possible recrystallization of dicalcium of hydroalumination (C_2AH_8) tricalcium hydroly-mint (C_3AH_6), accompanied by a decrease in the volume of tumors by about 25-30% and the occurrence of harmful stresses in the cement stone, causing a decrease in its strength.

Analysis of the research results on the gas permeability of sand (y_2) showed that this output parameter is significantly affected by the same input parameters as in the case of strength, but with the opposite quality. The reason for such relationship (4), obviously, is features of the flow crystallization processes at the interaction of monocalcium aluminate (CA) with water with the formation of the high density cement stone. In addition, the gaps between the crystals of dicalcium hydroaluminate filled with aluminum hydroxide, which has a dense structure. Therefore, those factors that contribute to the increase of strength properties of cement sand, oppositely affect its permeability. Moreover, as the results showed, the most important impact was made by the input parameter x_4 which is the content of the slag product in the molding mixture. Other parameters (x_1 and x_4) are equal.

3. Conclusion

Thus, the research results allow to conclude acceptability of sand properties using it as cementing component of the slag product of the process of obtaining SHS-cast iron of dispersed waste. Received adequate models allow to adjust sand strength and gas permeability through the parameters characterizing the charge composition of the SHS process, and the number in moulding mixture of the slag product – efficient substitute of alumina cement.

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