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To the Question of Optimization of the Process of Mechanical Activation of Metallurgical Slag

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Abstract: *As you know, mineral additives in the concrete mix compositions have become an almost indispensable component that can significantly improve the physical and technical performance of concrete. In comparison with other types of additives, they have the greatest impact on the corrected formation of the structure and properties of the designed concrete while simultaneously saving cement.*

Keywords: *Metallurgical, Mechanical.*

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The expediency of introducing mineral additives into concrete is explained by the practice of obtaining composites of different strengths on cement of the same grade. As is known, with a low consumption of mineral binder in concrete, there is a shortage of fine particles, which is compensated by the introduction of inactive mineral additives. As a result, voids are filled and the structure is compacted. The use of active mineral powders in an inflammatory degree contributes to the creation of favorable conditions for a more complete and deep understanding of the formation processes and interactions. [7-16].

As a mineral additive for concrete, as studies have shown, are the most effective fillers containing silicon-oxygen and aluminum-oxygen compounds that have the ability to self-hydration hardening? These include by-products of metallurgical production - slags and foundry molded mixtures, which in large quantities contain the indication above.

In the technology of production of building materials, one of the main labor- and energy-intensive operations is the grinding of solids in order to obtain a powdered substance with the required specific surface area to fully disclose its potential activity.

The process of grinding rock waste and obtaining powders of the required dispersion is very complicated and depends on a number of both technological (design features of mills) and physical and mechanical characteristics (structure, hardness, etc.) of materials.

Given the above, the article presents the results of optimizing the grinding parameters of steel-smelting slag (SP) and casting and molding waste (LFO) of the Tashkent Casting and Mechanical Plant of Uzbekistan JSC.

The process of grinding SP and LFO was carried out in a laboratory ball mill ShLM-100 in shock-abrasive (40 rpm) grinding mode. The material was crushed to a specific surface area of 500-5500 cm2/g with preliminary drying of the feedstock to a constant weight at a temperature of ±105ºC.

The fineness of grinding was determined on a PSKh-11A surface meter with the determination of the specific surface area (S, cm2/g) and the mass-average particle size (d, µm) of the powders under study.

In order to minimize the number of experiments while varying a large number of variable factors, the method of mathematical planning of experiments was used.

To improve the possibility of interpreting models and making technical and economic decisions on them, a transition was made from natural values of factors to coded ones. Dimensionlessness of factors is achieved by normalizing natural values (in SI units) [3] according to the formula:

$$x_i = \frac{x_i - x_{oi}}{x_i}, \qquad (1)$$

where x_1 – the value of the normalized factor; x_i – natural value *i*- th factor; x_{oi} – main level *i*-th factor calculated as:

$$x_{oi}=0,5(x_{imax}+x_{imin}) \quad , \qquad (2)$$

where x – half-range of changes *i*-th factor (variation interval is calculated as)

$$\Delta x_i = 0,5(x_{imax} - x_{imin}), \qquad (3)$$

The dimensionless values x have a clear meaning and in their absolute value show by what part of the maximum possible interval within the experiment this factor changes under control, and by the sign (+, -) in which direction it changes from the center of the experiment [3].

The main characteristics of the adopted plan of experiments in coded and natural values of the variables are given in Table. 1.2.

The following initial factors were chosen as variable ones:

x_1 – average particle diameter, µm; x_2 – porosity of the obtained powder, %; x_3 – bulk density, kg/m^3;.

The levels of other factors are stabilized for the entire experiment.

Normalized X-value factors are dimensionless and are used within -1...+1.

In table. 1 shows the selected experimental plan expressed in coded and natural values of variable factors.

To implement the task, experiments were carried out in accordance with applicable standards.

Table 1 Experimental plan in coded and natural values of variables in shock-abrasive grinding mode for SP

Experience number	Experiment plan			Natural values of the experiment		
	X_1	X_2	X_3	X_1	X_2	X_3
1	+1	+1	+1	49.7	0.36	1849
2	+1	+1	-1	27.6	0.37	1838
3	+1	-1	+1	22.5	0.4	1750
4	-1	+1	+1	19.7	0.41	1703
5	-1	-1	-1	15.2	0.47	1546
6	-1	0	0	12.5	0.49	1469
7	0	+1	0	11.1	0.52	1385

8	0	-1	0	10.4	0.54	1333
9	0	0	+1	10.7	0.5	1453

Таблица 2 План эксперимента в кодированных и натуральных значениях переменных при ударно-истирающем режиме измельчения для ЛФО

Experience number	Experiment plan			Natural values of the experiment		
	X_1	X_2	X_3	X_1	X_2	X_3
1	+1	+1	+1	44.2	0.38	1600
2	+1	+1	-1	21.8	0.42	1500
3	+1	-1	+1	16.7	0.43	1474
4	-1	+1	+1	11.3	0.47	1385
5	-1	-1	-1	8.6	0.53	1224
6	-1	0	0	7.5	0.54	1192
7	0	+1	0	6	0.6	1046
8	0	-1	0	6.2	0.58	1083
9	0	0	+1	5	0.62	1000

The average values of the experimental data for each point of the plan are given in Table. 3.
As a result of the implementation of the experimental plan, specific surfaces were obtained for various grinding modes. The range of experimental values of the studied parameters is given in Table. 4.

Table 3 Results of the implementation of the experiment plan

Experience number	Levels of variation factors			Average values of test results	
	X_1	X_2	X_3	for СП	for ЛФО
1	+1	+1	+1	416	522
2	+1	+1	-1	750	1058
3	+1	-1	+1	919	1386
4	-1	+1	+1	1049	2045
5	-1	-1	-1	1364	2682
6	-1	0	0	1655	3062
7	0	+1	0	1856	3868
8	0	-1	0	1987	3710
9	0	0	+1	1934	4655

Table 4 Range of changes of the main parameters

for СП, sm^2/g	for ЛФО, sm^2/g
416-4174	522-5300

The experimental results were processed using the methods of mathematical statistics [3]. As a result of processing, polynomial models were obtained, reflecting the relationship between the studied properties and their initial factors, which have the following form:

$$Y=c+a_1x_1^2+b_1x_1+a_2x_2^2+b_2x_2+a_3x_3^2+b_3x_3+.....+a_nx_n^2+b_nx_n ,$$

where Y – investigated property; x_i - input factors; a_i,b_i,c – regression equation coefficients.

In the process of mathematical processing of the experimental results, regression coefficients were established (Table 4), which, after checking for significance, formed the basis of the regression equations of the studied factors.

The reliability of the obtained regression equations was confirmed by calculating the adequacy variance (or residual variance) and determining the calculated value of the Fisher criterion F_p, which was compared with the table $F_т$. When the condition $F_p<F_т$ the resulting equation is considered suitable for describing the initial dependence within the studied limits of the change in factors [4, 5].

Table 4 Regression coefficients

Options	steel slag	Casting waste
c	7499.969	17691.63
a_1	1.228756	1.044367
b_2	18726.19	9043.608
a_2	-0.00039	-0.00334
b_2	-3329.34	-5254.96
a_3	-0.42835	-0.77005
b_3	-9.98514	-14.8018
a_4	2.8522	5.200705
b_4	7499.969	17691.63
a_5	1.228756	1.044367
b_5	18726.19	9043.608
a_6	-0.00039	-0.00334
b_6	-3329.34	-5254.96
R^2	0,91	0,99
S	0,08	0,05
F_p	0,0002	0,0015
$F_т$	19,3295	19,3295

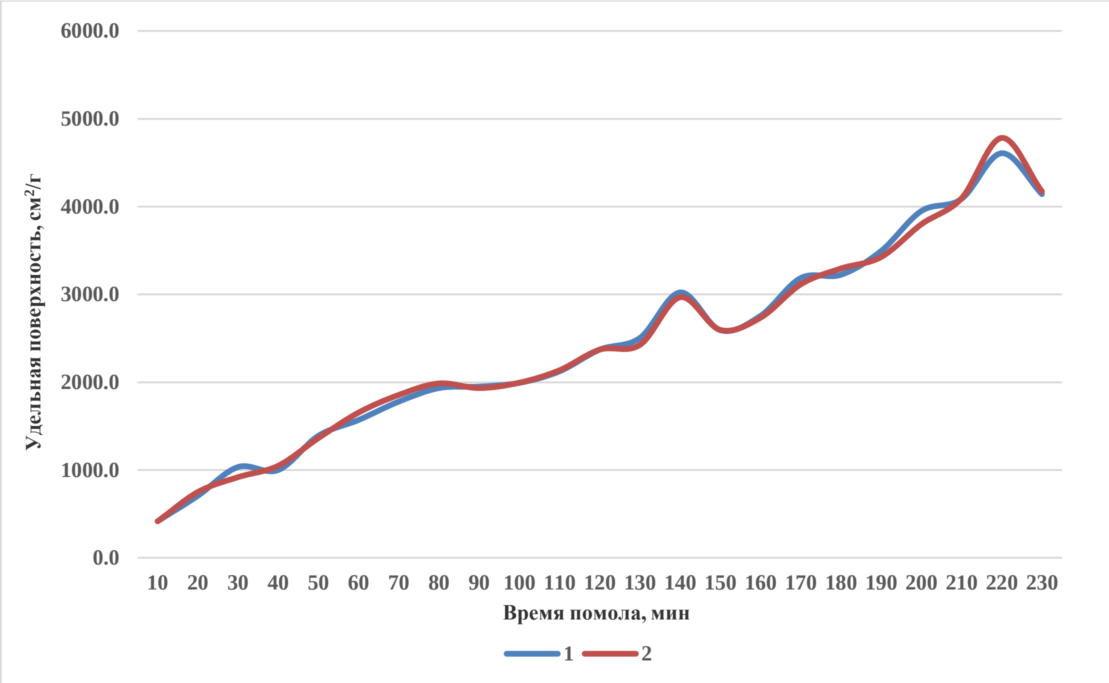
Thus, the resulting polynomial models that adequately describe the relationship between the studied properties and the initial variation factors have the form:
-for СП:

$$Y_{СП}=7499+1,22X_1^2+18726X_2^2-3329X_1X_2-0,42X_1X_3-9,98X_2X_3+2,85X_1X_2X_3$$

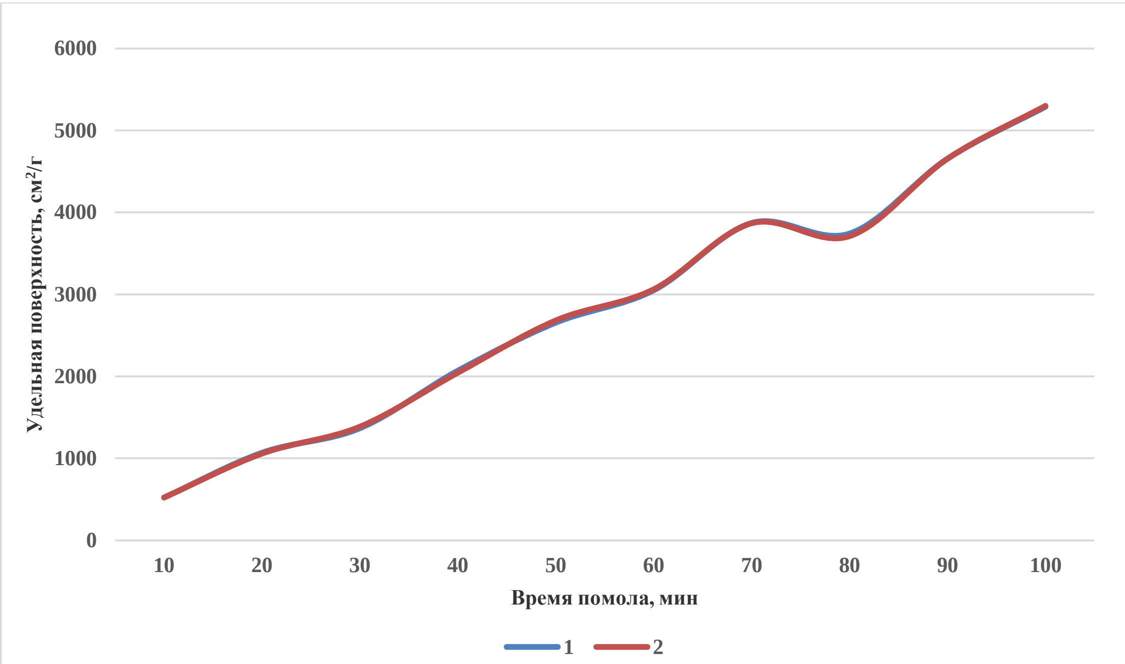
-for ЛФО:

$$Y_{ЛФО}=17689+1,044X_1^2+9043X_2^2-5254X_1X_2-0,77X_1X_3-14,8X_2X_3+5,2X_1X_2X_3$$

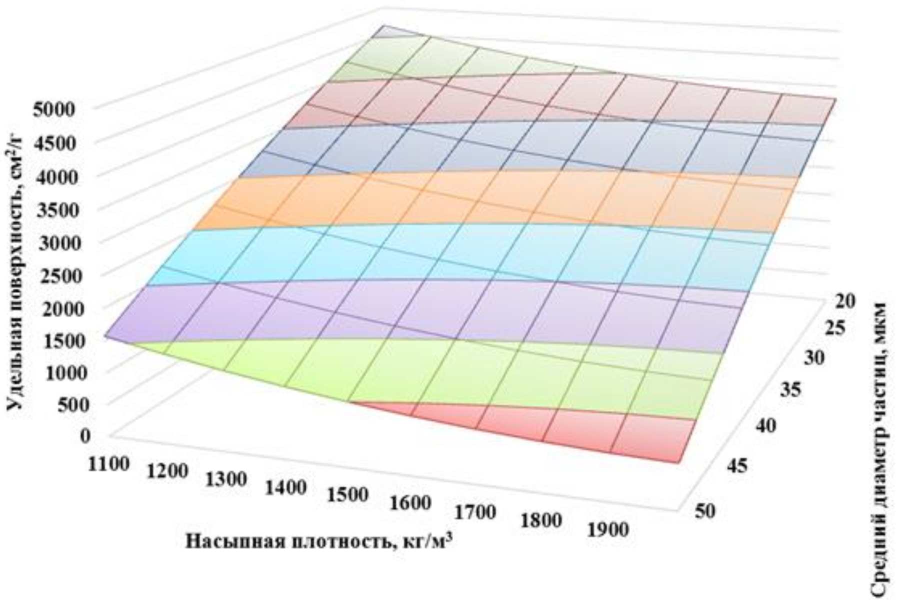
The analysis of the obtained models made it possible to establish the levels of variation factors that provide the required specific surface area of the spilfo. On fig. Figures 1 and 2 show the results of comparing the experimental and calculated values of the specific surface area obtained in the shock-abrasive mode, in addition, obtaining mathematical models made it possible to obtain iso- graphs of changes in the specific surface area and bulk density of metallurgical slags, which are shown in Fig. 3-4.



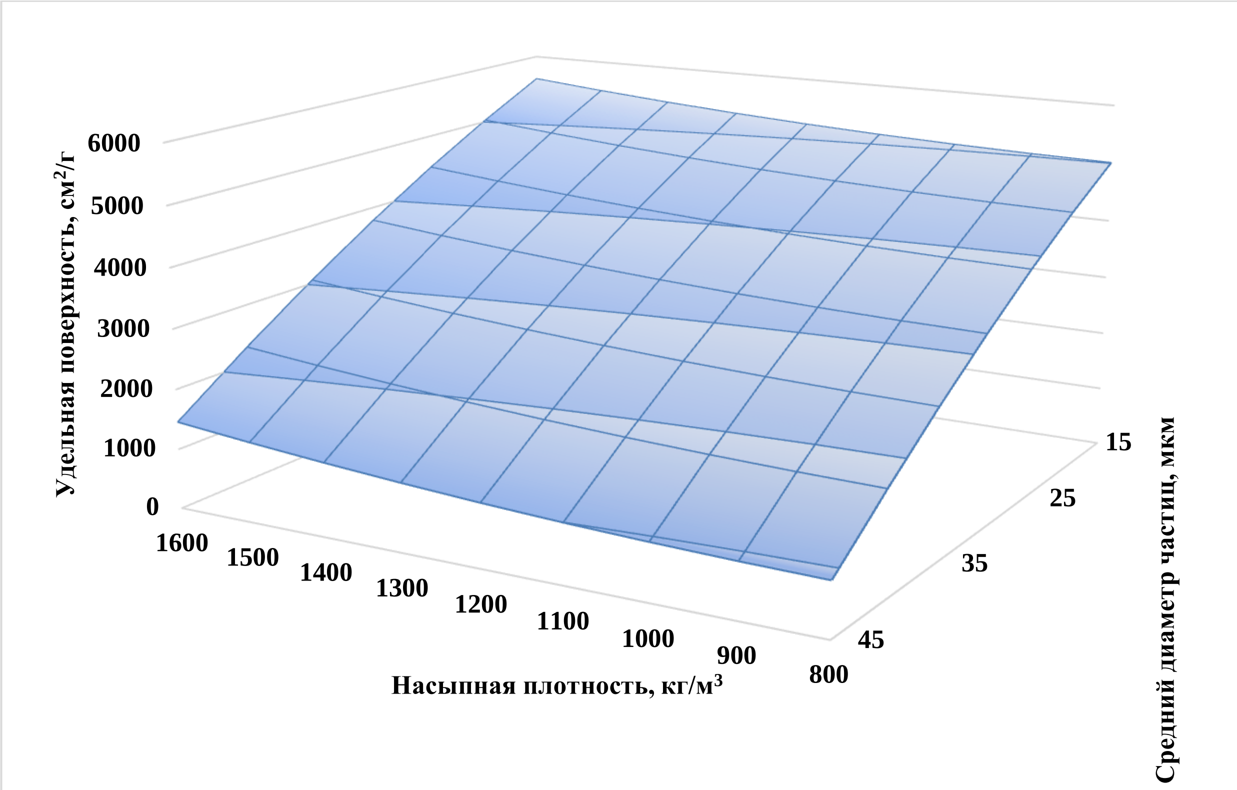
Pic. 1. Graph comparing the experimental (1) and calculated (2) values of the specific surface of the joint venture obtained in the shock-abrasive mode



Pic. 2. Graph comparing the experimental (1) and calculated (2) values of the specific surface of the LPO obtained in the shock-attrition mode



Pic. 3. Dependence of the specific surface area of SP on bulk density and average particle diameter



Pic 4. Dependence of the specific surface of LPO on bulk density and average particle diameter

As a result of processing the results of experiments, polynomial models were obtained that reflect the relationship between the studied properties and their initial factors. Determination coefficient R^2 real models is R^2=0,99. The reliability of the obtained equations is 97-99%.

Thus, it can be argued that the optimization of grinding parameters СП and ЛФО significantly reduces the energy and labor costs of the grinding process of this mineral and increases the efficiency of the equipment.

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