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Production of porous material with projected thermophysical characteristics

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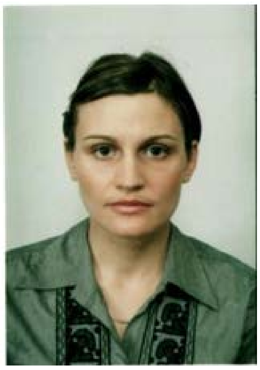

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Abstract
The paper presents experimental data, according to which the effect of various factors on the porosity is studied, thermal conductivity and strength of new heat insulating porous material. Mathematical model of the influence of these factors on these indicators is shown, which can be used to predict its properties.

Keywords: PORES OF RAW, WARMLY EXCHANGE, POROUS HEAT-INSULATION MATERIALS.

Introduction

Efficiency of use of energy resources in Ukraine under conditions of permanent shortages and high prices remains very low. Nowadays, one of the strategic objectives is to reduce the rate of energy saving of fuel and energy costs in different heat aggregates, in the construction and maintenance of buildings, industrial facilities, pipelines equipment, refrigerators, etc. Under the circumstances, taking into account the energy crisis in modern industrial and building insulation, there was an urgent need to develop and implement effective thermal insulation materials for all industrial enterprises of the country. Prevalence of natural deposits of siliceous rocks in the regions of Ukraine (32 deposits in 12 regions), cheap and affordable eco-friendly raw materials and production technology are an important argument for further research, development and deployment of new technologies for production of thermal insulation materials based on silicate. Research in the preparation of such thermal insulation materials should be directed to the improvement of their thermal and structural properties.

Statement of the Problem

Porous insulating materials have a wide range of applications in various fields of technology. Therefore, to impose these materials and the requirements for a range of values of thermophysical properties, in particular - the thermal conductivity, thermal stability and strength. Obviously, these parameters are interdependent. Therefore, in the manufacture of insulation one should solve optimization problem that can predict the level of the values of these characteristics.

The literature [1,2] describes the composition and properties of new insulating porous material obtained by using the swelling gasifier. The composition and the percentage of the raw material mixture components determines the overall thermal properties of the final material. Therefore, to produce it, it is important to know how these components are interconnected and technological modes with some, most of the technology properties, in particular - thermal conductivity, density and temperature resistance.

The aim of the work

To study the influence of various factors on the thermal characteristics of the porous insulating materials.

Materials and studies

Technology of siliceous rocks swelling or siliceous materials of anthropogenic origin are observed in the allocation of gaseous products in the whole volume of the material in the plastic-viscous state, in the heating process [3,4]. Medium temperature are hydrated water, sodium bicarbonate and clay that form gases when heated. Bloating flatulence suggests that stands out in the process of gasification gas remains in gas-tight plastic gel phase which crystallizes at a medium-impact 100-120 $^{\circ\,C,}$ with the formation of a cellular pore structure. In this case, the material transformations occur as follows:

1) formation of gel saturated with CGS uniformly distributed in the bulk of the material;
2) solidification of the gel without thermal effects;
3) granulation;
4) peak and formation of monodisperse porous structure with a fixed pore size, the surface of which is coated with a continuous film;
5) Final crystallization granules porous material in contact with medium temperature coolant.

If preliminary drying of granules air temperature 100-120 C, the viscosity of the material increases, while active gassing is beginning, which promotes the presence in the mixture of hydrate water, sodium bicarbonate and clay. The intensity of this process is regulated by temperature and time of exposure to the coolant, which are selected so that the cell gas increases to a certain predetermined size without merging and collapsing. Thus, the internal surfaces of gas cells stabilized, and the outer surface of the granules coated with a solid film [6]. Temperature exposure time defines how structural characteristics (porosity, pore size) and the mechanical properties of the material and its thermal stability. The final patterning material is at a higher short heat treatment.

Clay is an additional low-temperature gazifier. Strong alkali by reaction with the oxide dissolves the protective aluminum oxide film on the aluminum surface:

$Al_2O_3 + 2OH \rightarrow 2AlO_2^- + H_2O.$

Aluminium goes into solution as ion $Al^{3+,}$ wherein there are three moles of hydrogen:

$2Al\ ^{+}\ 6H + \rightarrow 2Al^{3+} + 3H_2 \uparrow.$

Clay improves heat resistance of the obtained material. The interaction with the clay mixture components subjected to high temperatures the formation of new chemical compounds with higher refractory properties.

To assess the impact of the raw material mixture and thermal modes of its treatment on thermal properties of the final sample of the mathematical model.

As indicators of the process characterizing the behavior of the material under thermal and mechanical loads there were taken porosity $Y_{1,}$ thermal conductivity Y_2, Young's modulus Y_3 and heat resistant material Y_4. The factors affecting these indicators are used: clay content X_1, content Na_2CO_3 - $X_{2,}$ $X_{3,}$ moisture content and temperature of the treatment $X_{4.}$

The data obtained in the course of the experiment is shown in Tables 1 and 2. In order to construct models there used orthogonal central composite design of the second order with the core4^2.

Table 1. Levels of variation factors

X	-1.414	-1	0	+1	1.414	Δ

X_1	16.7	25	45	65	73.3	20
X_2	2.17	3	5	7	7.83	2
X_3	11.7	20	40	60	68.3	20
X_4	258.6	300	400	500	541.4	100

Table 2. Values of Y_I

N	X_1	X_2	X_3	X_4	Y_1	Y_2	Y_3	Y_4
1	+1	+1	+1	+1	0,181	0,020	16.8	1200
2	-1	+1	+1	+1	0,362	0,031	16.2	800
3	+1	-1	+1	+1	0.395	0,08	35.3	1080
4	- 1	- 1	+ 1	+ 1	0.519	0,076	31.3	760
5	+ 1	+ 1	- 1	+ 1	0.154	0,023	39.6	1200
6	- 1	+ 1	- 1	+ 1	0,416	0,035	39	600
7	+ 1	- 1	- 1	+ 1	0.433	0,041	41.9	980
8	- 1	- 1	- 1	+ 1	0.429	0,039	41	590
9	+ 1	+ 1	+ 1	- 1	0.159	0,018	34	1240
10	- 1	+ 1	+ 1	- 1	0.428	0,044	32	810
11	+ 1	- 1	+ 1	- 1	0.444	0,048	37.7	1000
12	- 1	- 1	+ 1	- 1	0.433	0,046	37	740
13	+1	+ 1	- 1	- 1	0.190	0,025	40.6	1190
14	-1	+1	-1	-1	0.388	0,039	39	630
15	+	-	-	-	0.419	0,053	40.9	900
16	-	-	-	-	0,530	0,078	40.4	650
17	-1.414	0	0	0	0.321	0,047	31.4	1200
18	1.414	0	0	0	0,375	0,051	21.9	800
19	0	-1.414	0	0	0,322	0,046	18.4	960
20	0	1.414	0	0	0.353	0,050	38	900
21	0	0	-1.414	0	0,421	0,056	15	1100
22	0	0	1.414	0	0.519	0,076	31	980
23	0	0	0	-1.414	0,283	0,038	17.4	860
24	0	0	0	1.414	0.480	0,063	36	820
25	0	0	0	0	0,331	0,027	31	840

After the settlement of the simplex algorithm, there were produced the following estimates of the coefficients in the models. They are shown in Table 3.

To verify the effect of dependence factors and their interactions on the performance, as well as the adequacy of the obtained observational errors for each indicator in "zero" point $X_1 = X_2 = X_3 = X_4 = 0$ there were four replicates. Their results are shown in Table 4.

Table 3. Estimates of the coefficients in the models that characterize the degree of influence factors and their interactions on performance

№	X_1	X_2	X_3	X_4	Y_1	Y_2	Y_3	Y_4
1	+1	+1	+1	+1	0,181	0,020	16.8	1200
2	-1	+1	+1	+1	0,362	0,031	16.2	800
3	+1	-1	+1	+1	0.395	0,038	35.3	1080
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25	0	0	0	0	0,331	0,027	31	840

As a result, for the formula variance of estimation errors of observation:

$$S^2 = \frac{1}{3}\sum_{i=1}^{4}\left(Y_i \quad \bar{Y}\right)^2 \qquad (6)$$

where Y_1 - index of the observed value in the i-th re-experience, $\bar{Y}$ - the average Y value in the "zero" point of the received error variance observations (Table 4).

Table 4. The values of repeated experiments and error variances for the parameters Y

Indicator	Value of the index in repeated experiments				The dispersion of the observational errors
	1	2	3	4	
Y_1	67	72	73	68	8.667
Y_2	0.11	0.10	0.15	0.12	0.00047
Y_3	28.9	32.2	32.9	30	3,487
Y_4	820	870	850	820	600

"Significance threshold" for the estimated coefficients characterizing the power to influence factors and their interaction effects were as $h_i \cdot S$, where S -the standard deviation of the observation error, $h_i = t_{kp}(\alpha;\varphi) \cdot \sqrt{c_i}$, $t_{kp}(\alpha;\varphi)$- - the critical value of the t-distribution for the level of significance α and the number of degrees of freedom φ. In the studies $c_1 = 0,05$ for x_i, $c_2 = 0,125$ for x_i^2, $c_3 = 0,0625$ for $x_i \cdot x_j$, $i, j = 1,...4$. As a result of the settlement of the above formula there are obtained for the parameters Y «thresholds of significance" for the estimated coefficients are given in Table 5.

Table 5. "Significance threshold" for factors and their interactions

Indicators	Thresholds of significance		
	X_i	X_i^2	$X_i X_j$
Y_1	2,095	3,312	2,342
Y_2	0,015	0,024	0,017
Y_3	1,329	2,101	1,485
Y_4	17.429	27.557	19.486

Excluded factors and their interaction from the model, the magnitude of the coefficients of which are less than the module of "significance threshold" for the level of significance $\alpha = 0,5$ received the following dependencies.

$$\hat{Y}_1 = 83.52 + 3.73X_1 + +14.08X3 + 5.255X_4 - 11.2X_1^2 - 6.95X_2^2 - 7.2X_3^2 - 3.45X_4^2 + 2.5X_3X_4$$

R=0.19 (7)

$$\hat{Y}_2 = 0,041 - 0,052X_2 - 0,091X_3 - 0,016X_4 + + 0,055X_1^2 + 0,075X_2^2 + 0,032X_3^2 + 0,057X_4^2 + 0+,019X_2X_3 - 0,02X_3X_4,$$

(8)

$$\hat{Y}_3 = 23,332 - 3,796X_2 - 5,251X_3 - 3,345X_4 + + 3,41X_1^2 + 4,185X_2^2 + 3,435X_4^2 - 2,325X_2X_3 - - 1,683X_2X_4 - 2,7X_3X_4,$$

$$\hat{Y}_4 = 940 + 188,78X_1 + 52,742X_2 + 52,984X_3 + + 33,25X_3^2 - 66,75X_4^2 + 48,125X_1X_2 - - 24,375X_1X_3,$$

(10)

Verification of the adequacy of the obtained models was performed by the Fisher test. Estimated value of the F statistic is given by:

$$F_P = \frac{S_{rem}^2}{S^2}, \quad (11)$$

To provide a model residual variance was

$$S_{rem}^2 = \frac{1}{n-m} \sum_{i=1}^{n} \left(Y_i - \hat{Y}_i\right)^2, \quad (12)$$

where $n = 25$ - the number of experiments, m - the number of coefficients in the model.

The resulting residual dispersion are calculated and tabulated values of Fisher statistics are given in Table 6.

Table 6. Calculated and tabulated values of Fisher statistics

Indicators	Value S $_{East}$ ^{2,} F $_{calc.,}$ F $_{tab.}$		
	S $_{ost}$ ^{2}	F $_{calc}$	Table F.
Y_1	47.34	5.42	8.703
Y_2	0.0028	6,085	8.703
Y_3	22.335	6.406	8.703
Y_4	3229.52	5,383	0.683

Since F_p for all models is less than $F_{table.,}$ Both models are adequate with the reliability of 0.95 according to the true and can be used for technological process analysis and forecast values of the indicators Y.

Conclusion

Thus, the main factor determining the porosity, thermal conductivity, strength and heat insulating porous material is humidity raw mixture before the heat treatment. Heat resistance largely depends on the content of clay in the mixture. It is obvious that these factors provide the necessary intensity of heat and mass transfer of processes in the source material, which is interconnected with the main technological indicators - external coolant temperature.

Thermodynamic parameters are determined by steam water temperature and duration of thermal contact with the coolant. Thus, using the obtained data one can predict the properties of the porous material at the design stage of the process equipment or process.

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