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Use of Byproducts of Acidic Processing of Aluminium – bearing Raw Materials in Production of Heat Insulating Materials

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Abstract

The principal possibility to use byproducts of acidic processing of aluminium-bearing raw materials as the main component of batch to obtain a heat insulating material using low-temperature technology is established. The compositions suitable to obtain low-temperature frit and a foam glass material on its basis are developed. The obtained material has improved physical – mechanical properties in comparison with conventional foam glass from broken glass.

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Keywords: Foam glass crystal material, Si-stoff, low temperature synthesis, granulated material, strength

1. Introduction

The increased interest to environmentally safe heat insulation materials is observed at the present time. Such materials are fire proof, durable, do not evolve harmful substances at operation and do not rot. Foam glass is one of such materials. Problems of raw material base widening are solved both in Russia and abroad. European researches are directed mainly on use of various kinds of broken glass, for example, glasses of electron-beam tubes, computer screens and so on[1-3]. Domestic researches use both broken glass and various kinds of natural and technogeneous raw materials as feed composition[4-6].

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This paper considers foam glass materials obtained by two stage low temperature technology. On the first stage frit is synthesized at temperature not more than 900 ^oC. On the second stage the frit powder with additions of gas-forming agent is used to prepare foam forming mixture at 800 – 850 ^oC.

The main components of source batch to obtain foam crystal materials are natural and technogeneous siliceous and aluminosilicate materials[7,8]. Siliceous raw materials are presented by diatomite, gaize, marchalite, screenings of quartz sands, and microsilica. Aluminosilicate raw materials are presented by zeolites, perlites, ashes, and ash and slag wastes of heat power stations. Depending on raw materials, batch composition is corrected by various additions, for example, calcined soda and (or) dolomite.

The goal of the paper is to prove possibility to use acidic processing byproducts (further Si-stoff) of aluminium bearing raw materials as the main component of batches to obtain foam glass crystal materials using low-temperature technology.

The number of researchers showed possibility to use Si-stoff in production of various materials - ceramic tiles, grouting mortars, cellular concrete, and so on[9]. The problem of Si-stoff use in foam glass technology is considered in the paper[10], and its utilization in production of foam glass crystal materials using low-temperature technology is considered for the first time.

2. Objects and methods of research

The byproduct of the largest Russian producer of aluminium and alumina company "RUSAL" was selected as the research object. The chemical composition of Si-stoff is up to 90 % of SiO_2 with admixture of Al_2O_3, Fe_2O_3, TiO_2, CaO, i.e. it is high siliceous material. According to the data of granulometric analysis (Fig. 1) Si-stoff consists of 90 % of particles with diameter up to 37.5 μm and 100 % of particles less than 100 μm. It corresponds to the requirements applicable to siliceous raw materials suitable for synthesis of low-temperature frit. The mineral composition of Si-stoff is presented by quartz (Fig. 2), partly in amorphous form that is favourable for low-temperature synthesis of the frit.

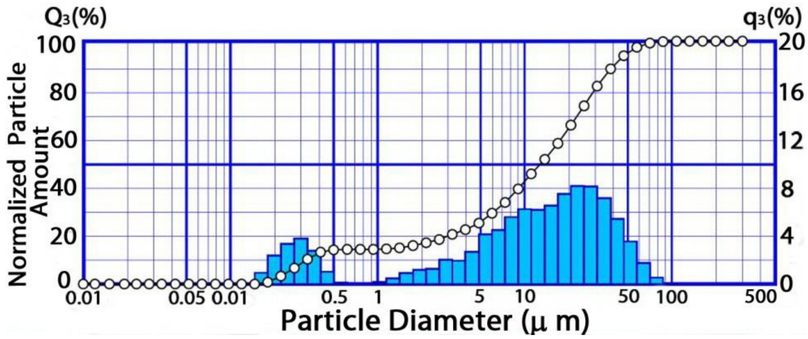

Fig.1. Distribution of source Si-stoff particles by size

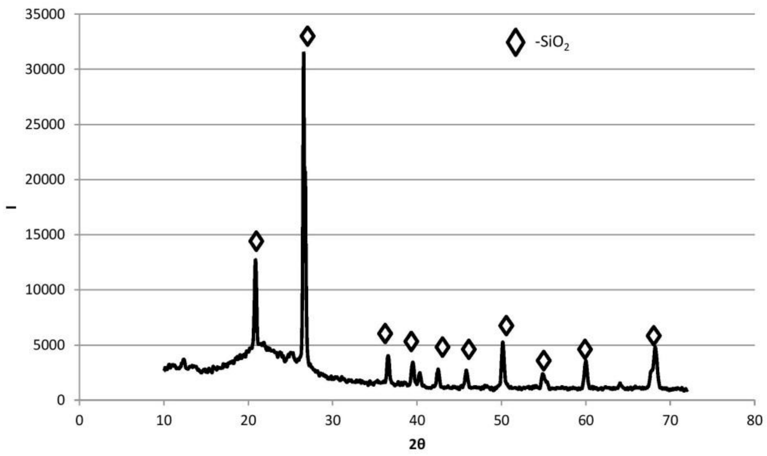

Fig. 2. X-ray picture of source Si-stoff

The phase composition of source materials and synthesis products was studied by X-ray analysis method with using diffractometer in Cu – radiation. The X-ray pictures were processed with program "Crystallographica Search-Match” to define qualitative mineral composition and program «Renex» to define quantitative phase composition. The grain size composition of materials was estimated using laser diffraction method with analyzer SALD-7101. The physical – chemical processes of frit synthesis were studied by method of differential - thermal analysis with scanning calorimeter DSC Q2000. The main properties of finished material, such as density, thermal conductivity, and water absorption were defined by standard methods.

3. Results and discussions

For selection of chemical composition of glass to obtain low-temperature frit it is necessary to fulfill the following requirements. The first requirement is to assure sufficient quantity of glass former (60 – 70 mass %) and alkaline metal oxides (60 – 75 mass %) in composition of glass. Therefore, it is necessary to take into account that foaming of silicate glasses occurs at viscosity of 10^5-10^7 Pas. It is necessary to use glasses that reach such viscosity at temperatures 750 – 900 ^oC. Besides, temperature and composition of system viscosity depends on quantity of crystalline phase in frit: if it exceeds 25 %, foaming is complicated. The second requirement that defines component composition of blend is quantity of forming melt that should not be less than 70 % at temperature not exceeding 900 ^oC that is stated by results of previous experiments.

Taking into account requirements for frit synthesis two compositions of Na_2O-CaO-SiO_2 system were selected and conditionally named low and high alkaline. To obtain the frit of these compositions the relationship of components was calculated in the source batches given in Table 1. Preliminary viscosity characteristics of glass can be estimated according to viscosity module. The optimal foaming value of melt viscosity module is within limits 1.7 ± 0.1 [8]. The value of viscosity module is calculated by formula (1), it falls within recommended interval for both compositions.

$$M_в = \frac{M_{SiO_2} + 2\times M_{Al_2O_3}}{2\times M_{Fe_2O_3} + M_{CaO} + 2\times M_{K_2O} + 2\times M_{Na_2O}} \qquad (1)$$

where $M_в$ is viscosity module; $M_{Rm\,On}$ is quantity of corresponding oxides, mass %.

Table 1. Compositions of the source batches and frit obtained on its bases

Boundary compositions of frit	Calculated composition of frit, mass. %			Component composition of blend, mass %			Viscosity module
	Na_2O	CaO	SiO_2	Si-stoff	Soda	Dolomite	
Low alkaline	16	11	73	61.6	22.3	16.2	1.8
High alkaline	21	5	74	63	29.6	7.4	1.6

Thermal analysis of batches of the selected compositions shows that the main reactions of silicate and glass formation is completed at temperatures of 850 °C and 800 °C for low and high alkaline compositions, accordingly, that confirms possibility of frit synthesis at temperatures up to 900 °C.

After mixing all components bends were compacted by pressing method using water as binder in quantity of 6 %. The obtained briquettes were heat treated in muffle furnace at maximal temperature during 60 min. Then, the quantity of glass and residue crystalline phase in the frit were defined by data of X-ray phase analysis. It was established by experimental way that optimal temperature for synthesis of the low alkaline frit is 900 °C and one for the high alkaline frit is 850 °C. The quantity of glass phase in the low alkaline frit was 94 %, and one in the high alkaline frit was 97 %, the remaining crystalline phase was presented by non-dissolved residue quartz (Fig. 3), such quantity of glass phase is sufficient to foam.

Foam forming mixtures were prepared on the basis of the obtained floured frit with addition of soot in quantity of 0.7 % as gas forming agent. At foaming of glass with carbon, the gas forming processes go by reaction (2) and suppose presence of 0.1-0.4 % oxidizing matter in glass, for example, SO_3, As_2O_3, Sb_2O_3, and so on. In this case, the oxidizer was additionally added to the finished foam forming mixture as sodium sulphate.

$$glassSO_3 + 2C \rightarrow glassS_2^- + CO + CO_2 \quad (2)$$

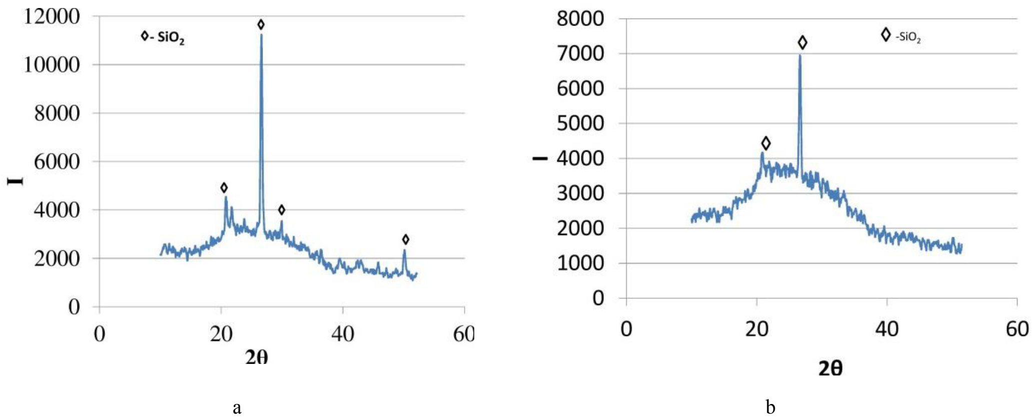

Fig. 3. X-ray pictures of the low alkaline (a) and high alkaline (b) frit

The finished foam material was obtained by heat treatment of granular mixture. After drying, granules foamed at temperature of 850 °C for 15 min. The main physical chemical properties (Table 2) were defined on granules obtained at optimal temperature – time mode. In whole, the obtained material is as good as conventional foam glass from broken glass and is distinguished by higher mechanical strength. Granulated foam glass crystal material is obtained on the basis of byproduct of acidic processing of aluminium bearing raw materials, it may be recommended as heat insulating material.

Table. 2. The physical chemical properties of the heat insulating material

Composition code	Bulk density (kg/m^3)	Compressive strength (MPa)	Heat conduction coefficient, W/(m·K)	Water absorption (wt.%)
Low alkaline	280 – 300	2.5 – 3.0	0.08 – 0.09	2.2 – 2.4
High alkaline	250 – 280	2.1 – 2.5	0.08 – 0.09	2.3 – 2.5

4. Conclusion

1. The principal possibility to use byproduct of acidic processing of aluminium bearing raw materials as the main component of the batch to obtain heat insulating material using low-temperature technology is stated.
2. The compositions suitable to obtain low-temperature frit and foam glass material on its basis are developed. The low alkaline frit contains 73 mass % of SiO_2, 11 % of CaO, and 16 % of Na_2O. The high alkaline frit contains 74 mass % of SiO_2, 5 % of CaO, and 21 % of Na_2O. With these compositions silicate and glass formation occurs at temperatures not more than 900 ^oC.
3. It is stated that the quantity of crystalline phase in the frit of both compositions does not exceed 6 % that assure optimal viscosity of the system in the foaming field at temperature of 850 ^oC.
4. The obtained foam glass crystalline material from the low temperature frit has improved physical chemical properties in comparison with conventional foam glass from broken glass and is distinguished by higher mechanical strength that is up to 3 MPa.

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