DOI 10.1007/s11148-014-9721-0
Refractories and Industrial Ceramics *Vol. 55, No. 4, November, 2014*

HEAT INSULATION MATERIALS MODIFIED WITH SILICA

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Translated from *Novye Ogneupory*, No. 8, pp. 25 – 28, August 2014.

Original article submitted May 6, 2014.

The possibility is demonstrated of preparing refractory heat insulation materials based on chamotte filler and kaolin wool using nanodispersed silica as a binder. It is established that with a change in molding mix parameters it is possible to obtain effective and highly efficient materials with density from 1.0 to 1.63 g/cm^3. The ultimate strength in compression of objects is 20 – 35 MPa.

Keywords: chamotte, kaolin wool, refractory heat insulation materials, nanosilica.

Recently under conditions of intense heating processes and an increase in energy efficiency developments in the field of new heat insulation materials for various branches of industry have become even more important. Heat insulation materials are varied and have quite contrary requirements: on one hand they should reduce the thermal conductivity of enclosing structures, and on the other they should exhibit structural properties providing prolonged heating unit service [1 – 4].

Different raw materials of natural and technogenic origin are used in the manufacture of heat insulation materials [5]. Nanodispersed silica may be a promising form of binder, and this material is used in the refractory industry as a modifying addition for low-cement concretes [6], and also for preparing composites based on a glassy binder [7]. In view of the this the aim of the present work is development of heat insulation materials that use nanodispersed silica Ludox (Grace Davison registered trade mark) grades SM, HS-30, AS-40, and TMA as a binder. This is an aqueous colloidal dispersion of silicon dioxide having an opalescent external appearance with a bluish color (light to moderate). The main properties of the Ludox grades used are given in Table 1.

The filler used in research work was kaolin wool whose properties are given below:

Content, %:
- Al_2O_3 . . . . 51 – 55
- SiO_2. . . . . 42 – 46

Application temperature, °C . . . . 1100 – 1200
Apparent density, kg/m^3, not more than. 130
Thermal conductivity at 600°C, W(m·K). 0.16
Heat capacity at 1000°C, J 1.047
Δm_{cal}, % 0.6

Vibration-ground chamotte was also used as a filler, containing, %: SiO_2 48.5, Al_2O_3 37.0, Fe_2O_3 1.2, TiO_2 1.6, MgO 1.5, K_2O 1.5. The pore-forming component for heat insulation materials was a foam-forming agent whose properties are provided below:

External appearance at 20 – 25°C . . . . . Uniform transparent liquid with light-yellow to brown color
Density at 20°C, kg/m^3 . . . . 1000 – 2000
Foam-forming agent hydrogen index (pH) . . . . 7.0 – 10.0

TABLE 1. Ludox Nanodispersed Silica Properties

Parameters	Grade*			
	SM	HS-40	AS-40	TMA
Counterpart ion	Na	Na	NH3	—
Content, %:				
SiO_2	30.0	40.0	40.0	34.0
Na_2O	0.56	0.41	0.05	—
NH_3	—	—	0.2	—
Maximum particle size, nm	7	12	22	22
Specific surface, m^2/g	360	240	140	140
pH	10.0	9.7	9.1	7.0
Relative humidity, %	66.4	59.0	58.0	64.0

* The surface charge of all grades of Ludox nanodispersed silica is minus.

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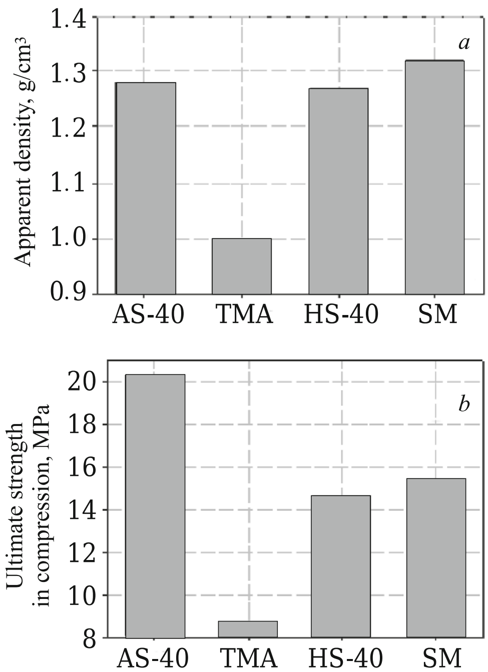

Fig. 1. Dependence of apparent density (*a*) and ultimate strength in compression (*b*) of heat insulation material specimens, heat treated at 1300°C, on Ludox additions of different grades.

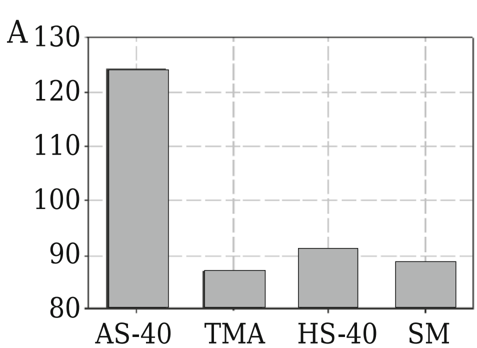

Fig. 2. Dependence of structural quality factor A for heat insulation specimens without kaolin wool, heat treated at 1300°C, on Ludox additions of different grades.

Ratio of working solution foam with volume faction of foam-forming agent of 4%, not less than 7.0
Foam stability, not less than 360
Toxicity . . . . Low-danger substance

Heat insulation materials were prepared by a foam method according to traditional technology [5], i.e., mixing foam, prepared previously on the basis of foam-forming agent, with addition of nanosilica and mineral component (vibration-ground chamotte). Kaolin wool was previously ground in a disintegrator, and then added together with the vibration-ground chamotte. Cubic specimens with a side of 50 mm were molded in metal knock-down molds by casting. Specimens were held in molds for one day, then the mold

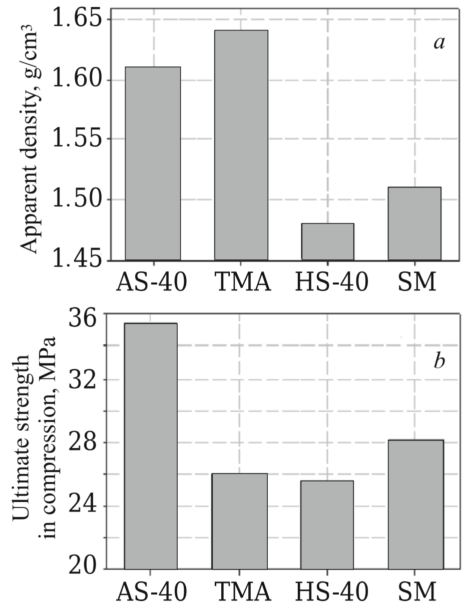

Fig. 3. Dependence of apparent density (*a*) and ultimate strength in compression (*b*) of heat insulation material specimens with addition of kaolin wool, heat treated at 1300°C, on Ludox additions of different grades.

was dismantled and specimens were also held for one day at room temperature. After this specimens were dried at 50°C for 5 – 6 h and 100°C for 24 h. Heat treatment was carried out at 1350°C with exposure for one hour.

In the first stage of the work the effect of different Ludox grades was studied on the properties of heat insulation properties based on vibration-ground chamotte, for this specimens were prepared containing, wt.%: chamotte 97, nanodispersed silica Ludox 3. The water to solid ratio was 0.33. The surfactant (SAS) used, which was added above 100%, was 3% aqueous foam-former solution. The main physicomechanical properties of the specimens obtained were studied for heat insulation materials after heat treatment (Fig. 1).

From analysis of the diagrams presented it follows that the minimum values of apparent density of 1.0 g/cm^3 and ultimate strength in compression 8.5 MPa are typical for the composition with addition of TMA, and the maximum strength of 20.5 MPa and high density of 1.2 g.cm^3 are typical for a composition based on AS-40.

For more precise evaluation of heat insulating material properties and comparison of them a design quality coefficient A was used in this work, which equals the ratio of strength to square of material density. All of the heat insulation materials were subdivided into dependence on values of design quality coefficient A into four groups [8]: low efficiency <50, efficient 50 – 125, highly efficient 125 – 200, and supermaterials >200.

Proceeding from data presented in Fig. 2, the greatest value of A (124) is typical for a composition within which the binder used was nanosilica grade AS-40, and specimens

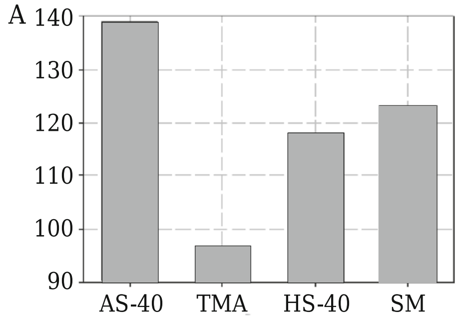

Fig. 4. Factor A for heat insulation specimens with addition of kaolin wool, heat treated at 1300°C, in relation to Ludox additions of different grades.

of the rest of the compositions have coefficient A 87 – 91, which is lower by 26 – 29%. All of the specimens of test compositions are classified as an effective type of heat insulation materials.

In the second stage of the work the possibility was considered of obtaining chamotte heat insulation material based on Ludox nanodispersd silica of different grades using addition of ceramic fibers in the form of kaolin wool. Ceramic fibers were previously mixed with foam, modified with nanosilica, and then the required amount of vibration-ground chamotte was added to the mixture. In each composition there was 96.85% chamotte, 3% Ludox, and 0.15% kaolin wool, and the water to solid ratio was 0.33. As in the first stage of the work, the surfactant was 3% aqueous foam forming solution. The formed foam mass was mixed by means of a laboratory propeller stirrer in order to prepare a uniform consistency and poured into a metal mold. Dried specimens were fired at 1300°C, after which the main physicochemical properties were determined. Results are shown in Fig. 3.

From analysis of the data presented it follows that the maximum strength of 35 MPa distinguishes the composition based on nanosilica grade AS-40, which is 20 – 25% higher than this index for specimens of the rest of the compositions. The minimum strength of 26 MPa is typical for specimens based on nanosilica grades TMA and HS-30, and the composition with TMA has the maximum density. The efficiency of specimens of heat insulation materials of the compositions studied was specified by values of coefficient A, and these are presented in Fig. 4. Specimens based on nanosilica grade AS-40 are classified as highly efficient heat insulation materials (A = 19), but compositions based on TMA, HS-30, and SM are classified as an effective group (A = 97 – 123).

Thus, as a result of this work it has been established that with use of different grades of Ludox nanodispersed silica as a binder it is possible to prepare efficient and highly effective heat insulation materials, and the most optimum grade is AS-40. Specimens with addition of AS-40 have the greatest values of ultimate strength in compression and structural quality coefficient. It has been demonstrated that due to changing the nanosilica grade, and additional introduction of kaolin wool to a molding mass, it is possible to prepare heat insulation materials with different density, i.e., from 1.0 t0 1.63 g/cm^3.

Research was performed within the scope of the program of strategic development of the V. G. Shukov BGTU.

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