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UTILIZATION OF ALUMINA CALCINING FURNACE DUST CONTAINING NANOPARTICLES

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A rational method is considered for utilizing alumina calcining furnace dust containing nanoparticles based on using technogenic alumina dust as a basic abrasive material component for decorative treatment of a natural stone surface.

Keywords: calcining furnace, alumina dust containing nanoparticles, abrasive material, natural stone, grinding, polishing, decorative treatment.

Currently up to 90% of the world aluminum production is based on the Bayer method, an important operation of which is calcination or roasting of aluminum hydroxide at high temperature in tubular rotary kilns or other equipment [1, 2].

As a result of thermal and mechanical action aluminum hydroxide is dehydrated and moves over a kiln length. There is a significant increase in material fineness with formation of a considerable amount of alumina dust, containing nanoparticles. Dust is extracted from a kiln by flue gases, and directed towards multicyclones and electric filters. The dust collected by electric filters as a rule is returned to a kiln and is mixed with production alumina.

Returned alumina dust containing nanoparticles in this case is returned ballast whose weight fraction reaches 14% of the overall amount of alumina obtained. Taking account of the fact that the annual volume of alumina production within the Russian Federation is estimated at 11.5 million tons, the weight of recycled alumina dust is a significant amount.

The main mass of alumina produced is used for preparing aluminum metal by electrolytic decomposition, and therefore mixing of coarse alumina with alumina dust is undesirable. The content of alumina dust nanoparticles due to increased hygroscopy is capable of absorbing a significant amount of atmospheric moisture. Hydrogen ions of absorbed water molecules, by discharging at an electrolysis bath cathode, increase aluminum metal hydrogen content, and this has an unfavorable effect on its properties [3].

We have performed a study of the properties of alumina dust containing nanoparticles, important for its pneumatic transport, and development of a rational method for its utilization.

Physicomechanical properties of alumina dust mainly differ from those of alumina. According to classification adopted in gas cleaning technology, dust of this size is an aerosol. For alumina dust there is typically a tendency towards caking and limitation of particle mobility, and this causes problems connected with its capture and discharge from bunkers, subsequent dispensing, and mixing. Dust of this class has a stable angle of repose and is poorly amenable to fluidization. Finely dispersed alumina dust, captured by electric filters, in the case of pneumatic transport should be classified as bonded loose loads, exhibiting limited particle mobility.

We dwell in detail on the physicomechanical properties of alumina dust. Results are given below for measurements of angle of repose φ for dust at different temperatures:

Alumina dust temperature, °C	20	60	100	140	200
Angle of repose φ, deg	60	55	50	45	40

Thus, with an increase in temperature from 20 to 200°C the angle of repose for alumina dust decreases by a factor of 1.5, i.e., with a reduction in temperature material outflow from a vessel deteriorates.

In addition, the external friction angle φ was determined for dust with respect to metal. Appropriate measurements

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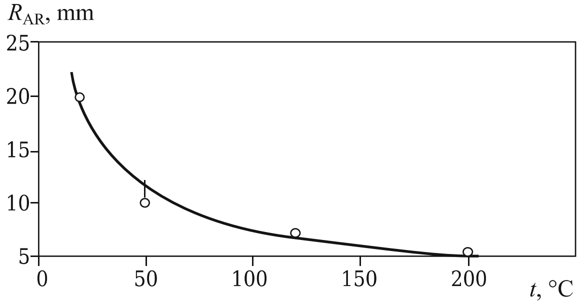

Fig. 1. Dependence of hydraulic radius R_{AR} on alumina dust temperature t.

were performed, recording the maximum uplift of metal a metal platform before the start of alumina dust movement.

At 20°C for alumina and a platform the average values of angle φ was 40°. On heating dust to 60°C and above it was observed to stick to the plate. In this case sliding of material over the platform was replaced by movement of material over material. When the platform itself was heated the external friction angle decreased significantly (to 5°), independent of alumina temperature. Consequently, on heating a steel vessel flow of alumina within it, and also its transport by dragging, for example by a flight conveyor, may be markedly intensified.

We note that with use of bunkers and silos in order to avoid arch formation during unloading the radius (in the case of a cylindrical-conical bunker) or half the side of a square (in the case of a prismopyramidal bunker) of the discharge opening should exceed the hydraulic radius (radius of greatest opening with which an arch does not form) R_{AR} for alumina. In this work the R_{AR} radius was determined in relation to alumina temperature, slope of the cone generating line, from which alumina flowed, to the horizontal, and height of a cone formed by flowing material [4 – 14]. Results of measurements showed that with an increase in dust temperature the hydraulic radius decreases by a factor of four (Fig. 1).

Finished technical grade alumina is moved from coolers through pipelines under action of compressed air with considerable velocity into tower silos. In this period, and also in settling from the top downwards in tower silos with a height of 20 – 30 m and diameter of 10 – 15 m, alumina is subjected to intense mechanical action. This again causes dust formation. Dust rises to the top and is captured in multibag filters. This dust also mixed with production alumina or sent to a dump [2].

TABLE 1. Dust Chemical Composition, %

Dust	Al_2O_3	R_2O_{tot}	SiO_2	Fe_2O_3	Δm_{cal}
1	Rest	0.69	0.12	0.06	2.80
2	The same	0.39	0.04	0.03	5.20

TABLE 1. Dust Fineness Composition, %

Dust	–15	15 – 26	26 – 40
1	88.2	91.2	94.1
2	72.0	92.0	96.0

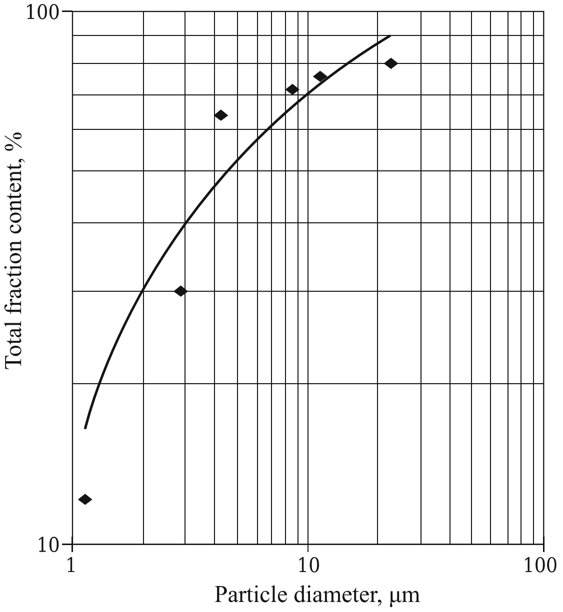

Fig. 2. Distribution of alumina dust fineness composition, $d_{50} = 4.4$ μm.

Alumina dust containing nanoparticles, collected in gas cleaning units in the course of a production process for preparing technical grade alumina, is subjected to intense heat treatment and mechanical action. From this point of view alumina dust may also be considered as a commercial product, exhibiting specific user properties. Therefore development of rational methods for using alumina dust is of practical interest.

In order to resolve this problem studies have been carried out for chemical, fineness, and phase composition of alumina dust captured on electric filters of a tubular rotary kiln (dust 1) and in multigbag filters of tower silos (dust 2) [2]. Corresponding results are presented in Tables 1 and 2.

Results of analysis showed that almost 90% of dust 1 is particles with a size less than 15 μm, whereas dust 2 from tower silos contains only 70% of these particles. Parameters were also determined for alumina dust from electric filters: the angle of repose $\beta = 54.973°$. bulk density $\rho_{bul} = 1685$ kg/m^3; true density $\rho_{tru} = 3160$ kg/m^3. OAO BAZ-SUAL electric filter dust fineness composition is given in Fig. 2. Collection conditions: air extraction through a rotameter $q = 10$ liter/min, air temperature $t = 25$°C.

It is well known that finely dispersed aluminum oxide is a required component for special high-quality cements, heat-resistant inert refractories, and abrasive materials [5]. This oxide is produced in considerable amounts in individual enterprises. Very fine dust may be used in production of special forms of sintered ceramic and electrocorundum. Mixed with refractory clay, particularly with addition of metal oxides and plastifiers, alumina dust may be the main raw material for producing high-alumina dense and heat-resistant ceramics, used extensively in ferrous and nonferrous metallurgy.

Alumina dust may be used as an additive in production of large high-alumina pipes for free extraction of raw material from gypsum molds, since it increases shrinkage during casting. It is possible to produce from alumina dust lightly fired foamed alumina cement, recommended for use in power units of flying equipment, guides, and other devices with existence of high temperature gas streams and aerodynamic vibrations.

In industrial glasses (sheet, bottle, table) contain 2 – 3% Al_2O_3, 1.2 – 5.0% Al_2O_3 is within the glass composition for electron beam television tubes, and about 1.5% aluminum oxide is within glass composition resistant to radioactive radiation and neutrons. Optical glasses contain 3 – 10% aluminum oxide, in glass for the production of glass fiber the Al_2O_3 content reaches 25%, and in glass for heat-resistant vessels it is 17 – 18%. Addition of alumina dust to a glass charge increases chemical and thermal strength of glass, surface tension, heat capacity, mechanical strength, thermal conductivity, and melt viscosity, significantly reduces the tendency of glass towards crystallization and reduces its linear expansion coefficient.

Application of a metal – aluminum oxide two-layer coating makes it possible to increase the life of metal objects operating in friction. Plasma coatings based on Al_2O_3 are used for application to the winding of aircraft generators, used for protecting wear of pump shafts, required in the production of synthetic resins, and teasing machine components.

A possible promising version of direct utilization of alumina dust is introduction into the composition of silicon carbide concrete instead of electrocorundum, which promotes mullite formation at lower temperature, thereby increasing concrete strength properties. Concrete strength on firing at 800°C with introduction of electrocorundum is 57.0 MPa, but with introduction of dust it is 64.3 MPa [15].

It is well known that alumina dust is applied as a proppant component, used in oil and gas recovery by seam fracking [16]. In a patent [17] alumina dust was used as a binder for preparing a charge for producing granules of aluminum-silicon raw material. In this work a version was considered of using of a alumina dust containing nanoparticles as the main component of required abrasive material, for examples decorative treatment of a natural stone surface.

Experimental abrasive materials have been prepared in the form of a consistent aqueous suspension with viscosity controlled by dilution. Suspension stability and uniform abrasive powder distribution throughout the whole volume of a suspension is provided by addition of organic binder substance. A universal modifier is added in order to improve the polishing capacity of a suspension, i.e., sodium silicate. The proportion in a suspension was determined by experiment and varied in order to realize its abrasive capacity both for fine grinding and for polishing, and to achieve high quality results without stone surface additional treatment by other materials.

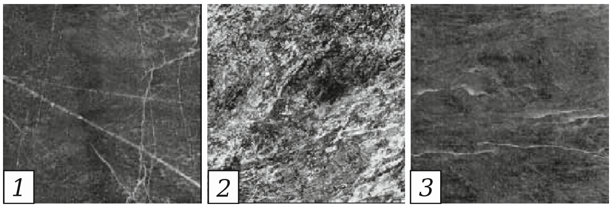

Fig. 3. External appearance of stone surface after polishing with experimental suspension based on alumina dust (×10): *1*) jasper; *2*) serpentine rock; *3*) nephrite.

Abrasive treatment of a stone surface with an experimental suspension was carried out in grinding and polishing machine by means of felted wheels, operating with applied suspension. Marble serpentine rock, and nephrite, used in production of wall plates, window sills, memorials, and other widespread objects made of natural stone, were treated. Taking account of the grain size composition of the original alumina powder, having relatively small particles, the stone surface was previously stripped and formed by coarse abrasive material, using corundum with a grain size of 80 – 100 μm.

On the basis of these experiments it has been established that a suspension containing alumina dust provides fine stone grinding. As a result of tis its surface becomes uniform and equally matt, without visible scratches and areas differing in luster.

Suspensions do not contaminate a stone surface, they are wetted well by water, and are ecologically safe. The productivity of grinding using suspensions is at a satisfactory level, comparable with productivity in the case of using widely used grinding pastes. Prolonged treatment of a stone surface with a suspension with the aim of polishing in the majority of cases makes it possible to achieve an intermediate result, corresponding to polishing for an average quality level (Fig. 3). In order to obtain a high quality mirror surface, giving stone especially good appearance, additional finishing polishing is necessary using special abrasive materials intended for removing fine polishing marks. An appropriate material is used, for example containing diamond powder with a fixed particle size from 10 to 14 μm. After this treatment a stone surface is uniform and equally matt, and there are no areas differing with respect to luster.

Thus, calcination kiln dust containing alumina nanoparticles may be used as basis for abrasive materials for general application, providing fine grinding and initial polishing of a natural stone surface. As possible finishing polishing of a stone surface requires preliminary fractioning of the alumina nano-containing dust with the aim of removing particles with a size of more than 14 μm.

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