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Research paper

Electrochemical modification of saponite for manufacture of ceramic building materials

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ABSTRACT

An effective method of recovering a saponite-containing product and desliming the circulating water of Severalmaz, JSC, has been proposed. The method is expected to enhance the efficiency of diamond recovery from ores and improve the ecological situation by introducing water recycling. Studies of the mineral composition have revealed a higher content of minerals of the smectite group in an electrochemically modified saponite sample (74.5% compared to the initial 68%) and lower (by 4%) quartz and dolomite contents. Using of electrochemically modified saponite in manufacture of building ceramics provides the product with enhanced compressive and bending strengths.

1. Introduction

The Archangelsk diamond-bearing province, discovered in 1980 and consisting of two diamond deposits named after V.P. Grib and M.V. Lomonosov, is the second largest diamond reserve in Russia after Yakutia (Gorkin, 2006). The Lomonosov deposit is the largest hardrock diamond deposit in European Russia accommodating ten kimberlite pipes (Snegurochka, Arkhangelsk, Piomerskaya, Lomonosov, etc.) with high-quality rough diamonds. Since commissioning of a processing plant in 2005, the Severalmaz JSC has been mining the Arkhangelsk pipe located in the province south.

Unlike the Yakutiya diamond province, with kimberlite pipes running through hard, solid rock, the country rock in the Lomonosov deposit pipes is almost totally displaced by clayey material (predominantly saponite). As revealed by research carried out by the Sergeev Institute of Environmental Geoscience of the Russian Academy of Sciences, the saponite content in the vent facies rocks is 90%, and it remains unaltered with depth. When in aqueous medium, this mineral generates a fine-grain gel-like suspension with particles under 7 μm which precipitate slowly and hinder the close-loop water circulation at the processing plant. As a consequence, the plant experiences a shortage of the required quality recycling water to be used in dressing circuits. The water shortage is particularly acute when the tailings pond is frozen and the concentration of clayey material exceeds 50 g/dm^3. The high content of clayey particles in the recycled water results in reduced recovery of diamonds at processing stages, increased consumption of chemical agent and pure natural water, diminishes the equipment lifetime, and causes environmental problems. It should be noted that none of the conventional techniques (gravity, filtration, reagent, physical and others) were successful in tackling the problem of recycled water clearing at the Severalmaz JSC plants.

In fact, saponite is a valuable marketable product with a broad range of applications in the following industries: foundry production and metallurgy, for pelletizing of iron concentrates and lubricating in rolled metal production; production of building materials; chemical industry, in sewage treatment; consumer goods industry, manufacture of adsorbents, paper and fabric filling, and emulsion balancer; medicine and pharmacology, manufacture of sorbents for body deintoxication, efferent action medications; mineral additive to fodder, increasing the grain and vegetables yield, and soil detoxication; food industry, for treatment of liquid organic media and potable water.

Saponite is a high-magnesium clay mineral, underclass of phyllosilicate minerals, smectite group. It contains Fe as an isomorphous impurity, sometimes Cr as well as Ni, Zn, Cu, Li, etc. (Colak et al., 2000). Saponite forms by weathering of mafic (magnesium-containing) minerals of ultrabasic rock (serpentine) and has the bentonite properties.

It is important to note that saponite and its capacity for modification have been intensively researched recently (Villa-Alfagemea et al., 2014; Gebretsadik et al., 2015). Thus, as reported in works (Nityashree et al.,

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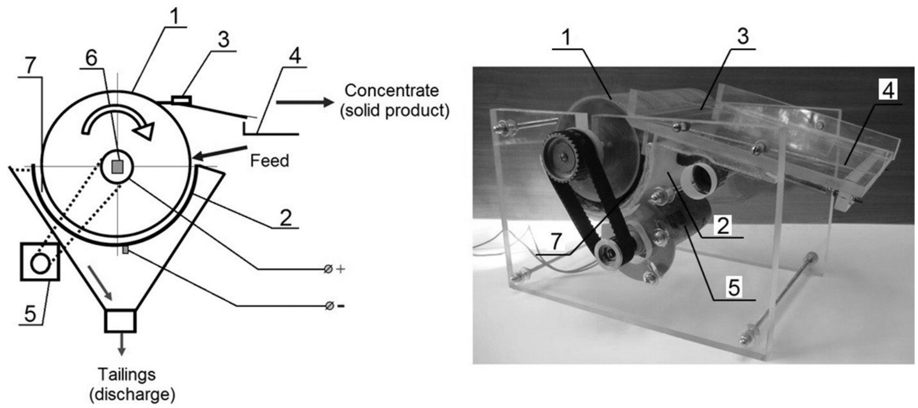

Fig. 1. Schematic diagram and outward appearance of the experimental laboratory electrochemical separator.

2014; Wang et al., 2015), saponite was used for synthesis of layered nanocomposites – attractive materials with a variety of properties and applications.

The only saponite deposit is located of the former USSR, Varvarovskoye, is now in Ukraine.

The purpose of our research was multiple, including the improvement of water circulation towards a higher diamond recovery in dressing circuits, mitigating of environmental hazard, and also substantiating a new source of a marketable saponite product.

Evidently, the slime volumes are so great that the consumer for the product can only be a resource-demanding industry, such as manufacturing of building materials. In recent years, much practical experience has been accumulated on the recovery of various industrial wastes, including dressing tailings and slimes, in production of ceramic materials (Suvorova et al., 2012; Contreras et al., 2014; Yang et al., 2014; Santos et al., 2015).

The Severalmaz JSC dressing tailings have also been analyzed for the possibility of converting them into building materials. Thus, a method has been proposed for controlling the water-cement ratio in the hardening concrete mixture by adding a fine-grained saponite-containing admixture, i.e. a thickened clay pulp (Morozova et al., 2015). The addition of a 7% saponite-containing material provided an almost two-fold increase in the concrete strength and improving of the frost-resistance brand to F150. It has been proved that the thickened saponite-containing material can be recovered as ceramic bricks (Oblitcov and Rogalev, 2012). The maximum compressive strength of the samples was 13 MPa. The same authors obtained a cement clinker of the 250 brand (75% of lime and 25% of thickened saponite-containing product) for the production of Portland cement.

2. Experimental

2.1. Methods

The electrokinetic potential of the mineral particles was determined by the electro-osmosis and electrophoresis methods using an electrophoretic cell described in work (Minenko, 2014) and a Zetasizer Nano ZS device.

The surface of saponite-containing products was examined with the aid of scanning electron microscopy (SEM) and the energy dispersive X-ray spectroscopy (EDS) at a LEO 1420VP analytical electronic microscope (supplied with an INCA Oxford 350 energy dispersive spectrometer) and JEOL JSM-6610LV.

The mineral composition of the electrochemical separation products was analyzed using the X-ray diffraction analysis (XRD) at an X'Pert PRO MPD diffractometer at 50 kV and 40 mA with CuKα radiation and graphite monochromator.

The differential scanning calorimetry (DSC) of the saponite samples was conducted at NETZSCH STA 449 F3 Jupiter® device affording a synchronous recording of the DSC and thermogram (TG) curves. The recording was performed at a rate of 10 °C/min, in corundum crucibles with closed lids, a weight of ~50 mg, in air or in argon.

The microscopic examination of the ceramic samples was performed using a Axioplan 2 imaging microscope.

2.2. Production of ceramic samples

The test ceramic samples were prepared in the following way. The dehydrated product was dried in air until the optimal moisture content

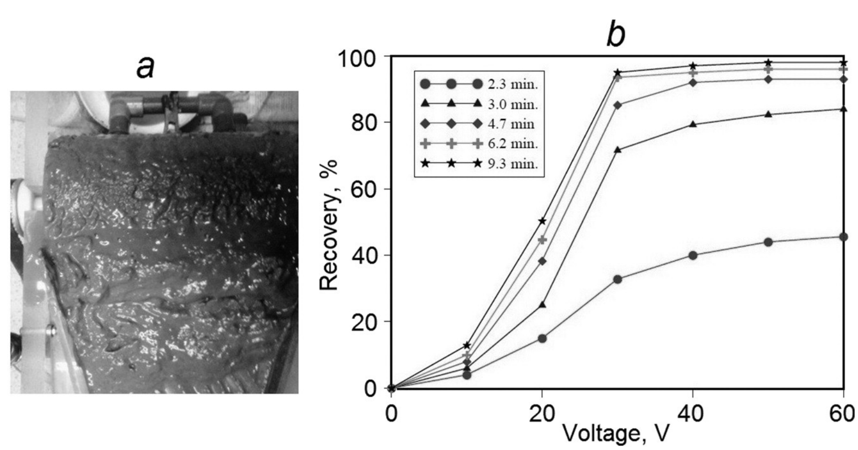

Fig. 2. Removal of clayey particles from the anode-drum of the electrochemical separator (a); recovery of clayey slime to thickened product versus the electrode voltage and time of electrochemical treatment of initial process water with containing about 200 g/dm^3 solids (b).