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Note

Comparison of hydrocyclone and flotation ability in reduction of kaolin ore calcite

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ABSTRACT

Kaolin, known as china clay, is a fine white clay with industrial usage. Kaolinite is the most common mineral in kaolin ores and iron, titanoferrous, and carbonate minerals are the major impurities. Calcium oxide (CaO) in carbonate form ($CaCO_3$) is the recent critical issue for Zonuz kaolin plant located in the North West of Iran. Therefore, a number of practical and inexpensive processing methods were tried on a raw crushed Zonuz kaolin sample. The sample contained 3.56% CaO. First, sizing based methods like sieve screening and hydrocyclone were tested, because of the smaller size of kaolinite particles compared with most other impurities. However, CaO was removed poorly, much Al_2O_3 was wasted, and Fe_2O_3 was enriched in the product. Then, flotation tests were performed on the raw ore. The results were remarkable, because of the highest calcite removal with the lowest Al_2O_3 loss and Fe_2O_3 enrichment. Although CaO content was reduced to 1.33% or even less in finer sizes using flotation, these finer sizes led to more Al_2O_3 loss. Acidic leaching was not evaluated, due to intense reaction between acids and $CaCO_3$, and damaging corrosive acidic conditions.

1. Introduction

Kaolinite ($Al_2O_3{\cdot}2SiO_2{\cdot}2H_2O$), an industrial mineral (Murray, 2000), is the most common mineral in kaolin ores (Kogel et al., 2006). Iron, micaceous, titanoferrous, and carbonate minerals are usual impurities (Chandrasekhar and Ramaswamy, 2002). General method of kaolin processing includes physical classification to remove sands, because clay minerals have particle sizes smaller than 4 μm (Weiss, 1985). Other processing methods, such as bleaching, flotation, magnetic separation, and flocculation are applied after classification to remove iron and titanium bearing minerals (Prasad et al., 1991; Murray, 2000). Asmatulu (2002) used both flotation and flocculation to remove titanium oxides, then dissolved the iron contaminants. Iron oxide removal using acids was also studied by Taran and Aghaie (2015). However, Hosseini and Ahmadi (2015) believe that microbial purification is preferred.

Carbon dioxide (CO_2) is given off before 900 °C from calcium carbonate, and leaves calcium oxide (CaO). This may produce pinholes in once fired raw glazed ware (Norsker, 1990). The CaO amount for crude product in Georgia kaolin is lower than 0.1% (Pruett and Webb, 1993). For the kaolin products manufactured in Brazil, the United States, and the United Kingdom, the CaO content is < 0.1% (Chandrasekhar and Ramaswamy, 2002). The acceptable content of CaO according to the selected properties of typical ceramic-grade products from Georgia is not > 0.4% (Kogel et al., 2002). Industrial limits of CaO, suitable for ceramics industry, are 0.1% (Abd El-Rahiem et al., 2009).

More than 70% of calcite was floated in Syrian kaolin ore by Abd El-Rahiem et al. (2008), and CaO amount decreased to 0.10% from 11.75%. Approximate 1000 g/t oleic acid and 1000 g/t sodium silicate were used as calcite collector and kaolinite depressant, respectively.

As a result, iron and titanium widely are removed from kaolin by various processing methods. However, calcite removal from high-calcite kaolin ore has rarely been investigated and reported. Recently, increase in calcite content in Zonuz kaolin ore (Marand, Iran) resulted in decreasing product quality. Therefore, removing of calcite in the kaolin processing plant is necessary. This research primarily emphasizes on the evaluation of appropriate methods for calcite removal from a high-calcite Zonuz kaolin ore. The studied methods include sizing (screening and hydrocyclone) and flotation.

2. Materials and methods

2.1. Sample characterization

A representative high-calcite kaolin sample (≈ 300 kg) was taken from Zonuz kaolin crushing unit. The detected chemical composition of the prepared sample by XRF is presented in Table 1. Despite in most of the kaolin ores, the TiO_2 amount in Zonuz kaolin ore is significantly low. Based on the XRD analysis (see Fig. 1), quartz and kaolinite are the

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Table 1
Chemical composition of the kaolin sample detected by XRF (%w/w).

SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	Na_2O	K_2O	L.O.I	Total	Quartz[a]
68.23	18.21	0.39	0.028	3.56	0.24	0.01	0.39	8.62	99.68	46.77

[a] Stoichiometric calculated content.

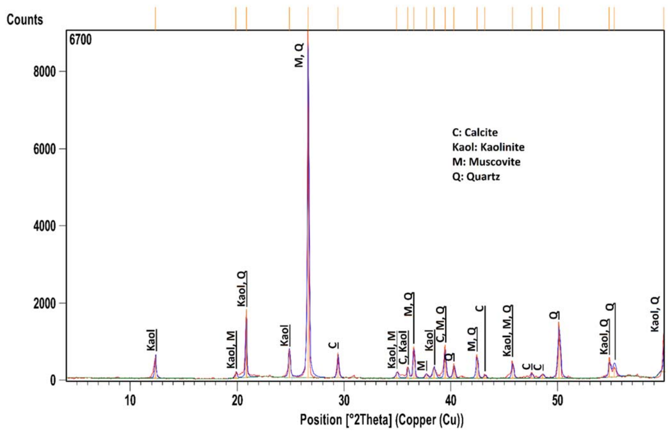

Fig. 1. XRD patterns (Model: Philips PW1800, 40 kV, 30 mA, Cu K-alpha, Ni Filter).

major mineralogical phases, and calcite and muscovite are the minor ones. Therefore, calcite was detected as the main CaO bearing mineral. Microscopic study proved that > 75% of calcite is liberated in − 300 + 200 µm size fraction. Mineralogical studies by XRD demonstrated limonite and hematite are less than detectable limit. Minerals such as quartz (a silicate), hematite and limonite (iron oxides), and calcite and dolomite (carbonates) were observed in the mineralogical polished and thin sections made of five size fractions from 300 µm to 37 µm (totally 10 sections). Sample pictures of four of all 10 sections are depicted in Fig. 2. Thin sections were viewed under polarized-light microscope, and polished sections were observed under reflected-light microscope.

Bond work index (W_i) for the sample is 9.15 kWh/t. Work index, which is an experimental parameter, expresses the resistance of the material to crushing and grinding from theoretically infinite feed size to 80% passing 100 µm. Higher work index means more required energy to break the ore. Bond work index is calculated by Bond's equation (see Eq. (1)). The work input in kWh/t is W and the sizes in µm which 80% of the product and feed pass are designated as P_{80} and F_{80}, respectively. A number of methods like standard Bond test, batch-type tests, and comparative method were defined to measure/estimate ores work index (Wills and Napier-Munn, 2006). In this case, standard Bond's ball mill test was applied.

$$W = 10W_i \times (1/\sqrt{P_{80}} - 1/\sqrt{F_{80}}) \quad (1)$$

3. Methods

3.1. Sizing

Screening was performed on the crushed sample using ASTM E11 standard sieves.

Sizing by hydrocyclones is the principal processing method in Zonuz kaolin plant. Therefore, numbers of tests were conducted using a laboratory hydrocyclone. Feed size and hydrocyclone drop pressure were selected as variable parameters. The internal and underflow (apex) diameters of the used hydrocyclone are 25 mm and 3 mm, respectively.

3.2. Fotation

Reverse flotation was used to remove calcite, because of its lower grade in contrast to kaolinite, and consequently lower need for

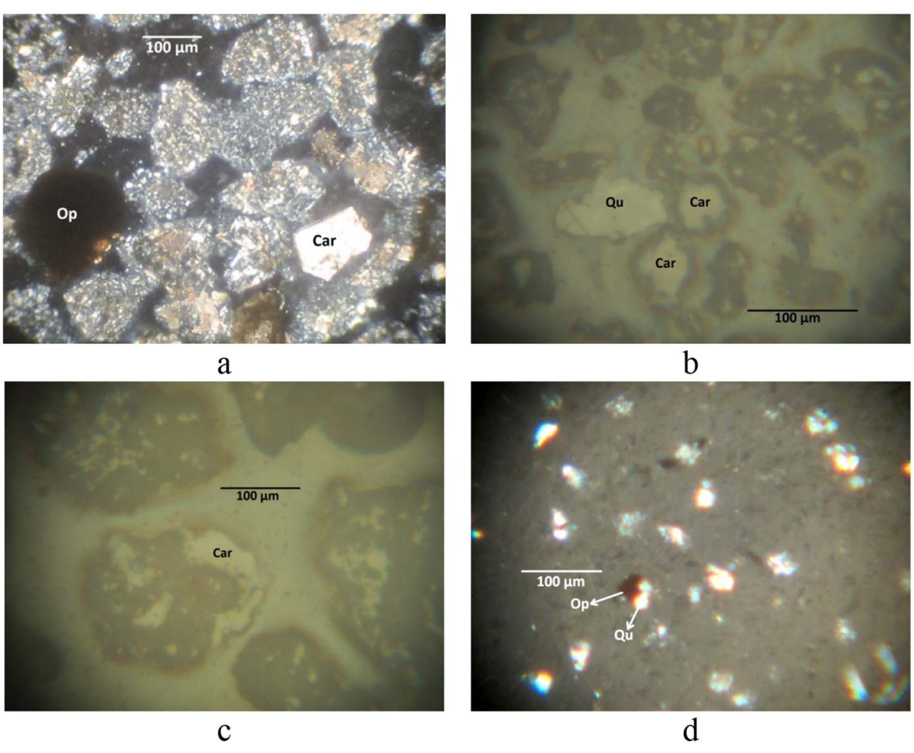

Fig. 2. Microscopic mineralogy, a) − 150 + 100 µm thin section, liberated carbonated and opaque minerals, b) − 300 + 200 µm polished section, liberated crystalline quartz and carbonated mineral, c) − 63 + 53 µm polished section, locked carbonated mineral, d) − 44 + 37 µm thin section, locked opaque mineral and quartz: Car, Op, and Qu are the symboles of carbonated minerals, opaque minerals like hematite and limonite, and quartz, respectively.