Use of Pinched Sluice in Albite Concentration

Ercan POLAT[1], Ali Arda AKSOY, Arzu BOZKAYA, Sedanur TUNÇ, Mehmet KÜÇÜKLER, Taki GÜLER[2]

[1] Muğla Sıtkı Koçman University, Mining Engineering Department, Muğla, Turkey; email: epolat@mu.edu.tr
[2] Prof. Dr.; Muğla Sıtkı Koçman University, Mining Engineering Department, Muğla, Turkey; email: takiguler@mu.edu.tr

Abstract

Albite ($NaAlSi_3O_8$) is an important industrial mineral especially for ceramic and glass production. Major Fe-containing impurity of albite ore is flaky mica minerals. This study was conducted to determine the applicability of pinched sluicing for pre-concentration of albite ore by exploiting shape effect. Effects of feed solid rate, tilting angle of pinched sluice, and splitter position on the rejection of Fe-containing flaky mica were tested. Pulp solid rate was determined to be the most important variable on the rate of mica rejection. Increasing the tilting angle adversely affected the separation efficiency especially above 17°. Distribution of gangue mica in the vertical cross-section of flowing film was tested manipulating the splitter height. Mica particles were observed to be crowded in upper layers of film thickness. So, flaky mica impurity was thought to be separated from feldspar ore, and a pre-concentrate was obtained. All Fe-containing coloring impurities could not be removed due to different mineralogical origins of them in the ore. Optimum operating variables were determined as follows: 56% feed solid rate, 17° tilting angle of pinched sluice, and splitter height lower or closer to 2/3 of the total pulp film thickness. Pulp solid rate of underflow stream almost linearly changed with respect to splitter height.

Keywords: albite; mica; gravity concentration; shape effect

Introduction

Albite ($NaAlSi_3O_8$) is an alumina-silicate mineral, and a member of feldspar group minerals.

Its specific gravity is about 2.62 g/cm³, and it has a Mohs hardness of 6-6.5. It is exploited mainly in ceramic and glass industries. Welding, paint, rubber and plastic productions are other important consumption areas of albite as filling material. Albite may present in Earth crust with Fe and Ti containing minerals, free quartz, and mica minerals. Fe and Ti oxides may come both from mica minerals and other oxides. Mica is the major gangue of albite ores. Generalized formula of mica minerals is given as "X2Y4-6Z8O20(OH,F)4", where X is K, Na or Ca; Y is Al, Mg or Fe; Z is Si, Al, Fe^{+3} or Ti. Its specific gravity varies between 2.8–3.2 g/cm³ depending on the types and rate of cations present in crystal structure (Marchal, 2014).

Quality of albite ore or concentrate is defined especially by Fe and Ti contents. They are classified as coloring impurities, and adversely affect the product quality. Therefore, Fe- and Ti-oxide grade of albite should be lower than 0.1% both for glass grade and ceramic grade concentrates (Bayraktar et al., 1998; Hacıfazıloğlu et al., 2012). Albite is concentrated traditionally by hand sorting, magnetic separation and flotation to reduce coloring impurities. Hand sorting is applied on the coarsely liberated feldspar ores utilizing the features such as brightness and color. Size reduction and classification may be applied to separate mica, major impurity of albite, due to its characteristic breakage property. It exhibits different breakage shape and the cleavage properties. Albite is crushed and ground producing irregularly shaped angular particles whereas comminuted mica minerals will keep their flaky shape. Thus, it is possible to separate the mica and albite from each other to obtain pre-concentrate only by classifying the liberated ore. Compared with albite, mica minerals and Fe-oxides exhibit different magnetic susceptibility. Then, magnetic separation is applied extensively in albite concentration (Amaranta et al., 1997; Bayraktar et al., 1998). Flotation of feldspar ore is generally applied using oxyhydryl type collectors together with amines. HF is usually used as modifying agent to satisfy selectivity although it is known to be an environmentally hazardous and corrosive chemical (Amaranta et al., 1997; Karagüzel and Çobanoğlu, 2010; Vidyadhar et al., 2006).

Pinched sluice is the simplest gravity equipment. It is a V-shaped concentrator that narrows down at the discharge end. As the feed pulp is crowded into a progressively narrower discharge opening, the heavy materials tend to migrate towards the bottom, and the lighter material is forced up over the heavy minerals. It is preferred in the beneficiation of beach sands. It is not a widely used concentrator due to low upgrading ratio in a single pass. On the other hand, its operating cost is significantly low as compared with the conventionally used gravity concentrators because it is a static separator, and need only pumping the pulp (Ergün and Ersayın, 2002; Jeyadevan and Subasinghe, 1990).

Efficiency of gravity separation depends not on only density difference and particle size but also on the shapes of valuable and gangue particle. Resultant total buoyancy force applied on a particle surface in

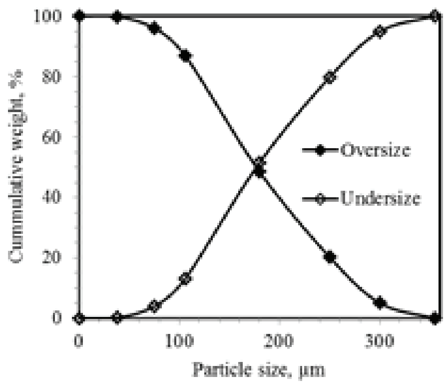

Fig. 1 Size distribution of albite ore sample

Rys. 1. Skład ziarnowy albitu

Tab. 1. Chemical composition of tested ore sample

Tab. 1. Skład chemiczny nadawy

	Oxide content, %								Loss on ignition, %
	SiO_2	Al_2O_3	Na_2O	K_2O	Fe_2O_3	TiO_2	CaO	MgO	
Sample	70.436	17.736	9.166	0.600	0.509	0.147	0.584	0.228	0.605

upward direction increases by an increase in deviation from ideal spherical shape. So, by the deviation, drag coefficient increases causing decreased terminal velocity (Ofori-Sarpong and Amankwah, 2011). This is the encouraging phenomenon to apply gravity methods on the separation of valuable and gangue minerals having closer specific gravities with different morphologies. This study was performed to investigate the applicability of pinched sluicing on the separation of flaky mica impurities from irregularly shaped angular albite particles.

Materials and methods

Ore sample was supplied from a feldspar beneficiation plant in Muğla, Turkey. Sample was taken in the ground and liberated form from feed stream of concentration circuit. Size distribution of sample was determined applying sieve sizing experiment (Figure 1). Majority of sample was observed to be above 100 μm. Mineralogical and chemical characterizations of sample were performed by XRD and XRF methods. Chemical composition of ore sample was given in Table 1. XRD results revealed that major constituent of ore was sodium feldspar ($NaAlSi_3O_8$) while mica minerals and rutile (TiO_2) were the gangue minerals.

Pinched sluice tests were made using a laboratory type pinched sluicing circuit. Components of experimental setup were a pinched sluice having 100 cm length, agitation tank, pumping and circulating system, and a pulp feeding unit. Feed side length of sluice was 22 cm and product end was 3.5 cm. Sluice was made from chromium steel. Feed was continuously circulated between tank and sluice using a pump. Pulp was agitated in the tank to avoid settlement of solid.

The tested operating variables in pinch sluice concentration process were feed pulp solid rate, inclination of sluice and splitter position. Pulp solid rate was varied between 47–65%. Tilting angle was adjusted to 13°, 15°, 17° and 19°. Splitter position was set to a certain value depending on the flowing film thickness using following equation, where RSH was “Rate of Splitter Height”. RSH was adjusted to 0.2, 0.4, 0.6 and 0.8.

$$RSH = \frac{\text{Splitter Height}}{\text{Total Thickness of Flowing Film}} \quad (1)$$

Results and discussions

Size reduction process of feldspar ore produces fine mica particles in the laminated-like form whereas comminuted albite particles have irregularly shaped angular form. Therefore, terminal velocity of mica particle is expected to be lower in a fluid medium than that of albite having the same size in spite of its higher specific gravity (Ofori-Sarpong and Amankwah, 2011; Piazza et al., 2013). Based on this phenomenon, pinches sluicing was applied to separate mica impurity from feldspar ore. In a flowing film, mica minerals were expected to be forced to upper layers of a flowing film due to shape effect. Flowing film was split into two streams at the discharge end of pinched sluice. Underflow stream was evaluated as concentrate, and mica-rich overflow stream was defined as tailing.

Solid rate is an important variable in pinched sluicing process (Ergün and Ersayın, 2002). Therefore, its

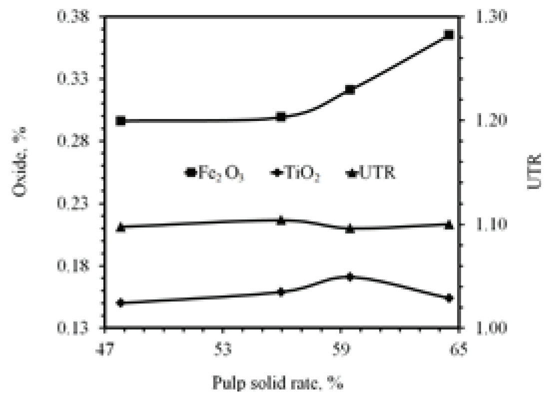

Fig. 2 Effect of solid rate on oxide content of underflow stream, and thickening rate

Rys. 2. Zależność zawartości fazy stałej od zawartości tlenków w strumieniu dolnym i zagęszczenia

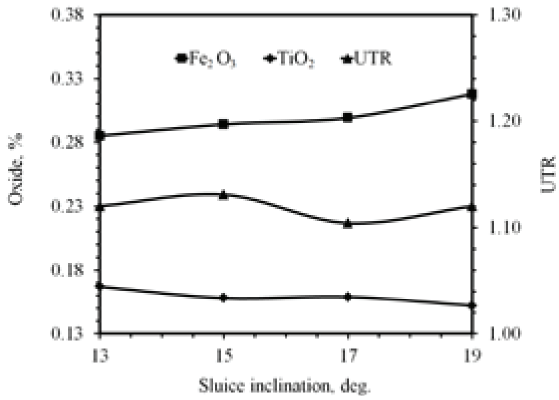

Fig. 3 Effect of inclination on oxide contents of underflow stream

Rys. 3. Wpływ kąta nachylenia na zawartość tlenków

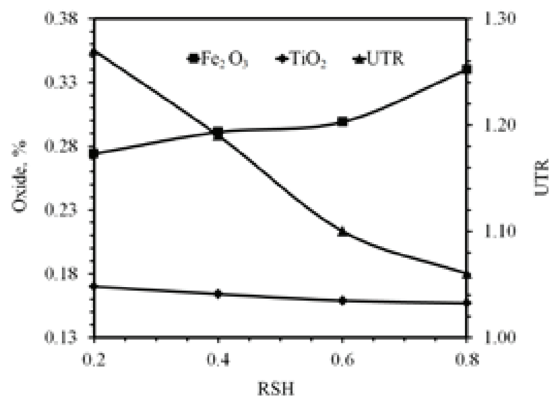

Fig. 4 Effect of splitter position on oxide content

Rys. 4. Wpływ położenia przegrody na zawartość tlenków

effect on separation efficiency was tested first. Figure 2 shows the effect of solid rate on Fe- and Ti-oxide grades of underflow stream in addition to the thickening ratio. Underflow thickening ratio (UTR) was calculated using equation (2). Solid rate in the underflow stream did almost proportionally increased with the increase in feed solid rate. Then, UTR value did not change with feed solid rate.

$$UTR = \frac{\text{\% Solid in Underflow Stream}}{\text{\% Solid in Feed Stream}} \quad (2)$$

Fe-oxide content did almost not change up to 56% solid rate. At higher solid rates, detrimental effect was observed on separation efficiency (Ergün and Ersayın, 2002). Rate of mica minerals, major source of iron oxides, increased in dense pulp conditions, and efficiency of pinched-sluicing decreased. On the other hand, solid rate slightly affected the TiO_2 content of concentrate. Up to about 60% feed pulp solid rate, slight increase in the Ti-grade of underflow stream was distinguished. Mineralogical characterization indicated that Ti was mainly found in the form of rutile mineral in sample. Rutile has reasonably high density (≈4.25 g/cm^3) as compared both with mica and albite. Therefore, increase in rutile grade might be viewed as that the gravity separation became apparent at higher feed solid rates (Ergün and Ersayın, 2002; King 1987). However, at the highest tested solid rate, its grade decreased possibly due to the deterioration in layer formation in the cross-section of the flowing pulp film (Jeyadevan and Subasinghe, 1990). Sharp increase in Fe_2O_3 grade at the highest solid rate did also pointed out the deterioration of separation.

Figure 3 shows the effect of sluice tilting angle on feldspar concentration. Fe-oxide grade of underflow stream increased gradually up to 17°, and then increase became steeper. Similar but inverse relation was observed in the case of TiO_2. Increase in the sluice inclination exhibited detrimental effect on segregation and layering of Fe- and Ti-containing components of ore sample. This finding became apparent especially above 17° possibly due to increasing flow rate of feed pulp. Flaky mineral particle could not find enough time to go to the correct stream by increasing the inclination (Ofori-Sarpong and Amankwah, 2011; Piazza et al., 2013). So, higher tilting angle caused higher rate of mica recovery in the concentrate. However, such a clear result was not observed in thickening ratio possible due to increased flowing speed of pulp film.

Splitter position is an important variable in pinched sluicing. It was manipulated to demonstrate the vertical classification of minerals depending on particle shape (Figure 4). Towards discharge end of sluice, flaky-shaped and low specific gravity particles are forced to upper levels of flowing film thickness while more spherical and high density particles settle down to lower levels of flowing film (King, 1987; Ofori-Sarpong and Amankwah, 2011; Piazza et al., 2013). Fe grade of underflow stream increased gradually up to 60% of total pulp thickness. It became closer to feed grade at higher splitter levels.

Ti-oxide content, on the other hand, decreased continuously. It drew a mildly inclined smooth line. Effect of splitter height was predominant on thickening ratio.

Conclusion

Use of pinched sluice concentrator in the beneficiation of Na-feldspar (albite) ore was investigated utilizing the shape effect of particles. Study was performed to remove flaky mica particles, major

Fe-oxide source in the ore sample, from irregularly shaped angular albite particles. Mica impurity could be separated from feldspar ore, and a pre-concentrate was obtained. All Fe- and Ti-containing coloring impurities could not be removed due to different mineralogical origins of them in the ore. Optimum operating variables were determined as follows: 56% feed solid rate, 17° tilting angle of pinched sluice, and splitter height lower or closer to 60% of the total pulp film thickness. Pulp solid rate of underflow stream almost linearly changed with respect to splitter height.

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Wykorzystanie wzbogacalnika poziomo-prądowego do wzbogacania albitu

Albit ($NaAlSi_3O_8$) jest ważnym surowcem przemysłowym, szczególnie w ceramice i produkcji szkła. Najważniejszymi zanieczyszczeniami żelazowymi występującymi w albicie jest łuskowata mika. Celem badan było określenie mozliwości wykorzystania wzbogacalnika poziomo-prądowego do wstępnego wzbogacania albitu z wykorzystaniem alnalzy kształtu.

Badano wpływ natężenia pzepływu nadawy, zawartości fazy stałej, geometrii strugi nadawy na ekekt wydzielenia miki zawierającej zanieczyszczenia minerałami żelaza. Zawartość fazy stalej w nadawie została określona jako najważniejszy czynnik wpływajacy na efektwośc procesu. Zwiększenie kąta nachylenia komory roboczej niekorzystnie wpływało na separację, szczególnie powyżej 17°. Badano wpływ rozdział miki w przekroju poprzecznym strumienia nadawy. Ziarna miki koncentrowały się w górnych warstwach strumienia. Stwierdzono, że drobne ziarna miki oddzielają się od rudy skaleniowej i można otrzymać prekoncentrat. Z uwagi na sposób występowania zanieczyszczeń nie można wydzielić wszystkich zanieczyszczeń barwiących. Okreslono optymalne parametry procesu: zawartośc fazy stałej w nadawie 56%, kąt nachylenia rynny podawczej 17°, a wysokość rozdzielacza strugi niższa od 2/3 całkowitej grubości warstwy materiału.

Słowa kluczowe: albit, mika, wzbogacanie grawitacyjne, efekt kształtu