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THE ROLE OF PARTICLE SIZE AND SOLID CONTENTS OF FEED ON MICA-FELDSPAR SEPARATION IN GRAVITY CONCENTRATION

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Abstract. In the present study, the role of particle size of mica with flaky shape on the separation efficiency of mica from feldspar by the shaking table and Reichert spiral (Model HG7) concentrators were investigated. An albite ore containing mica from the Cine region of Turkey was treated under various test conditions. During the study, particle size distribution, solids content of the feed and flow rate of the feed were changed in the spiral tests. Then, the flow rate of the feed was kept constant as 1 dm^3/s in the shaking table tests. It was observed that mica could be separated from feldspar, owing to its laminar morphology. Accordingly, the particle size, directly related to the laminar morphology of mica, is the most effective parameter in the separation process. The best results were obtained with spiral concentrators, which met the requirements of the glass industry.

keywords: shaking table, spiral, mica, shape factor, gravity concentration

1. Introduction

Mica is the primary source of iron in feldspar minerals, which causes colouring in ceramic and glass. The most common method for separating mica from feldspar is flotation. Nevertheless, flotation has some disadvantages such as detrimental effects on the environment because of chemical use, high investments and operation costs (Akar, 1994; Bayraktar et al., 1999; 2002; Celik et al., 1998; 2001). The separation does not always take place under conditions which are convenient for the concentration criterion. In order to allow for the differences in the particle shape, the concentration criterion must be multiplied by the shape ratio factor (Burt, 1984). When there is a marked difference in particle shape, the concentration criterion, which is the density of the heavy species minus the density of suspending fluid, divided the density of light species minus density of suspending fluid, approaches 1.0. Typical of this is the separation of mica from quartz and feldspar (Browning, 1973).

Mica and feldspar are close to each other in respect to their density. The densities of feldspar and mica minerals are approximately 2.65 and 2.7-3.4 g/cm^3, respectively (Ipekoglu and Asmatulu, 1996). As mentioned by Iverson (1932) the difference

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between their densities is not sufficient in achieving the efficient separation of these minerals by using gravity methods. Coarse mica grains are nearly equi-dimensional and spherical. However, in fine sizes the flaky shape character of the mica minerals is revealed. Mica normally takes the form of numerous single flakes, which are pliable, resilient and tough, and can be separated like the pages of a book (Schoement, 1989). This physical characteristic of the mineral has been responsible for its separation by gravity from feldspar. This distinguishing property of fine mica particles was first reported by Iverson (1932). He managed to separate mica from feldspar by tabling. Later, Adair et al. (1951) also showed the possibility of concentration of mica in the Humphrey spiral. Therefore, this method is considered as an alternative method to mica flotation.

The purpose of this study was to investigate the separation characteristics of mica from feldspar in a shaking table and the Reichert spiral by determining the role of the shape factor of mica in terms of particle size distribution and feed solids content on the separation efficiency. Industrial scale equipments were used in this study, in order for the results to be applied to the industry directly.

2. Materials and methods

The Na-feldspar (albite) samples were obtained from a feldspar deposit in the Cine Akmaden, which is in the Southwest of Turkey. The chemical composition of the samples used in the tests is given in Table 1. The samples were crushed with a jaw crusher to 2 cm of size, and then were gradually reduced with a roll crusher. The particles, finer than 74 µm, were removed by dry screening in order to prevent their adverse influence on the separation. Five samples with different size fractions and grades were prepared and tested (Table 2). The particle size distributions were given in Fig. 1.

Table 1. Chemical composition of feldspar sample

Content	%
SiO_2	65.01
Al_2O_3	20.09
Fe_2O_3	0.73
MgO	0.20
CaO	1.82
Na_2O	10.20
K_2O	0.48
TiO_2	0.25
L.O.I	0.42
Total	99.40

First of all, the tests were carried out in the Reichert spiral (HG7). The spiral was operated in a closed circuit, which included a tank and a pump. There were two splitters at the discharge. The position of the outer splitter was not suitable for controlling product streams due to the occurrence of a big gap largely free of particles between the tailing and the concentrate streams during the tests (Fig. 2). Therefore, this splitter was fixed for all conditions in the main series of the tests. The position of the inner splitter was adjusted to ¼, ½ and ¾ of the maximum opening (16 mm, L). Samples were fed into a spiral. Feldspar minerals, in the samples in the form of pulp, were moved close to the centre of the spiral, whereas the mica minerals were moved to the wall side of the spiral.

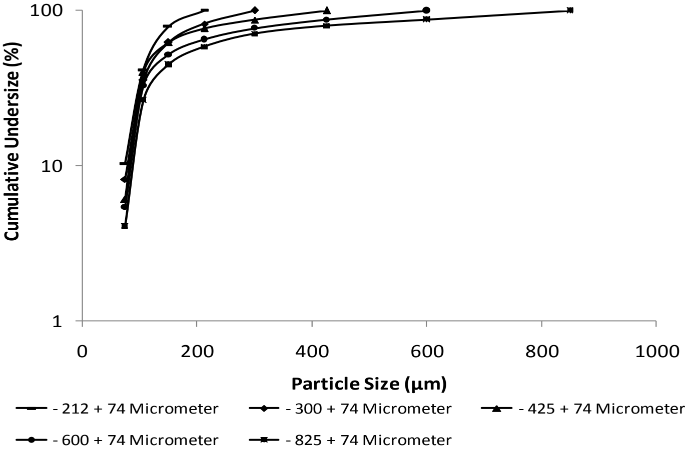

Fig. 1. Particle size distributions of feed sample

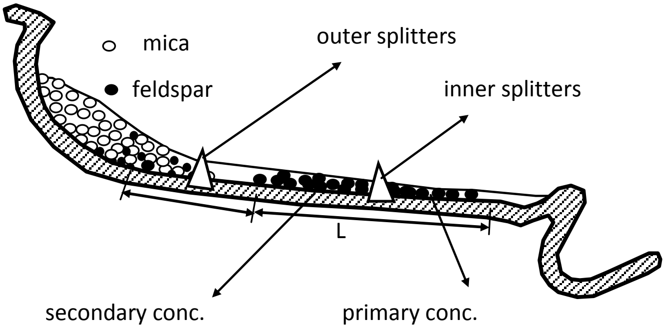

Fig. 2. The view of the spiral discharge

At the beginning of the tests, primary and secondary concentrates, and tailing were obtained as shown in Fig. 2. The Fe_2O_3 grades of the concentrates were determined by chemical assaying. The results showed that there was no significant difference between the primary and secondary concentrates.

Table 2. Chemical compositions of spiral feed and fines (–74 μm) fractions

Size fraction (μm)	Wt. % (Fines, -74μm)	Fe_2O_3 % (Fines, -74μm)	Fe_2O_3% (Feed)
-850 +74	4.20	0.03	0.74
-600 +74	5.28	0.06	0.74
-425 +74	7.10	0.07	0.76
-300 +74	8.54	0.08	0.77
-212 +74	10.25	0.12	0.78

Therefore, only one set of concentrate data representing the average characteristics of the two concentrates, and one set of the tailing data were used in the evaluation of the effect of particle size, solids % of feed and flow rate of feed on separation process. It was also not necessary to take a middling stream by using a second splitter in the separation process. Particle size distributions were:- 850 + 74 μm, - 600 + 74μm, - 425 + 74 μm, - 300 + 74 μm and – 212 + 74 μm. Pulp solids contents for these particle sizes were 15%, 20% and 25% by weight and flow rates were 1 dm^3/s, 1.5 dm^3/s and 2 dm^3/s in all tests. The 45 different conditions were tested and results of chemical assays were evaluated. Accordingly, the flow rate was fixed to its best value as 1 dm^3/s. The favourable conditions were tested in shaking table and results were compared to spiral concentrator.

The shaking table was operated as batch processes. There were two determined discharge units in the equipment. The positions of the discharge units were fixed for taking products as a primary concentrate, secondary concentrate and tailing. Samples were fed into the shaking table; the samples were moved in specific directions, which the mica minerals were moved with water in a vertical direction to the movement of the table because of the flaky shape while the feldspar minerals were followed table movement (Fig.3).

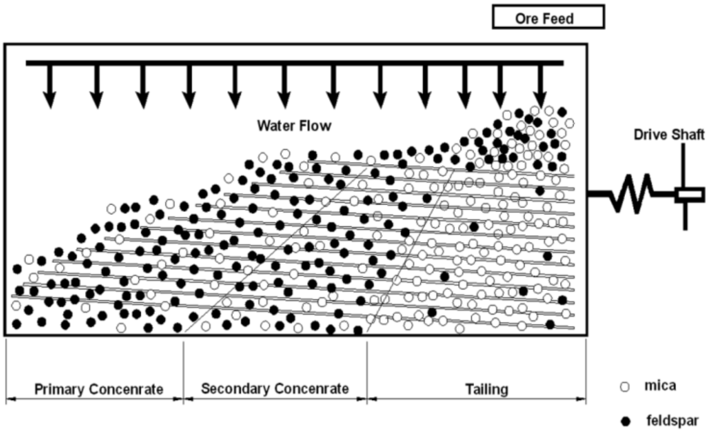

Fig. 3. The view of the shaking table discharge

Samples were taken simultaneously of primary and secondary concentrates and tailings during the tests in both concentrators. Prior to each test, the equipment was discharged, cleaned, and then operated in a manner appropriate to the new feed and solid contents. In order to make a comparison between the two methods, the concentrates of the shaking table were treated in the same way, one set of concentrate data representing the average characteristics of the two concentrates, as spiral concentrator. This enables the process to be used and controlled easily on the plant-scale

3. Results and discussions

In this study, the effect of the solids density of feed, the flow rate of feed and the flaky shape of mica, which depends directly on particle size, on the separation efficiency of mica from feldspar in a spiral concentrator were investigated. The favourable conditions were tested in shaking table by keeping flow rate constant at the value of 1 dm^3/s. The particle size distributions were varied between and -850 +74 μm and -212 +74 μm and solids % of feed were varied 25% to 15% by weight. These ranges stayed within the normal industrial operational limits of both equipments.

In the spiral concentrator, the major parts of the water in the feed were accumulated at the outside of the separation surface, carrying most of the flaky mica with it. The feldspar particles were moved predominantly to the inner part of the surface, forming a natural gap between the concentrate and the tailing streams. Therefore, the outer splitter was not very effective in controlling the concentrate quality. During the separation, the outer splitter was roughly adjusted by a visual judgement of the best position. The chemical analysis of the concentrate results for both concentrators (spiral and shaking table) are shown in Table 3.

Table 3. Fe_2O_3 grade of concentrates and mass recovery

	Particle Size (μm)	15% Solids Grade (%)	20% Solids Grade (%)	25% Solids Grade (%)	15% Solids Mass Recovery (%)	20% Solids Mass Recovery (%)	25% Solids Mass Recovery (%)
Spiral	-212+74	0.07	0.11	0.17	70.74	69.85	67.70
	-300+74	0.11	0.19	0.26	72.86	72.34	71.10
	-425+74	0.29	0.41	0.50	75.66	74.88	74.07
	-600+74	0.62	0.78	0.84	79.81	78.38	77.57
	-850+74	0.85	0.85	0.85	82.08	81.15	79.20
Shaking Table	-212+74	0.27	0.32	0.34	76.88	79.21	81.39
	-300+74	0.31	0.34	0.38	79.29	82.39	83.51
	-425+74	0.42	0.56	0.61	81.43	85.48	87.71
	-600+74	0.69	0.81	0.80	83.12	87.06	89.92
	-850+74	0.83	0.82	0.82	85.88	89.64	90.08

The minimum and maximum sizes of operating particle were determined according to the specifications of the spiral and shaking table used in the tests. Thus, three different solid contents that were 15%, 20% and 25% by weight, were selected and performed. The effects of the solid content on the Fe_2O_3 grade of concentrate, Fe_2O_3 removal, and the mass recovery were investigated for each feed size. The results are shown in Figs. 4–6 for the spiral concentrator and Fig. 7 for the shaking table.

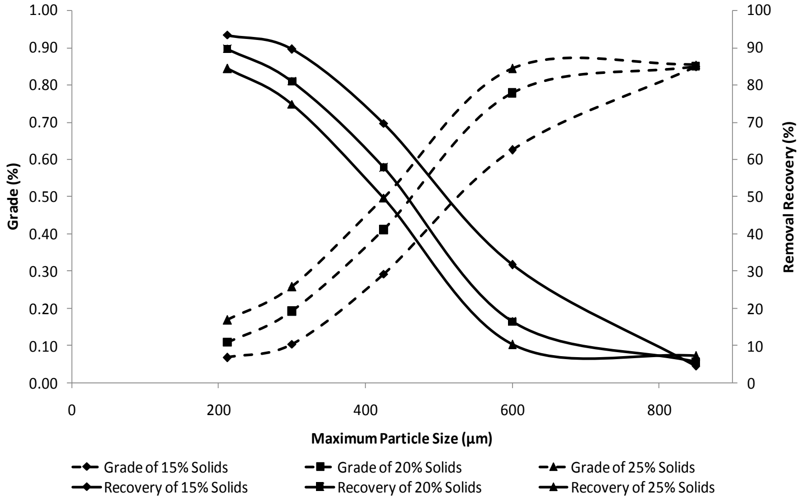

Fig. 4. A relationship between grade, recovery and maximum particle size in spiral concentrator at 1 dm^3/s flow rate

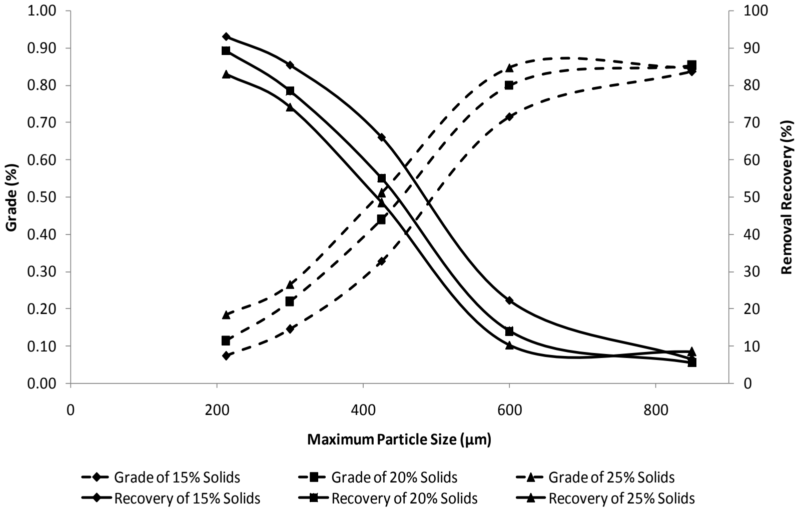

Fig. 5. A relationship between grade, recovery and maximum particle size in spiral concentrator at 1.5 dm^3/s flow rate

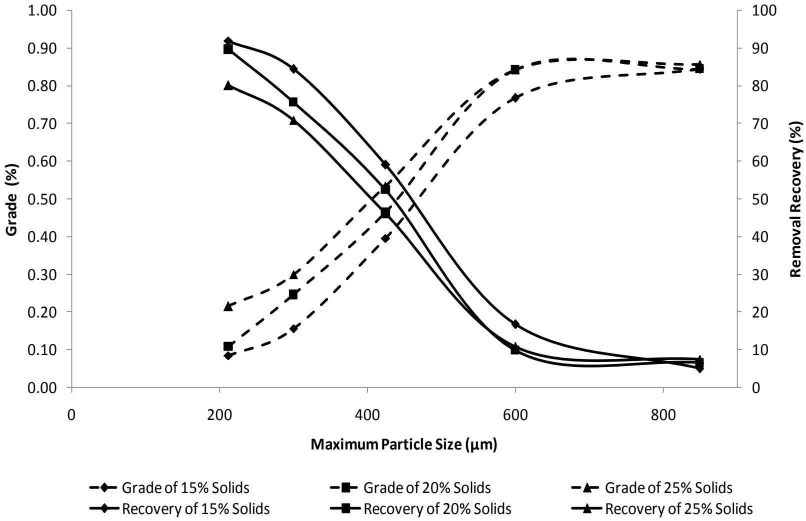

Fig. 6. A relationship between grade, recovery and maximum particle size in spiral concentrator at 2 dm^3/s flow rate

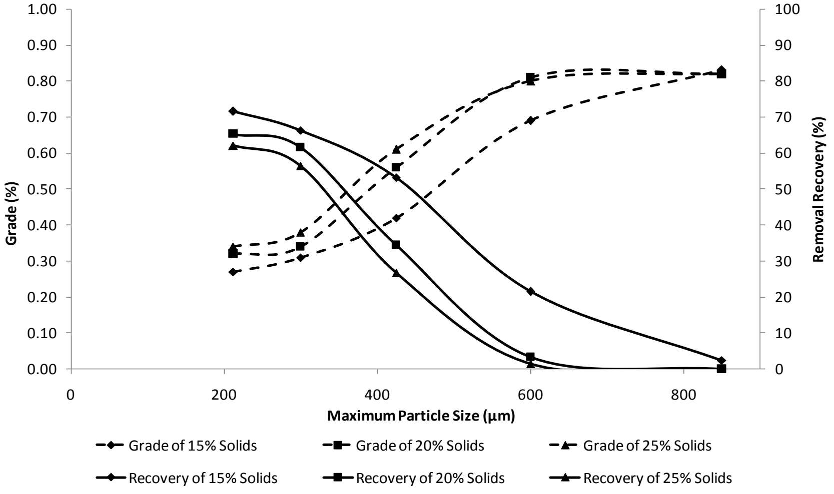

Fig. 7. A relationship between grade, recovery and maximum particle size in shaking table at 1 dm^3/s flow rate

From Figs. 4-7 it can be seen that the particle size distribution is the most effective parameter in the separation in both methods. In general, the separation efficiency of the gravity concentration methods is better for coarse particles than fine particles because the gravity force is more effective on coarse particles. However, the coarse mica grains are nearly equi-dimensional, and the difference in the specific gravity is not sufficient to make the separation of these minerals possible in this case. On the other hand, the flaky shape character of the smaller mica particles made the separation of the mica from the feldspar possible in the fine particle sizes. This situation is not related to the differences in the degree of liberation since mica was in the form of liberated particles even in the coarse fractions.

The Fe_2O_3 grade of the concentrate and the Fe_2O_3 removal and recovery of the feldspar were directly related to the change in the particle size. An increase in the particle size occurs with the Fe_2O_3 grade of the concentrate (Table 3) and decreases with the Fe_2O_3 removal. The removal recovery was calculated from equation:

$$RR = \left[1 - \frac{C_c}{F_f}\right] \cdot 100, \quad (1)$$

where RR is removal recovery (%), C mass of concentrate (kg), F mass of feed (kg), c Fe_2O_3 content in concentrate (%), f Fe_2O_3 content in feed (%).

The mass recovery decreased slightly with the finer particle size since the amount of particles carried by water to the tailings stream increased. This behaviour was observed in both concentrators. According to Table 3, increasing the solids % of the feed increased the Fe_2O_3 grade of the concentrate and decreased the mass recovery, except for the feed top size fraction of - 850 μm + 74 μm. As well as reducing the separation efficiency, an increase in the solids content slightly reduced the amount of concentrate.

In classical gravity concentration, the purpose of separation is to get maximum grade of metallic ore with maximum possible mass recovery. In this case, most important terms are Fe_2O_3 content of concentrate, removal recovery and mass recovery. That is why the purpose of separation is to remove Fe_2O_3 from the feldspar minerals and to get the minimum Fe_2O_3 contents, the best Fe_2O_3 removal and mass recovery values in order to meet the glass industry requirements. So, the lower Fe_2O_3 content is favourable for this kind of separation. The spiral concentrate has 0.07% Fe_2O_3 content with a 93% Fe_2O_3 removal recovery and approximately 70% mass recovery, whereas the shaking table concentrate has 0.27% Fe_2O_3 content with a 72% Fe_2O_3 removal recovery and approximately 76% yield. Although the mass recovery of shaking table is higher than spiral concentrator, % Fe_2O_3 content and Fe_2O_3 removal recovery do not meet the desired specifications of glass industry.

The results showed that the spiral concentrator is more favourable than the shaking table for this kind of separation process. According to the concentrators operating principles, the spiral concentrator has a very significant advantage such as the centrifugal force contribution. The most favourable results of both concentrators are given in Fig. 8.

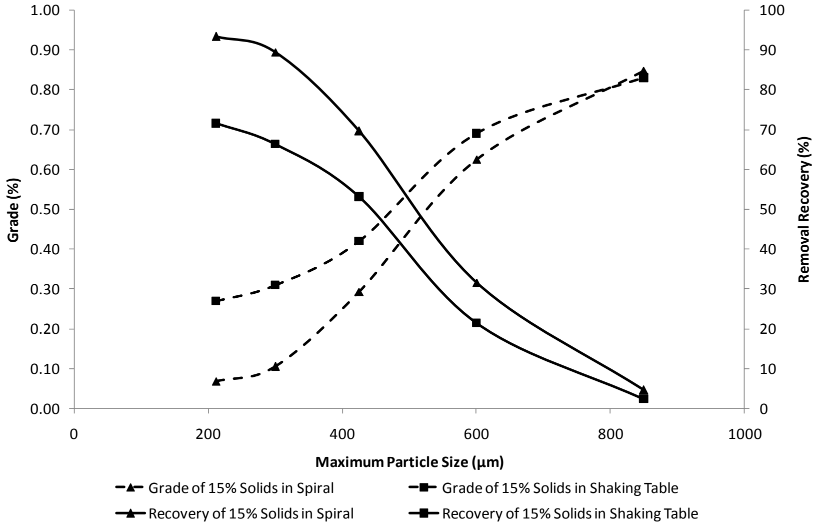

Fig. 8. Comparison of both concentrators in their best conditions

4. Conclusions

In this investigation, the role of mica flaky shape characteristics, which is achieved by decreasing the particle size of the feed, flow rate and the effect of the solids % in the feed on the mica separation from feldspar mineral, were examined. The results revealed that the increasing in particle size had an extreme effect on separation efficiency. Separation was not possible when the particle sizes were - 850 µm + 74 µm or - 600 µm + 74 µm.

The separation efficiency of the mica removal increased as the particle size distribution got finer, the most suitable particle size fraction being - 212 µm + 74 µm in both concentrators. In the spiral, the Fe_2O_3 content of the concentrate was reduced from 0.73% to 0.07% with 93% removal of the Fe_2O_3 and mass recovery of approximately 70%, whereas the Fe_2O_3 content of the concentrate was reduced from 0.73% to 0.27% with a 72% removal of the Fe_2O_3 and a mass recovery of approximately 76% in the shaking table concentrator.

The most favourable results were obtained in the spiral concentrator. There was a certain separation occurring in the shaking table, but the values did not meet the required specifications for the glass industry. On the other hand, the iron content, which was obtained in the spiral tests, met these specifications. Firing buttons with a pale pink colour confirmed these results.

It appeared that the particle size needed to be reduced to minus 212 µm in order to ensure that the mica had a flaky shape characteristic, which had the desired distinctive behaviour in these concentration processes.

Although the effect on the separation efficiency of the solids in the feed was less pronounced than that of the particle size, the increasing solids significantly reduced the separation efficiency. Only the concentrate obtained with the minimum solids (15%) met the desired specification.

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