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Investigation of the effectiveness of oleate in fine-sized magnesite flotation

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Abstract: In this work, effectiveness of oleate in fine sized magnesite flotation was studied by froth flotation. In the flotation experiments, conditioning time, flotation time and particle size were kept constant while collector dosage, solid ratio, pH, impeller speed, air rate, and flotation temperature were varied. The experimental results revealed that a concentrate of approximately 45 % MgO content with nearly 80 % MgO recovery was obtained. The $Si0_2$ content of concentrate was around 3.85 % indicating 80% reduction according to head sample.

Keywords: froth flotation, oleate, magnesite, quartz

1. Introduction

Magnesite is one of the most important raw materials for many products, especially in the metal, glass and cement industries. Magnesite is largely used especially in the production of high temperature resistant products. The most important factor that limits its utilization is the impurities, it contains. While it can be economically enriched in large sizes with various physical enrichment methods; as the grain size becomes smaller, flotation comes to the fore as an enrichment method.

Oleate is commonly used as the collector in magnesite flotation particularly magnesite-dolomite separation. For example, in a study, magnesite and dolomite were separated by flotation using α-chloro-oleate acid as collector (Zhong et al., 2020). In this work very high separation was obtained, nearly 95% of magnesite was recovered in the concentration while 82.5% of dolomite left in the flotation cell. In another study, sodium oleate was utilized as a collector in magnesite-dolomite flotation with great success (Sun et al., 2020). Since oleate was also used as a collector for dolomite, selectivity was obtained by a strong depressant (sodium hexametaphosphate) usage. A more recent study published by Luo et al., in 2024, flotation of magnesite from dolomite was achieved by using a modified depressant (sodium silicate modified with zinc sulphide).

Froth flotation is also used in the concentration of magnesite by reducing SiO_2 content in a numerous of study. For example, in a study published by Sun and Yin in 2022, a specially designed cationic collector, palmitoyl trimethylammonium chloride was used to separate artificial mixtures of magnesite and quartz without the need of a depressant by using the -0.074+0.045 mm fine size fraction. In another study (Zhu et al., 2022) on the artificial mixtures of magnesite-quartz separation, carboxymethyl cellulose was used as depressant in froth flotation.

Quartz can be floated with oleate (Vidyadhar at al., 2012), but in order to obtain sufficient efficiency in oleate flotation in alkaline medium, it must first be activated with an activator such as $CaCl_2$ (Ye and Matsuoka, 1993; Atay and Çırak, 2020). It has also been reported in the literature that quartz should be suppressed in oleate flotation (Wang at al., 2021). In this article, the effects of solid ratio, pH, impeller speed, air rate, flotation temperature factors, which are known to be effective in the oleate flotation of magnesite without using any quartz depressant, on the selectivity were investigated.

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2. Materials and methods

2.1. Materials

The study was conducted using a mixture of 96.4% pure magnesite and 98% pure quartz. The mixture ratio in the study was set to be 80% magnesite and 20% quartz. Samples were purchased commercially and its particle size was 80% passing 0.100 mm. Particle size analyses were performed using the Malvern Master Sizer 2000 MU (Malvern Panalytical Inc., England) device at laboratory of Eskişehir Osmangazi University Mining Engineering Department. The particle size distribution of the mixed sample is given graphically in Figure 1. Spectrochemical analyses were performed using the XRF Panalytical Zetium (Malvern Panalytical Inc., England) device at Eskişehir Osmangazi University Central Research Laboratory Application and Research Center (ESOGU ARUM) laboratories and the elemental compositions of the sample and products were determined. The XRF results of the magnesite-quartz mixture used in flotation studies are given in Table 1.

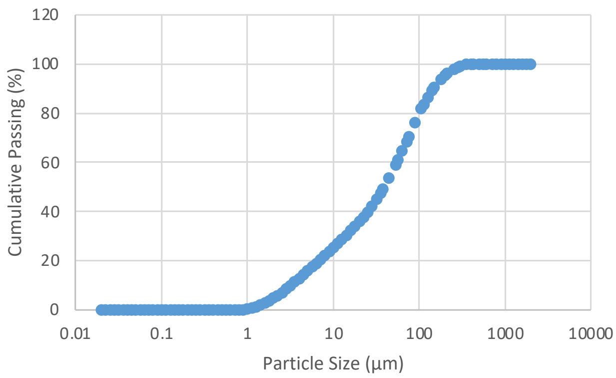

Fig. 1. Particle size distribution of mixed sample

Table 1. XRF analysis of flotation feed

Composition	Amount (%)
Al_2O_3	0.6
CaO	0.9
Fe_2O_3	0.2
K_2O	0.3
MgO	37.4
MnO	0.1
Na_2O	0.5
P_2O_5	<0.1
SiO_2	19.8
TiO_2	<0.1
Loss on ignition	40.1

High purity sodium oleate purchased from Sigma-Aldrich (Germany) was used as a collector in classical magnesite flotation. Since oleate has a strong foaming property, it was not necessary to use any reactive as a frother in the experiments. Analytical grade NaOH and H2SO4 (Sigma Aldrich, Germany) were used to adjust pulp pH.

2.2. Method

A 1.5 liter volume cell laboratory type mechanical stirred Denver Flotation device (Eskişehir Osmangazi University Mineral Processing Laboratory) was used in flotation experiments. In the flotation experiments; collector amount, solid ratio, pH, impeller speed, air rate and flotation temperature were varied to determine optimum separation conditions. In the experiments, conditioning time and flotation time were set as 8 min, and 150 secs, respectively. In the first set of experiments where the effect of the collector amount was studied, the solid ratio, pH, mixer speed, air speed and flotation temperature were taken as 30%, 8.5, 1250 rpm, 5 l/d, 26°C, respectively. When moving on to the next parameter, the optimum value of the parameter whose effect was investigated was used, and the parameters whose effect was not investigated were kept at the levels given above.

After each flotation experiments, MgO grade and SiO_2 content of the products were analyzed by XRF, the weight yield (WY) and MgO recovery were calculated according to equations 1-2, respectively.

$$WY = 100 * \frac{C}{F} \tag{1}$$

$$R_{MgO} = 100x\frac{C \, x \, c_{MgO}}{F \, x \, f_{MgO}} \tag{2}$$

where C is the amount of concentrate; F is the amount of feed; c_{MgO} is the MgO grade of concentrate; and f_{MgO} is the MgO grade of feed (%).

3. Results and discussion

The flotation experiments were carried out under the following conditions. In the flotation experiments, particle size, conditioning time, and flotation time were kept constant while collector amount, solid ratio, pH, impeller speed, air rate, and flotation temperature were varied.

Particle size	: 80% passing 0,100 mm
Collector conditioning time	: 8 min
Flotation time	: 150 sec
Collector amount	: 150-450 g/t
Solid ratio (w/w)	: 25-35 %
Pulp pH	: 7-10
Impeller speed	: 1100-1500 rpm
Air Rate	: 3-9 L/min
Temperature	: 23-32°C

3.1. The effect of collector amount

The dosage of sodium oleate was varied between 150 and 450 g/ton, and results were illustrated in Figure 2. Figure 2 shows that as the collector amount increases both weight yield and MgO recovery increased significantly. It should be noticed that MgO grade did not change up to 300 g/ton, slightly decreased afterwards. As the collector dosage increased, SiO_2 content of the concentrate decreased up to 300 g/ton then increased significantly at high collector dosage. It is thought that high collector dosage caused the flotation of excess amount of materials along with magnesite particles. It is noteworthy to point out that weight yield and MgO recovery increased from 40.92 % to 82.15 % and from 54.76 % to 90.29 %, respectively while lowest SiO_2 content was obtained at 300 g/ton collector dosage. A remarkable increase was obtained in MgO content of the concentrate according to head sample, ie from 37.4% to 43.37%. Therefore 300 g/ton collector dosage was chosen as optimum value. At optimum conditions, MgO content, MgO recovery and SiO_2 content of the concentrate were obtained as 43.37 %, 72.60 % and 4.92 %, respectively.

3.2. The effect of solid ratio

Flotation experiments were performed to determine the effects of solid ratio on results, and solid content was varied between 25-35 % while other conditions were kept constant. The results were presented in Figure 3, and it was seen that 30 % solid ratio produced the best results. At this point the lowest SiO_2 content while acceptable MgO content and MgO recovery were obtained. It was observed that the selectivity was decreased at high solids content, causing a reduction in both WY and MgO recovery and SiO_2 content in the concentrate fraction.

3.3. The effect of pH

The effect of pH on MgO content and recovery and SiO_2 content was investigated and the results are

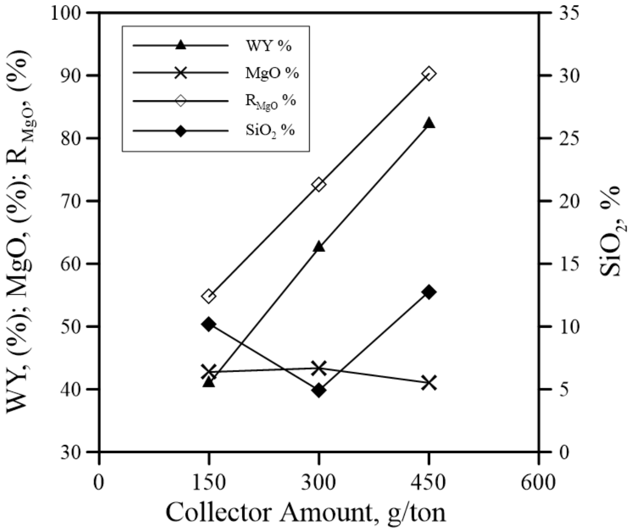

Fig. 2. The effects of collector dosage on flotation

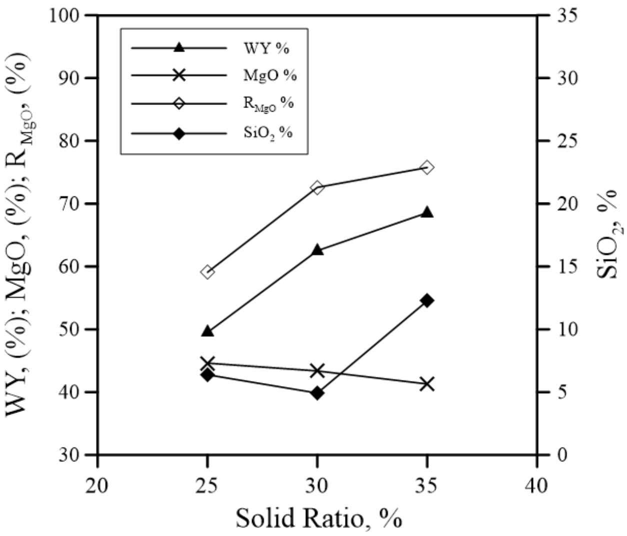

Fig. 3. The effects of solid ratio on flotation

shown in Figure 4. As expected variations in system pH effected all the response variables significantly. At low pH value (7), lowest WY and MgO recovery values were obtained. As pH increased from 7 to 10, WY and MgO recovery sharply increased. On the other hand, as the pH increased from 7 to 8.5 a slight decrease in SiO_2 content while a slight increase in MgO content were observed. while caused a slight increase in MgO content. A further increase in pH from 8.5 to 10 SiO_2 content of the concentrate increased significantly from 4.92 % to 17.66 % while MgO content decreased slightly.

It was proved in literature that sodium oleate is an effective collector in magnesite flotation at alkaline region (Luo et al., 2024). At the same study it was shown that the zeta potential of magnesite in the presence of sodium oleate has a large negative shift indicating sodium oleate adsorb onto magnesite's surface. The high recoveries at alkaline region are attributed to the chemisorptions of sodium oleate onto magnesite surfaces. Another study by Andrade et al showed that sodium oleate also adsorbed onto quartz surface at strong alkaline mediums and causes a remarkable increase in flotation recovery (Andrade et al, 2012).

The results obtained in this study are consistent with the results in the literature. As stated above at strong alkaline medium sodium oleate is an effective collector in magnesite flotation rendering high recoveries (Andrade et al., 2012; Lua et al., 2024). The similar effect was observed in our study and high recovery and weight yield were obtained. This high recovery and weight yield figures obtained through bulk flotation of magnesite and quartz resulted with a decrease in MgO and an increase in SiO_2 contents.

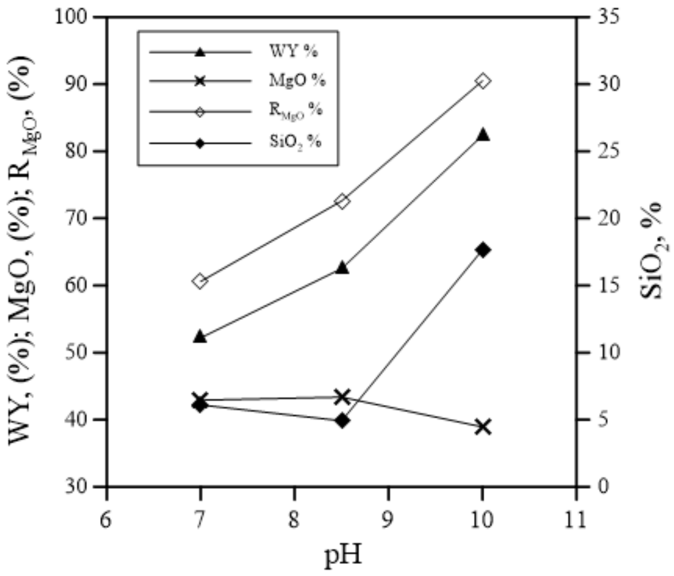

Fig. 4. The effects of pH on flotation

3.4. The effect of impeller speed

The effects of the impeller speed on the flotation results were given graphically in Figure 5. When the graph is examined, it is seen that the MgO yield and SiO_2 content are at the lowest level at the impeller speed of 1000 rpm. Although the lowest SiO_2 content was obtained at 1000 rpm, this value was not selected as the optimum value because the MgO yield was also at the lowest level. When the impeller speed was increased to 1250 rpm, a very small increase in SiO_2 (from 4.70% to 4.92%) was observed in the concentrate fraction, but a net increase in yield (from 57% to over 70%) was observed. Higher impeller speeds increased the SiO_2 ratio in the concentrate, significantly. Since there was no noticeable improvement in the other data, 1250 rpm was selected as the optimum value.

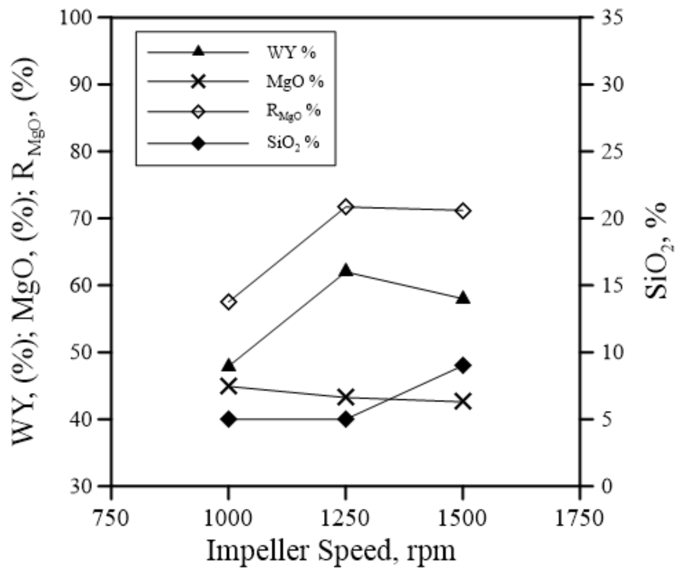

Fig. 5. The effects of impeller speed on flotation

3.5. The effect of air rate

The effect of air rate was presented in Figure 6. As seen from the graph, a slight increase in air rate caused a slight decrease in the MgO content while a remarkable increase in the amount of concentrate. Especially above 7 l/min air rate, the SiO_2 percentage of the concentrate increased significantly, and the

MgO content decreased inversely proportional to this situation. Despite a small decrease in MgO content and a small increase in SiO_2 content, 7 l/min air rate was selected as the optimum value due to the highest MgO yield.

3.6. The effect of flotation temperature:

In order to investigate the effect of flotation temperature on the results, experiments were conducted between 23-32°C under the conditions specified above. As seen in Figure 7, the best results were obtained at 29°C. At room and the highest temperatures (23 and 32°C), weight yield, MgO content and MgO recovery of the concentrate decreased significantly.

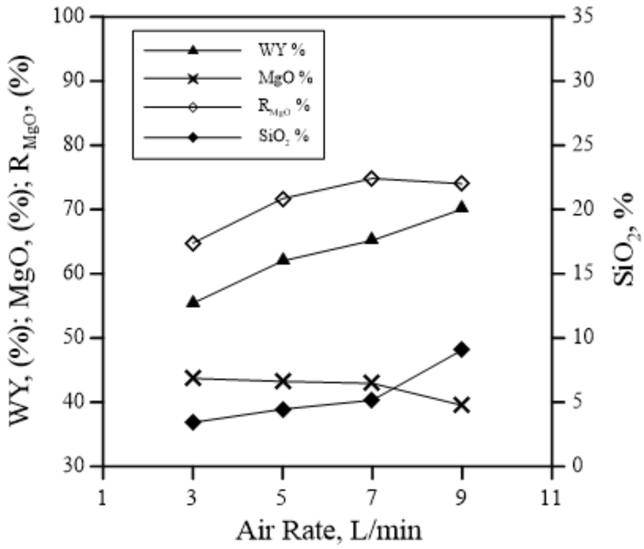

Fig. 6. The effects of air rate on flotation

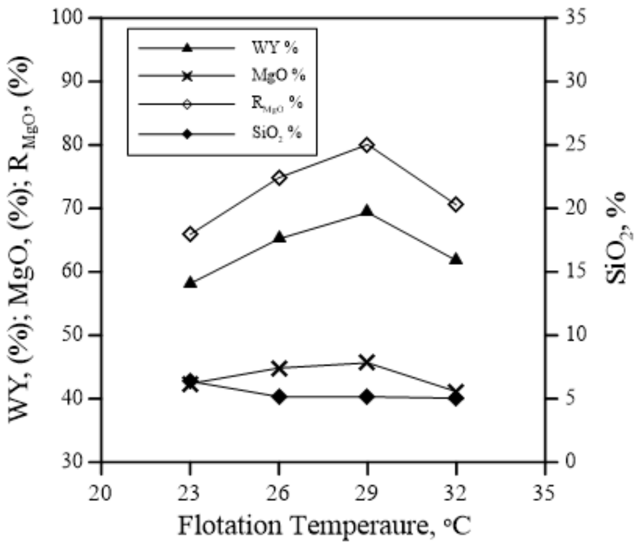

Fig. 7. The effects of temperature on flotation

Many researchers have mentioned that the solubility of sodium oleate increases with the increase in ambient temperature and as a result, the flotation efficiency also increases (Fuerstenau et al., 1985; Koca and Özdağ, 1994; Malayoğlu et al., 1997). This explains the decrease in weight yield, grade and efficiency at low temperatures (less than 26°C), but cannot explain the reason for the decrease in weight yield, grade and efficiency at the high temperature (32°C). This is also explained in the literature by the formation of micelles. When the concentrations of such collectors exceed the concentration called "Critical Micelle Concentration" (CMC) and at the same time the pulp temperature is above a certain temperature, they form aggregates called "Micelles" (Kelly et al., 1982; Leja, 1983). It is claimed by the same researchers that micelle formation depletes flotation efficiency significantly. It is thought that micelles formation was occurred at around 32°C and as a result, the floatability decreased.

It is seen that the results obtained in this study are compatible with the comments given in the literature. 29 degrees was selected as the most appropriate value.

4. Conclusions

The flotation of fine sized magnesite from quartz by sodium oleate was investigated using a laboratory scale mechanical flotation cell. The experimental results revealed that at optimum conditions, the MgO content of concentrate was obtained as 45.66 % with 80.07 % MgO recovery and 5.11 % SiO_2 content. The optimum conditions were determined as Na oleate dosage of 300 g/ton, solid ratio of 30 %, impeller speed of 1250 rpm, air rate of 7 L/min and 29^0C of flotation temperature.

It has been shown that in fine sized magnesite flotation, sodium oleate can be used as an effective collector. Apart from sodium oleate, other studied parameters, pH, solid ratio, air rate and flotation temperature also affected the results significantly; while impeller speed was not found effective as much as other parameters.

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