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SHEAR FLOCCULATION OF CHROMITE FINES BY AMINE

Shear flocculation of chromite fines using amine D acetate as collector was investigated by examining the effects of pH, collector amount, flocculation time, stirrer speed and solid amount. The degree of flocculation was interpreted in terms of reduction in turbidity and increase in the amount of settled material. Hydrophobicity and zeta potential are the dominant factors governing the extent of shear flocculation. The experiments carried out at optimum conditions indicated that turbidity was reduced from 10500 NTU to 946 NTU and the amount of settled material was increased from 11.3 to 86.92% by shear flocculation.

1. INTRODUCTION

Recovery of minerals below a certain size is difficult and these are often discarded as slimes. Recently the methods to recover fine particles such as oil agglomeration, carrier flotation, magnetic flocculation and shear flocculation are gaining importance. Among these methods, shear flocculation is advantageous for flotation systems since the aggregates are hydrophobic and thus suitable for direct recovery by froth flotation (Warren 1981). Shear flocculation can simply be defined as the aggregation of hydrophobic particles in a suitable stirring (shear) regime which is exceeding repulsive energy barrier. Some of the mineral systems whose shear flocculation was studied are scheelite (Warren 1975; Sivamohan and Cases 1989), cassiterite (Warren 1982; Bilgen 1992), hematite (Fuerstenau et al. 1988), fluorite (Sivamohan and Cases 1989), rutile (Song and Lu 1990), galena (Subrahmanyam et al. 1990), apatite (Yongping and Mulong 1988), and quartz (Raju et al. 1991). Shear flocculation of chromite fines has not been investigated yet. The aim of this study is to investigate the aggregation of chromite fines by shear flocculation.

2. MATERIALS AND METHODS

The sample used in this study was a gravity concentrate from the Üçköprü plant in Turkey. It was enriched by further tabling and beaker decantation. The grinding was carried out in a porcelain mill using pebble as the grinding media. Ground sample was

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washed in dilute HCl solution and then in distilled water a few times. Fine fraction (–10 micron) was obtained by beaker decantation calculated according to Stokes' law. Chemical analysis of the sample is as follows:

Cr_2O_3: 53.93%; FeO: 14.40%; Al_2O_3: 15.14%; MgO: 13.40%; SiO_2: 2.79% and CaO: 0.22%.

Particle size analysis determined by Coulter Counter is presented in Fig. 1.

Shear flocculation experiments were carried out in a 1400 ml cell using 0.50 to 5.00 g solid and double distilled water. The pH of the solution was adjusted by dilute HCl or NaOH.

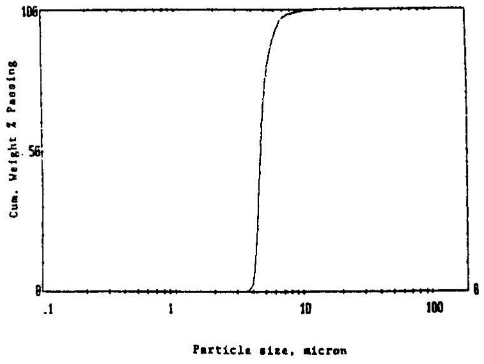

Fig. 1. Size distribution of the sample determined by coulter counter

Turbidity measurements were made at the beginning (T_i) and at the end (T_f) of each experiment. The ratio of final to initial turbidity (T_f/T_i) was defined as turbidity ratio and was used as a criterion to evaluate the results. Low turbidity ratios indicated the success of flocculation.

The other criterion of interpreting the results was the amount of settled material (%). At the end of each experiment, a portion of sample was transferred to an Andreasen pipette, while stirring was going on. 10 ml samples were withdrawn immediately (t = 0) and at the end of 18.5 minute from the Andreasen pipette. The initial weight (W_i) and the final weight (W_f) of suspended material were found and the amount of settled material was calculated as follows:

Settled Material (%) = $100 - (W_f/W_i . 100)$

High percentage of settled material means that flocculation is successful.

Zeta potentials were measured in a Rank Brothers microelectrophoresis apparatus.

3. RESULTS

Zeta Potential

Zeta potential of chromite at different pH values and at different concentrations of amine D acetate is given in Fig. 2.

Adsorption of positive amine ion on chromite surface increased the iep (isoelectric point) from pH 5.1 to nearly 9.

Effect of pH

The results of experiments carried out to investigate the effect of pH are given in Fig. 3.

Shear flocculation is possible within a high pH range (4–11) but most marked results were obtained at pH 9 where zeta potential was minimum.

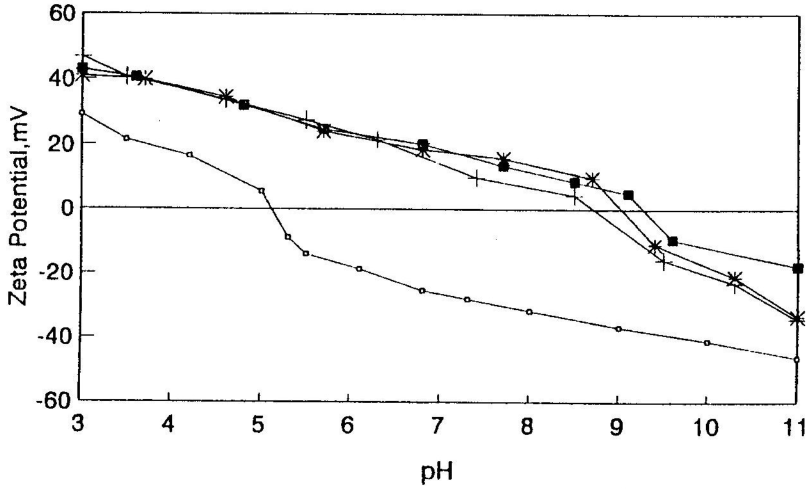

Fig. 2. Effect of different concentrations of amine D acetate on zeta potential of chromite: —▫— no collector, + 10 mg/dm³, -✳- 20 mg/dm³, -■- 70 mg/dm³

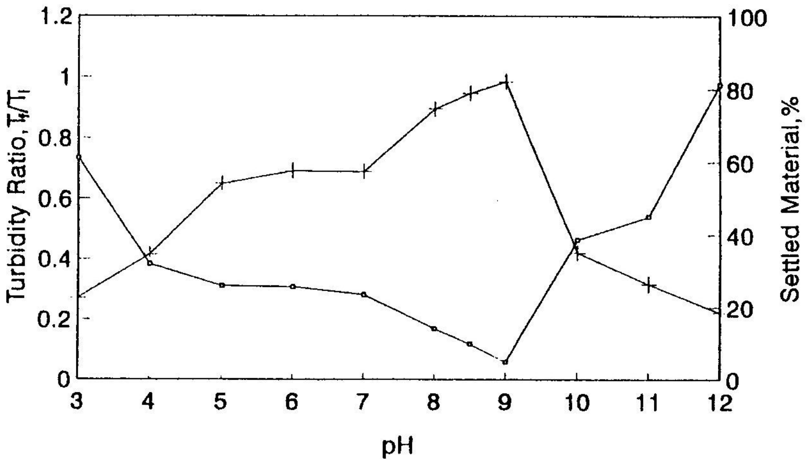

Fig. 3. The effect of pH on shear flocculation of chromite (collector: 20 mg/dm³, stirrer speed: 630 rpm, stirring time: 30 min.). —▫— turbidity ratio T_f/T_i, + settled material, %

Effect of collector concentration

Figure 4 shows the variation of turbidity ratio and amount of settled material with collector concentration from 0 to 100 mg/l. It is seen that shear flocculation is possible even with 10 mg/l amine D acetate and the extent increases with increasing concentrations. However, the rate of increase is not too high after a concentration of 20 mg/l. High turbidity ratio and low amount of settled material in the absence of collector indicate the significance of hydrophobicity induced by collector addition.

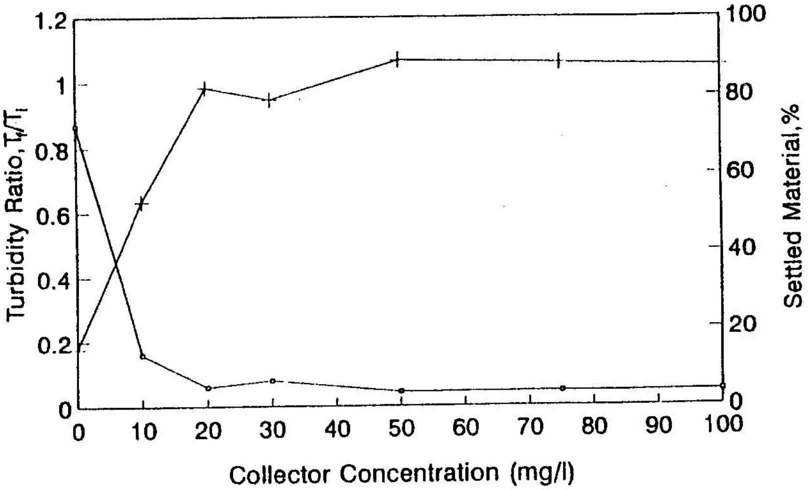

Fig. 4. Effect of collector concentration on shear flocculation of chromite (pH: 9.0; stirring speed: 630 rpm; stirring time: 30 min.). —▫— turbidity ratio T_f/T_i, + settled material, %

Effect of flocculation time

In contrast to Warren's experiments (1975) with ultrafine scheelite particles, shear flocculation of chromite fines was found to be a rapid process starting immediately and, in fact, ending after 30 minutes (Fig. 5). An interesting point was that flock-breakdown occurred with stirring times exceeding 30 minutes.

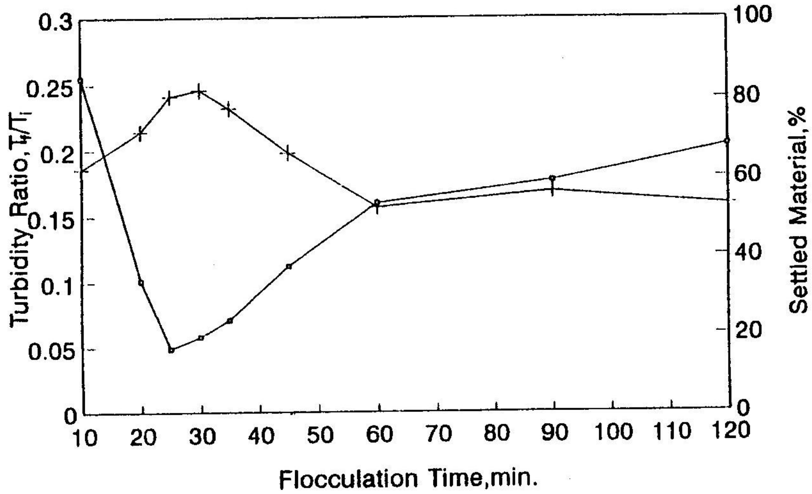

Fig. 5. Effect of flocculation time on shear flocculation of chromite (pH: 9.0; collector: 20 mg/dm³, stirring speed: 630 rpm). —▫— turbidity ratio T_f/T_i, + settled material, %

Effect of stirrer speed

Figure 6 indicates that shear flocculation is possible within a high stirrer speed range from 0 to 870 rpm but best results were obtained at medium speeds (580 and

630 rpm). Low amount of settled material at 1200 rpm shows the difficulty of particle aggregation at high stirring regimes.

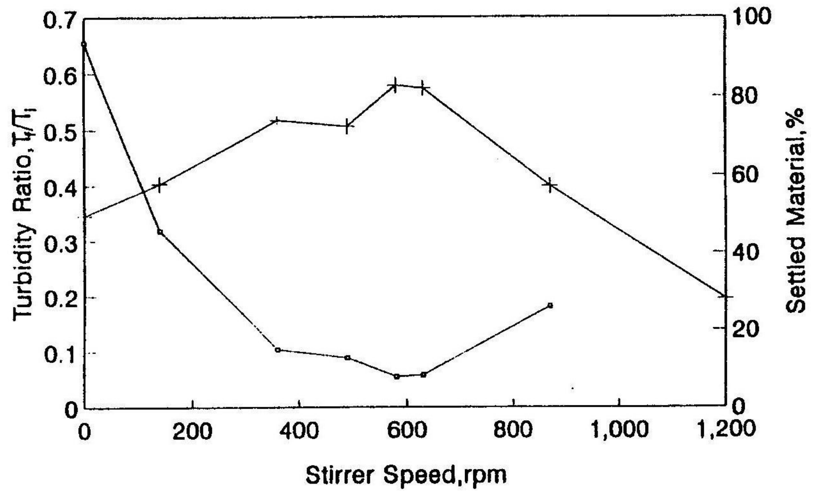

Fig. 6. Effect of stirrer speed on shear flocculation of chromite (pH: 9.0; collector: 20 mg/dm³, stirring time: 30 min.). —▫— turbidity ratio T_f/T_i, + setled material, %

Effect of suspension concentration

An increase in particle concentration increased the amount of collision rate hence the degree of shear flocculation (Fig. 7). However the rate of increase was lower than that of ultrafine scheelite particles (Warren 1975). The amount of suspended particles

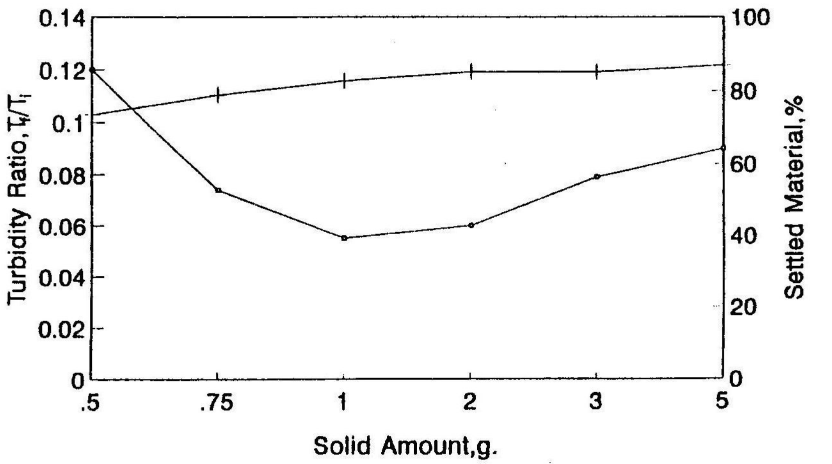

Fig. 7. Effect of particle cencentration on shear flocculation of chromite (pH: 9.0, collector: 20 mg/dm³, stirring speed: 580 rpm, stirring time: 30 min.). —▫— turbidity ratio T_f/T_i, + settled material, %

decreased only from 26 to 13% with increasing particle concentration from 0.5 to 5.00 g.

4. DISCUSSION

Most pronounced results obtained at pH 9 where zeta potential is minimum prove the findings of several authors (Sivamohan and Cases 1990; Raju et al. 1991) that zeta potential and shear flocculation are highly correlated. However, flocculation observed at pH 5 where zeta potential is around 30 mV contrasts with classical DLVO theory. In this case, hydrophobic association must be considered. According to this theory (Lu and Li 1984), the hydrophobic interaction energy has been reported to be 1–2 orders of magnitude greater than electrostatic repulsion and van der Waals attraction.

Shear flocculation of chromite fines was found to be a rapid process which is contradictory to Warren's findings (1975). This may be due to coarser particle size compared to ultrafine scheelite particles since kinetic energy of impact increases with increasing mass.

An interesting point is the possibility of flocculation at very low stirrer speeds in contrast to many studies. Flocculation at a low stirrer speed (140 rpm) shows that hydrophobic association may be more important than kinetic energy for aggregation.

According to Levich's equation (1962), the number of collisions and particle concentration are related as follows:

$N \sim a\, n_o^2$ where N is collision number and n_o is initial particle concentration. According to this, a ten-fold increase in concentration should increase the number of collisions 100-fold. Although it was not measured, the number of collisions in this study in per cent of fine material remaining as suspension does not decrease in this order, but still particle crowding is another factor increasing the extent of shear flocculation.

5. CONCLUSIONS

1. Shear flocculation of fine chromite is possible in amine D acetate solutions.
2. Optimum conditions for the flocculation were found as follows: pH: 9.0; collector: 20 mg/l; stirrer speed: 580 rpm; and flocculation time: 30 min. Turbidity was reduced from 10 500 NTU to 946 NTU and the amount of settled material increased from 11.3 to 86.92% in the experiment carried out in optimum conditions.
3. Hydrophobicity and zeta potential were found to be the most important parameters affecting the extent of shear flocculation. Best results were obtained at pH values where surface charge is minimum.
4. Other factors contributing to the degree of flocculation were stirrer feed, flocculation time and particle concentration. Experiments indicated that shear flocculation was a rapid process and that aggregation was possible at low stirrer speeds.

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W pracy badano przebieg procesu flokulacji ścinającej (*shear flocculation*) zawiesin chromitowych przy użyciu octanu aminy D jako kolektora. Określono wpływ pH środowiska, ilości kolektora, czasu flokulacji, prędkości obrotów mieszadła oraz zagęszczenia części stałych. Stopień flokulacji oceniano poprzez pomiar stopnia zmętnienia zawiesiny oraz ilości sedymentującego materiału. Zauważono, że głównym czynnikiem decydującym o stopniu shear flocculation jest hydrofobowość ziarn i wartość ich potencjału zeta. Stwierdzono doświadczalnie, że w warunkach optymalnych metodą shear flocculation zmętnienie zawiesiny można zmniejszyć z 10 500 NTU do 946 NTU a wychód materiału sedymentującego zwiększyć z 11,3 do 86,9%.