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Adsorption and column flotation studies on talc using anionic and cationic collectors

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Abstract−Adsorption properties and column flotation were studied to investigate the interaction of the anionic and cationic collectors and flotation recoveries for talc mineral. Adsorption capacity is dependent on pH, adsorption time, temperature, collector concentration, and particle size. Langmuir adsorption model was suitable for describing isotherms. Analyses were carried out using UV spectrometry. In this study, we analyzed some parameters affecting column flotation performance. It was determined that adsorption capacity, especially, had an important role in column flotation enrichment.

Key words: Adsorption, Column Flotation, Talc, Langmuir

INTRODUCTION

Being naturally hydrophobic, talc is a versatile industrial mineral that has been employed in a steadily increasing number of uses, such as in the paint, paper, plastic, ceramic and cosmetic industries [1]. Talc includes 63.5% SiO_2, 31.7% MgO and 4.85 H_2O in ideal compositions. Talc deposits generally contain calcite, dolomite, magnesite, chlorite, olivine, quartz, serpentine, graphite, mica and pyrite [2-4]. High purity talc is used in cosmetics, in cordierite ceramics, for pitch control in the paper industry, and as reinforcing filler in rubber. Products of intermediate purity are used as paper fillers, for plastics reinforcing, and in wall tile, paint, and dusting compounds for rubber. Lower purity products are used in roofing materials, polyester body patch compounds, flooring, and fertilizer formulations. Accessory mineral can have an important effect in some applications. Chlorite, being platy like talc, is acceptable in most end uses except steatite and cosmetics. Tremolite of acicular particle shape is beneficial in wall tile bodies, where it provides porosity, and in coatings, where it lowers viscosity; however, it has a negative effect in plastics due to abrasion and in cosmetics due to health concerns [2].

The Langmuir adsorption isotherm equation was developed to describe adsorption of gases onto clean solids and implies inform adsorption sites and absence of lateral interactions

$$x=\frac{bKc^{\beta}}{1+Kc^{\beta}} \tag{1}$$

Where is the amount adsorbed per unit mass; c, is the equilibrium solution concentration; and b, K and β are empirical parameters [5]. The Langmuir isotherm is a special case of Eq. (1).

Collectors play an important role in effecting selective separation of minerals from ores by flotation. Anionic collector and cationic collector are effective collectors of talc flotation. Aero 825 is an anionic collector, petroleum sulfonate promoters most widely used for flotation of metallic and industrial minerals. Tallow Amine Acetate (T.A.A.) is cationic collector which is generally used for selective flotation of silicate and oxide minerals [6].

To appreciate fully the role of surface modification in flotation, it is necessary to take a closer look at the boundary between two contiguous phases. Three modes of adsorption at the solid-liquid interface can be distinguished: physical adsorption, chemisorption and chemical reaction [7]. The adsorption of the collector on the solid particle is the most important factor affecting the floatability of silicate minerals. Anionic and cationic collectors are widely used collectors for silicate mineral flotation and their adsorption onto various minerals has been commonly studied. Same aspects of the surface and structure properties of talc have been the subject of a number of papers [8], adsorption of polysaccharide onto talc has been examined by Gushan et al. [9]. Recently, the influence of absorbed polysaccharides and polyacrylamides on talc flotation has been investigated by David et al. [10]; the effect of the adsorption of lead and cadmium ions on the interfacial behaviour of quartz and talc has been studied by Huang and Fuerstenau [11]. Giles et al. (1960) presented adsorption mechanisms in measurement of specific areas of solids [12].

$$Q=(C-C_0)\cdot\frac{m}{V} \tag{2}$$

where Q is adsorption capacity of Aero 825; Co is the initial concentration of Aero 825 in solution; C is corresponds to the amount of adsorbed at time t (or concentration solution of Aero 825); m is weight of mineral; V is volume of pure water, given Eq. (2).

Froth flotation is a separation process widely used in mineral processing. Conventional flotation cells are sometimes less than an ideal environment for separation of valuable minerals from gangue, because of turbulence and lack of bubble size control. As an alternative, column flotation is considered to be one of the most significant achievements in the field of mineral processing in recent decades. Column flotation provides bubbly flow regime separation conditions because of lack of turbulence caused by mechanical impellers. It allows for countercurrent flow of bubbles, and the wash

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water rate makes concentration fluency easy and makes it be back because of the fountain from the bubble and gangue minerals was rewashed and drop-back to tailing [13]. At the same time, it provides necessary water for collected solids in over flow, bias water and washed concentration. It can be known that after a long initial period the columns went successfully into production for the flotation of a number of ores, floatable coals and metallic-industrial minerals. Column flotation has been investigated for different minerals and studies parameters. For fluorite, column flotation produced higher concentrate grades than conventional fluorite flotation coarse-bubble column flotation of the fluorite produced higher grades and recoveries than fine-bubble column flotation [14].The recovery and whiteness of talc obtained from column flotation based and this study were compared with those of conventional agitation-type flotation from other studies [15]. It can be seen that recovery of copper increases as the gas flow rate is increased, showing a maximum at round 84%Cu for 1.5 cm/sec. gas rate [16]. Column capacity to process the feed is maximized when processing dense slurries at relatively low rates, compared to that observed when operating with diluted slurries and relatively high rates [17]. Many studies were evaluated like these researches [18-27].

The effect of adsorption on column flotation performance has not been studied as yet to anionic and cationic collectors. Therefore, the purpose of this study is to obtain the adsorption capacity and column flotation recovery experimentally and compare Aero 825 to T.A.A. in terms of the possible mechanism of adsorption and column flotation application.

MATERIALS AND METHODS

1. Materials

In this study, pure talc sample was taken from Sivas, Turkey. Talc sample used in experimental study is of carbonated type with calcite, dolomite and some copper minerals (cuprite, tenorite, native Cu) in minor quantities as gangue minerals. The chemical analysis and XRD pattern of the sample used in the experiments are shown in Table 1 [27] and in Fig. 1.

Different-sized fractions were collected after the samples were dry ground using ball mills. The −106+75 μm, −75+53 μm, −53+38 μm size fractions were used for the adsorption and column flotation studies. Aero 825 and Tallow Amine Acetate were used in all experimental testing. Aero 825 was supplied by Cyanamid; T.A.A.

Table 1. The chemical composition of talc mineral used in the study

Component	Content (%)
SiO_2	59.52
MgO	30.97
Al_2O_3	1.06
Fe_2O_3	1.94
NiO	0.26
MnO	0.02
CaO	0.19
Cr_2O_3	0.05
P_2O_5	0.02
LOI	4.76

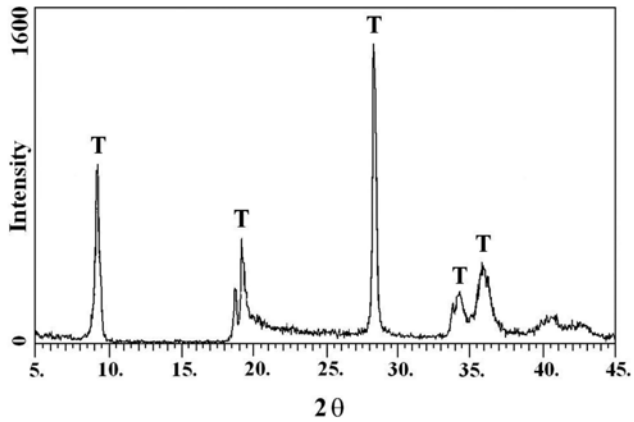

Fig. 1. The XRD pattern of talc sample used in the study.

(R^+-NH_3·CH_3COO^-) was obtained from the Akzo Nobel Company. The pH modifiers were used as H_2SO_4 and NaOH and deionised double distilled water was used for all adsorption and column flotation tests. All the chemical reagents were of analytical grade quality.

2. Methods

2-1. Adsorption Studies

Adsorption experiments were carried out to investigate the effect of pH, adsorption time, temperature, collector concentration, and particle size and column flotation on the adsorption capacity of anionic (Aero 825) and cationic (T.A.A) collector was studied for talc mineral. A Shimadzu Model 2401, double beam, UV spectrophotometer was used to record spectra to 3,065 nm. Here, in all adsorption tests, 9 g of talc powder was taken to make up to 21 ml pure water. Then the solution (pulp) was shaken in 100 ml Erlenmeyer flasks, centrifuged for 15 min at 4,000 rpm using a Hettich-Zentrifgen Universal 16A type Laboratory Centrifuge. The pulp was then filtered using blue ribbon filter paper and analyzed for adsorption capacity using UV-2401 spectrophotometer.

2-2. Column Flotation Studies

Column flotation is one of the most important new developments to emerge in mineral processing technology in the last years. In the experiments, the column height was 75 cm and the diameter was 5.5 cm. The column was run first with water and air until a steady state was reached. Peristaltic pumps were used for the feeding and the tailing exit. The pump performance was kept constant throughout the experiments. Air bubbles were generated with an air compressor (AC-9801 model) with a capacity of 1.8 *l*/min. Bubble diameters for a two-phase system (air-water) were measured by various software programs after visual imaging with a video camera. The air supplied to the column was regulated by an air flowmeter. Pulp was fed by a peristaltic pump at approximately two-thirds of the total height from the bottom of the column. Wash-water spray was added from 2 cm above the overflow level. The flow rate of the feed plus the water was equal to that of the drainage at the bottom of the column so as to operate the flotation column at a steady state. The experimental setup is shown in Fig. 2. The column flotation conditions used for the study were determined as follows: feed flow rate 10 cm^3/sec, tail flow rate 10.24 cm^3/sec, airflow rate 1 cm/sec, bias rate 0.24 cm^3/sec, the superficial flow rate of the wash water 2.5 cm^3/sec, wash water height 2 cm.

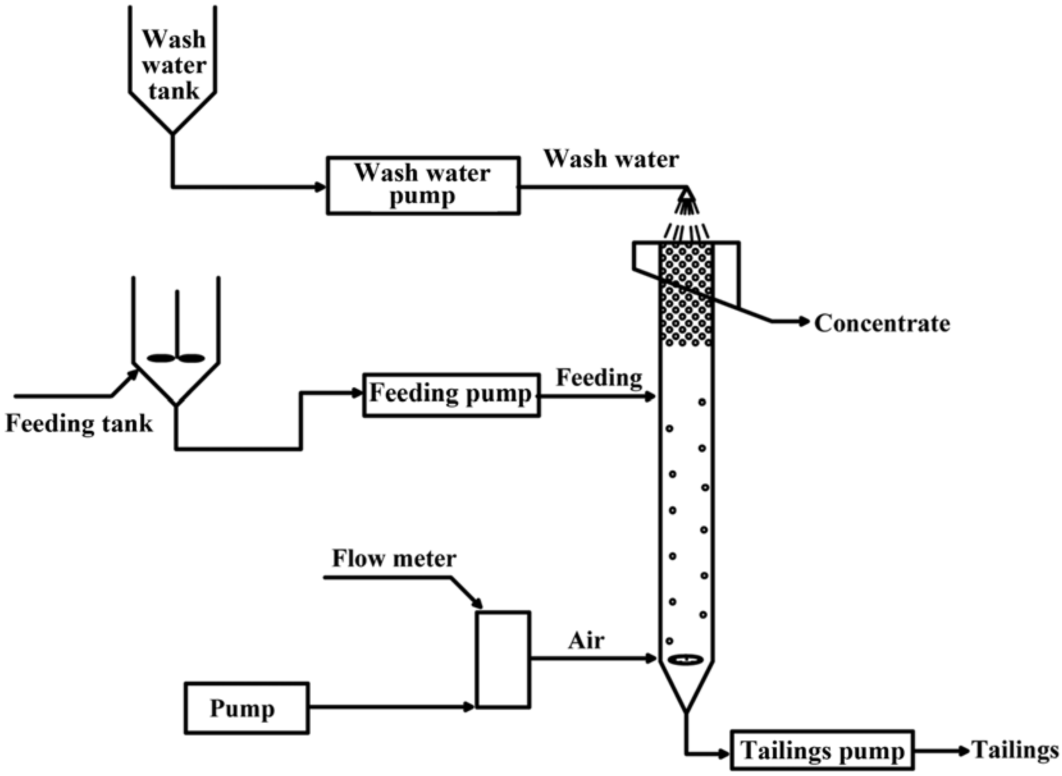

Fig. 2. The column flotation set-up used for the experimental study.

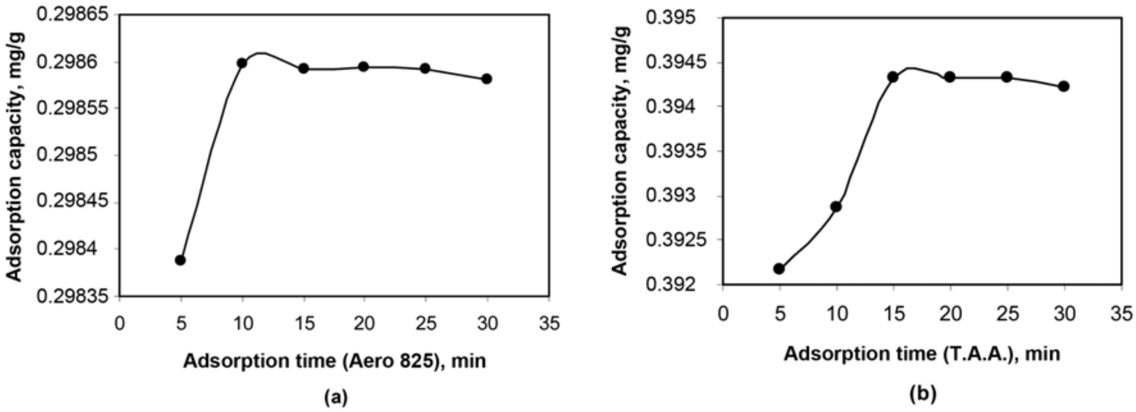

Fig. 3. The relationship between the adsorption time and adsorption capacity for Aero 825 and T.A.A. (–106+75 μm, 75 rpm, 20 °C and 300 g/t Aero 825, 400 g/t T.A.A).

RESULTS AND DISCUSSION

1. Adsorption Tests

Adsorption occurs when a gas or liquid solute accumulates on the surface of a solid or a liquid (adsorbent), forming a molecular or atomic film (the adsorbate). To study the effect of pH, the adsorption time, temperature, collector concentration and particle size were varied for the adsorption experiments of Aero 825 and T.A.A. onto talc.

1-1. Adsorption Time

Kinetic adsorption studies were carried out to determine the adsorption behaviour of T.A.A. and Aero 825 on talc. The result of experiments adsorption capacity at various adsorption times are shown in Fig. 3 for Aero 825 and T.A.A. The highest adsorption capacity was obtained at 10 minutes for Aero 825 and 15 minutes for T.A.A.

1-2. Effect of pH

The H^+ and OH^- ions are also the potential-determining ions for talc mineral with increasing the pH of the solution caused decreasing adsorption capacity. The effects of pH on the adsorption capacity of Aero 825 and T.A.A. on the talc are given in Fig. 4. The figure also shows that the adsorption capacity of Aero 825 and T.A.A. is dependent on pH in all ranges investigated. The highest adsorption capacity for T.A.A and Aero 825 was obtained at pH of 6-6.5.

1-3. Effect of Particle Size

The adsorption capacity of Aero 825 and T.A.A. onto talc as a function of pH for three different particle sizes, namely, −106+75,

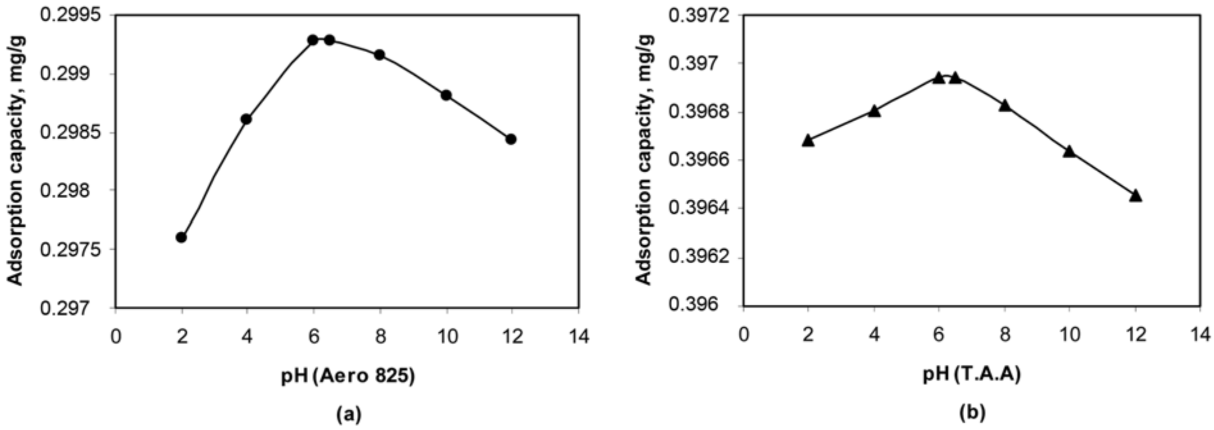

Fig. 4. Effect of pH on adsorption capacity of Aero 825 and T.A.A onto talc (−106+75 μm, 75 rpm, 20 °C, 300 g/t Aero 825, 400 g/t T.A.A).

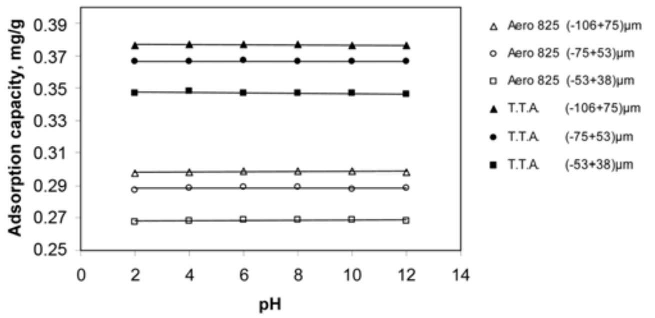

Fig. 5. Effect of pH on the adsorption capacity of Aero 825 and T.A.A for different particle sizes of talc (75 rpm, 20 °C, 300 g/t Aero 825, 400 g/t T.A.A).

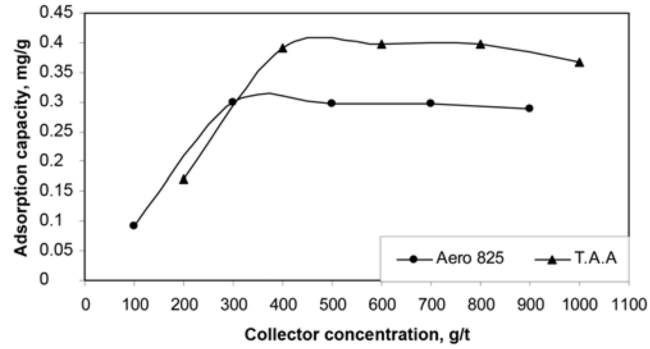

Fig. 6. Effect of collector concentration on the adsorption capacity of Aero 825 and T.A.A onto talc (75 rpm, 20 °C).

−75+53 and −53+38 μm, are shown in Fig. 5. The adsorption capacity of Aero 825 is lower than to that of T.A.A.

When talc particles are broken, two different surfaces are formed on some surfaces due to the easy cleavage between the layers; however, other surfaces are formed by the rupture of the ionic and covalent bonds, as a result of this termed "faces" and the latter "edges" [28]. The face-to edge ratio in the coarser sizes is higher than the finer sizes. These are nonpolar in water, present at a very low electrical charge and composed of fully compensated oxygen atoms. On the other hand, the edges made up of hydroxyl ions, silicon, oxygen and magnesium ions easily undergoing hydrolysis are polar water and present a relatively high electrical charge [9].

1-4. Effect of Collector Concentration

Fig. 6 shows the adsorption capacity that was obtained at different concentrations of Aero 825 and T.A.A. Aero 825 was adsorbed maximum onto solids in 300 g/t concentration, while T.A.A. was adsorbed minimum in 400 g/t concentration. Also, adsorption capacity in T.A.A. was higher than Aero 825.

1-5. The Effect of Temperature

The effect of temperature is shown in Fig. 7. The temperatures were set at 20, 25, 30 and 40 °C in an incubator shaker. The related figure shows that the equilibrium adsorption capacity decreases slightly, but shows steady decrease with increasing temperature. The highest adsorptions of both collectors were obtained at 20 °C ($Q_{Aero\ 825}$= 0.298 mg/g, $Q_{T.A.A.}$=0.397 mg/g). When the temperature was high, adsorption capacity was low.

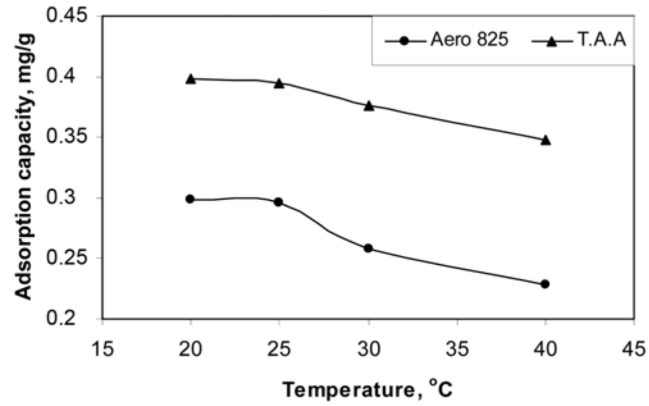

Fig. 7. The relationship between temperature and adsorption capacity in different concentrations (−106+75 μm, 75 rpm, 300 g/t Aero 825, 400 g/t T.A.A).

2. Column Flotation Tests

Column flotation experiments have been carried out to study the effect of pH, particle size, pulp concentration and effect of adsorption of Aero 825 and T.A.A. without frother on the mass flotation recovery.

2-1. Effect of pH

It is shown that the adsorption capacity and column flotation re-

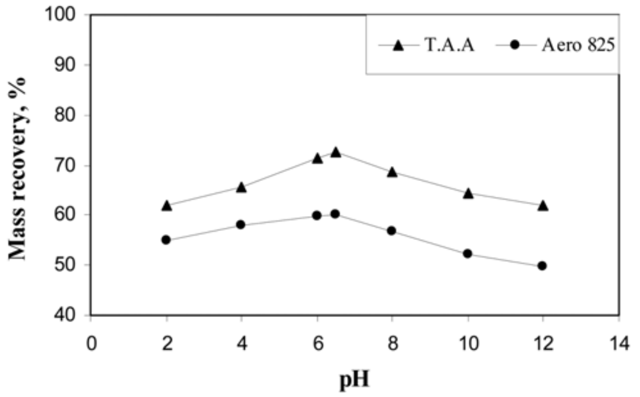

Fig. 8. Variation of mass recovery at various pH values (−106+75 μm, 300 g/t Aero 825, 400 g/t T.A.A).

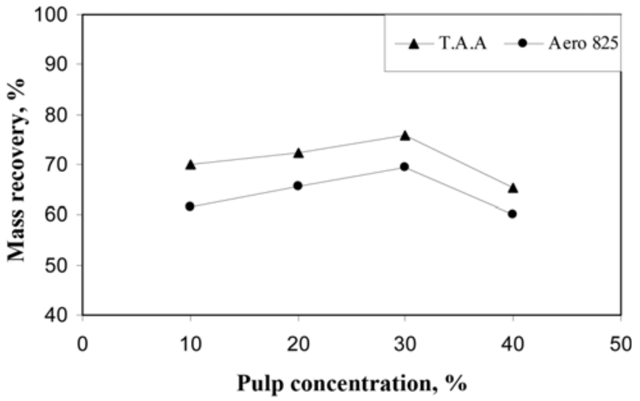

Fig. 9. The relationship between the mass recovery and pulp concentration (−106+75 μm, 300 g/t Aero 825, 400 g/t T.A.A.).

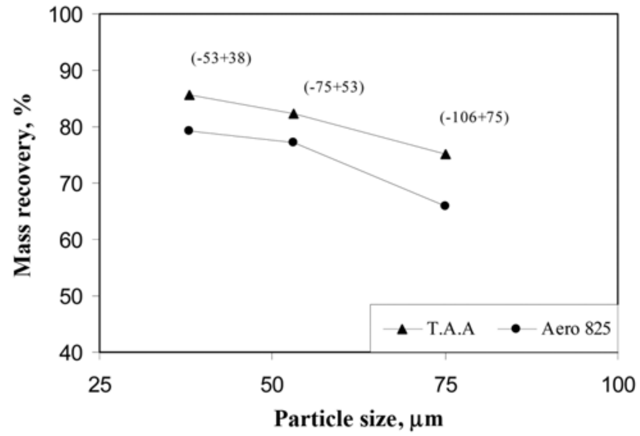

Fig. 10. The relationship between the mass recovery and particle size (30%, 300 g/t Aero 825, 400 g/t T.A.A).

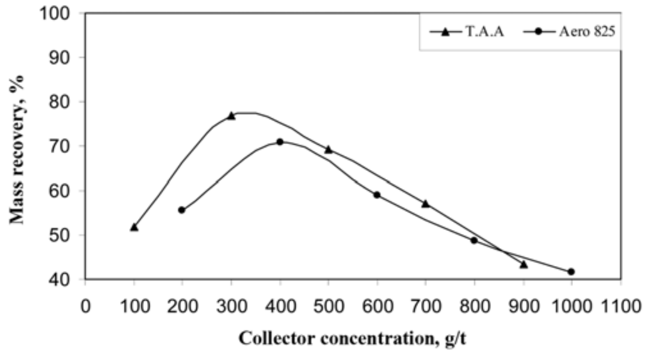

Fig. 11. The relationship between the mass recovery and collector concentration (30%, −106+75 μm).

covery of talc were dependent on pH. The results of experiments performed at various pH values are plotted: highest mass recovery was obtained at pH=6-6.5 for T.A.A (Fig. 8). The maximum mass recovery was obtained at pH 6-6.5 of 72.45% for T.A.A. and 60.11% for Aero825.

2-2. Effect of Pulp Concentration

As a matter of economics, flotation separations were performed as high pulp concentration for good selectivity and operating conditions [29]. The best solid rate in the experiments was determined as 30%, so bubble superficial is insufficient for the current operating values. The recovery decreased because they dropped back to the collection zone while particles left the bubble as a result of overloading of particles to bubble [30-32]. Further, above the pulp concentration 30% caused micelle on column flotation. When the pulp solid concentration was high, mass recovery was low (Fig. 9). The maximum recovery of T.A.A. (75.95%) is higher than that of the Aero 825 (69.33%).

2-3. Effect of Particle Size

Column flotation experiments were performed with −106+75 μm, −75+53 μm and −53+38 μm size fractions as indicated that the mass recovery increased when the particle size was finer. As it is easily seen from Fig. 10 the mass recovery increases with decreasing size. However, adsorption capacity was decreased when the particle size was decreased. It was thought that the mass recovery would increase due to entrainment of fine particles.

2-4. Effect of Collector Concentration

The experiments were carried out to investigate the effect of collector type and the quantities on adsorption capacity. As the mineral surface is negatively charge when Aero 825 is added, chemical adsorption mechanism has occurred, but if T.A.A. is added, physical adsorption mechanism has occurred (6). The maximum recovery of T.A.A. is higher than that of the Aero 825. The results of experiments for various quantities of Aero 825 and T.A.A. are shown in Fig. 11.

CONCLUSIONS

The adsorption of the collector on the solid particles was the most important factor that affects the floatability of talc. Floatability of talc was compared to anionic and cationic collector. It was dependent on pH, pulp concentration and the best adsorption capacity that appears to be the same value (pH: 6-6.5, Pulp concentration: 30%). The bubble raising speed was decreased, because the increase in pulp concentration causes high viscosity, and in this way, the residence time of particle in column was longer. The bubble raising speed and total air hold-up were decreased, because the solid quantity being constructed to the bubble would be decreased. The adsorption time of Aero 825 occurred earlier when compared to T.A.A. adsorption time, but decreased adsorption capacity. The result showed that T.A.A. was the best collector activity and it helped for better recovery during column flotation on the talc.

Adsorption capacity decreases when particle size decreases, due to the decrease of surface face-to-edge ratio in the surface of the finer particles. When the particle size became finer, the particles in the concentration with water increased in the column flotation. The entrainment increased as mass recovery increased. Because particle size highly affects the residence time and causes variations in bias rate, it was very important that there was great effect of the finer particles on the flotation recovery. Despite the low adsorption capacities per gram of absorbent (mg/g), the effect of column flotation was higher.

Consequently, in this study, we analyzed some parameters that affect column flotation performance and determined the adsorption capacity that had an important role in column flotation separations.

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