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A New Microscale Flotation Cell: Combination of Canadian Column and Partridge-Smith Cell

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ABSTRACT: Flotation is one of the most important physicochemical processes for mineral separations and other recovery operations. Flotation machines have been developed since the beginning of the 19 century and are still under intensive research and development. The devised cell is a combination of the Canadian Column Flotation Cell and Partridge-Smith Cell. The materials used for the construction of the newly-designed cell are cheap and available laboratory accessories and aquarium materials. The cell functions well in terms of its scale, the small samples required and control. It can be used anywhere in the laboratory for research and in the classroom for demonstrations of experiments. Some of the data obtained using this cell by the flotation method are in good agreement with the contact angles method measured independently on the same minerals. The measurements obtained in our experiments are comparable to those previously published for the same minerals used.

1 INTRODUCTION

Flotation is one of the most important physicochemical separation processes, used largely İn mineral separation operations. This method is not only used in mineral concentration and recovery operations, but also in water treatment and purification, the recycling of secondary materials, and the recovery of ionic and colloidal materials from aqueous solutions (Yarar, 1988a).

Flotation is a process for separating finely-ground minerals or solids dispersed in water (their slurry densities are usually 10-30% by weight) from associated worthless minerals or gangues. It is based on the adhesion of the minerals to air bubbles that are generated in the pulp. These air bubbles carry the floatable minerals or solids to the flotation cell surface, where they are taken as valuable solids or minerals referred to as 'concentrates*. The solids or minerals which do not float with the air bubbles stay in the pulp or at the cell bottom. They are known as 'tailings'(Weiss, 1985).

Flotation machines are made of a cell equipped with air, solution and mineral entry parts and exit parts. These machines perform the following functions:

- mixing and agitation of the slurry,
- aeration and promotion of particle-bubble collisions,
- formation of a froth layer and its removal for product recovery,
- continuous discharge of tailings.

A new version of an old flotation cell has led to the development of column flotation cells. These cells perform a good job of separating the highly hydrophobic minerals from their associated hydrophilic minerals (Yarar, 1988a).

2 THEORETICAL CONSIDERATIONS

The wettability characteristics of mineral surfaces can be defined in terms of their critical surface tension of wetting values (y_c) to achieve selectivity in froth flotation, adhesion and welding. Therefore, the y_c values of minerals can be used as a measure of their flotation behavior and response. The floatability or wettability characteristics of solids or minerals are estimated quantitatively by a number of experimental and empirical techniques. This quantifying parameter mentioned above is die critical surface tension of the wetting (y.) values of minerals or solids (Yekeler & Yarar, 1994a). The Zisman contact angle measurement technique and the flotation method are die two major techniques used to determine the Yc values of minerals among these experimental and empirical techniques (Kelebek, 1987, Yarar, 1988b, Parekh & Apian, 1974, Williams & Fuerstenau, 1986, Yekeleri Yarar, 1994b). The Zisman method, which uses a plot of Cos 6 (where 8 is the contact angle) against YLv (where ftv is the solution surface tension), gives a line that intercepts the x-axis at Yc = YLV- AS can be seen from Figure 1, at Yc > YLV the liquid spreads on the solid (mineral), while at Yc - YLV a contact angle, 6 > 0 is established İn the solid/liquid/vapor interfacial region (Yarar & Aksu, 1997).

The flotation method, on the other hand, estimates the Yc value of any mineral by plotting % recovery (%R) versus solution surface tension (YLV) with the extrapolation of the linear part of the R-YLV curve to the surface tension axis in order to obtain an intercept at %R = 0 as given in Figure 2.

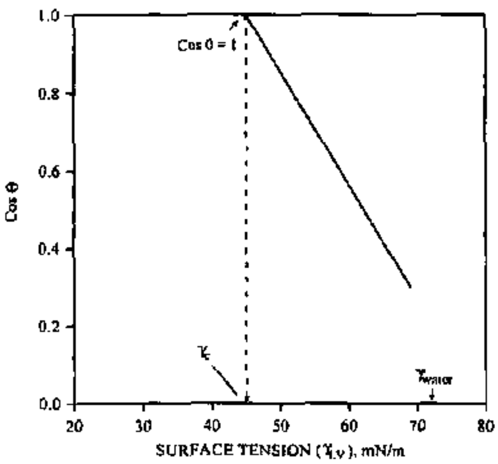
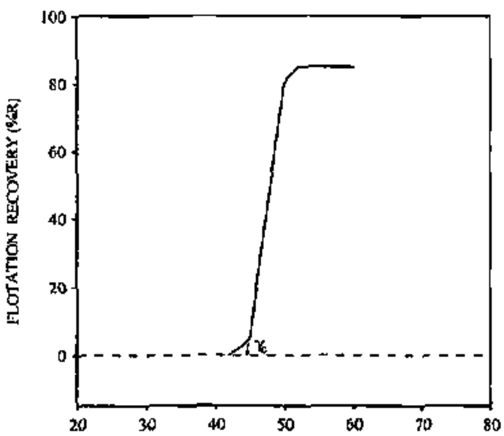


Figure 1, The Zisman contaci angle method to determine !he • % value (Shafrin & Zİsman, 1960).



SURFACETENSION (IJ.,). mNAn

Figure 2. Flotation method to determine the y_i value of any minerai (Yarar & Kaoma, 1984).

3 THE NEWLY-DESIGNED CELL

The devised cell is a combination of the Modified Partridge-Smith Cell (Partridge & Smith, 1971) and the Canadian Column Cell (Yoon, 1994) as shown in Figure 3. The cell is made from a graduate cylinder and various plastic materials. The total volume of the cell is 255 cm^3, the internal diameter is 36 mm and the height is 250 mm. There is an air-sparging system, which is used in aquariums as air stone, at the bottom of the cell. There are two channels (canals) to the microflotation column cell above the air-sparging system: one is the solution/liquid entry channel, the other one is the froth (floatable material) collecting channel, which is made of "'-'stic material. The main function of the air-sparg. system is to produce enough micro-bubbles to adhere to the mineral particles.

In order to produce the micro-bubbles required, there is an air-producing system (called the 1st air compressor, shown in Figure 3) which is turned on by button S3. The air flow rate to the cell İs 200 cmVmin, and this rate is adjusted by an air valve in the control panel. The liquid or solution is fed to the cell by a liquid reservoir which is made from a glassware separating funnel available in any laboratory. The feed part is a removable unit and it is taken apart from the cell after the feeding process is completed. In order to push the liquid to the cell, the 2nd air compressor, controlled by the S2 button, is employed to send the air at a feed rate of 75 cmVmin liquid flow. Both the air and liquid flow rates are adjusted by air and liquid valves located in the control panel shown in Figure 3. The 1st and 2nd air compressors, valves, plastic hoses and small motors are die same as those used in aquariums.

The main advantages of this newly-designed microscale flotation cell are as follows:

- The cell represents both the functions of the Canadian Column flotation and Modified Partridge-Smith Cell in small scale.
- It needs small amount of sample, solution, chemicals and air to perform tests.
- The cell works well in terms of sparger design, aeration rate, froth-collecting zone and operating pressure.
- It is easy to use, control and carry anywhere in the laboratories or classroom for demonstration.

The materials used for the constructing of the cell and its operating system are cheap and easily obtainable materials.

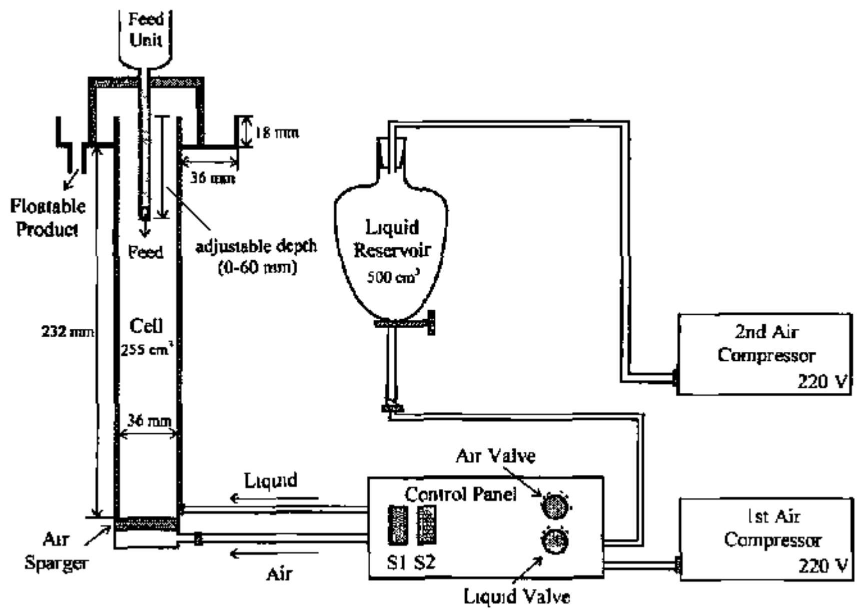


Figure 3 The new microscale flotation cell, which is a combination of the Canadian column and Partndge-Smithcell

3.1 *Operating the system*

The cell is operated at very low pulp density dilutions, which requires small amounts of sample to be separated from each other. After putting the solution in the reservoir, the S2 button is turned on to push the solution from the reservoir into the cell by means of pressured air. The SI button is used when the micro-bubbles are needed to float the particles from the particles that are unfloatable for the separation processes. Therefore, the floatable solids, known as the froth, are collected from the collecting channel as the 'floatable product* shown in Figure 3.

3.2 *Experimental test results*

3.2.1 *Flotation recoveries of some minerals*

Four minerals were tested in the new cell. These minerals are from different sources, being naturally floatable and non-floatable minerals. Two grams of sample was tested with 3 minutes of conditions and 1 minute of flotation. The floatable material (froth) was collected, filtered, dried and weighed in order to determine the % recovery values [(% Recovery = Floatable weight / Feed) x 100)].

These minerals were floated alone, in binary mixtures, without chemical reagents and with chemical reagents. The results are outlined in Table 1.

These results are comparable with the values in the literature (Kelebek & Smith, 1985).

3.2.2 *Determination of the y_c values of minerals*

Methanol solutions of different concentrations (%w/w) were prepared and used to obtain wettability data for construction of Cos 9 versus $y_{L}v$ and % Recovery versus YLV plots for talc and sulfur minerals. The solutions used in all the experiments were prepared with mono distilled water. The surface tensions of the solutions were measured by the drop-weight method (Padday, 1968). The surface tensions of methanol solutions determined against metiianol concentration are shown in Figure 4, with a comparison of the experimental data with data in the literature (Weast, 1987). The measured values of the surface tensions of the methanol solutions (by %v/v) were very close to the data in the literature.

The contact angle measurements were made with a Contact Angle Goniometer (Rame-Hart Inc., Model 100 NRL) in order to construct Zisman's wettability data. From these data, as shown in Figure 5, the y_c values of talc and sulfur were obtained; they were found to be 31 and 26, respectively. The y_c values of these minerals were also found to be 30 mN/m for talc and 28 mN/m for sulfur, using the same solutions as for the flotation medium in our newly-designed cell. The flotation results from the new cell are shown in Figure 6.

Table 1. The recoveries of some minerals obtained in the designed cell.

I. Individual Flotation with No Chemicals Used	Feed Sizes, µm	Recovery, %
Sulfur	-38	97.3
Calcite	-38	4.0
Talc	-38	46.0
Galena Concentrate	-20	6.6
II. Individual Flotation with Chemicals Reagents		
Calcite with Sodium oleate*	-38	56.8
Galena Concentrate with KAX**	-20	18 9
III. Binary Mixtures (1:1) with No Chemical Reagents		
Sulfur + Calcite	-38	43.3

*Sodium oleate (100 mg/L)
**Potassium amyl xanthate (250 mg/L)

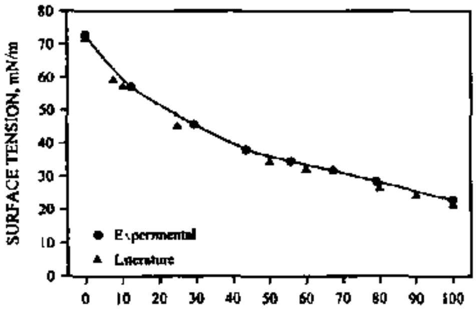


Figure 4, Surface tensions of methanol solutions used in the contact angle measurement and flotation tests to determine the Yc values of minerals.

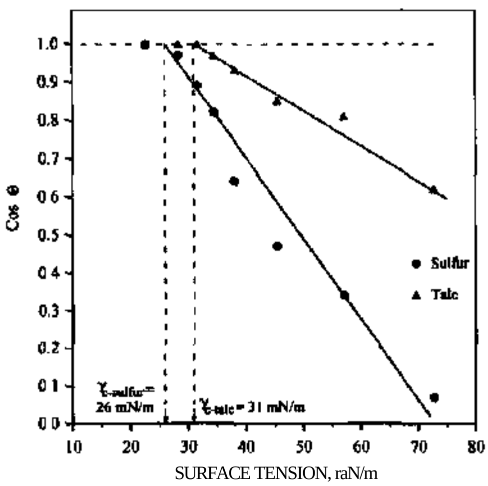


Figure 5 The y_c values of talc and sulfur by contact angle method using the goniometer.

The combined data obtained from the contact angle measurements and flotation tests are outlined in Table 2. As it can be seen, the y_c values obtained by goniometer are very close to fee values obtained in our newly-designed flotation cell, indicating that the new cell performs well.

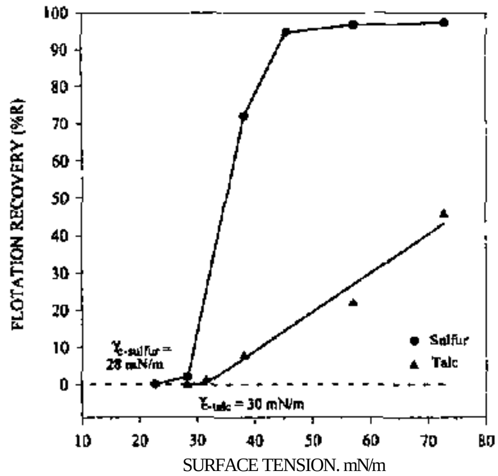


Figure 6. The y_c values of talc and sulfur by flotation, using the newly-designed cell.

Table 2. Comparison of the γ_c values of talc and sulfur obtained from the goniometer and the newly-designed cell.

Mineral	γ_c Values (mN/m) Obtained by	
	Contact Angle Goniometer	New Flotation Cell
Talc	31	30
Sulfur	26	28

4 CONCLUSIONS

The designed cell is a combination of the Canadian column flotation and Partridge-Smith Cell.

The materials used for 'the construction of the newly-designed cell are cheap and available laboratory accessories and aquarium materials.

The cell needs small amount of sample, solutions, chemicals and air to perform the experiments. It also works well in terms of the sparger design, aeration rate, froth-collecting zone and operating pressure. Therefore, it is easy to use, control and carry this cell anywhere in the laboratory or classroom for demonstrations.

The quantitative test results obtained from this cell are in good agreement with those obtained with other techniques and equipment.

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