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APPLICATION OF DIGITAL IMAGE ANALYSIS FOR SIZE DISTRIBUTION MEASUREMENTS OF MICROBUBBLES

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Application of Digital Image Analysis for Size Distribution Measurements of Microbubbles

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Abstract

This work employs digital image analysis to measure the size distribution of microbubbles generated by the process of electroflotation for use in solid/liquid separation processes. Microbubbles are used for separations in the mineral processing industry and also in the treatment of potable water and wastewater. As the bubbles move upward in a solid/liquid column due to buoyancy, particles collide with and attach to the bubbles and are carried to the surface of the column where they are removed by skimming. The removal efficiency of solids is strongly affected by the size of the bubbles. In general, higher separation is achieved by a smaller bubble size. The primary focus of this study was to characterize the size and size distribution of bubbles generated in electroflotation using image analysis. The study found that bubble diameter increased slightly as the current density applied to the system was increased. Additionally, electroflotation produces a uniform bubble size with narrow distribution which optimizes the removal of fine particles from solution.

Introduction

Many environmental and industrial treatment processes rely on the separation of solid particles from liquid solutions. Traditionally, solid particles are removed by sedimentation; however, sedimentation does not work well for low density particles like clay minerals, spores, and coagulated fulvic acids (Edzwald et al., 1992; Malley and Edzwald, 1991; Letterman, 1987). As a result, a method known as flotation, which floats rather than sediments low density particles, is being used more commonly. In flotation, small gas bubbles are generated at the bottom of the water column to be treated. The microbubbles then rise to the surface of the liquid through buoyancy. As the bubbles rise, they collide with and adsorb to particles in the

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solution; consequently, the low density solids are floated to the top of the column for removal by skimming. The process of flotation is known as dissolved air flotation if the microbubbles are produced by pressurizing air into water, as dispersed air flotation if the bubbles are produced by forcing gas through a sparger, and as electroflotation if the bubbles are produced through the electrolysis of water. This study will focus on bubbles generated by electroflotation.

Electroflotation has been used by the mineral processing industry for the recovery of mineral particles (Ketkar et al., 1991), and in environmental and industrial processes for the separation of oil from oil/water emulsions (Hosny, 1992; Balmer and Foulds, 1986), and for the removal of coagulated heavy metals from solution (Srinivasan and Subbaiyan, 1989; Ramadorai and Hanten, 1986). In all of these applications, the removal efficiency is strongly affected by the size of the generated bubbles. Smaller bubbles have a longer residence time in the system, have a larger surface area, and are more likely to adhere to solids after a collision (de Rijk et al, 1994). Consequently, the treatment process is optimized by generating the smallest diameter bubbles possible.

This paper examines the effect of the process variables of voltage, current, and ionic strength on the size of the bubbles generated during electroflotation. Bubble images were recorded with a long-distance, high-magnification microscope, and were printed and imported into a digital image analysis for measurement of equivalent bubble diameter. The average equivalent circular diameter for was calculated for each experimental condition; additionally, the volume distribution of the bubbles was calculated for each experiment.

Experimental

The rectangular test cell used in the experiments of this study was made of Plexiglas with dimensions of 58.4 cm by 7.6 cm by 2.5 cm. Inflow and outflow ports were drilled in the top and bottom of the cell and it was mounted vertically in order to allow gas flow out the top. After the cell was filled with the test solution, a soap-film flow meter was attached to one outflow port to measure gas flow rate and the remaining outflow ports were sealed. The electrodes used in the experiments were polished graphite electrodes (7.6 cm by 2.5 cm by 1.3 cm) and were mounted at the bottom of the cell with a separation of 13 cm. Electrical leads were attached to the electrodes using conductive epoxy, and then connected to an external power supply.

Twenty eight experiments were performed using aqueous solutions of deionized water mixed with Na_2SO_4 at ionic strengths of 0.1, 0.01, and 0.001 M. In the experiments, the voltage was varied from 15 to 86 V and the current was varied from 11 to 288 mA. Current was applied to the system using a high-voltage, high-current power supply and the generated bubbles were videotaped using a long-

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