ABSTRACT

Microbubble aided flotation has been widely employed in the various fields for the process intensification. They have been used for recovery of proteins, recovery of microorganism, removal of heavy metal ions from water, removal of dye and pigment. So an interest was felt to study the stability, rheology, dispersion characteristics of microbubble suspension in order to use them for the mineral beneficiation.

Based on the present status of research, this work was undertaken with the following objectives:

- ✓ Study the hydrodynamics such as rheology, pressure drop and friction factor of microbubble-suspension flow. Development of mechanistic model to analyze the interfacial stress of microbubble suspension flow considering the bubble formation, drag at interface and loss of energy due to wettability.
- ✓ Study the terminal rise velocity, microbubble size distribution and stability of microbubble. Development of correlations to interpret the bubble size and stability of microbubble.
- ✓ Investigation of the dispersion characteristic of ionic microbubble suspension in continuous plant prototype. Development of phenomenological model with consideration of liquid circulation to analyze the dispersion coefficient of the microbubble suspension.
- ✓ Study the mineral beneficiation by ionic microbubble in continuous plant prototype. Development of phenomenological kinetic model based on mixing, collision, attachment and detachment mechanisms of fine particles.

In the present study, experiments have been conducted to study the hydrodynamics and mineral beneficiation efficiency of microbubble suspension flow. The first attempt was made to explore the stability characteristics of microbubble. The stability of microbubble suspension was analyzed by drainage curve method and by electrical conductance method. The stability of microbubble dispersion can be evaluated in terms of its half-life, which is the time taken to drain half of initial liquid volume. Freshly prepared microbubbles were transferred to the measuring cylinder (0.03 m i.d.) and the volume of the drained liquid below the dispersion was measured at various times. Experimental results revealed that the stability of the microbubble can be significantly enhanced by increasing surfactant concentration. The half-life of SDS microbubbles increased from 72 s to 444 s as the SDS concentration increased from 5 ppm to 3000 ppm. For CTAB, the half-life of microbubbles increased from 101 s to 475 s as the CTAB concentration increased from 5 ppm to 500 ppm. In case of Tween-20, the half-life of microbubbles increased from 71 s to 364 s as the Tween concentration increased from 5 ppm to 100 ppm. From drainage curve analysis, it was observed that the liquid drainage curves of the microbubble dispersions followed the same trend for all kind of surfactants. Microbubble drainage process found to occur in three distinct phases.

Extensive experimental studies have been carried out to investigate the effect of physicochemical properties of phases on the size distribution and motion of rising microbubble. Liquid containing dispersed microbubbles was delivered from the microbubble generator in a short span of time to a transparent graduated glass cylinder (0.03 m i.d.). Immediately, the cloud of microbubbles in the suspension starts rising due to buoyancy, leaving a clear liquid interface. The terminal rise velocity of microbubble was determined by the rising trajectories of microbubble. The motion of rising microbubble was found to be significantly affected by

physicochemical properties of liquid and gas phase. In the present study three methods were used to calculate the size of microbubble. At low viscosity, the microbubble size was found to be dependent on surface tension of liquid. The microbubble size decreased from 52 μm to 25 μm as the surface tension deceased from 72 mN/m to 57 mN/m. The bubble size distribution of microbubble suspension for different concentrations was best fitted to Weibull distribution.

Next an attempt has been made to predict the gas holdup and rheological characteristics of microbubble in pipe. The gas holdup of system estimated by the electrical conductance method. The rheological characteristic of microbubble suspension flow was determined by the pressures drop across the pipe. The results reveals that the microbubble suspensions behave as a shear-thinning non-Newtonian liquid. An increase in surfactant concentration caused a decrease in shear stress and effective viscosity with shear rate. The drag coefficient and friction factor found to be decreased inversely with the Reynolds number. The results suggested that the presence of microbubbles can significantly reduce the frictional resistance. A mechanistic model has been developed to analyze the interfacial stress of microbubble suspension flow in a pipe by considering bubble formation, drag at the interface and loss of energy due to wettability. A correlation between the intensity factor of interfacial stress and the friction factor based on energy loss due to wettability has been developed. The functional form of the correlation appears to predict the hydrodynamics satisfactorily for the flow of a microbubble suspension in a pipe.

Extensive experimental studies have been carried out to measure the dispersion characteristics of microbubble suspension in continuous plant prototype developed for mineral beneficiation. The effects of different operating variables and physiochemical properties of liquid on the dispersion of microbubble suspension were also examined. It was observed that the dispersion coefficient increased with increase in surfactant concentrations. The value of

dispersion coefficient increased from 10.9 × 10^{-2} m^2/s to 12.41 × 10^{-2} m^2/s as the SDS concentration increase from 0 ppm to 15 ppm at fixed circulation velocity. For CTAB, value of dispersion coefficient increased from 11.10× 10^{-2} m^2/s to 12.10 × 10^{-2} m^2/s as the CTAB concentration increase from 34 ppm to 100 ppm. In case of Tween 20 dispersion coefficient increased from 11.3 × 10^{-2} m^2/s to 12.21 × 10^{-2} m^2/s as the Tween concentration increase from 0 ppm to 15 ppm at fixed circulation velocity. The value of dispersion coefficient decreased with increasing SCMC concentration. The effect of physicochemical properties of liquid on dispersion coefficient due to liquid circulation was also analyzed. A phenomenological model with consideration of liquid circulation was developed to analyze the dispersion coefficient of the microbubble suspension due to circulation. Generalized correlations for dispersion coefficient and the time to reach uniform dispersion were also developed based on the physicochemical properties of microbubble suspension.

Next an attempt has been made to investigate the mineral beneficiation by ionic microbubble in continuous plant prototype. The present study showed that fine particles can be significantly recovered by using microbubbles. The results revealed that the charge on the surface of microbubble is highly promising in separating opposite charged particles. The recovery of mineral particle was found to be dependent on surfactant concentration, size of microbubble and particles, zeta potential of microbubble, nature of surface potential of bubble and microbubble-particle mixture circulation velocity. It was also observed that the separation efficiency of microbubble increased with increase in mixture circulation velocity. The addition of surfactant in the mixture intensified the recovery efficiency. The recovery of ZnO and Al_2O_3 particles was maximum with CTAB. A maximum recovery of approximately 84 % and 72 % was obtained for ZnO and Al_2O_3 particle respectively by using CTAB. In case of CuO particles, the SDS and

Tween-20 were found to be more effective than CTAB. For CuO particles, maximum recovery of approximately 78 % was obtained by using SDS. A flotation model that includes the contributions from the efficiencies of collision, attachment and stability between particles and microbubbles was used to calculate the flotation rate constants. It was observed that rate constant is significantly influenced by the physicochemical properties of the liquid and particles. The flotation rate constant was also analyzed based on the mixing phenomena in the column.