Safoniuk M, Ph.D., "Application of Dimensional Similitude to the Hydrodynamic Study of Three-Phase Fluidized Beds", The University of British Columbia, July 1999 (co-supervised for the first 2 years, JR Grace of UBC as chief advisor).

Abstract

It is proposed that scaling of three-phase fluidized bed hydrodynamics can be carried out based on geometric similarity and matching of a set of five dimensionless groups: (i) the M-group, M=g× D r × m L4/(r L2× s 3); (ii) an Eötvös number, Eo=g× D r × dp2/s ; (iii) the liquid Reynolds number, ReL = r L× dp× UL/m L; (iv) a density ratio, b d=r p/r L; and (v) a superficial velocity ratio, b u=Ug/UL. These were varied in an experimental study where four dimensionless hydrodynamic parameters were measured: (i) gas hold-up, e g; (ii) bed expansion ratio, b be; (iii) the ratio of mean bubble diameter to particle diameter, db/dp; and (iv) the ratio of mean bubble rise velocity to gas superficial velocity, Ub/Ug. This approach was validated experimentally by matching the dimensionless operating conditions from a kerosene-nitrogen-ceramic three-phase system with those in an aqueous magnesium sulphate solution-air-aluminum particle fluidized bed. There was good agreement between the gas hold-ups and bed expansion ratios in the two systems.

A pilot-plant scale cold-flow co-current upwards-flowing three-phase fluidized bed column of inside diameter 292 mm was built and operated using three different liquids (tap water, an aqueous 44 mass % glycerol solution, and an aqueous 60 mass % glycerol solution), air, and cylindrical aluminum particles of diameter 4 mm and length 10 mm. The fluids and solids were carefully selected to result in dimensionless group values in the range of those of an industrial hydroprocessor. Specially built conductivity probes and pressure transducers were used to measure the hydrodynamic properties for different gas and liquid superficial velocities. Special attention was required to provide for drift and calibration when recording and analyzing data from the conductivity probes. Gas hold-ups were in the range of 5 to 20% by volume and were correlated as a function of liquid-phase Reynolds number and superficial velocity ratio. The gas hold-ups were a strong function of the velocity ratio with little influence of the liquid-phase Reynolds number. Bed expansion, in the range of 0-200%, was similarly correlated. Although bed expansion was dependent on the velocity ratio, the liquid Reynolds number had a much more significant influence. Bubble rise velocities, pierced chord lengths, and frequencies were also determined for a range of operating conditions.

A new approach for estimating gas hold-up based on the gas-perturbed liquid model, using calculated values of interstitial liquid velocity, was also developed. This approach gave favorable agreement with gas hold-up measurements based on pressure drops.