

Observation of bubble behavior in fluidized catalyst beds accompanied with mole number increase of fluidizing gas

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Abstract

An accurate evaluation of the mass transfer rate is important for the reactor design. The bubble size is one of the most important parameters. Although many bubble size correlations have been proposed, it is not always possible to calculate a reasonable value in industrial equipment¹⁾. There are many chemical reactions in which the total number of moles varies before and after the reactions. The mole number changes cause the volume changes at the constant temperature and pressure. As the gas volume changes, the number of bubbles and bubble size would differ from the predicted values at constant gas velocity. In addition, the mass transfer capacity coefficient between the bubble phase and the emulsion phase is also considered to be affected. However, very little research focusing on this point has been done²⁻⁴⁾, there is no knowledge about the influence on bubbles. Therefore, in this study, the gas volume was increased by evaporating the ethanol impregnated in the porous particles in two-dimensional fluidized bed, the influence of the gas volume expansion on the bubble behavior was directly observed.

The two-dimensional column was used in the experiments. It was prepared using glass plates coated with a transparent heater. Porous alumina was used for fluidized particles. A pressure sensor was connected to the other end, and the temporal change of the pressure drop was measured by a pressure sensor. Air was used as fluidizing gas. A fluidized state was photographed from the front using a video camera. An image was extracted from the obtained video. Binarization processing was performed on the images, and the bubble size was calculated. In this study, volume increase was simulated by liquid evaporation. In this study, ethanol was used to perform the experiments at lower temperature. In addition, when the fluidizing gas velocity was kept constant, particles impregnated with glycerol having a boiling point of 563 K were used to equalize the particle density.

Fig. 1 shows the average bubble size in a system with increasing gas volume and a system with constant gas volume. Change in average bubble size at the constant gas velocity is also shown in these figures for comparison. From Fig. 1 (a), under conditions where the gas volume expansion rate was small, the bubble size depending on the equilibrium relation of bubble splitting and coalescence was dominated by the gas velocity at that vertical position. Fig. 1 (b) shows the experimental results when the bed temperature was raised to 343 K. The inlet gas velocity was 1.0 cm s⁻¹ and the outlet gas velocity was 4.0 cm s⁻¹ in the system with increasing gas volume. In this condition, since the gas volume expansion rate is high, it seems that the gas velocity also rises considerably in the lower part of the bed. When the gas generation rate is large and bubbles adsorb much gases, the equilibrium relation of bubble splitting and coalescence shifts and bubble size would become larger. Bubbles were observed in a system in which the bed temperature was 333 K. The initial gas velocity was $U_{Gin} = 0.58$ cm s⁻¹, and the velocity increased with bed height. In this case, the outlet gas velocity was $U_{Gout} = 1.07$ cm s⁻¹. The bubbles that did not split or coalesce were chosen and observed. An image taken at 30 fps is shown in **Fig. 2**. Although these bubbles did not coalesce with others, they grew as ascending in the bed.

Reference

- 1) Levenspiel, O., *Ind. Eng. Chem. Res.*, **47**, 273–277 (2008).
- 2) Kai, T. *et al.*, *J. Chem. Eng. Jpn.*, **42**, s137–s141 (2009).
- 3) Wittmann, K. *et al.*, *Chem. Eng. Sci.*, **36**, 1673–1677(1981).
- 4) Li, T. *et al.*, *Powder Technol.*, **220**, 70–78(2012).

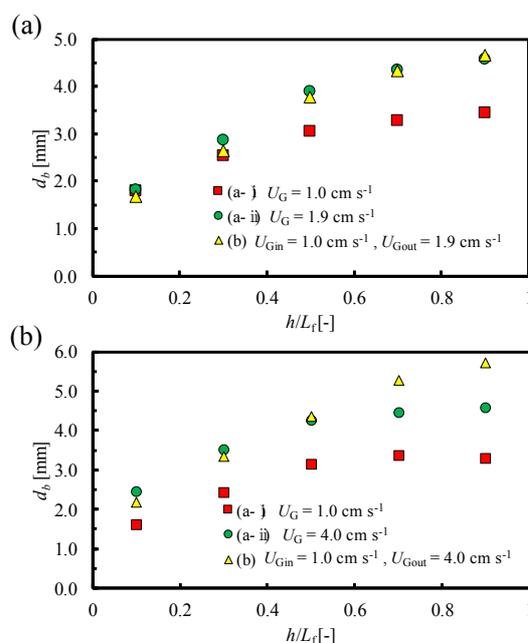


Fig. 1 Change in average bubble size with vertical position; (a) 333 K, (b) 343 K

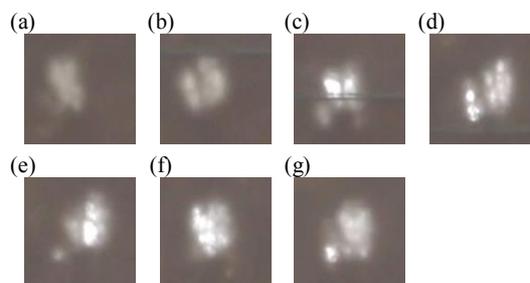


Fig. 2 Bubble growth in a system with gas volume expansion; (a) 0 s, (b) 0.033 s, (c) 0.067 s, (d) 0.10 s, (e) 0.13 s, (f) 0.17 s, (g) 0.20 s