Influence of gas volume expansion in a fluidized catalyst bed on bubble behavior

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Junya Shingu, Takami Kai, Tsutomu Nakazato

Abstract

Fluidized catalyst beds have been applied to many chemical processes since they were used in an FCC process. In the fluidized catalyst bed, reactions mainly occurs in the emulsion phase in which most of the catalyst particles exist. Therefore, it is important to increase the mass transfer rate between the bubbles and the emulsion phase. Since the interfacial area of the bubbles directly affects the mass transfer rate, it is important to generate small bubbles. A reactor model is required for the design of the fluidized bed reactor. Since the bubble size is an important parameter in the model, many researchers have studied the characteristics of the bubbles and have found knowledge of derived an understanding of the bubble behavior. Many correlations for bubble size estimation have also been reported[1)]. Bubble size will be affected by temperature, pressure, gas properties and gas volume change. A gas volume change is stoichiometrically caused by a change in the total number of moles of reactant gases before and after reactions. However, there are few studies on the effects of gas volume expansion, and there are many unclear parts about the effects on bubbles. In this study, the effect of the volume expansion of the fluidizing gas on the bed behavior was observed in a two-dimensional (2D) fluidized bed by using the method proposed by Kai et al.[2)]. The gas volume expansion was simulated by the evaporation of ethanol impregnated in the pore of porous particles. When the gas volume expands due to reactions, the physical properties of the gas change simultaneously. Therefore, the effect of volume expansion and the effect of gas properties on the fluidization behavior was separately evaluated.

The 2D fluidized bed was made of glass plates coated with transparent heaters to allow heating and visual observation. The height width and depth was 300 mm, 93 mm, and 2 mm, separately. The fluidizing gas was air. The fluidized material was porous alumina particles. The mean size was 61.8 μm and the density was 421 kg/m^3 when they were dried. The pressure drop was measured at the bed bottom using a pressure sensor. Porous particles impregnated with ethanol were fluidized at a temperature higher than room temperature, and the gas volume was expanded by the evaporation of ethanol. Under conditions where the gas volume was not expanded, particles impregnated with glycerin having a boiling point of 563 K were used to obtain the same particle density. The bed being fluidized was photographed with a video camera.

A color image utilizing the difference in porosity as shown in **Fig. 1** was created from a moving image taken by a video camera by image analysis. The image on the right shows a system with an expanding gas volume, and the two on the left show a system with a constant gas volume at the corresponding gas velocity. When the fluidizing gas expanded, the bubble size became a size corresponding to the gas velocity at that height. When the gas volume expands, it is considered that the bubble size reached a size corresponding to the gas velocity as a result of bubble coalescence, splitting, generation and absorption of the gas generated in the emulsion phase. However, when the gas expansion rate was further increased, the equilibrium bubble size was slightly larger than expected from the gas velocity at that height. This is probably because the bubble growth due to gas absorption became predominant over bubble splitting. When the inlet superficial gas velocities were the same, it was expected that the fluidized bed height would also expand because of the increase in bubble hold-up. However, those differences were not observed. Possible causes include that the bubble hold-up was not affected due to the increase in the bubble size and also rising velocity. From the image analysis, we investigated the effect of gas volume expansion on bubble behavior. The effect of gas composition was also investigated by image analysis.

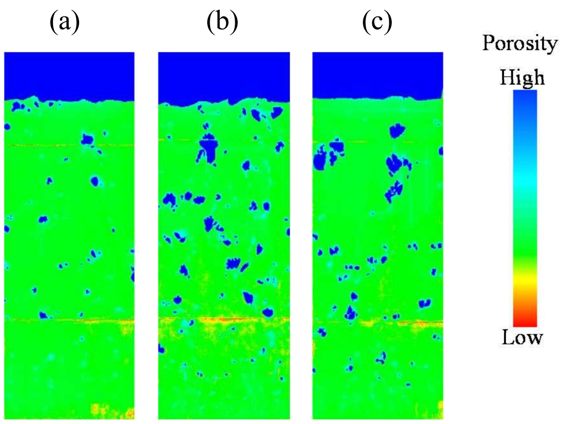

Fig. 1. Fluidization behavior; (a) Constant gas volume (U_G = 1 cm/s), (b) Constant gas volume (U_G = 1.84 cm/s), (c) Gas volume expansion ($U_{G,in}$ = 1 cm/s, $U_{G,out}$ = 1.84 cm/s)

References

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Department of Chemical Engineering, Kagoshima University, Kagoshima 890-0065, Japan