

Evaluation of a model considering concentration distribution in emulsion phase of fluidized catalytic beds

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Abstract

The fluidized catalyst beds have been used for many reaction processes. However, the information obtained by academic research is limited, and it is not necessarily enough for the scale up and design method of industrial equipment¹⁾. Although reactor model is essential for scale up and design of fluidized beds, it has been established enough. One reason is that it is not possible to estimate the bubble diameter in industrial scale reactors accurately. In the fluidized bed reactor, the reaction mainly occurs in the emulsion phase where most catalyst particles are present. When the catalytic activity is high, the mass transfer rate between the bubbles and the emulsion phase becomes the rate-determining step. Therefore, it is necessary to increase the surface area of bubbles by reducing the bubble size diameter, and to increase the mass transfer rate between the two phases. In addition to the mass transfer resistance between the two phases, there is also the influence of back mixing of the emulsion phase gas. Therefore, it is considered that the selectivity of the intermediate product of successive reactions decreases as compared with the tubular reactor that can approximate the piston flow.

However, Tsutsui³⁾ analyzed a model of fluidized catalyst bed for successive reactions, and described that the high reactor performance could be obtained by utilizing the direct contacting particles and improvement of the mass transfer between the two phases. In this study, the effects of the mode of contact between catalysts and reactant gases in the fluidized catalyst beds on the selectivity of successive reactions are studied.

For the first order successive reaction represented by $A \rightarrow R \rightarrow S$, the mass balances for components A and R in the bubble phase are described. Assuming that the gas exchange rate between the upward flow and the downward flow in the emulsion phase is sufficiently fast, the concentrations in each phase at the same vertical position can be approximated to be equal. In the case of fluidized catalyst bed, the gas flow in the emulsion phase can be ignored because it is much smaller than the gas flow as bubbles. By assuming piston flow for the reaction in the dilute phase, the equations are obtained for each component.

Many reactor models proposed previously uses the mass transfer coefficients obtained from bubble diameters, so many correlations of bubble diameters have been also proposed⁵⁾. However, these models cannot be applied successfully to the scale-up and design of fluidized bed reactors. It was pointed out that one of the major reasons was the accurate estimation of bubble diameter in a large-sized fluidized bed²⁾. In addition, the bubble diameter is strongly influenced by gas physical properties and temperature⁶⁾, and it is considered that the bubble diameter obtained by fluidization with ambient temperature air is greatly different from that of the actual reaction system. Therefore, calculation is performed with the mass transfer capacity coefficient as a variable parameter.

The selectivity in the successive reaction is affected by the direct contact particles. **Fig. 1** shows the relationship between the reaction rate and the selectivity of component R. The results for two ideal flows, piston flow (PF) and completely mixed flow (CMF) are also shown. When the direct contact particles are not considered, even if the reaction rate is increased, the maximum conversion is only 78%. This is because that the mass transfer between two phases becomes the rate-limiting step. In addition, the selectivity of this reactor is lower than that of a reactor in which a completely mixed flow is assumed. On the other hand, when the direct contact particles are considered, the selectivity is not much different from the case of completely mixed flow at the conversion of 50%. However, the selectivity approaches the result with piston flow as the conversion increases. On the other hand, when the final product of the successive reaction is a desired product, the larger selectivity of component S can be obtained compared with that in a completely mixed flow reactor by reducing the direct contact particles.

References

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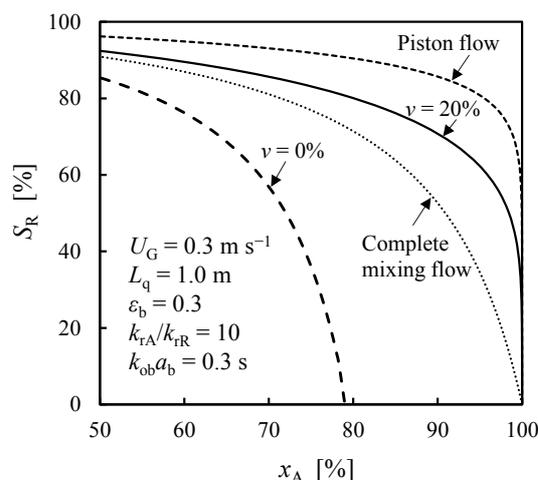


Fig. 1 Effect of direct contacting catalysts on the selectivity of component R.