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Study of Fluid Flow and Transport in Packed Bed Compact Reactors

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1. Introduction

Among multiphase reactors in the chemical and pharmaceutical industries, packed bed compact reactors with internal diameters on the order of millimeters or micrometers are of interest. However, the design and operation method of packed bed compact reactors has not been established because it is difficult to analyze the flow pattern, which greatly influences heat and mass transfer performance, by visualization. In this study, an experimental system consisting of a packed bed compact reactor is constructed, and a method of estimating the flow pattern in the reactor is developed through experimental analysis of the measurement results of voltage or differential pressure. In addition, CFD simulation is performed to understand the flow and its interaction with reaction and transport. This abstract focuses on the estimation and analysis of fluid flow patterns in the packed bed compact reactor.

2. Method

A schematic diagram of our developed experimental system is shown in **Fig. 1** (left). Nitrogen and water are fed into a T-shaped mixer to form gas-liquid slug flows, and they then enter a packed bed compact reactor. A PTFE tube with an inner diameter of 3.2 mm and a length of 150 mm is used as the reactor, where spheres with a diameter of 1.0 mm are filled. Electrodes and pressure sensors are installed at three locations of 10 mm, 60 mm, and 110 mm from the reactor inlet, and they are used to estimate the flow patterns.

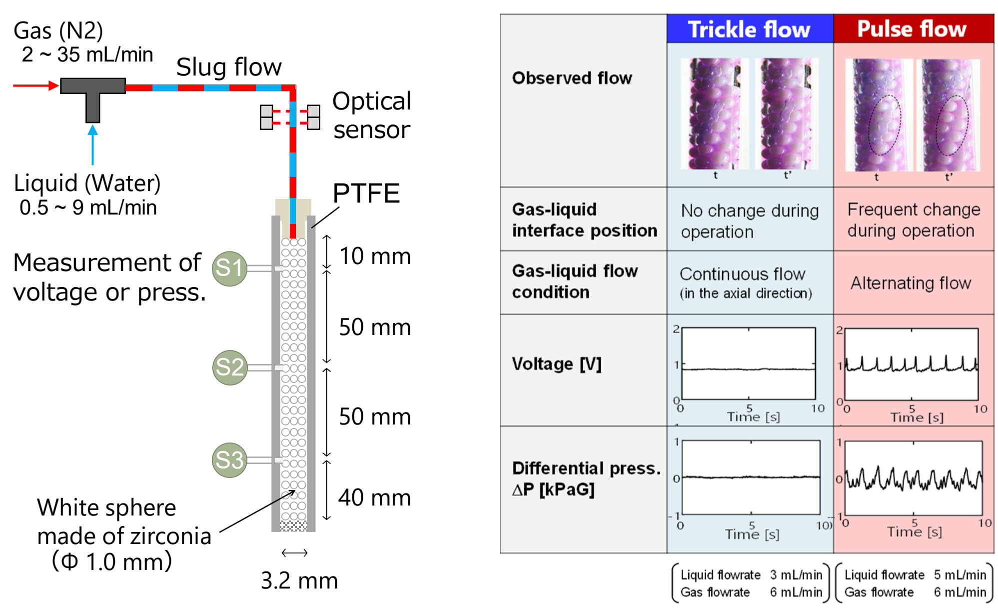

Figure 1. A developed experimental system (left) and observation results (right).

3. Results and discussion

In the developed experimental system, the gas flow rate was changed from 2 to 35 mL/min, and the liquid flow rate was changed from 0.5 to 9 mL/min. As a result, two types of flow patterns, pulse flow and trickle flow, were observed as shown in **Fig. 1** (right). In addition, it is shown that the measurement results for both voltage and differential pressure differed depending on the flow patterns. That is, in the case of trickle flow, there was almost no fluctuation in voltage and differential pressure, and in the case of pulse flow, fluctuations in voltage and differential pressure were observed, as shown in **Fig. 1** (right). It can be said that the measurements of voltage and differential pressure are useful in distinguishing between the flow patterns.

Figure 2 (left) shows a flow pattern diagram, in which the observed flow patterns were plotted, with reference to the literature [1]. The region surrounded by the broken line in the figure shows that the flow patterns changed from trickle flow to pulse flow when the liquid flow rate was increased under the fixed gas flowrate. **Figure 2** (right) shows the power spectral density obtained by frequency analysis of the measurements of voltage and differential pressure. As a result, it is confirmed that the peak frequency was 0.90 Hz and 3.06 Hz when the liquid flow rate was 5 mL/min and 9 mL/min, respectively, under the pulse flow conditions. Compared to the results of the gas-liquid flow video analysis, it is confirmed that these peak frequencies coincided with the frequency of gas and liquid pulses passing through the reactor. As the peak frequency becomes high, the gas-liquid mixing efficiency is improved. Therefore, the frequency analysis of the measurements of voltage and differential pressure is useful in grasping the degree of mixing of gas and liquid.

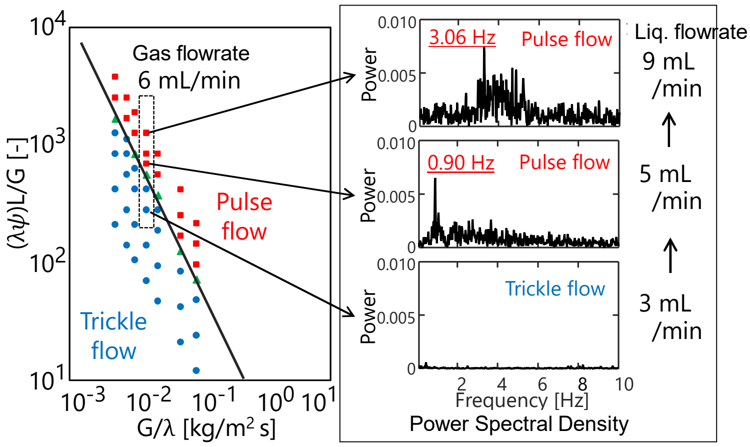

Figure 2. Flow pattern diagram (left) and power spectral density (right).

4. Conclusions

Our developed method made it possible to distinguish the flow patterns, i.e. trickle flow and pulse flow, from the shapes of the measured voltage or differential pressure, and to estimate the pulse frequency of pulse flow (namely, peak frequency of power spectral density), which is useful in grasping the degree of mixing of gas and liquid. In addition, although not described in detail in this abstract, CFD simulation was performed to quantitatively evaluate the fluid flow and its interaction with the reaction and transport.

Reference

[1] J.C. Charpentier and M. Favier; AIChE J., 21 (1975) 1213-1218