

Analysis of defluidization due to gas adsorption by fluidized particles

Yuya Taira, Takami Kai, Tsutomu Nakazato

Abstract

Fluidized beds are widely used in chemical processes. An unexpected decrease in fluidization quality is sometimes observed during the operation of fluidized beds. One of the reasons is that the gas velocity decreases in the emulsion phase. When it decreases below the velocity required for fluidization, the gas drag force becomes too small to balance the gravitational and buoyancy forces acting on the particles. Consequently, the particles agglomerate, resulting in defluidization. In industrial processes, the fluidizing gas is switched at the startup and shutdown of the operation. Defluidization after gas switching was observed when the adsorptivity is higher for the fluidizing gas after the gas switching^{1, 2)}. Lu *et al.*³⁾ also reported that pulverized coal particles were not discharged from a hopper when the fluidizing gas was switched from air to CO₂. In this case, defluidization occurred with the decrease in the pressure drop. Understanding the aforementioned phenomena is important when attempting to determine the conditions necessary to maintain good fluidization in industrial processes. In the present study, the effect of the difference in gas adsorptivity on the fluidization behavior was analyzed.

An acrylic resin tube was used for the construction of fluidized bed. The inner diameter and height were 52 mm and 1500 mm, respectively. The settled bed height was 30 cm. A pressure sensor was connected to the port attached to the wall surface of the bottom, and the temporal change of the pressure drop was measured. Activated carbon, porous silica, porous alumina and glass beads were used as fluidizing particles. The first and second fluidizing gases were Ar and CO₂, respectively. They have different adsorption properties, whereas the molecular weight are close. This is because the effect of non-equimolar diffusion⁴⁾ due to the difference in molecular weight should be avoided.

In the experiments, Ar gas was supplied at a constant superficial gas velocity. After the stable fluidization was confirmed, the pressure data sampling was started, and the fluidizing gas was switched to CO₂ gas. The pressure drop was recorded and the measurement was finished after confirming that the fluidized state recovered and was stable.

Visualization of the fluidization was performed using a two-dimensional (2D) fluidized bed. Its width and depth of the bed cross section were 130 mm and 5 mm, respectively. The bed was illuminated with back lighting, and the motion of the bed was recorded from the front side of the bed using a video camera. Grayscale values of each image were affected by the intensity of light transmittance. The difference in the particle density in the bed was described graphically by the conversion of grayscale values into colors in the RGB space.

Two types of defluidization phenomena were observed in the case of porous particles. **Fig. 1** shows the temporal change of the fluidization behavior when the fluidizing gas was switched from Ar to CO₂ in a 2D fluidized bed. The superficial gas velocity was 1.5 cm/s for the first gas and 1.9 cm/s for the second gas. The fluidized particles were porous silica with a particle size of 48.7 μm. Fourteen seconds after the fluidizing gas was switched, it can be seen that the emulsion phase aggregated in the bottom of bed and the bed height decreased due to the adsorption of CO₂. The bubbles disappeared after 27 s, and a channel was completely formed. Some of channels were formed. The fluidization restored after 170 s after the channel walls were destroyed by the gas flow. This phenomenon was mainly observed for particles smaller than 100 μm.

Fig. 2 shows the time series of the pictures when the porous silica with 142 μm size was used. The other conditions were the same as those in the experiment represented in Fig. 1. Aggregation of the emulsion phase started immediately after the gas was switched and bubbles completely disappeared, and the whole bed became a fixed bed after 7 s. After 10 s, the bed was plugged by the contracted upper part of the bed. It was lifted by the fluidizing gas. Afterwards, the bottom of this zone gradually collapsed, and fluidization completely recovered after about 80 s. This phenomenon did not depend on the CO₂ adsorption capacity, but was observed for larger particles.

References

- 1) Kai, T., Y. Tashiro, Y. Hirano, T. Nakazato, *Powder Technol.*, **237**, 153–159 (2013)
- 2) Kai, T., T. Takahashi, *AIChE J.*, **44**, 491–494 (1998)
- 3) Lu, H., X. Guo, S. Tao, X. Gong, *Powder Technol.*, **281**, 193–199 (2015)
- 4) Kai, T., K. Terachi, S. Wada, T. Nakazato, *Kagaku Kogaku Ronbunshu*, **44**, 229–235 (2018)

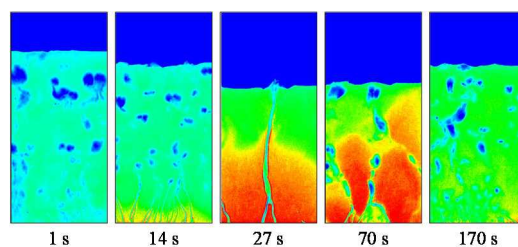


Fig. 1 Channeling behavior after gas switching

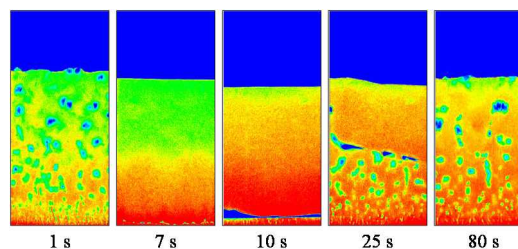


Fig. 2 Plugging behavior after gas switching