The 10th TSME International Conference on Mechanical Engineering
10th – 13rd December 2019
Pattaya, Thailand

Pressure Response in Large Amplitude Oscillation Flow of Concentrated Particle Suspension

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Abstract

Flow of particle suspensions dispersed solid particles in liquid, can be seen in various fields such as manufacturing of composite materials, food processing and pharmaceutical development. In general, it is known that the particle suspensions are classified in non-Newtonian fluids, and that the fluid properties of suspensions depend on various factors such as the particle size and shape and the volume fraction of particles in fluids. Therefore, suspension flow shows complex phenomena that are not seen in a Newtonian fluid, and have some interesting behaviors in the points of rheological view. Especially, in the case of concentrated suspension, it has been reported that the characteristic behaviors called the particle flocculation and self-filtration appear in a flow. From previous reports, these phenomena are considered to relate to the hydraulic and colloidal interaction among particles induced by a flow. However, the particle interaction was mainly examined for a relatively simple flow, while there are few reports about complicated flow fields. In this study, we focused on the oscillation flow with large amplitude as the complex flow. In general, the large amplitude oscillation flow is often used in the examination of non-linear response with respect to complex fluids like polymer solutions, and the flow regime is generated by the coaxial rotation of a bob in a cup. In the concentrated suspensions, however, it is expected that the effect of flow regime will be more pronounced in the squeeze flow than in the rotational one. Consequently, in the present experiments, we used the oscillation flow generated by making a bob (φ15 mm) in a cup (φ15.7 mm) move up and down. The gap between the bob and cup was 0.35 mm in the radius direction. The oscillation flows were generated by the reciprocal movement of the bob. For the reciprocal movement, the amplitude was constant at 3 mm and the oscillating period varies. Furthermore, the movement of the bob was controlled by a linear moving system using a servomotor, and the signal supplying the motor was sinusoidal. We carried out the experiments about the measurement of hydrostatic pressure at the bottom of cup and the flow visualization near the tip of bob, and evaluated the effect of interaction among particles by the change in flow resistance in the reciprocal movement of the bob. As the concentrated suspension, we used the mixture of glycerin and solid particles with a mean diameter of about 50 μm. The volume fraction of the solid particle in suspension was 40 %. In the measurement of pressure response, we confirmed that the difference in pressure response accompanying with the reciprocal movement of the bob occurred. Drawing the Lissajous figure using the temporal data of pressure and bob displacement, we found the hysteresis of pressure response occurred. Especially, when the moving direction of the bob switches from a pushing to a pulling, the response meaning a time delay appears in the pressure curve. The delay becomes more remarkable as the oscillating period shortens. It is expected that such time delay in pressure response suggests the occurrence of particle flocculation. Furthermore, in pulling of the bob, it was observed that the irregularity of particle concentration occurred in the region neighborhood of the tip of bob. These results in the flow visualization might imply the occurrence of the particle flocculation.

Keywords*:* Particle suspension, Oscillation flow, Pressure response, Particle flocculation.