Direct numerical simulation of the particulate flow with anisotropic Janus magnetic particles

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ABSTRACT

We present the dynamics of elliptic Janus magnetic particles suspended in a viscous fluid and the fluid flow in the presence of an externally applied uniform magnetic field. Since a Janus particle is compartmentalized into two areas with two distinct magnetic properties, the particles is an anisotropic particle with asymmetry and directionality in a single particle [1-2]. A previously developed direct simulation method [3], which is based on the finite-element-based fictitious domain method, is employed to solve the magnetic particulate flow. As for the magnetic problem, the two Maxwell equations are converted to a single differential equation using the magnetic potential. The magnetic forces acting on the particles are treated by a Maxwell stress tensor formulation, enabling us to consider the magnetic interactions among the particles without approximation. In the flow problem, the inertia of particles and the fluid are neglected. The hydrodynamics interactions are treated by the modified rigid-ring description, implemented by means of Lagrange multipliers defined on the particle boundaries and the internal interface between the magnetic and non-magnetic materials in a particle.

First, the dynamics of a single elliptic particle in an externally applied magnetic field is studied, focusing on the effect of the aspect ratio of the particle and the magnetic susceptibility on the particle motions. The orientation angle at equilibrium varies with the aspect ratio of the particle. Then, we extended our interest to multi-particle problems, trying to investigate the effect of the initial configuration of the particles on the particle motions. In the uniform magnetic field, particle motions of the two elliptic particles are completely different from those of circular magnetic particles. The particle dynamics and the fluid flow induced by the particle motions are significantly affected by the orientation and the configuration of the particles. In addition, final assembly structure is not fixed but varies with the particle shape and the initial distribution of the particles. Magnetic anisotropy caused by the non-uniform distribution of magnetic material and (or) the shape anisotropy lead to more complicated particle motions compared with those of magnetically isotropic particles.

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