Study of Rotation of Ellipsoidal Particles in Combined Simple Shear Flow and Magnetic Fields

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Abstract

Jeffery's theory describes the periodic rotation of ellipsoidal particles in a simple shear flow at vanishing Reynolds number limit. In this paper, we present a numerical method to study the motion of ellipsoidal particles in a simple shear flow subjected to a uniform magnetic field. Magnetic field around the ellipsoidal particle is simulated using AC/DC module in COMSOL Multiphysics® software (Figure 1). Modelling of fluid-structure interaction (FSI) is realized by combining Creeping Flow component in Fluid Flow module, Global ODEs and DAEs and Moving Mesh components in Mathematics module as shown in Figure 2. Creeping Flow component is used to simulate flow field around the ellipsoidal particle by setting a constant wall velocity on the top and bottom of the same magnitude but of opposite directions. The rotational motion of the particle is determined by solving ordinary differential equations (ODEs) in Global ODEs and DAEs component. Moving Mesh component is used to describe the deforming mesh at the particle-fluid boundaries. To simulate the rotation of ellipsoidal particle in a magnetic field, the magnetic torque is added to the FSI model. We investigated the effect of several parameters, including aspect ratio (major axis's length / minor axis's length) of particle, magnetic field intensity, and angle of magnetic field, on rotation period and asymmetry of particle rotation. It is shown that the period of rotation increases as aspect ratio increases, in good agreement with Jeffery's theory. When a magnetic field is applied perpendicular to the flow direction, the rotational period became longer, and the magnetic field breaks the symmetry of cyclical up-down motion of the ellipsoidal particle as shown in figure 3. As the magnetic field strength increases to a large enough value, the particle could not perform a complete rotation and reaches a steady angle. With different direction of the magnetic field, the period of rotation and asymmetry of the angular dynamics is also modified.