Anisotropic Particle in Viscous Shear Flow: Navier Slip, Reciprocal Symmetry, and Jeffery Orbit

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The hydrodynamic reciprocal relations and the Jeffery orbit, both of which arise from the motion of a slippery anisotropic particle in a simple viscous shear flow, are investigated theoretically and numerically. For a slippery elliptical particle in a linear shear flow, the hydrodynamic reciprocal relations between the rotational torque and the shear stress are studied and related to the Jeffery orbit, showing that the boundary slip can effectively enhance the anisotropy of the particle. By replacing the no-slip boundary condition with the Navier slip condition at the particle surface, the cross coupling between the rotational torque and the shear stress is enhanced, reflected in the hydrodynamic reciprocal relations and the Jeffery orbit. In addition, simulations for a circular particle patterned with portions of no-slip and Navier slip are carried out, showing that the particle possesses an effective anisotropy and follows the Jeffery orbit as well. This effective anisotropy can be tuned by changing the ratio of no-slip portion to slip potion. The connection of the present work to nematic liquid crystals' constitutive relations is discussed.

This presentation is based on the work supported by Hong Kong Research Grants Council.