DOCTORATE THESIS

Angular dynamics of small particles in fluids

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Akademisk avhandling för avläggande av doktorsexamen i fysik vid Göteborgs universitet. Avhandlingen försvaras vid ett offentligt seminarium måndagen den 14 december 2015, kl 09:00 i PJ-salen, Institutionen för fysik, Fysikgården 2, Göteborg. Avhandlingen försvaras på engelska.

Fakultetsopponent	Prof. Eric Shaqfeh, Stanford University
Betygskommitté	Prof. Anna-Karin Tornberg, KTH
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Particles suspended in fluid flows are common in nature. Important examples are drops of water or particulate matter in the atmosphere, and planktonic microorganisms in the ocean. Due to fluid velocity gradients, non-spherical particles are subject to a hydrodynamic torque. The torque leads to rotational motion of the particle. This thesis describes our work on the orientational dynamics of non-spherical particles suspended in fluid flows. We consider the viscous Stokes regime, where the particle Reynolds number $\mathrm{Re_p} \ll 1$ ($\mathrm{Re_p} = u_0 a/\nu$, where u_0 is a typical flow speed, a is the particle size and ν is the kinematic viscosity of the fluid). In this *advective limit*, the hydrodynamic torques are given by Jeffery's theory [JEFFERY, G. B. *Proc. R. Soc. Lond. A* **102**, 161–179 (1922)].

First, we describe a microfluidic experiment where we observe periodic and aperiodic tumbling of rod-shaped particles. We argue that the aperiodic tumbling is commensurate with the quasi-periodic and chaotic tumbling predicted by the inertia-free limit of Jeffery's theory.

Second, we calculate a modification to Jeffery's theory for axisymmetric particles, that takes into account the first effects of particle inertia. In a simple shear flow the particle inertia induces a drift towards a limiting orbit. We describe how the stationary orientational distribution of an ensemble of particles is determined by the competition between particle inertia and Brownian noise.

Third, by averaging Jeffery's equation along particle trajectories, we make a connection between rotation rates and the third-order Lagrangian correlation functions of the flow. Our result explains recent numerical and experimental observations of different tumbling rates for disks and rods in turbulence.

Finally, this thesis contains a non-technical introduction to the study of particle dynamics in fluid flows, aimed at a wider audience.

Keywords: *Fluid dynamics, particles, orientational dynamics, non-spherical particles, suspensions, rotational diffusion, tumbling, turbulence*