Annual International Meeting on
Complex Fluids and Soft Matter
CompFlu 2025, Bangalore

CompFlu 2025
13-17 December 2025

Beyond a Sphere: Orientation of an Asymmetric Sedimenting Particle

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An understanding of the motion of rigid particles in viscous fluids is crucial for industrial, medical and biological processes. In this work [1], we experimentally, numerically and theoretically study translation and rotation of single particles with shapes having two orthogonal symmetry planes: cones, arrowheads, crescent moons, and rings, settling under gravity in a very viscous fluid at the Reynolds number much smaller than unity. We find that with time, each particle rotates and approaches a stable, stationary orientation.

In the experiments, the millimeter-sized particles settle in the glass tank filled with a silicon oil. The dynamics of hydrodynamically and geometrically similar microparticles can be rescaled accordingly. We record the evolution of the particle shapes by two synchronized cameras with perpendicular vertical planes of view. Based on the image analysis, we measure the particle terminal velocity. We also determine the rotational-translational mobility coefficients. One of them is positive, and the other is negative. This indicates that the particles belong to the class of shapes classified as settlers [2].

We model the particles as rigid conglomerates of approximately five thousand of identical touching spherical beads and evaluate their rotational-translational coefficients numerically using the Hydromultipole program [3], based on the multipole method of solving the Stokes equations. The theoretical and numerical values are approximately the same. We explain the reorientation dynamics based on the evolution equations for the Euler angles characterizing the inclination of a particle with two orthogonal symmetry planes [4].

The characteristic reorientation times for the investigated particles are relatively small, which is important for potential applications in engineering, environmental science, medicine, and biology.

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