Capillary disks : sliding friction, capillary attraction and wave-driven propulsion

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A body can be supported at the water-air interface by virtue of the equilibrium among its weight, surface tension and hydrostatic forces [1]. Quantifying the forces experienced by small floating bodies is of critical importance for understanding the motion of living organisms at the water-air interface [2] and can inform the design of aerial-aquatic microrobots for environmental exploration and monitoring [3]. We present recent work on the statics and dynamics of capillary disks.

In the first part, we experimentally show that the motion of centimetric *sliders* is dominated by skin friction due to the boundary layer that forms in the fluid beneath the body, which results in a friction force $F_D \propto v^{3/2}$ [4]. We develop a simple model that considers the boundary layer as quasi-steady, and is able to capture the experimental behaviour for a range of body sizes, masses, shapes and fluid viscosities. We define a dimensionless sliding number as the ratio between the fluid inertia and the body inertia, which allows us to assess the regime of validity of our model. Furthermore, we demonstrate that friction can be reduced by modification of the body's shape or bottom topography.

In the second part, we directly measure and rationalize the *capillary attraction* force between centimetric disks resting at the air-water interface [5]. We use an applied magnetic force to perform direct measurements of the capillary force, and characterize how this force depends on the disk mass, diameter, and relative spacing. Our measurements are compared to numerical simulations that solve the non-linear Young-Laplace equation by taking into account the disk's vertical displacement and spontaneous tilt, showing that both effects are necessary to describe the attraction force for short distances. We develop a scaling law that captures the observed dependence of the capillary force on the experimental parameters.

In the third part, we show that a capillary disk self-propels on the surface of a vibrating bath when the rotational symmetry of the disk is broken. We show that self-propulsion may be ascribed to the asymmetric pressure radiated by the capillary waves emitted by the oscillating disk. These self-propelled *surfers* interact with one another through their mutual capillary wavefield and resultant fluid flows, and exhibit a rich set of collective modes characterized by a discrete number of equilibrium spacings for a given set of experimental parameters. Collections of surfers thus have promise as a new wave-mediated active system at the fluid interface.

Références

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