Research Highlight: Distinguished limits of the navier slip model for moving contact lines

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When one fluid displaces another on a solid substrate, such as in the spreading of a droplet on a solid surface, a moving contact line is formed at the intersection of the fluid interface with the substrate. The no-slip boundary condition in classical fluid mechanics is violated at a moving contact line, and it leads to an infinite rate of energy dissipation when combined with hydrodynamic equations.

To overcome this difficulty, the Navier slip condition associated with a small parameter λ, named the slip length, has been proposed as an alternative boundary condition. In this work [1], we analyse two distinguished limits as the slip length λ tends to zero: one where time is held constant $t = O(1)$, and the other where time goes to infinity at the rate $t = O(|\ln \lambda|)$. It is found that when time is held constant, the contact line dynamics converges to the slip-free equation, and contact line slippage occurs as a regular perturbative effect. On the other hand, when time goes to infinity, significant contact line displacement occurs and the contact line slippage becomes a leading-order singular effect. In this latter case, we recover the earlier analysis, e.g., by Cox [J. Fluid Mech., 168 (1986), pp. 169–194], after rescaling time.

Reference:

[1] Zhen Zhang and Weiqing Ren, Distinguished limits of the Navier slip model for moving contact lines, SIAM J. Appl. Math. Vol. 79, No. 5, pp. 1654-1674