Dynamic wetting: models, experiments, and simulations

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ABSTRACT

Dynamic wetting drives numerous technological processes such as coating, detergency, flotation and oil recovery, involving different types of liquids (organic, polymer, metals, etc.) in contact with solid substrates and eclectic geometries, ranging from perfectly homogeneous flat surfaces to complex porous structures [1]. For the past 50 years and despite considerable efforts by many research groups devoted to wetting phenomenon, from theoretical, experimental, and numerical simulation aspects, our understanding of the underlying physico-chemical mechanisms controlling the interactions between solid, liquid and vapor phases remains incomplete and therefore significantly restricts our ability to model processes that are dependent on wetting. This difficulty mainly stems from the intrinsic multiscale character of wetting processes, extending from the macroscopic to the molecular scale, while experiments usually involve only macroscopic quantities such as wetting speed, viscosity, surface tension and the contact angle formed between the liquid and the moving solid. If nanoscale simulation techniques like molecular dynamics (discrete element modelling) can shed light on the nature of the interactions between atoms at the contact-line [2], the associated time and length scales remain incompatible with the classical continuous element modelling approach, which is itself usually deficient in describing a moving contact-line. From a theoretical point of view, it is now generally accepted that dissipation controls the dynamics. However, since several channels of dissipation are possible, the same scale problem still holds: the molecular-kinetic theory [3] focuses on the displacement of liquid atoms on the solid surface, whereas the hydrodynamic approach [4] obscures the role of the liquid/solid interaction and concentrates on the role of viscosity. Some combinations of these two main models can provide additional insights, but again they mostly remain phenomenological [5].

This talk therefore aims to first review the main dynamic wetting theoretical models and discuss how they are challenged against experimental and numerical data. The advantages and limitations of the current models, experimental and simulation techniques will be then highlighted with the final objective to identify the main bottlenecks and suggest numerical ways to unravel the complex behavior of dynamic wetting systems.

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