Forced Wetting and Hydrodynamic Assist

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Abstract

It is well known that air entrainment sets the ultimate limit to coating speeds. It is also known that air entrainment can be postponed to higher line speeds by manipulating coating flows to generate what has been termed 'hydrodynamic assist.' There is increasing evidence that the benefit is associated with geometric or hydrodynamic confinement of the moving contact line. In addition, experiments have shown that the conditions that produce higher coating speeds also reduce the apparent dynamic contact angle, suggesting a direct link. Nevertheless, the mechanism by which the flow might affect wetting speeds and the dynamic angle has not been established – although several theories have been advanced. Here we develop an earlier suggestion that an intense shear stress in the vicinity of the moving contact line, sufficient to cause slip at the solid-liquid interface, can assist surface tension forces in compensating for contact-line friction. This reduces the velocity-dependence of the contact angle and so postpones air entrainment. Hydrodynamic assist is then simply a natural consequence of forced wetting that emerges when the contact line is driven by a strong and highly confined flow. We will present the results of large-scale molecular dynamics (MD) simulations of Couette flow with free interfaces (Figs. 1 and 2) in support of these ideas and use the molecular-kinetic theory of dynamic wetting (the MKT) to rationalize our findings and place them on a quantitative footing. We will also show new evidence that the principal boundary condition that controls dynamic wetting has its locus at the molecular scale of the moving contact line.

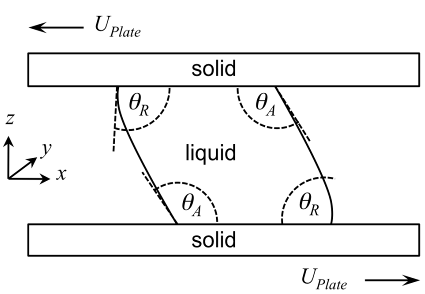

Fig. 1. System studied

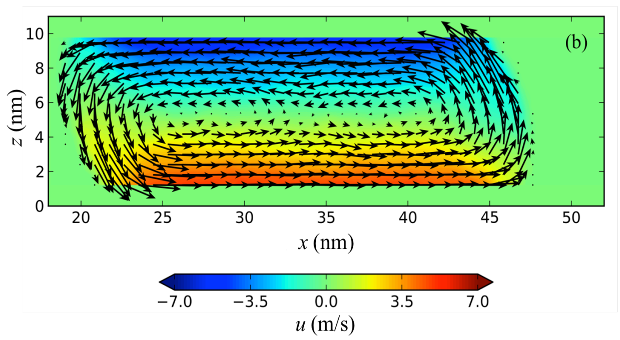

Fig. 2. Typical flow pattern derived from MD

Keywords: air entrainment; coating; confinement; contact-line friction; molecular-dynamics; molecular-kinetic theory; slip.

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