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Droplet migration: Quantitative comparisons with experiment

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Abstract. An important practical feature of simulating droplet migration computationally, using the lubrication approach coupled to a disjoining pressure term, is the need to specify the thickness, H^*, of a thin energetically stable wetting layer, or precursor film, over the entire substrate. The necessity that H^* be small in order to improve the accuracy of predicted droplet migration speeds, allied to the need for mesh resolution of the same order as H^* near wetting lines, increases the computational demands significantly. To date no systematic investigation of these requirements on the quantitative agreement between prediction and experimental observation has been reported. Accordingly, this paper combines highly efficient Multigrid methods for solving the associated lubrication equations with a parallel computing framework, to explore the effect of H^* and mesh resolution. The solutions generated are compared with recent experimentally determined migration speeds for droplet flows down an inclined plane.

1 Introduction

Droplet migration and wetting phenomena are ubiquitous throughout science and engineering and are crucial to several natural, engineering and manufacturing processes. A key issue in related theoretical studies is the alleviation of the stress singularity at dynamic wetting lines and for which several models have been proposed, see for example [1]. Analytical investigations apart [2], numerical solutions, based on lubrication theory coupled with a disjoining pressure term, to alleviate the stress singularity at dynamic wetting lines, have increasingly appeared, which explore droplet motion: (i) on chemically- and topographically-heterogeneous substrates [3,4]; (ii) driven by external body or Marangoni forces [5,6].

Despite the above successes, an important feature of using the disjoining pressure term, is the need to specify the thickness of a thin energetically stable wetting layer, or precursor film, H^*, over the whole of the substrate, which experimental evidence suggests lies in the broad range 1–100 nm [7]. To improve computational accuracy it is necessary to use small H^* values in order to achieve droplet migration speeds commensurate with experimentally observed ones [8]. This requirement increases the computational demands significantly since mesh resolution near wetting lines must be of the same order as H^* in order to avoid highly inaccurate, oscillatory or even negative film thicknesses being predicted. No systematic investigation into these effects on the quantitative agreement with experimental data has been performed to date. However, the need for such is highlighted in a recent comparison of numerical solutions [5] with the experiments of Podgorski et al. [8] and Le Grand et al. [9] for droplet migration down an inclined plane, see Fig. 1. Although good qualitative agreement can be obtained without highly

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