

Relaxation of surface tension under dynamic wetting conditions: a mesoscopic study

M.C.T. Wilson

*Institute of Engineering Thermofluids, Surfaces and Interfaces
School of Mechanical Engineering, University of Leeds, Leeds, LS2 9JT, UK*

Wetting is of course fundamental to coating processes — and indeed a host of other important liquid flows. The phenomenon has been intensively studied at various length scales ranging from molecular motion to continuum flow. Models based on the continuum hypothesis, i.e. those involving solutions of the Navier-Stokes equations, offer the greatest scope for efficiently capturing an entire coating flow, e.g. from distribution die to dryer. However, most such models suffer infamous difficulties in dealing with moving contact lines, namely an inability to determine the contact angle intrinsically and a need for some form of slip to be imposed or allowed on the solid surface [1].

A continuum model which does not exhibit these limitations is that now called the ‘interface formation’ model, developed by Shikhmurzaev [2]. Central to this model is the idea that the surface tensions in the liquid-gas and solid-liquid interfaces deviate from their respective equilibrium values as the contact line is approached. This model removes the stress singularities associated with other models, and produces the contact angle as part of its solution. Despite comparing very well to numerous experimental observations [3] and offering the potential to model ‘hydrodynamic assist’ [4], elements of the model have been criticised — particularly the relaxation of the surface tensions for pure liquids [5].

The purpose of this paper is to explore the relaxation of interfacial tensions using an alternative model, based on statistical physics, namely the lattice Boltzmann method (LBM). The LBM is growing in popularity as a numerical method for solving a wide range of hydrodynamic problems, including multiphase flows and porous media. There are several multiphase lattice Boltzmann models, but the one used here is based on that developed by He *et al.* [6], which is appropriate for a single-component two-phase system (i.e. a liquid and its vapour). The model uses the Carnahan and Starling [7] equation of state and features solid-liquid, liquid-vapour and solid-vapour interfaces of finite thickness, across which the fluid density varies smoothly but rapidly between the different phases. The surface tension in these interfaces can be calculated by integrating the square of the density gradient across the thickness of the interface [8] and hence provides a means of investigating hydrodynamic influences on the surface tension. A wetting model for this system has recently been developed [9] and is here applied to the two-phase cavity flow shown in Fig. 1.

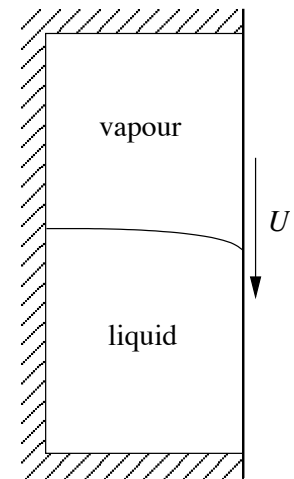


Figure 1: The two-phase cavity

Preliminary results are presented in Fig. 2, which plots the (dimensionless) solid-liquid interfacial tension as a function of position along the moving boundary. A clear variation in the interfacial tension is observed, which is influenced by the speed of the moving boundary. Work is presently underway to explore this phenomenon further — considering the other interfaces, offering more quantitative calculations of relaxation times, and investigating the variation of the contact angle and the compatibility of the results with Young’s equation under dynamic wetting conditions. These results will be presented in the full paper.

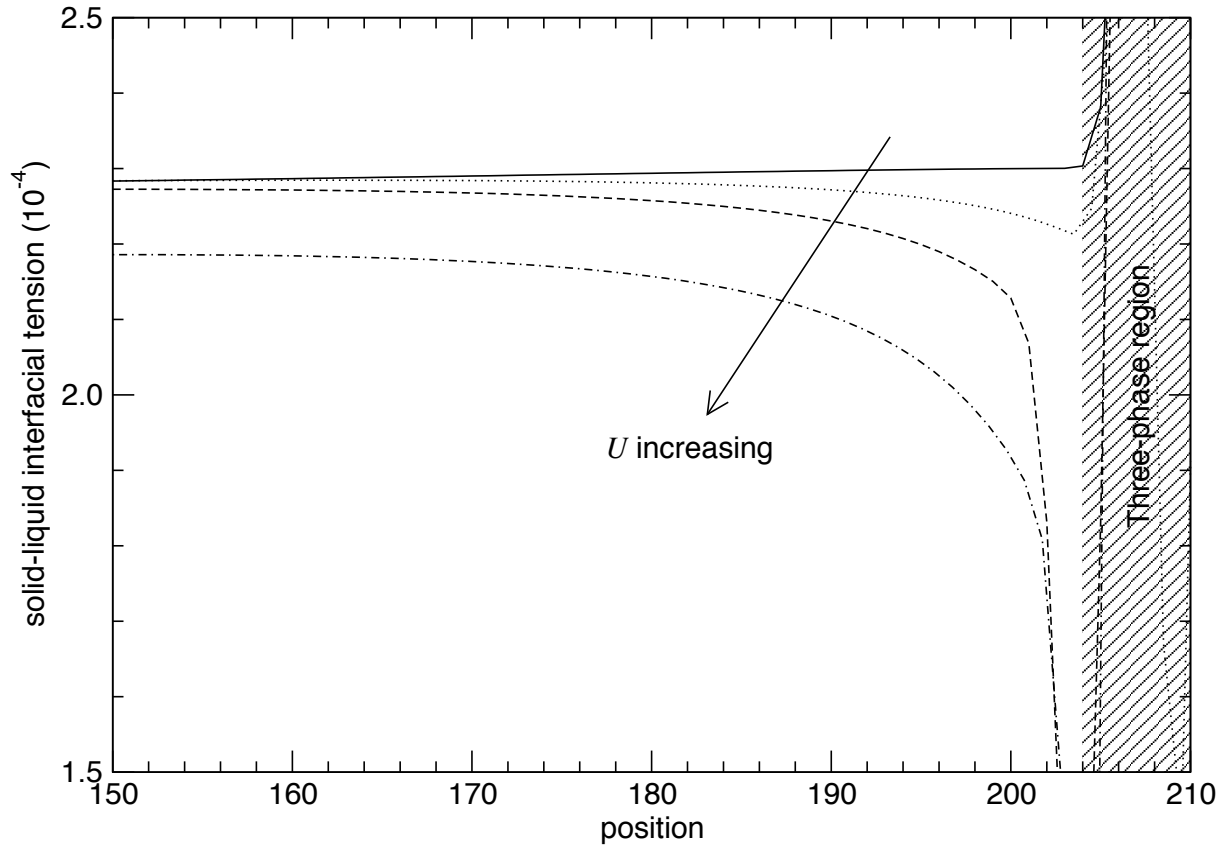


Figure 2: Dimensionless solid-liquid interfacial tension as a function of position along the moving solid boundary. The three-phase region represents the confluence of the three diffuse interfaces.

1. M.C.T. Wilson, J.L. Summers, Y.D. Shikhmurzaev, A. Clarke & T.D. Blake (2006) *Phys. Rev. E*, **73**, 041606.
2. Y.D. Shikhmurzaev (1993) *Int. J. Multiphase Flow*, **19**(4), 589.
3. T.D. Blake & Y.D. Shikhmurzaev (2002) *J. Colloid Interf. Sci.* **253**, 196.
4. T.D. Blake, M. Bracke & Y.D. Shikhmurzaev (1999) *Phys. Fluids* **11**, 1995.
5. J. Eggers & R. Evans (2004) *J. Colloid Interf. Sci.* **280**, 537.
6. X. He, S. Chen & R. Zhang (1999) *J. Comp. Phys.* **152**, 642.
7. N.F. Carnahan & K.E. Starling (1969) *J. Chem. Phys.* **51**(2), 635.
8. J.S. Rowlinson & B. Widom (1982) *Molecular Theory of Capillarity*, Clarendon Press.
9. A.R. Davies, J.L. Summers & M.C.T. Wilson (2006) *Int. J. Comp. Fluid Dyn.* **20**(6), 415.