# Dynamic modelling of the deformed contact line under partial wetting conditions: quasistatic approach

Stanimir Iliev, Nina Pesheva
Institute of Mechanics-Bulgarian Academy of Sciences,
Acad. G. Bonchev St. 4, 1113 Sofia, Bulgaria,
and Vadim S. Nikolayev*
ESEME, Service des Basses Températures, CEA-Grenoble France, and
PMMH, ESPCI, 10 rue Vauquelin, 75231 Paris Cedex 5 France

The dynamics of a liquid wedge (i.e. of the straight contact line) has been extensively studied both theoretically and experimentally. The models used for its description can be put into two wide classes, hydrodynamic and quasistatic. The hydrodynamic models calculate the truly dynamic surface shape. Their assumptions concern usually much smaller scale and are required to relieve the well known contact line singularity prohibiting the application of the classical hydrodynamic description (Navier-Stokes equations and the no-slip condition at the solid surface). Whatever the assumption is, these models result in a strong curvature that liquid surface exhibits near the contact line during its motion. It means that the interface slope varies strongly near the contact line so that the "apparent" contact angle (measured at a macroscopic scale) depends strongly on the contact line speed. This feature can be used to justify quasistatic approaches that make use of a prescribed relation between the contact line velocity and the apparent dynamic contact angle. By assuming that the fraction of the surface where the hydrodynamic stresses are important is limited to the close vicinity of the contact line, the shape of the liquid surface is calculated as if it were in statics for the given contact line position. These approaches are thus much easier to use in more sophisticated situations where the contact line is deformed and a 3D problem need to be solved. In this work we apply a quasistatic approach based on introduction [1, 2] of only one phenomenological parameter, a dissipation coefficient $\xi$ to simulate numerically the relaxation of the contact line that has an initially periodical shape. We present also a detailed quantitative comparison with the existing experimental data [3, 4] in order to check the validity of such quasistatic approach. The Wilhelmy plate experiment is considered: a plate with the static contact angle $\theta = 51.5°$ is pulled from the liquid bath with a constant speed $u$ that defines the capillary number Ca. First, the contact line height $h$ with respect to the liquid bath level is studied as a function of Ca (Fig. 1). The fit based on the quasistatic theory allows $\xi$ to be

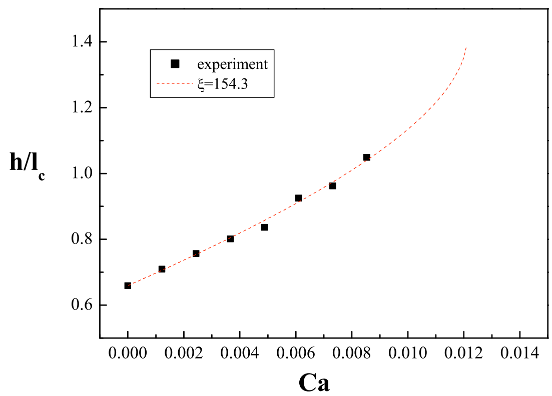


Figure 1: Contact line height expressed in the units of capillary length $l_c$ as a function of the capillary number. Squares: experimental data from [4]. Line: quasistatic theory result calculated with $\xi = 154.3$ Pa·s.

*Corresponding author. E-mail: vadim.nikolayev@espci.fr

obtained. This value is then used in a 3D simulation which shows the exponential relaxation of the contact line deformation in agreement with the experiment. The experimental data for the relaxing contact line positions at equidistant time intervals [3] are shown in Fig. 2 together with the simulation results.

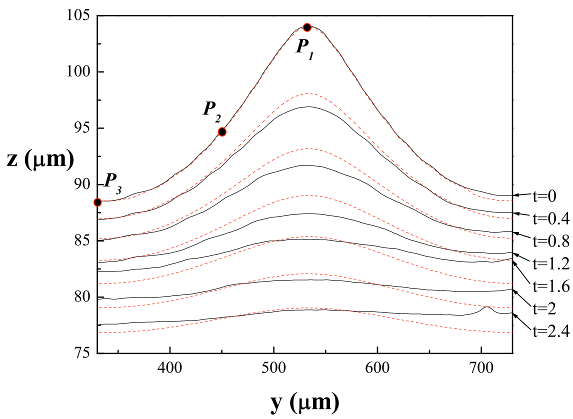


Figure 2: The contact line profiles at Ca= 0.00476 are shown at time step $\Delta t = 0.4$ s. Only one period, of the initially periodically perturbed contact line at wavelength $\lambda = 400\,\mu$m is shown. The numerical results are shown with dashed lines and the experimental results are shown with solid lines.

A good (within 2-4%) agreement shows that the quasistatic approach can be used for the description of the contact line dynamics in the partial wetting regime. Such an approach is much more convenient when the contact line is deformed due to the presence of surface irregularities than the full hydrodynamic description [4] which leads to a much more complicated modelling.

## References

[1] V.S. Nikolayev, D.A. Beysens, Equation of motion of the triple contact line along an inhomogeneous surface, *Europhysics Letters*, **64**, 763 (2003).

[2] S. Iliev, N. Pesheva, V.S. Nikolayev, Quasi-static relaxation of arbitrarily shaped sessile drops, *Phys. Rev. E*, **72**, 011606 (2005).

[3] G. Delon, M. Fermigier, J.H. Snoeijer, B. Andreotti, Relaxation of a dewetting contact line Part 2: Experiments, *J. Fluid Mech.*, in press.

[4] J.H. Snoeijer, B. Andreotti, G. Delon, M. Fermigier, Relaxation of a dewetting contact line. Part 1: A full-scale hydrodynamic calculation, *J. Fluid Mech.*, **579** , 63 (2007).