DROPLET DYNAMICS ON ROUGH SURFACES

N. Savva and D. Groves

Cardiff University, Cardiff, United Kingdom

savvan@cardiff.ac.uk

We undertake a combined numerical and analytical approach to study the motion of partially wetting droplets on surfaces decorated with smoothly varying topographical features. This work is based on the associated thin-film equation for the evolution of the droplet thickness $h(\boldsymbol{x}, t)$, which accounts for the effects of viscous dissipation, capillarity, slip, and surface heterogeneities, cast in the form

$$h_t + \frac{\sigma}{3\mu} \boldsymbol{\nabla} \cdot \left[h \left(h^2 + 3\lambda^2 \right) \boldsymbol{\nabla} \nabla^2 (h + s) \right] = 0,$$

where μ and σ are the fluid's viscosity and surface tension, respectively, $s(\boldsymbol{x})$ describes the topographical features of the substrate and λ is the slip length, which allows us to alleviate the non-integrable stress singularity that would occur at a moving contact line.[1]

A matched asymptotic analysis is used to extend an earlier study on two-dimensional droplets moving on rough surfaces[2] to the arguably more realistic three-dimensional setting. Our methodology is based on a recent work on the dynamics of droplets on ideally smooth and chemically heterogeneous surfaces and pertains in the limit $\lambda \to 0$.[3] For sufficiently long timescales, the quasi-static approximation can be invoked to deduce a lower-dimensional surrogate model to describe the evolution of nearly circular contact lines.

This model constitutes a system of differential equations for the harmonics of the contact line and is reminiscent of the Cox–Voinov law[1] supplemented with higher-order corrections. Noteworthy is also that this analytical approach may be straightforwardly adapted for other contact line models, by suitably choosing the microscopic scale and formally linking it with with the dynamics in the vicinity of the contact line.[4]

A number of representative cases are discussed, demonstrating that the model typically exhibits very good agreement with accurate solutions to the full problem. A hybrid numerical scheme combining the boundary integral method and the relative merits of the surrogate model is also proposed, which offers improved agreement with the predictions of the full model for strongly deformed contact lines, whilst requiring considerably fewer computing resources.

ACKNOWLEDGEMENTS: We acknowledge financial support from the Engineering and Physical Sciences Research Council (EPSRC) of the UK through the grant EP/P505453.

REFERENCES:

1. Bonn D., Eggers J., Indekeu J., Meunier J. and Rolley E. 'Wetting and spreading' *Reviews of Modern Physics*, 2009, **81**, 739–805.
2. Savva N. and Kalliadasis S. 'Two-dimensional droplet spreading over topographical substrates' *Physics of Fluids*, 2009, **21**, 092102.
3. Savva N., Groves D. and Kalliadasis S. 'Droplet dynamics on chemically heterogeneous substrates' *Journal of Fluid Mechanics*, 2019, **859**, 321–361.
4. Sibley D.N., Nold A., Savva N. and Kalliadasis S. 'A comparison of slip, disjoining pressure, and interface formation models for contact line motion through asymptotic analysis of thin two-dimensional droplet spreading' *Journal of Engineering Mathematics*, 2015, **94**, 19–41.