Simulation of Elasto-Capillary Interactions

E. Harald van Brummelen*, Mahnaz Shokrpour-Roudbari*, Kristoffer G. van der Zee† and Görkem Simsek*

*Eindhoven University of Technology, Department of Mechanical Engineering / Department of Mathematics and Computer Science, Den Dolech 2, 5612 AZ Eindhoven, The Netherlands
E-mail: {e.h.v.brummelen,m.shokrpour.roudbari,g.simsek}@tue.nl

† School of Mathematical Sciences, The University of Nottingham, University Park, Nottingham, NG7 2RD, United Kingdom.
E-mail: kg.vanderzee@nottingham.ac.uk

ABSTRACT

Binary fluids are fluids that comprise two constituents, viz. two phases of the same fluid (gas or liquid) or two distinct species (e.g. water and air). A distinctive feature of binary-fluids is the presence of a fluid–fluid interface that separates the two components. This interface generally carries surface energy and accordingly it introduces capillary forces. The interaction of a binary-fluid with a deformable solid engenders a variety of intricate physical phenomena, collectively referred to as *elasto-capillarity*. The solid–fluid interface also carries surface energy and, generally, this surface energy is distinct for the two components of the binary fluid. Consequently, the binary-fluid–solid problem will exhibit wetting behavior [1,2]. Elasto-capillarity underlies miscellaneous complex physical phenomena such as *durotaxis* [3], i.e. seemingly spontaneous migration of liquid droplets on solid substrates with an elasticity gradient; *capillary origami* [4], i.e. large-scale solid deformations by capillary forces. Binary-fluid–solid interaction is moreover of fundamental technological relevance in a wide variety of high-tech industrial applications, such as inkjet printing and additive manufacturing.

In this presentation, we consider a computational model for elasto-capillary fluid-solid interaction based on a diffuse-interface model for the complex fluid and a hyperelastic-material model for the solid. The diffuse-interface complex-fluid model is described by the incompressible Navier–Stokes–Cahn–Hilliard equations [5] with preferential-wetting boundary conditions at the fluid-solid interface. The corresponding fluid traction on the interface includes a capillary-stress contribution, and the dynamic interface condition comprises the traction exerted by the non-uniform fluid-solid surface tension. We consider several aspects of the formulation and of the simulation techniques. To validate the presented complex-fluid-solid-interaction model, we present numerical results and conduct a comparison to experimental data for a droplet on a soft substrate [6].

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