6th European Conference on Computational Mechanics (ECCM 6)
7th European Conference on Computational Fluid Dynamics (ECFD 7)
11-15 June 2018, Glasgow, UK

Adaptive isogeometric analysis of elasto-capillary fluid-solid interaction

E. Harald van Brummelen[1], Mahnaz Shokrpour-Roudbari[1], Jacco Snoeijer[2] and Gertjan van Zwieten[3]

[1] Eindhoven University of Technology, PO Box 513, 5600 MB Eindhoven, NL
e.h.v.brummelen@tue.nl, M.Shokrpour.Roudbari@tue.nl
[2] University of Twente, Drienerlolaan 5, 7522NB Enschede, NL
j.h.snoeijer@utwente.nl
[3] Evalf Computing, Rotterdamseweg 183 C, 2629 HD Delft, NL
gertjanvanzwieten@evalf.nl

Keywords: *Elasto-capillarity, fluid-solid interaction, adaptivity, isogeometric analysis*

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 fluidfluid 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 solidfluid interface also carries surface energy and, generally, this surface energy is distinct for the two components of the binary fluid. Consequently, the binary-fluidsolid problem will exhibit wetting behavior [4, 5]. Elasto-capillarity underlies miscellaneous complex physical phenomena such as durotaxis [9], i.e. seemingly spontaneous migration of liquid droplets on solid substrates with an elasticity gradient; capillary origami [6], i.e. large-scale solid deformations by capillary forces. Binary-fluidsolid 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 binary fluid and a hyperelastic-material model for the solid. The diffuse-interface binary-fluid model is described by the incompressible NavierStokesCahnHilliard equations [7] with preferential-wetting boundary conditions at the fluid-solid interface. To resolve the fluid-fluid interface and the localized displacements in the solid, we apply adaptive hierarchical spline approximations. A monolithic solution scheme is applied to enable robust solution of the coupled FSI problem. 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 [2, 1, 3, 8].

REFERENCES

[1] E.H. van Brummelen, H. Shokrpour Roudbari, and G.J. van Zwieten. Elasto-capillarity simulations based on the Navier-Stokes-Cahn-Hilliard equations. In *Ad-*

vances in Computational Fluid-Structure Interaction and Flow Simulation, Modeling and Simulation in Science, Engineering and Technology, pages 451–462. Birkhäuser, 2016.

[2] E.H. van Brummelen, M. Shokrpour Roudbari, G. Simsek, and K.G. van der Zee. *Fluid Structure Interaction*, volume 20 of *Radon Series on Computational and Applied Mathematics*, chapter Binary-fluid–solid interaction based on the Navier–Stokes–Cahn–Hilliard Equations. De Gruyter, 2017.

[3] J. Bueno, H. Casquero, Y. Bazilevs, and H. Gomez. Three-dimensional dynamic simulation of elastocapillarity. *Meccanica*, pages 1–17, 2017.

[4] P.-G. de Gennes, F. Brochard-Wyart, and D. Queré. *Capillarity and Wetting Phenomena: Drops, Bubbles, Pearls, Waves*. Springer, 2004.

[5] P.G. de Gennes. Wetting: statics and dynamics. *Rev. Mod. Phys.*, 57:827–863, 1985.

[6] C. Py, P. Reverdy, L. Doppler, J. Bico, B. Roman, and C.N. Baroud. Capillary origami: Spontaneous wrapping of a droplet with an elastic sheet. *Phys. Rev. Lett.*, 98:156103, Apr 2007.

[7] M. Shokrpour Roudbari, G. Simsek, E.H. van Brummelen, and K.G. van der Zee. Diffuse-interface two-phase flow models with different densities: a new quasi-incompressible form and a linear energy-stable method. *Math. Mod. Meth. Appl. Sci.*, (accepted), 2018.

[8] R.W. Style, R. Boltyanskiy, Y. Che, J.S. Wettlaufer, L.A. Wilen, and E.R. Dufresne. Universal deformation of soft substrates near a contact line and the direct measurement of solid surface stresses. *Phys. Rev. Lett.*, 110:066103, Feb 2013.

[9] R.W. Style et al. Patterning droplets with durotaxis. *PNAS*, 110(31):12541–12544, 2013.