Direct Numerical Simulation of Drop Impact with Contact Angle Hysteresis

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Droplet dynamic processes such as jet atomization or sprays are very common in industrial applications and often involve the interaction with a solid surface. Examples are spray cooling technologies or AdBlue injection. To understand such complex processes, first the elementary process of a single drop impacting on a smooth or structured surface is investigated. This still provides challenges regarding the contact line movement or the air entrapment during impact. For practical applications, Direct Numerical Simulations can help investigate the underlying mechanisms and provide the basis for modeling these dynamics on a larger scale.

One of the major challenges here is the treatment of the three phase contact line. While static configurations can be captured quite accurately, the dynamics of contact line movement still pose unsolved problems. On the micro scale, the capillary forces dominate while on the numerically and experimentally accessible subscale also inertial and viscous effects come into play. Analytic descriptions as well as empirical correlations give a relation between contact angle and contact line speed, but so far neglect inertial effects and therefore can exhibit qualitative differences to experiments [2, 5].

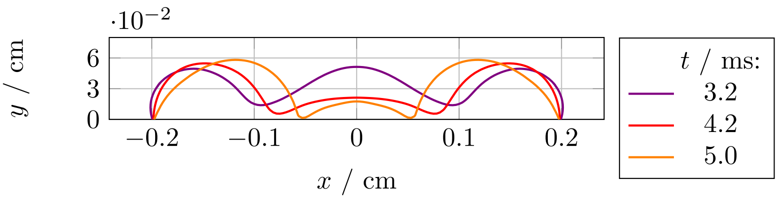

Figure 1: Droplet contours for different time steps during the contact angle hysteresis. After the drop reaches its maximum spreading ($t = 3.2$ms), a pinning of the contact line can be observed, while the contact angle changes continuously.

This problem of scales leads to strongly mesh-dependent results when applying a dynamic contact angle model. Mesh-dependent contact angle models can improve the grid convergence as well as using a finite slip length [1]. We apply the dynamic contact angle model by Mathieu [4], which is a polynomial approximation of Cox' hydrodynamic theory [3], and see good grid convergence. On nonideal surfaces, however, also the contact angle hysteresis has to be taken into account. It is the difference between advancing and receding contact angle and is caused by surface roughness and chemically heterogeneous surfaces. Our implementation in the DNS code Free Surface 3D (FS3D) allows the hysteresis to be taken into account, as can be seen from Fig. 1. Based on this, a study of drop impact onto structured surfaces is intended.

References

[1] Afkhami, S., Zaleski, S. and Bussmann, M. 2009. A mesh-dependent model for applying dynamic contact angles to VOF simulations. *Journal of Computational Physics*, 228(15), pp. 5370–5389.

[2] Blake, T. D., Bracke, M. and Shikhmurzaev, Y. D. 1999. Experimental evidence of non-local hydrodynamic influence on the dynamic contact angle. *Physics of Fluids*, 11(8), pp. 1995–2007.

[3] Cox, R. G. 1986. The dynamics of the spreading of liquids on a solid surface. Part 1. Viscous flow. *Journal of Fluid Mechanics*, 168, pp. 169–194.

[4] Mathieu, B. 2003. Etudes physique, expérimentale et numérique des mécanismes de base intervenant dans les écoulements diphasiques en micro-fluidique. *Thèse de Doctorat, Université de Provence-Marseille, France.*

[5] Šikalo, Š., Wilhelm, H.-D., Roisman, I. V., Jakirlić, S. and Tropea, C. 2005. Dynamic contact angle of spreading droplets: Experiments and simulations. *Physics of Fluids*, 17(6), pp. 062103.