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A droplet-phase approach to solve thin-film flows

Anand Bharadwaj S[1], Pratik Suchde[2] and Joerg Kuhnert[3]

[1] Fraunhofer ITWM, Kaiserslautern, anand.bharadwaj@itwm.fraunhofer.de
[2] University of Luxembourg, Luxembourg, pratik.suchde@itwm.fraunhofer.de
[3] Fraunhofer ITWM, Kaiserslautern, joerg.kuhnert@itwm.fraunhofer.de

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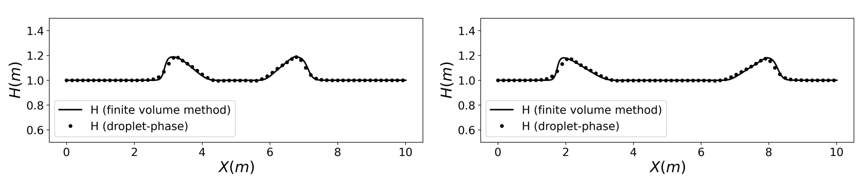
Thin-film flows, observed in varied applications, are commonly seen in automobiles moving through rain. The prediction of the behaviour of such films is an important aspect that needs consideration during the design of vehicles with regard to their effect on exterior sensors, changes in aerodynamic behaviour, seepage of water into parts of the vehicle, etc. The droplet-phase model is a novel method that models the development and evolution of thin-films in the form of droplets. It consists of moving droplets on a 2-D manifold and allows the use of computational resources more efficiently in comparison to fully 3-D Navier-Stokes solvers to capture the same behaviour[1]. In the droplet-phase approach, the 2-D manifold contains droplets. The film height at a given location, is a function of the location of droplets in its neighbourhood. The momentum equation takes into consideration various forces that act on the droplet (hydrostatic pressure, viscous forces, etc.), and solves for the velocity of the droplets. The derivatives are estimated using weighting kernels and their derivatives, as in SPH. The advection of droplets at the solved velocity results in the evolution of the height function. In this approach, therefore, the evolution of the height function is captured through the movement of droplets that are treated as discrete particles, as in DEM, although the approach considered in the present work does not feature a contact model for droplet collisions. This facilitates the use of this approach for both DEM simulations such as droplets in free-flight as well as for thin-film flows. In this work, comparisons of the droplet-phase approach with shallow-water models are made for both 1-D and 2-D test cases. Only the 1-D case (for brevity) with a collapsing water hump is compared in Fig 1. The results show the reliability of the method and highlight the potential of this method to solve problems with thin-films.



(a) $t = 1.5s$ (b) $t = 2.5s$

Figure 1: Comparison of 1-D collapsing wave: Droplet-phase model vs shallow-water model using FVM

REFERENCES

[1] Suchde, Pratik, and Joerg Kuhnert. ”A meshfree generalized finite difference method for surface PDEs.” Computers Mathematics with Applications 78.8 (2019): 2789-2805.