Proceedings of the 8th World Congress on Mechanical, Chemical, and Material Engineering (MCM'22)
Prague, Czech Republic – July 31, 2022 - August 02, 2022
Paper No. HTFF 127
DOI: 10.11159/htff22.127

Modelling Droplet Evaporation with an Improved Coupled Level Set and Volume of Fluid (i-CLSVoF) Framework

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Extended Abstract

Modelling droplet evaporation is of great importance for many applications, such as inkjet printing, spray coating and combustion of fuel droplets [1, 2]. The key issues in the context of modelling droplet evaporation involve free-surface capturing [3], the phase change from liquid to vapour [4], and accurate calculations of the surface tension force [5]. Inaccurate calculations of surface tension force generate spurious currents or velocities which appear around the interface. Spurious currents destabilize the simulations and even influence the internal flow inside the droplets when studying droplets numerically [6].

In view of the issues mentioned above, we develop an improved Coupled Level Set and Volume of Fluid (i-CLSVoF) framework without explicit interface reconstruction for modelling micro-sized droplets with and without evaporation. A new surface tension force model with additional filtering steps is developed and implemented in the i-CLSVoF framework to suppress un-physical spurious velocities. Numerical benchmark cases demonstrate the excellence of the i-CLSVoF framework in reducing the un-physical spurious velocities (the un-physical spurious velocity converges to 10^{-10} which is small enough to eliminate the influence of un-physical spurious velocities on the numerical stabilities). A simple yet efficient velocity-potential based approach is proposed to reconstruct a divergence-free velocity field for the advection of the free surface when the phase changes. The new approach fixes the numerical issues resulting from the evaporation-induced velocity jump at the interface. The smeared mass source term approach proposed in this work guarantees more numerical stability than the non-smeared approach. Two different evaporation models (constant mass flux and thermally driven evaporation models) are implemented into i-CLSVoF. Extensive numerical validations are conducted to validate the evaporation models. The agreement between the numerical and corresponding analytical solutions is encouraging and promising. The model developed in this work demonstrates exemplary performance in modelling surface-tension dominant flow with and without evaporation [7].

References

[1] A. E. Saufi, A. Frassoldati, T. Faravelli, and A. Cuoci, "Interface-resolved simulation of the evaporation and combustion of a fuel droplet suspended in normal gravity," *Fuel*, vol. 287, 2021.
[2] H. Wijshoff, "Drop dynamics in the inkjet printing process," *Current Opinion in Colloid & Interface Science*, vol. 36, pp. 20-27, 2018.
[3] J. U. Brackbill, D. B. Kothe, and C. Zemach, "A continuum method for modeling surface tension," *Journal of Computational Physics*, vol. 100, no. 2, pp. 335-354, 1992/06/01/ 1992.
[4] J. Palmore and O. Desjardins, "A volume of fluid framework for interface-resolved simulations of vaporizing liquid-gas flows," *Journal of Computational Physics*, vol. 399, 2019.
[5] D. Zang, S. Tarafdar, Y. Y. Tarasevich, M. Dutta Choudhury, and T. Dutta, "Evaporation of a Droplet: From physics to applications," *Physics Reports*, vol. 804, pp. 1-56, 2019.
[6] T. Abadie, J. Aubin, and D. Legendre, "On the combined effects of surface tension force calculation and interface advection on spurious currents within Volume of Fluid and Level Set frameworks," *Journal of Computational Physics*, vol. 297, pp. 611-636, 2015.
[7] H. Xia and M. Kamlah, "An improved Coupled Level Set and Volume of Fluid (i-CLSVoF) framework for droplet evaporation," *arXiv preprint arXiv:2202.01019*, 2022