A new kernel function of smoothed particle hydrodynamics for modeling liquid dynamics

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Abstract

Smoothed particle hydrodynamics (SPH), as a Lagrangian meshfree particle method, has been widely applied to modeling viscous liquid drop with surface tension and wetting dynamics [1]. In the SPH model, the van der Waals (vdW) equation of state is usually used to describe the gas-to-liquid phase transition similar to that of a real fluid. However, the attractive forces between SPH particles originating from the cohesive pressure of the vdW equation of state can lead to tensile instability, which is associated with unphysical phenomena such as particle clustering or blowing away [2].
To overcome the challenge of tensile instability for better modeling viscous liquid drop, this paper develops an improved SPH method by presenting and using a new kernel function. The inherent stretching instability of SPH is eliminated by using the new quartic spline kernel function with a non-negative second derivative which is globally differentiable in the support domain. The formations of viscous liquid drops in 2D are tested and it is demonstrated that the tensile instability can be effectively removed. The results show that the pressure and temperature fields of the stable droplet obtained by using the new kernel function are smoother than those obtained by using the hyperbolic kernel function with non-negative second derivatives [3]. The improved SPH method is also used to simulate other numerical examples, including the binary collision of droplets with Weber numbers less than 1 and Weber numbers equal to 2 and 10 respectively [4]. The obtained numerical results also showed that this new kernel function with smoothed and non-negative second derivative can effectively remove tensile instability when modeling liquid drop dynamics.

Keywords: Smoothed particle hydrodynamics; Liquid drop; Tensile instability

References

[1] Nishio Y , Komori K , Izawa S , et al. Simulation of collisions of two droplets containing two different liquids using incompressible smoothed particle hydrodynamics method[J]. Theoretical and Computational Fluid Dynamics, 2020, 34(1-2):105-117.
[2] Yang X , Liu M , Peng S . Smoothed particle hydrodynamics modeling of viscous liquid drop without tensile instability[J]. Computers & Fluids, 2014, 92:199-208.
[3] 杨秀峰, 刘谋斌. 光滑粒子动力学 SPH 方法应力不稳定性的一种改进方案[J]. 物理学报, 2012, 61(22):8.
[4] Yasmin, Meleán, and, et al. Coalescence of colliding van der Waals liquid drops[J]. International Journal of Heat and Mass Transfer, 2005.