Center for Environmental & Applied Fluid Mechanics

"Impact of Vaporization on Drop Breakup"

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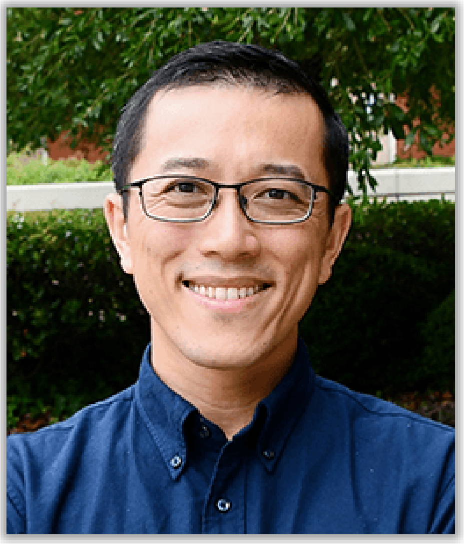

In many droplets and spray applications, such as liquid fuel injection and spray cooling, drop breakup and vaporization occur simultaneously. For a drop is accelerated in a gas stream with non-zero relative velocity, the gas dynamic pressure tends to deform the drop, while the surface tension and the liquid viscosity stabilize the deformation. The force balance lead to two key dimensionless parameters, Weber and Ohnesorge numbers, which generally characterize the drop breakup dynamics. Typically, when the Weber number is higher than the critical value, the drop will experience topology change and break into smaller children drops. The critical Weber number is generally expressed as a function of the Ohnesorge number. When the temperature of the surrounding gas is superheated, the drop acceleration and breakup will be accompanied by strong vaporization. The dimensionless parameter to characterize the intensity of vaporization is the Stefan number (aka Spadling/Jakob numbers). To systematically characterize the impact of vaporization on drop breakup, we have developed a new Volume-of-Fluid method to resolve interfacial two-phase flows with phase change. The method has been implemented in the open-source solver, Basilisk, which uses adaptive octree mesh for spatial discretization and thus will allow for adaptive mesh refinement (AMR) on interfaces and other user-defined regions. The developed simulation framework has enabled large-scale simulations of vaporizing two-phase flows using a large number of octree meshes, refinement levels, and CPU cores. The code has been validated through benchmark test cases before it is applied to simulation of vaporizing drop breakup. In the limit of low Weber and Stefan numbers, the simulation results agree well with the experimental measurement. Then parametric simulations for different Weber and Stefan numbers were performed to investigate the effect of drop deformation/breakup on vaporization and the also reverse effect of drop vaporization on the drop deformation and breakup. As expected, the Nusselt number for vaporization is observed to increase significantly with Weber number. More importantly, we have observed that the breakup of the drop can be suppressed by vaporization, due to the modulation of Rayleigh-Taylor instability by the Stefan flow. As a result, the critical Weber number to determine drop breakup will depend not only on the Ohnesorge number but also the Stefan number.

Fall 2022 CEAFM Seminar Series

December 2, 2022 ⌘ 3:00 PM ⌘ Gilman Hall 50

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