JOHNS HOPKINS
Center for Environmental & Applied Fluid Mechanics

Weekly CEAFM Seminar: Spring 2012

Friday, April 13, 2012 11:00 a.m. – 12:00 p.m.
Gilman 50 (Marjorie M. Fisher Hall)

"EXPLORING LIQUID ATOMIZATION WITH SUPERCOMPUTERS"

Presented by
Dr. Olivier Desjardins
Cornell University

Abstract: In the context of rising environmental concerns and record-high oil prices, the need for cleaner and more efficient combustion devices becomes pressing. Thanks to the steady progress in computer power and computational fluid dynamics (CFD) methods, computational modeling of combustion systems emerges as a promising tool that can drive the design of future devices. In these systems, fuel is usually injected in liquid form. Atomization of the liquid fuel, or the process by which a coherent liquid flow disintegrates into droplets, represents one of the key challenges that remain to be tackled to make predictive simulations possible. Because atomization governs the size of the fuel droplets, and therefore their subsequent evaporation rate, it has far-reaching repercussions on many aspects of the combustion process, for example pollutant formation. However, the inherent multi-physics and multi-scale nature of this process limits both experimental and numerical investigations.

In an effort to improve the numerical schemes available for simulating of multiphase flows, a novel numerical method is developed to track the interface location. This method combines the excellent mass conservation properties of the accurate conservative level set (ACLS) method of Desjardins et al. [J. Comp. Physics 227 (18), 8395–8416] with a discontinuous Galerkin (DG) discretization. DG provides an arbitrarily high order representation of the level set function without requiring a large computational stencil, resulting in a highly accurate and parallelizable method. A conservative re-initialization equation, discretized with DG as well, is used to reset the level set function to a hyperbolic tangent profile, ensuring the good conservation properties. Finally, a height fraction approach is developed in the context of a high order polynomial representation of the level set function for accurate curvature calculation. The performance of the method is demonstrated for a variety of test cases. Combined with a new discretization of the momentum convection term in the Navier-Stokes equations, and an immersed boundary methodology that allows to use non body-fitted grids while conserving both mass and momentum discretely, this scheme provide both accuracy, scalability, and robustness even in the presence of turbulence, high shear, and large density ratios.

This new methodology is then employed in a detailed study of the turbulent airblast atomization of n-dodecane. Numerical predictions are compared to experimental measurements, showing the satisfactory behavior of the proposed level set scheme. In particular, the onset of break-up, most unstable wavelength, and drop size and velocity distributions are in good agreement, suggesting that the fundamental physics of air-blast atomization are well captured by the simulations. Then, a more realistic configuration corresponding to a pressure-swirl atomizer is considered. Ultimately, these studies have the potential to provide realistic spray conditions for reactive large-eddy simulations of combustion chambers.

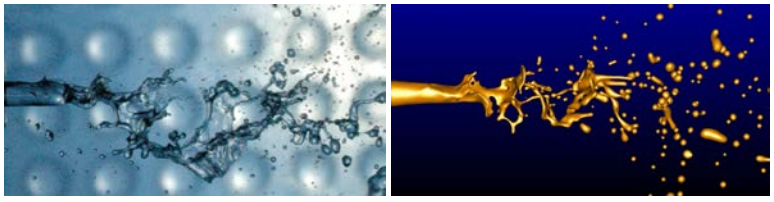

Figure 1: Comparison of atomizing jet from experiment (left) and simulation (right).