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MODELING MULTIPHASE FLOW: SPRAY BREAK-UP USING VOLUME OF FLUIDS IN A DYNAMIC LES FEM METHOD

Jiajia Waters[*,§] and David Bradley Carrington[*]
[*]Los Alamos National Labratory, T-3 Division, Los Alamos, NM, USA
[§]Correspondence author. Email: jwaters@lanl.gov

ABSTRACT Sprays are of primary importance in engine combustion, particularly in modern engines using fuel injection, where efficiency and low emission is the goal, and of paramount importance. Improvements in engine and fuel efficiency have a grand economic and environmental impact, where a mere gallon of fuel saved per mile, decreases enormously fuel consumed, essentially providing hundreds of millions of dollars in economic stimulus in the U.S. alone, while decreasing greenhouse gas and NOx emissions into the atmosphere. Engine designers, and researchers in the industry have relied on expensive and limited range experiments to determine how best to design and implement the spray injection process. Modelling of sprays have extended the operating range of the experimental results helping to provide faster design progress and changes inclusive of computer system control of injection and variable injection operation.

Currently all commercial software for engine modelling investigate the dispersed droplet phase of the injection process. The earlier KIVA codes (II, 3, 3v by Amsden et al. [1989]) and KIVA-4 by Torres and Trujillo [2006] use Lagrangian Particle Transport (LPT) for the droplet phase simulation. The particle transport portion of the LPT model being developed by Dukowicz [1980]. This method is also currently used in the new KIVA-hpFE code Carrington [2011]. Solution of the dispersed spray equation requires initial conditions for the droplets after it transforms from a continuously connected fluid. Atomization of a liquid injected occurs after the liquid is forced through a nozzle, forming a liquid core and subsequent ligamentation from stress the liquid core experiences. This ligamentation breaks into fine droplets as a result of the stresses as well where the liquid drops begin to experience convective evaporation processes. Understanding the effect of the geometry of the injector nozzle, the initial jet conditions, the fluid properties in the liquid film, the break-up and the resulting droplet sizes and distribution are of primary importance to improve fuel efficiency and lower gas emissions. We developed an innovative computational method and models to make this atomization more predictive: a multiscale, multiphase fluid simulation, using a Volume-of-Fluid (VOF) method implemented in within a Large Eddy Simulation (LES) algorithm found in the new KIVA-hpFE, a Finite Element Method (FEM) flow solver for all flow regimes.

The proposed multiscale and multiphase approach will help remove uncertainty of initial conditions from the LPT method. Initial phase-space information for solving the LPT multi-component spray equation will be supplied without a priori information of the breakup process. Geometrical concerns and fluid dynamic behaviour of the initial injection process will be properly modelled, mitigating uncertainty of their effects in the spray's downstream behaviour. The proposed methods will remove a need for extensive experimentation as geometries and operation conditions change from cycle to cycle and from design to design. The innovative and novel methods will result in reduced computational time and improved accuracy for realistic simulation of sprays from injector to evaporation.