Large Eddy Simulation of GDI Spray Evolution in a Realistic IC-Engine

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Abstract

In the present study, an effort is made to investigate the real unsteady behavior of evaporating GDI spray in a realistic engine configuration (with moving piston and valves) by applying large eddy simulation (LES) together with a spray module using KIVA-4mpi Code. A comprehensive model set is integrated in a Eulerian-Lagrangian framework allowing to describe the spray evolving from the injector nozzle and propagating within the combustion chamber. It includes sub-models to account for various relevant sub-processes. The atomization is described using combined primary and secondary atomization sub-models. Instead of performing costly level set method or volume of fluid (VOF) technique a linear instability sheet atomization (LISA)-based sub-model is applied for the primary atomization. The secondary atomization is modeled by a Taylor analogy break-Up (TAB) model. A new model is proposed for droplet-droplet interaction that is independent of mesh size and type. It takes into account possible four regimes, such as, bouncing, separation, stretching separation, reflective separation and coalescence of droplets. The droplet evaporation is described by an appropriate evaporation model and the turbulent dispersion by the filtered velocity only. The spray module is coupled to LES of the carrier phase in which a Smagorinsky model is used for the filtered flow field. The sub-grid scale (SGS) scalar flux in scalar transport equations (of mass fraction and temperature) is captured by a simple gradient assumption. The spray wall interaction is taken care by the wall film model that include droplet splash, film spreading due to impingement forces, and motion due to film inertia. An appropriate approach is used to describe the moving boundary conditions for the piston and valves movement.

An optical gasoline engine, designed to support the development and validation activities for the CFD software is used for the simulation of evaporating spray here. The primitive validation is carried out for cylinder pressure curve (see Figure 1) for motored case. Then, a numerical analysis is carried out on interactions of the GDI spray with high speed intake air. The CFD model is able to capture the transient behavior of evolving spray. The result shows influence of the intake charge motion considerably influences spray dynamics and vice versa, thereby air-fuel mixture formation (see Figure 2). The simulation results also show the evidence of the formation of liquid film on the piston wall which is undesirable for the optimum engine performance. The presented result can be used as a basis for further analysis of unsteady effects along with cycle-to-cycle variations in real engine configurations.

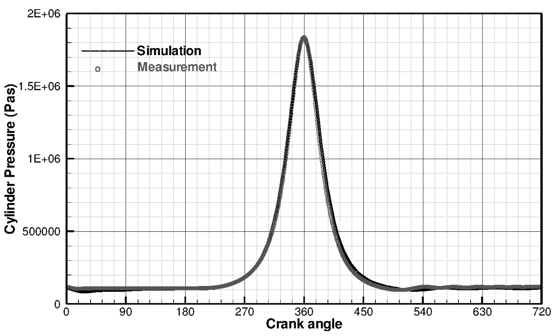
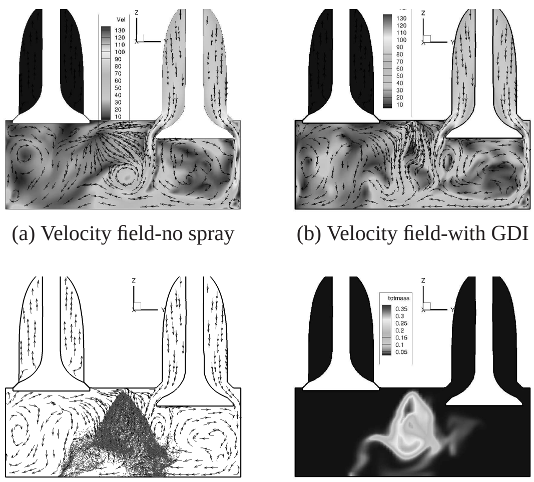


Figure 1. Comparison of pressure curve: computed (black line), and experimental data (gray circle)



(a) Velocity field-no spray
(b) Velocity field-with GDI
(c) spray profile
(d) fuel mass fraction

Figure 2. Sectional view (x-plane) at 59^o ATDC

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