Numerical Analysis of Multihole Gasoline Direct Injection Sprays

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Abstract

Multi-hole gasoline direct injection (GDI) injector sprays have been studied numerically. This study is actually an extension of the previous work of R. Rotondi [1]. Main part of this work focuses on air entrainment, droplets sizes and velocities in the spray plumes under the hot and cold conditions, which are very important for jet to jet interactions, spray propagation and mixture formation.

A typical advantage of Multi-hole GDI injector is to increase the fuel efficiency by reducing fuel injection timing, penetration and increasing the fuel-air mixture quality for better combustion in the engines. But since there is a presence of multiple spray plumes at the same time therefore it is necessary to avoid jet to jet interactions in order to maintain the intended spray targeting and produce sufficient vapour homogeneity for better evaporation and ignition. Experimentally in multi-hole injectors it is very difficult to look at the air entrainment inside the six holes injectors with narrow cone angle. That is why to go more in detail and understand the physics better, numerical study becomes very important.

The experimental investigations of the PIV air entrainment were performed at IFPEN with operational conditions: injection pressure (P_i) = 200 bar, chamber pressure (P_c) =1.54 bar, fuel Temperature (T_f) = 90°C, chamber temperature (T_c) =33 °C. PDA measurements of droplets sizes had been carried out in the Loughborough University with P_i=100bar, P_c=1 bar and $T_c = T_f$ = 20°. Continental's special XL 3-hole 90° and 6-hole 60° injectors were used for all experiments. The Reynolds Average Navier Stokes (RANS) simulations were performed on OpenFOAM ® version 1.7.1, where the gaseous phase was modeled by the standard K-Epsilon approach and the liquid phase was modeled by the Lagrangian approach. A compressible reacting spray solver equipped with automatic mesh refinement (AMR) was used with a computational domain of size 112 mm x 112 mm x 112mm and minimum cell size of 0.375mm after the AMR. AMR was based on the scalar fields of kinetic energy and vapour mass fraction for non-evaporating and evaporating conditions, respectively. Automatic time step adjustment was also included to keep local courant number to be less than 0.5 with initial time step of 10^{-7} sec.

The droplets' size, liquid penetration and the air entrainment profiles show good agreement with experimental PDA and PIV data respectively. The air entrainment is relatively high in the near nozzle region and at the spray tip leading edge because of the high spray momentum for both the 3 and 6-hole injectors. In 3-hole injector the spray-induced air motion is found to be relatively weak in the zone between the two adjacent plumes and air is entrained in the plumes up to the near nozzle region without any jet to jet interactions. However 6-holes injector shows strong jet to jet interactions with a significant amount of vapour inside the spray cone. The gas inside the upper region of the spray cone is observed to be pushed downwards along the spray propagation which interacts with the oppositely directed air from the bottom half. This interaction produces a radial flow which deflects the spray plumes from their original path and also pushes out the vapor present inside the cone. The deflection angle of the spray cone in the simulations is measured roughly to be between 6° to 9°.

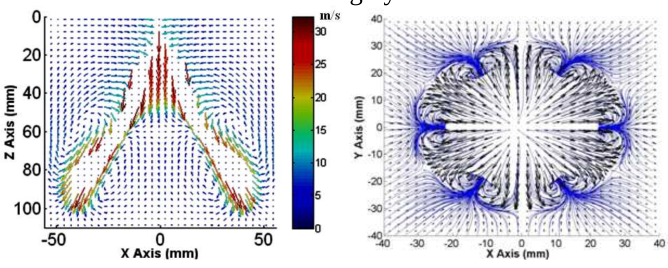

Fig 11: Plots of air & gas entrainment at 3.1ms After the Start of Injection; Axial (left), Radial (right)

Reference

[1] Rotondi R., Hélie J., Leger C., Mojtabi M., Wigley G., *ILASS Europe, Czech Republic, (2010).*

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