Measurement and Simulation of DI Spray Impingements and Film Characteristics

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Abstract

Spray impingement of liquid fuel on the combustion chamber wall and piston head in the direct injection engine is difficult to avoid and mostly undesirable, because it delays the gas-phase fuel-air mixture preparation processes and is a possible source for unburned hydrocarbons and soot emissions. This work investigated wall impingement and surface fuel film formation by sprays emerging from a side-mounted six-hole gasoline injector, one of the most dominant direct injection (DI) gasoline engine combustion configuration used today. In the meanwhile, numerical study was conducted for the same operating conditions as the experiments to study the spray behavior and fuel film characteristics.

The spray wetted area, fuel film thickness, and the resultant footprint mass were derived using the Refractive Index Matching (RIM) technique. In this method, the difference in index of refraction between the impinging surface and air results in the scattering of light off the roughened surface, which is modified by the presence of a liquid that closely match the index of refraction of the impingement window. A flat optical ground glass diffuser with polished top surface was placed in the pressurized camber horizontally. The six-hole injector was mounted on the cylinder wall of the chamber with angle of 25 deg to replicate the piston injector orientation of a side-mounted DI Engine. Calibration experiments were carried out to obtain the correlation between fuel film thickness and variation of reflection. A liquid mixture of iso-octane and dodecane with known deposit volume was used for calibration procedure. The fuel was injected on the rough flat window surface at various ambient conditions, injection conditions and distance between the injector tip and window, using the same optical setup. Multi-dimensional computational fluid dynamics (CFD) simulation with selected models of spray validated first for its transport in the air is used to compare the impingement models with the experimental measurements. The Kelvin-Helmholtz/Rayleigh-Taylor (KH-RT) breakup model was used to predict the spray behavior of multi-hole injector. The interaction of liquid drops and solid surfaces is molded using wall film model, which is a hybrid model of assuming individual particle-based quantities and film-based quantities. The numerical simulation of characteristics of spray impingement and fuel film were compared with the experimental results of back-lighting visualizations and RIM method.

The Refractive Index Matching technique was investigated to measure the fuel film thickness of sprays of side-mounted multi-hole injector. As expected, the deposit area of each spray plume is effected by the injection pressure and distance between injector tip and window. The effect of ambient temperature on fuel film thickness is significantly, and the film evaporation rate is strongly affected by the ambient pressure especially at lower temperature. Higher pressure at the same fuel amount tends to reduce film thickness. The CFD simulation models of spray and wall impingement were validated by compared with spray visualization on the free spray transport. The numerical investigation of spray behavior and film characteristics agrees in general with the experimental observations in terms of overall spray shape, tip penetration and wall impingement pattern, and the maximum fuel film thickness.

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