Liquid and Vapor Phase Detection of GDI Sprays Impacting on a Heated Surface

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In internal combustion engines, the injection of the fuel at elevated pressures could result in a strong impact on the piston head or chamber walls, especially in small-bore sizes for passenger cars. This effect is relevant for the combustion development and sometime results in an increasing of pollutant emissions and in a reduction of the engine performances. The fuel dispersion in the combustion chamber is governed by the nozzle design, the injection pressure and timing and the interaction of the fuel with the cylinder/piston walls [1,2]. Spray droplets hitting on the surface may rebound, stick and forming a film, or undergoing to heating and secondary evaporation [3]. The deposited fuel on the wall evaporates more slowly than free droplets, and could not realize the desired spatial distribution of the air-to-fuel ratio prior to ignite. This may determine non-effective combustion development and formation of pollutants. Wall wetting results in a strong impact on the mixture formation and unburned hydrocarbons emission while the GDI technology applied to s.i. engine shows troubles at the exhaust because of the intolerable emission of particulate matter [4].

This work aims to report the effects of the fueling pressure and wall temperature on the macroscopic behavior of the impinging sprays on the wall.

The spray-wall interaction was realized inside an optically accessible quiescent chamber and characterized by a Z-shaped schlieren-Mie scattering set-up using a high-speed C-Mos camera as imaging system. The arrangement was capable to acquire alternatively the schlieren and Mie-scattering images in a quasi-simultaneous fashion using the same line-of-sight. This methodology allowed complementing the Mie scattering images, adapt to investigate the liquid phase, with the schlieren ones useful for the gradient variation in the gas/vapor phases during the injection cycle. Two injectors, a single-hole axially disposed and a multi-hole, were used with the injection pressure in the range 5.0 - 20.0 MPa and the wall temperature between ambient to 573 K, respectively. Iso-octane fuel was used as mono-component fluid having a density ρ= 692 kg/m^3@25 °C. A 80 mm diameter aluminum flat plate was positioned into the vessel 22.5 mm downstream the injector tip and orthogonally to the injector axis. The images of the impacting fuel, cycle-resolved, were processed by a customized algorithm able to catch the contours of the liquid phase and the vapor/atomized zone. Spatial and temporal evolutions were measured for both the phases in terms of width slipping and thickness growth.

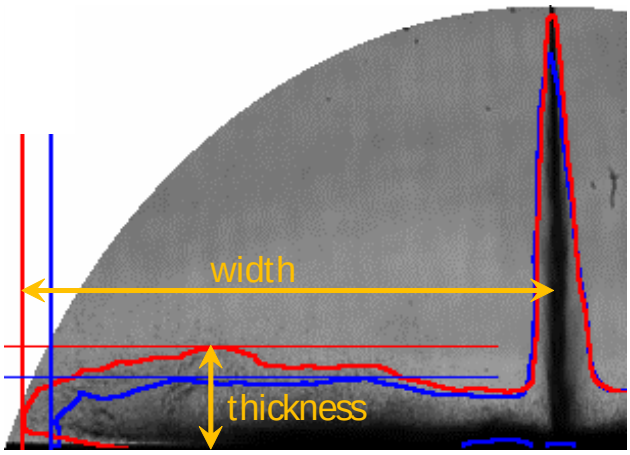

Figure 1. Overlay of width and thickness outlines on schlieren image

Figure 1 reports an overlay of width and thickness outlines on a schlieren background for the single-hole injector. The blue line contour refers to the liquid phase of the fuel, recognized by the elastic-scattering technique, with the blue bars indicating the maximum width and height. The red lines, instead, result from the schlieren technique and indicates the contour of atomized/vapor phase. The red bars indicate the elongation and thickness of the vapor phase. Per each image, the distance of the farthest point of the rebound fuel from the impact site (intersection of the spray-axis with the wall) along the radial direction is considered as the width value and while the highest one, with respect to the plate, as thickness one for both the liquid (blue) and vapor (red) parts. The effects of both the injection pressure and wall temperature on the width and thickness for the liquid and the vapor will be discuss.

Figure 2 shows the effect of the wall temperature on the morphology of the multi-hole impinging spray at the injection pressure of 20.0 MPa and 460 μs after the impact time. The spray images highlight the growth of the vapor mass with respect to the liquid one (black area) at the increasing of the wall temperature. Basically, the heat exchange from the wall to the droplets contributes strongly to the vaporization on the boundary of the jets where less dense and more atomized the spray is and near the wall surface.

*speaker

Figure 2. Schlieren spray sequence at p_{inj}: 20.0 MPa for different temperatures of the wall

Moreover, the increment of the vapor mass is promoted by the injection pressure increment, too, and produces a stronger atomization with an easier vaporization.

Summarizing, at fixed injection pressure, the effects of the wall temperature highlighted a linear increasing of the liquid and vapor width vs. the time from the start of the impact and showed a proportional increasing with respect to the increasing of the temperature. Vice versa, at the fixed temperature, the injection pressures determined a linear and well-scaled behavior of the fuel slipping along the radial part with linearly increasing values vs time.

References

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