

## The effect of a cross-flow on secondary atomization in multipoint fuel injection systems

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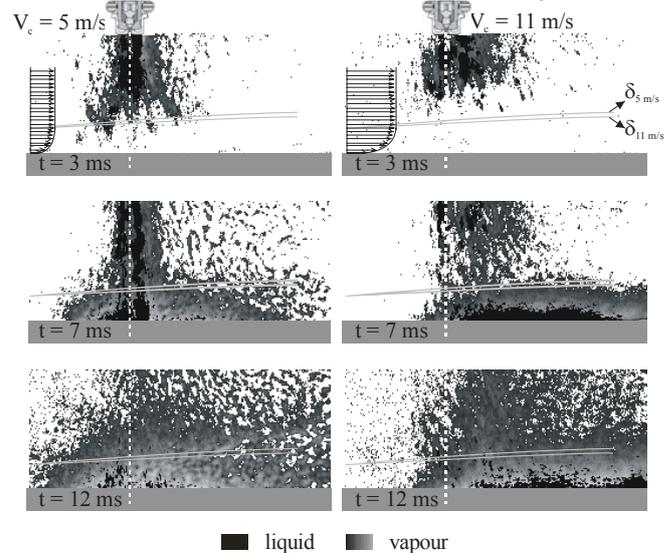
The use of multipoint injection systems for HCCI engines requires a mixture composition precisely controlled in order to obtain the optimum auto-ignition timing. The most favorable injection timing to achieve it is when the intake valve is open, in which case the fuel spray interacts with the air flow and impacts onto interposed surfaces where it may form a liquid film, especially at engine cold-start, and eventually generate smaller droplets by mechanisms of secondary atomization. An accurate description of the physics of spray-wall impact under cross flow conditions and of the effects of the latter on secondary atomization are key issues to devise appropriate strategies to optimize the injection system and to control mixture preparation. This is the aim of the work reported here. The experiments consider overlapping of Mie and Shadowgraph visualization techniques and a phase-Doppler anemometer to visualize and quantify the effects of a cross-flow on spray impact and secondary droplets. Furthermore, the experiments were conducted for well-defined boundary conditions, thus providing results useful for the development spray/wall interaction models. Analysis show that: the cross-flow decelerates the axial velocity of impinging droplets, thus decreasing the energy available at impact; because drag is more efficient on those droplets more prone to adhere to the wall, the net effect is the formation of thinner films; this, in turn, enhances the generation of secondary drops which are then dragged away from re-impacting onto the wall.

### 1. Flow Visualization

Visualization of the spray/wall interaction is made with a macroscopic Mie scattering system making use of a 9W Argon-Ion laser light source. A beam with a diameter of 2 mm is expanded into a thin sheet (1 mm) with a cylindrical lens and enters the working section from the open end in a plan containing the axis of the injector. The light scattered by the droplets is recorded with a CCD camera (Kodak SR-Series) triggered by the same TTL pulse provided by the injection system to control the aperture of the injector. Recording is made with an image acquisition rate of 1000 Frames per second, a resolution of 256x120 pixel<sup>2</sup> and an exposure time of 0.1 ms.

The large volatilization rate of gasoline allows visualizing the transport of fuel vapor by small scale eddies in the cross flow, as the main mechanism contributing to enhance fuel-air mixing, to provide efficient combustion and smooth engine operation. It is noteworthy that the length scale of the turbulent structures is smaller for 11 m/s as a result of an increasing capacity for mixing, and appears to be confined within the turbulent boundary layer limits. Also, fuel vaporization rate appears to be larger for the highest

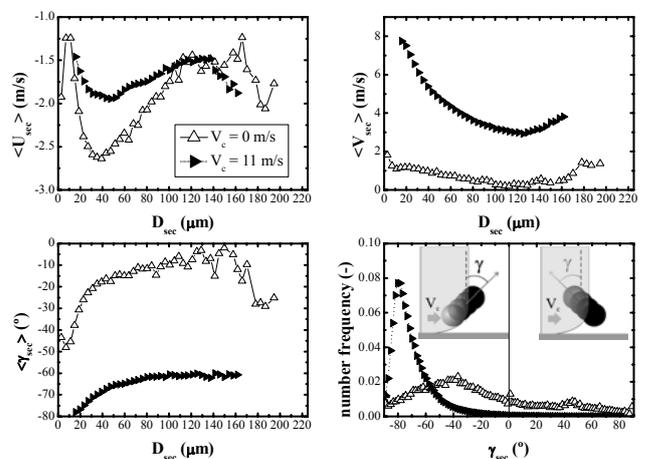
cross-flow velocity used in these experiments. The black area above the surface, at 7 and 12 ms ASOI, show that secondary atomization is enhanced as the cross-flow velocity increases.



**Fig. 1** Overlapping Mie - shadowgraph images of spray impact for different cross-flow velocities.

### 2. Phase-Doppler Anemometer Measurements

Local time-resolved measurements of droplet size and velocity are simultaneously measured with a two-component (514.5 nm – green; and 488 - blue) phase Doppler DANTEC system consisting of a 55X transmitting optics, a 57x10 PDA receiving optics and a 58N10 Covariance processor. Figure 2 shows the influence of the cross-flow on the secondary droplets characteristics.



**Fig. 2** Effect of cross-flow on secondary droplets dynamic characteristics.