Spray Formation Dynamics

1. Background

The physical characteristics of Diesel sprays are heavily influenced by internal nozzle flow and conditions in the near field of high-pressure fuel injectors. In these regions, visualization of the spray structure is challenging due to the presence of dense clouds of fuel droplets which obscure the field of view. The aim of this project is to measure formation dynamics of diesel fuel injection by means of a detailed investigation of the near-field behavior of Scania XPI injectors over a range of nozzle geometries. These injectors are designed to function at unusually high injection pressures and enable investigation of a real production geometry over a range of conditions. The form and content of this near-nozzle region is a point of contention in current research. As Figure 1 shows, a continuous liquid column at the nozzle exit should undergo breakup and shed mass. Using a dense-media imaging approach, known as ballistic imaging it is possible to visualize the liquid structures buried in the dense cloud of droplets surrounding a diesel spray.

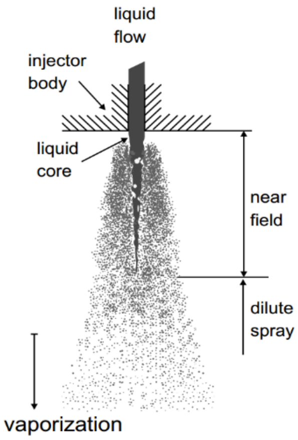

Figure 1. Schematic of jet breakup regimes

2. Method

The project will explore effects of nozzle geometry interactions on the spray behavior using specially designed nozzle tips which are selected to test assumptions with respect to the in-nozzle flow. Three main types of nozzles will be studied: a single-hole nozzle with on-axis orifice (baseline case), a single-hole nozzle with off-axis orifice, and a symmetric two-hole nozzle. This third geometry provides the opportunity to investigate hole-to-hole interactions in spray formation. Variations of these base geometries (e.g., with different k-factor and/or degrees of hydrogrinding) can be investigated as well.

A collinear ballistic imaging arrangement will be used to capture high resolution and time resolved images of the spray. By obtaining images from consecutive pulses with a sufficiently short time-delay, we can compute the velocity of resolved spray structures to develop statistical speed maps of the near-field under conditions relevant to fuel injection applications. These results can then be used to validate CFD of spray formation, or be used directly for detailed model-based design of future XPI applications.

Naturally, the injector conditions such as injection pressure, fuel temperature and the ambient pressure are important to the spray formation behavior. To control these conditions experimental work in this project will be carried out in two spray chambers which afford different optical access and available conditions: a low pressure chamber, which operates at room temperature and up to 30 bar, and the HP/HT chamber, which can provide up to 100 bar backpressure and temperatures up to 900 K.

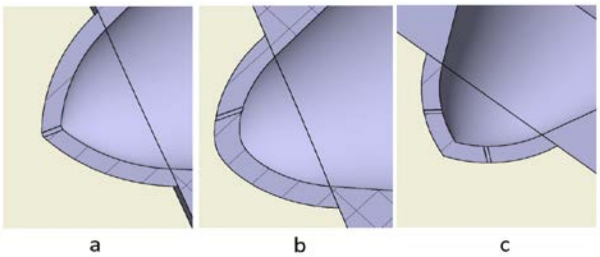

Figure 2. Nozzle geometries a) Single hole, On-axis orifice, Parallel nozzle and orifice axes, b) Single hole, Off-axis orifice, Parallel nozzle and orifice axes, c) Double hole, Deviated orifice axes

3. Results

To date, most of the work in this project has focused on CAD and design the nozzle hardware and mounts for imaging measurements. An injector holder has been designed to mount the XPI hardware on the LP chamber for the first experiments. Current work focuses on constructing the imaging beamline and aligning a collinear BI setup which can separately image each spray chamber.

4. Conclusions and outlook

The main outcome of this research is establishing fundamental knowledge of XPI spray dynamics for close control of fuel mixing in XPI applications. The results of this experimental work will also be made available as a resource for validating CFD models of mixing, combustion prediction, and spray breakup.