Diesel spray velocity and break-up characterization with dense spray imaging

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Abstract

High pressure diesel sprays often exhibit large variations in structure, breakup length, cone angle, droplet and structure size, and overall morphology which cannot be directly attributed to or characterized by the main injection parameters (pressure, orifice geometry, fluid properties, etc). In addition, the large optical depth of the near-field and the sensitivity of the spray formation to disturbances in the flow field effectively prevent the application of conventional imaging or velocity diagnostics in many regions which are important for understanding spray formation. However, a number of emerging optical techniques have demonstrated that specialized optical measurements can be applied in the near-field, despite the severe attenuation and scattering noise endemic to dense spray regions.

Ballistic imaging (BI) is a technique which selectively attenuates light transmitted through the spray to form a 2-D spatial intensity dominated by light which has been minimally distorted by scattering interactions. The primary effect of the filtering is to increase the image contrast, while decreasing overall signal intensity.

Ultrafast shadow imaging (USI) is a modified shadowgraphy arrangement, which takes advantage of intense ultrashort laser illumination and the efficiency of a set of collection optics to create a spatially resolved 'shadow image'. This arrangement trades the sensitivity of a shadowgram for a high-resolution, spatially resolved view of very strong refractive index gradients in the object plane of the collection optics.

This work presents quantitative methods to categorize breakup morphology in a diesel spray produced by a single-hole, plain orifice diesel injector issuing into ambient atmospheric conditions. Velocity data and high-resolution images of the diesel spray were obtained using both time-gated BI and high-resolution USI measurements. The USI results provide high-resolution visualization of the spray edges and resolved droplets within the depth-of-field of the collection optics, while the BI results provide a view of the spray at a modified dynamic range which is unbiased by internally refracted light (caustics) and multiple-scattering noise, revealing additional spatial information.

Time-correlated image-pairs obtained by both techniques were filtered and cross-correlated on a variety of scales to produce velocity profile data and identify structures and features which differentiate the breakup modes observed in the diesel spray over a variety of injection pressures.

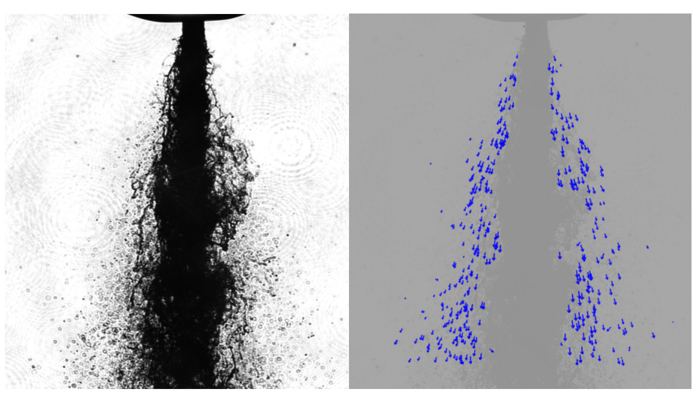

Fig 1. Diesel spray (400 bar injection pressure, 100µm plain orifice nozzle) shadow image and velocity vectors calculated from normalized cross-correlation of time-resolved image-pairs.

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