A Comparison between One and Two Component Velocity and Size Measurements in a Dense Spray

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Abstract
Dense spray plumes produced by two multi-hole gasoline direct injectors have been charactrised in the near nozzle region using single shot CCD imaging and the phase Doppler technique in one and two component velocity configuration.

Introduction

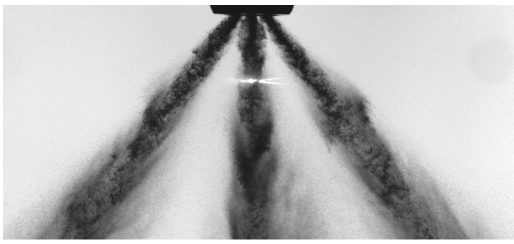
PDA measurements in the near nozzle region of GDI fuel sprays have been attempted successfully [1]. It was revealed that the major problem to obtaining successful PDA data in the near nozzle region of the hollow cone spray was the obscuration of the input beams when the measurement volume was aligned with the inside surface of the spray cone. When the measurement volume was positioned on the spray cone centre line multiple scatter from droplets and remnants of the liquid sheet in, or near, the measurement volume resulted in a significantly reduced signal validation rate, the effects of which could be reduced by increased data acquisition times [1].

The probability of successful PDA measurements can be increased by minimising the dimensions of the measurement volume, maximising the probability of laser beam crossover and droplet detection. Reducing a PDA system configuration from two component to one component velocity provides another option for maximising the probability of the formation of the laser beam crossover.

Materials and Methods

The two component PDA system and atmospheric spray rig and its application to GDI fuel sprays have been well documented [1] and [2]. The multi-hole injector was supplied by Continental Automotive, however, whereas normal production injectors would have a 6 hole nozzle this was made to provide only three nozzles with a total cone angle 90o and 120o circumferentially between sprays. The advantage for this study is that the input laser beams only interact with the spray stream under analysis.

The injector was fuelled with 95 RON unleaded gasoline with a fuel line pressure of 100 bar pressure. The injection pulse duration time was 3 ms comprising of 1 ms soak time and 2 ms fuel delivery. The injection frequency was 4 Hz. A single shot and mean image are shown in Figure 2 with the laser beams at Z = 5 mm and R = 6.5 mm, the radius corresponding to maximum axial velocity. It illustrates the measurement problem by showing severe disruption of the beam crossover in the former while the mean image shows intense levels of light scatter.



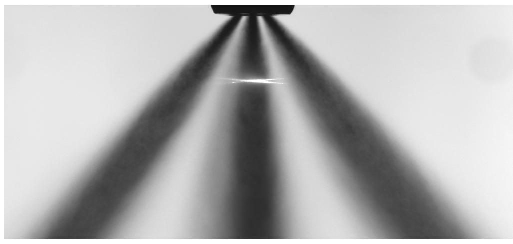


Figure 1. Single shot, left, and mean image, right, showing spray-laser beam interaction

The two component PDA transmitter configuration for the 488 and 514 nm laser beam wavelengths produced coincident measurement volumes of diameters of 56 and 59 microns with fringe spacings of 3.10 and 2.94 microns respectively for the two wavelengths. The standard Dantec 57X10 receiver optical system was positioned at a scattering angle of 70 degrees with an aperture micrometer setting of 0.5 mm. The Dantec PDA covariance processor was set to acquire validated data samples at each measurement position for a fixed acquisition

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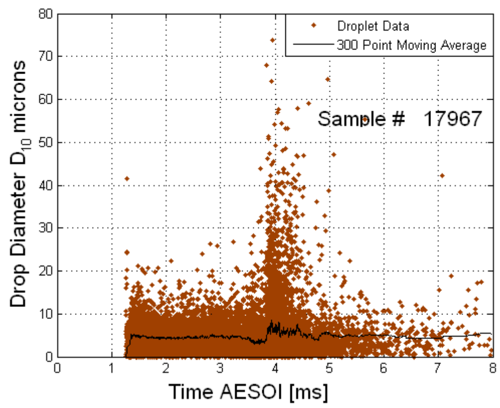
time of 50 seconds i.e. for 250 injections. Measurement scans to acquire the one and two component data were made for Z = 3, 5, 7.5 and 10 mm below the injector nozzle.

Results and Discussion

An example the raw dropsize data are presented in Figure 2 for the spray stream axis at z = 3 mm. The origin for the time history is after electronic start of injection, AESOI, it is followed by the 1 ms soak time for the injector solenoid. The 0.2 ms before any data samples are seen is due to the injector response time and the time of flight of the spray stream. A near steady state condition is established between 1.8 ms and 3.4 ms ASEOI after which the needle starts to close and larger dropsizes are produced. Time bins of 0.50 ms have been used to produce time varying mean profiles for this steady state period.



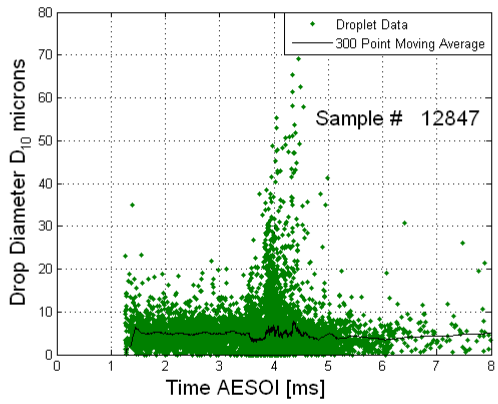
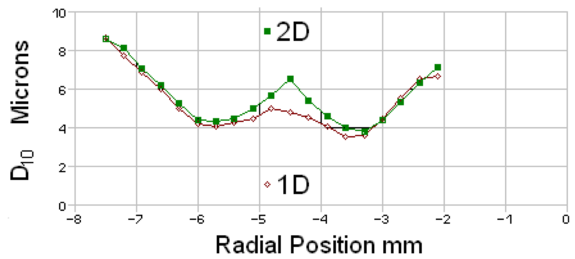


Figure 2. 1D (left) and 2D (left) raw dropsize data at Z = 3 mm and R = 4.5 mm

The spatial plots of D10 for the 1D and 2D measurements are compared for the ‘steady state’ period of the spray in Figure 3. Smaller dropsizes are recorded for the one component measurements across the spray stream axis. The greater obscuration for the two component case has lead to a discrimination for the smaller dropsize classes. This can be quantified by referring to the superposition of PDFs. There is gradual improvement in validated sample numbers with increasing dropsize signifying that reduced beam quality does not lead to a simple exclusion of the lowest sizes.



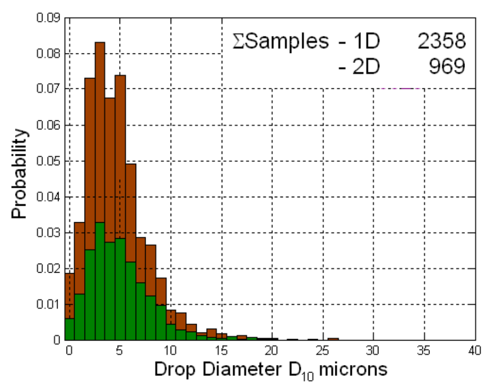


Figure 3. Radial profiles of dropsize at Z = 3 mm with the corresponding PDFs on the stream axis

The conclusion is that in dense sprays only one component measurements should be attempted to provide the best estimates of dropsize. However, a more detailed analysis of the data has shown that it is not just a simple discrimination of the lowest size classes.

References

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[2] Wigley, G., Pitcher, G., Nuglisch, H., Helie, J. and Ladommatos, N. “Fuel Spray Formation and Gasoline Direct Injection”, *AVL 8th. International Symposium on Combustion Diagnostics*, Baden-Baden, Germany, 2008.