PDPA MEASUREMENTS OF A BIODIESEL FUEL SPRAY

APPLICATION NOTE PDPA-007

In this time of unstable petroleum prices and concern for renewable energy and pollutant emissions, it is becoming more important than ever to achieve clean, efficient combustion in compression ignition engines. In the past, diesel fuel contained high levels of sulfur and other constituents, and fuel injection systems were of the pump-line-nozzle type. Injection pressures were generally under 100 Ma, and the fuel injectors were predominately mechanical. A lot has changed in the past ten years, as indicated in the modern filling station shown in Fig. 1. Diesel fuel has been reformulated in many world markets, and now contains very little sulfur. In fact, one of biodiesel's biggest advantages is that it contains no sulfur. Fuel injection systems are approaching 200 MPa injection pressure and piezo injectors are allowing multi-shot injections due to their fast response. All these changes are prompting many researchers to make a renewed effort at phase Doppler particle analyzer (PDPA) measurements of fuel sprays from current fuel injection systems.

Diesel and biodiesel fuel sprays present several measurement difficulties: They are relatively dense, have high velocity regions, contain an enormous velocity range, and last only about 1 msec in duration. Additionally, heated and pressurized enclosures may be used to achieve near engine-like ambient conditions. In order to handle these extreme measurement requirements, a phase Doppler system with high sampling rate, high laser power, flexible transmitting optics, and large aperture receiver are required. The TSI PDPA system meets these needs precisely. The patented FSA4000 signal processor has a true 800 MHz maximum sampling rate with 8 bit data conversion to measure the highest velocity droplets. It does not rely on speed-up techniques like quadrature sampling to generate artificially high "effective" sampling rates. A 5W argon ion laser provides ample beam power to penetrate the dense fuel spray. The exclusive TSI Fiberoptic transmitter probe offers internal ***and*** external beam expansion for an overall 4.22 ratio. This enables <50 µm beam waist at a 500 mm stand-off. The TSI RV100 series receiver probe offers the largest collection aperture in the industry: 106 mm, for enhanced detection of smaller droplets typical of fuel sprays.

Figure 1: Biodiesel and ethanol fuel dispensing station

Courtesy www.theautochannel.com

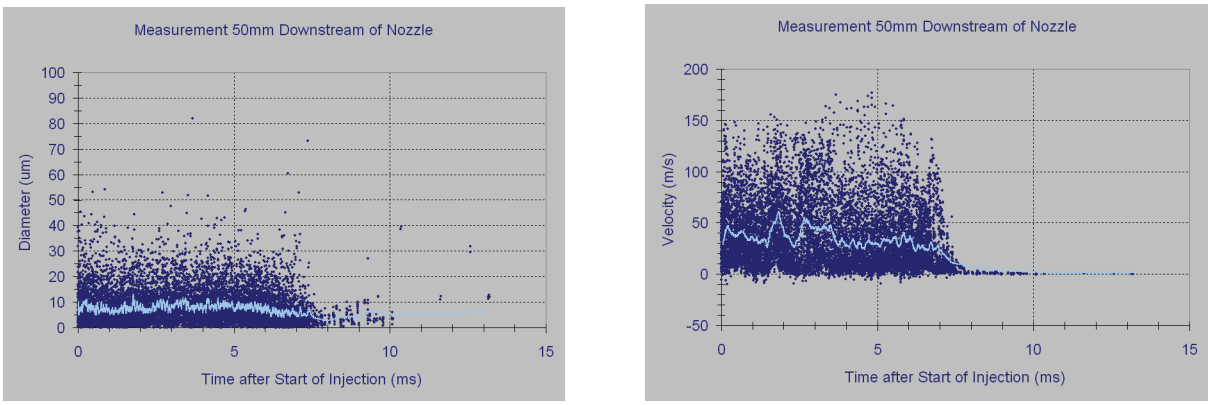

Figure 2: Measured Diameter (left) and velocity (right) for a biodiesel spray.

Other components include a FBL series fiberlight™ beam generator and PDM1000 series detector module. Key processor features, such as patented dynamic automatic sampling rate selection, burst centering, SNR-based burst detection, and intensity validation enable the PDPA to make accurate and detailed measurements on biodiesel fuel sprays.

Diesel engines typically operate in a multi-injection mode, where the fuel injector deposits fuel over two or more injection events per engine cycle. The fuel injected first evaporates and autoignites, thus, providing an ignition source for the following injections, which burn as the fuel is being injected. Note that this is not an “explosion” but rather a combustion event that is controlled by the injection event. One quickly realizes that spray characteristics play an important role in achieving clean, efficient diesel engine combustion. That's where the PDPA comes in.

The PDPA is designed to measure droplet size, velocity, concentration, flux, and a host of diameter statistics like the Sauter mean diameter and various volume mean diameters. Results from a 100% soy based fatty acid methyl ester (FAME) fuel spray are shown in Fig. 2. The data are from 8 injection events. Spray duration is about 8 ms. The running D10 mean diameter (light blue line) is about 8 to 10 µm, but some droplets exceed 50 µm in diameter. The mean velocity is about 40 m/s with some droplets approaching 200 m/s. Table 1 provides other properties of this biodiesel spray as measured by the PDPA.

Table 1. Biodiesel spray properties

Parameter	**Value**
D10 (µm)	8.2
D32 or Sauter Mean Diameter (µm)	21.6
DV50 (µm)	26.3
DV90 (µm)	54.8
Flux –X (cc/cm^2 s)	0.060