



Physical Sciences

Probing a Spray Using Frequency-Analyzed Light Scattering

Intact length and breakup frequency are determined by a relatively simple technique.

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Frequency-analyzed laser-light scattering (FALLS) is a relatively simple technique that can be used to measure principal characteristics of a sheet of sprayed liquid as it breaks up into ligaments and then the ligaments break up into droplets. In particular, through frequency analysis of laser light scattered from a spray, it is possible to determine whether the laser-illuminated portion of the spray is in the intact-sheet region, the ligament region, or the droplet region. By logical extension, it is possible to determine the intact length from the location of the laser beam at the transition between the intact-sheet and ligament regions and to determine a breakup frequency from the results of the frequency analysis. Hence, FALLS could likely be useful both as a means of performing research on sprays in general and as a means of diagnostic sensing in diverse applications in which liquid fuels are sprayed. Sprays are also used for drying and to deposit paints and other coating materials.

Figure 1 depicts a laboratory setup for analyzing a spray by use of FALLS. A laser (or, in principle, any other suitable light source) generates a beam of light that is formed into a horizontal sliver by use of a beam-expanding lens and a cylindrical lens (the lenses are not shown in the figure). The spray to be analyzed is directed downward, and the sliver of light illuminates a thin probe volume that amounts, in effect, to a small cross section of the vertical spray. The principal characteristics of this region will be assessed. A rapid-response photodiode is positioned to receive forward-scattered light at an angle of 30° off the laser-beam axis. The output of the photodiode is digitized and frequency-analyzed by means of a fast Fourier trans-

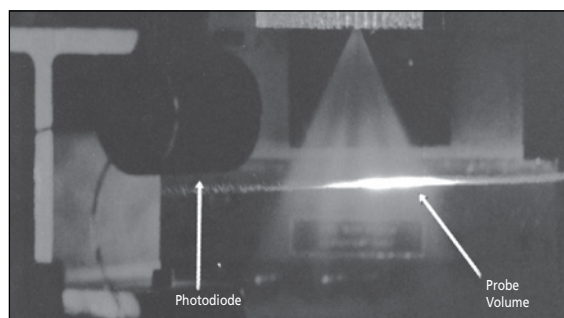


Figure 1. A **Horizontal Cross Section** of a vertically oriented conical spray is illuminated with a sheet of laser light. Light scattered off-axis from the laser beam is detected and frequency-analyzed.

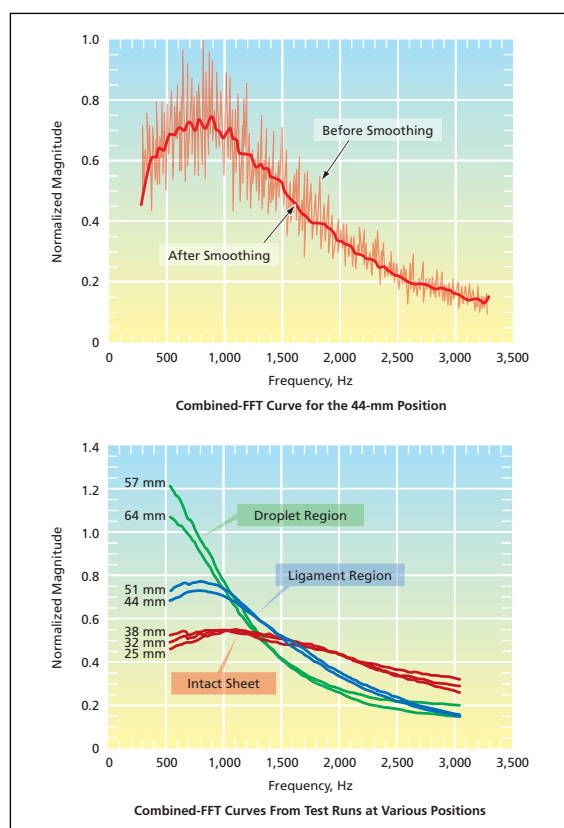


Figure 2. **Normalized FFT Magnitudes** from the three spray regions of interest are clustered into distinct shapes representing the distinct frequency responses and their causative physical mechanisms in those regions.

form (FFT). The nozzle and, thus, the spray can be translated vertically to enable optical probing of the spray at various axial distances from the nozzle.

In a series of tests in the setup of Figure 1, the technique was applied to a conical spray of water at a mass flow rate of 0.1 kg/s generated by use of a swirl coaxial injector nozzle with an upstream pressure of 830 kPa. Illumination power of 400 mW was generated by an argon-ion laser. The photodiode output was sampled at a rate of 20 kHz. Raw data were collected in sets of 4,096 samples (representing an observation interval of 0.2048 second per set). The spray was photographed with a stroboscope to obtain images of the spray for correlation with the FFT data. In addition, by use of phase Doppler anemometry, the spray speed 51 mm from the nozzle tip was estimated to be 14.2 m/s.

Each test run, lasting about 10 seconds, yielded 50 such sets. The 50 FFTs from each run were combined to obtain a single normalized FFT curve shown by the fluctuating thin curve shown in the upper part of Figure 2. A smoothing routine was invoked to suppress noise in the data, yielding the thick smoother curve shown superimposed on the thinner fluctuating one. Normalization was effected by dividing each FFT magnitude by the greatest magnitude in the noisy combined-FFT curve obtained from the test run in which the nozzle was positioned 44 mm above the light sheet. As shown in the lower part of Figure 2, the shapes of the normalized FFT curves were found to lie in three clusters corresponding to the intact-sheet, ligament, and droplet regions, respectively.

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