Application Example: Spray Nozzle Analysis

Motivation

Information on the droplet size distribution generated by a high-pressure spray nozzle at various operating points is required for the CFD modeling of a combustion process. This detailed information is not provided by the nozzle manufacturer, as it depends on several process parameters, such as the liquid used. It is also known that droplet size distribution varies considerably within the spray cone due to the complex nature of interaction between adjacent openings. Thus, detailed mapping of droplet characteristics inside the spray cone is required to produce a meaningful numerical analysis of the process.

Measurements

A Pixact Spray Analysis (PSA) system was installed on a spray test rig on a traversing system that enables the easy scanning of the spray cone. The measurement of a single measurement spot takes about 1 minute, after which the measurement system is traversed to the next spot. Typically, measurements are conducted with a standard pattern at a few distances from the nozzle. In each measurement spot, a set of 1000 images is collected, and the PSA algorithm is used to detect and analyze the droplets in the images. The statistics computed for $O(10^6)$ droplets in each measurement spot include droplet size and velocity distributions, mist flux and droplet velocities as a function of droplet size.

In addition to spot-specific droplet analysis, the Pixact technology can also be used for spray cone visualization. For this purpose, a larger field of view is used to visualize the atomization process. This image data can be processed further to measure for example the spray opening angle.

Results

Figure 1 shows a visualization image of the spray cone. This image covers the first 50 mm of the spray. Some ligaments are visible near the nozzle openings, but the spray soon turns into a relatively homogeneous mist. The figure also illustrates an example image acquired for droplet analysis. The size of this image is approximately 6 x 9 mm. The largest droplets in the image are about 300 µm in diameter.

Figure 2 presents some results from the measurement campaign. In these figures, data measured with two different nozzles are compared at three pressure levels. In the graph above cumulative droplet size distributions are presented. In the graph below the velocity distributions for the same measurement points are shown. The results indicate that nozzle 1 produces smaller droplets than nozzle 3. Larger droplets typically have a higher velocity.

Benefits

Detailed statistics of the droplets at different distances from the nozzle and different distances from the cone center line are reported and the data is used as input for CFD modelling.

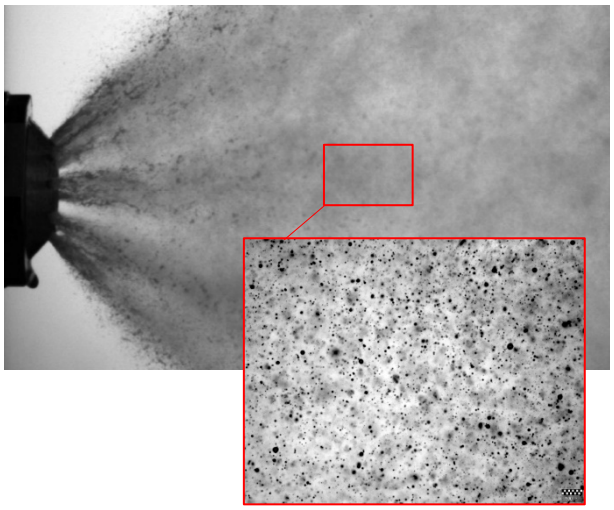

Figure 1. Examples of spray visualization and image data used for the droplet analysis

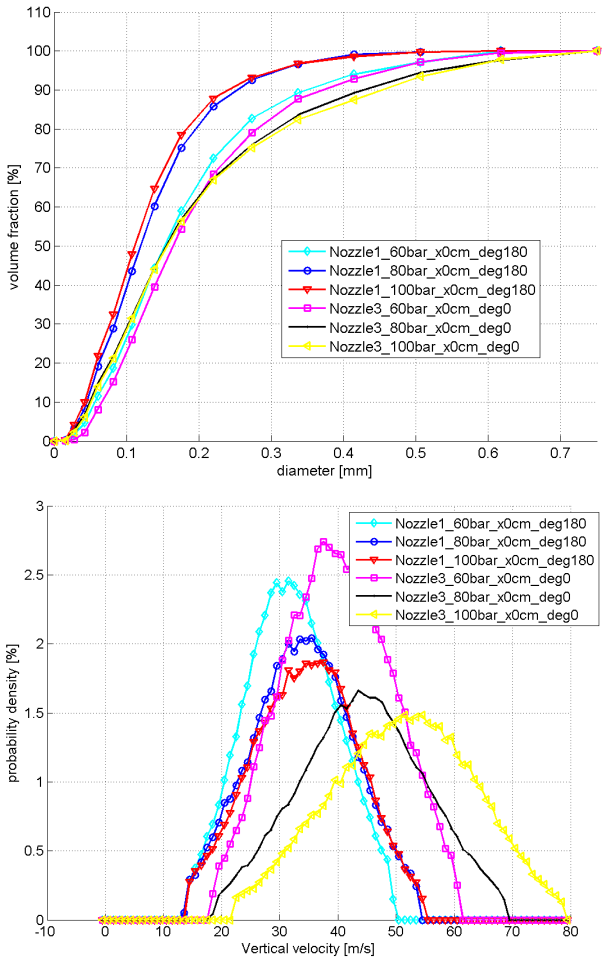

Figure 2. Comparison of droplet size and velocity distributions generated by two spray nozzles at three operating points

Technical implementation

The PSA system is based on the same technology as the Pixcell and Pixscope imaging units, i.e. transillumination of a flowing suspension with a high-magnification camera system and subsequent detection and analysis of droplets from the image data. A photo of the imaging unit is presented in Figure 3, and Figure 4 presents a schematic drawing of the layout of the measurement setup. The imaging unit is installed on a 3D traversing system to scan the spray.

A summary of the specifications of the measurement system is presented in the table below.

Imaging unit	Pixact Spray Analysis
Material	Stainless Steel AISI316L
Gaskets	NBR
Windows	NA
Imaging resolution	3.45 µm/pix
Image area	8.8 mm x 6.4 mm
Optimal measurement range	Size: 10-1000 µm Velocity 0-100 m/s
Software	Pixact Spray Monitoring

Figure 3. Photo of the imaging unit in action

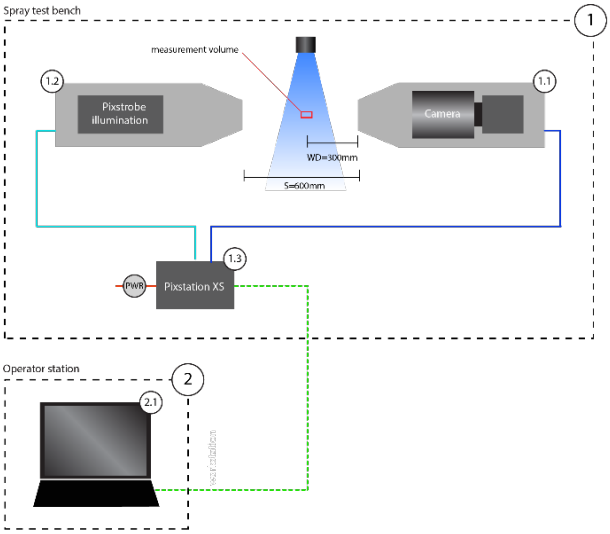

Figure 4. Layout and connection diagram of the system components