Spray Droplet Size and Velocity Measurement using Light-field Velocimetry

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Abstract

The past decade has seen considerable activity regarding light-field (LF) cameras and their application to photography. The ability to refocus images over a finite depth range has consequently led to interest in measuring the distance of objects from the camera. While originally developed for imaging structured opaque surfaces, interest has led to successful application in volumetric flow-fields using a commercially developed light-field camera. This paper focuses on the measurement of droplets in a spray using a light-field camera. While previous measurement techniques utilized a limiting 2D shadowing technique, measuring the size and velocity of droplets silhouetted from behind with uniform illumination, light-field measurements open the possibility of accessing the depth position, and thus the 3D position and velocity of individual droplets in a well-defined volume.

The general principle behind light-field camera can be described as follows: a micro-lens array mounted directly onto an image sensor, with the same f-stop as the main objective, reconstructs at selected positions virtual images representing focus planes within the measurement volume. Particles appear in micro-images within several micro-lenses, albeit at slightly different perspectives, thus allowing for depth determination. Essentially, the microlenses act as local stereo systems. The downside of light-field cameras, however, is the loss of spatial resolution. The loss, however, can be mitigated by applying multiple-focus micro-lens techniques used by a commercially available plenoptics camera. In such cases roughly 25 percent of the spatial resolution is retained, thus the 11 MP camera used in this study had an effective resolution of 2.6 MP.

Measurements were conducted on a agricultural nozzle using water. Images were recorded for the entire spray and for a specific region-of-interest (ROI) within the fully developed region. Comparison measurements were made using a phase-Doppler (PDA). Time-averaged results were compared between PDA and LF, showing good agreement. In general, the light-field camera simplifies the measurement and calibration process for 3D flow analysis. Another added value of LF over the shadow measurement technique is in resolving out-of-focus particles, a persistent problem for conventional imaging. The investigation also focused on the uncertainties involved with LF measurement. This work is still considered preliminary. However, these early results show promise and point to the practical usefulness of light-field technology in 3D measurement.