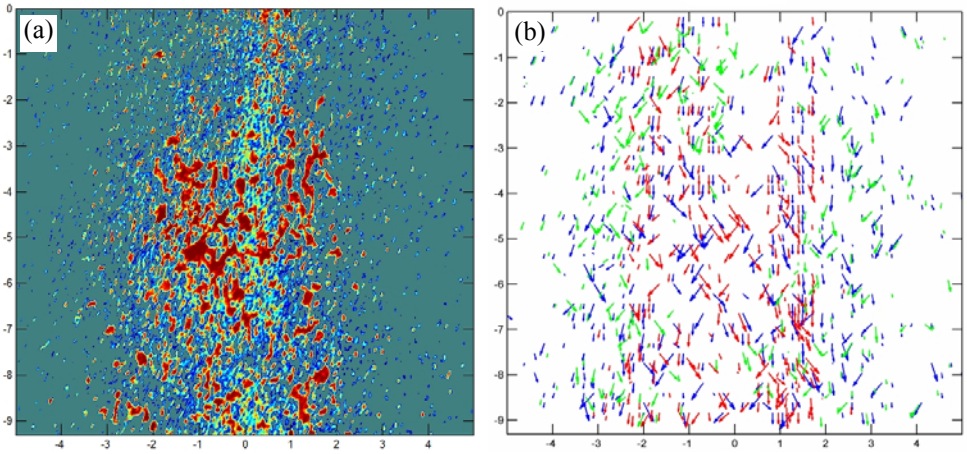
Velocity analysis of fluid structures from ballistic images in the near field of an aerated spray

D. L. Sedarsky *
Department of Physics, Lund University, Lund, Sweden
J. Gord, B. Kiel, C. Carter
Air Force Research Laboratory, Wright-Patterson AFB, USA
T. Meyer
Iowa State University, Ames, IA 50011, USA
M. A. Linne
Sandia National Laboratories, Livermore, CA 94551, USA

Abstract

This work presents an application of the diagnostic technique commonly known as ballistic imaging, which is adept at resolving internal structures in optically dense media. A time-gated imaging system specifically designed for transient fuel sprays was applied to a nitrogen aerated water jet issuing into ambient air. The images acquired by this system reveal fluid structures undergoing breakup in the near-nozzle region of the flow. To unambiguously describe the forces that act to break apart the liquid core in a spray, one must directly measure the force vectors themselves. To this end, obtaining velocity and acceleration data from near-field fluid features is essential to understanding spray breakup dynamics. By employing a fast-framing CMOS camera and a new ultrafast laser source, consecutive ballistic images with a temporal separation of 10 µs were acquired. This fast detection scheme allows the determination of velocity information from pairs of ballistic images using cross-correlation methods. Three approaches were applied to obtain velocity information: particle-tracking correlation analysis was applied to obtain velocity for small droplets resolved in the images, conventional non-adaptive grid correlation analysis was applied across the entire field-of-view, and image segmentation with subsequent grid correlation analysis was applied over the resolved fluid features larger than a reasonable size threshold. The results presented here are an important step in understanding how primary breakup occurs in dense sprays, and opens the way for analysis of spray breakup dynamics using time-resolved single-shot ballistic imaging.

Key words: diagnostics, spray control



Aerated water spray with 10% gas-to-liquid ratio. (a) shows the time-gated ballistic image taken at time, t_1. (b) shows the velocity field generated from ballistic image pair, taken at times t_1 and t_2.

*david.sedarsky@forbrf.lth.se