Single-Shot Ultra-Fast Phase-Contrast X-ray Imaging of High-Pressure Diesel Fuel Sprays

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Abstract

By taking advantage of high-intensity and high-brilliance x-ray beams available at the Advanced Photon Source (APS), ultrafast (150 ps) propagation-based phase-enhanced imaging was developed to visualize the high-pressure high-speed diesel spray breakup process in the optically dense near-nozzle region. The sub-ns temporal and μm spatial resolution allow us to capture the morphology of the high-speed fuel sprays traveling at >500 m/s with negligible motion blur. Both qualitative and quantitative information about the spray breakup can be readily obtained. In the experiment, two types of single-hole nozzles were used, a hydroground nozzle with rounded orifice inlet and a non-ground nozzle with a sharp inlet. The fuel sprays are extremely dynamic from both injectors. In the quasi-steady state of the injection, the jet from the hydroground nozzle (to a stagnant gas of 0.1 MPa) remains as a column showing two distinct instability regions showing surface instability waves and ligament-dominant breakup. The surface instability waves appear to be aerodynamics independent, while the downstream breakup is due to aerodynamic interaction between the jet and the ambient gas. Helium, nitrogen and sulfur hexafluoride at 0.1-MPa pressure are used as the ambient gases to test the aerodynamic interaction. In comparison, fuel injected from a nonground nozzle breaks up within several nozzle diameters from the nozzle exit. We speculate that internal-cavitation causes the jet to break up. For the hydroground nozzle, the surface waves exhibit as a new instability phenomenon at a condition with both high Weber and Reynolds numbers. These wave characteristics are extremely sensitive to the injection pressure, hence, the jet speed. The downstream aerodynamic breakup can be used to validate the theory proposed previously by Reitz.

Key words: fuel injection, diesel spray, surface instability waves, breakup, ultrafast phase-contrast x-ray imaging

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