Effects of Injection Pressure on Spray Atomization Characteristics with Measurement Technique Cross-Validation

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Abstract

Fuel sprays are produced in various types of engines to form air-vapor mixtures for the combustion process. This mixture quality helps determine the combustion and emission performances. Thus, the transformation from a liquid into spray, in a gaseous medium, has significant importance in models predicting spray characteristics. The main objective of this research is to experimentally study the breakup characteristics of pressure-swirl hydraulic injector nozzles. This study consisted of two nozzles characterized as Flow number (FN) 0.4 and 1.7 respectively and injection pressures (0.3-4MPa) to investigate the effects on the atomization characteristics utilizing solely water. Using the appropriate scaling analysis the nozzles were characterized as a non-dimensional mass flow rate number ($\dot{m}^*$) and the injection pressures transformed into a pressure-Reynolds number which ranged from 7000-26000. The experimental study was conducted using three laser diagnostic techniques, Shadowgraph, PIV (Particle Image Velocimetry), and PDPA (Phase Doppler Particle Anemometry) for a complete study of the atomization process. By utilizing these techniques a cross-validation comparison between the measurements could be made. The results present the effects of non-dimensional mass flow rate number and pressure driven Reynolds number on the breakup characteristics, such as spray angle, droplet velocity, and diameter distributions axially. Utilizing the Shadowgraph technique the spray angle, film length, and breakup characteristics for each nozzle, as a function of Reynolds number, was achieved. Results indicate that both nozzles produce similar profiles for spray angle as a function of Reynolds number, increasing to a critical value at a certain Reynolds number respectively then becoming asymptotic. The PIV, Shadowgraph, and PDPA were all used in order to determine the velocity and diameter distribution throughout the spray cone. PDPA and Shadowgraph were used for diameter measurements and PDPA, Shadowgraph, and PIV for velocity measurements. The cross-validation comparison between the three techniques compared well with each other, but limitations were found. The droplets being around 10-20μm near the nozzle tip, caused this area to be extremely dense and measurements made with the PIV near this region were found to be impossible. The Shadowgraph and PDPA produced adequate results for velocity measurements at this location with the Shadowgraph producing slightly higher values. However, when diameter measurements were made similar to the PIV, the PDPA results produced low validation percentages. An optimal distance of 12.7mm from the injector nozzle was found to achieve measurement comparison between the different techniques. Results indicate that velocity decreases as a logarithmic decay axially. While the diameter decreases away from the nozzle, the droplets however, coalesce to make the effective diameter larger. The effects are functions of Reynolds number.