A Study of the Primary Breakup Process and Macroscale Characteristics of Impinging Diesel Spray Nozzles

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Abstract

The use of impinging-spray nozzles has been suggested to lower emissions and increase combustion efficiency in direct injection (DI) diesel engines. It has been reported that an impinging-spray nozzle with a relatively small impinging angle (<20 deg,) is favorable in conventional DI diesel engines, especially at high loads, while a nozzle with a larger impinging angle (30-90 deg.) is proposed for early-injected HCCI engines to provide a more homogeneous mixture with shorter penetration and avoid wall contact. The current work is an effort to understand the primary breakup process and macroscale characteristics of diesel sprays with small impinging angle. Two groups of experiments were designed: 1) the near-field of diesel sprays from an impinging-spray nozzle was visualized via an ultrafast X-ray phase-contrast imaging technique. The interior structure and dynamics were elucidated, as compared to the single-hole nozzle spray; 2) to clarify the macroscale characteristics, including the tip penetration and cone angle, equivalent impinging gas jets with various angles were investigated using high-speed schlieren imaging due to the similarity between diesel sprays and gaseous turbulent jets. The results show that an earlier breakup and a complex morphology arises in the impinging spray under steady flow conditions in contrast to the column-like and fairly unperturbed morphology of the single-hole nozzle spray. This is due to instabilities created within the nozzle (presumably geometry-induced turbulence or cavitation). This indicates that the impinging spray nozzle is capable of enhancing fuel atomization, especially in the near-nozzle region. Moreover, it was found that the two jets from an impinging-spray nozzle are already fully atomized before they intersect, and the breakup length is only one or two hole diameters. From the equivalent gas jet experiments it was found that the tip penetration of impinging jets is quite similar to the corresponding single jet. The penetration of the impinging gas jets with small angle (<15 deg. in this study) was found to follow the theoretical correlation established for turbulent single round jets.

Key words: Impinging diesel spray; gas jet; primary breakup; x-ray phase-contrast imaging; schlieren imaging

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