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Effect of Extreme Compression on Diesel Spray Penetration and Dispersion

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Abstract

Increasing the compression ratio of a simple-cycle engine beyond 100:1 can enable first-law efficiency approaching 60%, if losses relative to the ideal cycle can be maintained similar to existing engines. Achieving this in practice will require understanding and managing the combustion process in the very high gas density that results from such a compression ratio. In addition, a desire to reduce the time scale for heat transfer by more rapid compression and expansion constrains the time available to initiate and complete combustion. The highest ambient density studied in existing combustion-bomb research is around 60 kg/m^3, or approximately equivalent to top dead center for a compression ratio of 53:1. As a first step in characterizing combustion at compression ratios up to 100:1, this paper studies the penetration and dispersion of a vaporizing, non-reacting diesel spray in a free-piston extreme compression device for compression ratios from 30 to 100:1. High-speed schlieren photography through full-bore optical access in the end wall of the combustor provides imaging of the spray. Spray penetration and dispersion via spray angle are measured as functions of time for each compression ratio. The recorded data are compared to the existing literature by use of a correlation developed from the high-ambient-density, combustion-bomb research mentioned above. The data for spray angle correlate reasonably well with expectations extrapolated from the existing literature for all compression ratios studied. Penetration in the extreme compression device was found to correlate very well with the prior research at lower compression ratios, with penetration decreasing as compression ratio is increased. Above 60:1, however, penetration rate did not further decrease as expected, but rather remained essentially constant from 60 to 100:1. This result is explained by the fact that, for the free-piston combustor, the volume profile becomes steeper in time with increasing compression ratio, resulting in the density at start of injection remaining nearly the same as compression ratio is increased from 60 to 100:1. Comparing penetration rate for early and late portions of the injection to correlations for density at that point in time, indicates that the existing correlation continues to predict penetration rate as a function of density even up to densities of 100 kg/m^3.

Key words: diesel spray penetration

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