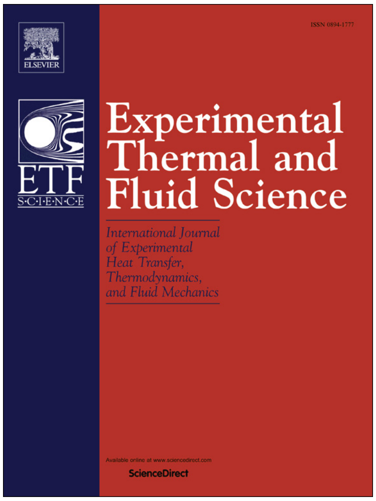

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EXPERIMENTAL THERMAL FLUID SCIENCES

An experimental investigation of gas fuel injection with x-ray radiography.

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ABSTRACT

In this work, an outward-opening compressed natural gas, direct injection fuel injector has been studied with single-shot x-ray radiography. Three dimensional simulations have also been performed to compliment the x-ray data. Argon was used as a surrogate gas for experimental and safety reasons. This technique allows the acquisition of a quantitative mapping of the ensemble-average and standard deviation of the projected density throughout the injection event. Two dimensional, ensemble average and standard deviation data are presented to investigate the quasi-steady-state behavior of the jet. Upstream of the stagnation zone, minimal shot-to-shot variation is observed. Downstream of the stagnation zone, bulk mixing is observed as the jet transitions to a subsonic turbulent jet. From the time averaged data, individual slices at all downstream locations are extracted and an Abel inversion was performed to compute the radial density distribution, which was interpolated to create three dimensional visualizations. The Abel reconstructions reveal that upstream of the stagnation zone, the gas forms an annulus with high argon density and large density gradients. Inside this annulus, a recirculation region with low argon density exists. Downstream, the jet transitions to a fully turbulent jet with Gaussian argon density distributions. This experimental data is intended to serve as a quantitative benchmark for simulations.

1. Introduction

The use of gaseous fuels for transportation has been identified as either an alternative to liquid fuels or a complementary fuel for dual fuel combustion strategies. Natural gas engines have several potential advantages when compared with conventional petroleum engines. These include lower knock tendency, improvement in thermal efficiency, lower levels of CO2, lower particulate matter, and lower NOx levels [1]. With recent increases in unconventional sources of natural gas and low estimated prices in the near future [2], natural gas will have longevity as a fuel source and will likely remain cost competitive for some time [3].

Direct injection (DI) of compressed natural gas (CNG) has the potential for high thermal efficiency and power density along with the ability to stratify the fuel in-cylinder [4]. The higher knock resistance of CNG, compared to gasoline, allows for larger compression ratios compared to gasoline spark ignition, resulting in increased thermal efficiency [5]. Compared to port-fuel injection, DI increases the degrees of freedom of control in the engine injection strategy [6]. Schmitt et al. [7] highlight the need of studying DI-CNG flows due to the importance of understanding the contribution of gaseous flow mixing to cycle to cycle variation and the difficulties associated with performing large eddy simulations (LES) of transient under-expanded jets in three dimensions. Schmitt failed to capture the minimum and maximum pressure traces, and

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