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Full Length Article

Spray cyclic variations of multicomponent fuels under subcooled, transitional, and superheated conditions

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ABSTRACT

The superheated spray has attracted attention due to its enhanced atomization in gasoline direct injection (GDI) engines. Even though spray characteristics of multicomponent fuels under superheated conditions have been studied before, the connection between plume-to-plume interaction and spray cyclic variation (SCV) has not been adequately addressed. Moreover, the lack of physical understanding of SCV for multicomponent fuels hampers effort to reduce GDI engine cyclic variations. Thus, this work investigates the SCV of binary and ternary multicomponent fuel blends under superheated conditions. Three pure components of n-pentane, isooctane, and n-decane were analyzed and compared to their twelve binary and ternary blends. The experiments were conducted using the laser Mie-scattering technique in a spray chamber at a fuel temperature of 70 °C and ambient pressure of 50 kPa. This test condition facilitated the occurrence of subcooled, transitional, and superheated sprays for all 15 fuel blends. Five spray plume-to-plume interaction levels are defined to reveal the relationship between the SCV and plume-to-plume interaction. The results show that the spray structure is constrained by the blending ratio of n-pentane (high volatility component). The transitional spray exhibited higher plume-to-plume interaction with larger SCV on the variations of partially connected plumes. Both the non-collapsed spray (no plumes interaction) and totally collapsed spray (wholly merged plumes) showed less SCV. However, the total collapsed spray showed higher SCV compared to non-collapsed spray.

1. Introduction

The fuel atomization in gasoline direct injection (GDI) engines can be highly random because of the unstable liquid jet from small nozzles at high pressures and temperatures [1]. This randomness could induce the engine cyclic variations, misfire, pool firing, low thermal efficiency, and more emissions, prohibiting GDI engines from achieving their full advantages [2,3]. Therefore, researchers investigated several factors that affect engine stability, including spray cyclic variations (SCV), ignition parameters, airflow, and fuel distribution [4–6]. Although SCV remains a major cause of engine cyclic variations, it has been less considered compared to other factors.

Superheated atomization is one of the novel techniques to realize the precise fuel injection control for achieving stabilized combustion [7–9]. Even though the superheated atomization suffers from spray collapse and injector tip wetting [10–12], several studies reported less engine cyclic variation (COV_{imep}) using superheated spray characteristics [13–16]. Dong et al. [17,18] studied the impact of superheated atomization on fuel distribution using planar laser-induced fluorescence (PLIF). They reported superheated spray produced a more repeatable fuel distribution pattern with more stable flame kernel propagation and less COV_{imep}. Although previous research show that injecting superheated spray into engine cylinder could reduce engine cyclic variations (COV_{imep}), the mechanisms of the SCV under superheated conditions were not elucidated in these engine studies. Meanwhile, most research on superheated spray focuses on the impact of several factors, such as injection and ambient pressures and the fuel temperature, primarily using pure components, such as alkanes and alcohols [19–21]. However, studying pure components' spray characteristics has many limitations since gasoline is a complex fuel with many components [22].

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