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Macroscopic and microscopic characterization of diesel spray under room temperature and low temperature with split injection

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ABSTRACT

The diesel spray morphology characteristics in the near-field and far-field were studied under both room temperature (RT, 25 °C) and low temperature (LT, −2 °C) with high speed imaging technique. The microscopic characteristics, namely droplet velocity and droplet size were then investigated with a Phase Doppler Particle Analyzer (PDPA) under the same conditions. Single injection and split-injection strategies were employed. It was found that the increased viscosity under LT caused less injected fuel and obviously poorer dispersion thus smaller spray area and slower penetration compared with RT. Split-injection strategy significantly varied spray characteristics under LT while the raised injection pressure greatly narrowed the difference between split injections caused by this cutting-edge injection strategy. The higher surface tension under LT enabled the droplets to keep stable and retain the spheroidal shape. Consequently, higher droplet velocity and larger size were detected under LT. In addition, strong collision for split injection strategy resulted in larger droplets compared with single injection and LT further deteriorated the poor dispersion.

1. Introduction

The cutting edge multiple-injection strategy is beneficial to engine performance by increasing IMEP and reducing emissions [1,2]. For instance, pilot injection regulates the heat release rate and noise, while post-injection reduces soot by increasing the combustion rate [3]. More importantly, split-injection reduces the penetration length and the possibility of impingement thus lower CO and HC emissions. Multiple-injection strategy is proved to be favorable for cold operation by considerably increasing combustion stability and reducing misfire for cold idle operation [4]. Carlucci [5] reported that the ignition delay was reduced and that multiple-injection strategy could effectively control the start of ignition, flexibly controlling the emissions.

For split injection strategy, various factors except for the traditional ones affect the spray characteristics, further complicating the spray. Dwell interval is thought to be very important for interaction between split injections and the resultant spray behavior. The spray/combustion interaction correspondingly varies according to the variation of dwell interval [6]. The duration of the first split injection considerably affects the second split injection by varying the start of the injection for the second injection. In addition, the number of split injections also exerts profound influence on spray because the interaction changes significantly [7].

Although the macroscopic characteristics (cone angle and penetration) of split injection strategy have been studied, the features of microscopic characteristic (particle sizes and velocity) are still unclear. More importantly, the spray behavior under low fuel temperature which is expected to be quite different due to the changed fuel properties has not been fully studied. In addition, how the varied fuel properties under cold start condition impact the spray behavior and interaction between split injections when split injection strategy is employed requires deep study. Aiming to solve these unknowns, the morphology characteristics in the near-field and far-field under both RT and LT were first studied with high speed imaging technique. The microscopic characteristics under the same conditions were then investigated with PDPA technique.

2. Experimental setup

The fuel temperature was set to room temperature (RT, 25 °C) and low temperature (LT,–2 °C) while the ambient temperature was set to RT in this study. Keeping the fuel temperature stable is very essential for all tests. A special cooling system (the blue part shown in Fig. 1) was used to keep the fuel temperature as stable as possible. The warm pressurized fuel was first precooled by the mixture of ice and water filled in the pre-cooling barrel. A thermocouple installed in the pre-cooling barrel was employed to measure the ice-water mixture temperature. The range of the ice-water mixture temperature was from 0 to 1 °C during the tests.

An additional cooling system which had an injector cooling barrel, a freezer and a low pressure pump was used to cool the injector. To sufficiently cool the injector and the fuel, all of the injectors except the tip were inserted into the cooling barrel. The freezer can cool the coolant

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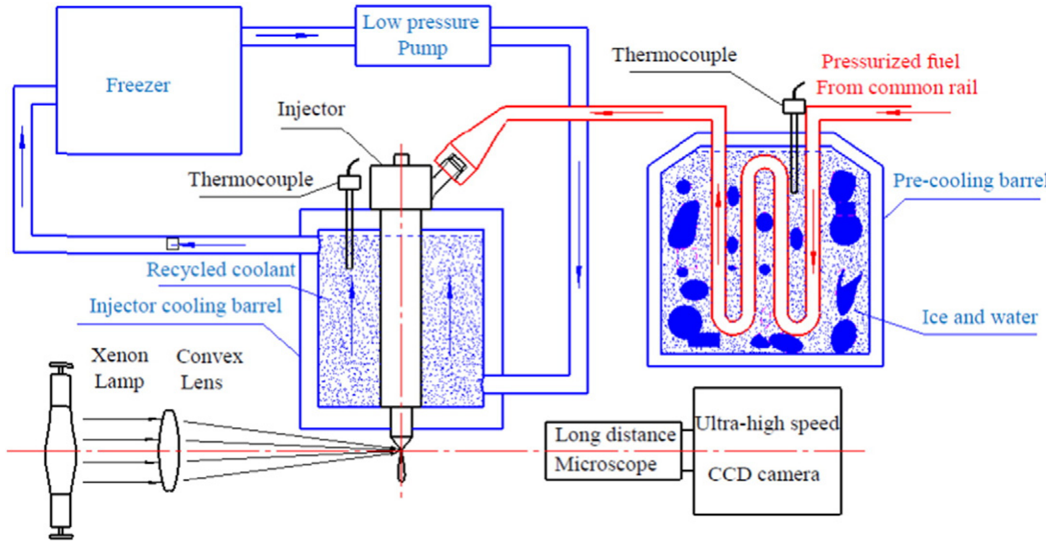

Fig. 1. Layout of the cooling system and high speed imaging setup.

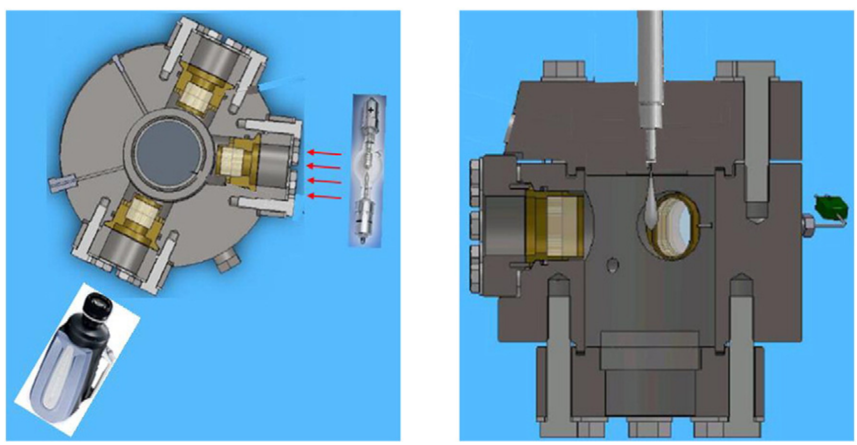

Fig. 2. Set up for the high speed imaging (adapted from [8]).

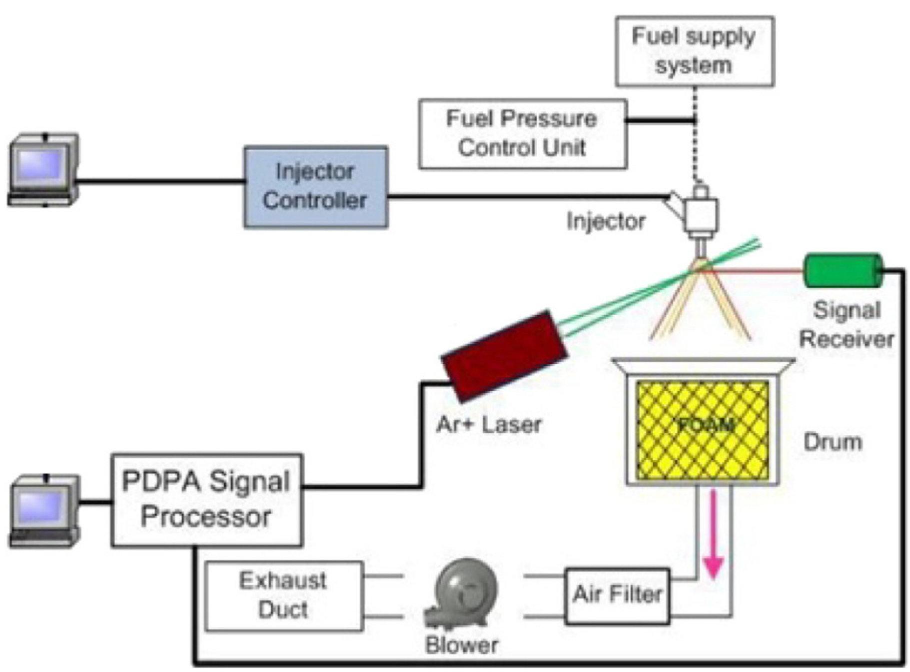

Fig. 3. Setup for PDPA (adapted from [8]).