Improvement of Atomization of High Viscosity Liquid through Injection Rate Modulation

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Abstract

The improvement of atomization of high viscosity fuels such as heavy fuel oil is one of the most important issues in the field of marine diesel engines, since the quality of heavy fuel oil used in this field is becoming worse, whereas the requirements of cleaner exhaust emission is becoming more stringent. In the field of diesel engines for automobiles, fuel injection pressures have been increased up to 200 MPa to improve the atomization characteristics, which have successfully improved the combustion and emission performances of recent engines. However, it is difficult to use such high injection pressures in marine diesel engines as they will reduce the reliability of the injection pump and nozzles. Consequently, an alternative technique for improving the atomization other than the high pressure injection is required. Against this background, the authors are trying to improve the atomization characteristics of high viscosity liquids by employing high-frequency modulation of the fuel injection rate, i.e., periodical fluctuation of the injection rate. In previous studies, the authors examined the effect of injection rate modulation on the spatial dispersion of fuel droplets and the inner structure of the fuel spray under atmospheric condition, and found that the spray becomes wider with the increase of modulation amplitude and with the increase of modulation frequency in the case of spray with diesel oil. Following on from these studies, the present study investigates the effect of injection rate modulation on the spatial dispersion of droplets of high viscosity silicon oil.

The fuel injection system used in the present study is an electronically controlled accumulator type fuel injection system. In this system, the pressure pin of a conventional diesel nozzle was extended to attach a piezoelectric actuator by which to control the movement of pressure pin directly, enabling the fuel injection rate to be set arbitrarily. The nozzle used is a single hole type one with the hole diameter of 0.24 mm. The main experimental parameters were the modulation frequency, the modulation amplitude, the viscosity of the liquid, and the ambient pressure. The liquids used in this study were silicon oils with kinematic viscosities in the range of 10 to 30 cSt to simulate the viscosity of heavy fuel oil. The fuel injection system was installed on top of a constant volume high pressure vessel with two large observation windows. The fuel was injected downward into the vessel. The pressure inside the vessel was varied from atmospheric pressure to 1.5 MPa. The spray was illuminated by light from a metal halide lamp and photographed by an ICCD camera. To obtain an image of the averaged spray shape, the exposure time of ICCD camera was set to 2.5ms. To visualize the instantaneous images of spray, the ICCD camera was used in high-speed photography mode with an exposure time of 10 μs. From the systematic experiments it is explored that applying injection rate modulation improved the atomization characteristics of a viscous liquid. The spray shape becomes wider and the spray angle becomes larger with increasing amplitude and frequency of the injection rate modulation. This tendency was observed at different ambient pressures, although the atomization was improved as the increase of the ambient pressure. The mechanism of this phenomenon is discussed based on the temporal movement of the droplets cloud visualized by the high speed camera. It is found that interactions between injected fuel droplets close to the nozzle, such as catching up and overtaking motions, produces the expanding motion of fuel droplets perpendicular to the spray movement, resulting in a wider spray.

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