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Short communication

Fuel injection characteristics and spray behavior of DME blended with methyl ester derived from soybean oil

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ABSTRACT

The objective of this work is to analyze the fuel spray injection characteristics and macroscopic behaviors of the dimethyl ether (DME) blended methyl ester derived from soybean oil at different blending ratios. The injection characteristics of the blended fuels such as injection delay, injection rate, and effective velocity in the nozzle flow passage were investigated under the various DME and its blended fuels. In comparison with the injection delay of blended fuels, the lower blending ratio of DME blended fuel with biodiesel showed a shorter injection delay than the higher blending ratio of the blended fuel. At the same energizing period and injection pressure, the DME fuel with a higher blending ratio showed a longer injection duration than that of the lower blending ratio. The higher DME blended with biodiesel also showed a low peak value of injection rate compared to the lower DME blended fuel at the same injection time. As the blending ratio of DME fuel was increased, the effective initial velocity of neat biodiesel and lower DME blended with biodiesel increased compared to the higher DME blended fuel. In comparison of spray penetration of blended fuel, biodiesel and blended fuel have a similar spray length at the same condition except the neat DME fuel.

1. Introduction

In order to meet stringent environmental regulations, the reduction of diesel engine emissions such as NO_x, P.M., and soot has become a more important goal for the clean combustion of automotive vehicles. Biodiesel is a clean-burning alternative fuel produced from renewable and biodegradable resources. It is non-toxic and essentially free of sulfur and aromatics. However, it has a problem to be solved of higher viscosity closely related to the atomization characteristics of the biodiesel and is hard to atomize and mix with air compared to conventional diesel fuel.

Dimethyl ether (DME) was used at first to improve ignition in methanol fueled compression ignition engines (CI engines) [1] since it has good evaporation property, high cetane number, and low soot emission in the CI engine. However, DME has low viscosity and heating value compared to diesel fuel [2,3]. McCandless et al. [4] developed the dimethyl ether pump for a common rail and they investigated the pump performance and variable displacement feature. Low viscosity of DME fuel causes wear for moving parts of fuel injection systems.

One solution of the problem is to add the additive material into DME [5,6]. From the view point of physical properties, DME is soluble into the biodiesel, and the mixed fuel with DME has much lower viscosity than conventional diesel reported by Chapman et al. [7]. Thus, there exists a possibility of good atomization of biodiesel fuel when DME blended biodiesel fuel is injected into the engine combustion chamber.

This study is to investigate the injection characteristics of DME blended with biodiesel from biodiesel under various injection pressures, energizing durations, and blending ratios of biodiesel. In order to analyze the effect of DME mixing with biodiesel methyl ester derived from soybean oil on the injection characteristics, the injection rate and effective velocity were investigated for the various blending ratios and injection conditions.

2. Experimental

In this investigation, test fuels are DME, biodiesel (BD), biodiesel blended DME fuels such as B25, B50, and B75 fuels (B75 means 75% biodiesel and 25% DME blended fuel by weight). Fig. 1 shows the schematic diagram of injection rate measuring system and visualization system. In order to study the injection characteristics, the injection rate measuring system based on Bosch's suggestion [8] was used to analyze the effect of mixing ratio of blended fuel on the injection characteristics at various injection conditions. The test injector used is composed of a solenoid-driven type injection system with single hole and nozzle body with diameter of 0.3 mm and depth of 0.8 mm. The fuel

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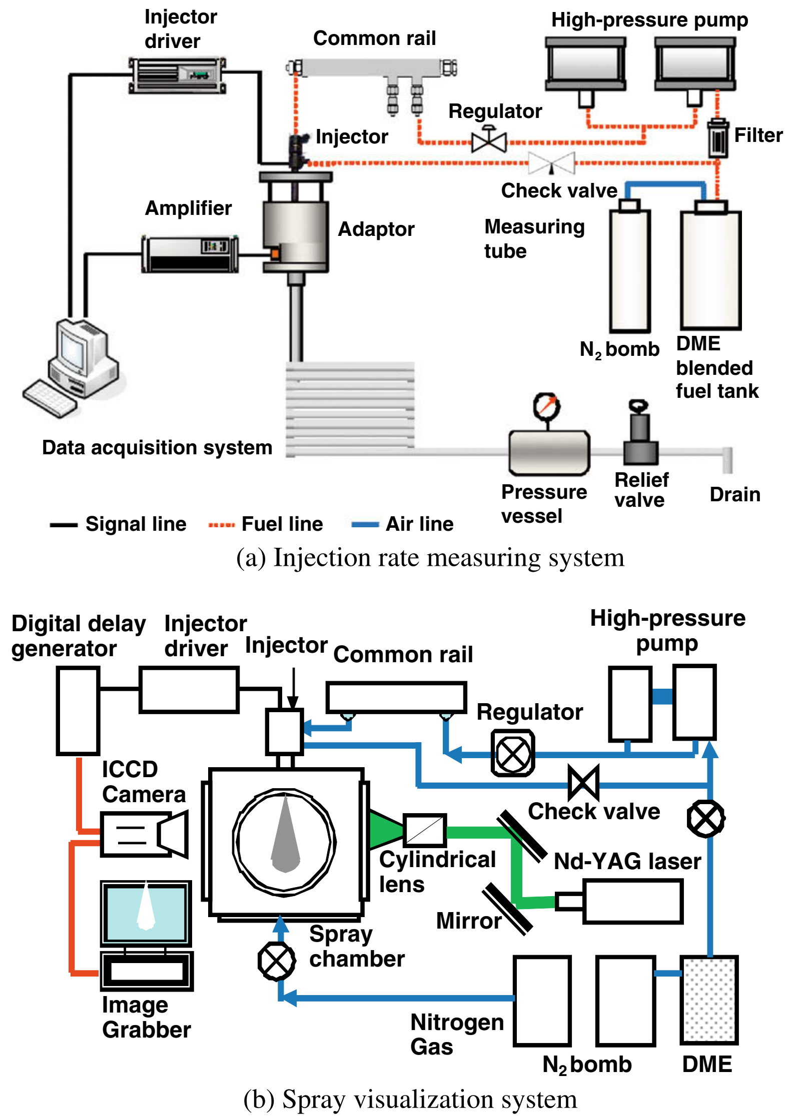

Fig. 1. Schematic diagram of injection rate and spray visualization system.

injection system of DME and DME blending with biodiesel consisted of high-*pressure injector* and fuel pump (HSF-300, Haskel) operated by compressed air. Injection rate measuring apparatus was based on the pressure variation within a tube filled with each blended fuel. The fuel flows in the fuel tube created a pressure variation that detected by a piezo-type pressure sensor (Type 4045A50, Kistler). In the tube, the pressure was kept constant at 4 MPa during the fuel injected duration by using a relief valve. In this work, the energizing time was defined as the duration between the start of the current rise and termination point of the operating current of the injector driver, and the injection delay was defined as the duration from the switch on the injection nozzle to the start of injection. The process of spray development was visualized using a spray visualization system composed of an ICCD camera with resolution of 1280(H) × 1024(V) (Dicam Pro, Cooke Co.), an Nd:YAG laser (SL2-10, Continuum, 532 nm and 150 mJ), and a signal synchronization system such as injector driver (TDA-3200H, TEMS) and digital delay generator (Model 555, Berkeley Nucleonics Corp.) and a PC-installed image grabber. The visualized images of the fuel spray are captured in the conditions of injection pressure (P_{inj}) 40 MPa and 4 MPa of ambient pressure (P_{amb}).

3. Results and discussion

Fig. 2 shows the effects of blending ratio of DME and biodiesel fuel on the injection delays according to the variation of fuel injection pressure. The injection delay was defined as the time interval between the energizing of the injector and the start of fuel injection from the nozzle tip. Biodiesel, B50, and B75 show longer injection delay at low injection pressure compared to the injection delay of DME fuel. The injection delay was decreased in accordance with the increase of injection pressure due to the increasing of deformation rate in the fuel line. As shown in the relation of viscosity and blending ratio, the higher viscosity has the low deformation rate and longer delay of fuel injection. The viscosity of DME is influenced by the density due to the increase of pressure as illustrated in density–temperature chart of DME [3]. In the case of biodiesel fuel, the injection delay is influenced by the fuel viscosity. The main reason for the longer delay of biodiesel is caused by higher viscosity of biodiesel (4.2 cSt) compared to the diesel fuel (2.4 cSt). Therefore, the higher viscosity is influenced on the injection delay of the injector. It is clear that the comparison with the injection delay of biodiesel fuel and the other blended fuels show a large difference for the all pressure ranges. The injection rate as a