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Alcohol Diffusive Combustion Technique as an Alternative Diesel Combustion (Fourth Report)

- Effect of reducing diesel fraction in dual-fuel injection -

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Achieving carbon neutrality (CN) will require the decarbonizing transportation fuels. Among the various CN fuel candidates, short-chain alcohols (methanol and ethanol) are particularly attractive because they are liquids at normal pressure and temperature and thus can be stored and distributed with relative ease. However, for high-load running where a high torque is demanded, a knock-free, mixing-controlled (diffusive) combustion concept for alcohol fuels has yet to be developed. Unfortunately, this is made difficult by the high latent heat of vaporization and the low cetane number of alcohol fuels, which together impede compression auto-ignition. Therefore, a dual-fuel strategy has been pursued in which a small amount of diesel fuel is pilot-injected to provide an ignition source and initiate diffusive combustion of the alcohol main spray.

In our previous work, considering vehicle applicability, we prototyped a dual-fuel, high-pressure pump by adding an alcohol-boosting unit to a conventional high-pressure diesel pump, and developed a dual-fuel injector that combined a common-rail electronically controlled injector with a single-needle nozzle (Fig.1(a)). Using in-cylinder combustion visualization and single-cylinder engine tests, we identified the pilot-injection parameters that enable diffusive combustion of the main injection over a reasonably wide range, while noting that the optimal pilot timing and quantity depend on the engine speed and ambient conditions. Moreover, luminous flames associated with soot oxidation were observed not only in the diesel-dominant pilot combustion but also during the main combustion in which diesel and alcohol are co-injected, suggesting soot formation during the main combustion phase. While the single-needle dual-fuel injector is relatively simple in structure, it cannot independently control the amount of diesel and ethanol being injected. In addition, the need to increase the diesel fraction during the pilot injection tends to cause an excessive diesel fraction during the main injection, which can promote soot formation.

In this study, we fabricated a "reduced-diesel" nozzle by adjusting the diameter and number of orifices provided in the diesel flow passage inside the dual-fuel injector (Fig.1(b)), thereby minimizing the diesel fraction during the main injection while maintaining the amount of diesel for the pilot injection as much as possible. Experiments using two nozzles (a baseline nozzle and the reduced-diesel nozzle) showed that the diesel fraction at an injection quantity corresponding to an indicated mean effective pressure of 800 kPa decreased from 55% to 28%. With the baseline nozzle (high diesel fraction), the smoke increased sharply with EGR rate. In contrast, with the reduced-diesel nozzle (28% diesel fraction), the observed smoke increased more gradually with EGR and was markedly lower than that of the baseline nozzle. This is possibly reason due to the reduced-diesel nozzle producing (i) a smaller fraction of diffusive combustion, (ii) a shorter residence time in the soot-forming regions, (iii) a higher in-cylinder gas temperature leading to soot oxidation, and (iv) more time being available for soot oxidation, leading to lower net smoke emissions (Fig. 3).

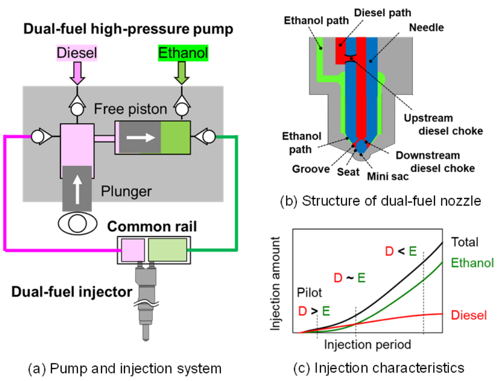

Fig. 1 Dual-fuel pump and injection system

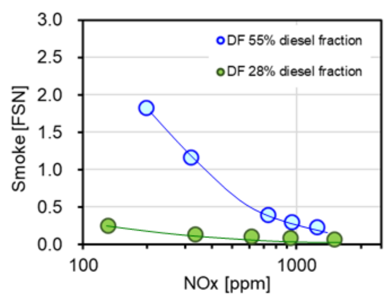

Fig. 2 Dual-fuel pump and injection system

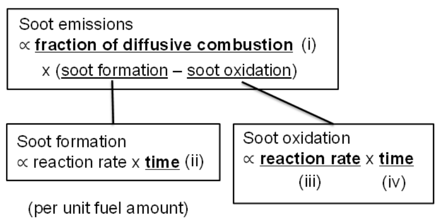

Fig. 3 Factors of soot formation and oxidations