Investigation of Optimal Combustion Concept for Oxymethylene Dimethyl Ether (OME)

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This study investigates an optimized combustion concept for oxymethylene dimethyl ether (OME) through a combined methodology involving CFD simulations, single-cylinder engine experiments, and high-speed OH chemiluminescence imaging. OME, a synthetic fuel and candidate for carbon-neutral (CN) energy pathways, is characterized by low soot emissions and suppressed late combustion due to its oxygenated molecular structure. However, OME also presents several challenges when directly applied to conventional diesel engines. Its lower heating value requires a larger fuel quantity to achieve the same energy input as diesel, leading to a longer injection duration. Moreover, its higher oxygen content promotes dilution within the spray core, increasing the local flame temperature near the wall and consequently enhancing heat losses. These factors result in a deterioration of indicated thermal efficiency under conventional diesel injection conditions.

To address these problems, the present study investigates an OME-specific combustion concept combining large-orifice nozzle, low injection pressure, and high compression ratio. CFD simulations were first conducted to evaluate the influence of these parameters on indicated thermal efficiency, heat losses, and emissions. The simulation results showed that reducing the injection pressure while employing a large orifice nozzle improved indicated thermal efficiency and suppressed NOx and soot emissions. These results demonstrated the potential of the proposed OME-specific concept, and experimental verification was conducted. Figure 1 and 2 show comparison of indicated thermal efficiency and soot emission in the case of OME and diesel fuel for various nozzle diameters, injection pressure and compression ratio. OME achieved indicated efficiency comparable to diesel while reducing soot and NOx emission by combining of large-orifice nozzle, low injection pressure, and high compression ratio. However, total heat losses for OME were consistently higher than those of diesel despite the reduced injection pressure as shown in Fig. 3.

To identify the mechanism responsible for the increased heat losses, OH chemiluminescence imaging was conducted using a bottom-view optical engine. Figure 4 shows the spatial distribution of OH chemiluminescence obtained from visualization images. Under low-pressure injection conditions, the high-temperature reaction zone remains near the combustion chamber wall for a longer duration than under high-pressure conditions. This extended near-wall residence time of high-temperature regions enhances convective heat transfer and explains the experimentally observed increase in heat losses for OME. To further improve thermal efficiency using the OME-specific combustion concept, reduction of heat loss is necessary.

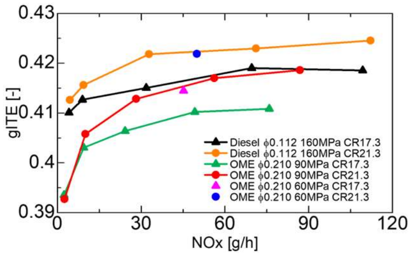

Fig. 1 Comparison of indicated thermal efficiency

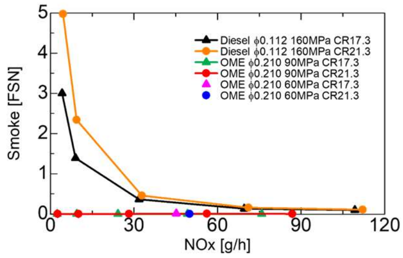

Fig. 2 Comparison of smoke emission

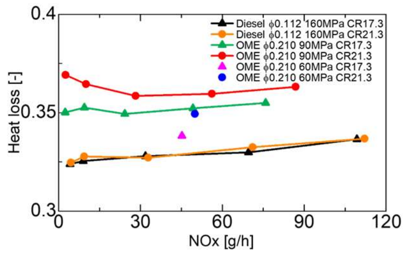

Fig. 3 Comparison of heat loss

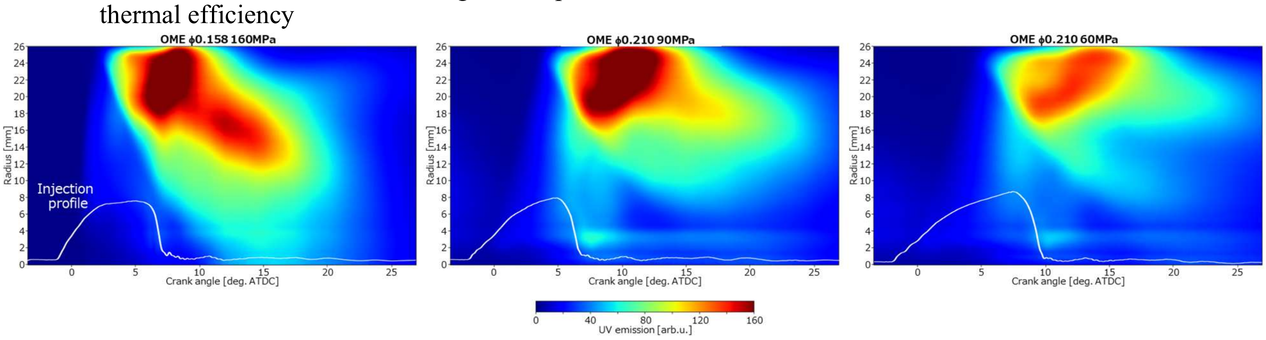

Fig. 4 Spatial distribution of OH chemiluminescence