

Effects of Intake Gas Conditions and on the Carbon Crystallite Size of Soot Particles from a Diesel Engine

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Soot particles emitted from diesel engines are captured by DPFs, and their removal requires periodic regeneration. The energy required for DPF regeneration depends on the oxidation reactivity of soot, which is strongly influenced by its nanostructure. Previous studies have reported that EGR affects the nanostructure and oxidation reactivity of soot. However, the effects of intake pressure and temperature on these soot properties have not been sufficiently clarified. Therefore, this study investigated the effects of intake oxygen concentration, intake pressure, and temperature on the carbon crystallite size (L_a) and oxidation reactivity of soot particles emitted from a 1.0 L single-cylinder, direct-injection diesel engine, which were evaluated by Raman spectroscopy and thermogravimetry (TG), respectively. Additionally, the effects of fuel properties were examined using diesel fuel, hydrogenated vegetable oil (HVO), and a 50/50 vol.% blend of diesel fuel and HVO (HVO50).

Figure 1 shows the L_a of soot particles under different intake gas conditions. The L_a increased with decreasing intake oxygen concentration and increasing intake pressure and intake temperature, regardless of the fuel. The increase in L_a was particularly pronounced under high-load conditions with reduced intake oxygen concentration. Under these conditions, soot emissions also increased significantly, suggesting that conditions promoting soot formation were also associated with enhanced carbon crystallite growth. In contrast, changes in intake pressure and intake temperature caused relatively small changes in soot emissions, while L_a changed. This indicates that the amount of soot emitted and its nanostructure are not necessarily governed by the same factors. Increasing intake pressure increases the mass of air supplied to the cylinder and changes the mixing process between the fuel spray and surrounding gas. Increasing intake temperature shortens the ignition delay and changes the combustion process. These changes in the local equivalence ratio and temperature during soot formation may affect the growth and graphitization of soot, resulting in changes in L_a even when the total soot emission remains almost unchanged.

Figure 2 shows the thermogravimetric profiles of soot obtained under different intake gas conditions. The TG profiles shifted toward higher temperatures as the intake gas conditions were changed, indicating a decrease in oxidation reactivity. The effect was more pronounced at high load than at low load. In particular, the largest decrease in oxidation reactivity was observed under high-load conditions with increased EGR, followed by the effect of increased intake pressure. The decrease in oxidation reactivity under high-EGR conditions can be associated with the increase in L_a , indicating that enhanced graphitization results in more oxidation-resistant soot. The positive relationship between L_a and the temperatures corresponding to 10% and 90% soot mass loss further supports this interpretation. On the other hand, the changes in oxidation reactivity caused by intake pressure and intake temperature occurred without significant changes in soot emissions. These results suggest that intake gas conditions can modify the nanostructure and oxidation reactivity of soot independently of the amount of soot emitted.

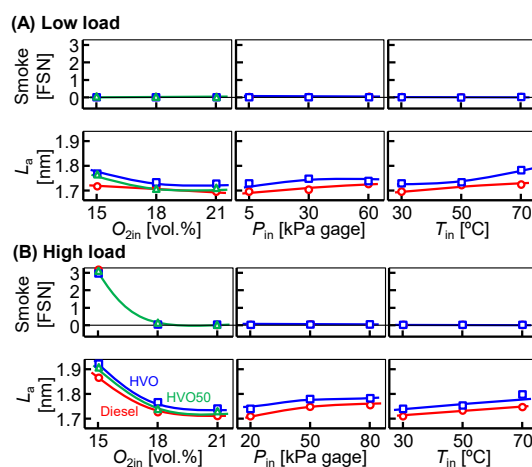


Fig. 1 Smoke emissions and L_a

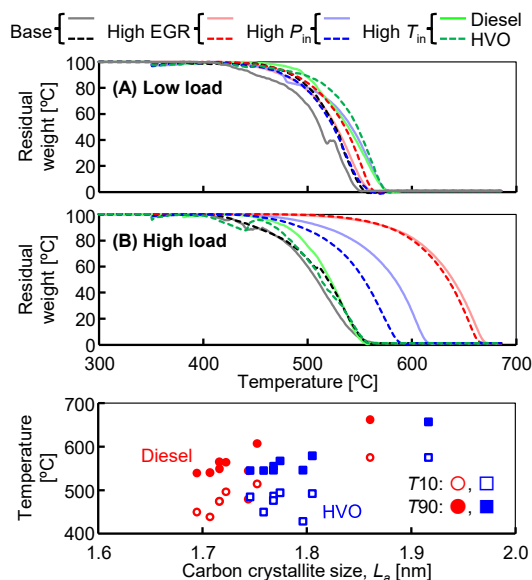


Fig. 2 Thermogravimetric analysis results of soot