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Numerical Calculation of PM Trapping and Oxidation of Particulate Filter

-Evaluation of catalyst loading position dependence-

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While the transition to electric vehicles has been very active in recent years, it is also important to improve the exhaust gas purification of vehicles still in production. Diesel-engine vehicles are used mainly as transport vehicles due to low fuel consumption, high torque, high durability, and the advantage of emitting 30 % less CO2 than petrol engines. However, diesel engine exhaust contains particulate matter (PM), which harms the environment and human health, so emission limits are becoming stricter yearly. A diesel particulate filter (DPF) is used to control the emission of PM into the atmosphere. In many cases, a PM oxidation catalyst is loaded inside the DPF, which constitutes one of the catalysts for diesel engine exhaust treatment. At the same time, various studies have been conducted on its use (1-14). The wall thickness of a typical DPF is about 300 - 400 µm. They are alternately blind-sealed, and exhaust gases enter through an unsealed inlet channel. The PM is collected on the wall of the DPF as it passes through the porous DPF wall, and only the exhaust gases after PM has been removed from the sealed outlet channel are discharged downstream. The system is operated in a closed-loop. This process is the PM deposition process. Over time, PM accumulates in large quantities on the walls of the DPF, eventually causing an increase in the pressure drop. The pressure drop places a load on the engine, so the PM deposited in the DPF needs to be removed regularly. PM, mainly composed of carbon, undergoes oxidative combustion at about 650 °C, so it is unnecessary to add fuel to the exhaust pipe. The exhaust temperature must be increased by adding PM to the exhaust gas to remove it. This process is the regeneration process. It is common practice to use a PM oxidation catalyst in the regeneration process to reduce the temperature of the regeneration process.

Without a catalyst, it can be assumed that the exhaust gas temperature needs to be higher (>650°C) to oxidize the PM, which is mainly composed of carbon. In this study, the relationship between regeneration efficiency and pressure drop reduction, where PM oxidation is accelerated, was investigated, considering the position and amount of catalyst coating. For the removal of pressure drop, it was assumed that the entire surface of the DPF would be coated with a catalyst and that only part of the DPF would be coated with a catalyst. In this study, the previous studies' numerical models (16-21) are improved. The study focuses on the dependence of catalyst loading position on PM oxidation and the pressure drop due to catalyst coating and exhaust gas temperature, assuming a CeO2-based catalyst commonly used in DPFs.

In this study, the dependence of the catalyst loading position and the pressure drop are discussed using numerical calculations, leading to the following conclusions.

(1) Effect of catalyst loading on pressure drop
Comparing the pressure drop during PM deposition and regeneration without catalyst and with catalyst over the entire range, the pressure drop was higher when the catalyst was loaded. The pressure drop during deposition was lower than with a catalyst without a catalyst. Still, the exhaust gas had to be regenerated at a higher temperature, resulting in a higher pressure drop.

(2) Dependence of catalyst loading position on PM combustion
When considering the catalyst loading position, the results showed that the catalyst loaded in the first stage (0-50 %) resulted in lower residual PM and lower pressure drop than when the catalyst was loaded in the second stage (51-100 %). In the case of high PM inflow, the difference in PM deposition between the full range of catalyst loading and catalyst loading only at the front suggests that the catalyst in the DPF could be reduced.

These results suggest that there may be a more advantageous way to load the catalyst against pressure drop than to load the catalyst over the entire DPF.

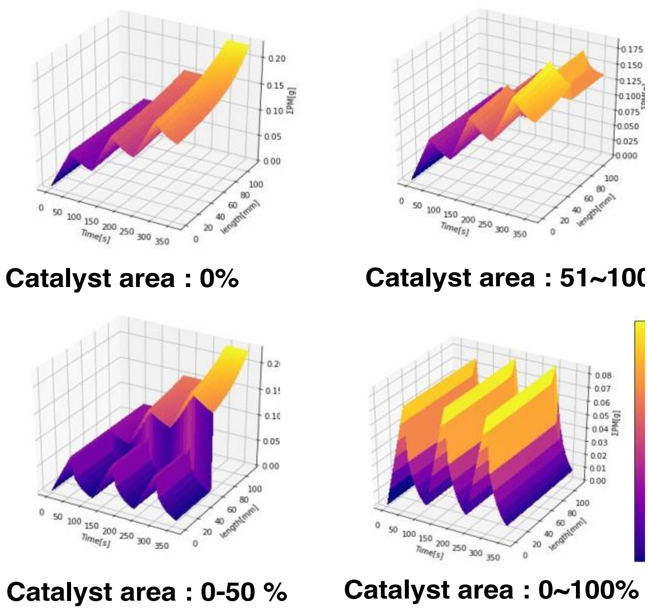

Figure PM distribution inside the DPF. The x-axis is the elapsed time [s], the y-axis is the longitudinal direction of DFF [mm], and the z-axis is the amount of PM deposited [g]. The color indicates the magnitude of the amount of PM deposited (z-axis). The yellow color indicates a higher deposition rate, and the closer the color is too blue, the lower the deposition rate.

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