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Next Generation Diesel Particulate Filter for Future Tighter HDV/NRMM Emission Regulations

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Heavy Duty Vehicle (HDV) Diesel emission regulations are set to be tightened in the future. The introduction of Particle Number (PN) Portable Emissions Measurement Systems (PEMS) testing for Euro VI Step E, and the expected tightening of Particle Matter (PM)/NOx targets set to be introduced by California Air Resources Board (CARB) in the US beyond 2024 are expected to create challenging tailpipe PM(PN) conditions for Original Equipment Manufacturers (OEMs). Additionally, warranty and the useful life period will be extended from current levels. Improved fuel efficiency (reduction of CO_2) also remains an important performance criteria. Furthermore, future non-road diesel emission regulations may follow tighten HDV diesel emission regulations, and non-road cycles evaluation needs to be considered as well for future.

In response to the above tightened regulation, higher PN filtration performance, lower pressure drop, higher ash capacity and better pressure drop hysteresis will be required for Diesel Particulate Filter (DPF) technologies. Additionally, lower heat mass DPF is desirable to prevent significant heat loss toward downstream Selective Catalytic Reduction (SCR).

This paper investigates the development of a new Cordierite DPF, compares its performance both in the laboratory and on engine bench. Results of simulations to validate the performance of the base material are also presented.

Basically, the ash capacity can be adjusted based on independent requirement by a cell structure modification. NGK already has thin wall asymmetric cell structure technology for DPF. Therefore, the cell structure is kept the same as the current DPF in this paper. However, to improve filtration performance, Pressure Drop (PD), PD hysteresis and decrease heat mass, new Cordierite material development is required.

In order for the new Cordierite material to achieve those requirements, the challenges are to optimize the Mean Pore Size (MPS), achieving reasonable filtration performance with minimal pressure drop drawback, and to identify the DPF parameters which impact on PD hysteresis. The pressure drop increases rapidly at first when soot starts to accumulate, and then it rises slower. The amount of rapid increase in pressure drop due to soot penetration is called “dP Pore”.

To minimize the dP Pore, optimization of the Pore Size Distribution (PSD) on the substrate wall surface was performed by using the simulation of the gas flow in the filter model. New Cordierite material, which has smaller MPS, more uniform PSD, and higher porosity compared to current Cordierite material, looks smaller but more uniform flow path according to simulated flow image (Fig.1). Uniformity Index (UI) in surface pore area which is uniformity of gas flow and resulting dP Pore were also compared in Fig.2. These quantitative evaluation results show New Cordierite material has the lowest dP Pore.

To confirm the selected design of new Cordierite material, engine and lab testing were performed. Lower pressure drop and better pressure drop hysteresis were achieved by a new Cordierite material with higher porosity and uniform pore size distribution. By porosity optimization, required isostatic strength was achieved for canning. Higher PM(PN) filtration performance was achieved by applying smaller MPS. Next Gen. Cordierite-DPF shows faster light-off performance than thin wall SiC-DPF and thus is expected to have NOx performance advantage for cold start. Finally, PN filtration performance did not change after the Hot Vibration Testing.

NGK developed a Next Gen. Cordierite-DPF to meet above requirements. A new material with further smaller MPS and more uniform pore size distribution is under development for EuroVII which is expected to have much stricter PN limit.

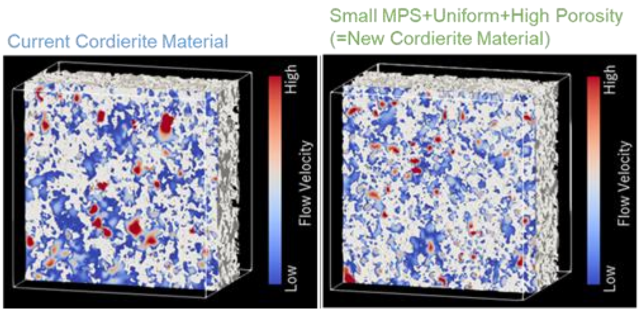

Fig.1 Simulated flow image in surface pore area

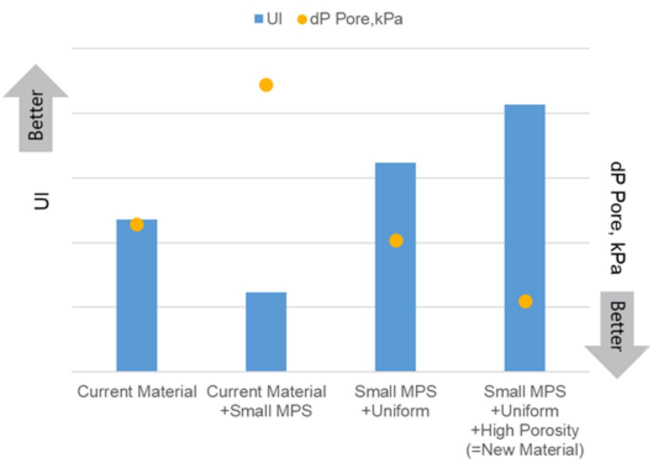

Fig.2 Calculated UI and dP Pore comparison