

New Design Concept for Diesel Particulate Filter

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ABSTRACT

The Inlet-Membrane DPF, which has a small pore size membrane formed on the inlet side of the body wall, has been developed as a next generation diesel particulate filter (DPF). It simultaneously achieves low pressure drop, small pressure drop hysteresis, high robustness, and high filtration efficiency. Low pressure drop improves fuel economy. Small pressure drop hysteresis has the potential to extend the regeneration interval since the linear relationship between pressure drop and accumulated soot mass improves the accuracy of soot mass detection by means of the pressure drop values. The Inlet-membrane DPF's high robustness also extends the regeneration interval resulting in improved fuel economy and a lower risk of oil dilution while its high filtration efficiency reduces PM emissions.

The concept of the Inlet-Membrane DPF was confirmed using disc type filters in 2008 and its performance was evaluated using full block samples in 2009. The Inlet-Membrane DPF showed low pressure drop and small pressure drop variation under several engine operation conditions, as well as sufficient durability verified under several evaluation conditions in 2010. This paper adds new data on an Inlet Membrane DPF for light duty (LD) application. Furthermore, the potential of the Inlet-Membrane technology for Heavy Duty (HD) and Selective Catalytic Reduction (SCR) on DPF applications were evaluated.

INTRODUCTION

Because of global environmental issues, improved fuel economy and a reduction of CO₂ emissions have been strongly demanded from vehicles in recent years. Under this same pretext, much hope has been placed in diesel-powered vehicles because they exhibit better fuel economy when compared to gasoline-powered vehicles. Nevertheless, with diesel engines, there is the problem of particulate matter (PM) emission. A good countermeasure that has been widely adopted is a wall flow type filter. However, a diesel particulate filter (DPF) causes pressure drop and, with it, fuel economy decreases because of the fuel consumption required for PM regeneration. Therefore, a DPF must necessarily lower pressure drop and extend the regeneration interval so as to minimize its impact on fuel economy. Meanwhile, with regard to PM, regulations on the number of particles are tentatively to be added to existing regulations on weight, hence demanding a higher PM filtration efficiency than ever before. A next generation DPF that meets all of these requirements is desperately needed.

DESIGN CONCEPT OF INLET-MEMBRANE DPFs

Though the design concepts of the Inlet-Membrane DPF were described in 2008[1] and 2010[2], they are also briefly explained in this section. As shown in [Figure 1 \(a\)](#), a thin membrane is formed on the inlet side of the wall. Due to its small pore size, the membrane prevents soot penetration into the wall. Therefore, the magnitude of the pressure drop curve

plotted against soot loading is less and more linear compared to the DPF substrate without the membrane technology (Figure 1 (b)). The membrane also improves the initial filtration efficiency (Figure 1 (c)). A low porosity substrate has high soot mass limit capacity due to its high heat capacity, but also causes high pressure drop with soot. However, membrane technology results in low pressure drop since the pressure drop behavior with soot loading is determined by the membrane characteristics. Therefore, the combination of membrane technology and low porosity material achieves low pressure drop with soot and high soot mass limit simultaneously. This means that the tradeoff relationship between pressure drop and soot mass limit will be improved as shown in Figure 1 (d).

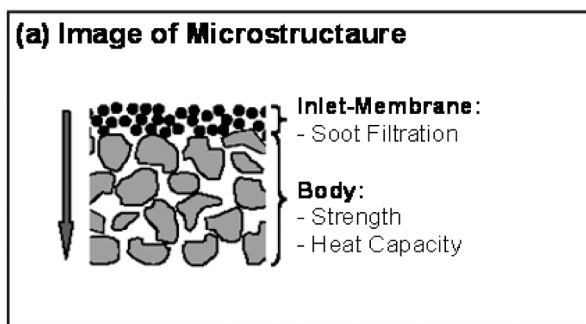


Figure 1-a. Image of Inlet Membrane DPF

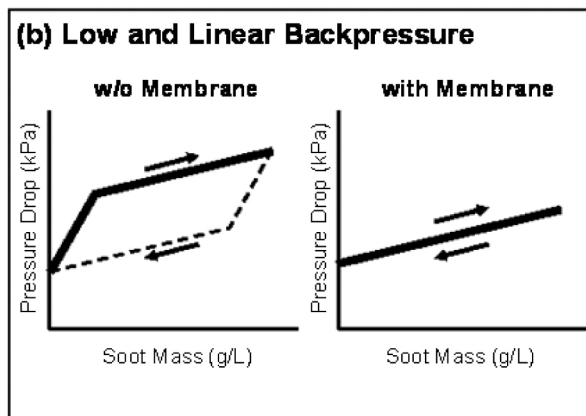


Figure 1-b. Pressure Drop curve of Inlet Membrane DPF

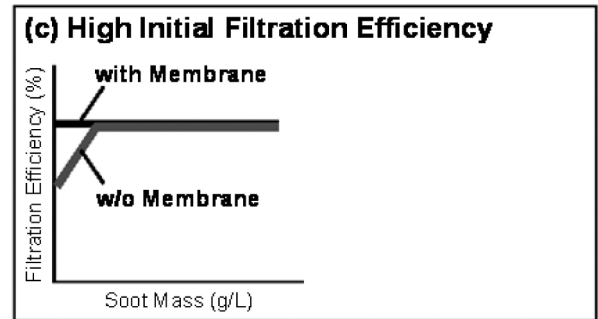


Figure 1-c. Filtration Efficiency of Inlet Membrane DPF

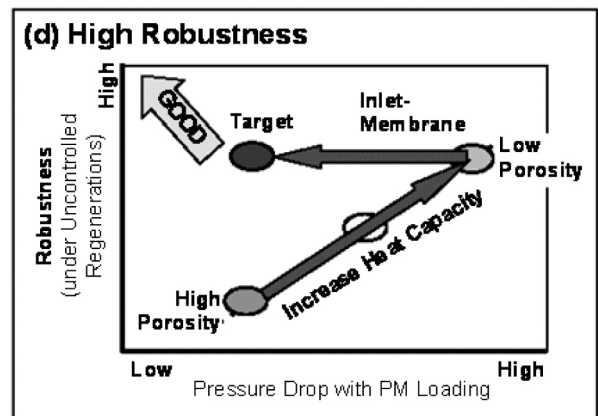


Figure 1-d. High Robustness of Inlet Membrane DPF

DEVELOPMENT HISTORY

2008: Design Concept - The membrane concept was proposed in 2008 [1]. Basic concept studies using disc type specimens were carried out. It was confirmed that the Inlet Membrane structure reduces pressure drop with soot resulting in linear pressure drop behavior.

2009: Practical Studies - The effects of the Inlet Membrane DPF were validated using full block samples (basically in bare conditions) in 2009 [2]. Pressure drop performance was evaluated using simulators, such as a soot generator.

2010: Verification - Evaluations by engine bench testing were carried out including pressure drop and regeneration performance. Furthermore, the durability of the membrane was confirmed under several conditions.

2011: This report added new validation data for LD (light duty) application. In addition, the effectiveness of the Inlet Membrane technology for HD (heavy duty) and SCR on DPF applications were evaluated.

1. PERFORMANCE VERIFICATION UPDATE OF INLET-MEMBRANE DPF FOR LIGHT DUTY APPLICATIONS

The 2010 report described the pressure drop reduction effect, hysteresis reduction, improvement to regeneration efficiency, and durability of the Inlet-Membrane observed in engine bench tests and soot generator tests (described in [6]). This report adds test data from evaluation of the pressure drop reducing effect in simulated transient driving and the effect of fuel economy on vehicle.

1.1. EXPERIMENTAL SAMPLES

The experimental samples were 143.8 mm in diameter and 152.4 mm in length. Wall thickness was 0.31 mm, while cell pitch was 1.47 mm. The DPFs were made of Si-SiC with a porosity of 41%. Evaluations were conducted on two types of samples: with and without the Inlet-Membrane. (See Table 1)

Table 1. Experimental Samples

Sample	Non-MT*(Coated)	MT(Coated)
Catalyst	Coated	Coated
Membrane	None	Formed
Material	Si-SiC	
Wall Thickness	0.31 mm	
Cell Pitch	1.47 mm	
Wall Porosity	41 %	

*MT: Membrane Technology

1.2. ENGINE BENCH TESTS

Experimental Setup

In order to examine the effect of the Inlet-Membrane in actual driving conditions, engine bench tests were done with representative driving patterns of the NEDC mode used in Europe. The driving patterns were simply repeated with the inlet gas temperatures matched to the ECE mode and the EUDC mode during the NEDC mode as shown in Figure 2. The first test mode (Fig. 3-a) was a simple single cycle at a DPF inlet gas temperature of 150 - 200°C that was repeated to simulate city driving of the ECE mode. The second test mode (Fig. 3-b) was also as single cycle at a DPF inlet gas temperature of 250 - 300°C that was repeated to simulate high speed driving of the EUDC mode. The pressure drop of the DPF was measured in these two driving modes. The engine was a 2-liter Euro 4, and the DPF was installed under the floor.

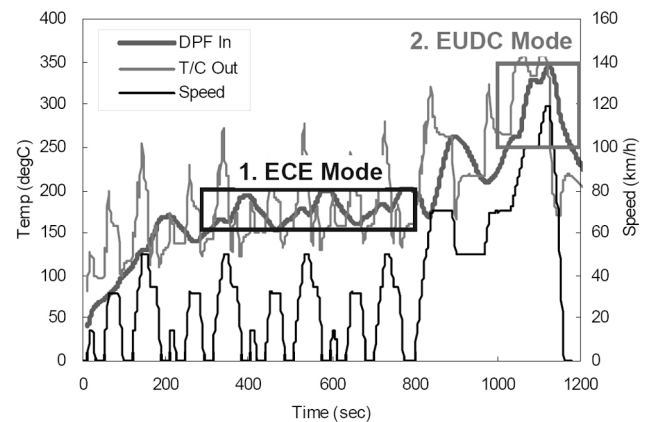


Figure 2. Temperature Profile of NEDC Mode

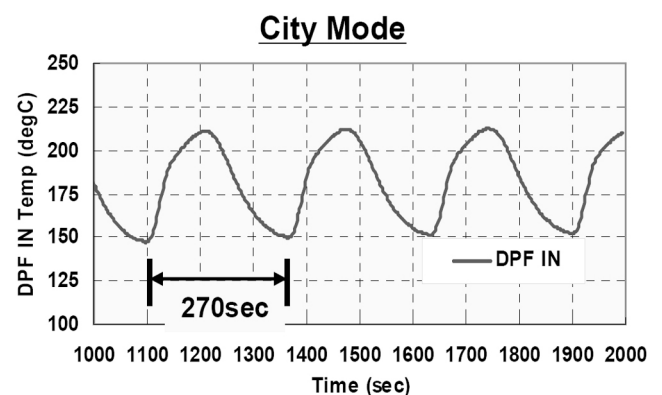


Figure 3-a. DPF Inlet Gas Temperature of Simulated City Mode

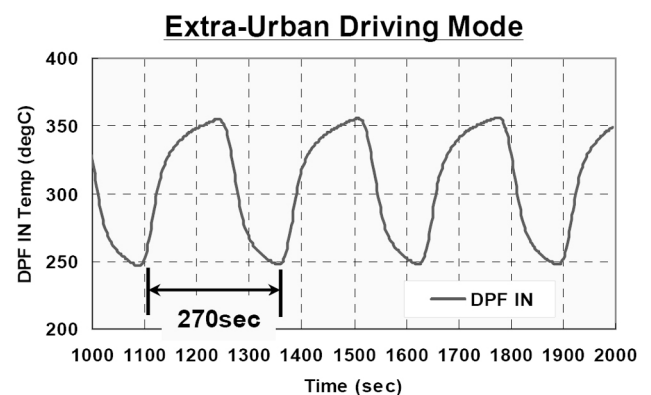


Figure 3-b. DPF Inlet Gas Temperature of Simulated Extra-Urban Driving Mode

Results and Discussion

1. City Mode

Figure 4 shows the pressure drop against soot loading in repeated simulations of city driving. Results indicate that the pressure drop of the Inlet-Membrane DPF was about 30% lower than that of the Non-Membrane DPF. This occurred