Visualization of Particulate Matter Trapping and Regeneration in Micro-structural Pores on Diesel Particulate Filter Wall

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Abstract:
In recent years, diesel exhaust gas emission regulations have become more stringent as a result of increased environmental awareness in each region of the world. DPF (Diesel Particulate Filter) is used behind engine to reduce PM (Particulate Matter) in exhaust gas. Long-term exposures to PM can lead to chronic, more serious health problems, even lung cancer.

DPF is made from ceramic material mainly SiC (silicon carbide) and cordierite. When exhaust gases go through ceramic wall, PM can be easily trapped by the micro-structural pores of ceramic material. High melting point allows rise temperature up to 700 °C during regeneration process. Usually a fuel burner or engine management is used to raise exhaust gas temperature to oxidize PM trapped inside DPF.

Many studies are focused on filtration efficiency and pressure drop caused by DPF. However micro-structural phenomena inside the DPF wall have to be studied through real-time visualization. In the current study, using All-In-Focus microscope, the trapping of particulates and the oxidation reaction were investigated for better understanding modeling and future designing of ideal DPF configuration.

Figure 1 shows the experimental setup for visualization during trapping process. The high deep All-In-Focus microscope is used for better visualization. The SiC DPF 4x4 flow channels was cut into a cross-section of 8mmx8mm and a length of 15mm and alternate channels were blocked with cement at each end. Next, the top of each vertical-wall was polished to be mirror-like surfaces, and then put a 0.5mm thick quartz glass plate on. Trapping and regeneration process are observed and recorded by special computer software.

Fig.1 Setup for visualization part
In figure 2 the first instants of the trapping process can be observed. Exhaust gas flows at a reduced superficial velocity of 2.8 cm/s through the 400 µm thick DPF wall. During the first 0.2 seconds, PM is trapped in the first 70 µm of the DPF wall (color change can be observed in the bottom side but not in the interior pores). After that, PM layer (Fig. 3) starts growing on the DPF wall surface towards the inlet channel.

During regeneration process, gas flow temperature at a reduced superficial velocity of 1.9 cm/s is risen up to 600-650 °C using methane-oxygen burner with an excess of 10% oxygen in order to burn PM. In figure 4 can be observed that PM in the surface layer have a higher regeneration rate than PM trapped inside the pores.