

Impact of Soot Loading on CO Oxidation in Catalytic Particulate Filters with Various Coating Structures

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Highlights

- Deposited soot does not affect the CO light-off temperature.
- Diffusion-limited CO slip at high flow rates increases with soot loading.
- The dependence on soot loading is non-linear, it levels off at higher loadings.
- On-wall and in-wall coating structures shows similar trends.

1. Introduction

Catalytic particulate filter is a multifunctional device combining a catalytic converter and a particulate filter for exhaust gas aftertreatment [1]. It consists of parallel channels that are alternately plugged at one end. This design forces exhaust gas to pass through the porous wall between the channels and the soot particles remain trapped in the filter [2]. A catalytically active layer is deposited on and/or inside the filter wall to eliminate gaseous pollutants [3]. Despite the gas flowing directly through the porous wall with a coated catalyst, diffusion limitations may exist on the micro-scale [1,4,5]. The coating structures thus exhibit differences not only in pressure drop and filtration efficiency, but also in catalytic conversion of gaseous pollutants [4,5]. The performance of catalytic filter further changes with the soot loading [2]. In this contribution we present the results of our experimental study quantifying the relationship between the amount of deposited soot and reactant slip in diffusion-limited regime for catalytic filter samples with various microstructures of catalytic coating.

2. Methods

Cordierite filter substrate from Corning with 300 cpsi, wall thickness 220 μm , 66% porosity and mean pore size 24 μm was used for the sample preparation. The samples were cut to a length of 6 cm and a diameter of 1 inch and then coated with the suspension of Pt/ γ -Al₂O₃ catalyst. Two suspensions with different particle size distributions of catalyst were used: $d_{90} = 0.3$ and 12 μm . The sample microstructure was characterized by scanning electron microscopy. The catalytic activity of clean samples was tested at moderate (50 000 h⁻¹) and high (200 000 h⁻¹) space velocity with constant inlet mixture of 1000 ppm CO, 5% O₂ and 94.9% N₂. The temperature was gradually increased from 100 to 300 °C at a rate of 5 °C/min and the outlet CO concentration was measured by FTIR MKS 2030HS. The sample was then moved to a second apparatus where it was fouled with soot particles from propane burner with concentration of 200 000 #/cm³ at 50 000 h⁻¹. The particle concentration and size distributions were measured using ELPI+ and HORIBA MEXA-2000SPCS. After the soot loading period, another CO light-off curve was measured, and the sample underwent additional soot deposition. This cycle was repeated five times, allowing us to quantify the impact of soot loading on the CO conversion. In addition to that, a dedicated experiment was performed to verify that soot does not oxidize in our temperature range (100-300 °C).

3. Results and discussion

Coating microstructure of the samples is shown in **Figure 1**. Both samples have different spatial distribution of the catalyst while keeping similar mass of the deposited catalyst. The sample coated with $d_{90} = 0.3$ μm suspension shows catalyst located mainly inside the wall pores, while the sample coated with $d_{90} = 12$ μm possesses catalyst layer on top of the wall. CO light-off curves for the on-wall coated sample at the higher gas hourly space velocity are shown in **Figure 2a**. Soot does not affect the light-

off temperature, but it increases the transport limitation causing higher CO slip above the reaction light-off. **Figure 2b** shows the evolution of CO conversion with soot loading at high space velocity for both studied samples. For low degrees of fouling, the conversion decreases steeply and slows down gradually. The trend was similar for both coating structures, even for lower space velocity.

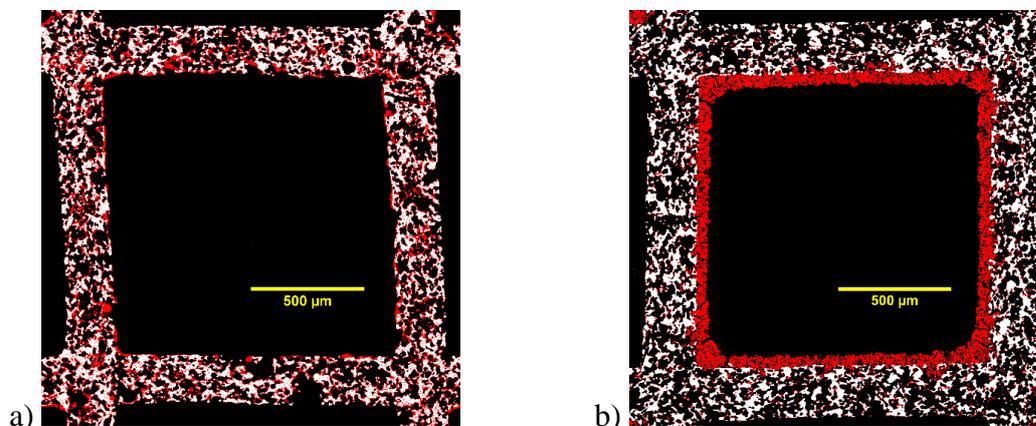


Figure 1. Microstructure of filter samples on segmented cross-section SEM images in 3 cm from the inlet; Red = Pt/Al₂O₃ catalyst, white = cordierite substrate, black = void space. a) $d_{90} = 0.3 \mu\text{m}$ - in wall; b) $d_{90} = 12 \mu\text{m}$ - on wall

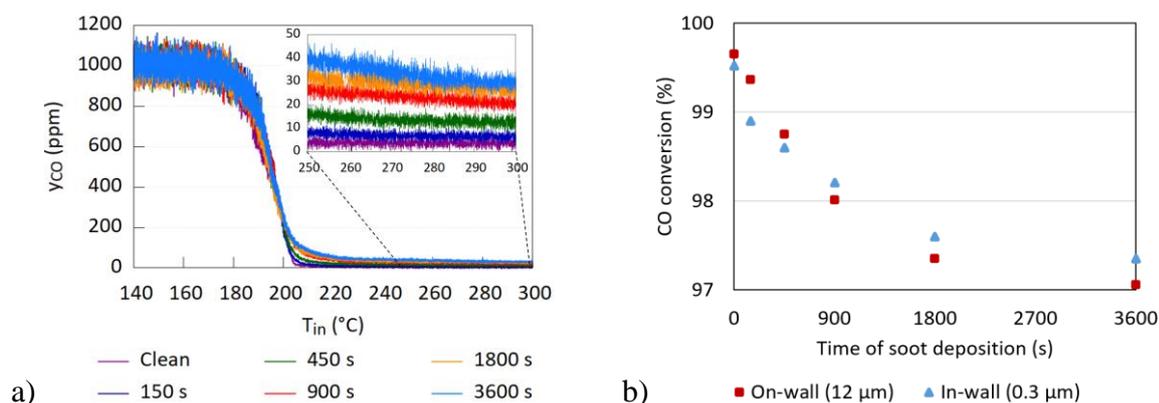


Figure 2. a) CO light-off curves after soot deposition periods in the on-wall coated sample at high space velocity of $200\,000 \text{ h}^{-1}$; b) CO conversion at $300 \text{ }^\circ\text{C}$ depending on soot loading time

4. Conclusions

Soot affects CO conversion on both studied coating structures to a similar extent. Soot does not change the light-off temperature, but it imposes an additional diffusion barrier that increases the CO slip at high flow rates. The initial fouling shows more significant impact on the catalytic conversion. With further increase of the soot loading, the dependence levels off. The measured data will be used for the development of a mathematical model enabling predictions of transport-limited conversion depending on the amount of deposited soot.

References

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Keywords

Catalytic filter; soot; CO oxidation; diffusion limitation