Catalytic filters for SCR DeNO$_x$ as method of process intensification in flue gas emission abatement

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Highlights

- Catalytic filters allow for decreasing plant footprint size for treatment of dusty flue gas.
- Both SCR DeNOx, CO and VOC oxidation can be catalyzed over advanced filter materials.
- SCR DeNOx activity follows intrinsic catalytic rate control.

1. Introduction

SCR DeNO$_x$ is traditionally conducted by monolithic catalysts in the industry, and V_2O_5/TiO_2-based catalysts with NH_3 as reductant is the *de-facto* standard for NO$_x$ abatement from stationary sources like thermal power plants or other high-temperature chemical processes.

Many high-temperature process flue gases contain considerable amounts of dust – such as glass works, ore sintering plants, cement plants, waste incinerators, biomass-fired boilers etc. Often the dust can be detrimental to the SCR catalyst, both as poison and as cause of erosion. Dust removal is often required by authorities. The most efficient way of abating dust and often the only one efficient enough to comply with environmental regulation is a dust filter, either as a rigid ceramic dust filter candle (at higher temperatures) or a flexible filter bag (for lower temperatures).

In later years, Topsoe as well as other companies have marketed dust filters that also have SCR DeNO$_x$ functionality – by using the well-known V_2O_5/TiO_2 as catalytic material on filter substrate. A scientific review is given in [1]. The testing of such catalyst filter substrates and relating it to known catalyst performance is the topic of the current work.

2. Methods

Catalytic filters were prepared by in-house methods. Loading of active phase (V_2O_5/TiO_2) on materials was controlled by ICP-OES elemental analysis.

Testing at industrially relevant conditions should be performed with identical gas velocity and within catalytic filter test reactors. Catalytic filter material was prepared by cutting a piece of the catalytic filter; 12-15 cm in diameter and 30 cm in length and afterwards loaded on a filter cage cut-out (as in industry) to keep their dimensions and gas velocities as under real operations (cf. Figure 1). 0 to 1000 ppm NOx at variable $NH_3/NO_x/O_2/N_2$ ratios, and with the ability to potentially add various pollutants well-known to SCR.

At the same time, intrinsic kinetics must be determined to ensure basis. This is established in a powder-TPX flow setup with <0.5 mm powder particles of the catalytic material. Low-temperature SCR DeNO$_x$ normally takes place at intrinsic reaction rate control and so should be comparable to the full filter test.

3. Results and discussion

A sketch of the functionalities in a catalytic filter solution is seen in Figure 1 *left-hand-side*. The actual filtration of solids takes place on the outermost layer of ceramic filter substrate or filter bag and by the filter cake itself. Several types of catalyst functionalities relevant to flue gas cleaning can be integrated

into the SCR DeNO$_x$ catalysts, such as oxidation of aromatics, dioxins, CO or other organics [2],[3]. This further serves to intensify process layout.

Comparative measurements of rate constants at both powder TPX and a cut-out piece of filter cloth were performed at SCR conditions: 400 ppm NO, 320 ppm NH_3, 8% O_2, 10% H_2O, balance N_2. A reactor model using 1st order kinetics in NO_x and NH_3 is used. Rate constants were normalized to the amount of V_2O_5. Ideally rate constant ratios powder PTX to cage filter test should be close to 1.00.

It is seen in Figure 1 *right-hand-side* that almost identical rate constant ratios at ca. 0.67 are obtained at 180, 220 and 240°C. However, it is likely that the temperature has not been accurate to setpoint, since the filter test units have heat elements in the reactor at higher temperature and at a distance from the filter cloth to sufficiently heat the gas, while the temperature is only measured with a single thermocouple.

Simultaneously the powder TPX is small and subject to heat loss and inaccuracy in placing the measurement thermocouple in the catalyst bed. This may explain the even lower ratio of powder-to-filter rate constants at 200°C.

Temperature differences of 5-7°C would be enough to explain the differences in observed rate constants. Another difference between powder TPX and that the flow is forces through the filter wall (with deposited catalyst) during filter cage test, but not during powder TPX tests. It is seen that comparative measurements require additional experimental work to eliminate heat and maybe flow effects.

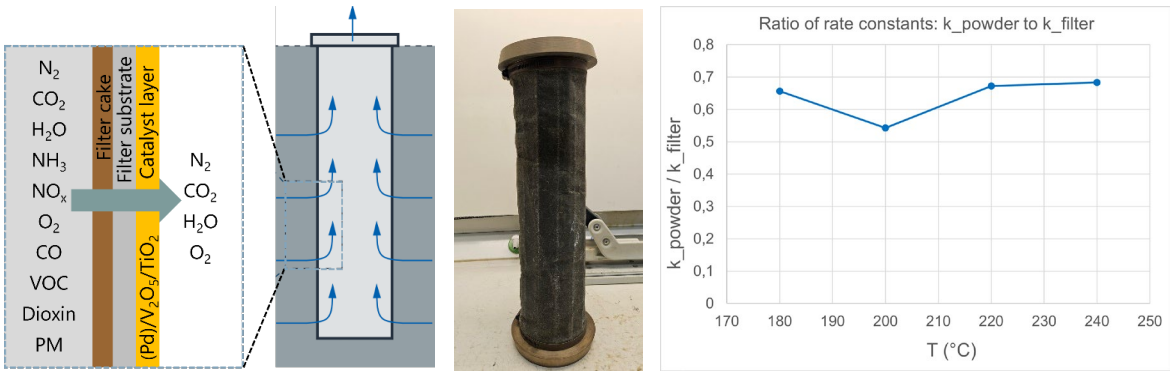

Figure 1. *left-hand-side:* Sketched principle of a multifunctional DeNOx catalytic filter; *center photo:* filter cage with cylindrical catalytic filter cloth on; *right-hand-side:* plot of NH_3-SCR activity from powder TPX relative to catalytic filter.

4. Conclusions

With catalytic filters, several reactions, unit processes and catalytic functionalities can be performed in a single unit operation – the filter house – thus simplifying process layout and plant footprint.

Sorbents can be injected to precipitate undesired components, such as acidic gases or like HCl or SO3 on the filter cake. This prevents side reactions like precipitated NH_4HSO_4 in the DeNOx catalyst. Furthermore, adding multifunctionality to the catalyst can further enhance cleaning of the gas.

References

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Keywords
SCR DeNOx; Catalytic Filters; Dust removal; multifunctional catalysis