

Evaluation of SCR Catalyst Technology on Diesel Particulate Filters

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ABSTRACT

Selective Catalytic Reduction (SCR) catalysts have been demonstrated as effective for controlling NO_x emissions from diesel engines, maintaining high NO_x conversion even after the extended high temperature exposure encountered in systems with active filter regenerations. As future diesel emission regulations are expected to be further reduced, packaging a large volume of SCR catalysts in diesel exhaust systems, along with DOC and particulate filter catalysts, will be challenging. One method to reduce the total volume of catalysts in diesel exhaust systems is to combine the SCR and DPF catalysts by coating SCR catalyst technology on particulate filters. In this work, engine evaluation of SCR coated filters has been conducted to determine the viability of the technology. Steady-state engine evaluations demonstrated that high NO_x conversions can be achieved for SCR coated filters after high temperature oven aging. The effect of soot loading on back pressure as well as the time for soot regeneration was investigated for SCR coated filters and compared to conventional oxidative catalyst coatings. Hydrocarbon, CO, and NO_x emission performance during a filter regeneration condition has also been evaluated. The SCR coated filter technology has also been demonstrated on several filter materials.

INTRODUCTION

To meet U.S. Tier 2 NO_x emission requirements, many diesel engine manufacturers have chosen to use SCR catalysts with urea injection. Base metal urea-SCR catalysts have a wide temperature window of high NO_x conversion and offer cost advantages compared to precious metal based NO_x Adsorber Catalysts.

Urea SCR emission systems for Tier 2 diesel vehicles will contain DOC, SCR, and CDPF catalysts in either DOC + SCR + CDPF or DOC + CDPF + SCR configuration. Each configuration has advantages and disadvantages; the choice of configuration will depend on such issues as the need for rapid light-off of the SCR, for maximizing passive regeneration, for adequate urea mixing, and for packaging space. The last issue is an especially important issue for smaller diesel vehicles such as passenger cars.

Furthermore, new emission regulations will require even lower NO_x emissions for diesel vehicles in the future. Under high exhaust flow conditions, the NO_x conversion of SCR catalysts can be improved by increasing the volume of the catalyst (effectively reducing the space velocity). This will necessitate further increases in catalyst volumes causing packaging problems and increasing system costs.

In order to meet the need for reducing packaging space or to increase catalyst volume within existing space, development work is being conducted to combine the SCR and filter functions by washcoating the filter with SCR catalysts. Previous work [1] demonstrated that SCR-DPF catalysts could achieve 86% NO_x conversion during FTP cold-start tests, indicating that SCR-DPF catalysts have potential to meet low NO_x emission requirements.

However, SCR catalysts coated on filters must have high thermal durability to withstand repeated soot regenerations. Various investigations [2-4] have been undertaken to understand the deactivation of Cu-zeolite SCR catalysts since compared to other base metal zeolite catalysts, Cu-zeolite SCR catalysts are effective at converting NO_x at low temperatures even in exhaust streams with low NO₂ and can tolerate urea overdosing

at high temperatures due to lower selectivity in utilizing NH_3 for NO_x reduction. Partly as a result of this work, advances in the thermal durability of Cu-zeolite SCR catalysts have recently demonstrated durability up to 900 °C [5,6]. These developments have greatly improved the chance of implementation for Cu based SCR-DPF catalysts, as these SCR catalysts can withstand a wide range of exhaust conditions, as well as demonstrating greater resistance to coking.

In this work, advanced Cu-zeolite SCR catalysts have been coated on several high porosity filters to demonstrate the potential for DOC + SCR-DPF systems. Engine dynamometer testing was conducted on oven-aged filters to demonstrate that high NO_x conversions are achievable after high temperature aging. In addition, since SCR-DPF catalysts would replace current CDPF catalysts, the SCR-DPF must also have similar characteristics as the CDPF catalyst in that it must have a low impact on back pressure and be able to regenerate soot in a comparable time as the CDPF. Thus, the SCR-DPF catalysts are also compared to a current production oxidative filter.

EXPERIMENTAL

Advanced Cu-zeolite SCR catalysts were washcoated on high porosity cordierite (C650) or SiC (MSC-14) filter substrate, 46.5 cells/cm² (300 cells/in²) with 0.03048 cm (12 mil) wall thickness. The washcoat loading was the same for both filter types. An additional C650 filter was wash coated with 75% the washcoat loading (SCR C650 Reduced WCL) of the other C650 filter to investigate the effect of lower washcoat loading on NO_x activity and back pressure. These catalysts will be compared to a current oxidative filter catalyst (2008 MY oxidative filter catalyst) which was washcoated on standard SiC filter substrate, 31 cells/cm² (200 cells/in²) with 0.04064 cm (16 mil) wall thickness.

All filter catalysts were hydrothermally aged in an oven at 800 °C for 64 hours with 5% water to simulate long-term durability. This would represent the SCR-DPF being regenerated every 300 miles, spending 10 minutes during each regeneration at 800 °C over the required lifetime of an LDD diesel vehicle (120,000 miles).

Testing was performed on a 2008 MY diesel engine mounted on a dynamometer, using a prototype 2010 calibration. All tests were conducted using a DOC + SCR-DPF (or CDPF) configuration. Urea was injected after the DOC using an airless injector, and static mixers were utilized with a 1 meter length before the SCR-DPF to insure good mixing in the exhaust. The DOC used for testing was a Pt:Pd catalyst at 2:1 ratio, with total PGM loading of 2.7 g/L, and was aged 800 °C for 64 hours. SCR-DPF and CDPF catalyst volume was 2x engine displacement.

Steady-state tests were performed by running the engine at a constant speed and adjusting the load on the dynamometer to achieve inlet temperatures to the SCR-DPF from 205-440 °C. For the range of steady-state temperatures tested, the SCR-DPF space velocity ranged from 23-32K hr⁻¹; for LA-4 testing the space velocity ranged from 5-55K hr⁻¹; for US06 testing the space velocity ranged from 5-80K hr⁻¹. Urea injection was performed upstream of the SCR-DPF catalyst using a 32.5% urea solution and injecting at an ANR = 1. The catalysts were pre-saturated with ammonia before steady-state and transient testing by injecting urea at ANR = 1.5 at 200 °C. Regeneration experiments were performed by using post-injection to generate an exotherm in the DOC such that the filter temperature was 600-650 °C.

NO_x and CO emissions were measured using FTIR analyzers, HC emissions were measured using a HFID analyzer. Pressure measurements were made with a traditional pressure transducer. Soot loadings in the filters were measured by weighing the filters warm.

RESULTS

As indicated in the introduction section, in order for SCR-DPF catalysts to replace SCR + CDPF catalysts, the SCR-DPF must have high HC, CO, and NO_x activity, low impact on back pressure, and must be able to regenerate soot within a similar time compared to CDPF catalysts.

SCR-DPF CATALYST NO_x PERFORMANCE - The NO_x conversion over advanced Cu-based SCR catalysts coated on cordierite and SiC filters after the 800 °C aging for 64 hours was measured as a function of temperature in steady-state testing on the engine. The SCR-DPF testing shown in Figure 1 was carried out with no/little soot on the filter. As expected for these advanced Cu SCR catalysts, high NO_x conversion was measured across the temperature window. For both the SCR coated cordierite and SiC filters, the NO_x conversion is greater than 90% in the temperature range from 200-440 °C, showing that the NO_x conversion is independent of the filter material. This demonstrates the potential for a DOC + SCR-DPF system to achieve Tier 2 emission requirements. When the amount of catalyst is reduced on the C650 filter (SCR C650 Reduced WCL), the NO_x performance decreases slightly, as expected, but is still greater than 90% in the temperature range of 220-440 °C. This indicates that there is the potential to further optimize the amount of SCR catalyst coated onto the filter without severely affecting NO_x performance and consequently decrease the overall back pressure. The optimization for NO_x performance and back pressure can be adjusted for each application and filter material.