Combination & Integration of DPF-SCR Aftertreatment

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**Typical HDD EPA 2010 Layout**

- Engine Exhaust
- DOC
- cDPF
- SCR

**Possible Future HDD Layout**

- Engine Exhaust
- DOC
- DPF/SCR
GM (SAE 2011-01-1140) – integrated system able to meet cert. requirements w/ significant reduction in A/T volume; coating process & wash-coat loading need optimization; approach does not address passive soot oxidation feasibility.

JM (SAE 2011-01-1312) – addressed passive soot oxidation feasibility by turning EGR off. SCR/DPF with EGR off (elevated NO\textsubscript{x}) demonstrated improved passive regeneration capability.

Ford (SAE 2010-01-1183) – oven aging tests indicate DOC-SCRF-SCR configuration able to meet T2B5 tailpipe NO\textsubscript{x} standards through 120k miles.

BASF (DEER 2010) – operating window (NO\textsubscript{x} conv., dP) determined by porosity, PSD. Filter type, porosity determines catalyst utilization.
OBJECTIVE: Fundamentally understand the integration of SCR & DPF technologies for HDD to provide a pathway to the next generation of emissions control systems

- CRADA with PACCAR, working intimately with PTC and DAF Trucks N.V.

- Evolving field of work (mostly LDD, some HDD); this effort focused on:
  1. Optimizing SCR catalyst wash coat
  2. Facilitating passive soot oxidation

- Working relationship with BASF (HD Systems Development)
  - SCR catalyst (Cu/Z) expertise
  - Washcoating, manufacturability
  - UHP cordierite substrate samples coated
SEM IMAGING

- BASF Cu-Zeolite
- Directionally loaded on filter

Bare filter, no catalyst

60 g/L catalyst loading
SEM IMAGING

- 90 g/L loading, distributed (in varying amounts) across full width of filter wall
- 150 g/L loading, significant deposition on channel wall

90 g/L catalyst loading

150 g/L catalyst loading

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PHYSICAL EXAMINATIONS

150 g/L

Significant catalyst present on channel wall

90 g/L

Small amount of catalyst on channel wall

60 g/L

No catalyst on channel wall

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Physical examinations of integrated system

- Pore characteristics – high porosity cordierite

- 60 g/L appears to deposit completely into the porous microstructure.

- 60 – 90 g/L appears to largely deposit into the porous microstructure as well, with a small amount of catalyst remaining on channel walls.

- The majority of >90 g/L does not appear to go into the porous microstructure, only goes into a small number of very large pores (>20 mm).
**Significant effect of catalyst location on pressure drop during soot loading** (2003 Jetta, ~300°C, 55k GHSV)

- Both **amount** and **location** of SCR catalyst have measureable significant impact on dynamic permeability of filter during soot loading.
Standard SCR reaction – 500 ppm NO, 500 ppm NH₃, 35k GHSV

1. Effect of configuration (& catalyst loading) without soot

- Detrimental effect of configuration (i.e. flow through versus wall flow)*
- Catalyst deposited within porous structure (60 – 90 g/L) affects greater improvement in activity versus catalyst deposited on channel wall (90 – 150 g/L)

*Disagrees with previous SiC-based work (Boorse et al, DEER 2010)
EFFECT of SOOT on NRE

- SCR reaction, varying NO$_2$ fraction – 35k GHSV, ANR = 1
  - Subtle detrimental effect of the presence of soot on standard SCR reaction <280°C; >280°C no effect
  - Higher NO$_2$ concentrations see measureable benefiting effect of soot at low temperatures
Passive soot oxidation reaction – 150 g/L catalyst downstream

- Effect of NO₂ concentration – 200 ppm (left) versus 500 ppm (right)
- 1000 ppm NOₓ, ANR = 1, 35k GHSV
- More NO₂ minimizes retardation of passive soot oxidation reaction

200 ppm NO₂

500 ppm NO₂
Passive soot oxidation reaction – catalyst configured downstream

- Effect of catalyst loading – 90 g/L (left) versus 150 g/L (right)
- 500 ppm NO₂, 500 ppm NO, ANR = 1, 35k GHSV
- Greater retardation of passive soot oxidation reaction observed <350°C with 150 g/L versus 90 g/L

90 g/L SCR catalyst

150 g/L SCR catalyst
500 ppm NO₂, 35k GHSV

ANR = 1

4 g/L soot loading

NO₂/NOₓ = 0.33

1500 ppm NOₓ

Negligible impact of NO₂/NOₓ fraction <0.5
► 500 ppm NO₂, 35k GHSV
► ANR = 1
► 4 g/L soot loading

~150 g/L Catalyst Loading

NO₂/NOₓ = 0.65
769 ppm NOₓ

Significantly less retardation of passive soot oxidation at NO₂/NOₓ fraction >0.5
500 ppm NO₂, 35k GHSV
- ANR = 1
- 4 g/L soot loading

〜150 g/L Catalyst Loading
- [CO₂ + CO], ppm
- Pressure Drop, relative
- Temperature, °C

〜90 g/L Catalyst Loading
- [CO₂ + CO], ppm
- Pressure Drop, relative
- Temperature, °C

90 g/L SCR catalyst exhibits less retardation of PSO (~40°C) versus 150 g/L (~60°C)

Indicates optimum catalyst loading target exists for facilitating PSO

NO₂/NOₓ = 0.5
1000 ppm NOₓ
Optimizing SCR catalyst wash coat
- Catalyst better utilized embedded within wall microstructure versus channel wall
- Location of catalyst has significant impact on wall permeability when loaded with soot
  - Preferred location is on downstream portion of filter
- Suspected that cordierite does not facilitate optimum catalyst dispersion (and thus utilization) in porous wall microstructure

Facilitating passive soot oxidation
- Maximize NO$_2$ concentration; maximize NO$_2$/NO$_x$ fraction
- Optimize SCR catalyst loading (e.g. 90 g/L system exhibits less retardation of passive soot oxidation reaction versus 150 g/L)
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