**Contents**

- What are diesel exhaust gas emissions
- What are diesel oxidation catalysts
- How do they function
- Why are they still needed
- Conclusion

**What are diesel exhaust gas emissions**

**Origin of exhaust emissions**

- Inorganic remainder of lube oil additives
- Inorganic remainder of fuel additives
- Engine wear
- Condensation and agglomeration effects: particulate matter
- Complete combustion: CO₂, H₂O, SO₂
- Incomplete combustion: CO, HC₃₄, oxygenates
- Zeldovich reaction: NO
- Thermal cracking: Carbon nuclei, HC₃₄
- No combustion: Fuel and lube oil molecules HC₃₄

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What are diesel exhaust gas emissions

Structure of Particulate Matter

Advanced diesel oxidation catalyst technology for passenger cars
28 September 2004 Aaqius & Aaqius Symposium Paris - France

Contents

• What are diesel exhaust gas emissions
• What are diesel oxidation catalysts
• How do they function
• Why are they still needed
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What are diesel oxidation catalysts

Summary

• Passive exhaust aftertreatment devices
  → no interaction with EMS needed
• PGM containing catalysts
  → PGM - content 2 - 180 g / ft³
  → today mainly Pt - only formulation
  → historically also Pd and Pt / Pd-used
• Applied on flow through monoliths
  → mainly ceramic 300 cps / 8 mill & 400 cps / 6.5 mill
  → more recently also on advanced metallic substrates
• Used on PC since 1989 and HDT since 1993
• Various technology generations exist

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How do they function

**Working principle of the Diesel Oxidation Catalyst**

- CO
- Adehyde
- HC
- PAH
- SO₂
- NO

Monoth with catalytic coating

How they function

**Comparing exhaust gas temperatures in NEDC**

- Diesel
- Otto-DI
- Otto-MPI

**How do they function**

**Key design and operation features**

- **Selective catalysis of oxidation reactions**
  - excellent conversion of CO, HC₂-₄ & HC₁₀-₂₄
  - good conversion of C₅H₁₀₂
  - preferably no conversion of SO₂
  - conversion of NO only in special applications
- **Catalysis at low temperatures**
  - good light off needed
  - avoid deposition of PM, SO₂ & HC₁₀-₂₄
  - still good thermal stability needed
- **Able to handle three phase flow**

Possible mechanical deactivation phenomena

**Diesel oxidation catalyst - inlet side - after 90 Tkmd road ageing**
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How do they function
Possible chemical deactivation phenomena
Conventional Diesel Oxidation Catalysts

Ageing – Poisoning

- S/C/HC deposits on the platinum and in the pores
- Potential clogging of pores, decrease of accessible specific surface area
- Poisoning is only partially reversible

Poisoning (S, C, HC)

How do they function
Possible thermal deactivation phenomena
Conventional Diesel Oxidation Catalysts

Thermal Ageing

- Sintering of highly dispersed platinum particles
- Decrease of catalytically active surface area of platinum
- Thermal ageing is irreversible

Median gas temperature in NEDC

EU raw emission (g/km) NEDC

€U1

DOC Gen. 1
- high PM mass reduction
- high SOF removal
- no SO2 formation
- medium CO /HC removal
- high odor reduction

IDI Engine
High Sulfur Fuel
How do they function
Exhaust system architecture: generation 1

Underbody Cat

IDI Diesel Engine

Fuel

EGR cooler

Inter cooler

CO raw emission (g/km) NEDC

EU1

EU2

EU3

Median gas temperature in NEDC

How do they function
Operation conditions & legislation: generations 2 & 3

How do they function
Performance & boundary conditions: generations 2 & 3

EU 1

EGR

EU 2 & 3

DI +

SOF

EU3

EU1

EU2

High Sulfur Fuel

Medium Sulfur Fuel

High PM mass reduction

high SOF removal

no SO4 formation

medium CO/HC removal

high odor reduction

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3rd Forum Aaqius & Aaqius
“Control of Diesel Emissions”
Le Mondial de l’Automobile, Paris
Contribution from Umicore

How do they function
Operation conditions & legislation: generation 4

CO raw emission (g/km) NEDC

EU1

EU2

EU3

EU4

How do they function
Performance & boundary conditions: generation 4

EU 1

DOC Gen. 1
• high PM mass reduction
• high SOF removal
• no SO2 formation
• medium CO -HC removal
• high odor reduction
• (high SO4 formation)

EU 2&3

DOC Gen. 2&3
• very high CO removal
• high HC removal
• (high SOF removal)
• high odor reduction
• (high SO4 formation)

EU 4

DOC Gen. 4
• heating function
• very high CO removal
• high HC removal
• (high SOF removal)
• (high SO4 formation)

How do they function
Exhaust system architecture: generation 4

Collector Cat ?

Preturbo Cat ?

Underbody Cat

DI Diesel Engine

Fuel

Exhaust

Air

Inter cooler +

Close Coupled Cat

Effect of preturbo catalysts on CO emissions in NEDC

Source: Emitec & Umicore publication
Breendon Motoren symposium 2004
Contents

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Why are they still needed

Overview

Fifth generation passive DOC
• excellent CO & HC performance
• very high CO & HC raw emission
• ultra-low sulfur fuel

Future of advanced oxidation catalysts

Why are they still needed

Operation conditions & legislation : generation 5

CO raw emission (g/km) NEDC

Partial HCCI
EU5?

EU1

EU2, EU5?

EU3

EU4, EU5?

Median gas temperature in NEDC

CO light-off for HCCI-Applications - model gas testing

Why are they still needed

CO light-off for HCCI-Applications - model gas testing
Why are they still needed

Overview

Fifth generation passive DOC
- excellent CO & HC performance
- very high CO & HC raw emission
- ultra-low sulfur fuel

Future of advanced oxidation catalysts

EGR DOC
- pre-EGR-cooler
- oxidise HC 10-23
- prevent fouling

Why are they still needed

New applications - EGR cooler protection catalyst

Overview

Fifth generation passive DOC
- excellent CO & HC performance
- very high CO & HC raw emission
- ultra-low sulfur fuel

Active DOC
- pre-DPF
- heating DPF
- NO2 generation

EGR DOC
- pre-EGR-cooler
- oxidise HC 10-23
- prevent fouling

Why are they still needed

EGR cooler protection catalyst - Toyota IAA 2003

Future of advanced oxidation catalysts

EGR Cooler Protection Cat

Why are they still needed

Overview

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EGR DOC
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- prevent fouling
Why are they still needed
Catalytic combustion for enabling the DPF regeneration

![Temperature before DPF](image)

Temperature before DPF

![Temperature before DOC](image)

Temperature before DOC

Why are they still needed
CO & HC & PM emissions after a DOC + DPF system

NEDC results after 90 Tkm on road ageing

Emission (g/km)

<table>
<thead>
<tr>
<th>CO</th>
<th>HC x 10</th>
<th>PM x 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.54</td>
<td>0.08</td>
<td>0.37</td>
</tr>
<tr>
<td>0.50</td>
<td>0.06</td>
<td>0.35</td>
</tr>
</tbody>
</table>

Why are they still needed
Active DOC + DPF system enables Pt/Pd use in DOC

Vehicle Test:
- 3.0 L CR-TDI engine
- 2 x 1.09 L catal. Volume
- pre catalyst only
- NEDC testing

Catalyst states
- fresh state
- low temp, sulfur aged with 2400 ppm S-fuel

Catalyst
- Advanced Pt / Pd DOC
- total PGM loading : 70 g/ft³

Why are they still needed
Cost reduction of DOC + DPF by use of Pt/Pd in DOC

Catalyst size: dia 5.66" x L 3.5"; PGM loading: 120 g/ft³; Vehicle: 2.2l CR TDI

NEDC Emission [g/km]

<table>
<thead>
<tr>
<th>CO</th>
<th>HC</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw</td>
<td>Degreened; 3.000 km</td>
<td>Degreened; 15.000 km</td>
</tr>
<tr>
<td>Degreened; 3.000 km</td>
<td>Road aged; 15.000 km, after regeneration cycle</td>
<td></td>
</tr>
</tbody>
</table>

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Why are they still needed

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Active DOC
• pre-DPF
• heating DPF
• NO2 generation

C-DPF
• high CO & HC conversion
• local DPF heating
• multiple NO/NO2 cycle

Future of advanced oxidation catalysts

Fifth generation passive DOC
• excellent CO & HC performance
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EGR DOC
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Why are they still needed

Integration of DOC in Particulate Trapping Substrate

Why are they still needed

Dedicated Diesel oxidation catalyst use in SCR systems
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Conclusion

• DOC are a proven technology
• technical potential still not exhausted
• new tasks emerge for the DOC
• DOC become active system components
• DOC will be part of EU5 catalyst systems!

Please contact the author by mail for an electronic copy of the presentation.

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Thank You