High Performance TWC Technologies for Gasoline Powered Vehicles

AVECC 2004, Beijing/China
April 27 - 29, 2004
The development of automotive emission control technology over the last three and a half decades is one of the greatest environmental success stories of this century. Compared to the 1960s, the emission of motor vehicles has dropped to a fraction, and the fuel economy has doubled. We still have cars with superb performance and excellent driveability.

Great success stories are continuing...
Emission challenges

US legislation

- LEV 1, 100 k
- LEV 2, 120 k
- ULEV 2, 120 k
- SULEV, 120 k

EU & China legislation

- EU-II, Beijing 2003
- EU-III, EC 2000, Beijing 2005
- EU-IV, EC 2005, Beijing 2008 (?)
Importance

Emission CO/HC/NOx

Emission CO

Energy consumption

1990

2000

2010

year

Environment

Trend ...

Source: Volkswagen Environmental Report 2001
Complicated interface between engine and catalyst at modern vehicle

- Engine and catalyst jointly optimized and developed for..
  - Performance
  - Drivability
  - Efficiency
  - Raw emissions
  - $\lambda$ control, etc..
  based on knowledge of combustion engine, electronics and catalyst as well...

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Close-coupled catalyst

- Importance of CC outweighs UC
- Challenge of development of CC:
  - high temperature stability
  - fast light-off at low load exhaust
Emission influence of close-coupled catalyst

**Vehicle test results*** ---
Total emissions influence of close-coupled catalysts after 40,000 km vehicle aged

**UCC**: 2 x 1.1 l and 2 x 0.8 l, 70 g/cu.ft., 1 Pt/14Pd/1Rh

**CC + UCC**: UCC: 2 x 0.8 l, CC: 2 x 1.1 l, 70 g/cu.ft., 1 Pt/14Pd/1Rh

Source: SAE 980663

*Clean air is our business*
Emission influence of close-coupled catalyst

Comparison of catalyst temperature of CC with UCC, after 40 T km vehicle aging

Source: SAE 980663
Development of a close coupled catalyst

Challenge of development of a close-coupled catalyst

Important parameters considered for designing a close-coupled catalyst

PGM type & content
Washcoat & OSC content
Close-coupled catalyst
Volume
Substrate

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# Application of different type PGM catalysts

<table>
<thead>
<tr>
<th></th>
<th>Pd</th>
<th>(Pt)/Pd/Rh</th>
<th>Pt/Rh</th>
<th></th>
<th>Pd</th>
<th>(Pt)/Pd/Rh</th>
<th>Pt/Rh</th>
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<tbody>
<tr>
<td>CC</td>
<td>😊</td>
<td>😊</td>
<td>😞</td>
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<td>😊</td>
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<tr>
<td>UF</td>
<td>😞</td>
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<td>😊</td>
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</table>

1990

2000

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Improvement of PGM thermostability

Hydrothermal oven aging at 980 °C for 4 hrs.

Pd - Obsoleted Process

Pd - Advanced Process

Effective use of PGM provides better
- light-off
- HC, CO/NOx performance
- durability

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Improve of OSC thermostability

The high temperature stable 3rd generation OSC relative OSC of CeO₂, Ce/Zr- and Ce/Zr/XYZ-mixed oxides after aging at 1100 °C for 4 hrs.

TPR-H₂ Uptake

- Lower H₂-uptake temperature of advanced Ce-rich material (→ high oxygen mobility in bulk)
- Higher H₂-uptake compared to old Ce-rich powder

Excellent OS-Capability !!
Improvement of alumina; washcoat poisoning

Improvement of $\gamma$-$\text{Al}_2\text{O}_3$ thermostability

<table>
<thead>
<tr>
<th>Relative in surface area in %</th>
<th>950°C</th>
<th>1100°C</th>
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<tr>
<td>Reference Type</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>New Development</td>
<td>115</td>
<td>150</td>
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Deactivation by poisoning materials will be less important in future.
Characteristics of new technologies

From the aspect of catalyst ....

- Applied the latest high thermostable PGM containing powder manufacturing process
- Adopted special designed high thermostable OSCs and washcoat materials
- Architected catalyst layer with tailor-made design

From the aspect of optimization ....

- PGM loading and ratio by DOE offered to max. activities with economical solution
- OSC onto individual catalyst layer enabling to maximize dedicated specific functions
- oxyge storage capacity
New TWC technologies applicable not only for the markets of the advanced legislation, but also for the emerging markets, e.g., China, India and SEA
DF (deterioration factor) of new catalyst

SAE 2004-01-1276
Catalyst Design for High Performance Engines Capable to Fulfill Future Legislation

S. Eckhoff, W. Mueller, D. Lindner, J. Leyrer, T. Kreuzer
Umicore AG & Co. KG
G. Vent, C. Schoen, J. Schmidt, J. Franz
DaimlerChrysler AG

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Case study for performance comparison

- 2.0 L, EU-IV EMS calibrated vehicle
- Raw emission [g/km]:
  - CO (5.81), HC (1.57), NOx (2.32)
- $V_{\text{cat}}/V_{\text{eng}} = 0.40$
- Lean, SAI cold start
- Engine bench aging 890 °C, 96 hrs. with fuel-cut
- NEDC test cycle
- PGM loading: 47 g/cft, 2Pt/40Pd/5Rh

![Graph showing emissions comparison](image)
Case study for PGM cost reduction potential

- 1.2 L, EU-IV EMS calibrated vehicle
- Raw emission [g/km]
  CO (6.65), HC (1.45), NOx (1.73)
- $V_{\text{cat}}/V_{\text{eng}} = 0.62$
- Stoich./lean cold start
- Engine bench aging
  890 °C, 96 hrs.
  with fuel-cut
- NEDC test cycle
- Old: 100 g/cft, 14Pd/1Rh
  New: 60 g/cft, 9Pd/1Rh
  35 % PGM cost down !!
Summary

- Trend of emission development in NA and EU/China.
- Integrated system development required to meet the future legislation.
- Close-coupled converter plays predominant roll for today and future legislation.
- Test results show a significant improvement of high temperature stability of new technology, compared to old one.
  - applicable to the advanced future legislation, e.g., EU-IV
  - significant cost reduction potential
Thank You for Your attention!

Umicore goes near to you...