Selective ammonia slip catalyst enabling highly efficient NOx removal requirements of the future

Milica Folić, Lived Lemus, Ioannis Gekas and Andreas Vressner
Outline

- Motivation
- Design goals
- Catalyst development
- Results of engine tests
  - 12L ASC
  - 3L ASC
- Concluding remarks
Motivation

- Ammonia slip also regulated
  - 10ppm (Euro VI), 25ppm (Stage IV)
Design goals

- Ammonia Slip Catalyst
  - High oxidation activity
  - Low formation of N\textsubscript{2}O
  - Low formation of NOx
  - Low PGM loading
  - Hydrothermal resistance

Catalyst development
Pt load optimization: Powder tests (40mg)

- 500 ppm NH₃, NHHSV=100000h⁻¹, 6% H₂O
- Measuring: NH₃, NOx, N₂O and N₂
Support modification: Small monolith test (D: 2”, H:3”)

- 200 ppm NH$_3$, NHSV=100000h$^{-1}$, 4% H$_2$O
- Measuring: NH$_3$, NOx, N$_2$O

Conversion (%) vs Temperature (°C)
Effect of Ageing (16h @550°C) – small monolith test

- 2.5g/ft³ Pt, modified support
Catalyst development conclusions

- Ammonia oxidation activity is proportional to the Pt load.

- A good compromise between activity and cost is achieved at Pt load of 2.5g/ft$^3$.

- Modification of support improves the selectivity without significant loss of the oxidation activity.

- Catalyst is hydrothermally stable.
Engine Tests: Experimental setup

- HDD 12L engine
  - Scania D12-13 L01 EUROIV
  - Disabled EGR

<table>
<thead>
<tr>
<th></th>
<th>NOx [g/kWh]</th>
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</thead>
<tbody>
<tr>
<td>WHTC</td>
<td>12</td>
</tr>
<tr>
<td>NRTC</td>
<td>13.8</td>
</tr>
<tr>
<td>ETC</td>
<td>9.5</td>
</tr>
</tbody>
</table>
Engine Tests: 12L ASC

- Test protocols
  - World Harmonized Transient Cycle (WHTC)
  - Non-Road Transient Cycle (NRTC) – cold and warm

- Dosing strategies
  - Constant ANR, sweep between 0.7 – 1.2
  - Overdosing algorithm

- Configurations tested
  - 34L VSCR + 12L ASC
  - 10L DOC + 17L DPF + 24L ZSCR + 12L ASC
WHTC. Space velocity and temperature

- Average NHSV = 32000 h\(^{-1}\)
WHTC. Results of ANR sweep
Example of WHTC result

- NH₃ in
- NH₃ out
- NOx formed
- N₂O formed
- T before ASC (°C)
WHTC. Comparison with previous formulations
WHTC. Overall system performance

- 97% NOx removal at <10ppm NH₃ slip (10% increase from SCR only)
WHTC. Overall system performance

- Similar ASC performance regardless of the system configuration
NRTC. Space velocity and temperature

- Average NHSV = 61000 h⁻¹
NRTC. Cold and warm cycle performance
Engine Tests: 3L ASC

- Test protocols
  - European Transient Cycle (ETC)

- Dosing strategies
  - Constant ANR, sweep between 0.7 – 1.2
  - Overdosing algorithm

- Configurations tested
  - 22L VSCR + 3L ASC
  - 25L VSCR only (for comparison purpose)
ETC. Space velocity and temperature.

- Average NHSV = 190000 h\(^{-1}\)
ETC. Overall system performance

- 92% NOx removal at <10ppm NH$_3$ slip (10% increase from SCR only)
Concluding remarks

<table>
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<tr>
<th>Engine out</th>
<th>System out</th>
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<tr>
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<td>WHTC (34L VSCR+12L ASC)</td>
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- New ASC enables NOx emissions close to EURO VI at maximum mean 10ppm NH₃ and N₂O
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