A Study about Particle Filter Application on a State-of-the-Art Homogeneous Turbocharged 2L DI Gasoline Engine

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Dow Automotive Systems

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• Introduction & Background
• Results On Roller Chassis:
  • Tailpipe Particle Number Emissions
  • Gaseous Emissions & Fuel Consumption
  • Peak Pressure Drop
• On-road Testing:
  • Fuel Consumption
  • Soot Accumulation Behavior
• Summary & Path Forward
Dow Powertrain Technologies

Dow Automotive

- Lubricants (Reduced Ash)
- GPF
- DPF (CSF, SCRF)
- Waste Heat Recovery
- Li-Ion Cell Materials
- Li-Ion Cells & Packs (JV)

Dow Powertrain Technologies
Automotive Systems

299-51813/11-10
Application Benefits of AERIFY vs competitive substrates:

- Low backpressure → Reduced fuel penalty
- Downsizing → Reduces needed packaging
- Heavy coating / system integration → space & system cost
- High filtration efficiency → Euro 6 particulate number limit

Technology Description:
High porosity filters made from Acicular Mullite crystals
Objective of This Presentation

- State-of-the-art DI Gasoline engines produce low particulate mass emission but significant nanoparticle emission
- EU legislation will limit tailpipe Particulate Number (PN) tailpipe emission for Gasoline light passenger cars in 2014-15 timeframe (Euro 6)
- Current expectation is to apply the PN measurement technique and limit for Diesel light passenger cars (e.g. $6 \times 10^{11}$#/km)
- OEM are preparing technical solutions:
  - Via engine-in means
  - Via usage of Gasoline Particulate Filter (GPF):
    - Uncoated GPF → Topic of this presentation!
    - Coated GPF
Baseline Close-Coupled Concept of Actual Exhaust Systems (w/o GPF)

- Engine → TWC → TWC

Integration of Uncoated GPF for Euro 6 Applications

- No modification of TWC concept
- Continuous soot clean-out?
- GPF underfloor in extra canning

- Continuous soot clean out!
- GPF close-coupled in TWC canning
- TWC system must shrink. GPF length constrained by packaging.
GPF Performance Requirements

Sufficient PN Filtration in Clean State
(engineering target: $\sim 3 \times 10^{11}$#/km)

Low $\Delta p$ over Filter
(target: $\sim 100$ mbar)

Tested Samples

<table>
<thead>
<tr>
<th>Material</th>
<th>Diameter, inch</th>
<th>Length, inch</th>
<th>Honeycomb structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acicular Mullite</td>
<td>4.66</td>
<td>3</td>
<td>DPF</td>
</tr>
<tr>
<td>Acicular Mullite</td>
<td>4.66</td>
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<td>4.66</td>
<td>5</td>
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<tr>
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<td>2</td>
<td>GPF</td>
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</tbody>
</table>
### Audi A5 Coupe 2L TFSI Multitronic

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combustion system</td>
<td>Turbocharged homogeneous DI Gasoline engine</td>
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<tr>
<td>Displacement</td>
<td>1.984 L</td>
</tr>
<tr>
<td>Exhaust system</td>
<td>Close-coupled TWC</td>
</tr>
<tr>
<td>Emission compliance</td>
<td>Euro 5</td>
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<tr>
<td>Maximum speed</td>
<td>226 km/h</td>
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<tr>
<td>Max power</td>
<td>132 kW at 4000-6000 rpm</td>
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<tr>
<td>Curb weight</td>
<td>1460 kg</td>
</tr>
<tr>
<td>Mileage at test begin</td>
<td>Approx. 1500 km</td>
</tr>
</tbody>
</table>
Flow and GPF canning were not optimized to deliver lowest possible backpressure.
AERIFY DPF and GPF deliver PN tailpipe emissions below the engineering target in fresh state regardless of the filter length.
Significant PN emission is formed in:

- Cold start
- Catalyst heating
- Rapid accelerations
No negative impacts on:

- Tailpipe NO\textsubscript{x}
- Tailpipe CO\textsubscript{2}
- Fuel Consumption

in NEDC.
Total exhaust pipe backpressure after ~80 sec in free full load acceleration. AERIFY GPF delivers $\Delta p < 100$ mbar at 4 and 5 inch length.
- No pressure drop increase observed after 532 km nonstop cruising in low load cycle.

- The GPF inlet face was white or slightly grey after de-canning.
- No pressure drop increase observed after 806 km nonstop cruising in fuel consumption cycle.

- The GPF inlet face was white or slightly grey after de-canning.
Consumed fuel measured by weighing refilled quantities. Variations may occur caused by daily traffic variations. No relevant difference in average consumption observed (w/ GPF versus w/o GPF).
Fuel Penalties at Constant Speed

Fuel consumption data from ECU. Increase of 2-3% found for vehicle speeds of 180 – 200 km/h. No relevant increase at lower vehicle speeds.
• The anticipated Euro 6 PN limit of $6 \times 10^{11} \#/km$ and its engineering target (e.g. 50%) can be safely demonstrated by application of AERIFY honeycomb filters

• AERIFY GPF delivers excellent PN filtration and very low pressure drop regardless of its length

• No fuel consumption increase observed up to 180 km/h constant cruising with the given test vehicle

• No soot accumulation observed in standardized onroad cycles with the given test vehicle
Onroad ash accumulation in progress to investigate ash production, ash storage, and pressure drop behavior over filter lifetime.

Sufficient PN Filtration in Clean State (engineering target: $\sim 3 \times 10^{11} \#/km$)

Low $\Delta p$ over Filter (target: $\sim 100$ mbar)
Thank You