Experiments and Analysis of DPF Loading and Regeneration

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Introduction

Particulate filter system consists of a filter and a regeneration strategy

Commercial filters are very effective at removing PM, but regeneration is a challenge

In addition to removal of PM it is important to reduce other pollutants including NO\textsubscript{x} from diesel engine exhaust
Particulate filter regeneration strategy can include catalysts, fuel additives, engine control, and fuel injection.

Regeneration

500-600 °C without catalyst

Near 350 °C with fuel additive or catalyst-coated DPF

Experimental

- Engine test cell
  - Soot loading and regeneration (burn-off) experiments
  - \( \text{NO}_x \) reduction experiments

- Hot gas flow reactor
  - Kinetic measurements of uncatalyzed and catalyzed filters
Objectives

- Soot loading and regeneration
- Engine test cell and flow reactor
- With and without platinum-based coating
- Fuel injection initiated regeneration
- Catalytic NO\textsubscript{x} reduction assisted by supplementary fuel injection

Test Cell – details

Navistar 7.3 L

Designed for Ford F-250

Rated 175 kW (235 hp), 691 N-m (510 ft-lb)

Water-brake dynamometer

Data acquisition system
## Test Cell – Catalyst Configuration

<table>
<thead>
<tr>
<th></th>
<th>DOC</th>
<th></th>
<th>DPF</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Substrate</td>
<td>Coating</td>
<td>Substrate</td>
<td>Coating</td>
</tr>
<tr>
<td>A</td>
<td>-</td>
<td>-</td>
<td>100 cpsi</td>
<td>None</td>
</tr>
<tr>
<td>B</td>
<td>-</td>
<td>-</td>
<td>100 cpsi</td>
<td>Pt-based</td>
</tr>
<tr>
<td>C</td>
<td>200 cpsi</td>
<td>Pt-based</td>
<td>100 cpsi</td>
<td>Pt-based</td>
</tr>
</tbody>
</table>

## Test Cell – Experimental Procedure

<table>
<thead>
<tr>
<th></th>
<th>Loading</th>
<th>Regeneration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load (ft-lbs)</td>
<td>90</td>
<td>470</td>
</tr>
<tr>
<td>(N-m)</td>
<td>122</td>
<td>637</td>
</tr>
<tr>
<td>Speed (RPM)</td>
<td>2800</td>
<td>2050</td>
</tr>
<tr>
<td>Calculated Exhaust Flow (scfm)</td>
<td>480</td>
<td>410</td>
</tr>
<tr>
<td>(lb/min)</td>
<td>36</td>
<td>30</td>
</tr>
<tr>
<td>Calculated Space Velocity (hr⁻¹)</td>
<td>63,000</td>
<td>57,000</td>
</tr>
<tr>
<td>Exhaust Temperature (°C)</td>
<td>290</td>
<td>485</td>
</tr>
</tbody>
</table>
Coated DPF regenerates much faster than uncoated DPF in test cell.

Fuel injection can effectively initiate regeneration.
Active Filter Regeneration with Fuel Injection

Fuel injection is an alternate method to initiate regeneration
HGFR - details

- Allows controlled regeneration in soot- and SOF-free gas; low NO\textsubscript{x} and SO\textsubscript{2} levels
- Temperature range 25 - 700°C
- Oxygen concentration 13 - 18%

HGFR - Experimental Procedure

- DPF loaded with soot on test cell
- Pre-weighed DPF installed in HGFR test section
- Air flow started, burner ignited
- Temperature of DPF rises in 30-60 seconds
- Regeneration begins, and is stopped while dP decreasing linearly
- After cooling, DPF reweighed to find mass loss
Comparison of Soot Oxidation over Catalyzed and Uncatalyzed DPFs at 600°C and 70,000 h⁻¹

HGFR Kinetic Results
**Apparent Activation Energy of Diesel Soot Oxidation**

Pt-Catalyzed DPF 38 kJ/mol

Uncatalyzed DPF 85 kJ/mol

Literature
(uncatalyzed DPF) 80-180 kJ/mol

18% O₂, SV 35,000 to 70,000 hr⁻¹

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**O₂ Concentration Effect on Catalyzed DPF Regeneration**

![Graph showing the effect of O₂ concentration on catalyzed DPF regeneration.](chart.png)

- without EGR 18% O₂
- with EGR 13% O₂
Conclusions

Pt-coating causes faster regeneration

Fuel injection assisted regeneration is effective

Soot oxidation exhibits Arrhenius-type behavior

Catalytic coating increased soot oxidation rate by a factor of 6-16

Future Testing and Development

HGFR Upgrades

Fuel injection

NOx injection

Improved diagnostic equipment

Test Cell Experiments