Impact of Biodiesel Metals on Aftertreatment System Durability

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Vehicle Technologies Program Merit Review – Fuels and Lubricants Technologies

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Project ID: FT011

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Overview

Timeline
Start date: Oct 2011
End date: Sept 2012
Percent complete: 66%
*Program funded one year at a time*

Budget
Total project funding
FY11: $1.1 M
FY12: $1.3 M – estimated
*NBB cooperative research and development agreement (CRADA) provides around $500K to cost-share biodiesel research*

Barriers
VTP MYPP Fuels & Lubricants Technologies Goals
- By 2015 identify heavy-duty (HD) non-petroleum-based fuels that can achieve 15% petroleum displacement by 2030

Partners
- National Biodiesel Board (NBB) and member companies
- Manufacturers of Emission Controls Association (MECA) and member companies
- Engine Manufacturers Association (EMA) and member companies
- Coordinating Research Council (CRC) and member companies
- Ford Motor Company
- Caterpillar
- Oak Ridge National Laboratory (ORNL)
Relevance/Objective

- Alkali and alkaline earth metals can be found in biodiesel at very low levels (ASTM D6751 allows < 5ppm Na + K and < 5ppm Ca + Mg in B100)

- These fuel metals form exhaust ash that can impact catalyst durability

- Project Objective – Determine the impact of biodiesel metals on the full useful life durability of modern diesel exhaust aftertreatment systems

- Relevance – Help remove technical barriers to the more widespread use of biofuels for petroleum displacement
### Milestones

<table>
<thead>
<tr>
<th>Date</th>
<th>Milestone or Go/No-Go Decision</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aug-11</td>
<td><strong>Impact of biodiesel ash-forming constituents on selective catalytic reduction (SCR) catalyst performance.</strong> Effects of Na and K on both light-duty (LD) and HD configurations are being measured in accelerated tests.</td>
<td>Complete</td>
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</table>
Approach

- Conducted accelerated catalyst aging
- Accelerated metal exposure by doping fuel with high levels of metal impurities (Na, K and Ca)
- Tested multiple catalyst systems from both HD and LD applications
  - Catalyst aging included diesel oxidation catalyst (DOC), diesel particulate filter (DPF) and SCR catalysts
  - Catalyst aging and emissions testing conducted by NREL
  - Materials characterization and further emissions testing conducted by ORNL, Ford and MECA
Test Apparatus

- Aging full production exhaust systems from 2011 Ford F250 pickup
- Aging conducted on Cat C9 engine
- Engine is oversized for these catalysts so engine operating points were selected to achieve appropriate space velocities and temperatures
Test Cycle

- A three-mode, one-hour test cycle was developed for catalyst aging.
- Space velocity and catalyst temps were selected from data from an F250 truck operating on the FTP and US06 cycles.
- 100-hour accelerated test simulates 150k miles of B20 operation.
- Emissions evaluation conducted every 10 hours on an F250 truck over the FTP on a chassis dynamometer.

<table>
<thead>
<tr>
<th>Engine Mode</th>
<th>Time (min)</th>
<th>SCR Space Velocity (1/hr)</th>
<th>SCR inlet T (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (low-temp operation)</td>
<td>15</td>
<td>20k</td>
<td>200</td>
</tr>
<tr>
<td>2 (high-temp operation)</td>
<td>15</td>
<td>57k</td>
<td>340</td>
</tr>
<tr>
<td>3 (regen operation)</td>
<td>30</td>
<td>57k</td>
<td>700</td>
</tr>
</tbody>
</table>
Test fuels

Four separate catalyst systems were tested, one each with the following four fuels:

1. ULSD (baseline test)
2. B20 + 14 ppm Na doped using dioctyl sulfosuccinate sodium salt
3. B20 + 14 ppm K doped using potassium dodecylbenzene sulfonate
4. B20 + 14 ppm Ca doped using calcium naphthenate
## Temperature and Ash Exposure

<table>
<thead>
<tr>
<th></th>
<th>SCR &gt; 600 C (hrs)</th>
<th>Avg SCR temp (deg C)</th>
<th>Ash Exposure (grams)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ULSD</td>
<td>45.8</td>
<td>486</td>
<td>28</td>
</tr>
<tr>
<td>B20 + Na</td>
<td>43.9</td>
<td>488</td>
<td>66</td>
</tr>
<tr>
<td>B20 + Ca</td>
<td>44.8</td>
<td>493</td>
<td>82</td>
</tr>
<tr>
<td>B20 + K</td>
<td>45.1</td>
<td>484</td>
<td>59</td>
</tr>
</tbody>
</table>

Example of 10-hour aging cycle

![Graph showing temperature fluctuations](image-url)
NO$_x$ Emissions

All four systems met NO$_x$ emission standard after simulated 150k miles.
HC Emissions

All four systems met HC emission standard after simulated 150k miles.
Summary

• Accelerated test method simulates aftertreatment aging to 150k miles of thermal and fuel ash exposure
• F250 pickup met NO\textsubscript{x} and HC emissions standards after simulated 150k miles of exposure to B20 + Na, B20 + K and B20 + Ca
• ORNL and Ford are currently conducting post mortem analysis of aged parts
Collaboration and Coordination

• Research was conducted under a CRADA between NREL and the NBB

• This study was a collaboration with ORNL and Ford

• Significant technical input was provided by an industry steering committee that includes: Manufacturers of Emission Control Association, Engine Manufacturers Association, Caterpillar, Cummins, Case - New Holland, NGK, BASF and Umicore
Proposed Future Work

• Work in 2012 will focus on how biodiesel metals will impact the full useful life durability of HD catalyst systems. HD catalyst systems have a much longer 435,000-mile limit for full useful life durability.

• Research will determine if lower metal limits are necessary to protect catalyst durability during these longer periods of exposure.

• Research will also determine which of the metals (Na, K or Ca) has the most severe impact on catalyst durability.