DPF Performance with Biodiesel Blends

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Project Objectives and Approach

How are DPFs impacted by blending with biodiesel?

Phase I CRADAs w/ Cummins & NBB (completed)

- **Transient testing** – Confirm operation of DPF with ULSD and B20 (HDT FTP)
- **Balance point temperature testing** – Understand how biodiesel blends impact temperature of soot oxidation on DPF (DECSE method)
- **Regeneration rate testing** – Understand how biodiesel blends may impact actively regenerated systems (Slope method)
- **Soot characterization** – Understand fundamental differences in biodiesel soot (Raman Spec, SEM-EDX, TGA)

Phase II CRADA w/ NBB (FY07)

- Moving to a 2007 compliant engine
- **Transient testing with controlled exhaust temps** – Understanding of how DPF design criteria could be affected by biodiesel blends
Experimental Configuration

• Cummins ISB 300
  – 2002 Engine, 2004 Certification
  – Cooled EGR, VGT
• Johnson Matthey CCRT
  – 12 Liter DPF
  – Passively Regenerated System
  – Pre Catalyst (NO₂ Production)
• Fuels: ULSD, B100, B20, B5

• ReFUEL Test Facility
  – 400 HP Dynamometer
  – Transient & Steady State Testing
• Cummins
  – Soot Characterization
Heavy Duty Transient (HDT) Test Results

- Installation of DPF (base fuel):
  -97% CO, -99% THC, -99% PM, +1% BSFC
- B20 results in 24% PM reduction w/o DPF, 27% reduction w/ DPF
BPT and Regen Rate Test Procedures

• Balance Point Temperature (BPT) – DPF temperature where rate of PM collection equals rate of PM oxidation
• BPT is determined by monitoring DPF back pressure
• Regeneration Rate Test – simulates active regeneration strategy
Balance Point Temperature Test Results

- Repeatability of test method shown with multiple repeats for each test fuel
- BPT determined by linear curve fit between two points nearest zero slope
- BPT with B20 and B100 is lower than 2007 Cert by 45 °C and 112 °C
Regeneration Rate Test Results

- Regeneration rate increases with increasing biodiesel content
- Even at 5% blend levels biodiesel PM measurably oxidizes more quickly
- 2007 Cert has positive regen rate slope, consistent with findings from BPT tests

\begin{align*}
\text{2007 Cert} & \quad y = 1.0E-05x \quad (1.6 \text{ g/L}) \\
& \quad y = 1.1E-05x \quad (1.5 \text{ g/L}) \\
\text{B5 Blend} & \quad y = -0.8E-05x \quad (1.6 \text{ g/L}) \\
& \quad y = -0.8E-05x \quad (1.3 \text{ g/L}) \\
\text{B20 Blend} & \quad y = -1.5E-05x \quad (1.6 \text{ g/L}) \\
& \quad y = -2.0E-05x \quad (1.3 \text{ g/L})
\end{align*}
Availability of NOx for Soot Regeneration

- Catalyzed DPF’s use NO₂ to oxidize soot
- There is no evidence to higher availability of NOx from biodiesel fuels

Regeneration Rate Test

- ULSD = 2.01 g/bhp-hr
- B5 = 1.97 g/bhp-hr
- B20 = 2.15 g/bhp-hr

No statistical difference (at alpha = 0.05)

Balance Point Temp Test

- B100 BPT
- B20 BPT
Soot Characterization – Industrial Collaboration w/ Cummins

- Lower combustion temperature for biodiesel soot – (TGA)
- Higher disordered carbon content for B100 soot – G/D Carbon Ratio (Raman Spec)
  \[ G/D_{ULSD} = 0.836 \quad G/D_{B100} = 0.586 \]
- Higher oxygen content for B100 soot – Carbon/Oxygen Ratio (SEM-EDX)
  \[ C/O_{ULSD} = 25.34 \quad C/O_{B100} = 20.34 \]
Biodiesel DPF Summary

• B20 vs. ULSD Transient test results
  – Both fuels < 0.01 g/bhp-hr PM with CCRT installed
  – PM reduction from B20 vs. ULSD still measurable with CCRT installed
    27% reduction with CCRT vs. 24% reduction without CCRT

• BPT and Regeneration Rate Testing shows measurable differences with increasing biodiesel blends
  – BPT decreased by 45 ºC with B20 and 112 ºC with B100
  – Significant differences in regeneration rate with blend levels as low as 5%

• Soot Characterization
  – TGA confirms higher reactivity of biodiesel soot
  – Higher oxygen content for biodiesel soot
  – Higher ratio of disordered carbon for biodiesel soot

• Phase II Test Plan
  – 2007 compliant engine
  – Transient testing with controlled avg exhaust temps
  – Quantify fuel penalty associated with active systems
  – Evaluate maintenance and durability issues through fleet testing