Impact of Fuel Properties on Light-Duty Engine Performance and Emissions

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FEV, Inc.
Overview

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- Fuel Specifications
- Combustion Behavior with Varying Cetane
- Test Results
  - Part Load Comparison
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    - 2000 rpm, 6 bar BMEP
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Project Goal

Evaluate the impact of 7 different fuel blends on the emissions and performance of a 2.5 l light-duty HSDI diesel engine:

- Wide range of fuels were subject to the investigation ranging from CN = 26 to CN = 76 (including biodiesel)
- Determine the emissions characteristic of each fuel as function of combustion parameters (PI, MI, EGR, Boost, Rail Pressure, …)
- Determine the full load performance of the fuels using identical operating parameters
Hardware Specifications

**Engine Specifications:**
- 2.5 L 4 Cyl DI
- Bore = 93 mm
- Stroke = 92 mm
- Displacement = 2493 cc
- Compression Ratio = 18:1
- Power = 105 kW @ 3200 rpm
- Torque = 330 Nm @ 2000 rpm

**Injection/Control System:**
Bosch 2nd Gen. Common Rail
1600 bar peak pressure
Bosch EDC16
# Fuel Specifications

<table>
<thead>
<tr>
<th></th>
<th>Cetane Number</th>
<th>Carbon wt%</th>
<th>Oxygen wt%</th>
<th>Hydrogen wt%</th>
<th>Fuel Density at 293 K kg/m³</th>
<th>Net Heating Value MJ/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECD Ultra Low Sulfur</td>
<td>53.2</td>
<td>86.19</td>
<td>0.00</td>
<td>13.56</td>
<td>829.8</td>
<td>43.62</td>
</tr>
<tr>
<td>HF0695</td>
<td>32.4</td>
<td>87.14</td>
<td>0.00</td>
<td>12.86</td>
<td>841.1</td>
<td>42.76</td>
</tr>
<tr>
<td>MIX sample NAPTHA</td>
<td>26.0</td>
<td>86.25</td>
<td>0.00</td>
<td>13.75</td>
<td>768.2</td>
<td>43.61</td>
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<tr>
<td>T23</td>
<td>75.8</td>
<td>85.56</td>
<td>0.00</td>
<td>14.44</td>
<td>788.0</td>
<td>43.66</td>
</tr>
<tr>
<td>B-100 - Biodiesel</td>
<td>52.0</td>
<td>76.84</td>
<td>11.38</td>
<td>11.78</td>
<td>880.1</td>
<td>37.41</td>
</tr>
<tr>
<td>B-20 - Biodiesel</td>
<td>43.1</td>
<td>84.95</td>
<td>2.37</td>
<td>12.68</td>
<td>852.9</td>
<td>41.48</td>
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<tr>
<td>B-5 - Biodiesel</td>
<td>42.4</td>
<td>86.48</td>
<td>0.61</td>
<td>12.91</td>
<td>847.9</td>
<td>42.43</td>
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</tbody>
</table>
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Combustion Behavior

Blue=76 Cetane  Green = 44 Cetane  Red=26 Cetane

Mass Burn Fraction

Cylinder Pressure

Heat Release Rate
Test Results – 2000 rpm 2 bar BMEP

<table>
<thead>
<tr>
<th>Base Settings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start of Injection</td>
</tr>
<tr>
<td>Distance Main-Pilot I</td>
</tr>
<tr>
<td>Pilot I Quantity</td>
</tr>
<tr>
<td>Desired Air Mass</td>
</tr>
<tr>
<td>Boost Pressure</td>
</tr>
</tbody>
</table>

![Graphs showing test results for NOx, BSFC, Smoke, and HC vs. Railpressure at 2000 rpm and 2 bar BMEP.](image)
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Test Results – 2000 rpm 2 bar BMEP

Base Settings

- Railpressure: 630 bar
- Distance Main-Pilot I: 1500 micro s
- Pilot I Quantity: 2 mg / stroke
- Desired Air Mass: 550 mg / stroke
- Boost Pressure: 60 %
Test Results – 2000 rpm 2 bar BMEP

- Railpressure: 630 bar
- Start of Injection: 2 deg Crs
- Distance Main-Pilot I: 1500 micro s
- Pilot I Quantity: 2 mg / stroke
- Boost Pressure: 60 %
Impact of Fuel Properties on Light-Duty Engine Performance and Emissions

Test Results – 2000 rpm 6 bar BMEP

- Start of Injection: 2 deg Crs
- Distance Main-Pilot I: 3600 micro s
- Pilot I Quantity: 2 mg / stroke
- Desired Air Mass: 650 mg / stroke
- Boost Pressure: 65 %
Test Results – 2000 rpm 6 bar BMEP

- Rail pressure: 1000 bar
- Distance Main-Pilot I: 3600 micro s
- Pilot I Quantity: 2 mg / stroke
- Desired Air Mass: 650 mg / stroke
- Boost Pressure: 65 %
Impact of Fuel Properties on Light-Duty Engine Performance and Emissions

Test Results – 2000 rpm 6 bar BMEP

- Railpressure: 1000 bar
- Start of Injection: 2 deg Crs
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- Pilot I Quantity: 2 mg / stroke
- Boost Pressure: 65 %
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Test Results – Full Load

- NOx [g/kWh]
- BSFC [g/kWh]
- Smoke [FSN]
- HC [g/kWh]

Graphs showing the performance and emissions across different speed ranges for various fuel samples.

- 26 - Mix Sample
- 42.4 - BD-5
- 52 - DD-100
- 75.8 - T23
- 32.4 - HF0695
- 43.1 - BD-20
- 53.2 - ECD ULG
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Test Results – Full Load

 Thermal Efficiency [%]

 Torque [Nm]

 Temp. bef. Turbine [°C]

 Inj. Quantity [mm³/3/cyc.]

 Speed [rpm]
Summary and Conclusion

- High cetane fuel (76) exhibits best fuel consumption but suffers from high smoke level resulting from a short mixing time.
- Extreme low cetane fuel (26) suffers from poor fuel consumption and high HC emissions due to late combustion.
- Higher loads and optimized timing make low cetane fuels more attractive from a smoke and fuel consumption perspective.
- While NOx is elevated, oxygen content of biodiesel fuels (B20, B100) has a significant impact on smoke level.
- Low heating value and high density of B100 greatly effects fuel consumption throughout the load range.
- Performance trends vary significantly with the engine operation and combustion system making it difficult to identify ideal fuel properties.