Emission Characteristics of CI Engine Running with Biodiesel

B Tesfa, R Mishra, F Gu and A D Ball
Agendas

- Introduction
- Experimental facilities and test procedures
- Experimental results
  - Effects of biodiesel sources on engine emission
  - Effects of biodiesel blend ratio on engine emission
- Conclusions
Introduction

- On the past three decades, considerable efforts have been made to develop alternative fuels.
- Why do we need alternative fuels?
  - Depletion of non-renewable oil reserves in the coming 30 - 50 years.
  - Stringent emissions legislation for the transport sector (30% of emission caused by transport sector)
  - Vulnerability of fossil fuel resource to political instability
Introduction (Cont.)

Oil Demand (billion tons/year) vs Years from 1995 to 2050

- **Biofuel**
- **New discoveries (Fossil fuel)**
- **Current available (Fossil fuel)**

Oil Supply – Demand (Conemann, 1999)
### EU Emission Standard for Passenger Diesel Cars (g/km)

<table>
<thead>
<tr>
<th>Stage</th>
<th>Date</th>
<th>CO</th>
<th>HC</th>
<th>HC+NOx</th>
<th>NOx</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euro I</td>
<td>1992.07</td>
<td>2.72</td>
<td>-</td>
<td>0.97 (1.13)</td>
<td>-</td>
<td>0.14 (0.18)</td>
</tr>
<tr>
<td>Euro II, ID</td>
<td>1996.01</td>
<td>1.0</td>
<td>-</td>
<td>0.7</td>
<td>-</td>
<td>0.08</td>
</tr>
<tr>
<td>Euro II, DI</td>
<td>1996.01</td>
<td>1.0</td>
<td>-</td>
<td>0.9</td>
<td>-</td>
<td>0.10</td>
</tr>
<tr>
<td>Euro III</td>
<td>2000.01</td>
<td>0.64</td>
<td>-</td>
<td>0.56</td>
<td>0.50</td>
<td>0.05</td>
</tr>
<tr>
<td>Euro IV</td>
<td>2005.01</td>
<td>0.50</td>
<td>-</td>
<td>0.30</td>
<td>0.25</td>
<td>0.025</td>
</tr>
<tr>
<td>Euro V(a)</td>
<td>2009.09</td>
<td>0.50</td>
<td>-</td>
<td>0.23</td>
<td>0.18</td>
<td>0.005</td>
</tr>
<tr>
<td>Euro V(b)</td>
<td>2011.09</td>
<td>0.50</td>
<td>-</td>
<td>0.23</td>
<td>0.18</td>
<td>0.005</td>
</tr>
<tr>
<td>Euro VI</td>
<td>2014.09</td>
<td>0.50</td>
<td>-</td>
<td>0.17</td>
<td>0.08</td>
<td>0.005</td>
</tr>
</tbody>
</table>
Introduction (Cont.)

This challenges are forced the world to develop alternative fuels:

• Ethanol
  ✓ limited only to spark ignition engines
  ✓ Limited with only 15% blend due to its effects on engine parts

• Hydrogen based fuel cells
  ✓ Complexity of hydrogen production
  ✓ Storage and transport challenge
  ✓ High cost fuel cell production
Introduction (Cont.)

- Biodiesel – most convenient for diesel engine

Advantage of biodiesel:

✓ Easy portable
✓ Global availability
✓ Higher combustion
✓ Lower sulphur
✓ Higher cetane number and high biodegradability

We are working on:

- Physical characterisation
- Combustion
- Performance
- Emission
- Engine life time
Selected publication

Lapuerta et al. and Xue et al. reviewed 158 and 162 articles respectively about biodiesel engine performance and emissions, published by highly rated journals in scientific indexes covering up to 2008 and 2010.
Introduction (Cont.)

The objective of this study is to investigate the emission characteristics of CI engine running with biodiesel blend by varying biodiesel types and blends ratio for heavy duty engine.
Materials and Test Procedures

- A four-cylinder, four-stroke, turbo charged, water-cooled and direct-injection CI engine
- 4.4 litre capacity, 75kW
- The unit with a 200kW AC Dynamometer
Materials and Test Procedures

- Diesel tank
- Biodiesel tank
- Fuel pump
- Fuel flow meter
- Control unit
- Temp. & pressure sensors
- Control host PC
- Load cell
- Fresh air
- 4 cylinder engine
- Turbocharger
- Emission analyser
- Host PC
- Dynamometer
### Materials and Test Procedures

- Corn oil biodiesel, Rapeseed oil biodiesel, Waste oil biodiesel, Diesel and its blends were used.

<table>
<thead>
<tr>
<th>Property</th>
<th>Diesel (B0)</th>
<th>B10</th>
<th>B20</th>
<th>B50</th>
<th>B75</th>
<th>B100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (kg/m³)</td>
<td>853</td>
<td>859</td>
<td>865</td>
<td>871</td>
<td>872</td>
<td>879</td>
</tr>
<tr>
<td>LHV (MJ/kg)</td>
<td>42.67</td>
<td>42.26</td>
<td>41.84</td>
<td>40.58</td>
<td>39.54</td>
<td>38.50</td>
</tr>
<tr>
<td>Viscosity (mm²/s)</td>
<td>3.55</td>
<td>3.91</td>
<td>4.28</td>
<td>4.68</td>
<td>4.74</td>
<td>5.13</td>
</tr>
</tbody>
</table>
Materials and Test Procedures

- Preconditioning procedure at high speed and high load was implemented to purge any of the remaining effects from previous tests.
- The measurements of gaseous emissions were carried out using a gas test bench HORIBA.
- The sample line of the equipment is connected directly to the exhaust pipe and it is heated to maintain a wall temperature of around 191°C and avoid the condensation of hydrocarbons into the line.
- The test was carried out for a range of engine speeds (from 1000 to 1800 rpm with 200 rpm increment) and at maximum engine load (420 Nm).
Effects of biodiesel source on emissions

(a) 420Nm

(b) 420Nm
Effects of biodiesel source on emissions

(a) 420Nm

(b) 420Nm
Effects of biodiesel source on emissions

<table>
<thead>
<tr>
<th>Speed (rpm)</th>
<th>THC (ppm)</th>
<th>THC reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel</td>
<td>ROB</td>
<td>COB</td>
</tr>
<tr>
<td>1000</td>
<td>5</td>
<td>-10</td>
</tr>
<tr>
<td>1200</td>
<td>7</td>
<td>-8</td>
</tr>
<tr>
<td>1400</td>
<td>8</td>
<td>-6</td>
</tr>
<tr>
<td>1600</td>
<td>9</td>
<td>-4</td>
</tr>
<tr>
<td>1800</td>
<td>10</td>
<td>-2</td>
</tr>
</tbody>
</table>

(a) 420Nm

(b) 420Nm
Effects of biodiesel source on emissions

(a) 420Nm

(b) 420Nm
Effects of biodiesel blend fraction on emissions

(a) 420Nm

(b) 420Nm

<table>
<thead>
<tr>
<th>Speed (rpm)</th>
<th>Diesel</th>
<th>10B</th>
<th>20B</th>
<th>50B</th>
<th>100B</th>
</tr>
</thead>
<tbody>
<tr>
<td>900</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1300</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1500</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Speed (rpm)</th>
<th>CO₂ reduction (%)</th>
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<tr>
<td>900</td>
<td></td>
</tr>
<tr>
<td>1100</td>
<td></td>
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<tr>
<td>1300</td>
<td></td>
</tr>
<tr>
<td>1500</td>
<td></td>
</tr>
</tbody>
</table>
Effects of biodiesel blend fraction on emissions

(a) 420Nm

(b) 420Nm
Effects of biodiesel blend fraction on emissions

(a) 420Nm

(b) 420Nm
Effects of biodiesel blend fraction on emissions

(a) 420Nm

(b) 420Nm
Conclusions

1. The source of biodiesel does not show significant effect on the CI engine’s emissions (CO\(_2\), CO, NOx and THC) as long as the fuel physical and chemical properties remain same.

2. The emission analyses of the CI engine running with biodiesel highlights a significant reduction in CO\(_2\), CO and THC emission at working engine operation conditions.

3. It is also found that when the biodiesel content increases a further reduction in emissions is observed. This emission reduction is a result of the oxygen content in biodiesel and the low carbon hydrogen ratio.

4. For all biodiesel contents the NOx emission increases for all operating conditions during of the CI engine. This increase is mainly due to the higher oxygen content present in biodiesel and the advanced injection characteristics.
Thank you