Recent Developments in BMW’s Diesel Technology

DEER Conference 2003 – Newport, USA

August 2003

BMW Group
Recent Developments in BMW’s Diesel Technology

BMW Diesel History

![Engine Diagram]
Recent Developments in BMW’s Diesel Technology

BMW Diesel Production

![Bar chart showing BMW Diesel production by year and generation from 1983 to 2002. The chart includes data for the 1st, 2nd, and 3rd generations, with cumulative production figures for each.

- **1st generation:**
  - Years: 1983-1984
  - Engines produced: 262,000

- **2nd generation:**
  - Years: 1994-2002
  - Engines produced: 635,000

- **3rd generation:**
  - Years: 1998 onwards

The chart indicates a significant increase in production from 2000 onwards, particularly for the 3rd generation. A legend for the chart is also present, indicating the different generations.
Recent Developments in BMW’s Diesel Technology

BMW Market Share 04/2003

World wide
- Petrol: 65%
- Diesel: 35%

Europe
- Petrol: 32%
- Diesel: 68%

X5
Recent Developments in BMW’s Diesel Technology

BMW Diesel Engine Family

Displacement [ l ]

Power [kW]

- 4-cylinder 2.0 l
- 6-cylinder 2.5 / 3.0 l
- 8-cylinder 3.9 l
Recent Developments in BMW’s Diesel Technology

BMW Diesel Product Range

<table>
<thead>
<tr>
<th></th>
<th>4 cylinder</th>
<th>6 cylinder</th>
<th>8 cylinder</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-Series</td>
<td>85 kW</td>
<td>110 kW</td>
<td>150 kW</td>
</tr>
<tr>
<td>5-Series</td>
<td>100 kW</td>
<td>120 kW</td>
<td>160 kW</td>
</tr>
<tr>
<td>7-Series</td>
<td></td>
<td>160 kW</td>
<td>190 kW</td>
</tr>
<tr>
<td>X5</td>
<td>135 kW MJ 03</td>
<td>160 kW MJ 04</td>
<td></td>
</tr>
</tbody>
</table>

Power Output
Recent Developments in BMW’s Diesel Technology

Key Technologies

Core engine
- Durability for cylinder pressures up to 180 bar
- High thermal resistance
- Low friction

Injection system
- High hydraulic performance
- Sophisticated application strategy

Combustion concept
- Combustion chamber layout
- Port design for efficient swirl generation

Air management
- VNT-Turbochargers
- Optimised intake / exhaust system with intercooling

Outstanding performance
Low consumption and emissions
Recent Developments in BMW’s Diesel Technology

Core Engine Design

Cylinder head
- Aluminium alloy with specific thermal treatment
- Design based on sophisticated simulation methods
  - Mould filling
  - Residual stress simulation
  - Strength and fatigue analysis

Crank case
- Material GGV-500
- Cracked main bearing walls
- Two main bearing bolts
Recent Developments in BMW’s Diesel Technology

Combustion Chamber and Port Design

**6-Cylinder Engine**
- Swirl port from the top
- Tangential port with swirl flap from the side

**8-Cylinder Engine**
- Inlet ports coming from one side
Recent Developments in BMW’s Diesel Technology

Fuel Injection System

Common rail system 2nd Generation

- 1600 bar
- Fuel metering
- Small pilot quantities
- High flexible injection strategy
- Reduced dispersion
Recent Developments in BMW’s Diesel Technology

Injection Strategy

![Graph showing engine speed vs. specific work with injection strategies labeled as Pil (Pilot Injection), MI (Main Injection), and Pol (Post Injection).]
### Recent Developments in BMW’s Diesel Technology

#### Characteristics Diesel Electronic Control Units

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ECU-Type</td>
<td>DDE1</td>
<td>DDE2</td>
<td>DDE4</td>
<td>DDE5</td>
</tr>
<tr>
<td>Data Length</td>
<td>bit</td>
<td>8</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>Computer Performance</td>
<td>MIPS</td>
<td>&lt;1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Number of Transistors</td>
<td>Mio</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Memory</td>
<td>kByte</td>
<td>33</td>
<td>64</td>
<td>256</td>
</tr>
<tr>
<td>Number Labels for Calibration</td>
<td>500</td>
<td>1500</td>
<td>4500</td>
<td>7800*</td>
</tr>
<tr>
<td>Number of ECU - Pins</td>
<td>55</td>
<td>55</td>
<td>121</td>
<td>154</td>
</tr>
</tbody>
</table>

*With Master / Slave ECU’s: 15600 Labels for Calibration*
Recent Developments in BMW’s Diesel Technology

Spontaneous Glow System

- Pre Glow Phase < 3 sec
- Reduction Power Consumption
- ECU Mounted to the Engine

Previous Engine
12V Glow Plug

New Engine
6V Glow Plug
Recent Developments in BMW’s Diesel Technology

Spontaneous Glow System

Temperature Glow Plugs

Pre Glow Time

- New Engine
- Previous Engine
Recent Developments in BMW’s Diesel Technology

Air Management
Recent Developments in BMW’s Diesel Technology

Air Management
Recent Developments in BMW´s Diesel Technology

Improvements DI 1\textsuperscript{st} to 2\textsuperscript{nd} Generation

<table>
<thead>
<tr>
<th></th>
<th>1\textsuperscript{st} gen.</th>
<th>2\textsuperscript{nd} gen.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Base Engine:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cylinder pressure</td>
<td>160</td>
<td>180</td>
</tr>
<tr>
<td>Compression Ratio</td>
<td>18:1</td>
<td>17:1</td>
</tr>
<tr>
<td><strong>Injection System:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rail pressure</td>
<td>1350</td>
<td>1600</td>
</tr>
<tr>
<td>Number of Injection</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Min. Pilot quantity</td>
<td>1.6</td>
<td>1.0</td>
</tr>
<tr>
<td>Fuel metering</td>
<td>without</td>
<td>with</td>
</tr>
<tr>
<td><strong>Turbocharging:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max. Boost pressure</td>
<td>2.1</td>
<td>2.3</td>
</tr>
<tr>
<td>Pressure ratio</td>
<td>2.48</td>
<td>2.72</td>
</tr>
<tr>
<td>Max. Turbine Eff.</td>
<td>64</td>
<td>70</td>
</tr>
<tr>
<td>Max. Compressor Eff.</td>
<td>59</td>
<td>63</td>
</tr>
</tbody>
</table>
Recent Developments in BMW’s Diesel Technology

Engine Performance 6-Cylinder in X5

<table>
<thead>
<tr>
<th>Engine Speed [1/min]</th>
<th>Power [kW]</th>
<th>Torque [Nm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel MJ 03</td>
<td>135 kW</td>
<td>260</td>
</tr>
<tr>
<td>Diesel MJ 04</td>
<td>160 kW</td>
<td>300</td>
</tr>
</tbody>
</table>

Diecsl MJ 03 135 kW Engine

Diecsl MJ 04 160 kW Engine
Recent Developments in BMW’s Diesel Technology

Performance / Fuel Consumption - X5 AT

- Acceleration 0-100 km/h: X5 MJ 04 - 10.5 sec, X5 MJ03 - 8.8 sec
- Maximum speed: X5 MJ 04 - 210 km/h, X5 MJ03 - 200 km/h
- Fuel Consumption: X5 MJ 04 - 27.0 mile/gal, X5 MJ03 - 27.0 mile/gal
Recent Developments in BMW’s Diesel Technology

Fuel Consumption in X5 AT – Comparison Diesel / Petrol

**X5 with 3.0 6-cylinder engines**

<table>
<thead>
<tr>
<th>Engine Type</th>
<th>Acceleration 0-100 [sec]</th>
<th>CO₂ Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel MJ 03 135 kW</td>
<td>9.5</td>
<td>20 percent</td>
</tr>
<tr>
<td>Diesel MJ 04 160 kW</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Petrol</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

**FC [mile/gal]**

- **Petrol**: [Data points for Petrol]
- **Diesel**: [Data points for Diesel]
Recent Developments in BMW´s Diesel Technology

NOx- and PM-Reduction for BMW 5 Series Diesel cars

![Graph showing NOx and PM emissions reduction for BMW 5 Series Diesel cars over time, with EU emissions standards and potential with DPF.]
Recent Developments in BMW’s Diesel Technology

Emission Legislation in USA

![Graph showing emission levels and technological developments in BMW's diesel technology.](image-url)
Recent Developments in BMW’s Diesel Technology

Conclusion

- Modern BMW Diesel technology offers powerful, clean and economic engines for the new decade
- Improved combustion systems combined with filter technologies can virtually remove PM-emissions
- The 2007 US NOx-limits are the biggest challenge
  - Technology for highly efficient NOx-aftertreatment
  - Time scale for 2007 very demanding
- The introduction of diesels with durable and enabling emission control technologies should be supported by:
  - Better fuel quality similar to ECE 2005+
  - Slightly legislation adaptations to take account of the specific diesel advantages (long term emission stability, CO2)

Diesel engines could play a major role in saving crude oil and reducing CO2-emissions in USA too
Recent Developments in BMW’s Diesel Technology

DEER Conference 2003 - Newport USA