The BMW Approach to Tier2 Bin5

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Contents.

• Challenges in the US market

• Tier2 Bin5 Concept
  → Internal Engine Measures
  → Aftertreatment: SCR System
  → OBD

• Summary
• Stringent emission legislation
  → limits and test-procedures

• High requirements to OBD
  → new engine control functions

• Intensified climatic edge conditions
  → altitude up to 4000 m

• Customer expectations
  → noise, vibrations, harshness

• Various fuel quality with large dispersions
  → combustion noise, driveability

→ New technologies are necessary
→ Robust, sustainable solutions are required
BMW Diesel.

NOx Challenge BIN 5.

Tier 1 LDT3

Tier 2 Bin 10 (till MY´08)

Tier 2 Bin 8 (MY´09)

Tier 2 Bin 5 (MY´09)

X5 3.0d with EU4 technology incl. DPF

NOx

0,98 g/mi

-94%

0,60

0,14

0,05

0,075

0,23

CO

6,4 g/mi

NMHC

0,32 g/mi

PM

0,08 g/mi

0,10

0,10

0,08
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Test cycles.
BMW Diesel.

Targets for BMW US Diesel.

- BMW typical fun to drive
- Fulfill 50 state legislations (\(\rightarrow\) Tier2 Bin5)
- BMW Diesel Strengths:
  - Low fuel-consumption
    \(\rightarrow\) 20-30\% below comparable petrol cars
    \(\rightarrow\) cost saving, sometimes supported by low fuel costs
    \(\rightarrow\) high cruising range
  - Fun to drive, outstanding torque characteristics
    \(\rightarrow\) relaxed cruising
    \(\rightarrow\) torque on demand
    \(\rightarrow\) good NVH due to low engine speed
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TIER2 BIN5 Concept.

- Modified Combustion with 2-stage Turbocharging
- Diesel Particulate Filter
- SCR-System (Urea)
- Advanced EGR-System
- Piezo Common-Rail Fuel Injection System
- OBD Sensors and Functions
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Combustion.

→ Central injector position
→ 4 valves per cylinder
→ Symmetrical combustion chamber
→ Variable air control

Inline 6.
Displacement 2992 cm³
Single Cylinder Displ. 499 cm³
Bore / Stroke 84/90 mm
Max. Combustion Pressure 180 bar
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Piezo Common-Rail System.

- Very quick needle opening and closing for effective combustion
- Up to 5 shots per combustion stroke
- Very low tolerances of injection quantities
- Long term learn-algorithm for injection control
- High pressure pump with feed volume control
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2-Stage Turbocharger (Variable Twin Turbo).
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Variable Twin Turbo – even more powerfull.

Variable Twin Turbo 3,0 l :
560 Nm at 2000 min⁻¹
200 kW at 4400 min⁻¹

Base engine 3,0 l (MJ 05) :
500 Nm at 2000 min⁻¹
160 kW at 4000 min⁻¹
Variable Twin Turbo – compact design.
Effect of Low Pressure EGR:
• Reduced charge temperature
• Higher boost pressure (efficiency turbocharger)
• Better fuel economy
• 30% NOx-advantage
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Closed Coupled Particulate Filter.

Particles are filtered and burnt off in the ceramic filter with its catalytic coating.

- No power loss (low flow resistance)
- No significant increase in FC
- Reduced HC/CO-emissions
- Reduced system effort
Core Components:

- Urea Tank
- Dosing Module
- Mixer
- SCR-Catalyst
- NOx-Sensor
- Control Unit / ECU

Source: Bosch
**Reduction**

- \( \text{NO} + \text{NO}_2 + 2 \text{NH}_3 \rightarrow 2 \text{N}_2 + 3 \text{H}_2\text{O} \)
- \( 4 \text{NO} + \text{O}_2 + 4 \text{NH}_3 \rightarrow 4 \text{N}_2 + 6 \text{H}_2\text{O} \)
- \( 6 \text{NO}_2 + 8 \text{NH}_3 \rightarrow 7 \text{N}_2 + 12 \text{H}_2\text{O} \)

**Oxidation**

- \( \text{NO} + \frac{1}{2} \text{O}_2 \rightarrow \text{NO}_2 \)

**Thermolysis**

- \((\text{NH}_2)_2\text{CO} \rightarrow \text{NH}_3 + \text{HNCO}\)

**Hydrolysis**

- \(\text{HNCO} + \text{H}_2\text{O} \rightarrow \text{NH}_3 + \text{CO}_2\)
Targets

- Improve Ammonia distribution → maximum conversion
- Reduce Ammonia slip, because of overloaded catalyst cells
- Best possible usage of mixing element
- Analysis of pressure drop and optimisation

Modelling Approach

- Transient CFD Simulation with StarCD
- Two component droplets (water, urea)
- Spray break-up and wall interaction
- Turbulenz modelling: k-ε RNG
- Modelling of wall film
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Droplet Distribution.

Base Mixer

Optimized Mixer

Droplet Diameter

high

low
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Droplet Distribution.

huge amount of droplets pass the mixer untouched

optimized mixer

improved droplet break-up

Droplet Diameter
BMW Diesel.

NH₃-Vapour Distribution.

Base Mixer

Optimized Mixer

TIME = 0.250 s

NH₃ Vapour

high

low
Ein Teil der Tröpfchen wird gegen die Wand geschleudert und verdampft.

Verdampfung zentraler am Mischer.

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NH₃-Vapour Distribution.

Base Mixer

Optimized Mixer

less urea evaporates on cooler exhaust pipe wall

better evaporation on hot Mixer

NH₃ Vapour
NH₃-Vapour Distribution.

Base Mixer

inhomogeneous NH₃ - distribution

Optimized Mixer

optimized NH₃ - distribution

NH₃ Vapour
test result: 43 mg/mi NOx

- Ammonia slip
- high efficiency of SCR-catalyst
- exhaust temperature
SCR-Catalyst Monitoring

→ NOx converting efficiency of the SCR-catalyst is calculated using downstream and upstream NOx-concentration

\[ \eta = 1 - \frac{\int NO_x \text{ downstream}}{\int NO_x \text{ upstream}} \]

NOx-sensor tolerances are very important!
Monitoring of Dosing / Long Term Adaptation of the System

→ Deviation from optimum converting efficiency is detected by NOx-sensor and adaptation is carried out

• Ammonia cross sensitivity of the sensor is used
• Progression of signal curve is elementary to keep the optimum
Example: X5 3.0d

- Advanced Combustion
- Improved EGR
- DPF + SCR

-94% NOx reduction

Tier 1 (MDV 2) till MY´2003

EPA Bin 10 till MY´2008

US application based on EU 4-technology

EPA Bin 8

EPA Bin 5 = ULEV II
• BMW at leading edge of Diesel technology.

• A whole package of technologies is necessary to fulfill the challenging Tier2 Bin5 limits
  • Engine internal measures (combustion, boost-concept, EGR)
  • Aftertreatment (DPF + Urea-SCR)

• Clean Diesel technology can contribute a lot to save the future mobility.

• Mid- and long-term potentials for further reduced emissions, fuel consumption and increased power are under development.
Thank You for Your Attention!