Injection System and Engine Strategies for Advanced Emission Standards

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Content

- Emission Legislation
- Strategies for US 2010 Engine Certification
- Consequences for FIE
- Summary
Main Modules for US 2010 Strategies

NOx limit
PM limit
Test Cycles
Specific engine power
Engine/vehicle life time position
Synergies with other markets

SCR
- conversion rate
- T.-Mgmt. at cold start

Air Mgmt.
- boost pressure
- VGT/2-stage TC

FIE
- max. inj. pressure
- rate shaping capability
- multi inj. capability

Control Strategies

EGR
- EGR rate
- cooling capacity

DPF
- open system
- closed system

SCR = Selective Catalytic Reduction
FIE = Fuel Injection Equipment
EGR = Exhaust Gas Recirculation
DPF = Diesel Particulate Filter
VTG = Variable Turbine Geometry
TC = Turbo Charger
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HD Engines - Emission Standards & Cert. data

- **EU 3 (10/00)**
- **HD Engines**
- **Emission Standards & Cert. data**
- **PM (g/kWh)**
- **NOx (g/kWh)**

- **ESC limits**
- **ETC limits**

- **US '04**
- **US '98**
- **US '10**

- **EU 3 – small engines**
  
- **up to now: SCR strategy only, EGR strategy announced**

- **EU 5 (10/08)**
- **EU 4 (10/05)**

- **EGR or SCR strategy**

- **EU 6 - EC scenarios**

- **EU 6 - UBA proposal (2012)**

- **EC scenarios**

- **EGR strategy**

- **ETC limits**

- **ESC limits**

1) \( V_{Cyl} < 0.75 \text{ dm}^3 \) and \( n_{\text{Rated}} > 3000 \text{ rpm} \)

2) **NMHC+NOx limit / values**

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US 2010 Engine Certification

ESC test results

Conversion rate:
- $\eta_{\text{NOx}} = 75\ldots85\%$
- $\eta_{\text{PM}} = 60\ldots95\%$

Eng. goal:
- NOx $\Rightarrow 20\%$
- PM $\Rightarrow 30\%$

High-end TC and cooling allows top rating at very low emissions / bsfc

c.a. 2 l/Cyl., ca. 30 kW/l, CRS 1800…2000 bar
ca. 1 l/Cyl., ca. 35 kW/l, CRS 1800…2000 bar
ca. 0.5 l/Cyl., ca. 43 kW/l @ 3800 rpm, CRS 1800 bar
HD Engines – FIE requirements

Inj. Pressure demand = f (air system parameters)

Injection pressure ↑

BSFC

Boost pressure ↑

λ_{full load} = 1.3...1.6

EGR rate ↑

Cooling ↑

NOx

soot = const.
HD Engines – FIE requirements

Multiple Injection

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US 2010 Engine Certification

Summary – US 2010 requirements

Injection System

- Injection pressure CRS ≥ 1800 bar (depending on quality of air system)
- Advanced injection timing for optimum fuel consumption
- Multiple injection
  - coupled post injection for soot reduction
  - pilot injection for NOx reduction at upper loads, for combustion noise reduction at part load

Air system

- cooled high-pressure EGR, EGR rates up to 30% at full load
- Advanced turbocharger (high-end VGT or 2-stage TC with IC)
- High-end charge-air and EGR cooling for best performance / emissions

Exhaust Gas Treatment

- Combination of SCR ($\eta_{NOx} \geq 75\%$) and DPF with active regen. strategy
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Improvement of specific fuel consumption of engine

Measured benefit of specific fuel consumption for a MD application by improved FIE

Reduced driving power by:
- optimized injector
- dethrottled system

Load

100 %
75 %
50 %

Speed

A
B
C

0.7%
0.7%
0.9%
1.0%
1.7%
CRSN Hydraulic Optimization Measures

Measures to increase injection pressure

 Benefit:

Average injection pressure

Minimum injection pressure

with measures
w/o measures

Average injection pressure

Minimum injection pressure
Efficiency of injection nozzle

HD Engine (ca. 2 l/Cyl.) with CRS: C100

- Soot index [g/kWh]:
  - 0.00
  - 0.02
  - 0.04
  - 0.06
  - 0.08
  - 0.10
  - 0.12

- isfc [g/kWh]:
  - 185
  - 195
  - 205
  - 215
  - 225
  - 235
  - 245
  - 255
  - 265

- NO\textsubscript{X},indi. [g/kWh]:
  - 0.00
  - 0.02
  - 0.04
  - 0.06
  - 0.08
  - 0.10
  - 0.12

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ks nozzles with significant soot reduction potential
LD/MD/HD Engine Common Rail Injector - Evolution

CRIN1
LD - HD
1400 bar

CRIN1.6
LD - MD
1600 bar

CRIN2
LD - HD
1600 bar

CRIN3
LD - HD
1800 bar

CRIN3.3
LD - HD
2000/2200 bar

EU3/4/5
US04

EU4/5
US07

“High efficiency”
EU6
US10

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Summary – Consequences for FIE

Scaleable FIE
CRSN1 to CRSN3
(1400 to 1800 bar)

High efficiency
CRSN3.3 System
(2000/2200 bar)

One ECU
concept
EDC17 for all
markets

EGT strategy
for all
emission
legislations

Plug & play components

Scaleable FIE for all segments from EU3 to US10

High efficiency as important as injection pressure
- Pump driving power
- Rail to nozzle efficiency
- Nozzle bore efficiency

High efficiency components have potential for >>2200 bar
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Summary & Outlook

- Engine test results @ Bosch show US 2010 engine-out emissions with CRS 1800…2000 bar for an engine range of 0,5 l/cyl. to 2 l/cyl.

- Best engine performance – in terms of soot/NO\textsubscript{X} emissions and fuel consumption – is achievable in combination with high-end turbocharger and high-end charge-air resp. EGR cooling.

- Additional fuel consumption benefit can be achieved by improved FIE efficiency (system, injector, nozzle) and increased injection pressure.

- Scaleable injection system with ECU supporting all EGT strategies supports world engines with applications from EURO3 to US10.

- In 2010 Bosch is offering CRS 1400 bar to 2200 bar high efficiency. FIE pre-development focuses on CRS injection pressures >>2200 bar based on high efficiency 2200 bar CRS.
Thank you for your attention

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