FUEL EFFICIENCY OF NEW EUROPEAN HD VEHICLES

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OUTLINE

• Background – Euro 4
• Test methods
• Test vehicles
• Truck & bus results
• Conclusions
BACKGROUND – EURO 4/5

- The Euro 4 requirements definitely entered into force in October 2006, Euro 5 will be introduced in 2009
  - the Euro 5 requirements roughly correspond to US 2007 requirements
- The new emission limits are forcing manufacturers to use high volume EGR or/and exhaust after-treatment systems
  - SCR (Selective urea catalyst system) is the preferred emission reduction technology in Europe
  - however, some manufacturers have opted for EGR technology
EQUIVALENCE OF EMISSION REGULATIONS

Oikawa et al 2005

DEER 2007 Conference, August 12-16, Detroit, Michigan
BACKGROUND – EURO 4/5

• Engine manufacturers’ choices to meet Euro 4 emission regulations
  • SCR (Selective Catalytic Reduction)
    • Volvo
    • Mercedes-Benz
    • Iveco
    • and others..
  • EGR (Exhaust Gas Recirculation)
    • Scania
    • MAN (+ partial particulate filter PM-KAT)
BACKGROUND – EURO 4/5

• How do new Euro 4 trucks and buses perform under real-world driving?
• What happens to fuel economy, is there an automatic fuel penalty for low emissions?
• Will more stringent emission regulations actually provide reduced real-life emissions?
TEST METHODS

• Real world transient driving cycles on a HD chassis dynamometer
  • City bus cycles
    • Braunschweig – city center driving
    • Helsinki 2 – city center driving
    • Helsinki 3 – suburban driving
  • Heavy duty truck cycles
    • Delivery – max 26t (metric tons)
    • Highway – max 60t
    • Freeway – max 60t (using cruise control)
TEST METHODS

Braunschweig Bus Cycle

Freeway cycle, original onroad data, 420 hp / 50 t

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TEST METHODS

• Significant work has been devoted to the development of realistic and accurate fuel consumption measurements
  • Realistic duty cycles, including road gradient simulation for HD trucks
  • Standardization of test conditions and elimination of variations
    • standardized test fuel (ultra low sulfur)
    • special sets of conditioned measurement tires
    • fixed test procedures, including warm-ups and conditioning of the vehicle
    • elimination of influence from, e.g., air compressor and cooling fan
    • etc..
Accuracy:
- fuel consumption $\pm 1\%$
- exhaust emissions $\pm 15\%$
TEST VEHICLES – CITY BUSES

Volvo – Brand A
  4x2 Euro 3 MY 2005
  4x2 Euro 4 SCR MY 2006
  6x2 Euro 5 SCR MY 2006

Mercedes-Benz – Brand B
  4x2 Euro 4 SCR MY 2006

Scania – Brand C
  4x2 Euro 3 MY 2005
  4x2 Euro 4 EGR MY 2006
  6x2 Euro 4 EGR MY 2006
TEST VEHICLES - TRUCKS

Euro 4 trucks, all model year 2006

• Scania R470, EGR
• MAN TGA.430, EGR + PM-KAT
• MB Actros 1844, SCR
• Volvo FH480, SCR
• Iveco Stralis 420, SCR
Fuel consumption in different cycles

- Braunchweig Helsinki
- Helsinki2
- Helsinki3

<table>
<thead>
<tr>
<th>Fuel consumption l/100km</th>
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<tr>
<td>Brand A Euro 3</td>
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<tr>
<td>Brand A Euro 4 SCR</td>
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<tr>
<td>Brand C Euro 3</td>
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<tr>
<td>Brand C Euro 4 EGR</td>
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<tr>
<td>Brand B Euro 4 SCR</td>
</tr>
<tr>
<td>Brand A Euro 5 SCR 3-axle</td>
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<tr>
<td>Brand C Euro 4 EGR 3-axle</td>
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FUEL CONSUMPTION – CITY BUSES

Study for the Finnish Public Transport Association

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FUEL AND UREA COSTS – CITY BUSES

Fuel and urea costs per 100 km, when diesel 74 c/l, urea 55 c/l

Expenses €/100km

- Brand A Euro 3
- Brand A Euro 4 SCR
- Brand C Euro 3
- Brand C Euro 4 EGR
- Brand B Euro 4 SCR
- Brand A Euro 5 SCR 3-axle
- Brand C Euro 4 EGR 3-axle
- Urea

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EMISSION RESULTS - CITY BUSES

NOx and PM emissions over the Braunschweig city bus -cycle

Summary of all VTT’s measurements conducted at VTT between 2002 and 2006

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First report disclosing vehicle brands and models


Nils-Olof Nylund, Kimmo Erkkilä & Tuukka Harukka

Fuel consumption and exhaust emissions of urban buses

| Performance of the new diesel technology
FUEL CONSUMPTION – HD TRUCKS

Fuel consumption on highway and freeway cycles.
Full trailers (max. 60t)

Euro3 Average
Scania R 470 Euro4
MAN TGA 26.430 Euro4
Iveco Stralis 420 Euro4
Volvo FH480 Euro4
MB Actros 1844 Euro4

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FUEL AND UREA COSTS – HD TRUCKS

Costs (Fuel 0.74 €/litre, Urea 0.55 €/litre) on highway and freeway cycles. Full trailers (max. 60t)

Average results for tested truck models:

E3 → E4 SCR => costs - 7%
E3 → E4 EGR => costs -1%
EMISSION RESULTS – HD TRUCKS

Full trailers (max. 60t)
PM- and NOx-emissions on highway and motorway cycles

Euro3 Average
Scania R 470 Euro4
MAN TGA 26.430 Euro4
Iveco Stralis 420 Euro4
Volvo FH480 Euro4
MB Actros 1844 Euro4
Freeway
Highway

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The Euro 4 truck results are included in the Annual Report for 2006 of VTT’s “RASTU” project on HD vehicles.

CONCLUSIONS

• European engine manufacturers have taken two different approaches to meet the Euro 4/5 emission regulations, the EGR and the SCR route (SCR being the more common solution)

• On an average, the introduction of Euro 4 emission regulations has not increased fuel consumption

• City buses:
  • most of the measured Euro 4/5 city buses produced Euro 3 equivalent emissions
  • one SCR bus demonstrated low emission levels in real world driving cycles
  • no clear winner (EGR vs. SCR) for fuel consumption or emissions
CONCLUSIONS

• HD trucks
  • SCR technology provided significantly better fuel economy than EGR technology
  • both EGR and SCR technology performed well regarding exhaust emissions as the real-world emissions corresponded to the anticipated Euro 4 level
  • along with the differences in exhaust control strategies, the differences in engine sophistication also affect the fuel consumption results
  • the results depict the performance of the first new Euro 4 vehicles
  • further improvements in exhaust performance and fuel efficiency is expected for both EGR and SCR vehicles
FUTURE WORK

• Some vehicles will be subjected to follow-up to define the emission stability of new emission control technologies in the long run
• Some measurements will be done to evaluate the emission performance in cold climate conditions
• One truck did not work properly (high PM emissions) -> measurements need to be redone
• VTT’s emission database will be updated with data on new bus and truck types
Thanks for your attention!