Effects of Diesel Particle Filters on Performance of In-Use Buses

Leonid Tartakovskiy, Rafael Fleischman, Ran Amiel
Technion – Israel Institute of Technology

Jan Czerwinski
Labs for IC-Engines & Exhaust Emission Control, University of Applied Sciences, Switzerland

Andreas Mayer
TTM – Technik Thermische Maschinen, Switzerland
Motivation

• Particle emissions: dangerous to human health
• Nanoparticles: even more dangerous
  • Penetrate the cell membranes and enter into the blood stream
  • Reach brain and other organs
• Road transport: main source of air pollution in Israel’s population centers
• Public transportation: based almost entirely on diesel engines
DPF retrofitting

• Diesel engine buses may be kept in service for 15 years or more
• Emission control technologies become obsolete
  • Old buses turn into big polluters
• Retrofitting with Diesel Particulate Filter (DPF):
  • Cost-effective measure to reduce particulate matter emissions

![Israeli Bus Fleet Composition](image)
Research Goals

• Evaluate the reduction in nanoparticle emissions of in-use diesel buses retrofitted with DPF

• Assess the impact of retrofitting on the buses performance in real-world usage conditions
DPF selected

- Temperature profile
- CRT (Continuously Regenerating Trap)
  - Collected soot is continuously oxidized by NO₂ (generated in an oxidation catalyst upstream of the filter)
- VERT-certified
- 3 different manufacturers
Buses tested

• 18 in-use Euro III buses
  • 9 urban Man NL313F buses
  • 9 intercity Mercedes-Benz OC500 coaches
• 3 different topographies
  • Flat terrain – Tel Aviv area
  • Hilly terrain – Jerusalem area
  • Combined terrain – Haifa area
• Control group of 18 identical vehicles in identical routes
Evaluated parameters

- PN concentrations and size distribution
  - Calculation of PM
    \[ m_i = \rho \frac{\pi d_i^3}{6} n_i \]
- Upstream and Downstream DPF
- Calculation of DPF filtration efficiencies (number and mass based)
  \[ PNFE = \frac{(TPN_B - TPN_A)}{TPN_B} \cdot 100 \]
  \[ PMFE = \frac{(TPM_B - TPM_A)}{TPM_B} \cdot 100 \]
- Effect on fuel consumption
- Effect on backpressure
Particulate Number measurement procedure

• 3 measuring rounds:
  • shortly after DPF installation
  • 4 months later
  • 10 months later

• 4 Operating Modes:
  • Low idle
  • High idle
  • Full Load, 85% rated speed
  • Free acceleration
Particulate Number Measurement: Experimental Setup

- **Particle Sizer:**
  - *EEPS 3090 TSI Inc.*

- **Sample dilution and conditioning:**
  - *379020A-30 TSI Inc.*

- **ECE-PMP-Protocol**
  - Sampling temperature: 300°C
  - Particles above 23 nm were considered
Fuel Consumption

Urban vs. Intercity
- Pilot: 18 buses
- Intercity coaches: better fuel efficiency

Seasonal variation
- Pilot & Control: 36 buses
- Hot summer: Air conditioning

Average: 2.35 km/l
Average: 1.70 km/l

Fuel Consumption [km/l]

<table>
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<tr>
<th>Intercity</th>
<th>Urban</th>
<th>DPF Installation</th>
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Difference [%]

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<th>Summer</th>
<th>Difference [%]</th>
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DPF effect on fuel consumption

- Evaluation of average natural deterioration of fuel efficiency due to vehicle aging
  - Equal periods, both without DPF retrofit (Pilot & Control: 36 buses)
  - Intercity: **1.82%** (per year)
  - Urban: **1.54%** (per year)

- Evaluation of DPF effect on fuel consumption
  - Equal periods, without and with DPF retrofit (Pilot: 18 buses)

Average increase of fuel consumption due to DPF:
- Intercity: **2.5%**
- Urban: **2.1%**
Backpressure

- Pressure sensors were installed upstream the DPF
- Pressure sensors frequency: 10 Hz
- Limit pressure increase: 150 mbar
Nanoparticle size distribution (IntercityI3)

- **Low Idle**
- **High Idle**
- **85% Load**
- **Acceleration (peaks)**

Graphs showing the lognormal particle number distribution ($dN/d\log Dp$) in [#/cm$^3$] for different conditions: Low Idle, High Idle, 85% Load, and Acceleration (peaks).
Nanoparticle size distribution (Urban U3)

Low Idle

High Idle

85% Load

Acceleration (peaks)
Filtration Efficiency

Particle count filtration efficiency > 97%
PCFE for intercity and urban buses

- Higher PCFE for Intercity buses

Average PCFE:
- Intercity: 98%
- Urban: 96%
Conclusions

• Average particle count filtration efficiency of the tested DPFs: 98% and 96% for intercity and urban buses, respectively

• Low idle regime: slightly lower filtration efficiencies

• Increase in fuel consumption due to air conditioning: 4% and 8.1% for intercity and urban buses, respectively

• Increase of fuel consumption due to DPF retrofitting: 2.5% and 2.1% for intercity and urban buses, respectively

• Backpressure increase values: below 80 mbar after 11 months of buses operation

• No deterioration in vehicle drivability was reported

• No unusual repairs or changes in maintenance operations
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Thank you!

Further info:

Leonid Tartakovsky  tartak@technion.ac.il