Experimental program with retrofit open particulate filters for diesel trucks

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Contents

1. Introduction
2. Objectives
3. Experimental set up
4. Test cycles
5. Test results
6. Discussion, Conclusions
1. Introduction

- In The Netherlands from 2006 onwards installation of HD retrofit soot filters (semi-open and closed) have been subsidized by the Dutch government.

- HD retrofit soot filters

<table>
<thead>
<tr>
<th>Type/Name</th>
<th>Req.eff. [%]</th>
<th>Subsidy [€]</th>
<th>Number installed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open / PM-cat</td>
<td>&gt; 50%</td>
<td>4250 / 0</td>
<td>6250 / 0</td>
</tr>
<tr>
<td>Closed / DPF</td>
<td>&gt; 90%</td>
<td>7000 / 5500</td>
<td>9000 / 0</td>
</tr>
</tbody>
</table>
2. Objectives

• Determination of the efficiency of used retrofit open particulate filters (PM-cat) for trucks in **real world** conditions

• PM-cat efficiency in urban areas?
• Effect of 1 hour motorway use on efficiency in urban areas?
• Aging effects?
• Soot loading versus efficiency?
• Regeneration behaviour
3. Experimental set up

Part 1:
• 1 HD-engine 355 kW Euro III on **engine dynamometer** (TNO-The Netherlands)
• 6 used PM-cats (open)

Part 2:
• 3 different Euro III delivery trucks on **chassis dynamometer** (VTT-Finland)
• 7 used PM-cats (open)
3. Experimental set up engine dyno

- 12 litre Euro III engine, 355 kW
- Full flow dilution tunnel + CVS
- AVL 439 smoke meter
- EN590 fuel (S<10 ppm)

- 6 used PM-cats of 1 type (pre oxicat + filter element)
- 65 emission tests engine out
- 130 emission tests PM-cat 1 - 6
3. Experimental set up chassis dyno

- 3 different delivery trucks Euro III
- Chassis dynamometer
- Full flow dilution tunnel + CVS
- EN590 fuel (S<10 ppm)

- 7 used PM-cats of 4 types
- 70 emission tests engine out
- 145 emission tests with PM-cat

<table>
<thead>
<tr>
<th>Number of emission tests</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>Engine out</td>
</tr>
<tr>
<td>Truck 1</td>
</tr>
<tr>
<td>Truck 2</td>
</tr>
<tr>
<td>Truck 3</td>
</tr>
</tbody>
</table>
3. History and use 13 PM-cats

PM cat history

- 10 PM-cats 80.000 – 140.000 km and 3 PM-cats 30.000 – 50.000 km
- Most PM-cats have run 1 – 1,5 year
4. Test cycles

<table>
<thead>
<tr>
<th>Engine dynamometer</th>
<th>Chassis dynamometer</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHTC urban part cold 900 s</td>
<td>City Cycle 11,5 tonne 1234 s</td>
</tr>
<tr>
<td>WHTC urban part hot 900 s</td>
<td>City Cycle 18,5 tonne 1234 s</td>
</tr>
<tr>
<td>ETC (Type approval PM-cat) 1800 s</td>
<td>Motorway 11,5 tonne 1272 s</td>
</tr>
<tr>
<td>Motorway (85 km/h)</td>
<td>Motorway 18,5 tonne 1272 s</td>
</tr>
</tbody>
</table>

Do the test cycles cover real world conditions?
4. Motorway total vehicle **weight** distribution truck
   (real world)

- **Minimum truck weight 11 tonne, Maximum truck weight 20 tonne**
- *(source: highway automatic truck weighing system, 4000 trucks)*
4. Delivery truck real world temperature distribution

- Data: 1 truck, 300 days, 24h per day
- User profile: Start 90% vehicle load, motorway. Generally re-load at mid day. Empty in 2-3 stops (half day)
5. Test results temperatures pre PM-cat

- Real world and laboratory PM-cat temperatures are similar
- Temperature pre PM-cat is adjusted to a real world level by adjustment of absorbed load
5. Test results PM-cat efficiencies per cycle
(minimum, average, maximum)

Some PM-cats have large variation in efficiency
5. Individual PM-cat efficiencies

Efficiency range PM-cats
engine and chassis dyno tests

- Real world average efficiency of 13 PM-cats is 29.3 %.
- 1 PM-cat has an average efficiency of more than 50%
6. Discussion and conclusions

- Strong variation in efficiency between different PM-cat truck combinations

- Real world PM-cat efficiency lower than type approval:
  - Total average = 29 %
  - City driving = 29 %
  - Motorway driving = 29 %

- PM-cat efficiency is very dependent on the historic load pattern
  - Start type approval with realistic loaded PM-cat (>1 week real world)
  - real world load pre-conditioning (250 – 275 °C) should be a part of the type approval

- Separate test cycles for city and motorway driving should be considered for type approval
Thank you very much for your attention!

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5. Results PM-cat 2 engine dyno (33.000 km/year)

PM cat 2 efficiencies, 30.000 km

- PM-cat 2 has negative efficiencies and probably is loaded with PM (history)
- Stored PM releases during ETC-tests (PM-cat efficiency -107% - -3%)
- Extreme regeneration (2 hours @ 500 °C) removes stored PM, PM-cat efficiency is 40 and 32%
- 16 hours WHTC-urban + idle + 1 hour motorway results in an inactive PM-cat (eff. -1 - +13%)
5. Results PM-cat 6 engine dyno (29,000 km/year)

- First tests PM-cat efficiency is 0% and increases to 20% at higher loads (history)
- Steady state testing: PM-cat efficiency is 35 - 50%
- PM-cat efficiency in WHTC-urban cycle is -6 – 5 – 16%
- After heavy regeneration PM-cat efficiency in ETC-test is 31 – 50%.
5. Results PM-cat 1

chassis dyno Truck 2, 45.000 km/yr

Truck 2, Efficiencies PM-cat 1 (53.000 km)

- PM-cat history determines efficiency
- After a period of city use, the PM-cat efficiency on the motorway is poor