Evaluation of measuring methods for particle emission from modern diesel vehicles in periodic emissions control – Studies and Results

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Introduction
As Work package 2 of the ENVEQ Plusmission project (6W11110, to 06/2013) (two metrolological institutions (PTB, DLR), METAS (CH), MIKES (FIN) and the JRC-IE evaluated measuring methods for periodic emissions controls of modern diesel vehicles. After the specification of consistent requirements for the novel measuring instruments a call of instruments were launched in March 2012 to appraise fifty European manufacturers and their associations for automotive emission testing instruments. Finally six manufacturers provided prototypes of their new developed instruments which were the following: four light scattering instruments (L1, L2, L3) which were developed for the periodic emission tests according to the German VI 38.9. Two instruments which works with the diffusion changing principle (DCC, DCC) and are already commercially available for other applications and one kanisionation chamber (CC) as an early stage prototype, based on a house hold smoke alarm detector, developed in the frame of a research program. All tested instruments were prototypes for this application. The evaluation of the instruments included laboratory tests, field measurements at the JRC-IE as well as on-road tests maintained under service conditions. This work will establish the metrolological background to support the efforts to bring the regulatory emission control equipment in control. To make progress with repect to the recent advances in diesel after treatment technologies. To establish a periodic emission control for modern diesel vehicles in the future.

Tasks and Objectives
- Future procedures will have to cover emissions of conventional high emitting diesel vehicles and DPF-equipped diesel vehicles (more than three orders of magnitude lower).
- If the purpose of a inspection check to identify malfunctions of the emission control device, in particular checks in the DPF, different procedures have to be applicable for non-DFP- and DPF-equipped vehicles.

Requirements for the laboratory tests
- EUT needs to be assessed through comparison to Particle Number and/or Opacity-based instruments.
- Checks should be performed over a large range of number concentrations and light extinction coefficients using a range of size distributions typical for light-duty diesel exhaust fuels.
- Tested parameters should be sensitivity, linearity, size response, response to particles below 100 nm, resistance, times response to volatile particles

<table>
<thead>
<tr>
<th>NIM</th>
<th>Base type</th>
<th>Generator</th>
<th>Size</th>
<th>Number concentration (cm⁻³)</th>
<th>Absorption-coefficient (µm²/νg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PTB</td>
<td>CAST</td>
<td>Modified high mass</td>
<td>50 - 200</td>
<td>1.6 - 2.2</td>
<td>1.16 - 1.16² - 1.16³</td>
</tr>
<tr>
<td>METAS</td>
<td>CAST</td>
<td>Prototype CAST, housebuilt</td>
<td>23 - 200</td>
<td>1.4 - 1.7</td>
<td>4.0 - 1.5² - 1.5³</td>
</tr>
<tr>
<td>MIKES</td>
<td>diesel soot</td>
<td>diesel soot generator, housebuilt</td>
<td>30 - 150</td>
<td>1.7 - 2.2</td>
<td>6.0 - 1.0² - 1.0³</td>
</tr>
</tbody>
</table>

Selected results of the laboratory tests

Limit volume from 5% to 0.7 m³ at least to 0.5 m³

Evaluation of novel measuring instruments for periodic emissions testing
- Determination of technical requirements for novel instruments (prototypes)
- Evaluation in laboratory tests
- Applicability of novel measuring instruments for periodic emissions control in field tests
- Tests under controlled conditions similar to the type/approval testing
- Tests under service conditions

Test under service conditions
- The measurements were performed as usual periodic emission tests at DEKA, Stuttgart (Germany) with three different vehicles:
  - Audi A4 (Euro5) with a full functioning DPF
  - VW Passat (Euro6) with a broken DPF
  - VW Multivan (Euro 6) with an upgraded DPF

Field test in Velat1 at JRC-IE
- Sampling performance during the practical viability tests at DEKA, Stuttgart, single sampling tubes for each instrument were emptied on a extension tube behind the exhaust pipe.
- Response of the reference instrument (L1, L2, L3, DCC) to the peak absorption coefficient and the blank difference between single values, measuring with ISO FEM (FEM 42.0800) and the instruments under test to the emitted particle concentration (primary vertical and particle concentration in µm²/µg).
- Comparison of the emission specific PM emissions measured by the reference instrument (CAST, OMPS, Counter, EMP, COMP) at VISU, at Velat1 and the devices under test.

Conclusions
- Future regulations regarding the periodic emission control for diesel vehicles should be based on opacity measurement or number concentration (PM) measurements. The instruments under test are able to display the two measurements (L1 or only PM, L2) depending on the measurement principle. The results of the laboratory tests demonstrated that the Diffusion charger as well as the kanisionation chamber was more sensitive to small particle sizes (below 20 nm) and very low concentrations (below 200 µm²/µg) than the light scattering instruments.
- The tests under service conditions at DEKA showed that all tested measurement instruments were able to detect DPF failures and the emissions of a Euro6 vehicle equipped with an upgraded DPF. The emitted particle concentration of the full functioning Euro 5 vehicle was too low to be detected by any instruments under test.


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