Tests for the evaluation of measuring methods for particle emissions from modern diesel vehicles in periodic emission control

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Introduction

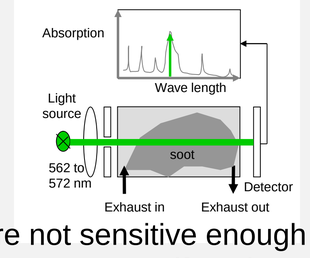
Due to decreasing particulate emissions of modern diesel vehicles, it has become necessary to bring the regulatory emission control equipment in line with technical progress. Therefore, the establishment of novel measuring instruments and procedures for periodic emissions control is required. In particular, the maintenance procedures have not been amended to reflect the recent advances in diesel aftertreatment technology, i.e. the use of diesel particle filters (DPF)). Also the changes in the certification procedures for diesel engines with respect to the measurement of the soot particle numbers. There is an increasing debate about the suitability of the currently used opacimeters for the quantification of the soot emission from DPF-equipped engines and about their ability to identify DPF malfunctions. However, significant progress has already been made in modern aerosol instrumentation: High-sensitivity instrumentation for soot emission has appeared in research applications and is currently being commercialized. These techniques can be used to determine opacity, soot mass concentration or particle number concentration in the exhaust gas with various detection principles and can significantly outperform the classical opacimeters used for vehicle inspection up to now. But the implementation of the improved analysers in legal metrology requires a well-founded metrological validation, which hasn't been realized so far.

Motivation

k < 3,0 m^{-1}

Opacimeter:

• attenuation of transmitted light



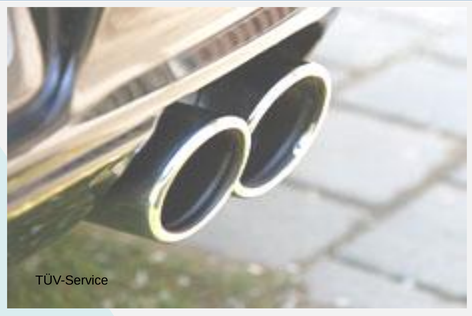
• are not sensitive enough to detect DPF malfunctions

Technical Progress

→ **decreasing particulate emissions of modern diesel vehicles**

→ **decreasing emission limits**

But regulatory emission control equipment have not been amended. Classical opacimeters used for vehicle inspection up to now



k < 0,5 m^{-1}

Novel instruments

Modern aerosol instrumentation for soot emission has appeared in research applications and is currently being commercialized. Measurands are: Opacity, Particle number (PN (/cm³)) or Particle mass (PM (mg/cm³))

prototypes with varying physical principles

Tasks and Objectives

As part of the "ENV02 PartEmission" project (06/2011, to 05/2014) within the framework of the European Metrology Research Programme (EMRP), four metrological institutions (PTB, METAS, MIKES and JRC-IE) are currently evaluating modern measuring methods for periodic emissions controls of modern diesel vehicles. Work package 2 in ENV02 lead by PTB currently evaluates soot detection instruments as well as the metrological procedures for the periodic emission inspection of diesel vehicles

1. Specification of consistent requirements for the novel measuring instruments
2. **Evaluation of prototypes in laboratory tests**
3. Field measurements with suitable instruments identified before
4. User handling experience with the novel instruments

➢ **Metrological background for the measurement of particle concentration in exhaust gases of diesel vehicles in periodic emission control**

➢ **Validation of novel instruments provides ideas for new developments of instruments**

➢ **Support for the adaption of the periodic exhaust emission control to technical progress**

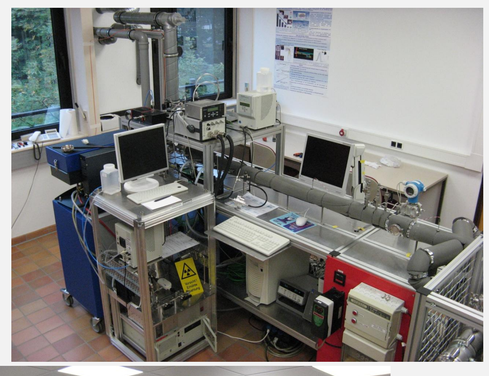
➢ **Trusted periodic emission control**

Laboratory tests

Devices under test:

3x light-scattering instruments
1x electrical particle sensor
1x measuring ionization chamber
2x diffusion size classifiers

Many thanks to the manufacturers providing the instruments

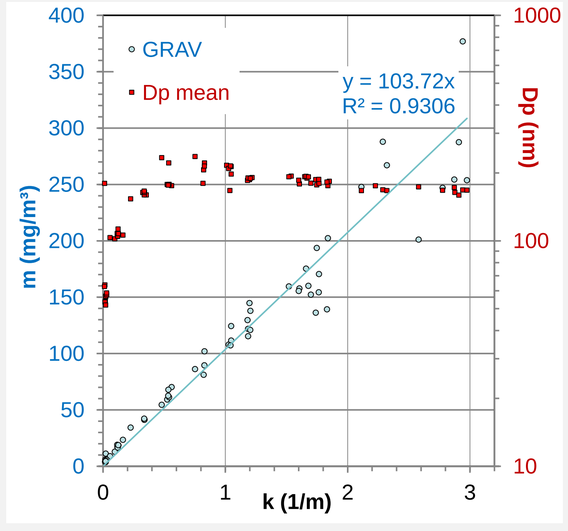


All instruments will be accessed together at each laboratory

(from Dec. 2012.:to Sep. 2013)

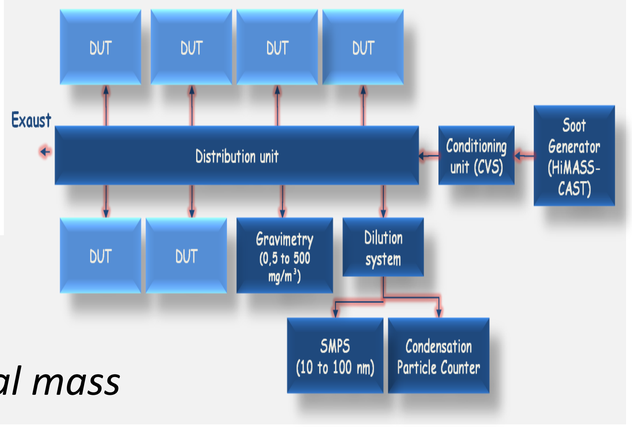
at PTB: PM, opacity, CAST-soot, high concentrations
at METAS: PN, CAST-soot, low concentrations
at MIKES: PM, PN, diesel-soot

Test-setup at PTB

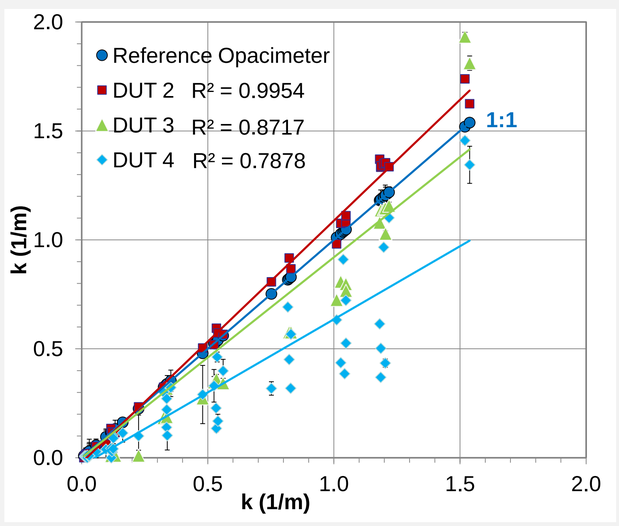


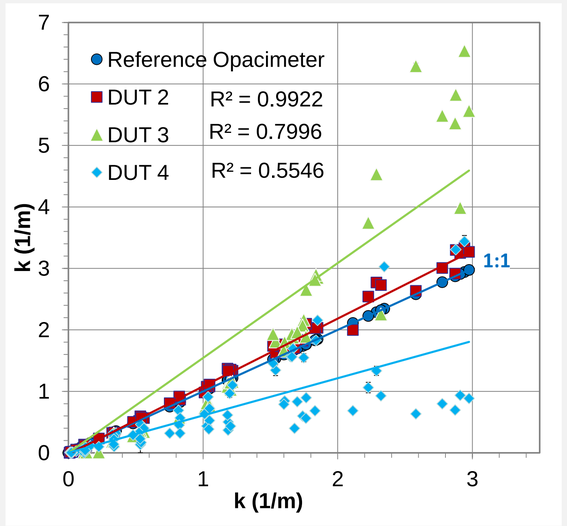
Comparison between reference opacimeter (AVL 439) and mass concentration from gravimetrical mass

• soot generator, HiMASS-CAST
•characterization of soot aerosol
• distribution to devices under test (DUT)

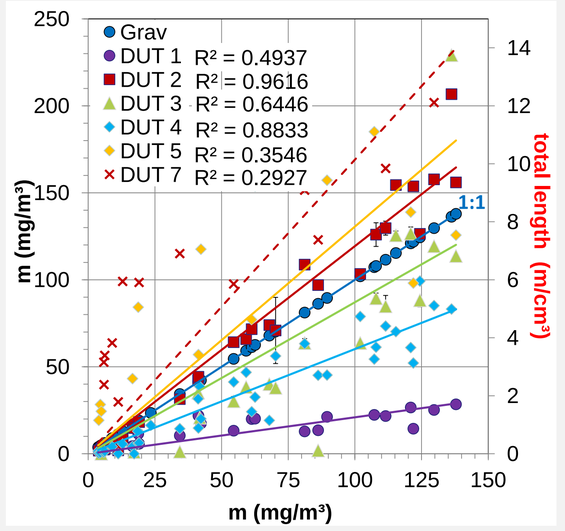


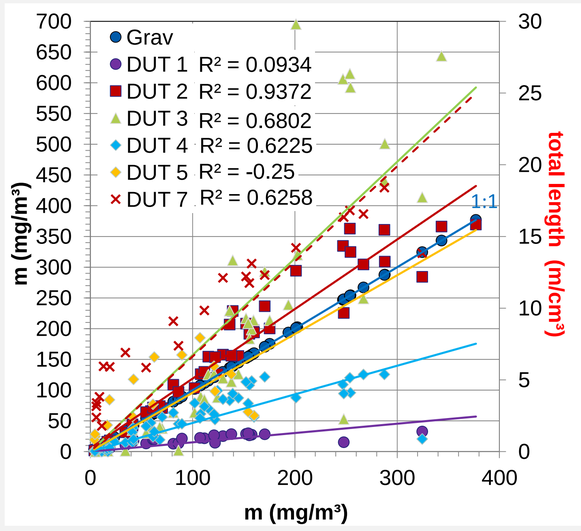
First results of the laboratory test at PTB





Comparison between reference opacimeter (AVL 439) and DUT displays the k-value; k= 0 to 1.5 m^{-1} and k= 0 to 3 m^{-1}





Comparison between mass concentration from gravimetrical mass and DUT displays the mass concentration(resp. total length[II] (m/cm³) for DUT7), m= 0 to 150 mg/m³ and m= 0 to 400 mg/m³

Conclusion and Outlook

Some of the investigated DUTs are developed for the regular emission test at garages. They measure opacity between 0 and 3 m^{-1}. Other DUT are developed measuring the particle mass respectively the particle number concentration for soot concentrations emitted by modern diesel vehicles. Their applications are the R&D in automotive industry. The presented results reflect this fact. One instrument calculating the opacity from a light scattering signal shows a good correlation with an correlation coefficient of R^2=0,9922 for opacity below k=1.5 m^{-1}. Also for higher soot concentrations a good correlation to the reference opacimeter was observed. All instruments, except DUT 7, display the mass concentration (mg/m³). The correlation to the gravimetrical mass of the soot aerosol is more or less satisfying for the used soot aerosol from the HiMassCAST (particle sizes: 50 to 240 nm), because some instruments are developed for particle sizes below 100 nm. The further investigations at METAS and MIKES will carried out for soot aerosol with smaller particle sizes. The evaluation of the instruments should consider all laboratory test. The full report of these investigations will be published end of 2013 at the ENV02 website.

[I] Consistent requirements specified for novel measuring instruments (prototypes) and comparison with European legislative requirements, http://www.ptb.de/emrp/partemission-publications.html
[II] Litton et al; Combined Optical and Ionization Measurement Techniques for Inexpensive Characterization of Micrometer and Submicrometer Aerosols; *Aerosol Science and Technology, 38:1054–1062, 2004*