Automated Validation and Calibration of Solid Particle Counters: Tackling the Accuracy Challenge

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22nd ETH-Conference on Combustion Generated Nanoparticles, June 18th – 21st 2018 at ETH Zürich, Switzerland

Abstract
Since its regulation in Euro 5b automotive emissions introduced in 2011\(^1\), determining particle number (PN) emissions from internal combustion engines has always been far more prone to measurement variation than any other regulated exhaust gas component. On the one hand, this is due to intrinsic nature of nanoparticles. Compared to gaseous emissions they consist of different materials, sizes and shapes, all affecting their physical and chemical properties. On the other hand, measurement systems defined by Global Technical Regulation (GTR) No. 15\(^2\) are also affected by calibration uncertainties allowing for certain mismatch between different units. In this work, we present a novel aerosol and flow calibration laboratory of outstanding reproducibility to automatically validate the calibration of our solid particle counting systems (SPCS) and to decrease the mismatch between different particle counters.

Motivation
Solid particle number counting system as defined by PMP in GTR No. 15:

- Problem: PN Comparability
  - SPCS accuracy: ±10%
  - Variety of calibration parameters
  - RDE legislation\(^3\)
  - PN conformity factor = 1.5

- Goal:
  - Mobile particle aerosol and flow calibration laboratory with full automation!

Example Results
SPCS Flow Calibration

- Intercomparison of Mass Flow Meters
- Correction of Flow Calibration Errors

- Relative accuracy: better than 1%
- Improvement of flow accuracy

Detection Efficiency Variation

- 152 curves @ 25 datapoints measured with very high reproducibility

Challenge of PN Counting

- Golden Reference for CPC Efficiency
- Ambient Temperature Drift of CPC

- All measured in parallel with same saturator and condenser temperatures
- Deviation w/o linearity correction < 10%

- Particle losses rise with temperature
- Smaller D\(_p\) particle losses CS > ET
- Larger D\(_p\) particle losses ET > CS

Automated Validation & Calibration System (SPCS-AVACS)

- SPCS-AVACS System Overview
  - Spoke-Exchange Nanoparticle Generator
  - Pre-classifier

- Aerosol Generation & Dilution Concept
  - Venturi mixer to decouple pressures between 2 dilution stages

Benefits from SPCS-AVACS

- Comparaibility
- Usability
- Troubleshoot
- Mobility

- “Golden instrument” to check all particle counters on site
- Automated checks of a SPCS with minimum user interference
- Root cause of errors (such as flow errors, clogging, drift,...)
- Easy installation & transfer between laboratories

References & Acknowledgements

[2] UN Global Technical Regulation No. 15

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