Calibration of a particle number sensor for PTI measurements based on pulsed-mode diffusion charging

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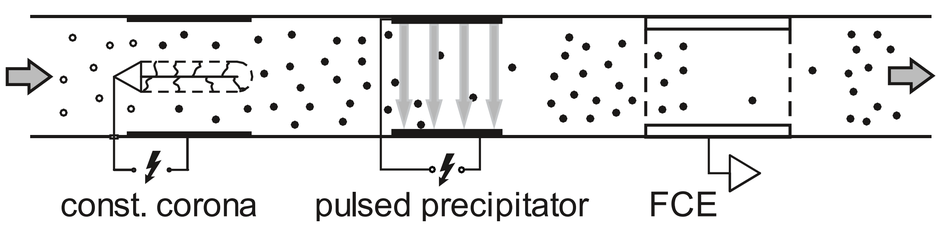
Backgrounds

- New emission legislations in several countries in Europe require measurement of particle number concentration (PN) during Periodic Technical Inspection (PTI)
- Affordable instruments for tailpipe PN measurements needed
- Low manufacturing costs require a simple calibration procedure preferably with a ‘easy-to-use’ test aerosol
- An eventual measurement bias caused by utilizing a test aerosol different than diesel soot has to be known

Instrument Prototype

- AVL DiTEST developed a sensor prototype for tailpipe PN measurements based on pulsed-mode diffusion charging [1]
- Particle size dependency is reduced by means of electrostatic precipitation [2]



- By default, the instrument is calibrated with monodisperse NaCl particles at a mobility diameter of 55 nm

Method

Counting Efficiency

- PN sensors are characterized by the counting efficiency (CE) as a function of the particle mobility diameter d_m

$$CE(d_m) = \frac{N_{DUT}(d_m)}{N_{REF}(d_m)}$$

N_{EUT}… PN value of device under test (DUT)
N_{REF}… PN value measured by reference instrument

Experimental setup

The experimental setup (Fig. 1) allows to study the influence of the test aerosol used for calibration and could be used for initial verification of the instrument. The CE can be measured with monodisperse test aerosol particles of different material and morphology.

- Aerosol Specification
  - NaCl particles (atomizer) stabilized with diffusion dryer
  - Soot-like particles (Jing MiniCAST) treated with Catalytic Stripper
  - Silver particles generated by evaporation condensation technique
    - without sintering: agglomerates with low fractal dimension
    - with sintering: compact particles
- Particle size classified by Differential Mobility Analyzer (TSI)
- CE measurement against reference CPC

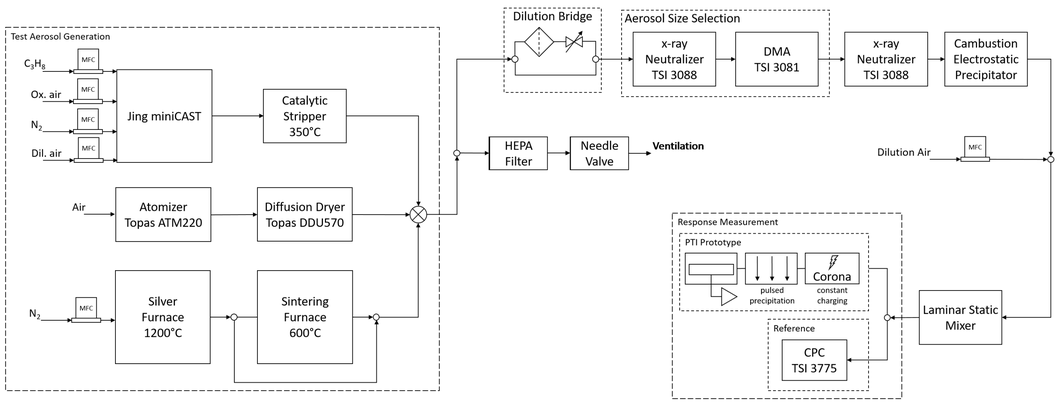


Fig 1: Experimental setup to study the test aerosol influence on the CE

Polydisperse calibration at METAS

The performance of the instrument was evaluated during a calibration at METAS using polydisperse CAST particles with varying

- particle size (geom. mean diameter): 23 – 180 nm
- concentration: 5×10^3 – ~10^6 cm^{-3}

CE was measured similar to the procedure applied for instrument certification according to the Swiss clean air act (VAMV) [4]

Results

Influence of test aerosol: Fig. 2 (a)

- good agreement of CE measured with CAST, NaCl and sintered silver particles up to a mobility diameter of 80 nm
- deviation between unsintered/sintered silver due to particle morphology
- strong deviation between NaCl and CAST for particles > 100 nm due to particle morphology

Calibration results at METAS: Fig. 2 (b)

- ~100% CE at 55 nm although the instrument has been calibrated with NaCl particles
- CE criteria acc. to VAMV [4] are easily met, showing the capability

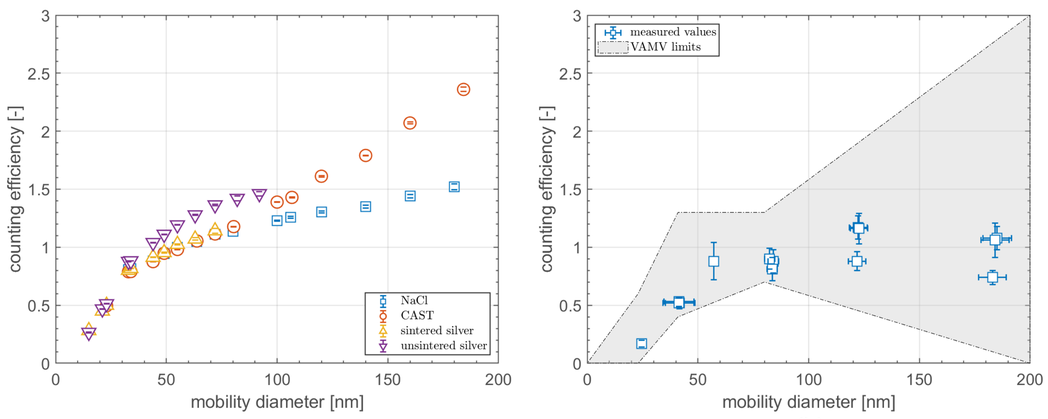


Fig 2: Test aerosol influence on CE (a), calibration results at METAS with CAST including VAMV limits (b)

Conclusions

- DC is a well suited technique to perform tailpipe PN measurements, but is influenced by test aerosol properties (size, morphology)
- Calibration with test aerosols of different morphology cause a measurement bias for big particles
- Influence of test aerosol is insignificant for particles < 80 nm → calibration with either of the used test aerosols possible
- Instrument performance was confirmed by measurements with polydisperse CAST aerosol against a traceable reference

Literature

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23rd ETH-Conference on Combustion Generated Nanoparticles
Zürich, Switzerland, 2019