Bringing the PMP methodology on-board

A Mamakos[1], T. Reinisch[1], A.Bergmann[1], M. Fierz[2], G. Brunnhofer[1], D. Roveda[1], V. Vescoli[1]
[1] AVL List GmbH, 8020, Graz, Austria
[2] Naneos, 5210, Windisch, Switzerland

Introduction

The upcoming Euro 6 legislation introduces the requirement for real world emissions assessment for the type approval of vehicles entering the European market in 2017. In the case of gaseous pollutants, on-board measurement with Portable Emission Measurement Systems (PEMS) was already decided. The suitability of PEMS instrumentation for Particle Number (PN) emissions is currently under evaluation by the European Commission.

The regulated PN measurement procedure only addresses the solid fraction of the exhaust aerosol. Volatile particles are removed by means of thermodilution [1]: a) the aerosol is heated in a tube maintained at 300 to 400ºC to bring volatile compounds in gas phase, and b) diluted to reduce their vapour pressure to level that would hinder their renucleation or at least growth to a size that could be detected by a Condensation Particle Counter (CPC) having a 50% detection efficiency at 23 nm.

Implementation of the regulated PN procedure in a PEMS device poses a number of challenges, especially for light duty applications, where weight and power constraints are more crucial compared to heavy duty installations. Perhaps the most challenging element however remains the on-board use of CPCs. While handheld devices are already commercially available, they are not robust enough to withstand the harsh environmental conditions under real-world driving, while the use of alcohol as working fluid also poses safety hazards.

Technical Implementation

We present in this work the development of a PN-PEMS device (figure 1) based on diffusion charging. The operating principle of the sensor is based on the measurement of induced currents produced by modulating the charge state of the particles [3]. This enables a real-time determination of electrometer zero levels, thus allowing for reliable measurements even at levels close to the instrument noise. Different approaches can be employed for the production of the space-charge pulses, allowing for an unparalleled control of the raw signal dependence on particle size (figure 2). A better than ±15% correlation against a reference, CPC-based, instrumentation can thus be established over a wide size range (geometric mean diameters in the 30 to 120 nm range), without the need for inversion algorithms and assumptions on the form of the underlying size distribution.

PN PEMS

Figure 1: Installation of the AVL PN and Gas PEMS iS on the trailer hook of a passenger car.

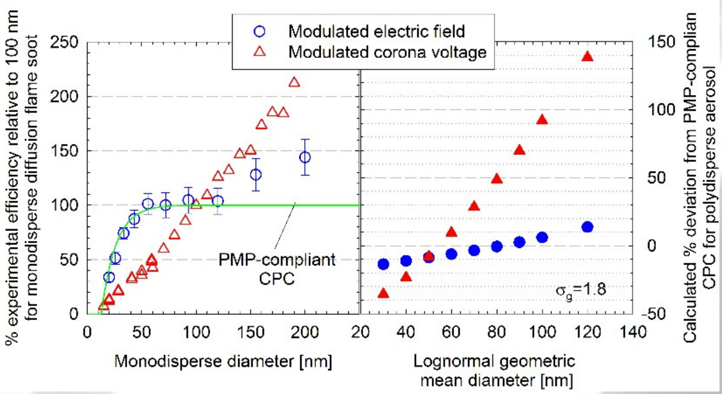

Figure 2: Left-hand panel: Experimentally determined size dependence on monodisperse soot particles for the original particle detector (modulated corona voltage) and a prototype one (modulated electric field) developed for the PN-PEMS. Right-hand panel: Calculated correlation of the two sensors against the a PMP-compliant CPC for polydisperse lognormal distributions (geometric standard deviation of 1.8).

The wide operating range of the sensor, also allows for the use of a simple and robust dilution scheme using critical orifices for sampling, and a single mass flow controller for the supply of conditioned dilution air maintaining a fixed dilution at 10:1, irrespective of the ambient pressure. The use of a temperature-controlled critical orifice also implies a fixed volumetric flow through the sensor irrespective of the ambient pressure, which is crucial for the optimal modulation of space-charge pulses.

To compensate for the rather low dilution compared to that typically employed in the regulated methodology (>1000:1 including the Constant Volume Sampler) a three-stage thermal treatment is employed, using an evaporating tube, an oxidation catalyst and a sulfur trap in series [4]. The two catalysts effectively reduce the concentration of organic compounds and sulfates with no need for dilution, while the evaporating tube allows for an efficient diffusion of the species on the catalyst sites.

Conclusion & References

A DC-based PN-PEMS system was developed. The unique design of the sensor allows for an adjustment of the signal dependence on particle size. While the operating parameters of the sensor are still being optimized, a prototype implementation exhibited a better than ±10% agreement with monodisperse CPC responses up to 120 nm, and a less than 50% overestimation at 200 nm. This small size dependence at large sizes comes at the benefit of a rigid and accurate dilution system, fast response times (important for tailpipe measurements) and proven robustness with respect to the harsh environmental conditions during on-board testing [2].

[1] UNECE Regulation 83
[2] R. Meier, et al. (2013) Aer. Sci. & Techn., 47:1, 22-28.
[3] M.Fierz, et al. (2014) Aer. Sci. & Techn., 48, 350-357.
[4] Amanatidis, S. et al. (2013). J. Aer. Sci., 57, 144-155.