Characterization and Modelling of a Novel Particle Number Detector

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Introduction

Recently, a novel aerosol sensor based on diffusion charging and subsequent measurement of the induced current to quantify lung deposited surface area (LDSA) was introduced (Fierz, 2014).

Due to the extension of the Real Driving Emissions (RDE) procedure to Particle Number (PN) a sensor principle corresponding to particle number concentration is needed (Giechaskiel, 2015; Reinisch, 2015). For that purpose a modification of the mentioned sensor was proposed (Burtscher, 2006). However, contrary to the original device the modification utilizes mobility dependent modulated precipitation in order to alter the particles' charging state (see Fig. 1). By selecting appropriate precipitation voltages and pulse lengths in combination with optimized flow profiles a signal approximately proportional to particle number concentration in a specific particle size range relevant for automotive exhaust can be achieved.

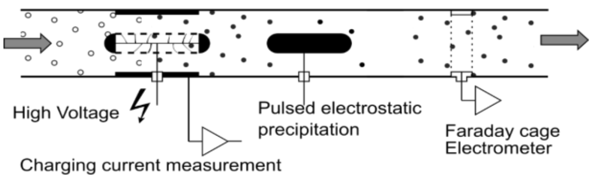

Figure 1: Measurement scheme

Experimental

In this work a multiphysical model was developed to characterize the sensor response with respect to particle size according to the aforementioned regulation. A first validation of the model was performed with combustion aerosol standard (CAST) generated soot particles. A tandem differential mobility analyzer (TDMA) setup was used to characterize the instrument response (counting efficiency vs. size) relative to a condensation particle counter (CPC) as a reference.

Starting with a simplified non-dimensional view of the measurement principle, consisting of charging, precipitation and induced current detection, a first qualitative model for the signal generation procedure was formulated. The model uses an analytical approach taking into account diffusion charging, electrostatic precipitation and plug flow conditions resulting in induced currents generated by the charged particles in dependency on their size. On the one hand the charging state of the particles was calculated using Birth-And-Death model based on Fuchs' limiting sphere theory. On the other hand the experimentally determined charging curve (mean charge as a function of particle size) of the instrument was used as input to the simulation.

Results

First results of the simulation show the potential of this device for acting as a particle number counter in the desired size range. As shown in Fig. 2, the simulated size dependence of the instrument response is within 40% for particles of sizes between 30 and 200 nm.

In addition, the device was validated experimentally. Besides the measurement of the charging efficiency, as well as electrostatic and diffusional losses, a counting efficiency curve was generated. The first experimental results agree nicely within a restricted size range. Bigger deviations were found for very small particles (see Fig. 2). Refinement of the model as well as of the experimental setup is ongoing in order to verify the observed differences in more detail (simulation of flow profiles and bigger particle ensembles, different aerosol sources with smaller geometric mean distribution).

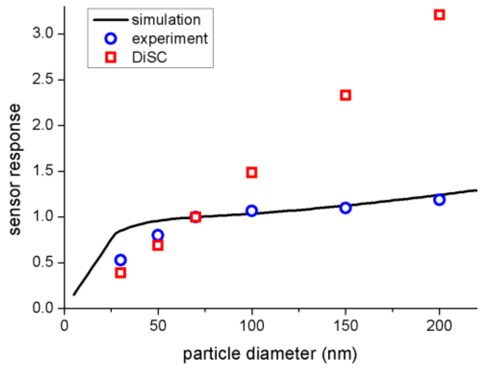

Figure 2: Preliminary results on the instrument response in comparison with the DiSC, a conventional diffusion charging device (Fierz, 2008)

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