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Title: Applying SMPS to hot exhaust gases for the evaluation of diesel particle filters

Abstract: (min. 300 - max 500 words)

Diesel engines produce exhaust gases which contain high amounts of soot particles. These particles are thought to be harmful to human health and the environment. As a consequence the emission of engines are regulated by law.

The SMPS, which measures the size and the concentration of particles smaller than 1 µm, allows for taking a closer look into the properties of motor aerosols. Unfortunately, the SMPS was designed for laboratory conditions and therefore is not suitable for exhaust gases at temperatures around 300 °C and a water mass content of 8 %. Furthermore, the particle number concentration in the exhaust line exceeds the system's range of operation. A system to achieve dilution, cooling and drying of the aerosol in a single step has been developed by the department of Mechanical Process Engineering of TU Dresden. In this system the size distribution of the exhaust aerosol is "frozen" immediately because the coagulation rate is lowered.

By employing this set-up in raw exhaust and after a particle filter the determination of the filter efficiency for particles between 30 and 600 nm becomes possible. Recording one size distribution takes 150 seconds which makes it is possible to explore how well the material of a particle filter works in the first minutes after regeneration. Some results of our cooperation with the Vehicle Research Institute of the University of Applied Science Dresden are given.

Applying SMPS to hot exhaust gases for the evaluation of diesel particle filters

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Thermodynamic conditions

The SMPS, which measures the size and the concentration of particles smaller than 1 µm, allows for taking a closer look into the properties of motor aerosols. However, the SMPS was designed for laboratory conditions and therefore is not suitable for exhaust gases at temperatures around 300 °C and a water mass content of 8 %. Furthermore, the particle number concentration in the exhaust line exceeds the system's range of operation.

Exhaust line		**SMPS**
100 – 600°C	**Temperature**	10 – 35°C
Up to 8,4 wt% (dew point: 51°C)	**Humidity**	Max. 80% r.H. (=1,25 wt%)
Up to 5•10^7 1/cm^3	**Particle number concentration**	Max. 1•10^6 1/cm^3

Sample conditioning

A system for taking aerosol samples from engine exhaust has been developed in the Department of Mechanical Process Engineering at TU Dresden. It enables dilution, cooling and drying of the aerosol in a single step.

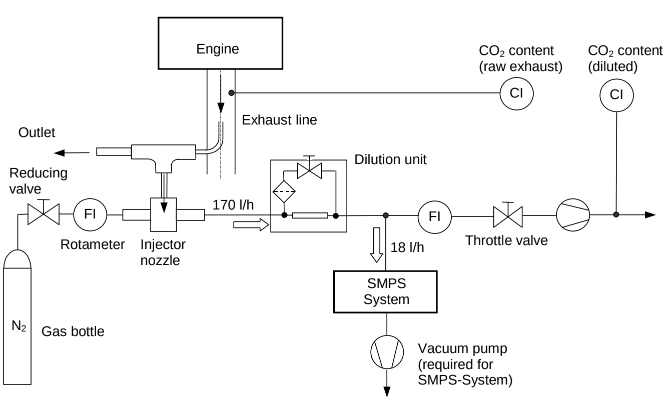


Figure 1: Set-up to measure particle size and concentration of exhaust with SMPS (taken from diploma thesis "Untersuchungen an einem keramischen Partikelfilter für Dieselmotoren", Steffen Blei, 2002)

In this set-up, a T-piece decouples the system from the pressure in the exhaust pipe. Dry nitrogen (5.0) is used to dilute exhaust in an injector nozzle. For working at high concentrations as in raw emission, a dilution unit is used to lower the concentration a second time.

$$\frac{dN}{dt} = -K_0 \cdot N^2$$

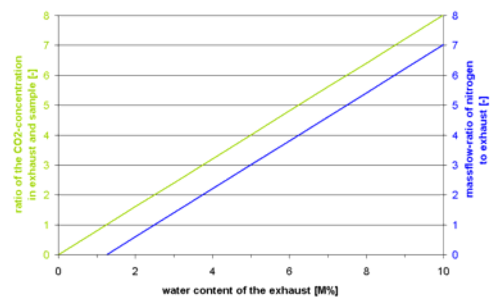
The correlation between the concentration and the coagulation rate is quadratic. Therefore it is important to dilute the aerosol immediately after sampling. This prevents alteration of the sample in the sampling tube.

Dilution ratio

The exhaust is diluted by a defined flow of nitrogen, so the dilution ratio can be determined with rotameters. In practice, a more exact method is to measure the content of carbon dioxide in raw and diluted exhaust according to the following equation:

$$\frac{c_{dil}}{c_{raw}} = \frac{\sigma_{CO2,dil}}{\sigma_{CO2,raw}} \cdot \frac{T_{raw}}{T_{dil}} \cdot \frac{p_{dil}}{p_{raw}}$$

Particle number concentration — CO2 volume concentration — Temperature — Pressure



λ	ξ_{H20} [M%]
1	8,4
3	2,9
6	1,5

Figure 2: To achieve 80% r.H. at 20°C in the sample stream a minimum mass flow of nitrogen is required. In practice it is easier to examine the CO2-concentrations.

Practical application

evaluation of particle filters for diesel engines:

raw emission

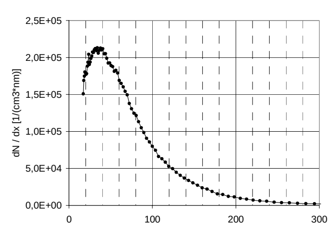


Figure 3: particle size distribution in the raw exhaust of a diesel engine

downstream of a particle filter

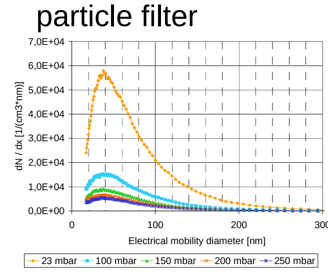


Figure 4: particle size distribution of the same engine, equipped with a particle filter. The pressure drop of the filter increases because the filter clogs.

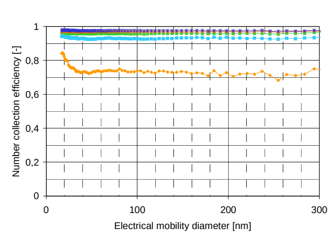


Figure 5: Efficiency of a particle filter versus particle size. Especially ultrafine particles are deposited by diffusion.

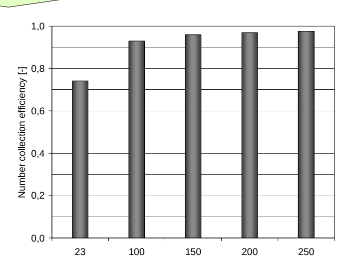


Figure 6: Clogging of the filter increases the pressure drop and the efficiency of the filter.

A particle filter for diesel engines does not reach its high efficiency until some soot is deposited on the filter media.