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Test of cabin air filter with soot-similar test aerosol

Cabin Air Filter Test with Soot Similar Test Aerosols

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We report about the development of new filter test block. Filters, especially cabin air filters, are conventionally tested with test dusts which are far away from real world conditions. Real world aerosols for cabin air filters are mainly dominated by soot emissions from combustion engines. For the development of a new filter test block with soot similar test aerosols the data from car emissions and from atmospheric measurements in the urban areas have been used.

Figure 1 shows emission particle size distribution as measured in the ACEA programme [1]. Here, eleven state of technology representing diesel vehicles have been investigated.

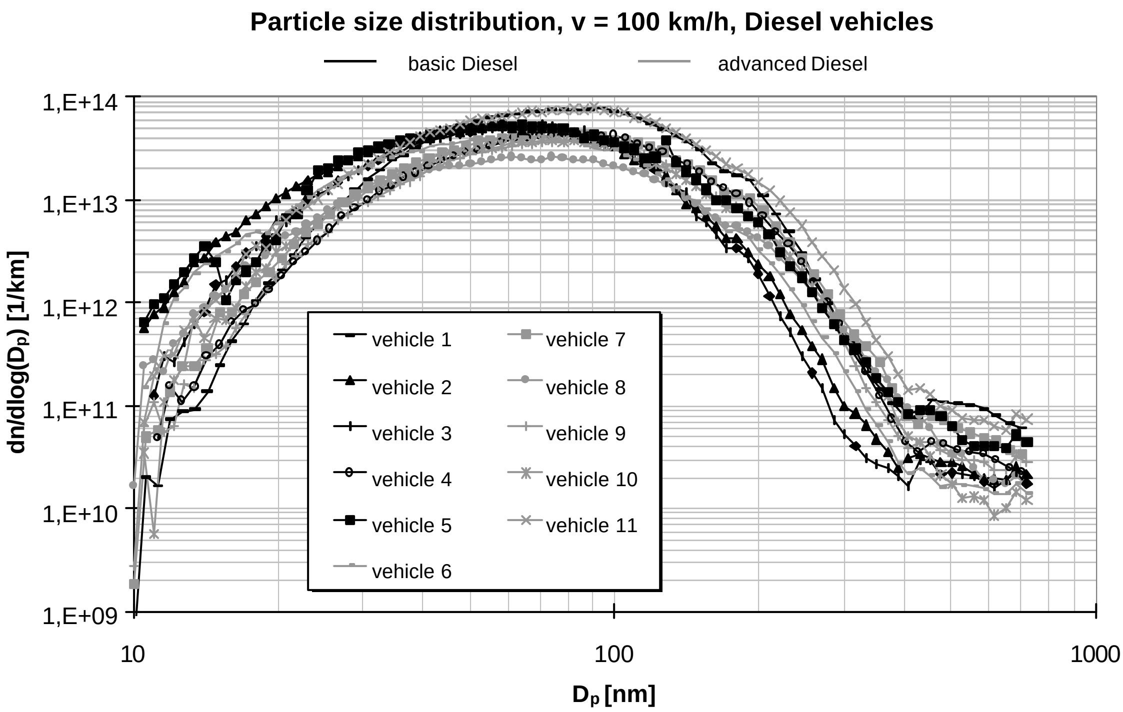

Fig. 1: Particle size distribution of Diesel engines measured at a constant speed at 100 km/h

The main part of the emission particles is, with respect to particle number, in the size range below 100 nm. Soot size distributions are conventionally measured using differential mobility particle sizer (DMPS). This is the only available method for high size resolution measurements in the ultrafine particle size range. The measured equivalent diameter is the mobility diameter.

Figure 2 shows measured imissions in the vicinity of a high traffic road. Here it can be also seen, that the main fraction of particles is below 100 nm.

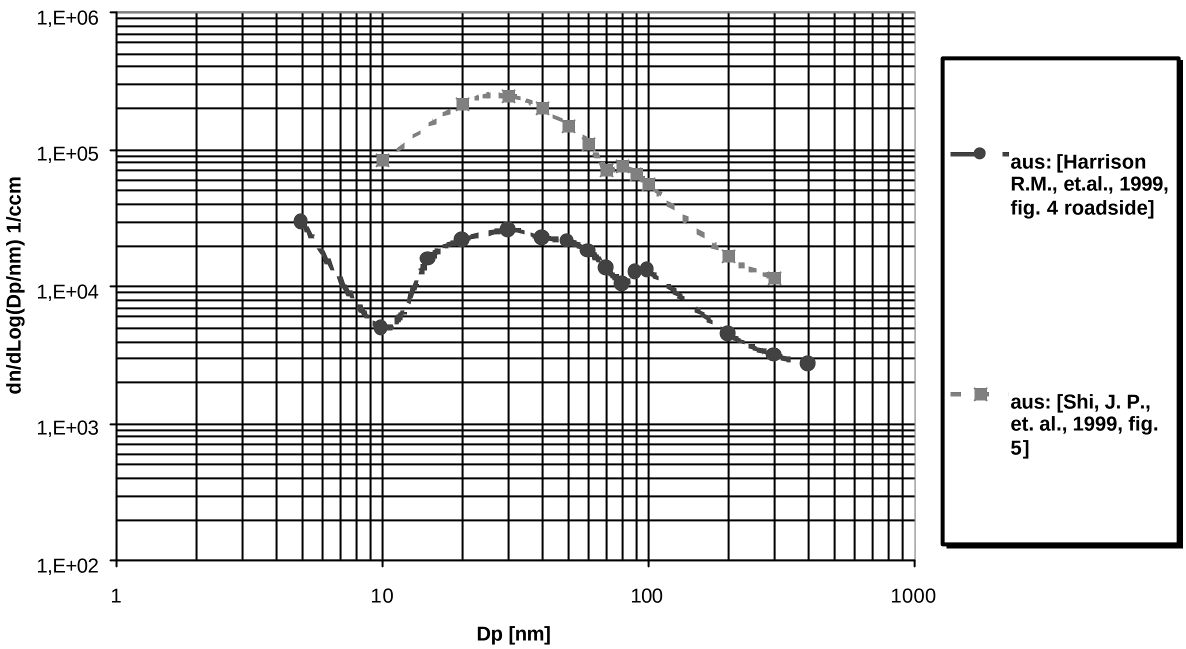

Fig. 2: Particle size distributions in the vicinity of high traffic roadways

The development the filter test block for soot similar particles had to consider also the structure of soot particles. Emission particles are agglomerates of primary, carbonaceous particles with diameters between 10 and 40 nm. The small primary particle size makes it impossible to detect the soot particles by optical methods. It is important to see, that the mobility diameter for such ultrafine agglomerates is not reflecting the equivalent optical diameter, which is for loose agglomerates structure more determined by the primary particle size, or the aerodynamic diameter, which is for agglomerates clearly smaller than the mobility diameter. Due to this, the filtration behavior is also expected to differ clearly from standard test aerosols. Standard filter tests are performed with test aerosols, which consist of compact particles, e.g. SAE fine, with sizes larger than the emissions particles shown above.

Two test generators have been developed for the filter test block. A spark discharge generator with pure carbon particles was used for particle size distributions with Count median diameters below 70 nm. For larger particle sizes a flame generator was developed. Here the combustion of C_xH_y gives soot similar particles. A set of nozzles for the burning, oxidization and dilution gases enables the adjustment of the soot particles with Count median diameters between 80 and 200 nm, and the variability of particle concentration over two decades. Both generation principles give soot agglomerates with the above described properties. Figure 3 shows the comparison between the test aerosol size distributions and the emission data. The bold black lines represents the size distributions for two different adjustments of the spark discharge generator. The mean size is in good agreement with the mean size of the emission distributions, but the distribution is very narrow and does not contain larger soot particles. These are expected to have the main impact on the filter loading, that means on the increase of the pressure drop. Therefore the flame generator had been adjusted to a larger mean size, as shown by the two bold gray lines and used mainly for the filter loading. The corresponding data are given on the right y-axis. The comparison with the data from figure 2 shows, that the concentrations of both test generators are in good agreement with real world conditions.

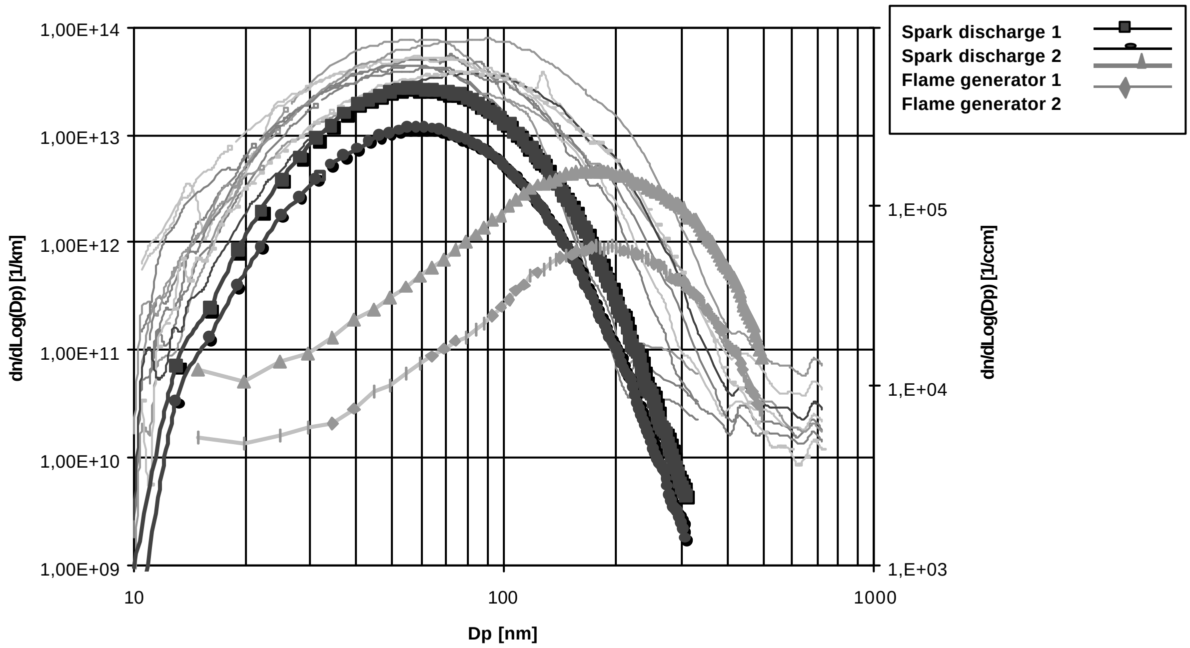

Fig. 3: Comparison of the test aerosol size distributions with emission data

The filter test block is schematically shown in figure 4. Cabin air filters are tested with flow rates between 1 - 7 m^3/min. The flow is established by a blower. The test aerosol generators can be operated singly or simultaneously. Particle size and concentration are measured by a DMPS-system. A computer controlled valve is switching between the down stream and up stream side of the filter. At first the filter efficiency is measured vs. Particle size.

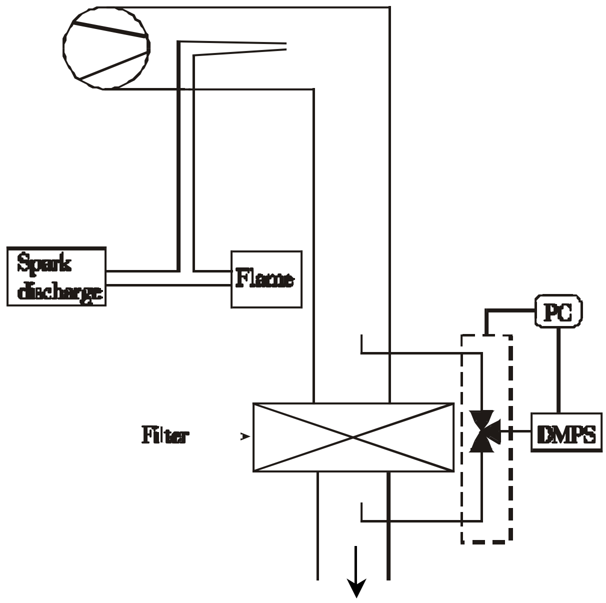

Fig. 4: The filter test block

The pressure drop is measured continuously. After every increase of 50 Pa the efficiency is measured again. The measurements are stopped after a total increase of the pressure drop of

200 Pa. Figure 1 shows the measured efficiency for the test aerosol generated with the spark discharge generator vs. particle mobility diameter for two different pressure drops.

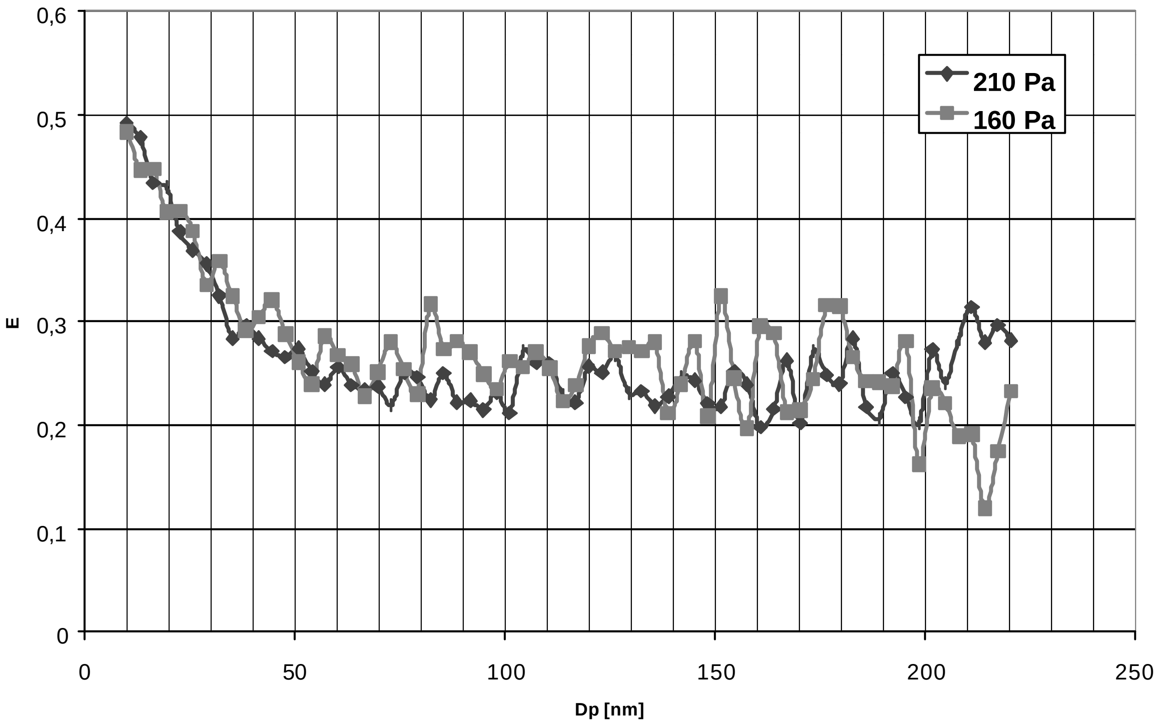

Fig. 4: Filter Efficiency E vs. particle mobility diameter (4,7 m^3/min)

The results show that the efficiency for the tested filter is rather low for soot similar particles. Such filters are mainly designed for particle deposition by impaction. This mechanism has a negligible influence for soot agglomerates in the used size range. The influence of diffusion can be seen for particles smaller than 50 nm. For larger particles, filtration seems to be dominated by the interception process.

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