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Particle Formation due to Fuel Additives

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A variety of fuel additives has been tested which should improve combustion efficiency and reduce particulate and gaseous emissions. Often these are Fe- or Ce-compounds. In combination with particle traps another reason to apply fuel additives is to aid filter regeneration by catalytic soot combustion. As the direct effect of the additives, i.e. reduction of emissions, is limited (typically elemental carbon (EC) emissions can be reduced by about 50%, see Fig. 1) this is today the main reason to use fuel additives.

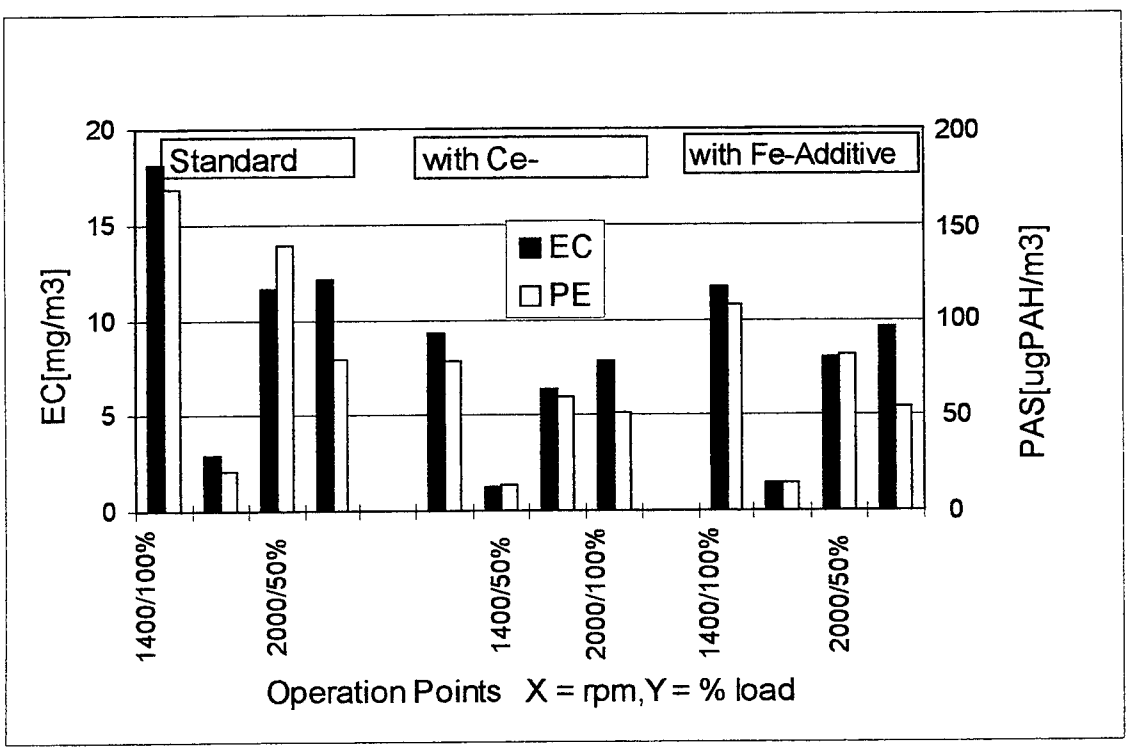

Fig. 1 EC-concentration with and without additive for 4 operating points of the engine. For comparison the corresponding signal of the photoelectic aerosol sensor (PAS) is also plotted. The good agreement shows that this - very much simpler measurement - yields similar information as the EC-value, determined by coulometry.

If additives are applied, the additive material will somehow appear in the exhaust. As these substances may be harmful, they have to be prevented from being emitted in the ambient air by adequate means (traps). To know the requirements for these filters one has to know how the additive is emitted. To study this question, a series of measurements has been made with a Liebherr heavy duty engine (914T) and for comparison with a small (4kW) naturally aspirated Yamaha diesel engine (EDA4700T).

The experimental setup for the measurement with the Liebherr engine is shown in Fig. 2. The setup for the Yamaha is similar, however, a rotating disk dilution system (Hüglin et al., 1997) is used instead of the partial flow dilution tunnel (AVL smart sampler).

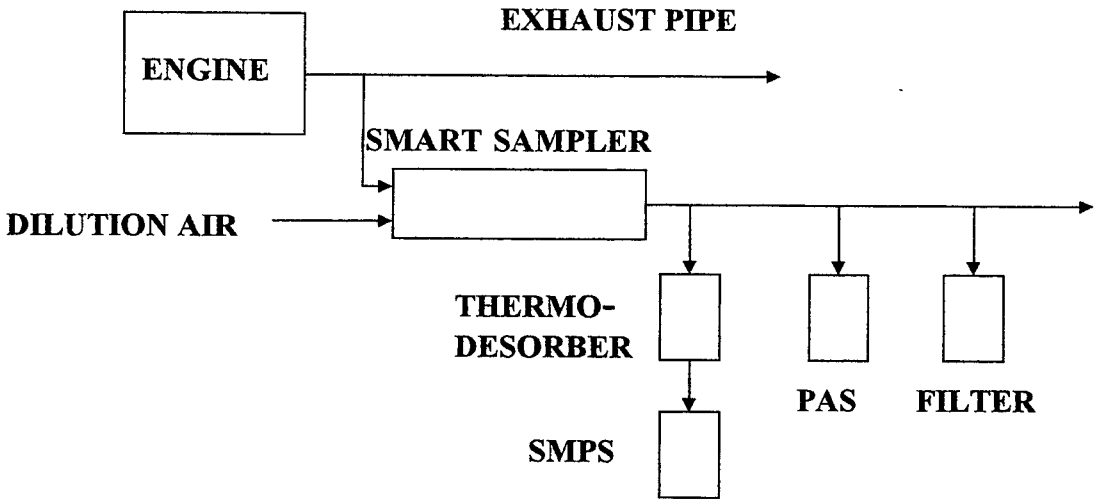

Fig. 2 Experimental setup

As a first result Fig. 3 shows the size distribution without additive and with two dosings of the Ce-Additive. In the large particle range (>60nm) a reduction in concentration by about 50% is observed, which is consistent with the EC-reduction. The lower dosage is sufficient, no benefit is obtained from higher additive concentrations. Further, very small particles are newly formed, if the additive is added. Their concentration significantly increases if the additive concentration is increased.

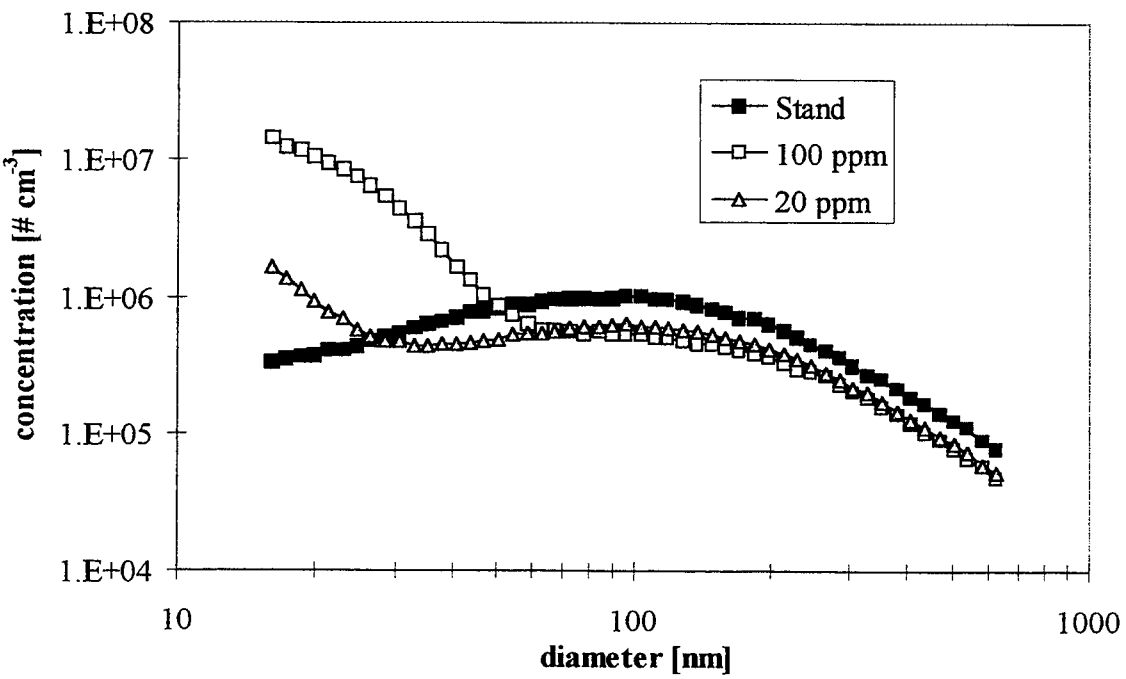

Fig. 3 Particle size distribution with and without additive

This indicates that the additive is emitted in the particle phase. To corroborate this hypothesis, filter samples were analyzed to determine the additive mass on the filter. Results are shown in table 1 and table 2. Table 1 shows results of filter analysis , sampling without size fractionation. The amount of additive found on the filter fits fairly well with that computed from the amount of fuel burnt and the additive concentration in the fuel. This shows that the additive is emitted in the particle phase, not in the gasphase. The results of filter analysis from filters, taken after the mobility analyzer, i.e. for a certain particle size, show that the small particles consist merely only of the additive material, the larger particles contain only some percent of additive. This result is consistent with measurements with the photoelectric aerosol sensor, which shows a strong signal for the larger (soot-) particles but none for the small fraction.

Additive	Additive conc [ppm]	computed Add. Mass [µg]	measured mass [µg]
Ce	100	313	249
Ce	100	324	296
Ce	50	162	138
Ce	50	162	137
Fe	120	135	79
Fe	120	134	101
Fe	60	69	67
Fe	60	69	72

Table 1: Measured and computed total additive mass in the filter (ICP-MS - analysis)

diameter	Ce-mass, measured [µg]	Ce-mass/tot mass
20 nm	0.12	1
80 nm	0.048	.125

Table 2: Ce-mass and total mass in the filter, when sampling after the DMA

These shows that one part of the additive is incorporated in the soot particles, another part forms new ultrafine particles, consisting only of additive material.
The measurements performed with the Yamaha engine give more information on the partitioning of these two fractions. In Fig. 4 and Fig. 5 the size distribution measured at two different load conditions (1 kW and 3 kW) are plotted for several additive concentrations. Comparison of the two graphs shows that the onset of formation of new particles is at higher additive concentrations for 3 kW. As this engine is naturally aspirated higher load (at constant speed) also means richer combustion and higher soot emissions.
Finally Fig. 6 shows the additive concentration, were particle formation starts plotted versus the emission factor. Results from both engines are included in this plot. This shows that obviously the emission factor determines, when particle formation starts, no difference between the two engines is observed. As long as no new particles are formed, the additive is incorporated completely in the soot particles, otherwise both particle types coexist.
A more detailed description of these experiments can be found in Skillas et al (1999).

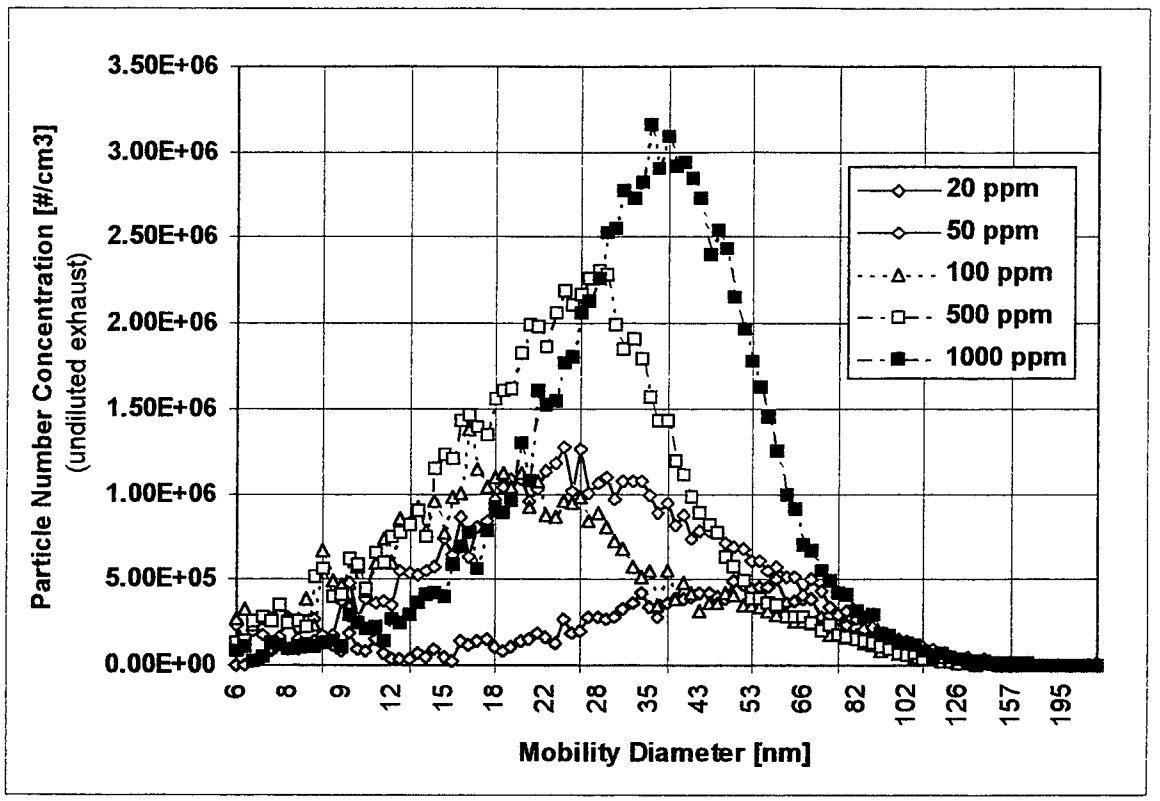

Fig. 4 Influence of additive concentation (Ce) at 1 kW

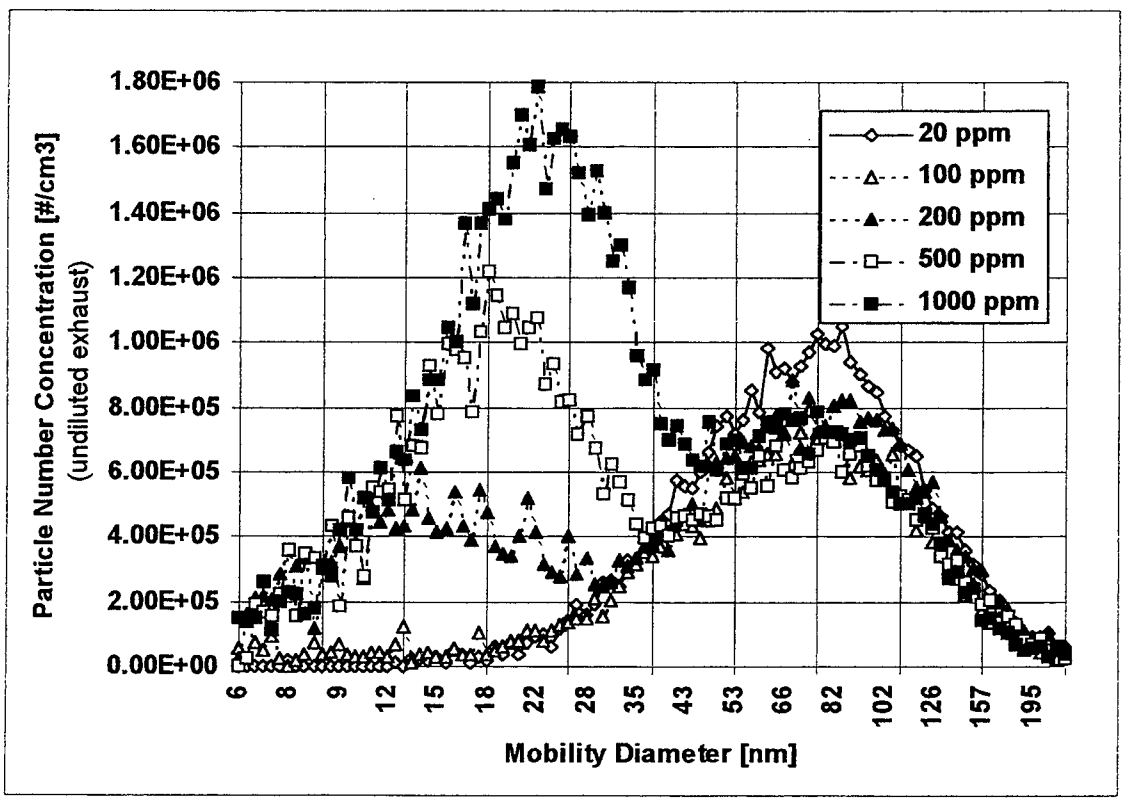

Fig. 5 Influence of the additve concentration (Ce) at 3 kW

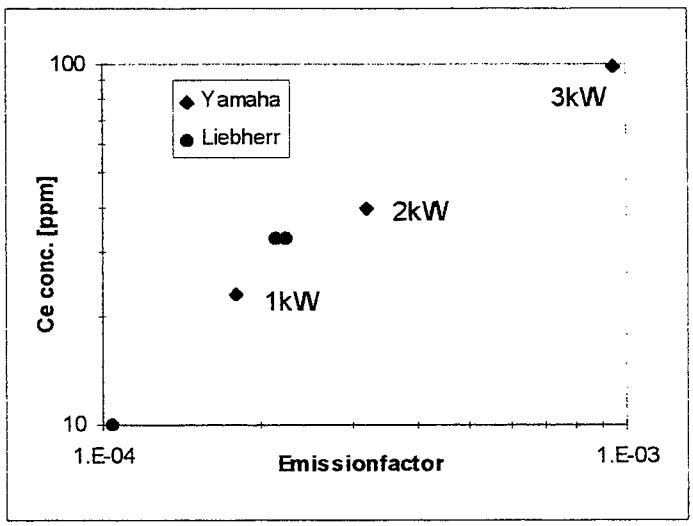

Fig. 6 Additive concentration, where particle formation starts plotted versus the emission factor.

Acknowledgements

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References:

Hüglin, C., Scherrer L., and Burtscher H. (1997) An accurate, continuously adjustable dilution system (1:10 to $1:10^4$) for submicron aerosols. J. Aerosol Sci. **28**, 1049

Skillas, G., Qian, Z., Baltensperger, U., Matter U., and Burtscher, H. (1999) The influence of additives on the size distribution and composition of particles produced by diesel engines. Comb. Sci. Technol. In press.