Fine Particle Emission from Diesel and Gasoline Vehicles at Constant and Transient Conditions

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It is well known that exhaust gas from diesel engines includes a significant amount of respirable particulates. The particles comprise of a solid core of unburned carbon which is coated with organic and inorganic condensates (Steiner and Burtcher, 1993). Due to their small size they penetrate deeply into the human respiratory tract and can have a negative effect on the human health. On the other hand, gasoline fuelled vehicles are considered to produce generally very low particle emissions based on mass measurements. However, there are still some open questions about the particle emission of gasoline cars:

- How is the particle emission based on number concentration?
- How is the particle emission affected by the driving conditions?
- What is the composition of the particles?

In this study the particulate emissions of diesel and gasoline passenger cars were determined and compared in the submicron size range at constant and transient loads. Particle number size distributions were measured using a Differential Mobility Analyser (DMA) and a Condensation Particle Counter (CPC) (Knutson and Whitby, 1975). For particle sampling a standard particle dilution tunnel (CVS) was used in the experiments. The motor vehicles were tested on a single 1500 mm roll chassis dynamometer at four constant velocities and using the European driving cycle (ECE+EUDC). The details of the test schedule is shown in Table 1. The cars run on gasoline were equipped with a standard three-way catalyst. At the steady state tests the vehicles and tunnel were preconditioned until a stable oil temperature, catalyst temperature and tunnel temperature were reached. All driving cycle tests were performed with cold engines. Since the SMPS cannot provide full size distributions at transient conditions the total particle number and the particles number in several discrete particle size classes between 25 nm and 600 nm were monitored by repeating the test procedure. The composition of the particles were determined by extraction with dichloromethane to distinguish the organic soluble (SOF) from the insoluble (INSOF) particle mass fraction. The amount of SOF was calculated as filter weight difference before and after the Soxhlet extraction.

Table 1. Details of the test schedule

	Speed	Gear	Preconditioning
steady state	50 km/h	3	warm
steady state	80 km/h	5	warm
steady state	120 km/h	5	warm
steady state	80 km/h full-load	5	warm
driving cycle: ECE+EUDC	0 - 120 km/h	1-5	cold engine start

Figure 1. Particle emission vs. time of a diesel car for three narrow size channels during a cold ECE+EUDC

The diesel vehicles produced a significant higher number of particles at all tested driving conditions than gasoline fuelled cars. At the steady state experiments the gasoline cars showed increased emissions at high loads. However, the total particle concentrations were still more than one order of magnitude below the values of the diesel cars. The mode of the distributions was in the range of 70 nm to 90 nm for the gasoline vehicle and between 80 nm and 110 nm for the diesel vehicle. Only for the diesel cars a slight shift to larger particles sizes was observed with increasing load. The chemical analysis of the particles results in about 80% SOF for the gasoline car and about 20% for the diesel car at high loads.

Figure 1 shows results of the transient tests with the diesel car. The normalised number of particles emitted vs. time is presented for three small size channels. It can be seen that very small particles ($d_p = 25$ nm) were mainly produced in the cold start period, whereas most of the large particles ($d_p = 600$ nm) were exhausted at the highest load. Particles of 100 nm diameter, which were dominant in absolute scale during the entire cycle, were weakly affected by the cold start and the highest load, but show a clear correlation with the speed and accelerations. This result is in good agreement with Rickeard et al. (1996). The gasoline fuelled vehicle shows a different particle emission profile. Here, the particle emission was highest for all size channel during the cold start period. Even at the highest load only a moderate particle number was produced in the investigated size channels.

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