Ultrafine particulate matter emissions from a gasoline direct injection engine

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Epidemiological studies have linked exposure to particles matter less than 2.5 microns in diameter ($PM_{2.5}$) with adverse health (cardiovascular or pulmonary diseases that would cause premature death). The contribution of the transport sector to the total concentration of $PM_{2.5}$ in the ambient air is 12% [1]. This value represents an average which likely is higher in areas near emission sources (i.e. urban area). PM abatement in exhausts of gasoline direct injection (GDI) engines, which aims to improve fuel efficiency, will be necessary due to the strengthening of the European legislations. GDI engines offer a number of opportunities for improving fuel efficiency, such as reducing pumping losses, charge air cooling, and downsizing when turbocharged [2]. However, direct injection of fuel into the engine cylinder is susceptible to incomplete fuel evaporation and to fuel impingement on piston and cylinder walls, both of which lead to combustion of liquid fuel and, consequently, to PM emissions increase [3]. Gasoline Particulate Filters (GPF) are currently developed to mechanically filter the soot particles emitted by GDI engines. The particle sizes in this case are typically smaller in comparison with diesel engines [4].

Ultrafine particulate (UFP) matter (1-40 nm) emissions from a GDI engine (1.6 L) were characterized as a function of the engine operating regime in terms of particle numbers and size distributions. Exhaust gas samples were analyzed upstream and downstream a three-way converter (TWC), as well as downstream a GPF, i.e. at the exhaust outlet. UFPs were analyzed with a Scanning Mobility Particle Sizer equipped with a dielectric barrier discharge, a differential mobility analyzer (176 channels) to classify the PM size range that enters into a Faraday-Cup Electrometer (FCE) to count the charged particulates (SMPS+E, Grimm). After a two stage dilution (realized by FPS4000, DEKATI), the sampled aerosol was analyzed in the range 1 to 38 nm. SMPS+E data were compared with those of a SMPS (TSI, model 3080, PM size range 3-150 nm) and a DMS (Differential Mobility Spectrometer, Cambustion, PM size range analysis 5-1000 nm). In addition, the fraction of the elemental carbon in PM was estimated with a Multi-Angle Absorption Photometer (MAAP, Thermo Scientific, model 5012). UFPs with diameters lower than 20 nm was detected upstream the TWC. UFPs total concentrations were high, in the range 2 – 20 10^{14} part/m^3 depending on the engine load. UFPs size distributions were found to be bimodal with mean diameters around 2-3 nm and 10 nm, respectively. The impact of TWC on UFP concentration and size was significant since a large part of UFPs, lower than 10 nm, was removed. Furthermore, the overall UFPs number was divided by one order of magnitude. The filtering efficiency for UFPs of the GPF was found to be high since no UFPs was detectable using the SMPS+E downstream the GPF (Fig. 1). These results will be discussed in relation with PM analysis in the range 5 – 200 nm, carbon elemental concentration as well as gas pollutant emissions.

Figure 1: UFPs size distributions at 2500 rpm/ 13 bar. Dilution ratio= 6.

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