Density of particles emitted from a gasoline direct injection engine.

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The need to reduce CO_2 emissions is driving automotive constructors to increasingly employ direct injection technology in gasoline engines. Compared to port fuel injection, this enables the use of higher compression ratios, lean unthrottled operation and has synergies with other CO_2 reducing actions such as forced induction and downsizing. (Zhao *et al.*, 1999). The engine used here was operated at low speed and light load (1000 rpm, 3.27 bar BMEP). EN228:2004 compliant gasoline was injected in the intake stroke through a multi-hole solenoid injector at a pressure of ~100 bar. The charge was thus nominally homogeneous at ignition.

The Couette Centrifugal Particle Mass Analyser (Couette CPMA, e.g. Olfert *et al.*, 2007) is an instrument which measures particle charge to mass ratio by subjecting particles to opposing electric and centrifugal forces. Particles enter the region between two concentric cylinders which have a potential difference between them. Each cylinder rotates at a slightly different speed, and this provides a stable force system, which increases particle throughput compared with the Aerosol Particle Mass (APM) analyser (Ehara *et al.*, 1996).

Aerosol sample was iso-kinetically extracted downstream of a three-way catalyst, then immediately diluted by a factor of 10 with an ejector diluter. Conductive tubing was used for sample transport from the diluter to the CPMA, and the Cambustion DMS500 and TSI SMPS used to obtain particle size spectra (Fig. 1).

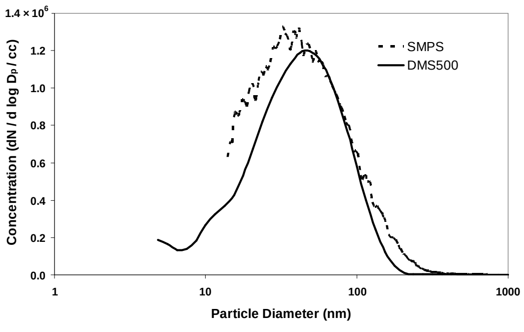

Figure 1. Particle size spectra, dilution corrected.

The density determination method involves size selecting and charging the aerosol with a DMA, mass-to-charge selecting with the CPMA, and measuring the concentration with a CPC (Olfert *et al.*, 2007). The process is repeated with a polystyrene latex (PSL) aerosol of known density for calibration purposes. A correction is made for any multiple charging of the engine aerosol by the DMA's neutraliser. From the density, a mass to diameter relationship was determined, with a power law fit yielding a fractal dimension, D_f, of 2.65 (Fig. 2).

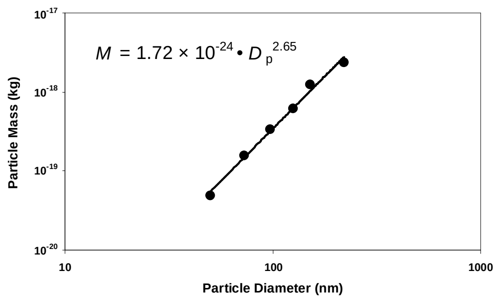

Figure 2. Mass of GDi particulate related to diameter.

The fractal dimension is somewhere between that measured for Diesel agglomerates by Park *et al.* (2003) using the APM (D_f = 2.33–2.41) or Olfert *et al.* (2007) using the CPMA (D_f = 2.20–2.48 for regular loads), and a spherical aerosol (D_f = 3.00). However, for high loads Olfert *et al.* observed D_f as high as 2.76, thought to be due to 'infill' of the Diesel soot agglomerate by condensed sulphate from a hot catalyst.

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Ehara, K., Hagwood, C., & Coakley, K. J. (1996). *J. Aerosol Science*, 27, 217–234.

Olfert, J. S., Symonds, J.P.R. & Collings, N. (2007). *J. Aerosol Science*, 38, 69–82.

Park, K., Cao, F., Kittelson, D. B., & McMurry, P. H. (2003). *Environmental Science and Technology*, 37, 577–583.

Zhao F., Lai, M.-C., & Harrington, D.L. (1999) *Progress in Energy and Combustion Science*, 25, 437–562.