Density of particles emitted from a gasoline direct injection engine.

J.P.R Symonds1, P. Price2, P.I. Williams3 and R. Stone2

1 Cambustion Ltd, J6 The Paddocks, 347 Cherry Hinton Road, Cambridge CB1 8DH, U.K.
2 Internal Combustion Engines Group, Department of Engineering Science, University of Oxford, Parks Road OX1 3PJ, U.K.
3 School of Earth, Atmospheric and Environmental Sciences, University of Manchester, Williamson Building Oxford Road, Manchester, M13 9PL, U.K.

Keywords: Vehicle Emissions, Mass Concentration, Instrumentation, Soot Agglomerates, Morphology

The need to reduce CO₂ 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 CO₂ 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.](image1)

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, Dₚ, of 2.65 (Fig. 2).

![Figure 2. Mass of GDi particulate related to diameter.](image2)

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

We would like to thank Jaguar Cars Ltd for providing the engine used, and Dr Jason Olfert, for his advice on the use of the CPMA.