On-line particle Density Measurements of Combustion Aerosols with the DMA-APM System and Comparison with Aggregation Theory

Rissler, Jenny; Pagels, Joakim; Nilsson, Patrik; Nordin, Erik; Malik, Azhar; Sanati, Mehri; Bohgard, Mats

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On-line particle density measurements of combustion aerosols with the DMA-APM system and comparison with aggregation theory

J. Rissler, J. Pagels, P. Nilsson, E. Nordin, A. Malik, M. Sanati, M. Bohgard
Division of Ergonomics and Aerosol Technology, Lund University, P.O. Box 118, SE-22100, Lund, Sweden

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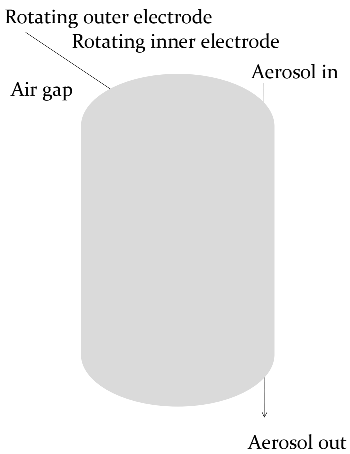
In order to allow conversion between aerodynamic and mobility diameters information about particle density and shape is required. Conversion is often necessary as different measurement techniques gives different size measures and different characteristics are needed when modelling aerosol dynamics.

The aim of this study is to perform determinations of density and morphology by using the novel DMA-Aerosol Particle Mass Analyzer (DMA-APM; McMurry et al., 2002) to measure the relationship between particle mass and mobility diameter (d_{me}) of aerosol particles originating from different combustion sources. A second aim is to investigate if aggregation theory can be used model characteristics of soot particles that often are composed of large porous aggregates. The particles here studied origin's from: **i**) two soot generators (quenched diffusion flame), **ii**) diesel exhaust (idling VW Passat -98 and Peugeot 307 -03), **iii**) gasoline exhaust – photooxidised secondary aerosol (idling Ford Fiesta -92), and **iv**) candle smoke.

The APM consists of two cylinders rotating at a rotational speed, ω. The aerosol is introduced in the gap between the cylinders and a radial electrical field is applied. The electrical force keeps the charged particles in orbit. The mass distribution of the particles is measured by stepping the APM voltage (V_{APM}) at a specific ω.

In the DMA-APM system a DMA and an APM is coupled in series. The DMA selects particles of one mobility diameter at a time and the mass distribution of the selected particles is determined by scanning the APM voltage. d_{me} and the particle mass are related as (transition regime):

$$m = \underbrace{\frac{\rho}{\chi^3}\cdot\left(\frac{C(d_{me})}{C(d_{ve})}\right)^3}_{\rho_{eff}}\cdot\left(\frac{\pi}{6}\right)\cdot d_{me}^3$$



From the effective density (defined as $\rho_{eff} = m/(d_{me}^3\cdot\pi/6)$ the mass fractal dimension were estimated, according to the theory presented in the work by Schmidt-Ott (1990). The mass fractal dimension (Df_m) is given by $m = K\cdot d_{me}^{Dfm}$, (Schmidt-Ott 1990).

The primary particle sizes were determined from SEM-analysis and used when applying the aggregation theory described in Lall and Friedlander (2006) to estimate the effective densities.

The exhaust particles from the two diesel engines showed similar effective densities, decreasing with increasing size from ~0.85 g/cm^3 for 86 nm particles to 0.40 g/cm^3 for 250 nm. This is similar to the results found in the work by Park et al. (2003). Particles from the combustion soot generator showed lower particle effective densities (from ~0,55 g/cm^3 for 80 nm particles down to 0.23 g/cm^3 for 250 nm).

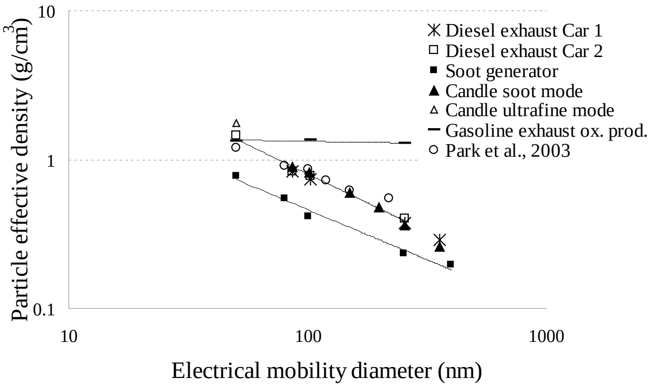


Figure 1. The Effective densities for the aerosols studied.

The primary particle emissions from the gasoline car were negligible, but after photo-oxidization of the exhaust, secondary particles were formed consisting of organic vapors. The density of these particles was ~1.3 g/cm^3, constant over particle size corresponding to spherical particles. The candle smoke consisted of a soot mode (~50-350 nm) and an ultrafine mode dominated by alkali nitrates (Pagels et al., 2009). The particles in the soot mode showed an agglomerate structure with effective densities close to that of the diesel exhaust.

The particle mass over the size interval covered in this study could be well described by a mass fractal dimension; for the diesel exhaust 2.2-2.5, soot burners 2.2-2.3 and for the candle smoke 2.07. The theory in Lall et al., 2006 could predict the effective densities for particles of $d_{me} \leq 100$ nm while for larger particles the effective densities were under estimated.

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