Particle Number Measurement from Engines with the DMS Series

Introduction

The Cambustion DMS500 and DMS50 are powerful tools for simultaneously determining the particle size distribution and number / mass concentrations of engine exhaust. This application note describes improved calibration methods for the DMS series to achieve better accuracy in particle number measurements, and shows how the unique real time data processing capabilities of these instruments can be used to provide a measure of solid particle number.

Calibration for Number

Instruments which use a corona discharge to achieve unipolar diffusion charging will charge fractal agglomerates more efficiently for a given mobility diameter than spherical particles[1,2] (probably due to the larger relative surface area of agglomerates).

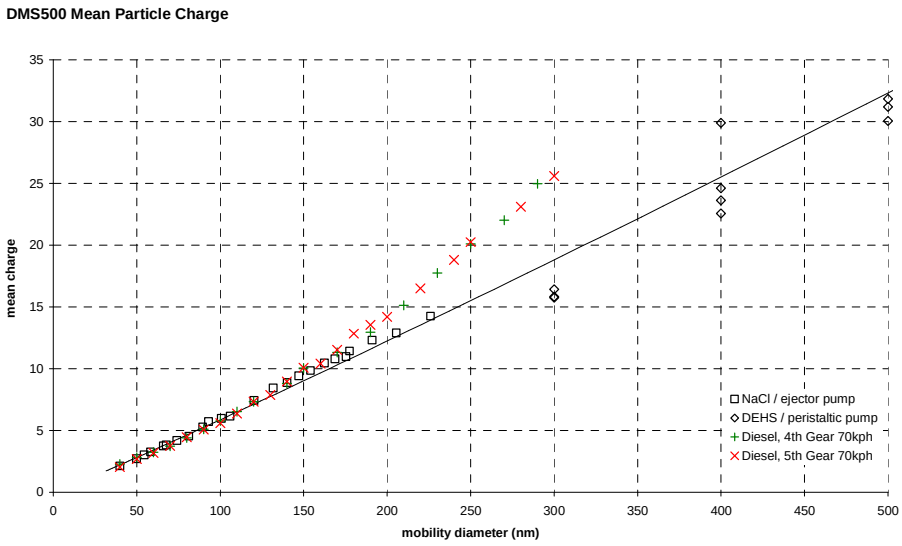

Figure 1: Charging of Agglomerates and Spherical Aerosols in the DMS500

For a particle spectrometer calibrated for spherical “laboratory” aerosols, the increase in electrical mobility leads to agglomerates appearing smaller than they truly are. The increased charge, detected by the electrometers, also leads to an overestimate of the particle number. These differences become more significant as the particle size increases:

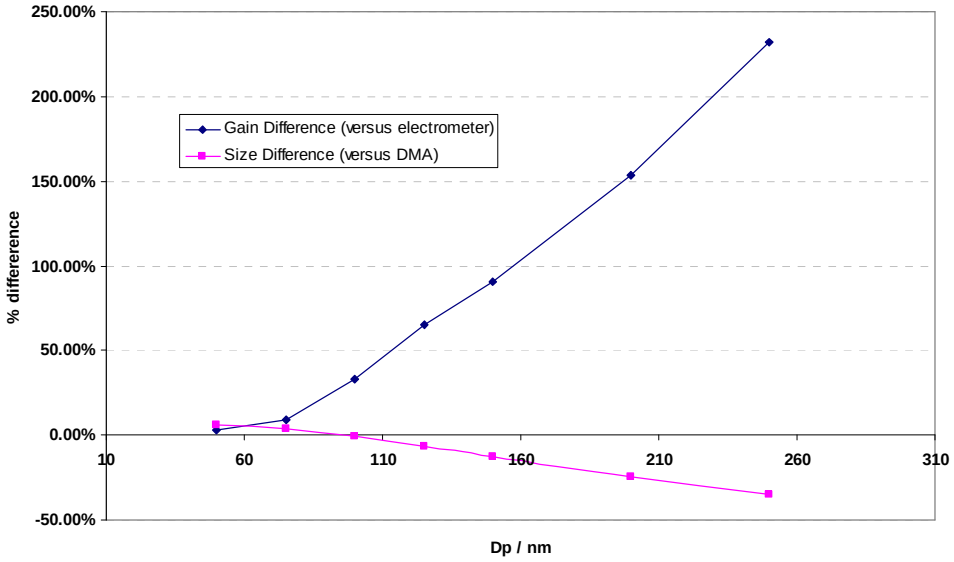

Figure 2: Size and gain errors with a "spherical" calibration

The solution is to empirically calibrate the DMS series with real soot rather than spherical laboratory aerosol. This “agglomerate” calibration is then used with high agglomerated aerosols, such as Diesel exhaust.

Within the size range of most interest for Diesel engine emissions (50–200 nm) each DMS is calibrated with soot from a mini-CAST by passing the soot through a tandem Differential Mobility Analyser (DMA) arrangement[†] to select particles of the appropriate size. The particle stream is then divided in two and one half passes into the DMS (via a charge neutraliser) and the other half is sampled by an aerosol electrometer to determine the particle number concentration. The note *Calibration of the DMS Series* explains the calibration procedure in detail.

The application of this new calibration varies slightly between the DMS500 and DMS50. Due to the difficulties in generating large soot particles and classifying them with a DMA (large size limit and multiple charging issues), the soot calibration is not performed for large sizes up until the 1 µm limit of the DMS500. Therefore the agglomerate calibration is only applied to the accumulation mode of the lognormal parameterisation. On the DMS50, due to the reduced size range of the instrument, the agglomerate calibration is applied to both the accumulation mode, and the entire discrete spectrum.

This calibration has been supplied with all new instruments since 2008, and is available to existing customers as an upgrade.

Experience and customer feedback indicates that the original “spherical” calibration usually works best for Gasoline Direct Injection emissions measurement; see application note DMS08 for further information.

Solid Particle Number Measurement

The lognormal parameterisation of the DMS series allows automatic identification of the nucleation and accumulation aerosol modes from engine exhaust (see DMS applications note #6).

[†] Two DMAs connected sequentially such that the first DMA selects particles slightly smaller than the final DMA. This reduces the likelihood of multiply charged particles entering the electrometer and biasing the result.

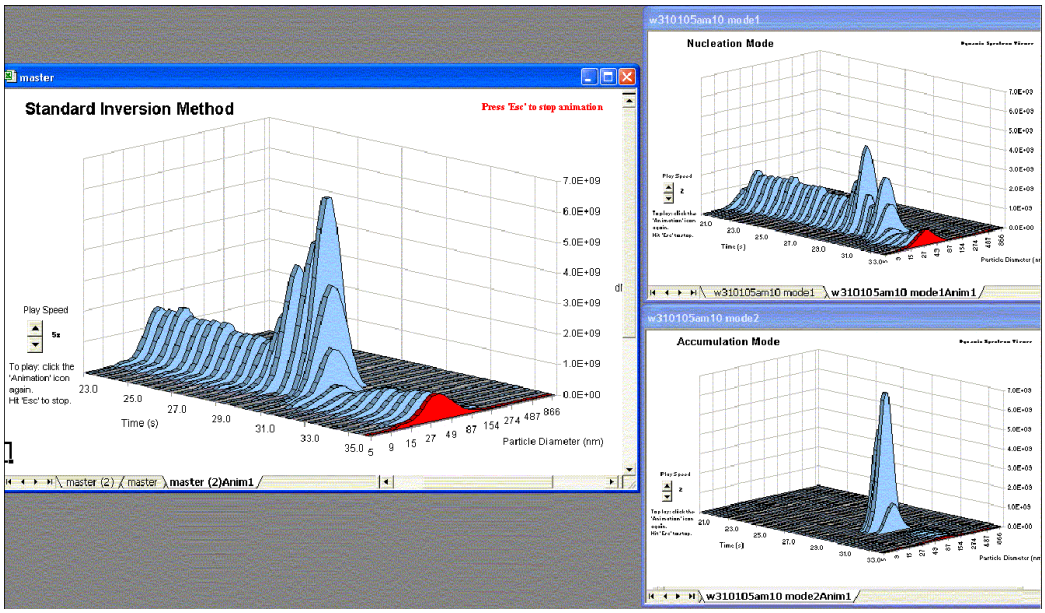

Figure 3: Lognormal Parameterisation identifies and separates nucleation and accumulation modes

This can be used to give a measure of solid particle number. The majority of purely volatile particles will be in the nucleation mode so if one equates the number of particles in the accumulation mode with the solid particle number and ignores the nucleation mode number, the DMS data processing acts as a "software volatile particle remover".

Example

This example is taken from ref #3. A Peugeot 406 2.2l HDi common rail Euro III diesel engine with a Diesel Oxidation Catalyst was connected to a constant volume sampling tunnel. A DMS500 and a PMP-like solid particle number measurement system both sampled simultaneously from the dilution tunnel. Both steady state and drive cycle tests were performed. Firstly the steady state tests:

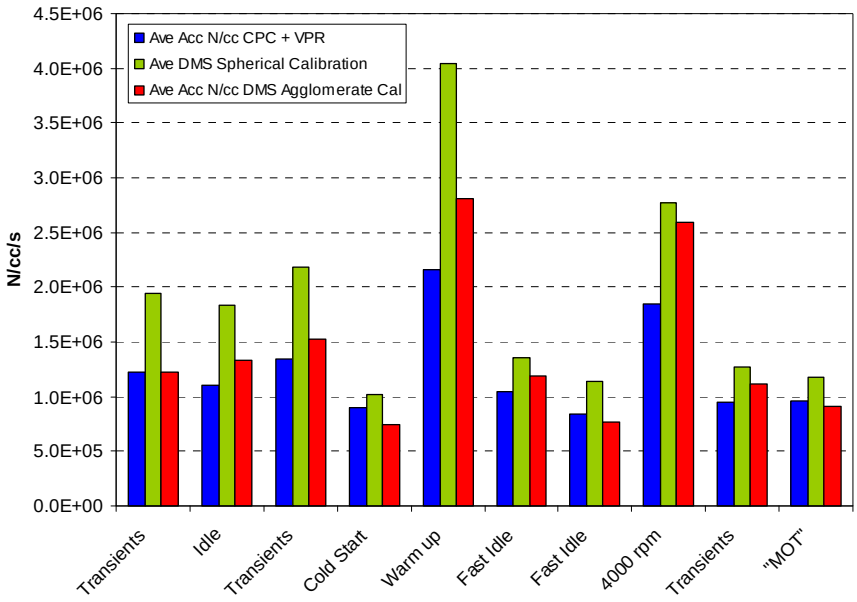

Figure 4: Agreement between DMS (with and without agglomerate calibration) and PMP-type system (steady state)

The data was processed with both “spherical” and “agglomerate” calibrations, and the improvement is clear. On average with the new calibration, the DMS over-reads the PMP-type system by 9%. With the “spherical” calibration, the difference is 44%.

Next, an example of a New European Drive Cycle:

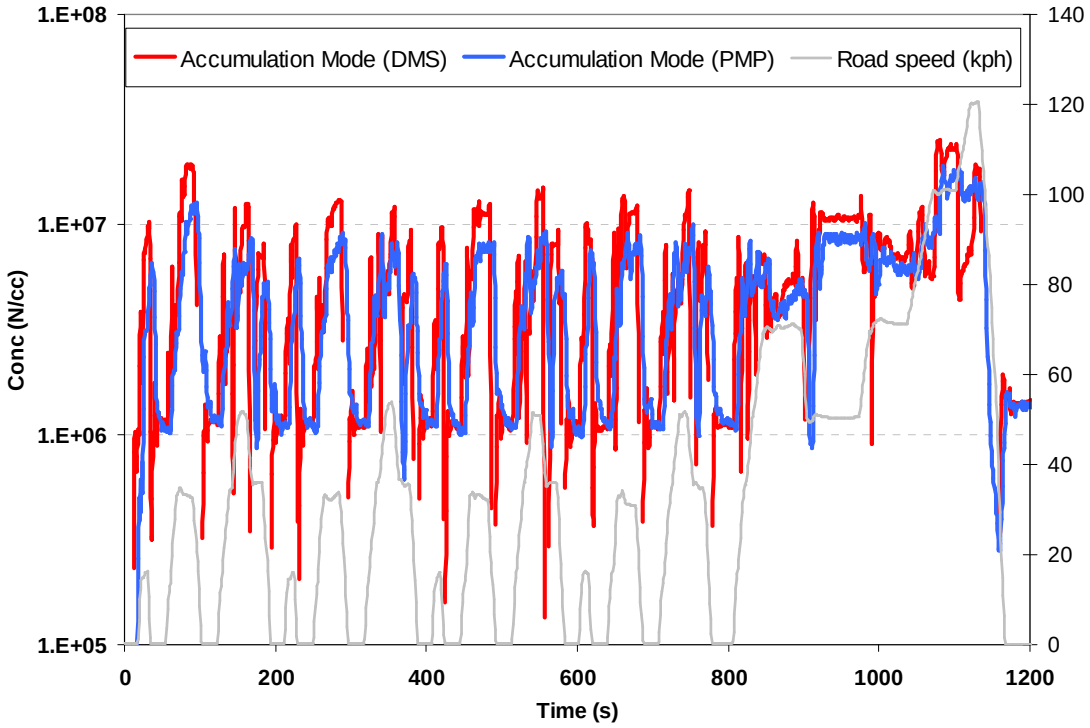

Figure 5: Transient solid particle number measurement

And finally we show the specific emissions from all transient tests:

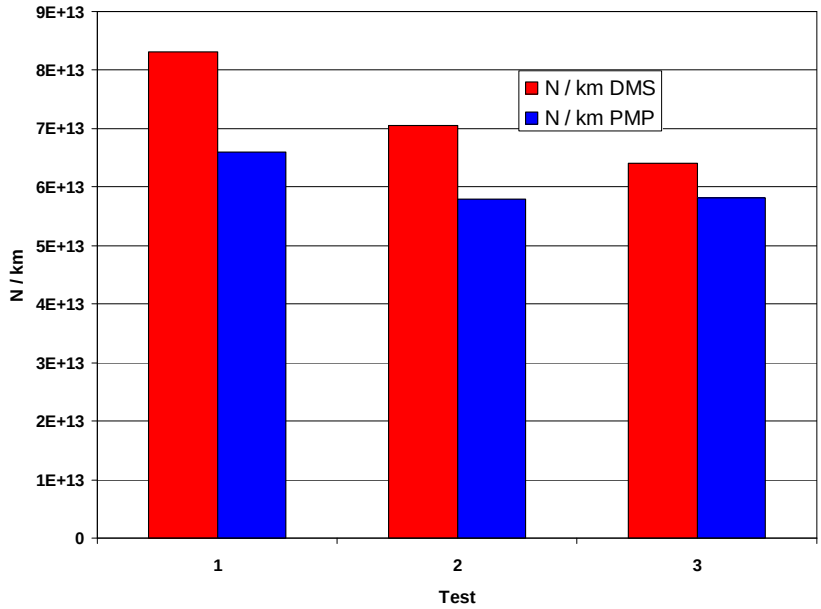

Figure 6: NEDC Summary

An example of the use of a DMS500 to determine Gasoline Direct Injection exhaust solid particle number is given in application note DMS08.

[1] Symonds, J.P.R., & Reavell, K.St.J. (2007). *Calibration of a Differential Mobility Spectrometer*, European Aerosol Conference, Salzburg, **T02A034**

[2] Ouf, F.X., Gensdarmes, F., and Sillon, P. (2008). *Influence of nature and shape of particle on corona charging efficiency of the Electrical Low Pressure Impactor*, European Aerosol Conference, Thessaloniki, **T04A028P**

[3] Reavell, K.St.J., & Symonds, J.P.R. (2007) *Calibration of Fast Electrical Mobility Spectrometers for Engine Particulate Measurement*, 11th ETH-Conference on Combustion Generated Nanoparticles, Zurich