Particle emissions from vehicle brakes

Introduction

Friction based brakes are widely used on motor vehicles.

Typically the braking system relies on friction between an iron disc (rotor) and a brake pad made of friction material bonded to a backing plate.

Actuation is hydraulic, and an element of friction between the disc and pad remains even when the braking pressure is not applied. Both disc and pad are consumable items and require periodic replacement as material is lost from both.

During braking, nanoparticles are released from the disc/pad interface.

These nanoparticles are of interest since they have cosmetic implications (dirt on wheel rims) and also due to concerns regarding potential health effects.

DMS500 Fast Particulate Spectrometer

The DMS500 Fast Particulate Spectrometer uses unipolar corona charging and parallel detection of particles of varying electrical mobility (using electrometers) to offer real-time measurement of the particle size spectrum between 5 and 1,000 nm (optionally between 5 and 2,500 nm).
Various design features allow the instrument to offer 10Hz data with a $T_{10\text{-}90\%}$ of 200 ms, which is well suited to the short duration of particle emissions from braking.

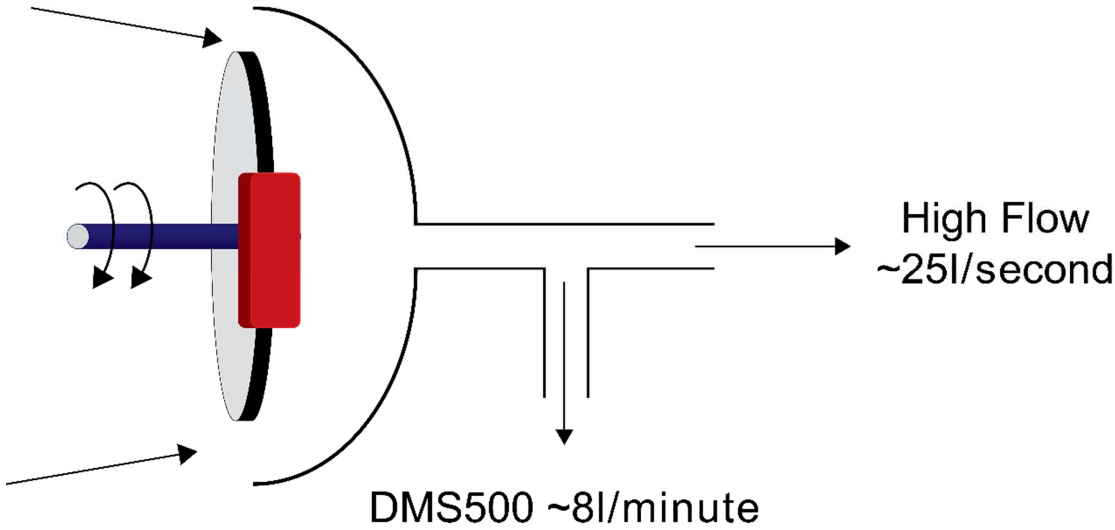
This is sufficiently fast to allow resolution of changes in emitted particle size during a single braking event.

Sampling Arrangements

Testing of brake emissions on a vehicle is complicated if the vehicle wheels are fitted, since these cause high turbulence, and prevent good access to the brakes.

For this application note, a passenger vehicle with the front (driving) wheels removed to allow good access was used. This does present some difficulties in accurately reproducing real-world braking forces and durations, but allows an initial investigation to be made.
Better controlled measurements could be made with access to a brake testing dynamometer.

To ensure all of the particles from the brakes are captured, a pseudo Constant Volume Sampling approach was used:



This has several advantages:

1. All the particles generated by the brake are captured by the high airflow. Variability in the measurement due to sampling location or sample tube alignment are therefore eliminated.

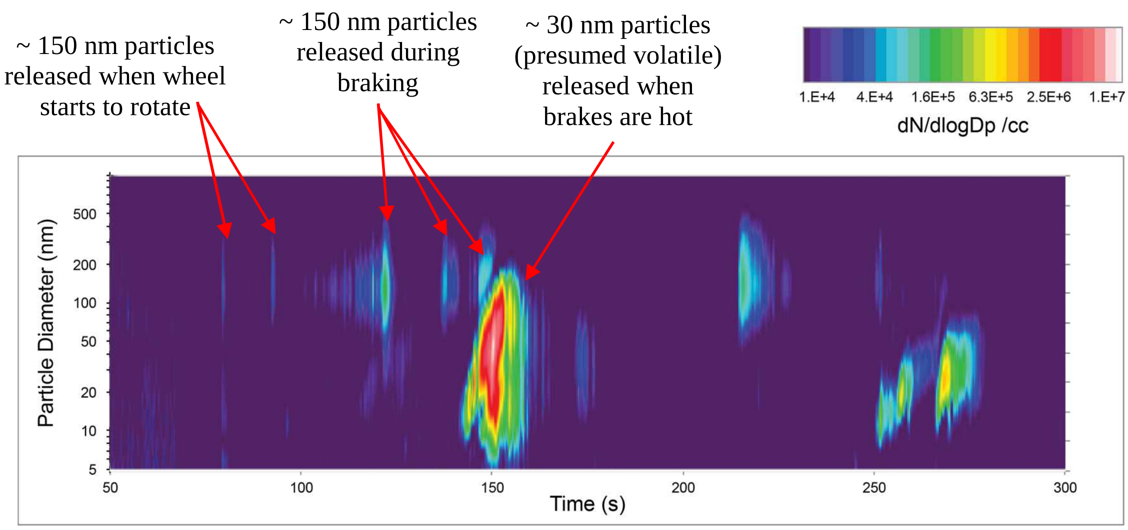
2. Although the native measurement of the DMS500 offers particle size distributions, concentration (N/cc) and mass concentration (ug/cc), of greater interest is the total emissions from a braking event- i.e. total particle number (N), or total particle mass (ug).

   The CVS principle greatly simplifies these measurements. Measured concentrations in N/cc can be multiplied by the total airflow rate (in the above example, the high flow + the DMS500 sample flow both of which are approximately constant) to give total emissions. (This presumes that the two airflows are well mixed at the measurement point).

   For example, N/cc * cc/s = N/s.

   This instantaneous number rate may then be integrated over the braking event, or a series of braking events.

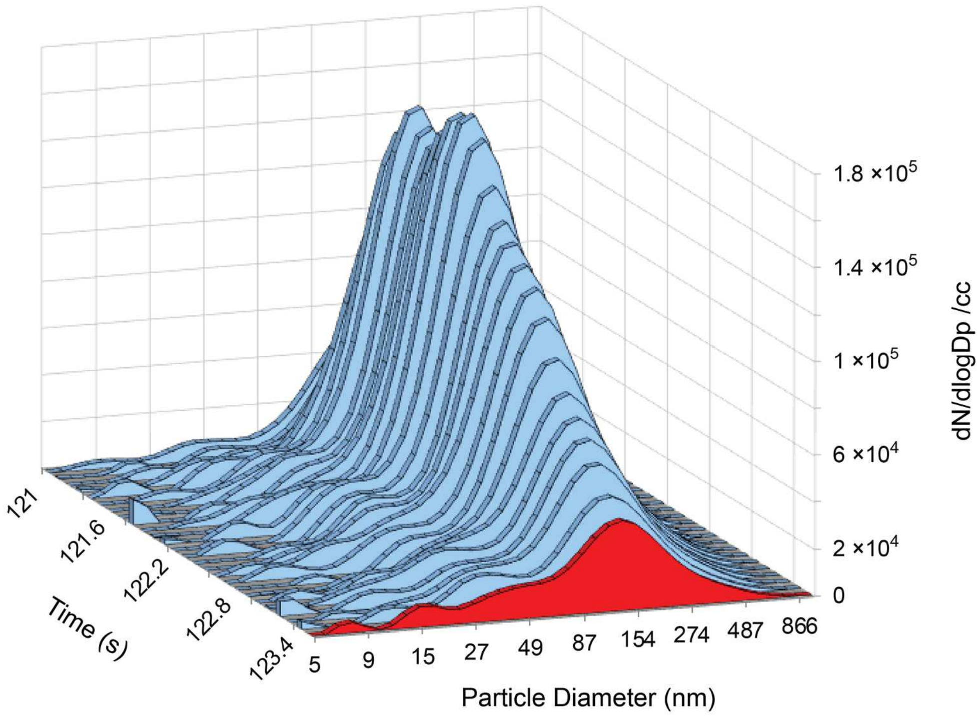
Example Data



Several feature of interest are visible:

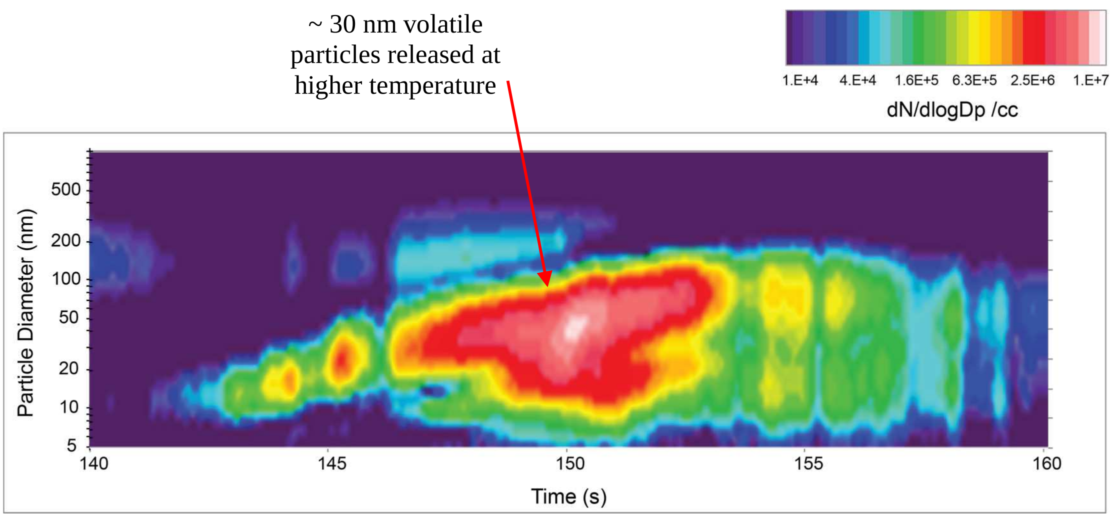
Particles are seen being released from the brakes when the wheels begin to rotate, and also during gear changes as the speed increases.

The typical size of particle produced during braking is observed to be ~ 150 nm in this case:



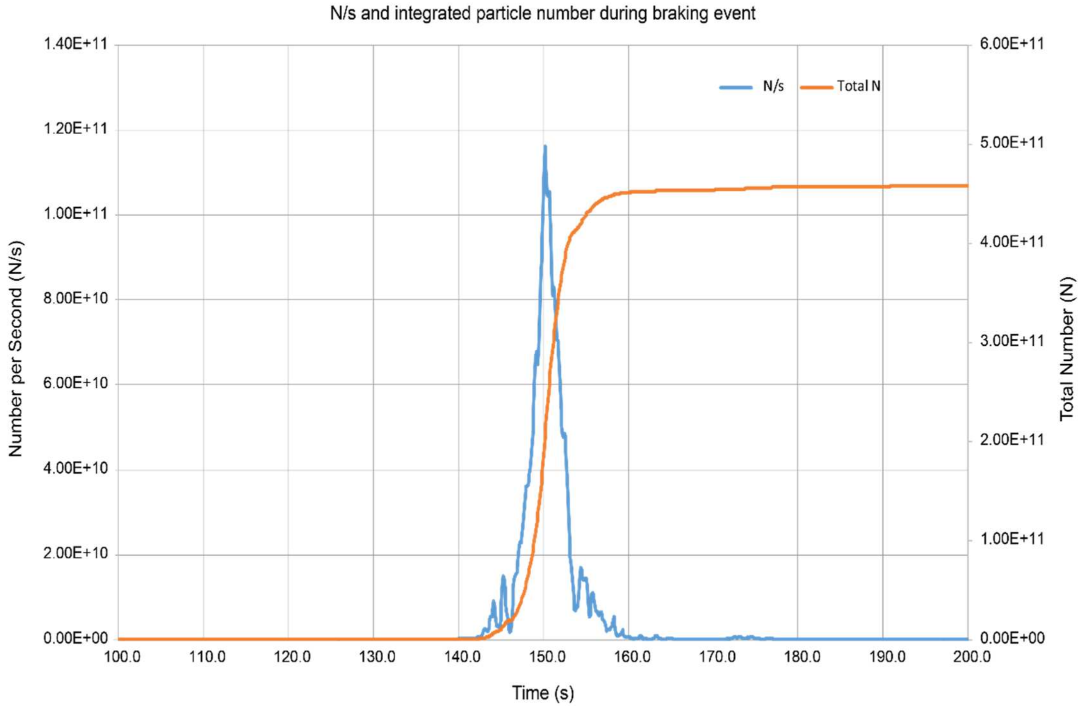
During repeated similar brake applications, the emission of particles increases with each application- it is presumed that this follows a trend with disc temperature.

Above a certain temperature, the disc/pad is observed to emit a high number of relatively small particles in the size range 10 – 100 nm. It is presumed that these may well be volatile- further investigation would be required to prove or disprove this assumption.

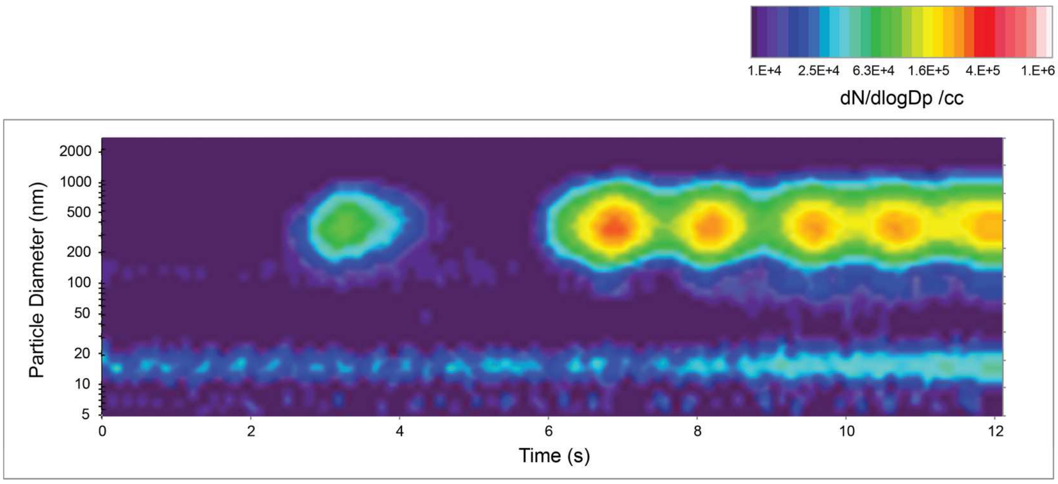


Data Processing:

The data presented above were further processed, to allow calculation of a total particle number emissions rate.



Historically, monitoring of particles from brakes has focused above 1 micron. The DMS500 was also operated on the 5 – 2,500 nm range to allow investigation over an increased size range.



The above data suggest that for the DMS500 measurements on this brake system, a 5 nm – 1,000 nm measurement range is appropriate, since no particles were detected between 1,000 – 2,500 nm.

Conclusions

The DMS500 is capable of resolving the particle emission from both gentle and high-energy braking events.

Particles in the size range 5 – 500 nm are observed. No particles were measured in the 1,000 – 2,500 nm size range.

On this braking system, particles during normal braking appear to be centred around 150 nm.

Small particles below 100 nm are generated at very high concentrations and are associated with higher braking temperatures.

Significant particle emission can be detected from the brakes even when not braking- as the disc begins to turn particle emissions are identifiable as a transient event, although the total number emitted in this condition is orders of magnitude below that during braking.

Further Reading:

DMS500: www.cambustion.com/products/dms500/aerosol