Mass Monitor and Fine Particle Sampler in Vehicle PM Emission Measurements

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Introduction

Dekati Mass Monitor (DMM) is a real-time device designed for automotive particulate mass emission measurement in the size range of 0.03 – 1.2 µm. The operation principle is based on particle charging, density measurement, particle size classification with inertial impaction, and electrical detection of charged particles (1).

Fine Particle Sampler (FPS) is a sampling system based on combination of porous tube and ejector diluters, allowing controlled sample transformation from raw exhaust to moderate temperature and concentration levels (2).

Together these two instruments form a powerful tool for vehicle particulate matter measurements. Known dilution ratios, controlled temperature change and reliable mass concentration measurement allow PM studies for most applications. In this work we verify the operation of the system.

Method

Particulate emission was measured from a SisuDiesel 44EWA, 4.4-liter, 108kW off-road diesel engine. Regulated PM emission was determined using an AVL SmartSampler, while real-time measurement was carried out with DMM and FPS. A parallel gravimetric filter sampling was applied to verify DMM mass concentration, while FPS dilution ratio calculation was verified using 2 Nox -analyzers, before and after the dilution.

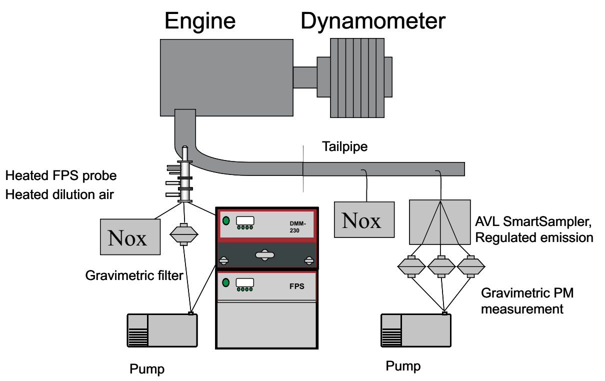

Figure 1: Measurement set-up

Results 1: Dilution ratio determination

Fine Particle Sampler probe and the primary dilution air were heated to 200 degrees C to remove condensed hydrocarbons and other semi-volatile particles. FPS then calculates the dilution ratio in second-by-second basis, which was verified using two Nox -analyzers, one of them measuring raw exhaust Nox- concentration and the other one diluted sample Nox.

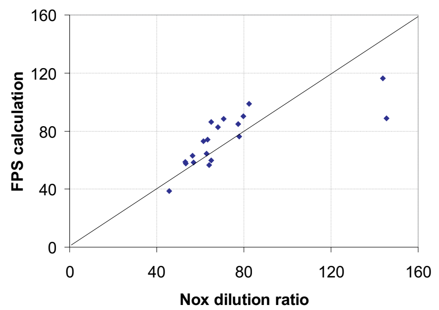

Figure 2: FPS dilution ratio accuracy

At high dilution ratios the diluted Nox concentration was less than 1 ppm, causing a significant uncertainty to the Nox measurement. At moderate dilution ratios the agreement is good.

Results 2: Mass concentration measurement accuracy

DMM result was compared against a gravimetric filter. Both systems were connected to a heated Fine Particle Sampler using identical sampling lines. The correlation as shown in Figure 3 verifies the accuracy of DMM result.

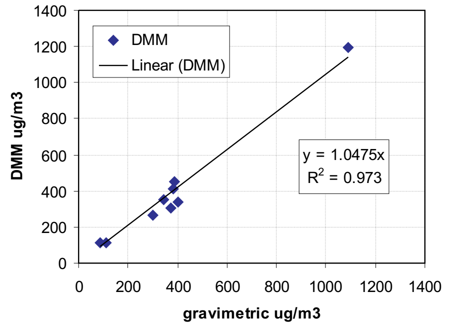

Figure 3: Mass concentration correlation, identical sampling

Results 3: Sampling system

Since heated FPS was used to remove the hydrocarbons from the sample it was expected that there is a difference between the regulated emission and DMM - FPS -combination. At low load conditions the emission measured after AVL SmartSampler was twice as high as compared to emission measured after heated FPS, as shown in the Figure 4. At higher load conditions the agreement was better due to lower HC concentration in the sample.

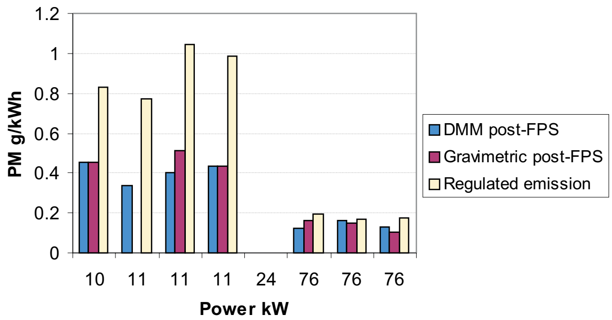

Figure 4: Emission correlation, regulated emission vs. DMM+FPS 2200 RPM, 45 and 330 Nm

Conclusions

DMM shows a good agreement against the total mass concentration measured with a filter when volatile material is removed from the sample. However, a significant difference can be caused by treatment of volatile material in different sampling systems.

Dilution ratio determined by the FPS shows good agreement with the dilution ratio measured using two gas analyses. However, a trace gas measurement is recommended for dilution ratio verification, especially at high dilution ratios at high temperatures and fluctuating flows.

References

(1) Moisio, M, Niemelä, V. (2002) Device for Continuous Measurement of Density and Mass Concentration of Vehicle Exhaust Aerosol IAC 2003

(2) Mikkanen, P., Moisio, M., Keskinen, J., Ristimäki, J., Marjamäki, M. (2001). Sampling Method for Particle Measurements of Vehicle Exhaust, SAE Technical paper series 2001-01-0219

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