Real-Time Measurement of Diesel Trap Efficiency

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Introduction

Determination of diesel particle filter (DPF) or other aftertreatment device PM removal efficiency is commonly done with a standard sampling system such as CVS tunnel and gravimetrical PM mass measurement. However, when the reduction of particle mass is measured with this method there are several uncertainties with new, highly efficient diesel traps. In this paper we discuss about these issues and introduce an alternative system for a more sensitive and better-controlled measurement.

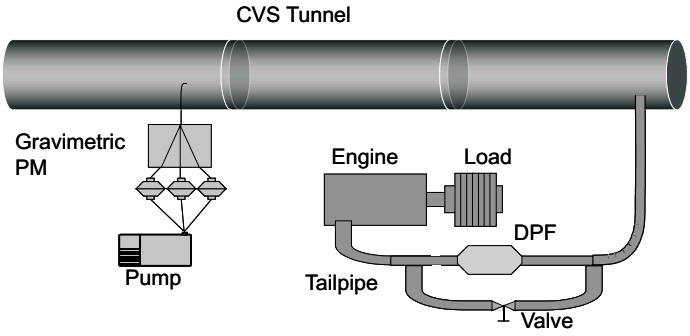

Figure 1: CVS tunnel system for DPF efficiency measurement

Problem I: Sensitivity

Concentrations downstream modern, high-efficiency Diesel Particle Filters are very low, setting high requirements for gravimetric measurements. The microbalance, weighing rooms and sampling systems have to be state-of-the-art in order to get as repeatable results as possible, since the collected mass can be as low as just few micrograms.

Problem II: Filter artefact

Filter papers collect all particles with high efficiency, but they are also collecting some gas-phase material [Chase et al]. With conventional diesels this artefact is almost negligible since solid particles dominate the mass, but downstream DPF there are no longer solid particles, and the gas-phase material might affects the results, depending on the filter material.

Table 1 shows data measured downstream DPF and with DPF bypass so that EURO IV PM criteria is met. It is clearly seen that at low emission level the used TX-40 filter shows more mass than the real-time Dekati Mass Monitor DMM. Also, it is not possible to use gravimetric measurement for the PM levels indicated by the DMM.

		Tailpipe concentrations [mg/Nm3]:	After 1:10 dilution [mg/Nm3]:	Collected mass [ug] (70 lpm, 30 min)
Post-DPF	Gravimetry	0.31	0.031	65.1
	DMM	0.005	0.0005	1.05
EURO IV-Level engine	Gravimetry	2.16	0.216	453.6
	DMM	2.56	0.256	537.6

Table 1: Measured mass concentrations from the DMM and gravimetric measurement, and estimated amount of particles collected to a filter paper in similar conditions [Mohr et al.]

Problem III: Volatile material behavior

Dilution parameters have a significant effect on the measured PM concentrations. Even though the amount of solid particles is constant the volatile material condensates, evaporates and nucleates depending on the dilution ratios and temperature profiles. In a CVS tunnel these parameters are not constant and controlled only roughly [Lamminen et al.]. This is especially an issue in post-DPF measurement s where basically all particles are volatile.

Problem IV: Engine Backpressure

Diesel Particle Filters or Catalysts affect to the engine back pressure, and this has an effect on the engine operation. Normally when the engine out emission is measured the aftertreatment device is removed and the backpressure is controlled with e.g. a valve in the tailpipe. However, in actual situation the delta P is not constant, and it depends on the filter loading and engine speed.

Solution I: On-line measurement

Electrical detection of particles is more sensitive method for particle detection than gravimetric measurement. Dekati Mass Monitor DMM is based on particle charging, inertial and mobility size classification and electrical detection of charged particles, and it provides better sensitivity and time resolution than traditional PM measurements [Mohr et al.]. Several international studies have proved that the result is comparable to gravimetric measurements.

Solution II: Tailpipe sampling system

Dekati Fine Particle Sampler FPS is a sampling system for tailpipe particle measurements. Dilution parameters are controlled, including dilution ratio control in the range of 1:15-1:200, temperature control (10-300°C) and real-time dilution ratio determination. It can take the sample from high overpressures in a controlled way.

Figure 2: DMM and FPS installed into a 19" rack

DMM + FPS

Together these two instruments are a transportable measurement system for diesel and gasoline PM measurements. The system can take the sample from upstream or downstream DPF, allowing measurement of the DPF PM removal efficiency. Its sensitivity goes down to a level of few micrograms / m3, and all the data is recorded in second-by-second basis. Result is also available via analog output signal, allowing its integration to a test cell equipment.

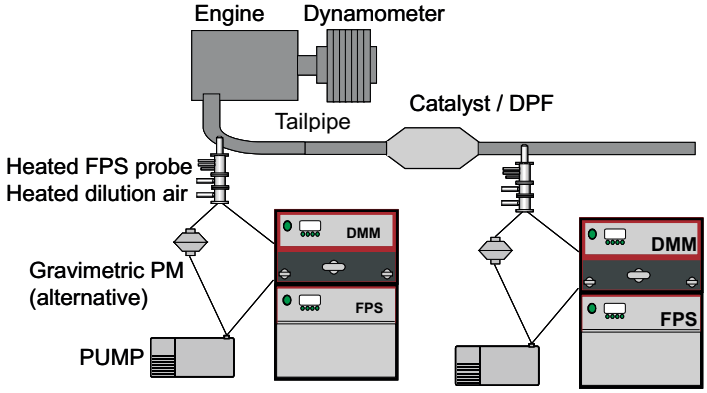

Figure 3: DMM and FPS set for DPF efficiency measurement

Results:

As seen in Table 1, the DPF efficiency measured with the DMM is much higher than when measured with a gravimetric filter and CVS tunnel (efficiencies 99.8% and 85.6%). However, number-based DPF efficiency measurements in the same study showed efficiencies higher than 99.9%. The main reason for the difference is the filter artefact, where the filter type plays important role. TX-40 used in Europe has higher tendency to collect gas-phase material than e.g Teflo® -filters used for US2007 measurements.

Conclusions:

Dekati Mass Monitor DMM and Fine Particle Sampler FPS are a complete system for diesel PM measurements. This system can be connected both upstream and downstream diesel aftertreatment device, and allows well-controlled method for PM removal efficiency measurements.

References:

Chase, R., Duszkiewicz, G., Richert, J., Lewis, D., Maricq, M., Xu, N. (2004): PM measurement artefact: organic vapour deposition on different filter media. SAE Technical Paper Series 2004-01-0967

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