Investigation of the correlation between a prototype Advanced Halfmini DMA and a commercial SMPS for combustion-generated solid sub-23 nm particles measurement

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INTRODUCTION

The problem

Modern diesel and G-DI vehicles, as well as CNG and LPG engines may emit nucleation mode particles in the sub-23 nm region, either under special conditions or as part of their normally emitted size distribution [1,2]

These findings led to the investigation of measurement approaches for reliable detection of sub-23nm particle emissions [3]. **Hot emission measurement with the *Advanced Halfmini DMA* (SEADM S.L.) coupled with a sampling system of minimum requirements** is also proposed for accurate detection of solid sub-23nm particles [4].

Alternative measurement approach proposed by SUREAL-23

The Advanced HalfMini DMA (HM-DMA)

The *Advanced Halfmini DMA* was initially developed by F. de la Mora & Kozlowski (2013) for high resolution measurement of 1-15 nm particles, at ambient temperature. After recent modifications [6,7] the system can measure exhaust aerosols with an **extended particle size range up to 30 nm**, **at high temperatures up to 200°C**. In this modified system, **particle charging occurs by a Secondary Electrospray Ionisation (SESI) charger which is adopted for hot charging (50–200°C)**.

The objective

However, understanding and determining the charging efficiency of such a unipolar charger is a challenging task. In this study, we performed a preliminary **experimental correlation of the prototype *Advanced Halfmini DMA* ions concentration signal to SMPS particle concentration** using aerosols of different concentrations, generated either by a standard propane burner or a diesel engine.

METHODOLOGY

Experimental Setup

Particle nucleation mode of different concentration levels was measured by the prototype *Advanced Halfmini DMA* in tandem with a reference SMPS system (TSI, NanoDMA 3085 and CPC 3776) in order to investigate their correlation.

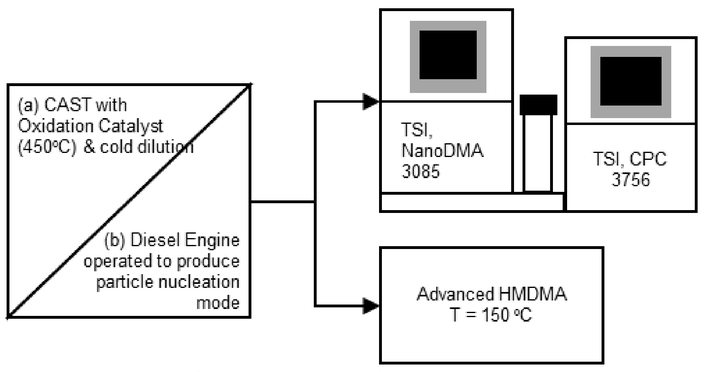

***Figure 1**. Experimental setup*

The generation of solid nucleation mode particles, in the range of 8 – 30 nm and in concentrations varying from $3*10^5$ to $2*10^7$ particles/cm^3 was obtained with a:

(a) CAST propane burner (Matter Engineering), operated at non-standard operating mode [3] : ○ at different dilution ratios (DR=20, 70) using a rotary diluter; ○ with no dilution (raw exhaust measurement).	**(b) Diesel engine** of single cylinder, 4-stroke, 5 kW, air-cooled DI (Hatz), operating in 23% engine load, fueled with: ○ Ce-based soot oxidation catalyst (ENVIROX, "DPF Assist"), 29.4 ml/lt fuel; ○ commercial lubrication oil (SOLVAY, LiquiMoly", 60 ml/lt fuel.

RESULTS

Correlation

Five sets of experimental data were obtained correlating *Advanced Halfmini DMA* ions concentration to SMPS particle concentration with the below mobility size-dependent Equation (1) (Figure 2).

$$\frac{HM-DMA\ signal\ [\frac{ions}{cm^3}]}{SMPS\ signal\ [\frac{particles}{cm^3}]} = 0.0011e^{0.1401*D_m} \quad (1)$$

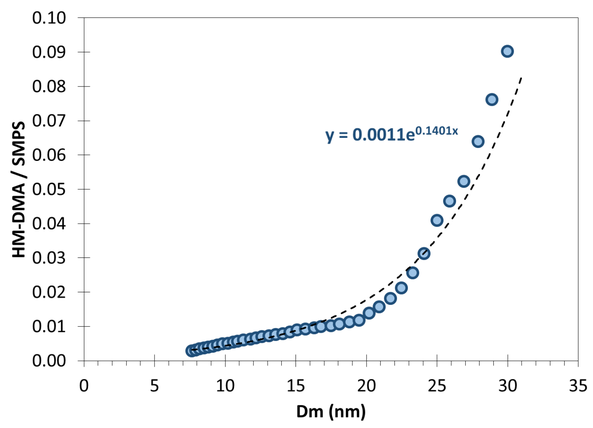

***Figure 2.** Correlation of Advanced HM-DMA (ions/cm³) to SMPS (particles/cm³).*

The overall correlation is considered good for the studied range of particle concentration values that is of interest for the engine exhaust measurements.

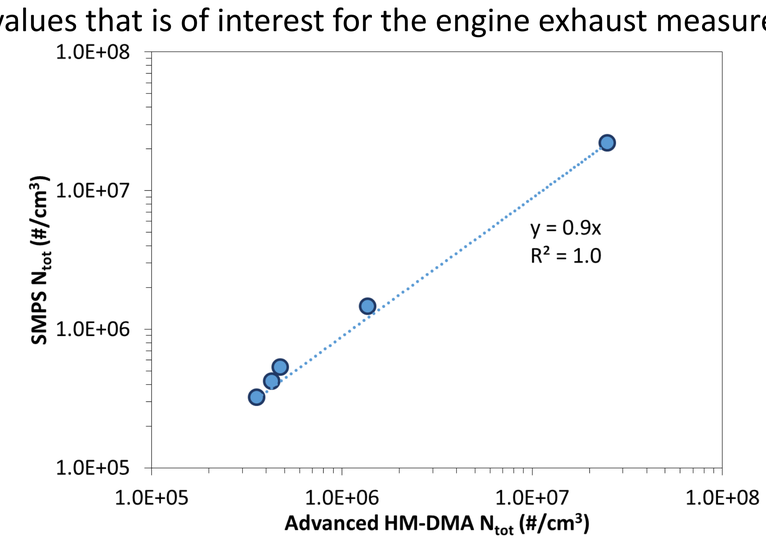

***Figure 3**. Correlation of corrected Advanced HM-DMA concentration signal to SMPS.*

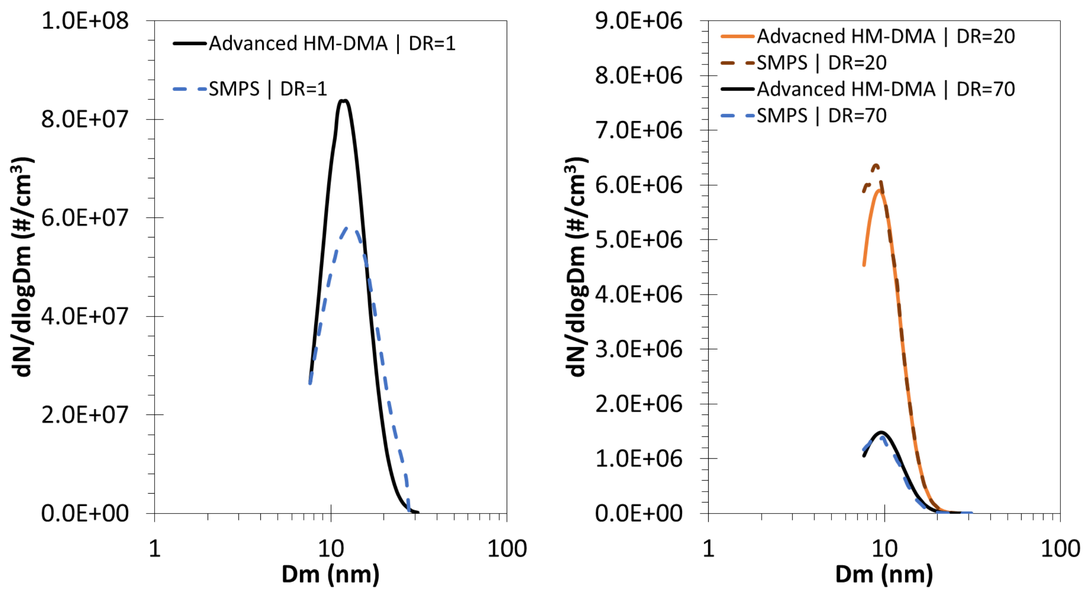

***Figure 4**. Comparison of corrected Advanced HM-DMA and SMPS PSDs [#/cm³] for three concentration levels as generated by CAST with DR=1, 20, 70.*

GDI implementation

For evaluation purposes, the produced correlation was implemented in a measurement of exhaust emitted by a last-generation, 4-stroke, GDI engine operating in steady state conditions (2000 rpm; 24 bar of BMEP), in comparison to the DMS500 (Cambustion) measurement.

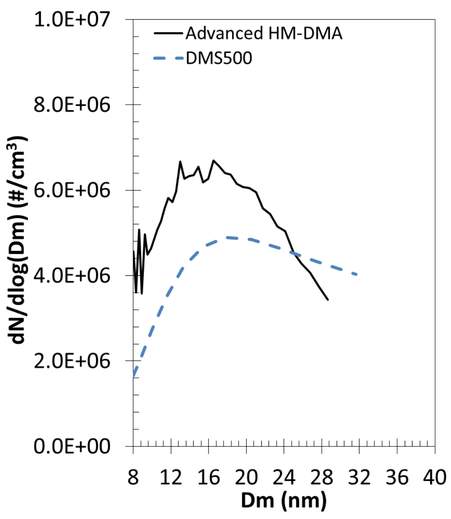

***Figure 5**. PSD comparison of corrected Advanced HM-DMA and DMS500*

CONCLUSIONS / FUTURE WORK

- *Advanced Halfmini DMA* is able to detect solid nucleation particles (sub-23nm region) due to hot particle charging with SESI; a unipolar charger that accommodate hot sample but has undefined charging efficiency.
- *Advanced Halfmini DMA* raw signal in ions/cm^3 was correlated with particle concentration following a size-depended, exponential relation.
- The overall correlation was considered good for the studied range of particle concentration values that is of interest for the engine exhaust measurements.
- Correlation was implemented for GDI sub-30nm particle measurement to correct prototype system's raw signal to particle number concentration. *Advanced Halfmini DMA* signal is higher than DMS500. The difference may attributed to the higher HM-DMA resolution and to losses in the 2-stage diluter integrated in DMS500 contrary to the 1-stage hot dilution coupled with HM-DMA.
- Establishing the charging efficiency of the SESI is necessary to fully exploit *Advanced Halfmini DMA* advantages for accurate and quantitative measurements of solid nucleation particles.

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