High-temperature solid particle emission measurements in the sub-23nm mobility size range with the *Advanced Half-Mini DMA*

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INTRODUCTION

The problem

Current particle number related vehicle emission legislation is **limited down to 23 nm.** The rationale behind the 23 nm cut-off size is based on the avoidance of significant uncertainties created during sampling and measuring sub-23 nm solid particles (i.e. **potential formation of particles in the sub-23 nm region, the so-called artefacts**).

Difficulties in introducing a robust measurement protocol in this particle size range led regulation authorities to ignore their contribution to ambient pollution. However, the sub-23 nm particles draw high attention since current gasoline engines emit almost equal fraction of sub- and above- 23 nm particles, while diesel engines with after-treatment devices may also emit such ultrafine particles under certain conditions (i.e. regeneration of particulate filters) (Giechaskiel and Martini, 2014).

The proposed approach

To overcome such uncertainties we investigate a novel approach - of minimum requirements - for sub-23 nm measurements that necessitates **a single hot dilution stage** and **a high-temperature particle number (and size)** counter as a potential alternative to the *Particle Measurement Programme* (PMP) working group protocol.

Alternative measurement approach proposed by SUREAL-23

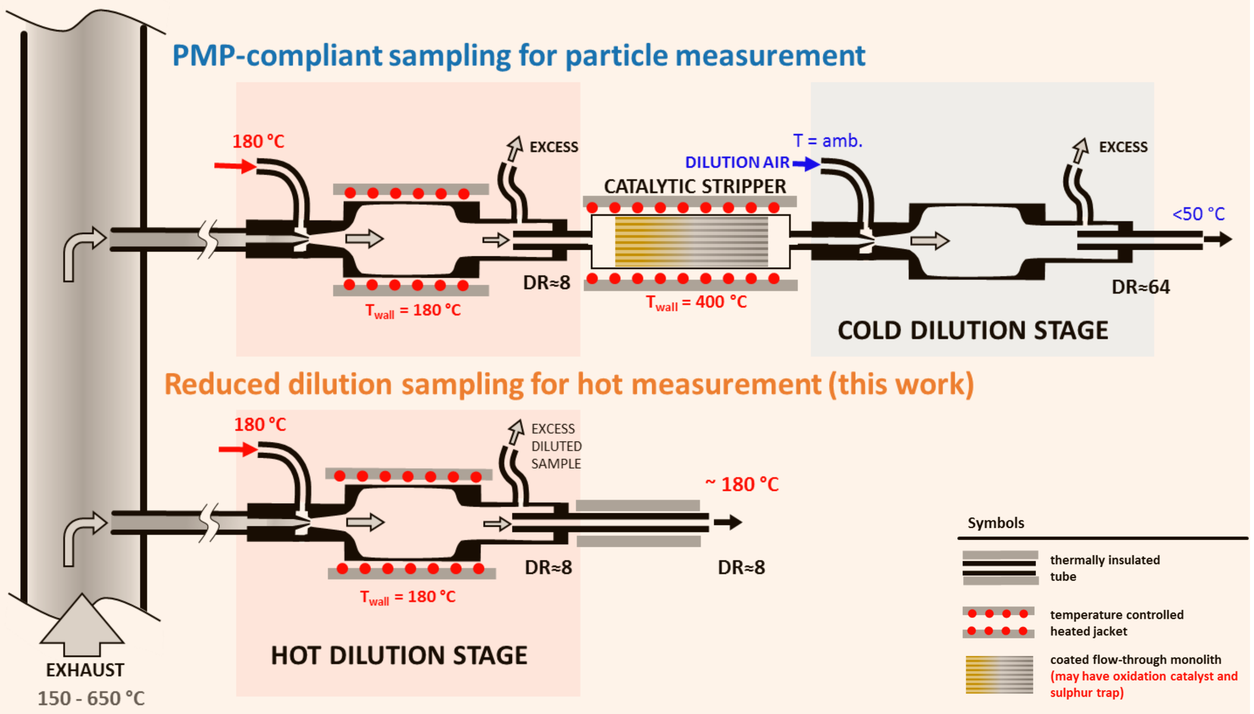


Figure 1. Engine exhaust sampling approaches: (a) PMP compliant Volatile Particle Remover (VPR) system and (b) proposed single stage hot dilution.

The Advanced Half-Mini DMA (HM-DMA)

In the current work single stage hot dilution sampling is accompanied with size specific measurements by the ***Advanced Half-Mini Differential Mobility Analyzer (Advanced HM-DMA)***; a supercritical DMA, with a 2cm working section, able to classify aerosol particles in the mobility size range 4–30 nm, with **high resolution** and **fast spectrum acquisition** (de la Mora, 2017). Due to recent upgrades on the insulating and semiconducting materials, it accommodates **hot sample flow up to 200 °C** (Amo et al., 2017). Its resolving power was recently tested under high temperature, using ions of known mobility (Amo et al., 2018, **AT2018 Presentation TA3-02**).

RESULTS

Preliminary tests of Advanced HM-DMA with sub-23nm standard solid particles

Advanced HM-DMA hot operation, was initially tested against SMPS with:

a. **solid sub-23nm NaCl particles**, generated by an Electrospray Aerosol Generator (TSI, 3482).

b. **solid sub-23nm soot particles** generated (& catalytically pre-treated) by a Combustion Aerosol Standard (CAST, Matter Engineering) burner.

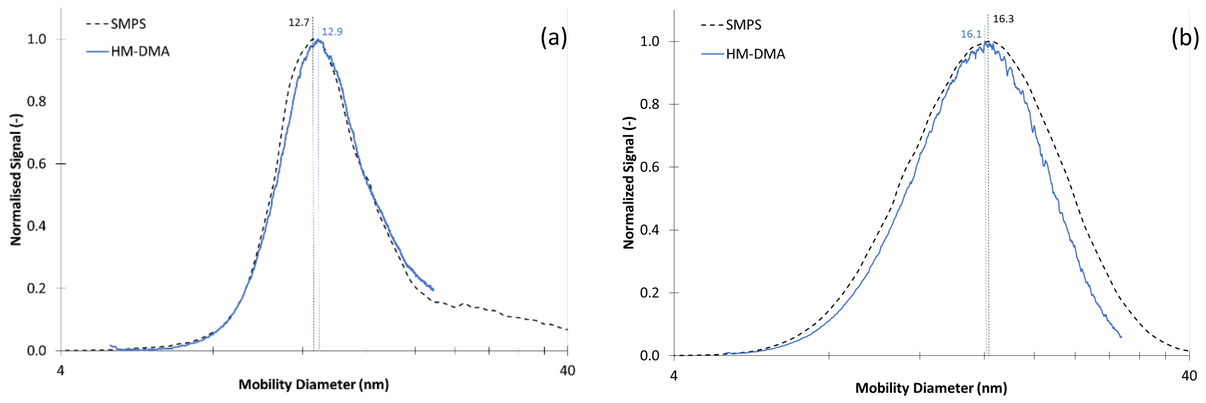
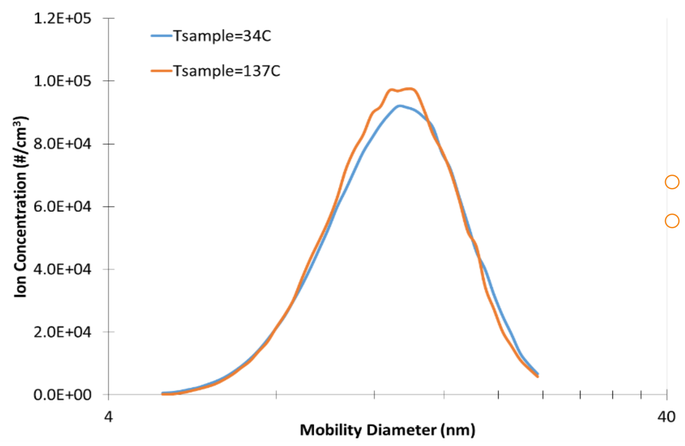


Figure 2. Normalized particle size distribution of (a) NaCl particles, and (b) CAST-generated soot particles, measured with *Advanced H-M DMA* at the hot temperature mode and compared with an SMPS (NanoDMA 3085, CPC 3776).

Preliminary tests: Advanced HM-DMA hot & cold operation

Hot against **cold operation of *Advanced HM-DMA*** was assessed with solid sub-23nm soot aggregates generated (catalytically pre-treated) by CAST.



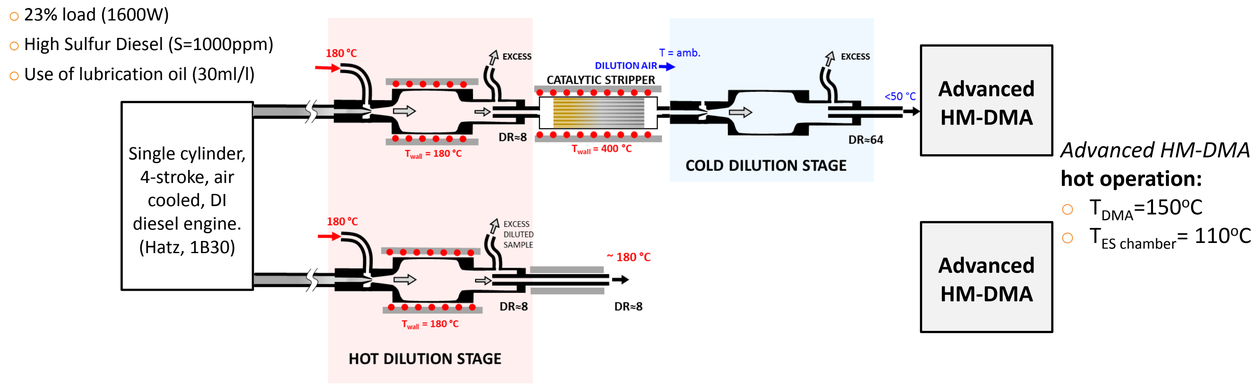
- Identical d_m=13.2 nm & σ_g=1.3
- Identical total ion concentration (<2% differences)

Figure 3. *Advanced H-M DMA* particle size distribution of CAST solid soot particles. Aerosol sample is measured either warm (137°C) or at close to ambient temperature (34°C).

Advanced HM-DMA tests with 1-stage hot dilution and PMP compliant sampling

Engine operating condition:

- 23% load (1600W)
- High Sulfur Diesel (S=1000ppm)
- Use of lubrication oil (30ml/l)



Advanced HM-DMA **hot operation:**

- T_{DMA}=150°C
- $T_{ES\ chamber}$= 110°C

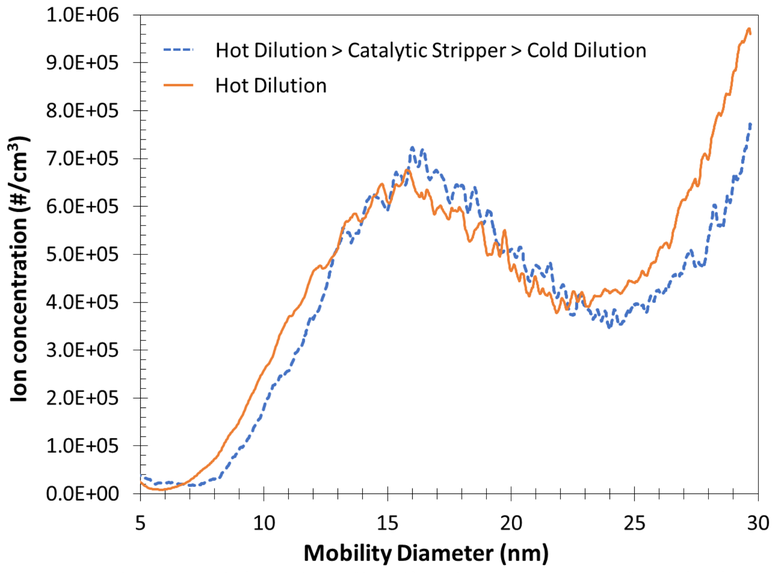


Figure 4. Sub-23nm engine particles size distribution measured with the *Advanced HM-DMA* in hot operation using (a) a PMP-compliant setup and (b) a single step hot dilution.

CONCLUSIONS / FUTURE WORK

- The **excellent agreement between PMP compliant** and **single hot dilution size specific measurements** (Fig. 4) confirms the reliability of the *Advanced HM-DMA* hot operation mode and indicates the **possibility of using a simple setup for solid particles measurement**.
- ***Advanced HM-DMA* size classification** of solid particles **in the sub-23nm region was successfully evaluated** against SMPS (Fig. 2).
- ***Advanced HM-DMA* hot and cold aerosol flow measurements of solid sub-23nm particles are in good agreement** (Fig. 3) showing that its resolution is not influenced in the hot operation mode and may measure without introducing errors.
- ***Advanced HM-DMA* charging efficiency** - under different engine exhaust operating conditions (injection, fuel, etc) - is planned to be studied in order to **convert ion to number concentration.**

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