Half-mini DMA modification for high temperature aerosols and evaluation on various combustion exhausts

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Keywords: Half-mini DMA, sub-23nm particle emissions, high temperature aerosol analysis.
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The reliable measurement and understanding of particles emitted by road vehicle engines below the currently adopted 23 nm size cut-off is now under intense study in an effort to derive future European legislation on particle emissions, as recommended by the JRC Science and Policy Report (Giechaskiel and Martini, 2014). Here we present the modification of a nano-DMA for better compatibility with exhaust aerosols and the subsequent evaluation of measurement capability improvements obtained on various engine exhaust streams. In particular, it is shown that the modified DMA facilitates the size-specific analysis of sub-23 nm exhaust aerosols especially at low solid particle concentrations, up to now challenging or inaccessible to analysis due to the extensive sample conditioning required to avoid artifacts.

The Half-Mini DMA (HM-DMA) is a Differential Mobility Analyzer operating at supercritical Reynolds numbers typically able to classify 1 to 15 nm particles with high resolution. Recently, the HM-DMA was extended to particle diameters up to 30 nm (de la Mora, 2017) fully covering the 1 – 23 nm particle size range of interest. Also, motivated by application to engine emissions, such an extended range HM-DMA has been successfully upgraded for improved compatibility with exhaust gas temperatures, mainly by use of a heat-tolerant semiconducting glass tube in the path from the inner electrode (held at high voltage) to the grounded outlet, yielding a device capable of high classification efficiency at sample temperatures approaching 200 °C.

The HM-DMA temperature is maintained by insulating it thermally from the environment while controlling the sheath gas temperature by methods previously developed at SEADM S.L.. The evaluation of the developed HM-DMA is performed on numerous streams of hot combustion exhaust. Laboratory exhaust streams are generated by custom operation of the Combustion Aerosol Standard (Matter Eng.) soot generator. Additionally, the HM-DMA is evaluated with exhaust from automobile internal combustion engines (Diesel and gasoline direct injection) at various degrees of exhaust sample pre-conditioning, from raw exhaust sampling up to standard conditioning protocols and including the variable use of a catalytic stripper for removal of sulphur and hydrocarbon compounds. The high temperature HM-DMA is benchmarked against cold (up to 50 °C) sample aerosol classifiers in terms of resolving power and output concentration of classified particles. The higher DMA working temperature allows for reduction of the exhaust sample pre-conditioning (sorptive/catalytic cleaning, hot dilution) normally required to avoid artifacts from condensible exhaust species. Downstream instrumentation compatible with higher temperatures can directly benefit from higher concentrations of classified solid particles, especially significant for composition analysis, by using total sample dilution factors nearly an order of magnitude lower than those normally required by vehicle emission evaluation protocols. Downstream particle instruments that require a colder aerosol sample still benefit from reduced dilution (required hot pre-dilution is partly supplanted by the DMA sheath flow contribution) as well as from reduced thermophoretic losses from the diluter and HM-DMA.

The new HM-DMA (Fig. 1) has been found to facilitate size-specific analysis of 1 – 30 nm exhaust particulate, complementing established sub-23 nm particle emissions measurements while also allowing the study of engine emission phenomena previously inaccessible due to size-classified particle quantities being below instrument measurement thresholds.

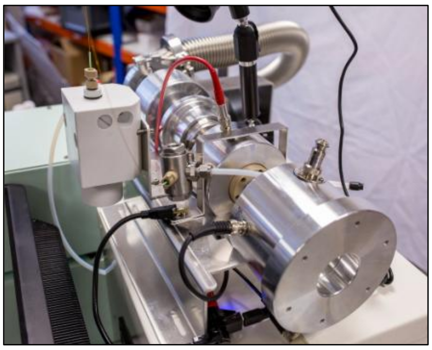

Figure 1. The high temperature capable half-mini DMA.

This work has received support from the “Horizon 2020” E.U. Framework Programme, through the SUREAL-23 project (Grant Agreement 724136).

Giechaskiel B., Martini G. (2014), *JRC Science and Policy Report:* “Review on engine exhaust sub-23 nm particles”, Joint Research Centre.

Fernandez de la Mora J. (2017) Expanded size range of high-resolution nanoDMAs by improving the sample flow injection at the aerosol inlet slit, *J. Aerosol Sci.*, under review.