Comparison of the Performance of Modified Vienna Type DMA and TSI Nano-DMA

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In this paper, the results of the comparison of two different DMAs – a modified Vienna type DMA and a TSI nano-DMA – are presented. Using a standard tandem-DMA setup, the transfer functions of these two devices were determined. Measurement results generally showed better performance for the modified Vienna DMA, except for the DMA resolution for the particle radiiuses below ~5 nm.

1. Introduction

Differential Mobility Analyzers have proven themselves as a valuable tool for aerosol research. As with any instrument, the properties of a particular DMA must be well known for correct measurements. Many studies have been conducted on the performance of different Vienna-based DMA designs; however, we could find only a few publications about the performance of the TSI nano-DMA (Chen et al., 1998; Hummes et al., 1996). During calibration experiments for a self-built Vienna-based DMA, an opportunity arose to investigate the nano-DMA from TSI as well. Thus the subject of this work was to measure the transfer functions of a Vienna-based DMA and a TSI nano-DMA in a broad range of particle sizes and to compare the results with each other and with results from previous studies.

2. Experiment Setup

Two different types of DMAs were used in the experiments: a self-built Vienna-based DMA design with a slightly modified aerosol inlet and a TSI nano-DMA (model 3085). The latter was used as a part of the TSI SMPS system which also included the TSI model 3025A CPC and model 3080 Electrostatic Classifier. Both DMAs were operated with the aerosol to sheath flow ratio of 0.1. However, for technical reasons, the nano-DMA was used without its bypass-air option turned on.

Silver or silver + DOP particles (for particle radiiuses above 15 nm) were used for the experiments; particle concentrations were measured with above-mentioned CPC. Experiments were controlled by a personal computer running a custom software package, which was responsible for setting the DMA voltages and collecting the data from CPC and air flow measurements.

For the experiments, a standard tandem-DMA setup was used, shown in Fig.1, where two DMAs were connected in series. During each measurement the voltage applied to the first DMA was fixed at a value corresponding to the particle mobility/radius of interest, while the voltage of the second DMA was varied so that the mobility interval
around the midpoint mobility of DMA1 was scanned.
First, two identical Vienna-based DMAs were connected together and their transfer functions were determined as described by Stratmann et al. (1997), for particle radiuses in the range of 1.5 – 50 nm. Care was taken to assure that the two DMAs were identical – equality of the geometric dimensions of the two devices was carefully checked and several additional experiments were conducted where the outlet aerosol distributions of both devices were measured with a third DMA. Then TSI nano-DMA was paired with a previously investigated Vienna-based DMA and its transfer function was also determined.

3. Experimental Data Processing
Collected scan data were first normalized to the total aerosol concentration downstream of DMA1, which was measured before and after every experiment by connecting the output of DMA1 to the CPC input. Effort was made to ensure that particle losses in the lines connecting DMA1 to DMA2 and in bypass lines to the CPC were the same, so that they would be canceled out by the normalization. Scan data were then deconvoluted using a simple iterative algorithm and assuming a triangular shape for the transfer function (Stratmann et al., 1997).

The deconvolution algorithm uses a least-squares method to fit a theoretical mobility distribution at the output of DMA2 to measurement data by varying the two transfer function parameters – the height of the triangle and its relative half-width at the given mobility. The values producing the closest fit are then taken as the actual values for the
4. Results and Discussion

The graphs for the size-dependence of the transfer function parameters $\alpha$ and $\beta$ for both DMAs are presented in Fig.2 and Fig.3. For both cases a function consisting of a sum of two exponents was fitted to the experimental data (growth or decay function accordingly).

As seen from Fig.2, for particle radiiuses below 5nm the two curves coincide, but for bigger particles the losses are about 10% higher in case of the TSI nano-DMA. The particle transmission efficiency for the Vienna-based DMA levels off around 0.85. For the transfer function relative half-width (DMA resolution), the Vienna-based DMA again has a better performance in case of particles with radiiuses above ~5 nm (Fig.3). The maximum difference is about 9% and goes down to 5% for bigger particles. For the Vienna-based DMA, $\beta$ levels off around 0.11 – close to the theoretical value of 0.1.
For smaller particles, however, the situation is different – below ~5 nm the nano-DMA has a significantly lower relative half-width compared to the Vienna DMA; the difference in $\beta$ is as high as 30%.

Comparing the results with previous investigations of the TSI nano-DMA (Chen et al., 1998, Hummes et al., 1996), it can be seen that the results are in a general agreement for the relative half-width – the difference remains below 10%, with $\beta$ having higher values (lower DMA resolution) in this work.

For the transfer function height, the results for the nano-DMA in this work also seem to be constantly 10-15% lower (meaning higher particle losses) for all investigated particle sizes. This suggests at the possibility that in the experiment setup, the particle losses between DMA1-DMA2 and DMA1-CPC might not have been as similar as intended.

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6. References

