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Modelling ultrafine/nano particle dispersion in two differential mobility analyzers (M-DMA and L-DMA)

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In the present work, the dispersion of ultrafine/nano particles in two differential mobility analyzers (DMA) namely, a medium DMA (M-DMA) and a long DMA (L-DMA) is numerically analyzed using the Lagrangian tracking method. Simplified geometries of the two DMA's (M-DMA and L-DMA) that are truly representative of a wide class of DMAs have been considered for the present analysis. The exact profiles of velocity and electric field are used for conducting the present investigation. The Langevin equation is numerically solved to track the particles inside the DMAs. The Brownian force has been modelled as a Gaussian white noise random process. The effect of Brownian force on the dispersion of ultrafine/nano particles is clearly evident from the present investigation. The performance evaluation of both the DMAs have been carried out by comparing the transfer functions obtained using the present methodology with the widely accepted transfer functions of Knutson & Whitby and Stolzenburg. The numerical results obtained using the present methodology compare quite well with the experimental data available. It is also shown that DMAs with smaller effective electrode lengths have higher collection efficiencies for real nano-sized particles.

1. Introduction

Urbanization and industrialization along with the increased usage of automobiles contribute significantly to air pollution. The pollutants that are released into the atmosphere pose an increased threat to the human health. The pollutants emitted by the combustion of fossil fuels are quite inevitable. The size of the aerosols/pollutants might range from less than a micrometre to a few nanometres. The measurement of such ultrafine/nano particles requires measuring devices of high accuracy and resolution. The classification/sizing of aerosols has remained as a challenging area of research in the past few decades [1–5]. Of the various means of classification/sizing, the electrostatic classification of ultrafine/nano particles proves out to be the most viable and promising technique. The electrostatic classification of ultrafine/nano particles is the process by which the particles are separated into classes according to their electric mobility. Different types of Differential Mobility Analyzers (DMAs) are used for ultrafine/nano particle classification like, Medium DMA, Long DMA, Nano-DMA, and so on. Though the principle of these DMAs remains the same, the inner and outer electrode radii, the size of particles measurable, the injection of the sheath gas might be different in these various variants of DMA.

The present study focuses on a Medium DMA and a Long DMA manufactured by GRIMM, for which we have experimental results. Such DMAs consist of two concentric cylinders, named the classification region. Before entering the DMA, the electrically charged particles are at first subjected to a neutralizer to achieve Boltzmann equilibrium (i.e., equal number of positively and negatively charged particles) (see Figs. 1 and 2). The neutralizer is a TSI neutralizer which uses a radioactive source to ionize the surrounding atmosphere into positive and negative ions. Particles carrying a high charge can discharge by capturing ions of opposite polarity. After a short time, the particles reach charge equilibrium such that the aerosol carries a bipolar distribution.

Particles enter the DMA through an axisymmetric inlet slit located at the top of the outer grounded cylinder. Clean air (sheath gas) flows axially between the two cylinders, under laminar conditions. A positive voltage is applied on the inner cylinder, and thus negatively charged particles migrate towards the inner cylinder. Based on the point of injection, the particle size and the applied voltage, the particles assume different trajectories. The

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