A portable Diffusion Size Classifier

M. Fierz, P. Steigmeier and H. Burtscher

University of Applied Sciences Northwestern Switzerland, 5210 Windisch

martin.fierz@fhnw.ch, heinz.burtscher@fhnw.ch, www.iast.ch

Introduction

Many state-of-the-art aerosol measurement instruments of today are large, heavy and expensive; and therefore not well suited for field measurements. We have built a diffusion size classifier (DiSC), which trades the accuracy and size distribution information of the larger instruments against simplicity and portability. DiSC is a simple modification of the well-known diffusion charger (DC).

Construction

The diffusion size classifier works as follows (see Fig. 1):

Aerosol is first charged in a unipolar diffusion charger, then it passes through 3 measurement stages:

- The induction stage, which is simply a Faraday cage through which the aerosol passes unhindered. During a rapid concentration change, a current is induced in both this stage and the diffusion stage.
- The diffusion stage, which consists of a number of stainless steel grids, where smaller particles are deposited by diffusion
- The filter stage, where all remaining particles are collected on a filter mounted in a Faraday cage

Sensitive current amplifiers measure the 3 currents I, D, and F (for the induction, diffusion and filter stage, respectively). For rapidly changing concentrations, the diffusion current D can be corrected with the induction current I.

The current signals are digitized and transmitted via Bluetooth to either a PDA or a PC. The diffusion classifier is about as large as 2 laptop computers placed on top of each other (see Fig. 2), and weighs 5.5kg. It is battery-powered with a battery lifetime of approximately 8 hours.

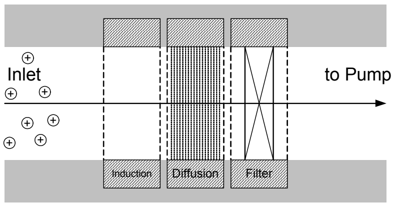

Figure 1: construction of the diffusion size classifier.

Figure 2: The diffusion size classifier with a PDA

Theory and calibration

The penetration of a screen stage with N screens of known geometry is a function of the particle diameter and the flow rate only, and can readily be calculated. These calculations show that for monodisperse aerosol, the ratio of the measured currents F/D is a monotonous function of the diameter in the size range from 0…400 nm. In addition, it is very well fitted by a linear function for the size range of about 10…150 nm. In figure 3, the measured ratio F/D for monodisperse aerosol is plotted. The line is a guide to the eye. Data inversion for monodisperse aerosol is thus very simple – the particle size is given by the ratio F/D; the particle number is calculated from the previously determined size, the total current F+D and the charger characteristics. For a polydisperse aerosol, the larger particles which carry more charge will contribute more to the measured F/D-ratio; F/D will therefore be higher for a polydisperse aerosol of mean diameter d than for a monodisperse aerosol of the same diameter. For a lognormal aerosol distribution with a geometric standard deviation σ of 1.7, this correction factor is about 25%.

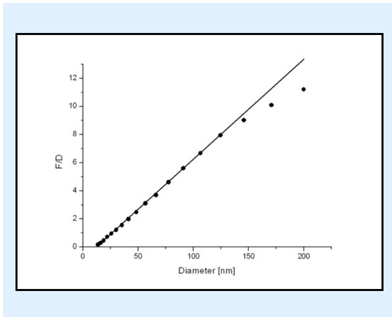

Figure 3: Filter current divided by diffusion current as function of particle size.

Results

To verify the performance of the diffusion size classifier, we operated it in parallel with a TSI SMPS system and sampled 3 different types of aerosols: Sodium chloride particles produced with a nebulizer, Tungsten Oxide aerosol produced with a heated tungsten wire, and three different-sized soot aerosols produced with a sooting gas flame. The results (with the polydisperse correction factors for σ=1.7 applied) are summarized in table 1. The results agree remarkably well with the SMPS; however, for broad size distributions larger errors can occur.

	SMPS d	DiSC d	SMPS N	DiSC N
NaCl	47.6	51.9	3.4E5	3.0E5
WO_x	15.6	17.4	3.7E5	3.3E5
Soot	24.3	23.1	2.7E5	2.3E5
Soot	47.8	45.5	3.0E5	2.7E5
Soot	86.1	77.6	4.1E5	3.7E5

Table 1: Mean diameter and total concentration as determined by SMPS and DiSC.

Applications

DiSC can be applied to any measurement task where portability is more important than high accuracy, and/or where a high time resolution is necessary. Since aerosol concentrations vary over many orders of magnitude, it is often more important to get the order of magnitude right than to measure the concentration with high accuracy. DiSC can be used as a tool to assess aerosol concentration levels rapidly. As an example, figure 4 shows the aerosol number concentration during a bus trip in the city of Zürich.

Conclusions

We have developed a new aerosol measurement instrument. It measures number concentration and an average diameter with a high time resolution (approximately 2s). After a correction for polydisperse aerosol, the measured numbers agree reasonably well with SMPS measurements. We believe that the diffusion size classifier is typically accurate to within +-30% in size and number. For many applications, this accuracy is good enough. The diffusion size classifier is comparatively small and lightweight. It is battery-powered and can be used with a PDA as a portable measurement unit. The measurable aerosol size range of the instrument is between 20 and 200 nm. Detectable aerosol concentration ranges are typically between 3E3…1E6 pt/ccm (with an additional dependence on particle size and sampling time constants).

Figure 4: Aerosol number concentration on a bus trip in Zürich, Switzerland