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ORIGINAL RESEARCH PAPER

Determination of Aerosol Particle Size Distribution using Electrical Differential Mobility Analyzer (DMA)

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ABSTRACT

Introduction: Determining the size distribution of the particles for assessing their effects on human health and their control mechanisms is very effective. One of the most important equipment used in determining particle size distribution is the DMA. In this study, in addition to the design and construction of a DMA, the size distribution measurement of aerosol particles was carried out.

Material and Methods: In this experimental-laboratory study, according to the theoretical principles, the geometric dimensions and operating conditions of the DMA were determined by Fortran programs. The design of the technical drawing of the DMA was done using the Salidworks-2017 software. The DMA designing was performed by studying the size distribution of 12 ranges of DOP particles in 15 voltages.

Results: The results of applying different voltages to the DMA showed that one range of particles size had the highest number of particles in the output of the DMA at each voltage. As the number of particles with the size of 0.26-0.3 µm at 3500 volts and those larger than 2 µm at 9000 volts is the highest at the output of the DMA.

Conclusion: DMA systems are a robust tool in determining the particle size distribution. As by knowing the required voltage to separate a specific size of the particles, the DMA will be able to specify the spectrum of unknown particles.

Keywords: *Particle Size Distribution, Differential Mobility Analyzer, Aerosol*

1. INTRODUCTION

Determination of aerosol size distribution is critical for understanding the impact of aerosol particles on human health as well as assessing their control mechanisms. The differential mobility analyzers (DMAs) have served a critical role in aerosol science, allowing separation of particles based on their electrical mobility. Since their initial development, DMAs have been extensively used for size classification and measurement of aerosols (1-4).

A typical setup of a DMA consists of two concentric electrodes between which an electric potential is applied. In this way, one of the electrodes is negatively charged and the other is positively charged, resulting in ceating an electric field between them. An aerosol flow containing charged particles is introduced adjacent to one of these electrodes. A particle-free (dry and clean) sheath air flow initially separates the aerosol flow from the opposite electrode. The electric field causes charged particles to move towards the opposite electrode across the space between the electrodes at distinct axial locations, according to their electrical mobility, which are related to their size. Therefore, particles with a narrow range of electrical mobility

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exit through a small slit located at the bottom of the collector electrode. These particles are transferred to a particle counter to determine their number concentration (2-8).

2. MATERIAL AND METHODS

This laboratory experimental study was carried out in 2017-18. The theoretical principles governing the development of the DMA device were extracted from texts and articles in order to determine the geometric dimensions and operating conditions of the DMA. Numerical calculations were carried out using FORTRAN programming software and the Excel 2016 program. The technical drawings of the constituent parts of the DMA were carried out using SOLIDWORKS-2017 software. The DMA set up was constructed based on the montage scheme of the constructing drawings.

The laboratory instrumentation including the high voltage DC power supply (HV35P model) with the ability to provide controlled electric potential difference in the range of 1 to 10 kV with 0.5 interval, Particle counter device (Grimm) with the ability to determine the numerical concentration of particles in 12 ranges of particle size from 0.26 µm to larger than 2 µm, TOPAS-ATM 225 particle generator with the ability to produce particles in the range of 0.15-3 µm of dioctyl phthalate (DOP), and dry and clean air supply system including pump, compressor, filter and its holder were used, also a diluent was applied to dilute the flow of aerosols. The flow-meters and multi-meter were used to measure the flow rate and voltage. After calibration of these instruments, their layout was determined. Figure 1 shows laboratory layout and equipment used in the study.

Experiments were carried out to determine the particle size distribution and the efficiency of the proposed DMA at the air velocity of 11.3 cm/s and necessary various electrical voltages. All tests were carried out under ambient air temperature and normal environmental conditions. Statistical analysis was carried out using SPSS-22 and Excell-2016 soft wares.

3. RESULTS AND DISCUSSION

The results revealed that at the applied voltages higher than 2KV, particles with a specific range of size were differentiated and detected at the output. By applying different voltages to the DMA, at each voltage, one range of particles' size had the highest number of particles in the output of the DMA. In other words, at a given voltage, this system allowed a range of particles to be exited exclusively while acted as a filter for the other particles. This led the polydisperse input particles to be separated like monodispersed particles. The single distribution of a specific domain of input particles depends on the velocity of the airflow and the systems' voltage. At the constant velocity of 11.3 cm/s, the particles

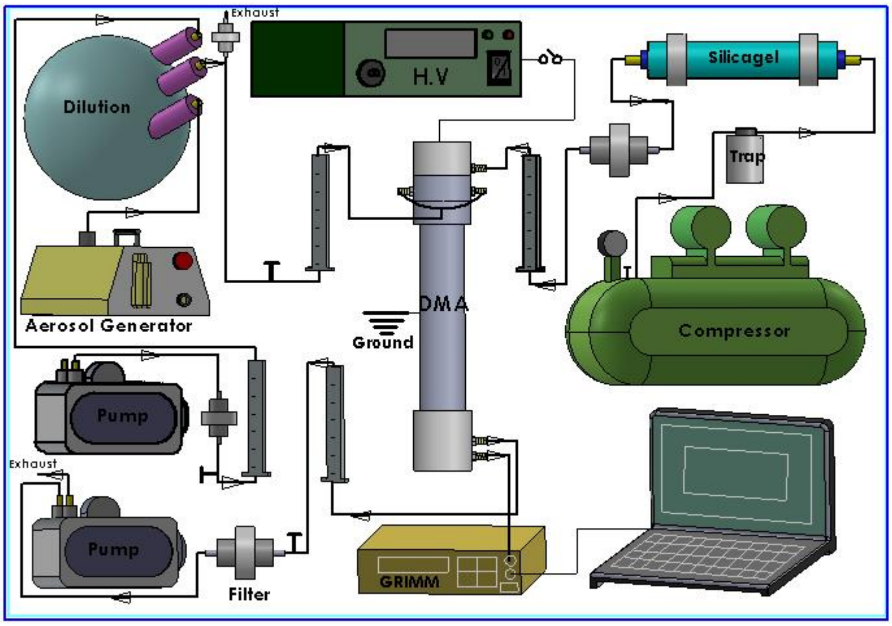

Fig. 1. Laboratory layout and equipment used in the study

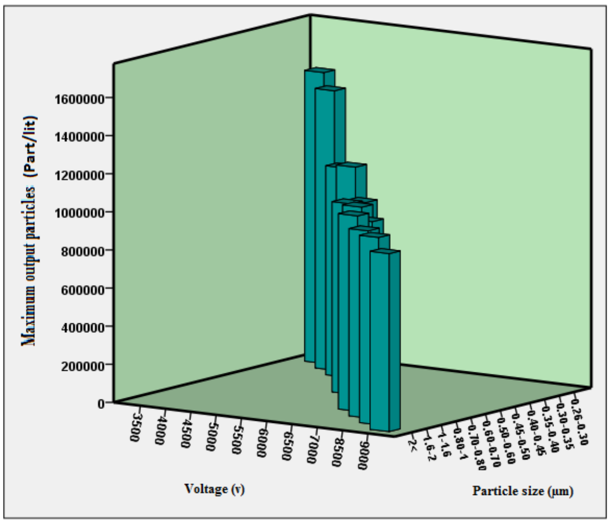

Fig. 2. Maximum output particles of DMA devices per voltage and particle size

Table 1. Two-way and multi-way analysis of variance in the study of the effect of voltage and particle size on the efficiency of DMA device

Variable	Efficiency (%)	
	P-value	R^2
Particle size (µm)	0.038	0.014
Voltage (v)	<0.001	0.676
Particle size * Voltage	<0.001	0.996

of 0.26-0.3 micrometer had reached their highest number at the output of the device at a voltage of 3.5 KV and larger than 2 microns particles at a voltage of 9 KV(Figure 2). Hence, it seems that in lower voltages, smaller particles, and at higher voltages, larger particles accounted for a greater portion of the output particle size distribution. As, up to 7 kilovolts, the dominant output particles, were under micron, and at voltages higher than 7 kilovolts, the dominant output particles were particles larger than micron. The maximum performance of the DMA system at the velocity 11.3 cm/s was 81.2%, for the monodisperse particles of 0.3-0.35 micrometer. The results of two-way and multi-way analysis of variance showed a significant relationship between electrical voltage and DMA efficiency (Table 1). It was also shown that the effect of voltage on the DMA performance in different particles size is different. The dispersion of the results of repeated experiments also showed that this device has a good repeatability.

4. CONCLUSIONS

DMA systems are powerful tools for determining the particle size distribution (2). In these devices, the electrical mobility of the particles is used to classify and determine the distribution of their size. By knowing the peak voltage for a particular particle size, we can determine the size distribution of the unknown particles by this device. The DMA devices can also be used as a calibration tool and single-distributive particle generator in order to test filters and assessment of the particles classification in different workplaces and environments. However, continuous researches on the improvement and evolution of these equipment seem to be required.

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