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PD7) 입자 분리를 위한 Virtual Cyclone의 실험적 연구

Experimental Study on Virtual Cyclones as Aerosol Separators

김대성 · Xiang Rongbiao · 이규원
광주과학기술원 환경공학과 분진공학연구실

1. INTRODUCTION

Virtual cyclones have been the subject of aerosol separation studies since they were first developed by Torczynski and Rader (1996). In the virtual cyclone (originally referred to as the anticyclone), the main particle-laden flow follows a wall that curves away from the original flow direction rather than curving into the original direction, as in a cyclone. Although a wall forms the inner boundary of the main flow, its outer boundary is formed by an adjacent flow, often a confined recirculating flow, into which particles are transferred by centrifugal action. Thus, in the virtual cyclone, particles are separated from the main flow by crossing a dividing streamline that separates the main flow stream from an adjacent flow stream.

The computational fluid dynamics code serves as a model for the flow and the particle motion inside a virtual cyclone (Torczynski and Rader, 1997). Chen et al. (1999) developed and fabricated a compact virtual cyclone for personal sampling. However, little experimental data are available, to allow the verification of the performance of the virtual cyclone. In this study, the design of the aerosol separators comes from virtual cyclones and impingers. Inlet and outlet sections were designed with multi-nozzles, which are used primarily for high-volume air sampling. Thus, aerosol separators are useful in a variety of fields, such as high-volume air sampling and the treatment of airborne aerosols. The objective of the present study was to develop impinger-type virtual cyclones as aerosol separators.

2. DESIGN AND EXPERIMENT

The design of the aerosol separators was taken from those of virtual cyclones and impingers. Virtual cyclones involve relatively small particulate centrifugal forces. The impinger-type virtual cyclones, however, provide inertial force as well as centrifugal force to the particles and thus, particle collection efficiencies will be increased. In addition, the aerosol separators have two stages, and these will increase the particle collection efficiency further. Inlet and outlet parts were designed with multi-nozzle.

The experimental procedures for characterizing performance of the aerosol separators are as follows. Polystyrene latex (PSL, 10% Solids, 1.05 g/㎤) particles ranging from 0.4 to 4.0 ㎛ in aerodynamic diameter were generated with an atomizer (TSI Inc., Model 9302). A silica gel diffusion dryer was used to remove water from the aerosol. After drying, the aerosol was introduced into a Kr-85 radioactive source to neutralize static charges. Before entering the aerosol sampler, the particles were diluted with filtered air using a HEPA cartridge-type filter (Gelman Science, Model 12144) in a mixing chamber.

Particle concentrations of both upstream and downstream of the aerosol separators were measured using an Aerosizer (API Inc., Model Mach II). To reduce errors due to time variations in the upstream aerosol concentrations, repeat measurements were commenced at least 5 minutes after the aerosol was introduced into the system. Measurements were conducted at flowrates of 30, 45, 60 and 75 L/min for each particle size tested and each model.

3. RESULTS AND DISCUSSION

'Figures 1 and 2' represent the performance curve for the aerosol separators (Models I & II) at sampling flowrates of 30, 45, 60 and 75 L/min. For particles smaller than 1 ㎛, the penetration efficiency increases rapidly as the particle size decreases, and penetration efficiency decreases for particle sizes larger than 1 ㎛, but the curves are not sharp. The penetration efficiency was found to be dependent on the sampling flowrate, as shown in Figures 1 and 2. It is apparent that the collection efficiency increases monotonously from a flowrate of 30 L/min to a flowrate of 75 L/min, because the inertial force acting on the particle is greater at the higher flowrate.

In general, the performance curves of Model II (L3 = 15 mm) were sharper than those of Model I (L3 = 0 mm). Model II had a higher collection efficiency than Model I, which indicated that longer nozzles give higher collection efficiencies. The $\sqrt{Stk_{50}}$ value was found to be independent on the sampling flowrate, and was calculated to be approximately 0.2, which is relatively low compared to that of impactors. Cutoff diameters were found to be dependent on both the nozzle length and the flowrate. Model II and the high flowrate result in small cutoff diameter, indicating a higher collection efficiency.

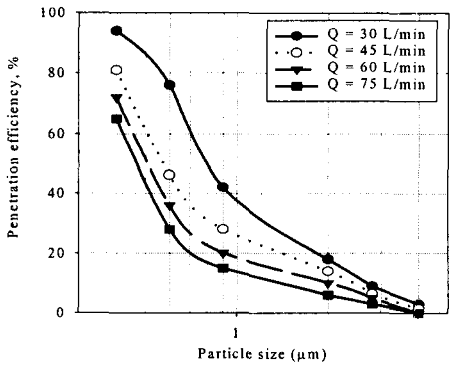

Fig. 1. Penetration efficiency curves of Model I.

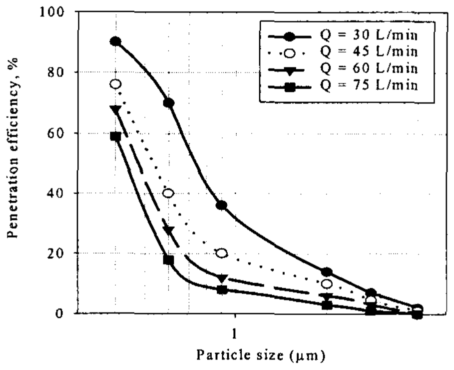

Fig. 2. Penetration efficiency curves of Model II.

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