Journal of Aerosol Science 89 (2015) 18–25

Contents lists available at ScienceDirect

Journal of Aerosol Science

journal homepage: www.elsevier.com/locate/jaerosci

Development of a single cyclone separator with three stages for size-selective sampling of particles

Chun-Woo Park, Dae-Hyun Song, Se-Jin Yook*

School of Mechanical Engineering, Hanyang University, Seoul 133-791, Republic of Korea

ARTICLE INFO

Article history:
Received 27 December 2014
Received in revised form
23 May 2015
Accepted 1 July 2015
Available online 9 July 2015

Keywords:
Cyclone separator
Size-selective sampling
Sampling fraction
GMD
GSD

ABSTRACT

In this study, a single cyclone separator composed of three cylinders of different diameters and one vortex finder was developed for size-selective sampling of particles. This cyclone separator had three particle traps, that is, dust bins, each of which was connected to each of the cylinders. A single cyclone separator with three stages was designed and manufactured. The numerically predicted sampling fractions agreed well with the experimental data. From both numerical and experimental results, three distinct sampling fraction curves with different geometric mean diameters (GMD) appeared and the size-selective sampling of particles was possible using the single cyclone separator with three stages. Then, the flow rate of aerosol introduced to the cyclone separator was varied to change the GMD of particles collected on the bottom of each particle trap.

1. Introduction

Size-selective sampling is essential for characterizing aerosol particles according to their size. Cascade impactors such as QCM impactor (Hering, 1987), MOUDI (Marple, Rubow, & Behm, 1991), and ELPI (Marjamäki, Keskinen, Chen, & Pui, 2000), are commonly used for size-selective sampling of particles. The cascade impactors, however, are usually operated at a relatively low flow rate and can have particle bounce and re-entrainment problem. If the impaction plates are coated with sticky material like grease to reduce particle bounce, the collected particles can be contaminated by the coating material. Therefore, it is needed to develop a device which is appropriate for size-selective sampling at a relatively high flow rate without using coating materials.

Cyclone separators are widely used in many fields due to their simple geometry and high sampling flow rate. Griffiths and Boysan (1996) successfully modeled the performance of three types of cyclone samplers using a computational fluid dynamics (CFD) package. Lee, Yang, and Lee (2006) investigated the effect of the cylinder shape on the collection efficiency of a long-coned cyclone. Chuah, Gimbun, and Choong (2006) and Xiang, Park, and Lee (2001) evaluated the influence of the cone dimensions on the cyclone performance. Ray, Luning, Hoffmann, Plomp, and Beumer (1997) installed a cylindrical annular shell on top of the vortex finder to trap dusts escaping from an industrial cyclone. Hsiao, Huang, Hsu, Chen, and Chang (2015) investigated the influences of geometric configurations on cyclone performance and proposed the optimal ranges for the geometric dimensional ratios. Dietz (1982) and Lim, Lee, and Kuhlman (2001) employed the electrical force to improve the collection efficiency of cyclone separators. So far, a lot of studies have been conducted on the enhancement of

* Corresponding author. Tel.: +82 2 2220 0422; fax: +82 2 2220 2299.
E-mail address: ysjnuri@hanyang.ac.kr (S.-J. Yook).

http://dx.doi.org/10.1016/j.jaerosci.2015.07.001
0021-8502/

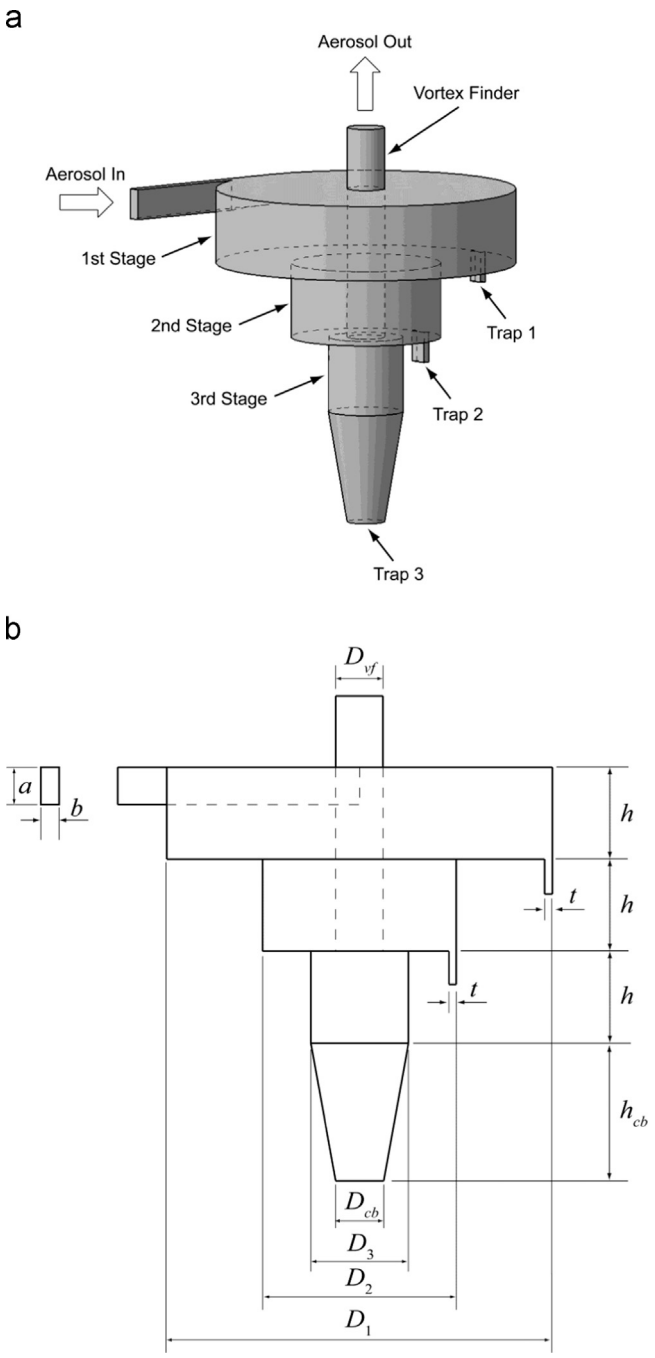

Fig. 1. Schematic of the single cyclone separator with three stages, developed in this study: (a) perspective view and (b) front view.

the cyclone performance. As a result, it is possible to efficiently separate particles from air stream using cyclone separators. However, if a single cyclone separator is used, only the particles larger than a cut-off size are collected and the size-selective sampling cannot be achieved.

Multiple cyclone separators with different cut-off sizes can be connected in series for size-selective sampling, similar to the cascade impactors. McFarland, Bertch, Fisher, and Prentice (1977) employed an apparatus consisting of a series of two cyclones and a centripeter, and fractionated fly ash from stack gas to have volume median diameters of 20 μm, 6.3 μm, 3.2 μm, and 2.2 μm with geometric standard deviations of about 1.8. Smith, Wilson, and Harris (1979) developed a five-stage cyclone system for in situ sampling with cut points of 5.4 μm, 2.1 μm, 1.4 μm, 0.65 μm, and 0.32 μm, by connecting five cyclone separators in series. Hsiao, Chen, Li, Greenberg, and Street (2010) developed a multi-stage cyclone system consisting