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Cyclone performance on removing fibrous particles generated from terry-towels and cotton clothes

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ABSTRACT

An experimental study was conducted on the removal of fibrous particles from particle-laden air using a single cyclone and a dual cyclone of the same volume. The fibrous particles were generated from terry-towels and cotton clothes. Prior to comparing the collection efficiency for fibrous particles between the single and the dual cyclones, the effect of a separating plate used for the inlet of the dual cyclone was investigated. The collection efficiency of the dual cyclone varied significantly depending on the length of the separating plate, that is, more than a certain length of the separating plate was required for the high collection efficiency. After the final configuration of the dual cyclone was proposed, collection efficiency and pressure drop of the single and the dual cyclones were measured at various flow rates ranging from 700 to 2000 L/min. From the comparison, the dual cyclone showed higher collection efficiency and lower pressure drop than the single cyclone. Especially, the dual cyclone developed in this study was able to remove the fibrous particles with the collection efficiency greater than 95%.

1. Introduction

It is known that fibrous dust is one of the main types of house dust that can be absorbed in people's bodies by inhalation [1–3]. A lot of people spend most of their time indoors, e.g., at schools, homes, and working places, and therefore to remove the house dust is an essential and important issue regarding people's health [1,4]. For this reason, dust removal devices, e.g., air purifiers and cyclone separators, have been used to remove the dust particles.

Air purifiers usually employ some filters like a high efficiency filter for removing fine particles and a prefilter for eliminating coarse particles. The efficiency of a conventional filter varies with operation time as the particles are collected on the filter media and block the air pathway, resulting in the need of maintenance process that may charge additional costs [5,6]. Meanwhile, a cyclone separator for collecting dust by using the centrifugal force is frequently used in industry because it has a simple structure and is cost-effective. Unlike filters, a cyclone separator can have an advantage of keeping the pressure drop and collection efficiency almost unchanged during operation because it collects particles separately in a dust bin by rarely interfering with the main flow. Therefore, in this study, a cyclone is considered as a pre-separator for eliminating coarse particles including the fibrous particles from air stream.

A lot of studies on the enhancement of cyclone performance have been conducted. Particularly, many researches have been presented to improve the cyclone performance by changing the cyclone shape. Qian et al. [7] investigated the influence of the prolonged vertical tube attached at the bottom of the dust outlet on the cyclone performance. Kim et al. [8] modified the inner surface of a cyclone by adding grooves and spiral guides, and suggested an effective design of the cyclone body shape. Zhu et al. [9] developed a double cyclone having an additional cylinder wall in the cyclone body to enhance the collection efficiency. Lim et al. [10] designed a double inlet cyclone by splitting the inlet into two parts using a thin plate, that is, by separately introducing particle laden air and clean air into the cyclone, and improved the collection efficiency. Furthermore, researches on the performance of two or more cyclones connected in series or in parallel have been conducted [11–13]. However, most of studies on the cyclone separators generally evaluated the collection efficiency using spherical particles like polystyrene latex (PSL) spheres. In other words, few studies included enough information about the cyclone performance on removing fibrous particles from air stream. Therefore, the objective of this study is to develop a cyclone separator for efficient removal of fibrous particles, for example, particles generated from textiles and clothing. The cyclone body is designed to be straight and cylindrical. The collection efficiency and pressure drop of a single cyclone and a dual cyclone of the same volume are experimentally determined and compared.

2. Experimental

2.1. Cyclone design

A single cyclone (model A) and a dual cyclone (model B) were designed and fabricated. Fig. 1 and Table 1 describe the plane figures and

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dimensions of the cyclones developed in this study. Differently from the conventional cone-shaped cyclone, the cyclone developed in this study was barrel-shaped and the dust bins for collecting the particles separated from the air stream were located on the side wall of the cyclone. Therefore, the new type of the cyclone was designed to fit into a space with limited height. By assuming that the space for installing a cyclone was limited, model A and model B were designed to have the same height and volume, that is, the diameter of model A was square root two times the diameter of model B, when $D = 94$ mm. In other words, the volume of model A was calculated as $\pi \cdot [(\sqrt{2})(D/2)]^2 \cdot H$, and the volume of model B as $2 \cdot [\pi \cdot (D/2)^2] \cdot H$. Elsayed and Lacor [14] investigated the effect of inlet dimensions on cyclone performance, and showed that the inlet height influenced the collection efficiency less significantly than the inlet width and the increment of the inlet height resulted in less pressure drop. In addition, the inlet width narrower than the gap between the barrel and the vortex finder was recommended for the better cyclone performance. Therefore, in this study, the inlet height of each cyclone was designed to be as large as possible, and the inlet width was determined to be the same as the space between the barrel and the vortex finder.

Table 1
Dimensions of the single and dual cyclones ($D = 94$ mm).

Parameter	Model A	Model B
Cyclone barrel diameter (D)	$\sqrt{2}D$	D
Vortex finder diameter (D_e)	$0.5\sqrt{2}D$	$0.5D$
Cyclone height (H)	$1.2D$	$1.2D$
Vortex finder length (S)	$0.5D$	$0.5D$
Separating plate length (L)	–	0 ~ $2D$

2.2. Determination of collection efficiency

Fig. 2 shows the schematic of experimental setup. Clean air generated using a blower and a HEPA filter was introduced to a particle generator, which was designed to produce fibrous particles from textiles or clothing. After the particle generator, a pressure transmitter (KIMO, Model CP300) was used to measure the flow rate of air containing the fibrous particles. The flow rates of fibrous-particle-laden air introduced into the cyclone separator were 700, 1000, 1500, and 2000 L/min, that is, the flow velocities at the inlet of the model A cyclone separator were 4.4, 6.3, 9.4, and 12.5 m/s, respectively, and those at the inlet of the model B cyclone separator were 3.1, 4.4, 6.7, and 8.9 m/s, respectively. A Magnehelic pressure gauge was used to measure pressure drop across the cyclone. A high efficiency filter was used downstream of the cyclone to trap the fibrous particles which were not collected in the cyclone. The experiments were conducted at room temperature and pressure.

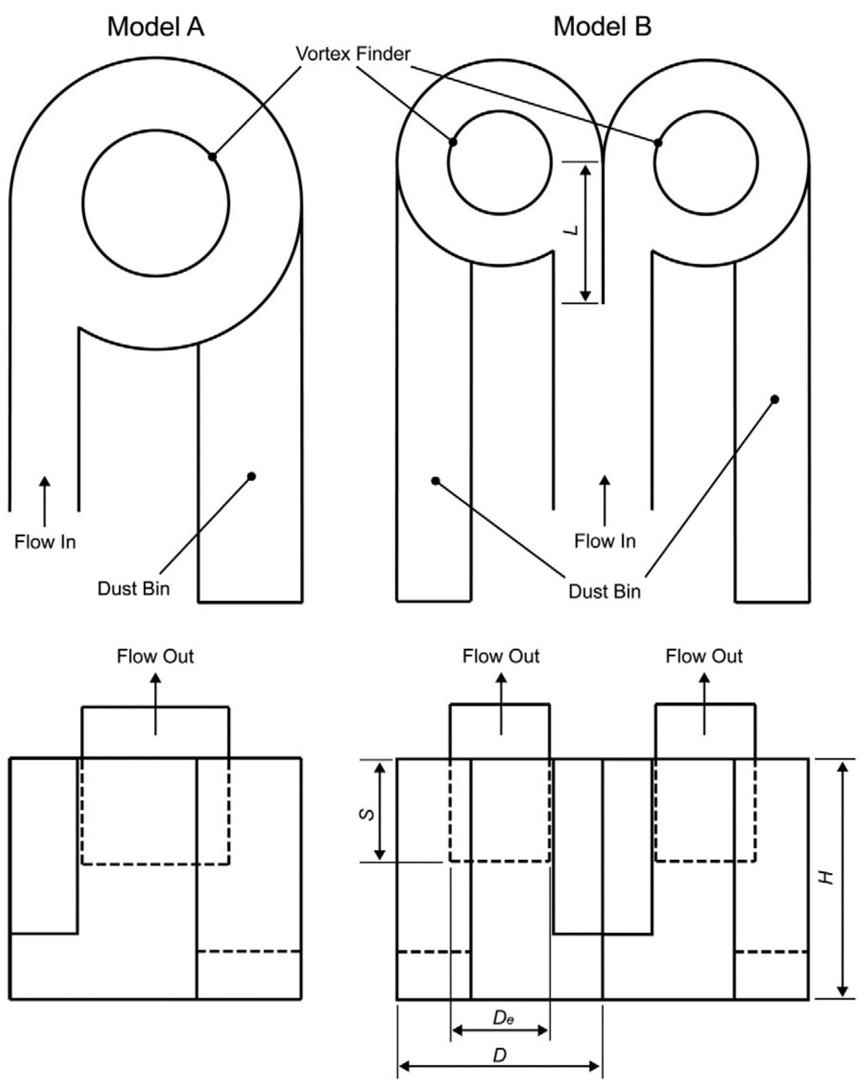

Fig. 1. Schematics of the single and dual cyclones.