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A Study on the Air Cleaning System of Electric Precipitator Adaptable in Multi-Use Facility

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Abstract- Recently, indoor air quality management was strengthened for various spaces, and in particular, indoor air quality management was strengthened, such as mandatory installation of ventilation facilities in multi-use facilities and introduction of indoor air quality safety facility certification system. The air purification system using electric dust collection technology can be used semi-permanently and is environmentally friendly because no waste filter is generated. This study aims to solve the problem of ozone generation, which is considered a disadvantage in electric dust collection technology. In addition, the electric dust collection method, which is mainly used in existing industrial sites, is converted into an air cleaning module to study and test its performance so that it can be used in multi-use facilities

Keywords*: Filter, Dust, Electric Precipitation, Multi-use facility, Ozone*

1. Introduction

Indoor activity has increased due to concerns about fine dust and new infectious diseases worldwide. Due to the increasing amount of indoor activity, there is a risk of indoor fine dust and harmful gases that may deteriorate up to five times compared to outdoor activities [1]. In addition, the number of patients with building syndrome and chemical hypersensitivity diseases is increasing due to the airtightness of buildings to save energy. In particular, multi-use facilities are required to improve performance and efficiency due to the increase in the use of air purification systems in multi-use facilities because fine dust, carbon monoxide, formaldehyde, and total floating bacteria are higher than average due to enclosed and limited space [2].

2. Design and Fabrication

2.1 Design

Electrical dust collection is a principle that fine particles such as inhaled dust are charged using high-pressure electricity, and then fine particles are ads[1]orbed on a dust collection plate having an opposite charge to remove dust [3]. In order to charge the dust in this way, the inflow speed of the dust must be lowered to induce it to be charged correctly. The electric dust collection system of this study introduces fine dust at a low rate of 1 m/s when inhaled. However, if dust is inhaled at a low speed in a large area of a multi-use facility, there is a disadvantage in that the purification ability that can be treated is low. To compensate for such shortcomings, the system was designed to inhale dust from both sides of the air purification system by dividing the system into two parts. In addition, the dust collection plate of the dust collection unit was designed in multiple divisions, and the dust collection unit was manufactured in an angular shape, so that the dust from the outside could stay in the dust collection unit for a long time. A brush electrode using carbon fibers was used to solve the problem of ozone emission, which is generally considered a disadvantage of electric dust collection. A low-power and high-voltage electric dust collection method was studied using carbon fibers, thereby reducing ozone emission.

2.2 Fabrication

The 3D design of the module of the air purification system was carried out. The overall appearance of the air purification system is large in size, 600 x 1000 x 1841 mm. An ozone filter and a photocatalytic filter module

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were added to remove fine dust and harmful gases. The two-division fan inhaled external air from the side of the system and treated the side with a vent hole to replace the pre-filter role. Fig. 1 is the appearance of the air purification system and Fig. 2 shows the internal module of the air purification system.

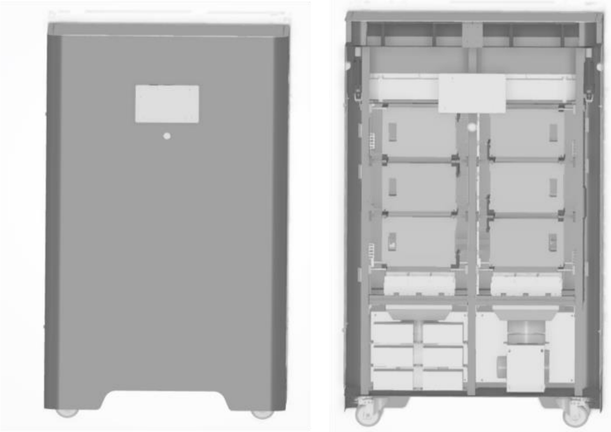

Figure 1- Exterior design of air purification system

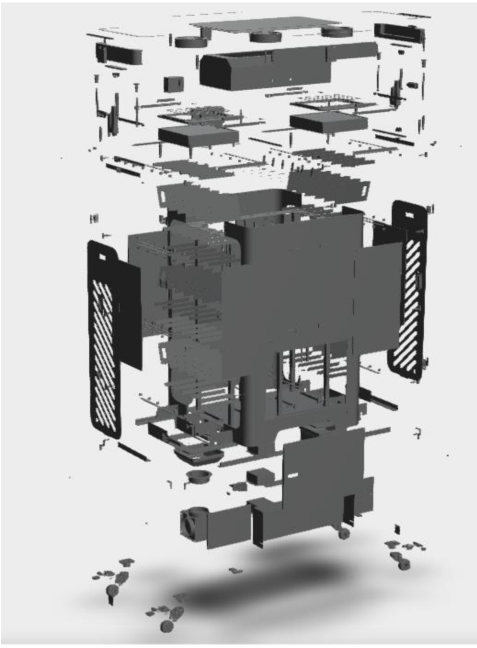

Figure 2- Internal module design

2.3 Test Method

In the fine dust removal capability test, an air purification device is set in a sealed test chamber and particles with a diameter of 0.3 μm of polydispersible solid-state potassium chloride (KCl) are injected to determine the removal performance. The measure of air cleaner performance by this test procedure Clean Air Delivery Rate(CADR) is defined as the measure of the delivery of contaminant free air, within the defined particle size(0.3 um(KCl)), by an air cleaner, expressed in cubic meter per minute(m3/min) [4,5].

The performance of an air cleaner is represented by a clean air delivery rate (CADR). The method for calculating the clean air delivery rate is:

$$\mathrm{CADR} = \mathrm{V}(k_e - k_n)$$

where:

CADR = clean air delivery rate (cu. m/min)

V = volume of test chamber, cu. m.

k_e = total decay rate, min^{-1}

k_n = natural decay rate, min^{-1}

Since the test chamber air exchange is negligible (maximum contribution to slope of 0.00051 min-1) the air exchange rate is not included in the calculations.

The decay constant, k, for particulate matter is based on the formula:

$$\mathrm{C}_{ti} = C_i e^{-kt_i}$$

where:

C_{ti} = concentration at time t_i (particles/cc)

C_i = concentration at t = 0 minutes

K = decay rate constant ($minutes^{-1}$)

t_i = time (minutes)

The decay constant, k, is obtained using the linear regression on the $\ln C_{ti}$ and t_i using the formula:

$$\mathrm{k} = \frac{S_{xy}}{S_{xx}}$$

where:

$$S_{xy} = \sum_{i=1}^{n} t_i \ln C_{t_i} - (1/n)\left(\sum_{i=1}^{n} t_i\right)(\sum_{i=1}^{n} \ln C_{t_i})$$

$$S_{xx} = \sum_{i=1}^{n} (t_i)^2 - (1/n)\left(\sum_{i=1}^{n} t_i\right)^2$$

When the air purification system was installed in a multi-use facility, the operating time was expected to be about 8 hours, and the product was put into the test chamber (29.5 ± 1 ㎥) and a 8 hour fine dust removal test was carried out. In addition, in order to confirm the ability to remove harmful gases, five harmful gases were injected into the same chamber to confirm the removal performance. The five harmful gases injected at this time are ammonia, acetic acid, acetaldehyde, toluene, and formaldehyde. The test operating time was equally performed at 8 hours.

3. Results and Discussion

3.1 Clean air delivery rate of dust

As a result of installing the air purification system in the test chamber and testing the ability to remove fine dust for 8 hours, the efficiency of removing fine dust was about 99.3%. It has already achieved more than 99% efficiency within 3 hours. Fig. 3 is a graph in which fine dust filled in a sealed chamber is removed after the air purification system is operated. However, since this test is a result of conducting in a 30m3 chamber, it is necessary to confirm the demonstration ability in a large space such as a multi-use facility.

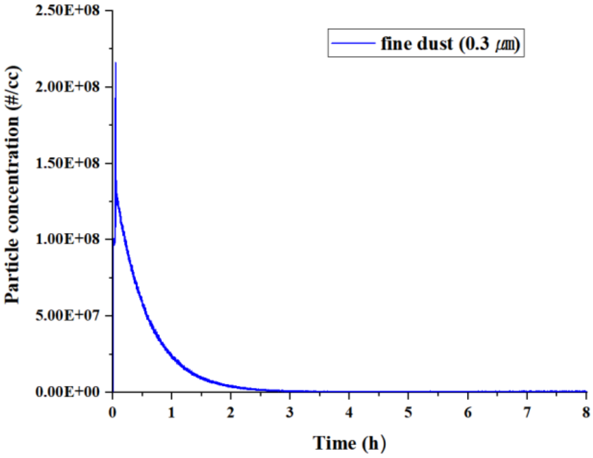

Figure 3- Fine dust removal capability test

3.2 Clean air delivery rate of harmful gases

As a result of installing the air purification system in the test chamber and testing the harmful gas removal ability for 8 hours, the average harmful gas removal efficiency of five types was about 93%. Table 1 shows the removal efficiency of each of the five harmful gases, and among them, the removal efficiency of ammonia was the lowest.

Table 1. Clean air delivery rate of harmful gases

Test items		Measurement value (μmol/mol)	Test results (%)
Formaldehyde removal rate	Initial value	9.912	100
	End value	0	
Ammonia removal rate	Initial value	10.186	71
	End value	2.967	
Acetaldehyde removal rate	Initial value	10.194	96
	End value	0.406	
Acetic acid removal rate	Initial value	10.242	100
	End value	0	
Toluene removal rate	Initial value	9.693	100
	End value	0	
Average hazardous gas removal rate		-	93

3.3 Ozone emission concentration test

An air purification system was installed in the test chamber and an ozone generation test was performed for 8 hours. In the case of Figure 4, the ozone value in the initial chamber and the ozone value generated in the air purification system are combined. For the normalization of the ozone concentration value, the ozone concentration value excluding the ozone value in the initial chamber is shown in Figure 5. As a result of the ozone generation test, it can be confirmed that the result value was lower than 0.03 ppm regulated by the Ministry of Environment of the Republic of Korea. This seems to be able to solve the problem of ozone generation in electric dust collection using carbon fibers.

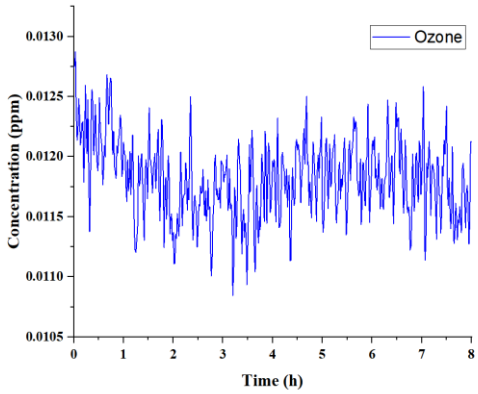

Figure 4- Ozone generation concentration

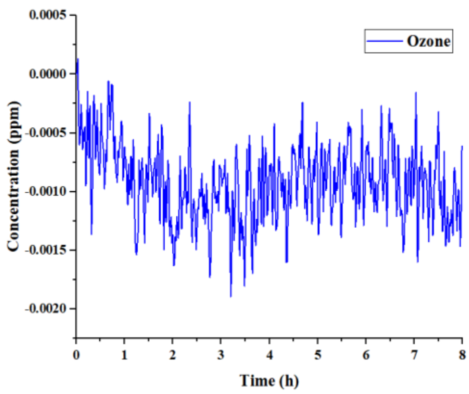

Figure 5- Normalized ozone generation concentration

4. Acknowledgments

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