# A Research on the Porous Analysis and Air Purification Efficiency for Air Clean Tower in the Outdoor

**Jeong-Gi Lee, Chul-Jun Choi, Nam-Su Kwak, In-Pyo Cha**

***Abstract*: *Recently, there has been a surge of fine dust emissions and alarms according to the influence of long-distance movement of dust from China due to the indiscriminate industrialization in domestic and abroad. In addition, respiratory and cardiovascular diseases due to long-term hu-man exposure of fine dusts are rapidly and markedly increasing. First, in this paper, we have derived the parameters to control the diameter and pore diameter of PES nano fiber in the process of fabricating filter fabric through electrospinning of polyether sulfone (PES) material. In order to evaluate the structural effect of the PES filter fabric according to the electrospinning conditions, the density of the polymer mixed solution, the applied voltage of the electrospinning column nozzle, the injection rate of the polymer mixed solution, and the feed rate of the fabric were varied***

***Index Terms*: *Use about five key words or phrases in alphabetical order, Separated by Semicolon.***

## I. INTRODUCTION

In recent years, domestic and foreign atmospheric environments have been rapidly deteriorating and the concentration of fine dust in air has been rapidly increasing, so there is a growing demand for development of outdoor fine dust reduction technology.[1-2] In order to investigate the correlation between micro-climate change and air safety in urban areas and to solve the problems, technology development for removing harmful substances from fine dust, parti-cles and gasses in road congestion areas is on the progress. In par-ticular, outdoor air purification devices are needed which is capable of reducing atmospheric pollutants having odor, potential toxicity and carcinogenicity as well as fine dust outside the room. CO and NO2 emitted from automobiles account for 65% of the total air pollutant emissions and air pollution levels on the roads are general-ly high due to the influence of automobile emissions.[3] The annual average concentration of fine dusts in 'Gwangju' is 132%, in the case of 7 urban airports and 2 roadside airports. Therefore, in order to reduce hazardous substances as particles, gasses and fine dust near the road side, in this study, deduced the parameters of predic-tion of the pressure drop and the dust collecting performance ac-cording to the inlet velocity of the fine dust suction for the installa-tion of the up-flow air type outdoor air clean tower.[4-7] To predict the required performance is ongoing when the air clean tower is designed and manufactured using air pollution reduction capability according to the operation condition of the air clean tower, the elec-tric dust collection, and the photocatalytic system. In this paper, we have derived the parameters to control the diameter and pore diame-ter of PES nano fiber in the process of fabricating filter fabric through electrospinning of polyether sulfone (PES) material. In order to evaluate the structural effect of the PES filter fabric accord-ing to the electrospinning conditions, the density of the polymer mixed solution, the applied voltage of the electrospinning column nozzle, the injection rate of the polymer mixed solution, and the feed rate of the fabric were varied. The analysis of the filter structure influence on electrospinning condition was confirmed by measuring the diameter, orientation and density of the nanofiber filter.[8-10,11-15]

## II. NUMERICAL ANALYSIS METHOD

ANSYS Fluent 15.0 was used to analyze fluid flow. The k-epsilon model was applied and Porous media equation was used in the fluid area of the calculation area.[11] Solar radiation energy has used Discrete Ordinates. As shown in Fig. 1, a body mesh was used with an element size of 6 mm, and a grid of 1,656,975 was used. Model and mesh of the air clean tower were expressed in Figure. 1. Only the fluid flow part is modeled and the filter shape has been done in the center part of the tower.

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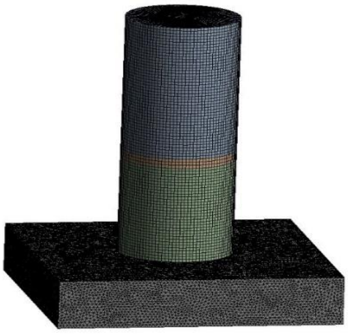


**Fig. 1** Modelling and mesh of an air clean tower

## I. RESULTS OF CFD ANALYSIS

Applied the analysis of the air clean tower was carried out, through whole process of numerical analysis. Figure. 2 shows the tempera-ture change when the air passes through the glasshouse and then the inside of the tower.

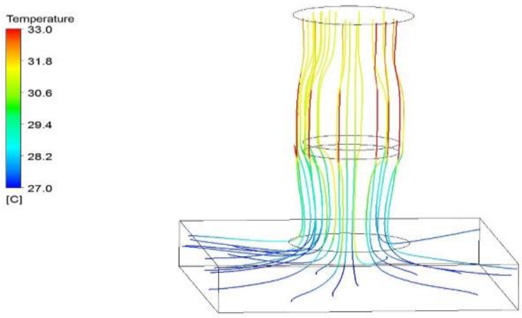
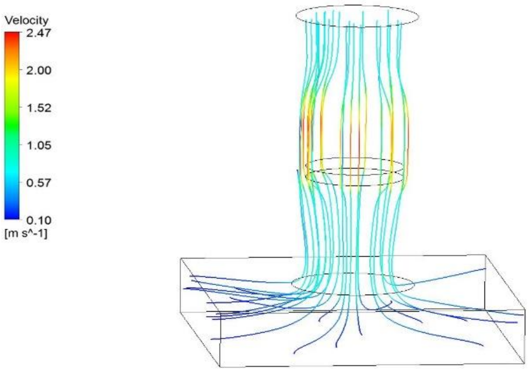
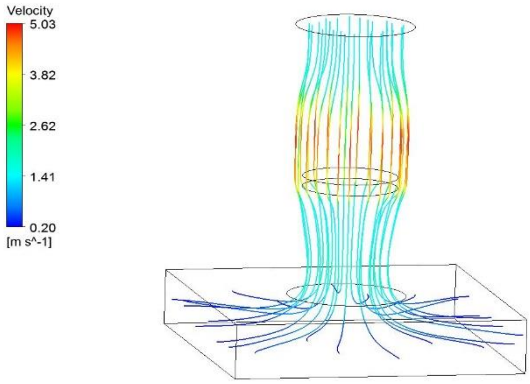



**Fig. 2** Temperature changes inside the tower

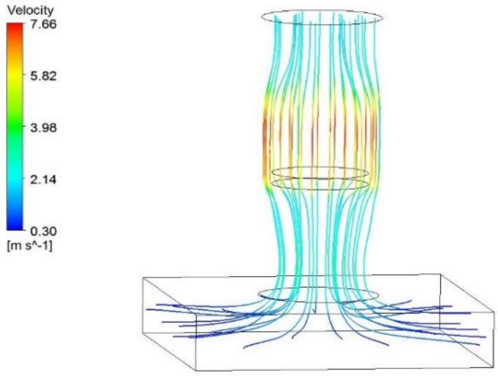
When the air was purified after passing through the glasshouse and the filter inside the tower, it was confirmed that the temperature was increased by solar energy about 6 °C. By increasing the temperature of the air, the motion of the molecules becomes active, which leads to an increase in the velocity of the air. The initial speed of entering the inside of the tower is increased, so that the load of the fan inside the air clean tower can be reduced. The adsorption rate of the filter (porous material) of the air cleaning tower is about 80%. The change in the suction speed inside the air clean tower and the velocity of the fluid changed by the fan inside the tower are shown in figure. 3.



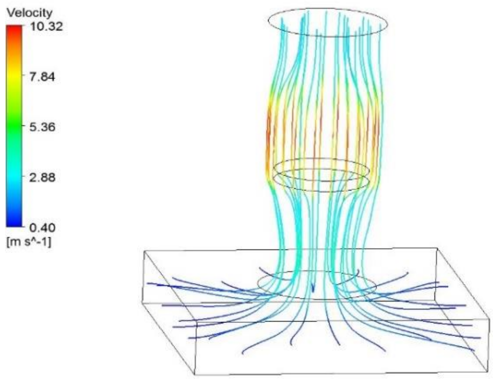

**(a) Distribution of velocity at inlet=0.1 m/s**




**(b) Distribution of velocity at inlet=0.2 m/s**




**(c) Distribution of velocity at inlet=0.3 m/s**




**(d) Distribution of velocity at inlet=0.4 m/s**

**Fig. 3** Results of velocity inside the air-purification tower



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When the inlet velocity was varied from 0.1 to 0.4 m/s, the velocity was increased to 2.47 m/s, 5.03 m/s, 7.66 m/s, and 10.32 m/s until it reached to the filter through the interior of the tower. By increasing the air velocity, the concentration distribution at the outlet section is lowered, the connection speed with the filter is increased, a larger pressure drop has been resulted. This is because the adsorption rate is increased between the filter and the air.

## III. EXPERIMENT OF CONDITION FOR ELECTROSPINNING

### A. Configuration of electrospinning system

The device for electrospinning was designed by modularizing to be able to cope with changes in test conditions and large area.

The detailed device consists of a fabric feeding part, a radiation part, a soaking part, a drying part, and a fabric transfer part, as shown in Figure 1. The radiation device is based on top-down radiation and the radiation column is composed of 12 columns with 10 nozzles per column.

To verify the effect of the electric field generated in the electrospin-ning, we made it individually controlled. Collector substrate applied (-) voltage is made of stainless steel and the electrospinning is per-formed by transferring the PES fabric to the upper surface of the substrate or stainless steel substrate.

Polyether sulfone (PES), which takes into account physical proper-ties such as tensile strength, elongation, and heat resistance, was used for electrospinning. Dimethylformamide (DMF), N-methyl- Pyrrolidone (N-Methyl-2-pyrrolidinone, NMP) was used at a constant ratio.

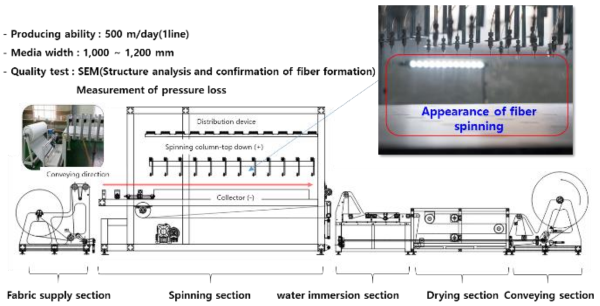


**Fig. 4** Configuration of electrospinning system

### B. Experiment of condition

In this study, we investigated the diameter and pore control of PES nanofibers by focusing on the process parameters such as concen-tration of polymer solution, applied voltage of spin column, and injection rate of polymer solution among various electrospinning parameters. Polyether sulfon (PES, BASF6020P) was used as a reagent for the test. Dimethylformamide (DMF), N-methyl-2-pyrrolidone -2-pyrrolidinone, NMP) was used for organic solvent.

In producing of the polymer solvent, PES was added according to the polymer concentration (26, 28, 30 wt%) DMF and NMP were mixed with a certain amount of the organic solvent, and then S.T.P status in especially self-made impeller-type mixing reactor. and the mixture was stirred for 20 hours.

### C. Analysis of nanofiber diameter by concentration of PES

Electrospinning was carried out to the mixed polymer solution under the conditions shown in Table. 1.

Samples with different PES concentrations emitted in the same electrospinning process parameters were analyzed by scanning electron microscope for nanofiber diameter except for the fabric feed rate, The data measured and calculated by Capillary Flow Porometer and the data obtained by Automated Capillary Flow Porometer are shown on Table. 2.

**Table 1** Condition of electrospinning for the effect of PES concentration

| No. | Condition | Value |
|---|---|---|
| 1 | Concentration(wt%) | 26, 28, 30 |
| 2 | TCD(mm) | 175 |
| 3 | Applied voltage(kV) | 20 |
| 4 | Injection rate(cc/min) | 0.5 |
| 5 | Conveying speed(mm/min) | 50, 100, 150 |

**Table 2** Results of capillary flow porometer

| Concen-tration (wt%) | Fiber diameter (nm) | Capillary Flow Porometer | | Filter characteristic | | Quality Factor |
|---|---|---|---|---|---|---|
| | | largest pore diameter (μm) | mean pore diameter (μm) | Differential pressure (mmAq) | Filter efficiency (%) | |
| 26 | 449.60 | 2.89 | 1.79 | 11.95 | 95.88 | 0.27 |
| 28 | 626.26 | 4.58 | 2.42 | 8.99 | 93.57 | 0.31 |
| 30 | 643.48 | 6.28 | 3.11 | 4.88 | 60.16 | 0.19 |

The average pore diameter and the maximum pore diameter increased with the transfer rate of the fabric, as the result of spinning the 26 wt% polymer solution at the transfer rate of 50, 100, and 150, respectively. This is related to the density of the nanofiber web described above, and as the transfer speed of the fabric increases, the density also decreases.

It was also confirmed that the polymer concentration increased from 26 wt% to 30 wt% at the same material


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transfer rate and the average pore size also increased. In addition, as a result of SEM photograph, shown in figure. 5, as the concentration of the polymer increases from 26 wt% to 30 wt%, the fiber diameter tends to increase. The average diameter was measured 449.60 nm at 26wt% of the feed rate of 50 mm / min, and the average diameter was 626.26 nm at 28wt% from the randomly sampling. The average diameter was gradually increased from 30wt% to 643.48 nm in Table. 2 and figure.7.

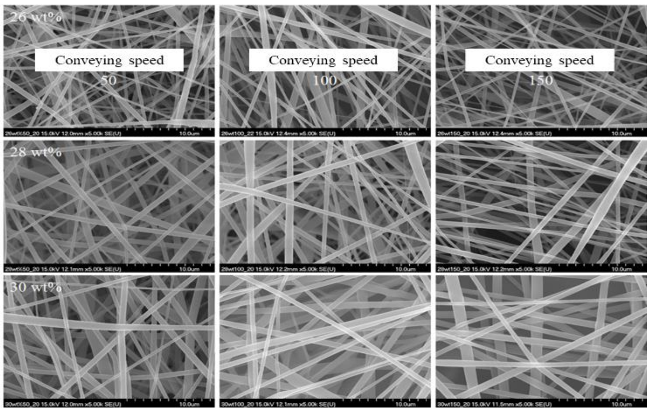


**Fig. 5** Results of SEM image by concentration of PES

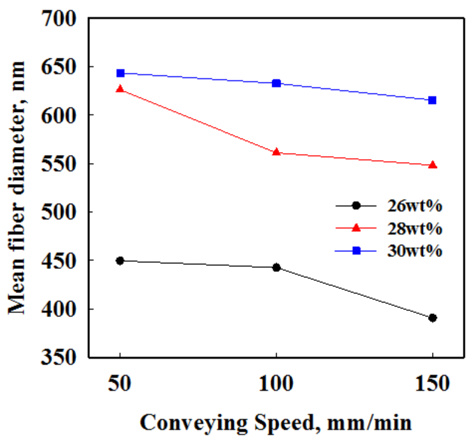


**Fig. 6** Relation of diameter change by concentration of PES solution

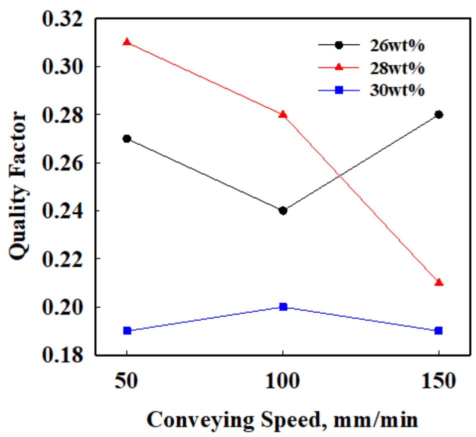


**Fig. 7** Results of quality factor by concentration of PES solution

**D. Analysis of nanofiber diameter by applied voltage**

In Table. 4 and Figure. 7, the average diameter of nanofibers tended to decrease linearly at 615.72 nm at 20 kV, 561.13 nm at 20 kV and 507.23 nm at 22 kV as the applied voltage increased from 18 to 22 kV. We can see the (SEM) photographs in Figure. 8.

**Table 3** Condition of electrospinning for the effect of PES concentration

| No. | Condition | Value |
|---|---|---|
| 1 | Applied voltage(kV) | 18, 20, 22 |
| 2 | TCD(mm) | 175 |
| 3 | Applied voltage(kV) | 20 |
| 4 | Injection rate(cc/min) | 0.5 |
| 5 | Conveying speed(mm/min) | 50, 100, 150 |

**Table 4** Results of capillary flow porometer

| Applied voltage(kV) | Fiber diameter (nm) | Capillary Flow Porometer | | Filter characteristic | | Quality Factor |
|---|---|---|---|---|---|---|
| | | largest pore diameter (㎛) | mean pore diameter (㎛) | Differential pressure (mmAq) | Filter efficiency (%) | |
| 18 | 615.52 | 18.33 | 3.33 | 2.83 | 55.30 | 0.28 |
| 20 | 561.13 | 7.29 | 3.20 | 3.31 | 59.78 | 0.28 |
| 22 | 507.23 | 9.01 | 2.48 | 2.74 | 50.26 | 0.25 |

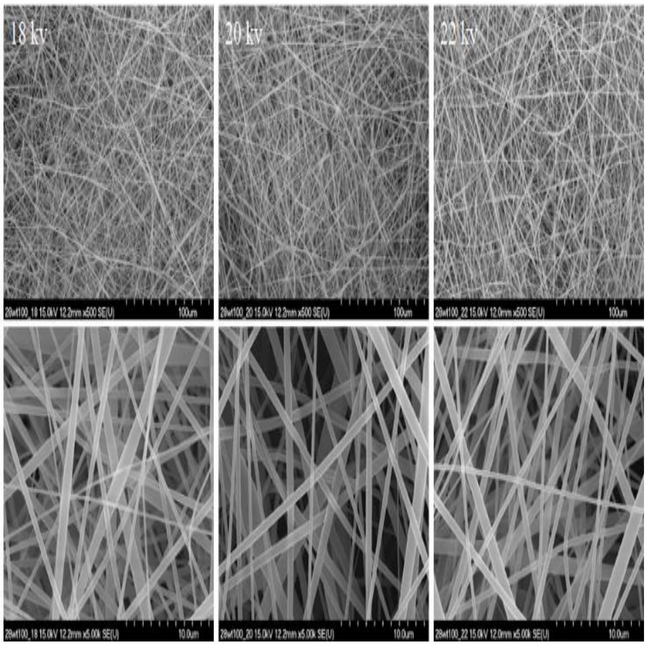

**Fig. 8** Results of SEM image by applied voltage

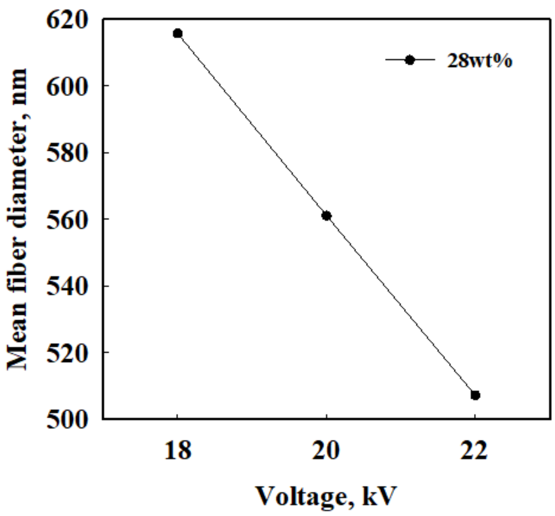

**Fig. 9** Relation of diameter change by applied voltage

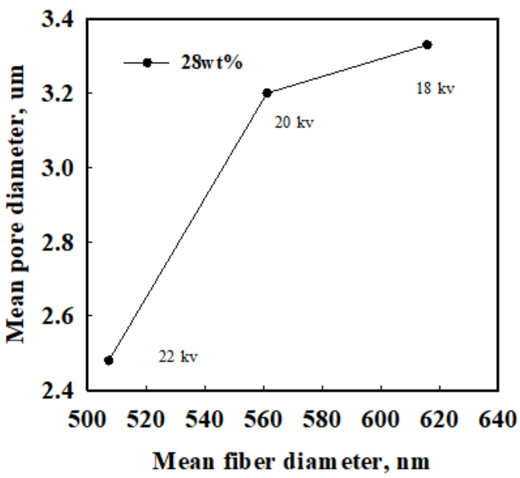

**Fig. 10** Relation of diameter change by PES concentration

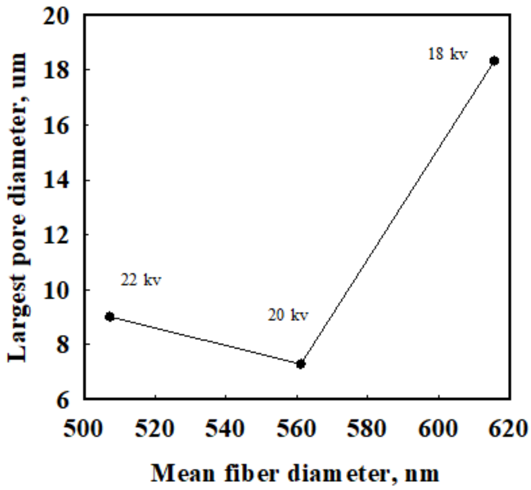

**Fig. 11** Relation of diameter change by applied voltage

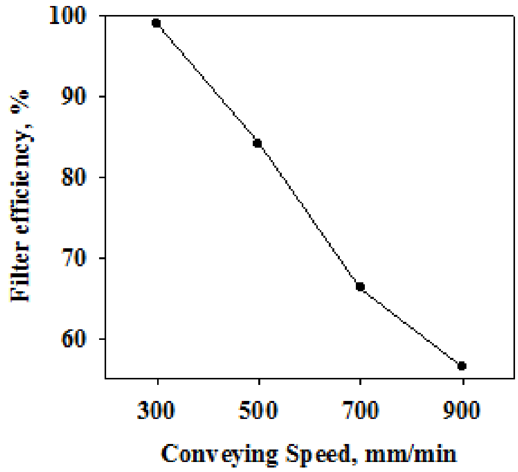

**Fig. 12:** Results of filter efficiency by PES media

When the applied voltage is 18 kV, it can be confirmed that the nanofibers are thick and thin, including beads that are elongated. The diameter deviation between the beads and each fiber gradually decreases as the applied voltage increases. The standard deviation of nanofiber diameter at each applied voltage is 245.84 at 18 kV, 183.52 at 20 kV, 232.43 at 22 kV, and 20.4 kV at 20 kV. It means more evenly emitted, it indicates that the nanofibers are unevenly radiated due to the effect of a strong applied voltage at 22 kV. Therefore, it is judged that the maximum pore diameter at 20 kV generally, uniformly radiated is smaller than the pore diameter at 22 kV

## IV.CONCLUSION

The results obtained from this study are as follows. It is related to density of nanofiber web, as the feed rate of fabric increases. The density is also lower, it was also confirmed


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that the polymer con-centration increased from 26 wt% to 30 wt% and the average pore size also increased at the same material transfer rate. The maximum pore diameter is less than 22 kV at an applied voltage of 20 kV, the standard deviation of nanofiber diameter at each applied voltage means that the fibers radiated at 20 kV from 18 kV to 245.84 nm, 20 kV at 183.52, and 22 kV at 232 kV were more uniformly emit-ted, it has been proved that the nanofibers are radiated unevenly due to the effect of the strong applied voltage at 22 kV. In addition, the porous media value of the tower internal filter (porous material) due to the pressure drop due to the velocity change was extracted when the fine dust removal rate of the air clean tower was 80%. When electrostatic precipitator and photocatalyst system are applied to the interior of the tower in the future, this can be used as a reference for designing the optimal shape of tower.

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