Korean J. Chem. Eng., **18**(4), 539-546 (2001)

Characteristics of Electrostatic Cyclone/Bag Filter with Inlet Types (Lab and Pilot Scale)

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(*Received 5 March 2001 • accepted 21 May 2001*)

Abstract−The main purpose of this study was to investigate experimentally the characteristics of an electrostatic cyclone/bag filter with inlet types (upper and bottom inlet) in order to overcome the low collection efficiency for submicron particles and high pressure drop, which were the main problems of general fabric bag filters. The experiment was performed to analyze the collection efficiency and pressure drop of the electrostatic cyclone/bag filter compared with that of conventional fabric bag filters with various experimental parameters such as the inlet type (upper and bottom), inlet velocity (filtration velocity) and applied voltages. From the results, the upper inlet type showed a slightly higher pressure drop reduction ratio as 40-90% than that of bottom inlet. In addition, the electrostatic cyclone/bag filter represented an increment of over 5% for the collection efficiency of submicron particles (around 1 μm) in comparison with the general fabric filter.

Key words: Electrostatic Cyclone/Bag Filter, Centrifugal Force, Electrostatic Force, Collection Efficiency, Pressure Drop Reduction Ratio

INTRODUCTION

Recently, the exchange and modification of conventional air pollution control equipment installed in industry have been seriously required due to the tightening emission control law for atmospheric pollutants. The fabric bag filter has been widely used as an air pollution control equipment because of its high collection efficiency (over 99%) [Beitez, 1993], but it has the disadvantages of low collection efficiency for submicron particles under 2 μm, limitation of treatment gas flow rates and high pressure drop compared to the other control system. To overcome the above problems of the bag filter, installing a cyclone [Sheperd and Lapple, 1939] as the pretreatment system has been combined with a conventional fabric bag filter system to reduce the dust loading on a fabric filter, although this causes an increment of installation area and maintenance cost. In spite of that, the high pressure drop and low collection efficiency for particles under 2 μm still remain as serious problems. Many studies are being carried out to increase the collection efficiency for submicron particles and decrease the excessive pressure drop combining the fabric filtration mechanism with electrostatic force [Frederick, 1961], but these also induce similar problems as mentioned above, due to the limitation of collection mechanism.

To overcome these problems, the present work analyzed the characteristics of the electrostatic cyclone/bag filter combined with the centrifugal force of cyclone, filtration collection of bag filter and electrostatic force in one unit system. In the present system, dust particles charged in a precharger inflowing tangentially into the system vessel are collected on the vessel inside-wall by centrifugal and electrostatic forces; and the collection is made by the electrostatic force and filtration mechanism in the fabric filter media [Humphries et al., 1984; Fjeld and Owens, 1988]. Therefore, the first collection causes a decrease of dust loading on the fabric filter, and the second decreases the pressure drop of fabric filter by the formation of a dendrite structure caused by the inter-repulse force due to the same polarity of particles deposited on the fabric filter [Frederick, 1980; Lastow and Bohgard, 1992].

In this work, we designed the lab and pilot scale experimental apparatus for the analysis of a collection system with two inlet types (upper and bottom inlet). The experiments were executed for the analysis of collection efficiency and pressure drop characteristics of the electrostatic cyclone/bag filter of upper or bottom inlet type in comparison with those of a conventional fabric bag filter with the various experimental parameters such as inlet velocity (filtration velocity), applied voltage and inlet type.

EXPERIMENTAL

1. Experimental Apparatus

The collection system is composed of a tangential inlet for centrifugal effect, a center inlet considering the characteristics of a conventional fabric filter, a precharger for charging of particles, a high voltage power supply, a particle feeder, a pulse-jet filter cleaning system, a hopper, an I.D. fan and measurement systems for collection efficiency and pressure drop. The layout of the experimental system for the lab scale with an upper inlet is shown in Fig. 1.

1-1. Main Body

A single fabric filter is installed inside the lab scale main body composed of the tangential and center inlets. The physical characteristics of the filter used in this experiment are presented in Table 1. The tangential inlet for a centrifugal effect is installed at the top

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‡Presented at the Int'l Symp. on Chem. Eng. (Cheju, Feb. 8-10, 2001), dedicated to Prof. H. S. Chun on the occasion of his retirement from Korea University.

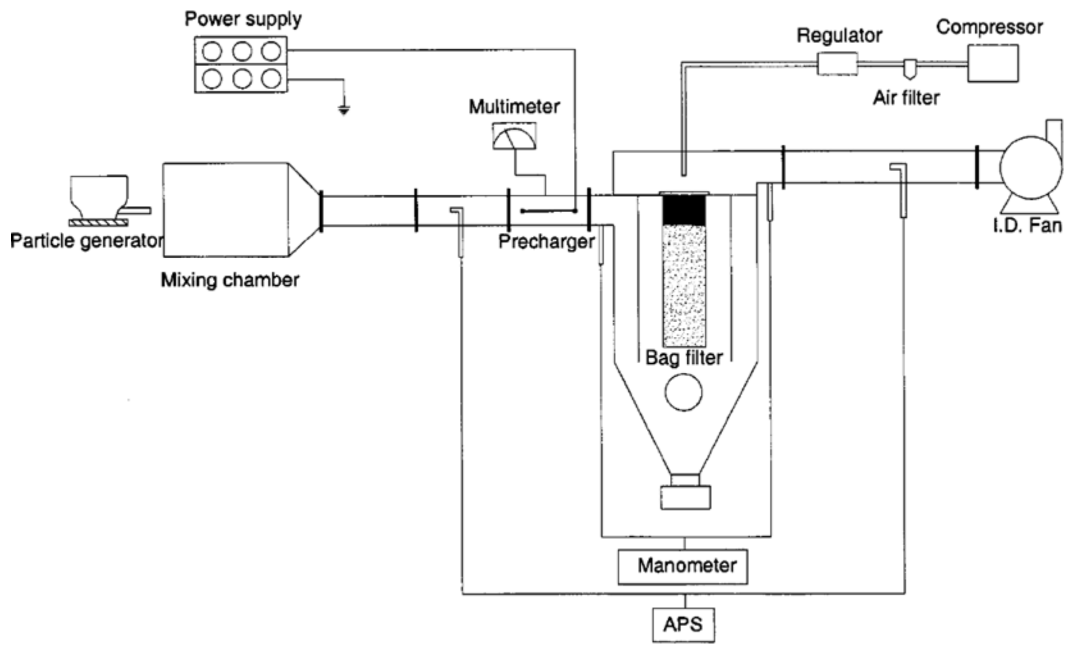
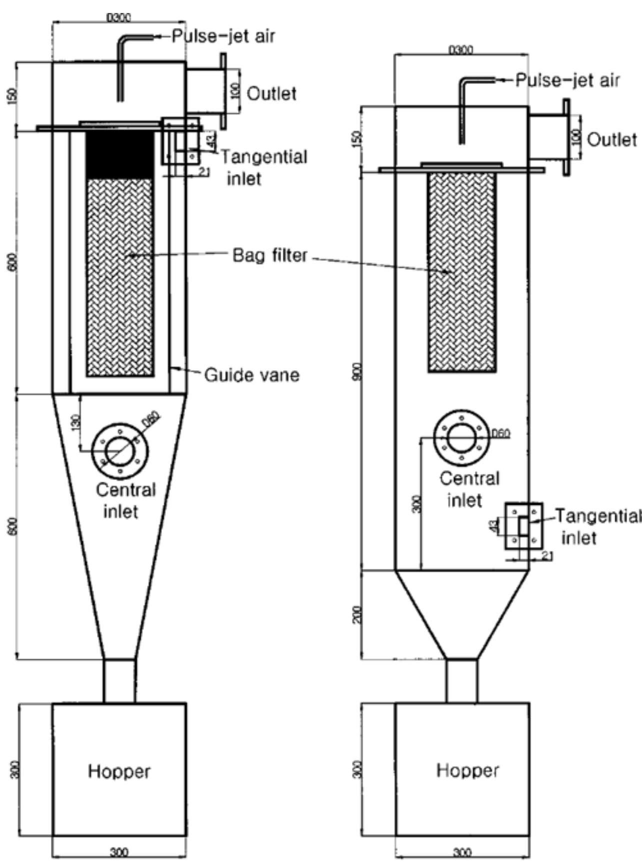


Fig. 1. Schematic diagram of experimental apparatus with upper tangential inlet.

Table 1. Physical characteristics of a fabric filter

Item	Content
Material	Polyester
Weight (g/m^2)	510
Thickness (mm)	2
Air permeability (cc/cm^2/sec)	20
Tensile strength (kg/5 cm)	165×150
Bursting strength (kg/cm^2)	37
Thermal resistance temp. (°C)	125



(a) Upper inlet type (b) Bottom inlet type

Fig. 2. Schematic of electrostatic cyclone/bag filter with upper and bottom inlet.

or bottom of main body, and the center inlet to compare the characteristics of the present system to a general fabric filter is installed at the bottom center of main body as in Fig. 2. In the case of the upper inlet type, a guide vane is installed for the separation of a downward outer vortex and upward inner vortex, and to prevent the disturbance of the outer and inner vortex flows. Fig. 2 shows the configuration of the main body with inlet types of a lab scale electrostatic cyclone/bag filter.

The basic configuration of a pilot scale experimental system is similar to that of the lab scale, and 9 filters for the upper inlet and 12 filters for the bottom inlet are installed inside the main body for the treatment of higher flow rate. Table 2 shows the main dimensions of the pilot scale experimental system.

1-2. Particle Feeder

The experimental dust is a coal fly ash sampled at coal-fired power plant and used after drying during 24 hours to prevent the change of size distribution with the humidity condition. The particle feeder is designed to change the inlet concentration by controlling the screw revolution speed to supply the suitable quantity of particles.

1-3. Precharger

Particles suspended in a gas stream may be charged through the electric field formed by applying a high voltage to a discharge wire located at the central axis of cylinder from a high voltage power supply. The lab scale precharger consists of cylinder 100 mm in

Table 2. Dimension of a pilot scale electrostatic cyclone/bag filter

	Upper inlet type	Bottom inlet type
Central inlet duct diameter	Ψ150	Ψ150
Tangential inlet duct size (wide×height)	63×126	83×167
Body length	850	2000
Body diameter	Ψ950	Ψ1100
Outlet duct diameter	Ψ150	Ψ150
Filter dimension	Ψ150×L810	Ψ150×L1060

diameter, 300 mm in length and wire of 100 mm in length installed at cylinder center.

2. Experimental Method

The collection efficiency and pressure drop of the present system are estimated with the inlet velocity, applied voltage and inlet type (upper and bottom inlet). Fractional collection efficiency is determined by aerodynamic particle sizer (APS3310, TSI Inc.) which can measure the number and mass density with particle sizes. Gas flow rates and filtration velocities are estimated by measuring the duct velocity with a micromanometer (FCO12, Furness Controls Ltd.). The velocity measuring and dust sampling points are selected at the point of 14.6% and 85.4% of cross section area of duct, and the averaged values of velocities, number and mass densities are measured. For the analysis of pressure drop characteristics with the inlet types (centrifugal effect) and electrostatic force, the pressure drop is measured by micromanometer at the points of 50 mm apart from the inlet and outlet of experimental apparatus for 30 minutes by 2 minutes interval with the inlet velocity and applied voltage. And the pressure drop data measured at 6 minutes after dust feeding is used for the comparison of pressure drop characteristics.

The experiments are performed on the various experimental conditions such as the inlet velocities (filtration velocities), applied voltages, and inlet types. The specific experimental conditions are described in Tables 3 and 4.

Table 3. Inlet velocity vs. filtration velocity (lab scale)

Tangential inlet velocity (m/s)	Flow rate (m^3/min)	Filtration velocity (m/min)	Center inlet velocity (m/s)	Precharger velocity (m/s)
12	0.65	2.8	5.54	1.38
15	0.815	3.5	6.92	1.73
18	0.978	4.3	8.30	2.08
21	1.141	5.0	9.69	2.42

Table 4. Inlet velocity vs. filtration velocity (pilot scale)

	Tangential inlet velocity (m/s)	Flow rate (m^3/min)	Filtration velocity (m/min)	Precharger velocity (m/s)
Bottom inlet	9	7.5	1.25	7.07
	15	12.5	2.08	11.79
	21	17.5	2.92	16.5
Upper inlet	9	4.27	1.25	4.04
	15	7.14	2.08	6.74
	21	10	2.92	9.43

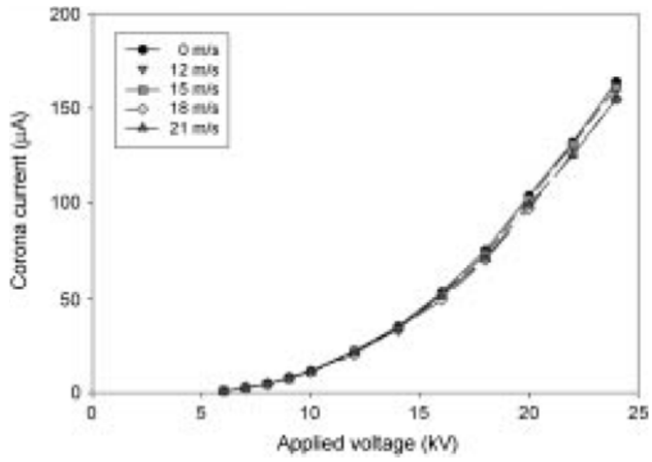


Fig. 3. Current vs. applied voltage with various inlet velocities (M_p= 0.0 mg/m^3).

RESULTS AND DISCUSSION

1. Experimental Results in Lab Scale

1-1. Voltage-Current Characteristics

For the analysis of voltage-current characteristics at the precharger, V-I experiment is performed on the various applied voltages, dust loadings and inlet velocities by multimeter (Fluke 27, LG DM-332). Fig. 3 represents the V-I characteristics with the inlet gas velocities without dust loading. As shown in the figure, the V-I characteristics are almost the same for the variation of inlet velocity. The slight difference of V-I with the gas velocity is similar to the experimental results performed by Jaworek and Krumps [1996]. It means that the gas velocity does not affect the current flow since the electron velocity is much higher than the gas velocity. As shown in Fig. 3, the applied voltages for this experiment are determined with 10 and 20 kV because sparkover occurs over 25 kV.

1-2. Collection Efficiency

1-2-1. Fractional Collection Efficiency

To analyze the collection efficiency characteristics of the present system, the particle number concentration is measured by APS at the inlet and outlet of the system, and fractional collection efficiency is estimated by Eq. (1).

$$\eta_i(\%) = \frac{N_{in,i} - N_{out,i}}{N_{in,i}} \times 100(\%) \quad (1)$$

Where η_i is fractional collection efficiency, $N_{in,i}$ is fractional particle number concentration at the inlet and $N_{out,i}$ is fractional particle number concentration at the outlet.

Fig. 4 shows the fractional collection efficiency with an applied voltage of 0 kV, inlet concentration of 300 mg/m^3 and filtration velocities of V_f=2.8, 3.5, 4.3 and 5.0 m/min (tangential inlet velocity $V_{i,t}$=12-21 m/s) for the upper inlet type. The fractional collection efficiency is over 95% for all size ranges and the collection efficiency becomes higher as the inlet velocity (filtration velocity) is increased. At an inlet velocity of 21 m/s, the collection efficiency is

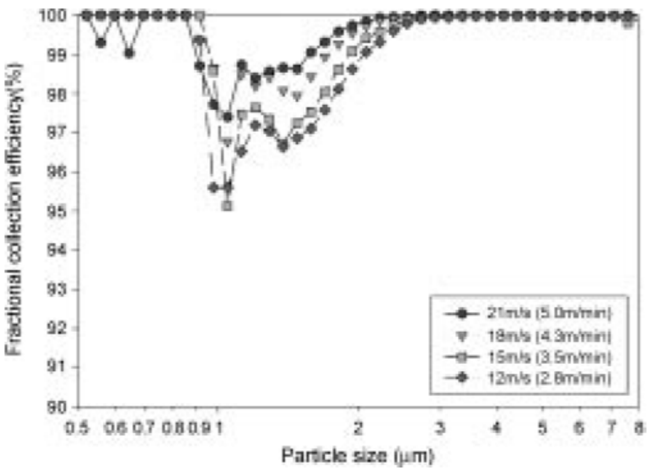


Fig. 4. Collection efficiency vs. particle diameter with various inlet velocities (upper inlet, M_p=300 mg/m^3, applied voltage=0 kV).

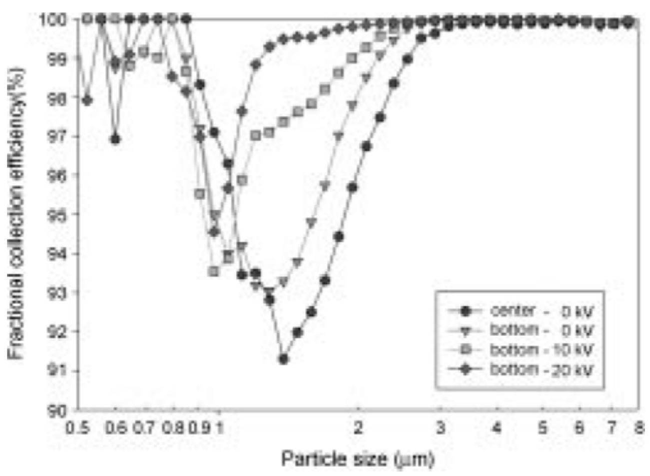


Fig. 5. Collection efficiency vs. particle diameter with various applied voltages (bottom inlet, M_p=300 mg/m^3, inlet velocity=21 m/s).

5% higher than that of 12 m/s. This means that the particles which are not captured on the fabric filter owing to seepage and pinhole plugs effects [El-Shobokshy et al., 1994] may be collected by the vortex flow generating the centrifugal force in tangential inlet, and this effect becomes higher as inlet velocity is increased.

Fig. 5 shows the fractional collection efficiency with inlet velocity of 21 m/s (filtration velocity of 5.0 m/min), dust loading of 300 mg/m^3, applied voltages of 0, 10 and 20 kV for the bottom inlet type. In the case of center inlet (applied voltage of 0 kV), the fractional collection efficiencies are maintained over 91% for all size ranges; however, the efficiency is minimum at the critical size of 1.3 μm corresponding to the transition point of efficiency. This characteristics are analyzed by diffusion, interception and inertia impaction which are the main collection mechanisms of a general fabric filter. And, at the applied voltage of 0 kV, the collection efficiency of the tangential inlet type is a little higher than that of center inlet type, which means a general fabric filter. This is explained from the particle collection [Zhou and Soo, 1990] by centrifugal force effect in the tangential inlet, as mentioned in Fig. 4. For tangential inlet type, as voltages are applied as high as 10 and 20 kV, the increment of collection efficiency is over maximum 6% than that of center inlet (applied voltage of 0 kV) around 1 μm in diameter. It is due to the effect of electrostatic cyclone increasing the particle mobility toward a body wall [Dietz, 1982], and electrostatic force on the filter media to be more effective for smaller particles. For an inlet velocity of 21 m/s and applied voltage of 0 kV, the upper inlet type shows higher collection efficiency than that of bottom inlet type. This higher efficiency is caused by the first collection effect of upper inlet type induced by the separation of inner and outer vortex flow (the effect of guide vane installed inside body) generating effectively the centrifugal force compared to the bottom inlet type.

1-2-2. Overall Collection Efficiency

The overall collection efficiency can be expressed as the following Eq. (2).

$$\eta_t(\%) = \frac{\sum(V_j N_{in,j} - V_j N_{out,j})}{\sum(V_j N_{in,j})} \times 100(\%) \quad (2)$$

Where η_t is overall collection efficiency, V_j is volume of particle for each size, $N_{in,j}$ is number concentration at inlet for each particle size and $N_{out,j}$ is number concentration at outlet for each particle size.

Fig. 6 shows the overall collection efficiency of the upper and bottom inlet with the inlet concentration of 300 mg/m^3, filtration velocities of 2.8, 3.5, 4.3 and 5.0 m/min (inlet velocities 12, 15, 18 and 21 m/s) and applied voltages of 0 and 20 kV. In the applied voltage 0 kV, the overall collection efficiency of tangential inlet type at least does not decrease with the increment of inlet velocity, while that of a conventional fabric filter decreases beyond the certain limit of inlet velocity owing to the seepage and pinhole plug effects as mentioned in Fig. 4. Moreover, the upper inlet type of applied voltage 20 kV, shows an excellent overall collection efficiency 99.9% under the all inlet velocity condition (12-21 m/s). It is due to the effective first collection based on the electric cyclone characteristics, and electrostatic force on the fabric filter in addition to a filtration mechanism as stated earlier. The present collection system combining a conventional fabric filter with the centrifugal and electro-

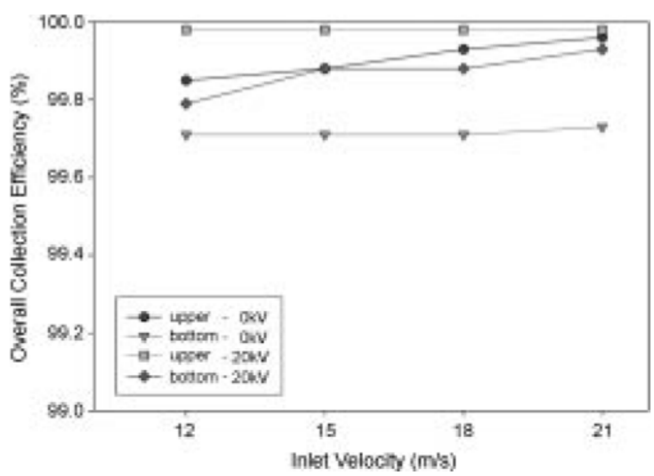


Fig. 6. Overall collection efficiency vs. inlet velocity with inlet types (M_p=300 mg/m^3).

static force is suitable to treat the various gas flow rates with no concern for the variation of inlet velocity.

1-3. Pressure Drop

The high pressure drop, which is one of the main problems of general fabric bag filters, is caused by a dust layer on the filter media. This pressure drop of a fabric bag filter system is presented by Darcy's pressure drop equation [Kim and Cho, 1990] as follows.

$$\Delta P = K_1 V_f + K_2 C_i V_f^2 t \quad (3)$$

Where K_1 and K_2 are resistance factors of filter media and dust layer, V_f is filtration velocity, C_i is dust loadings on filter, t is filtration time, K_1V_f is pressure drop by clean filter and $K_2C_i\ V_f^2t$ is pressure drop by dust layer on filter media.

One of the main purposes of this experiment is to decrease the high pressure drop caused by the dust loading on filter media shown in the second term of the right hand side of Eq. (3) by the effective combination of centrifugal and electrostatic forces to maximize the first collection efficiency, in addition to the formation effect of a dendrite structure by the charging particles deposited on the filter due to the electrostatic force. Figs. 7 and 8 show the pressure drop of a fabric filter with inlet concentration of 300 mg/m^3, inlet velocities of 12, 15, 18 and 21 m/s and applied voltages of 0, 10 and 20 kV for the upper and bottom inlet types. It is shown that the pressure drop of the fabric filter is increased with higher inlet velocities (filtration velocities). In case of tangential inlet and applied voltage 0 kV, the gradient of pressure drop increment becomes smaller than that of the center inlet. And this effect is more clearly represented as high voltages are applied with 10, 20 kV for the upper and bottom inlet types. For an inlet velocity of 12 m/s and applied voltage of 0 kV, the difference of filter pressure drop between tangential and center inlet types is 0.4 mmH_2O, but those are larger as 0.6, 1.0 and 1.4 mmH_2O for the higher inlet velocities of 15, 18 and 21 m/s, respectively. This is due to the combined effects of the first collection induced by the stronger centrifugal force with the increment of inlet velocity, and pressure drop of filter increasing with second power of filtration velocity as shown in the Eq. (3). We introduce Eq. (4) of next section to estimate indirectly the first collection effect (lower C_i than that of center inlet) caused by the only centrifugal force without considering the effect of filtration velocity increment (effect of V_f^2) for the pressure drop. In the tangential inlet and applied voltages of 10 and 20 kV, the pressure drop of the fabric filter is shown apparently lower than that of the center inlet (0 kV). The difference of filter pressure drop for the tangential inlet of 20 kV and for the center inlet of 0 kV is 0.9 mmH_2O in the inlet velocity of 12 m/s, while those are increased as 1.2, 1.7 and 2.1 mmH_2O for the higher inlet velocities of 15, 18 and 21 m/s. In particular, the pressure drop of the fabric filter for the tangential inlet of 20 kV may be reduced over 3 times in comparison with that of center inlet. Similar to the case of the tangential inlet of 0 kV, the particle migration velocity toward the body wall is increased by the properly combined effects of the enlargement of vortex strength for higher inlet velocity and electric force due to the high applied voltage. Based on the above statement, the pressure drop of fabric filter may be reduced by the first collection effect and increment of the filter surface area due to the formation of dust layer with dendrite structure caused by the electrostatic effect on filter media. Especially, the fact that the difference of pressure drop is increased as the inlet velocity is higher is related to the effect of filtration velocity increment (effect of V_f^2 in Eq. (3)) in addition to the reason discussed above. As the applied voltages are increased to 10 and 20 kV, the effect of pressure drop reduction is more clearly evaluated by the enlargement of particle migration velocity toward the body wall due to the high charging rate, and the easier formation of dendrite structure caused by coulomb force between the deposited particles on filter media. Thus for the tangential inlet of 0 and 20 kV, it is estimated that the treatment flow rates can be increased with 1.5-2 times than that for the center inlet of 0 kV at the same pressure drop condition. Furthermore, it is found that the experimental values of filter pressure drop for the upper inlet are larger than those for the bottom inlet due to the different initial dust layer as in Figs. 7 and 8.

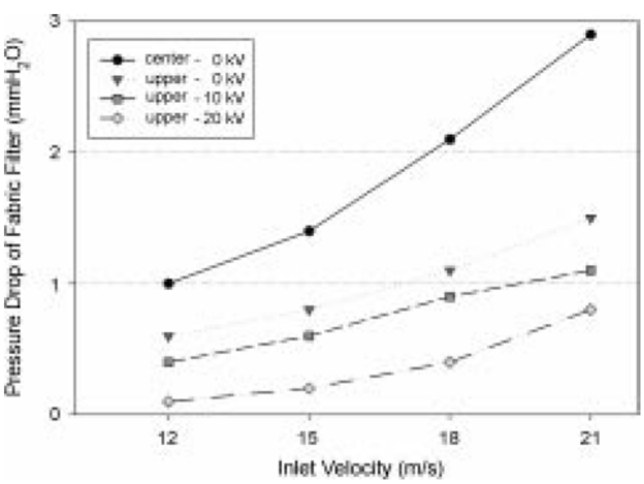


Fig. 7. Pressure drop of fabric filter vs. inlet velocity with various applied voltages (upper inlet, M_p=300 mg/m^3).

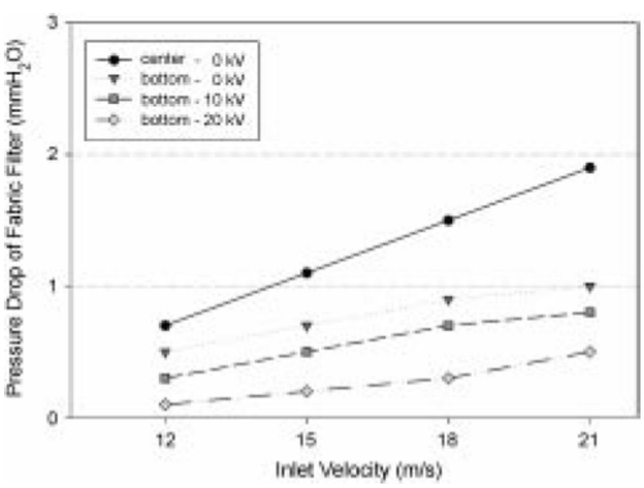


Fig. 8. Pressure drop of fabric filter vs. inlet velocity with various applied voltages (bottom inlet, M_p=300 mg/m^3).

1-4. Pressure Drop Reduction Ratio

The pressure drop reduction ratio (PDRR) defined in Eq. (4) is introduced to analyze quantitatively the pressure drop of fabric filter with the tangential inlet (upper and bottom) and center inlet type of a conventional fabric filter. Eq. (4) is obtained by modifying the equation of PDRR proposed from Greiner et al. [1981].

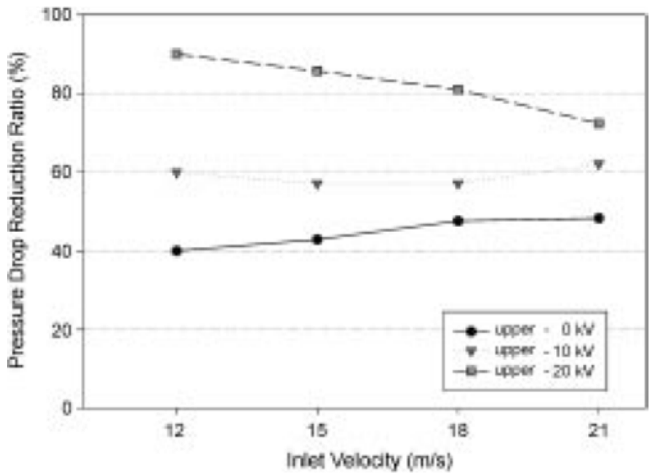


Fig. 9. Pressure drop reduction ratio vs. inlet velocity with various applied voltages (upper inlet, M_p=300 mg/m^3).

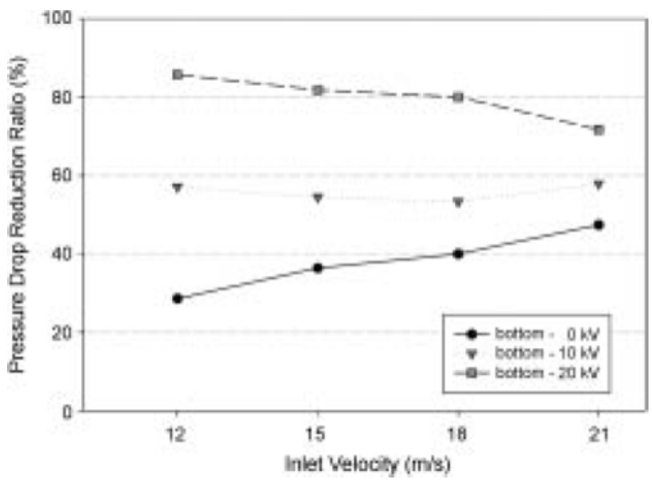


Fig. 10. Pressure drop reduction ratio vs. inlet velocity with various applied voltages (bottom inlet, M_p=300 mg/m^3).

$$\mathrm{PDRR}=\frac{(\Delta P_C-\Delta P_{Cr})-(\Delta P_T-\Delta P_{Tr})}{(\Delta P_C-\Delta P_{Cr})}\times 100(\%) \quad (4)$$

Where ΔP_C is a pressure drop of the center inlet of 0 kV, ΔP_T is that of the tangential inlet of 0, 10 and 20 kV, ΔP_{Cr} is that of the center inlet after cleaning and ΔP_{Tr} is that of the tangential inlet after cleaning, respectively.

Figs. 9 and 10 show the PDRR with inlet velocities 12, 15, 18 and 21 m/s and applied voltages 0, 10 and 20 kV for the tangential inlet types (upper and bottom). As shown in Fig. 9, it is found that PDRR is increased to 40-50%, when the inlet velocity becomes larger in 0 kV for upper inlet type. In Eq. (3), the pressure drop of the fabric filter may be determined by the combined effect of dust loading C_i and filtration velocity V_f. Thus, it is so hard to evaluate the centrifugal effect by the difference of pressure drop of the center and tangential inlet with the increment of filtration velocity (inlet velocity). However, as in the Eq. (4), the numerical value itself of filtration velocity may be almost negligible in PDRR which depends on the only dust loading on the fabric filter. Thus, in 0 kV, the increment of PDRR is directly connected to the first collection effect inducing the decrement of dust layer (lower C_i) by the larger centrifugal force with the increasing inlet velocity. At the applied voltage of 20 kV, PDRR are highly maintained over 70% for the upper and bottom inlet types, while decreasing for the larger inlet velocity because of the relaxation of electrical force by the decrement of charging rate. That is, the electrostatic effect indicates about 20% among PDRR 70% for the inlet velocity of 21 m/s. In the case of 10 kV, for the lower inlet velocity (12 and 15 m/s), the increment of PDRR compared to that of 0 kV becomes larger than that of high inlet velocity. It means that the electrical force is relatively more effective at lower inlet velocity, and the applied voltage of 10 kV may be considered as a transition point generating the electrical force effect in addition to the inertial force for the given inlet velocity range (12-21 m/s). And, it is shown that the PDRR of upper inlet type with the clearly separated vortex region is a little higher than that of bottom inlet in spite of similar trend for both inlet types.

2. Experimental Results in Pilot Scale

The experiment on a pilot scale is executed with inlet types (upper inlet and bottom inlet) by a similar method to that of lab scale for the analysis of characteristics of collection mechanism. The treatment flow rate is 20-25 times that of lab scale, that is, 5.1-17.6 m^3/min in bottom inlet and 4.3-10 m^3/min in upper inlet, respectively.

Fig. 11 shows the overall collection efficiency with the inlet velocities 9-21 m/s (filtration velocity, 1.25-2.92 m/min), applied voltages 0, 40 kV in the bottom, and center inlet. The collection efficiencies are maintained over 99.9% in the given experiment conditions. Additionally, in case of center inlet which means the characteristics of a conventional fabric bag filter, it is found that the collection efficiency decreases a little with the increment of inlet velocity. In tangential inlet, the collection efficiency increases for the larger inlet velocity, that is, it is due to the first collection effect by the centrifugal and electrostatic force.

The characteristics of pressure drop for an electrostatic cyclone/bag filter (tangential inlet type) are investigated compared to those of a conventional fabric filter (center inlet). The pressure drop is estimated by measuring the pressure before cleaning filter and after the formation of initial dust layer. Figs. 12 and 13 represent the pressure drop of fabric filter for the inlet velocity and applied voltage

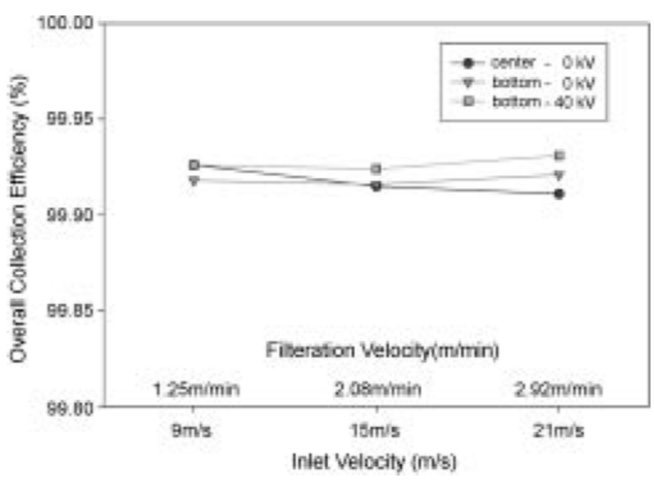


Fig. 11. Overall collection efficiency vs. inlet velocity with various applied voltages (bottom inlet, M_p=70 g/m^3).

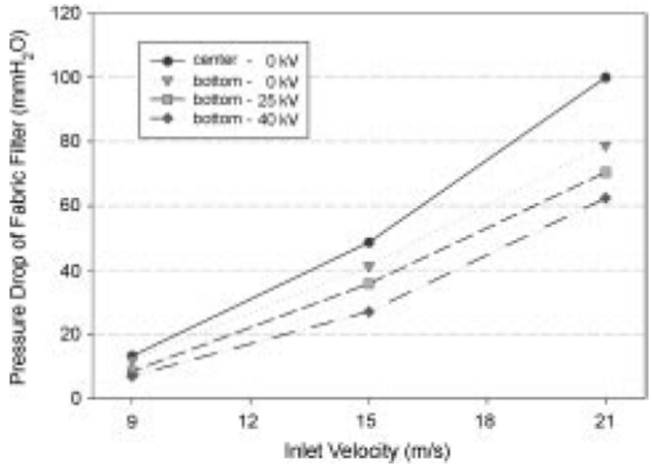


Fig. 12. Pressure drop of fabric filter vs. inlet velocity with various applied voltages (bottom inlet, M_p=70 g/m^3).

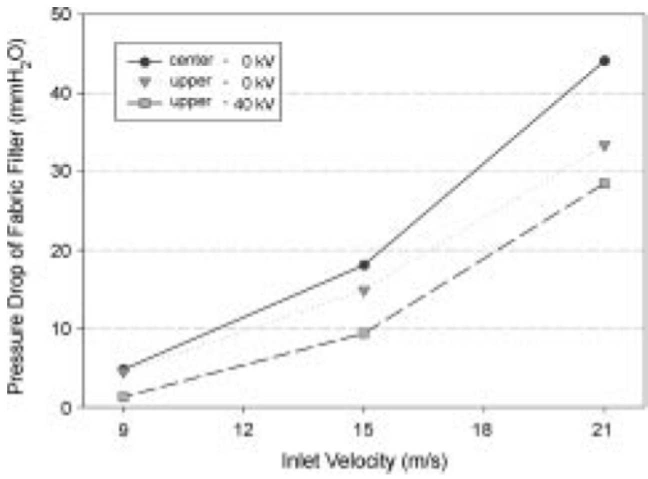


Fig. 13. Pressure drop of fabric filter vs. inlet velocity with various applied voltages (upper inlet, M_p=70 g/m^3).

with inlet types. On the whole, it shows a similar trend to that of lab scale, that is, the pressure drop becomes lower, as the tangential inlet type and applied voltages of 25 and 40 kV are applied. The gradient of pressure drop increment with inlet velocity is shown to be smaller in the case of tangential inlet compared to a center inlet of 0 kV since the particle loading added to the fabric filter decreases by the effect of the first particle collection to body wall. This effect is remarkably represented as higher voltages of 25 and 40 kV are applied for the both upper and bottom inlet type because of the first collection effect increased by the coulomb force of charged particles and the effective formation of dendrite structure on filter media. In Figs. 12 and 13, the pressure drops in the bottom inlet are larger than those of the upper inlet owing to the different initial dust layer conditions.

It is difficult to quantitatively compare the characteristics of pressure drop with inlet types in pilot scale because of the different experimental parameters such as the equipment scale, treatment flow rate, precharger, in the present experiment. Thus, it is desirable to estimate the pressure drop reduction ratio (PDRR) already mentioned in Eq. (4) for the pressure drop characteristics of the fabric filter. Fig. 14 shows the PDRR with the inlet velocity, applied voltage and inlet type. In case of 0 kV, the effect of pressure drop reduction becomes higher with the increment of the first collection effect by the centrifugal force as the inlet velocity is increased. As the high voltages 25, 40 kV are applied, the PDRRs are higher than those of 0 kV, and increased with the lower inlet velocity, since the electrostatic force may be dominantly applied in comparison with the centrifugal force for lower inlet velocity. It is highly estimated as 34-73% by the combined effect of centrifugal and electrostatic force in case of 40 kV. In the applied voltage 0 kV, the characteristics of PDRR with inlet type are shown as a similar trend and its difference is maintained within 5%. However, it is difficult to directly compare the effect on pressure drop with inlet type at the same applied voltage owing to the different precharger device.

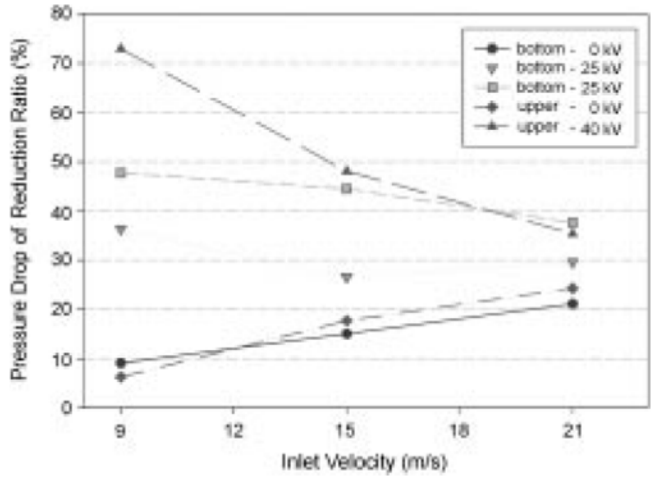


Fig. 14. Pressure drop reduction ratio vs. inlet velocity with various applied voltages (M_p=70 g/m^3).

CONCLUSION

The present study is aimed at the analysis of the characteristics of an electrostatic cyclone/bag filter combined with the centrifugal force of cyclone, filtration collection of a bag filter and electrostatic force in one unit system. Experimental studies have been performed to estimate the collection efficiency and pressure drop of electrostatic cyclone/bag filter (lab and pilot scale) with various experimental parameters such as the inlet velocity (filtration velocity), applied voltage and inlet types (upper tangential, bottom tangential and center inlet). The following conclusions are summarized.

1. Higher collection efficiency and pressure drop reduction ratio can be achieved by combining the centrifugal force, electrostatic force and filtration mechanism in one unit system in comparison with those of conventional fabric bag filters.

2. At the tangential inlet of 0 kV, the collection efficiency is increased with the inlet velocity increment by the particle collection due to the centrifugal force. In addition, this effect is clearly evaluated as the high voltage is applied.

3. For both cases of upper and bottom inlets, the overall collection efficiencies are over 99% on the present experimental condition, and the fractional collection efficiency of the upper inlet be-

comes higher over 5% than that of the bottom inlet around 1 μm diameter at the inlet velocity of 21 m/s and applied voltage of 0 kV.

4. At the upper inlet of 0 kV, the pressure drop of the filter is lower as 0.4 and 1.4 mmH_2O than those of the center inlet of 0 kV for the inlet velocities 12-21 m/s, and the gradient of pressure drop increment becomes much smaller for higher inlet velocity.

5. The PDRR is maintained over 70% at the tangential inlet of 20 kV (inlet velocities of 12-21 m/s) of lab scale. Thus, it can be expected that the treatment flow rate is increased over two times at the same pressure drop in comparison with that of a conventional fabric filter.

6. In lab scale, the PDRR of the upper inlet type is shown higher than that of the bottom inlet type. However, in pilot scale, it is found that the characteristics of PDRR are similar for both upper and bottom inlet types.

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