Measurement of effective filtration area of pleated bag filter for pulse-jet cleaning

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A B S T R A C T

A pleated filter cartridge is a potential component to reduce the installation space required for a bag house dust collection system. However, the optimal pleating method has not been suggested yet, and it has been dependent upon the manufacturer’s know-how and experience. In this study, a dimensionless parameter, α, which is the ratio of pleat height to pleat width, was introduced to determine the optimal pleat geometry of a pleated filter cartridge. Eight different pleated filters were prepared to determine the effect of α and pleat length, P, on the filter cleaning efficiency. A lab-scale pulse-jet bag house system which could install four filter bags and to be capable of on-line filter cleaning, was used to perform the filtration tests. Based on experimental data, a pleated cartridge filter with α = 2.21 had the maximum effective filtration area, and filter cleaning efficiency. However, we observed a drastic decrease in filter cleaning efficiency for a filter with an α value higher than 2.21. Therefore, we found that the tested cartridge filter had the optimal filter pleating geometry at α = 2.21, which folds a filter medium as a ratio of pleat height to pleat width, 2.21. In addition, the effective filtration area of a pleated filter cartridge was measured by the relationship between the increase in pressure drop during each filtration cycle, and multiplication of dust concentration and elapsed time. The ratio of the effective filtration area and theoretical filtration area, β, depends on the filtration cycle and the α value at the initial stage; however, it only depends on the α value at a later stage.

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1. Introduction

Bag house systems are applied to control particulate emissions and to recover valuable powders in many industries, such as coal-fired power plants, cement manufacturing plants, and powder production plants [1,2]. The cylindrical filter bag is the most commonly used component in a pulse-jet bag house [3–5]. However, in recent years, there has been great interest in developing a pleated filter bag with a larger filtration area than a cylindrical filter bag. Many researchers have tried to employ a pleated filter bag instead of a cylindrical filter bag in a pulse-jet bag house [5–12]. Using a pleated filter can decrease the amount of installation space required for a bag house. However, research on the geometrical optimization of a pleated filter is not enough, although its filtration performance and effective filtration area are highly dependent upon filter pleat geometry.

Chen et al. [13] considered the filter quality factor, which combines the collection efficiency and pressure drop, as an optimization criterion of pleat geometry for an air respirator. They suggested that the optimum pleat count was 2.15 pleats/cm. However, that method is quite far from a bag filter for pulse-jet cleaning. Filter cleaning performance should be considered to determine the optimal pleat geometry of a pleated filter cartridge. Lo et al. [1] introduced the pleat ratio, which is defined as the ratio of the pleat height to the pleat pitch. They tested six pleated filter cartridges fabricated from various materials and with various geometrical dimensions in a full-size dust collector. They suggested that clean-on-time mode was appropriate for a pleated filter with a pleat ratio lower than 4.0, and a clean-on-demand mode should be used for a filter with a pleat ratio lower than 4.0. However, they did not determine the optimal pleat geometry in their work.

Park et al. [8] also considered the pleat ratio to investigate the regeneration characteristics of pleated filter cartridges in their experiment. They investigated the optimal pleat geometries of a PTFE/glass foam-coated filter by a filtration test using filter cartridges with pleat ratios ranging from 1.36 to 2.67. They concluded that the pleat height should be 1.97 times deeper than the pleat width for a specific filter medium. However, the study had a drawback that the ideal filter cartridge having sharp pleating mountains and valleys, could not be prepared because the filter medium had a 0.9-mm thickness. Li et al. [12] investigated the effect of pleat geometry of conventional filter media and coated filter media on the filtration and cleaning characteristics of those filters. They found that the pleat geometry of the pleated filter by a
significantly influenced the pressure drop and cleaning adhesive force, and the cleaning efficiency decreased with increasing $\alpha$ (ratio of pleat height to pleat width) value. They suggested that the $\alpha$ value should be less than 1.59 to achieve a good filtration effect. However, the experiments were performed at an off-line pulse-jet bag house, which is different from an on-line pulse-jet system. Particles detached by filter cleaning in an off-line system migrate far away, which results in higher filter cleaning efficiency. Wakeman et al. [7] found that the folding of filter media reduced the air permeability and the effective filtration area due to media compression, pleat deformation, and pleat crowding. Kim et al. [11] showed that the effective filtration area of a pleated filter was approximately 50 to 60% of the theoretical filtration area. Li et al. [12] investigated the relationship between the effective filtration area and the pleat ratio for the pleated filter, and suggested a mathematical model to represent the relationship.

In this study, our goal was to determine the optimal pleating method to fabricate a pleated filter cartridge for an on-line pulse-jet system by introducing dimensionless parameter, $\alpha$. In addition, the effective filtration area of a pleated filter cartridge was measured from the relationship between the increase in pressure drop during each filtration cycle and the multiplication of dust concentration and elapsed time.

2. Theoretical approach to predict total pressure drop and effective filtration area

The total pressure drop in a dust-loaded filter medium consists of the pressure drop in the filter medium itself and the pressure drop across the dust cake. [14–18]:

$$\Delta P = \Delta P_f + \Delta P_c.$$  \hspace{1cm} (1)

where $\Delta P$ is the total pressure drop, $\Delta P_f$ is the pressure drop in the filter medium, and $\Delta P_c$ is the pressure drop across the dust cake. Here, $\Delta P_f$ and $\Delta P_c$ are expressed in Eq. (2), which is based on Darcy's law:

$$\Delta P_f = \frac{\mu D_f}{K_f} \Delta P_c = \frac{\mu D_c}{K_c}$$ \hspace{1cm} (2)

where $\mu$ is the fluid viscosity ($1.81 \times 10^{-5}$ kg/m·s); $v$ is the filtration velocity; $D_f$ and $D_c$ are the thickness of the filter medium and the dust cake, respectively; and $K_f$ and $K_c$ are the air permeability of the filter medium and the dust cake, respectively. The thickness of the dust cake, $D_c$, increases with capturing particles with dust mass concentration, $C$, during elapsed time, $t$, which is expressed as [19]

$$D_c = \frac{C_v t C}{P_c}$$ \hspace{1cm} (3)

where $P_c$ is the density of the dust cake layer.

Therefore, the total pressure drop, $\Delta P$, of a dust-loaded filter medium is expressed in Eq. (4), substituting Eqs. (2) and (3) into Eq. (1):

$$\Delta P = \left[ \frac{\mu D_f}{K_f} v + \left( \frac{\mu}{K_c P_c} \right) v^2 C t \right] k_1 v + k_2 v^2 C t.$$ \hspace{1cm} (4)

where $k_1$ is the filter medium resistance coefficient (mmH2O/(m·min^{-1})); and $k_2$ is the dust cake specific resistance coefficient (mmH2O/(g·m^{-2}·min^{-1})). [12,14–18].

The derivative of Eq. (4) with respect to $C_t$ is expressed as

$$\frac{d\Delta P}{dC_t} = k_2 v^2,$$ \hspace{1cm} (5)

where $d\Delta P$ is the increment of $\Delta P$, and $dC_t$ is the increment of $C_t$. The right-hand side in Eq. (5) shows the slope of a linear region in the curve, $k_2 v^2$, which plots the pressure drop as a function of $C_t$. Kim et al. [11] showed that the effective filtration area of a pleated filter is different from the theoretical filtration area. As the effective filtration area decreases, the filtration velocity increases at the equivalent gas flow rate. The relationship between the filtration velocity and filtration area is expressed as

$$Q = v_1 A_t = v_2 A_r,$$ \hspace{1cm} (6)

where $Q$ is the gas flow rate; $v_1$ and $A_t$ are the theoretical filtration velocity and theoretical filtration area, respectively; and $v_2$ and $A_r$ are the actual filtration velocity and the actual filtration area, respectively. In the first filtration cycle, the filtration area of a cylindrical filter bag is regarded as the theoretical filtration area. Therefore, the actual filtration velocity of a cylindrical filter at the first filtration cycle is equal to the theoretical filtration velocity. However, the actual filtration velocity of a pleated filter cartridge increases with decreasing filtration area rather than theoretical filtration area. Therefore, the $k_2$ value in Eq. (5) should be determined by increased filtration velocity. In addition, the actual $k_2$ value can be obtained from the ratio of the actual filtration velocity and the theoretical filtration velocity as shown in Eq. (7) [20]:

$$k_2 = \left( \frac{v_2}{v_1} \right)^{1/2},$$ \hspace{1cm} (7)

where, $k_2$ is the actual value of $k_2$ and $k_2$ is the theoretical value of $k_2$.

Rearranging Eqs. (5), (6), and (7), the ratio of $k_2 v^2$ to $k_2 v^2$ can be expressed as

$$\frac{d\Delta P_f}{dC_t} = \frac{k_2 v^2}{k_2 v^2} = k_2 \frac{v^2}{v^2} \frac{k_2}{k_2} \left( \frac{v_1}{v_2} \right)^{1/2} \left( \frac{A_t}{A_r} \right)^{1/2},$$ \hspace{1cm} (8)

where, $d\Delta P_f/dC_t$ is the slope of a linear region in the curve, $k_2 v^2$, which plots the pressure drop as a function of $C_t$ at the first cycle of a cylindrical filter bag, and $d\Delta P_f/dC_t$ is that of the pleated filter cartridges, which is equal to $k_2 v^2$.

Therefore, we can suggest the ratio of the effective filtration area to the theoretical filtration area, $\beta$, as shown in Eq. (9):

$$\beta = \frac{A_t}{A_r} = \left( \frac{k_2 v^2}{k_2 v^2} \right)^{1/5}.$$ \hspace{1cm} (9)

3. Experimental

3.1. Preparation of a pleated filter cartridge

The filter medium to prepare a pleated filter cartridge (diameter: 115 mm, height: 273 mm), had an antistatic property and was made of polyester fibers coated with aluminum. Therefore, the electrostatic charges on a particle can be easily released, so that the medium can be widely used to collect explosive particles. Fig. 1 shows an SEM image.
of the filter medium. The filter medium was 0.63 mm thick, had a 18.12 μm fiber diameter, and 0.43 solidity.

A pleated filter cartridge was prepared by folding the filter medium to have a certain pleat ratio. The thin thickness of the filter medium helped to achieve the ideal pleat geometry of a pleated filter cartridge. Fig. 2 [8] shows a schematic configuration of a pleated cartridge. Pleat geometry was determined by controlling the radius of the pleated filter, \( R \), the number of pleats, \( N \), and the pleat length, \( P_L \). The relationships between these design parameters are expressed in Eqs. (10) to (12):

\[
P_P = 2R \sin \left( \frac{180}{N} \right),
\]

\[
\theta = 180 - 360 \frac{R \sin (180/N)}{P_L} - 2 \arccos \left( \frac{R \sin (180/N)}{P_L} \right),
\]

\[
P_H = P_L \cos \left( \frac{\theta}{2} \right),
\]

where, \( P_P \) is the pleat pitch between a pleat and a neighboring pleat, \( \theta \) is the pleat angle, and \( P_H \) is the vertical distance from the vertex of a pleat peak to the inner surface of the pleated filter. Dimensionless parameter, \( \alpha \), which is the ratio of the pleat height, \( P_H \), to the pleat pitch, \( P_P \), was employed to represent the pleat geometry. The parameter \( \alpha \) can be rearranged as a function of \( P_L \), \( \theta \), \( R \), and \( N \):

\[
\alpha = \frac{P_H}{P_P} = \frac{P_L \cos(\theta/2)}{2R \sin(180/N)}.
\]

Eight different pleated filters were prepared to determine the effect of \( \alpha \) and pleat length, \( P_L \), on the filter cleaning efficiency. The detailed specifications and geometrical configurations are presented in Table 1 and Fig. 3. Six filters (B, C, D, E, F, and G) were pleated to have different \( \alpha \) values, and three filters (F, H, and I) were pleated to have different pleat lengths, \( P_L \), at the same \( \alpha \). In addition, their filter cleaning efficiencies were compared with that of a cylindrical filter A. The \( \alpha \) values ranged from 1.07 to 2.50, and the \( P_L \) values were 15, 20, and 25 mm. The whole surface areas of the pleated filters prepared in this study were 2.24 to 5.03 times larger than that of a cylindrical filter bag with the same dimensions.

3.2. Filtration tests

A pulse-jet bag house system was used to perform the filtration tests. The experimental apparatus of the system is shown in Fig. 4, and the operating conditions are listed in Table 2. The system consisted of a dust-feeding part to provide test particles, a filter-cleaning part for pulse-jet injection, and a dust-collection part (bag-house). The bag house was designed to install four filter bags and to be capable of on-line filter cleaning. Usually, the pressure drop across a filter bag increases with dust loading, which results in a decreased gas flow rate. An induced draft fan controlled by an inverter along with a pitot tube, was used to compensate the decrease in gas flow rate. Therefore, the filtration velocity was maintained during the filtration tests. The measured pressure drop during a filtration cycle was recorded every 5 s.

### Table 1

<table>
<thead>
<tr>
<th>Filter</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of pleats, ( N ) [each]</td>
<td>–</td>
<td>20</td>
<td>25</td>
<td>30</td>
<td>35</td>
<td>40</td>
<td>45</td>
<td>54</td>
<td>32</td>
</tr>
<tr>
<td>Radius of pleated filter, ( R ) [mm]</td>
<td>57.5</td>
<td>57.5</td>
<td>57.5</td>
<td>57.5</td>
<td>57.5</td>
<td>57.5</td>
<td>57.5</td>
<td>57.5</td>
<td>57.5</td>
</tr>
<tr>
<td>Pleat length, ( P_L ) [mm]</td>
<td>–</td>
<td>20.2</td>
<td>20.2</td>
<td>20.2</td>
<td>20.2</td>
<td>20.2</td>
<td>20.2</td>
<td>15</td>
<td>25</td>
</tr>
<tr>
<td>Pleat pitch, ( P_P ) [mm]</td>
<td>–</td>
<td>18.0</td>
<td>14.4</td>
<td>12.0</td>
<td>10.3</td>
<td>9.0</td>
<td>8.0</td>
<td>6.7</td>
<td>11.3</td>
</tr>
<tr>
<td>Pleat angle, ( \theta ) [°]</td>
<td>–</td>
<td>34.9</td>
<td>27.4</td>
<td>22.6</td>
<td>19.3</td>
<td>16.8</td>
<td>14.9</td>
<td>19.1</td>
<td>14.8</td>
</tr>
<tr>
<td>Pleat height, ( P_H ) [mm]</td>
<td>–</td>
<td>19.3</td>
<td>19.6</td>
<td>19.8</td>
<td>19.9</td>
<td>20.0</td>
<td>20.0</td>
<td>14.8</td>
<td>24.8</td>
</tr>
<tr>
<td>Surface area of filter, ( A_t ) [m²]</td>
<td>0.39</td>
<td>0.88</td>
<td>1.10</td>
<td>1.32</td>
<td>1.54</td>
<td>1.76</td>
<td>1.99</td>
<td>1.77</td>
<td>1.75</td>
</tr>
<tr>
<td>Dimensionless parameter, ( \alpha ) [−]</td>
<td>–</td>
<td>1.07</td>
<td>1.36</td>
<td>1.65</td>
<td>1.93</td>
<td>2.21</td>
<td>2.50</td>
<td>2.21</td>
<td>2.21</td>
</tr>
</tbody>
</table>

Fig. 2. Geometry of a pleated cartridge filter.
The system was operated under the clean-on-demand mode, in which filter regeneration was conducted at the maximum allowable pressure drop of 100 mmH₂O. Pulse-jet air with a pressure of 4 kgf/cm² was injected into the filter bag through four nozzles controlled by solenoid valves. The filtration tests were continued until the sixth filtration cycles had been completed.

Fly ash particles procured from a local coal-fired power plant, were used as the test dust. The particle-size distribution of the test particles was measured by an aerodynamic particle sizer (APS 3321, TSI Inc.), which detects particles ranging from 0.37 to 20 μm in aerodynamic diameter and has the aerodynamic size resolution of 0.02 μm at 1.0 μm and 0.03 μm at 10 μm. It had a geometric mean diameter of 1.07 μm and a geometric standard deviation of 1.64. The theoretical filtration velocity was set to 1 m/min, which is the typical value in conventional bag-house systems.

### 4. Results and discussion

#### 4.1. Filter-cleaning performance

Fig. 5 shows the changes in pressure drop across the filter medium as a function of elapsed time during filtration and filter cleaning. The total elapsed time to reach the sixth filtration cycle, depended on the dimensionless parameter, α. It decreased with increasing α, with durations of 1461 min, 997 min, 807 min, 568 min, 518 min, and 409 min for filters B, C, D, E, F, and G, respectively. Under the operating conditions, the dust feed rate was determined to have a constant dust concentration based on the theoretical filtration area of a pleated filter cartridge, as shown in Table 2. When the effective filtration area of each pleated filter cartridge is identical to the theoretical filtration area, it is expected that the same pressure drop changes will occur, regardless of α value.

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Fig. 3. Top-view and configurations of prepared filters.
Fig. 4. Experimental apparatus of the filtration test.

Table 2
Operating conditions for filtration tests.

<table>
<thead>
<tr>
<th>Filter</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>F-1</th>
<th>F-2</th>
<th>G</th>
<th>H</th>
<th>I</th>
</tr>
</thead>
<tbody>
<tr>
<td>v [m/min]</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>C [g/m³]</td>
<td>10.0</td>
<td>10.0</td>
<td>10.0</td>
<td>10.0</td>
<td>10.0</td>
<td>10.0</td>
<td>10.0</td>
<td>10.0</td>
<td>10.0</td>
<td>10.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Aᵣ [m²]</td>
<td>0.39</td>
<td>0.88</td>
<td>1.10</td>
<td>1.32</td>
<td>1.54</td>
<td>1.76</td>
<td>1.76</td>
<td>1.76</td>
<td>1.76</td>
<td>1.76</td>
<td>1.76</td>
</tr>
<tr>
<td>Q [m³/min]</td>
<td>1.99</td>
<td>1.76</td>
<td>1.76</td>
<td>1.76</td>
<td>1.76</td>
<td>1.76</td>
<td>1.76</td>
<td>1.76</td>
<td>1.76</td>
<td>1.76</td>
<td>1.76</td>
</tr>
<tr>
<td>Feed rate [g/min]</td>
<td>3.9</td>
<td>8.8</td>
<td>11.0</td>
<td>13.2</td>
<td>15.4</td>
<td>17.6</td>
<td>10.6</td>
<td>8.4</td>
<td>19.9</td>
<td>17.6</td>
<td>17.6</td>
</tr>
<tr>
<td>Assumed dead space [%]</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>40</td>
<td>50</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Assumed filtration area, Aₑ [m²]</td>
<td>0.39</td>
<td>0.88</td>
<td>1.10</td>
<td>1.32</td>
<td>1.54</td>
<td>1.76</td>
<td>1.06</td>
<td>0.88</td>
<td>1.99</td>
<td>1.76</td>
<td>1.76</td>
</tr>
</tbody>
</table>

Other parameters: Jet pressure (4 kgf/cm²), Maximum allowable pressure drop (100 mmH₂O).

Fig. 5. Changes in pressure drop as a function of elapsed time at various values of dimensionless parameter, α.
However, the experimental results in Fig. 5 revealed the decrease in effective filtration area and filter cleaning efficiency.

The filter cleaning efficiency of each filter, $\varepsilon$, was calculated by Eq. (14). It expresses the relative correlation factor between the residual pressure drop and the initial pressure drop:

$$
\varepsilon = \frac{\Delta P_{\text{max}} - \Delta P_{\text{res}}}{\Delta P_{\text{max}} - \Delta P_{F}}
$$

(14)

where, $\Delta P_{\text{max}}$, $\Delta P_{\text{res}}$, and $\Delta P_{F}$ represent the maximum allowable pressure drop, the residual pressure drop immediately after filter cleaning, and the pressure drop of a fresh filter medium without dust loading, respectively.

Fig. 6 shows the filter cleaning efficiency of a pleated filter with various values of dimensionless parameter, $\alpha$. Filter cleaning efficiency decreased with proceeding filtration and filter cleaning. The highest filter cleaning efficiency was found at $\alpha = 2.21$ under the same test cycle. This result is similar to the result of Park et al. [8].

Filter cleaning characteristics were investigated to determine the effect of pleat length on filter cleaning at the same $\alpha$. The filter cleaning efficiencies of pleated filters (Filter F, H, and I) with three different $P_t$ values at the same $\alpha$, were compared, and the results are shown in Fig. 7. Although there were slight differences in filter cleaning efficiencies at each filtration cycle, we could not find apparent differences among the test filters. In addition, those filters clearly showed higher filter cleaning efficiencies than other filters. Therefore, we can conclude that filter cleaning efficiency depends on $\alpha$ value rather than pleat length.

4.2. Physical properties of filter medium and dust cake

The air permeability of the filter medium, $K_F$, was calculated with cylindrical filter A. Fig. 8 shows the measured pressure drop across a test filter medium as a function of filtration velocity. The slope corresponds to the term, $\mu D_F K_F$ in Eq. (2). The calculated air permeability of the filter medium was $4.02 \times 10^{-12}$ m$^2$. The coefficient of determination, $r^2$, was 0.9994.

The filter medium resistance coefficient, $k_1$, can be calculated by Eq. (4). The $k_1$ value is equal to the measured pressure drop of a fresh filter medium without dust loading divided by filtration velocity. The pressure drop of a fresh filter medium without dust loading, $\Delta P_1$, was obtained through our experiment. The calculated $k_1$ values were 4.81, 4.81, 5.02, 4.71, 4.70, 4.71, and 5.30 mmH$_2$O/(m·min$^{-1}$) for filters A, B, C, D, E, F, and G, respectively. The mean value of $k_1$ was 4.88 mmH$_2$O/(m·min$^{-1}$). In these experimental results, there was no significant effect of pleat geometry on the filter medium resistance coefficient.

In addition, the theoretical dust cake specific resistance coefficient, $k_2$, was calculated by Eq. (4). The value was obtained by dividing $k_2$, which is the slope of the linear region in the pressure drop curve of a cylindrical filter bag in Fig. 9, into $v_t^2$. The calculated $k_2$ was 0.020 mmH$_2$O/(g·m$^{-2}$·m·min$^{-1}$). In this calculation, we have to assume the uniform dust cake buildup on the filter surface of pleated filter cartridges.

4.3. Effective filtration area

Filtration area is the most critical parameter to determine the number of pleated filter cartridges which is required to treat a certain amount of gas flowrate. However, filtration area in a pleated filter cartridge depends on its geometrical configuration and particle deposition over time. As the number of pleats and the amounts of deposited particles increase, the effective filtration area is getting smaller than theoretical filtration area (total area of a filter medium). Therefore, the effective filtration area of a pleated filter cartridge is essential to design the required number of filter bags in a pulse-jet bag house. It was calculated by Eq. (9) in this study. Fig. 9 shows the pressure drop as a function of $C_t$. The slope with a linear relationship in each curve during an

![Fig. 6. Filter cleaning efficiency of a pleated filter with various values of dimensionless parameter.](image_url)

![Fig. 8. Pressure drop across a test filter medium as a function of filtration velocity.](image_url)
individual filtration cycle means the $k_2v_2^2$ value of a prepared filter as shown in Eq. (8). The values are listed in Table 3. Fig. 10 shows the ratio of the effective filtration area to the theoretical filtration area, $\beta$, as a function of $\alpha$ (Fig. 10(a)), and the effective filtration area as a function of $\alpha$ (Fig. 10(b)). Here, $\beta$ decreased with increasing $\alpha$, and with proceeding filtration cycle. However, it remained nearly constant, after the third filtration cycle. The $\beta$ values at the sixth filtration cycle of three filters (F, H, and I) which had the same $\alpha$ value, were approximately 0.45. As seen in Fig. 10(b), the effective filtration areas of whole pleated filters were higher than the total surface area of a cylindrical filter, and they increased with increasing $\alpha$. However, the effective filtration areas of filters F, H, and I ($\alpha = 2.21$) at the sixth filtration cycle, were similar to that of filter G ($\alpha = 2.50$). To predict the effective filtration area of a pleated filter cartridge, we need to determine the
relationship between $\beta$ and $\alpha$ values. Although $\beta$ depends on the filtration cycle and $\alpha$ value at the initial stage, it depends on the $\alpha$ value at a later stage. The $\beta$ value at a specific $\alpha$ value converged to a certain value at a later stage, which had stable dust filtration. The relationship between the $\beta$ values of the sixth filtration cycle and the $\alpha$ value can be expressed as $\beta = 0.838 - 0.358\ln(\alpha + 0.828)$.

Following our previous study [11], operating conditions were controlled by the assumed filtration area. The filter cleaning efficiency of the pleated filter F was measured and compared with that of a cylindrical filter bag. Fig. 11 shows the filter cleaning efficiency at each filtration cycle of filters A, F, F-1, and F-2. The cleaning efficiency of filter F-2, which had an assumed dead space of 50%, was similar to that of a cylindrical filter. Therefore, we could estimate that the effective filtration area of the filter F ($\alpha = 2.21$) was approximately 50% of the theoretical filtration area. This result is similar to the value calculated by Eq. (9) and the previous study of Kim et al. [11].

5. Conclusion

The filtration area and filter cleaning efficiency were found to be highly dependent upon filter pleating geometries. Dimensionless parameter, $\alpha$, which is the ratio of pleat height to pleat pitch, was introduced to determine the optimal pleat geometry. A higher $\alpha$ value provided a larger filtration area, which can decrease the installation space required for a bag house. However, there was an optimal pleat geometry at $\alpha = 2.21$, which led to no drastic decrease in filter cleaning efficiency. Therefore, it is recommended that the pleat height should be 2.21 times deeper than the pleat width for optimal folding of the filter medium.

Instead of increased filtration area of a pleated filter cartridge, filter pleating influenced the effective filtration area. The ratio of the effective filtration area to the theoretical filtration area, $\beta$, was investigated in this study. The $\beta$ value depended on the filtration cycle and the $\alpha$ value at the initial stage; however, it only depended on the $\alpha$ value at a later stage. The relationship between $\beta$ and $\alpha$ at the later stage can be expressed as $\beta = 0.838 - 0.358\ln(\alpha + 0.828)$. The calculated effective filtration area did not increase further at $\alpha$ values higher than 2.21, which supports the feasibility of the optimal pleat geometry.
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References


