Performance improvement of wave plate mist eliminator through geometry modification

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Abstract

In this study, the geometry of a popular wave plate type mist eliminator used in the wet flue gas desulfurization process was improved. Subsequently, the equipment was fabricated and experimentally evaluated. A mist eliminator is a type of inertial particle collector, whose collection efficiency is proportional to the velocity of the gas phase. However, as the amount of re-entrainment is also proportional to the gas phase velocity, the gas phase flow rate is limited. Re-entrainment is one of the most crucial issues in a mist eliminator and likely to occur as the input of the liquid phase and flow rate of the gas phase increase. To resolve this problem, the projection angle of the improved mist eliminator is modified by 30° compared to that of the conventional one while maintaining the cross-section. Under low flow rate conditions, the modified mist eliminator showed a similar pressure drop and overall collection efficiency compared to those of the conventional equipment. However, under conditions where re-entrainment was significant, the modified mist eliminator showed better performance in draining droplets than the conventional one. As a result, the modified mist eliminator attained higher overall collection efficiency.

\textbf{Keywords:} Collection efficiency, Droplet, Flue gas desulfurization, Mist eliminator.
1 INTRODUCTION

The mist eliminator, a kind of inertial particle collector, was developed to remove the droplets contained in gas flow. It exhibits low pressure drop and high collection efficiency as it has a very large contact area with flow compared to other dust collectors. Thus, the mist eliminator is mainly used in the manufacturing process of chemicals to improve product purity and in the exhaust gas post-treatment devices, such as desulfurization equipment in thermal power plants. Moreover, it is used to protect the equipment located behind the mist eliminator.

The mist eliminator types can be mainly divided into wire mesh and wave plate architectures. Factors that affect the droplet removal performance are as follows. First, for the wire mesh type mist eliminator, droplet removal performance is affected by the wire density, grid creation method, pad thickness, wire diameter, and internal air velocity (Brunazzi and Paglianti, 1998; Al-Dughaither et al., 2010). For the wave plate type mist eliminator, the distance between plates, geometry of the hooked vane, number of bends, and internal air velocity are the main factors (Gharib and Moraveji, 2012; Narimani and Shahhoseini, 2011; Galletti et al., 2008). For both types of mist eliminators, main performance factors mostly differ as they have different geometry; however, they share the internal air velocity factor as both are inertial particle collectors. It is known that there is an optimal internal air velocity range that leads to the highest collection performance for the mist eliminator. As the internal flow velocity increases, higher collection efficiency can be achieved because droplets are strongly guided toward the wall. However, the optimal flow velocity
range exists due to the re-entrainment inside the mist eliminator. Re-entrainment refers to the scattering of the droplets adsorbed to the surface of the mist eliminator into air. High flow velocity is likely to cause re-entrainment, resulting in a reduction in collection efficiency.

The re-entrainment problem is one of the main problems occurring in the mist eliminator; thus, numerous previous studies have been conducted on re-entrainment. Azzopardi and Sanaullah (2002) simulated conditions in which re-entrainment occurs inside a wave plate type mist eliminator. They experimentally revealed that there is a correlation between the water film thickness formed on the plate surface owing to the adsorption of droplets and critical speed at which re-entrainment occurs. They also found that re-entrainment mainly occurred in curved areas rather than flat surfaces inside the wave plate type mist eliminator. Mao et al. (2018) mathematically modeled the occurrence of re-entrainment due to the water film formed on the wave plate type mist eliminator surface. They revealed that at the highest critical speed, re-entrainment was less likely to occur when the bend of the mist eliminator formed an angle of 26.6° with the vertical plane. James et al. (2003) proposed a geometry in which drainage channels were additionally installed at each corner of the wave plate type mist eliminator based on the concentrated formation of water films at the corners. The model with the drainage channels effectively inhibited re-entrainment and exhibited higher droplet removal performance than the model without. Kim M. W. et al. (2021) proposed a geometry in which a slit plate forming an angle of 90° was attached to the front of the drainage channel. The
slit plate was effective in altering the airflow direction and improved the collection efficiency of large droplets owing to inertia. Therefore, the geometry improved the performance of the mist eliminator by increasing collection efficiency by more than 10% compared to the reference model and forming a 5 to 10% lower pressure drop for 2 μm-droplets. Fabian et al. (1993) compared the performance of 200 μm- and 10 μm-wire mesh type mist eliminators at the same packing density. In their experimental results, the 10 μm-model exhibited high removal performance at low speed but exhibited the re-entrainment problem even at a lower speed than the 200 μm-model. Therefore, the 200 μm-model exhibited high removal performance when the flow velocity was higher than a certain level, revealing that there was a correlation between the wire diameter and critical speed. Kouhikamali et al. (2014) modeled a wire mesh type mist eliminator that exhibited a certain pattern using a commercial computational fluid dynamics software and implemented re-entrainment through multi-phase simulation considering air and water. The simulation results showed that efficiency was improved as the wire density increased and wire diameter decreased; moreover, the highest collection efficiency could be achieved when the flow velocity was approximately 8 m s⁻¹ because re-entrainment clearly occurred at a speed of 10 m s⁻¹ or higher.

This study aimed to improve the performance of the mist eliminator used in wet desulfurization equipment through geometrical modification. Accordingly, the wave plate type mist eliminator was targeted. In addition, because the flow in the absorption tower of actual desulfurization equipment
was directed upward, the mist eliminator was arranged accordingly. Fig. 1 shows the geometry of
the two types of mist eliminators used in this study. Fig. 1(a) shows the commonly used wave plate
type mist eliminator, which was named Model A. Fig. 1(b) shows the wave plate type mist
eliminator improved in this study, which was named Model B. Observe from Model A that the
wave plate was arranged perpendicularly to the flow direction in the conventional geometry. This
makes it difficult to drain the droplets adsorbed to the mist eliminator surface. Accordingly, water
films were easily generated on the surface and re-entrainment of droplets occurred at relatively low
speeds. In this study, the wave plate was designed to form an angle of 30° with the ground to
improve drainage efficiency compared to that of the conventional geometry; accordingly, the
performance change was observed.

2 EXPERIMENTAL METHOD

Fig. 2 shows the geometric parameters of the proposed mist eliminator. The mist eliminator with
the conventional wave plate geometry and improved mist eliminator share the same cross section;
thus, the geometry of the commonly used mist eliminator was referred to for the cross section. The
gap between plates, W, was set to 20 mm while the length of the bent section of the mist eliminator,
L, was set to 110 mm. The angle of the mist eliminator passageway, θ, was 100°. The hooked vane
is a hook-shaped vane at the end of the plate, the length of which, l, was designed to be 5 mm. In
this instance, the height of the mist eliminator, H, was set to 80 mm while the angle between the
bend of the mist eliminator and horizontal plane, $\alpha$, was set to 30°. The value of $\alpha$ is 0° for Model A, which corresponds to the only difference between Models A and B.

An experiment was conducted to compare the performance of Model A with that of Model B. A method of measuring the collection efficiency according to the diameter can be used to evaluate the droplet removal performance of a mist eliminator. However, accurate measurement of the collection efficiency according to the diameter is significantly challenging compared to solid particles owing to the fact that the size of droplets may reach several millimeters, which can be merged or split due to interactions inside the mist eliminator, and droplets collected on the mist eliminator surface can be resuspended. Owing to these characteristics, when the performance of a mist eliminator is evaluated, solid particles that can maintain a certain shape are used instead of droplets. Alternatively, a method of comparing the mass of the input droplets with that of the collected droplets can be used (El-Dessouky et al., 1999; Atia and Lee, 2003). This method was also used in this study to obtain overall collection efficiency to compare the performance of each model. The formula used is as expressed follows.

$$\eta = \frac{M_{\text{trap}}}{M_{\text{in}}} \times 100(\%)$$  \hfill (1)

where $M_{\text{in}}$ and $M_{\text{trap}}$ are the mass of the water injected into the mist eliminator and mass of the water collected from it, respectively.
Fig. 3 shows the photograph and schematic diagram of the experimental setup. The mist eliminator was vertically installed as shown in the figure to simulate the desulfurization equipment used in thermal power plants. The air required for the experiment was supplied through the blower fan, which passed through a HEPA filter to remove external particles before entering the mist eliminator. The blower fan could adjust the discharged flow rate through a speed controller, and the flow velocity value measured at the top of the mist eliminator was adjusted between 2 and 8 m s\(^{-1}\). Droplets were injected through an ejector, which was fabricated by our research team. Compressed air and water were supplied to the ejector. Compressed air maintained a pressure condition of 5,000 Pa, and a needle valve was installed in the pipe connected to the water tank to control the water flow rate by adjusting the valve opening. The water flow rate was adjusted between 0.2 and 0.8 L min\(^{-1}\). Before the experiment, the discharge amount was examined using a water container with scale marks. The droplets injected from the ejector were introduced into the lower part of the mist eliminator via a tube. Rectangular geometry was applied to the end of the tube so that droplets could be uniformly introduced into the cross section of the mist eliminator. The droplets injected in this manner could not pass through the mist eliminator, and a significant portion of which fell and were collected in a container located at the bottom of the mist eliminator. After the experiment, the overall collection efficiency was calculated by comparing the mass of the collected water with that of the injected water using a scale. The experiment was performed for
nine cases based on the water flow rate and air velocity; subsequently, the efficiency was calculated based on the results obtained after repeating the experiment three times over three minutes for each case.

3 NUMERICAL ANALYSIS METHOD

Numerical analysis was conducted to simulate the internal flow distribution, cut-off size, and pressure drop of Models A and B. While the mist eliminator used in actual wet desulfurization equipment had more than dozens of channels, only one channel was selected and analyzed in this study. Because each channel was separated by a wall, one channel had sufficient representativeness. In previous studies, analysis was mainly conducted by assuming two-dimensional flow. In this study, however, three-dimensional analysis was conducted for both Models A and B owing to the presence of the angle between the bend of the mist eliminator and ground. ANSYS FLUENT Release 16.1, a commercial software program, was used for the analysis, and flow analysis was conducted using the standard k-ε model, which is known to be suitable for analyzing the mist eliminator (Galletti et al., 2008; Gharib and Moraveji, 2012; James et al., 2005; Zhao et al., 2007).

The governing equations used for the flow and particle behavior analyses of the mist eliminator are explained in equations (2) to (6).

- Mass conservation equation:
\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \vec{u}) = 0 \quad (2)

- Momentum conservation equation:

\frac{\partial (\rho \vec{u})}{\partial t} + \nabla \cdot (\rho \vec{u} \vec{u}) = -\nabla p + \nabla \cdot (\mu \nabla \vec{u}) \quad (3)

- Transport equation for turbulent kinetic energy \( k \):

\frac{\partial (\rho k)}{\partial t} + \nabla \cdot (\rho \vec{u} k) = \Delta \left[ \left( \mu + \frac{\mu_k}{\sigma_k} \right) \nabla k \right] + G_k + G_b - \rho \varepsilon - Y_m \quad (4)

- Transport equation for turbulent dissipation rate \( \varepsilon \):

\frac{\partial (\rho \varepsilon)}{\partial t} + \nabla \cdot (\rho \vec{u} \varepsilon) = \nabla \left[ \left( \mu + \frac{\mu_\varepsilon}{\sigma_\varepsilon} \right) \nabla \varepsilon \right] + C_{1\varepsilon} \frac{\varepsilon}{k} (G_k + G_3 \varepsilon G_B) - C_{2\varepsilon} \rho \frac{\varepsilon^2}{k} \quad (5)

- Equation of motion of Discrete Phase Model (DPM) particles:

\frac{d(m_p \vec{v}_p)}{dt} + \vec{F}_{\text{drag}} + \vec{F}_{\text{pressure}} + \vec{F}_{\text{virtual mass}} + \vec{F}_{\text{gravitation}} + \vec{F}_{\text{other}} \quad (6)

where, \( \vec{F}_{\text{other}} \) constitutes the equivalent force due to the rotational force, thermophoretic force, Brownian force, Saffman’s lift force, and virtual mass force.

Fig. 4 shows the geometry used for analysis. The velocity inlet condition was provided to the regular air and compressed air inlets where air was introduced, and the 5,000 Pa pressure condition was additionally set for the compressed air inlet. The velocity inlet condition was also implemented at the water inlet, where only the introduced fluid type was changed. The pressure outlet condition was provided to the outlet so that both air and water could escape, and the no-slip condition was
applied to all walls. Steady-state and non-steady state analyses were conducted separately. The steady-state analysis was conducted to measure the pressure drop and flow velocity distribution of the mist eliminator and measure the cut-off diameter using DPM. Only the air was analyzed, excluding the ejector. In the non-steady state analysis, the ejector was simulated, and the droplet removal performance was evaluated by injecting droplets and measuring the amount of water collected in the lower water tank. The grid dependency test of the analysis was conducted using one, two, and four million grid cells for the mist eliminator part. Because the analysis results demonstrated no significant difference in pressure drop and maximum flow velocity depending on each grid level, one million grid cells that were most efficient in terms of analysis time were used.

In this instance, the \( Y^+ \) value was set to 30, which is commonly recommended in the standard k-\( \varepsilon \) model. Accordingly, the grid spacing near the wall was set to 1 mm or less. In the steady-state analysis, particle analysis was conducted using DPM after flow analysis, and spherical non-reactive particles with a density of 1,000 kg m\(^{-3}\) were assumed. In the particle analysis, gravity, Stokes drag force, and Brownian motion were considered and evenly introduced over the cross section of the mist eliminator.

When particles collided with walls, they were assumed to be trapped and the computation was terminated. The cut-off diameter according to the flow velocity could be calculated by comparing the number of input particles with that of the collected particles. In the non-steady state analysis,
multi-phase fluid analysis was conducted, and Eulerian multi-phase models were utilized. The time step size was set to 0.01 second, and performance was evaluated by comparing the volume of the injected water with that of the water collected in the lower water tank.

**4 EXPERIMENT AND NUMERICAL ANALYSIS RESULTS**

In this section, the performances of Model A and that of Model B were compared. Fig. 5 compares the velocity distribution in the center section between Models A and B at a flow velocity of 4 m s\(^{-1}\). Because the cross sections of Models A and B were completely identical, the internal flow velocity was also found to be almost identical. Both the cross-sectional velocity distributions of the two models showed that the flow velocity significantly changed before and after the hooked vane. The hooked vane accelerates and guides the flow inside the mist eliminator to the wall on the opposite side. Therefore, the hooked vane removes droplets by sharply changing the flow direction and thereby increasing the inertial effect of the droplets. It is the main area where droplets are collected inside the mist eliminator and area where re-entrainment easily occurs due to the thick water film formed by the collected droplets simultaneously.

As the flow velocity distribution over the cross section was similar, the pressure drop inside the mist eliminator was similar for Models A and B. Fig. 6 shows the static pressure distribution inside the mist eliminator for Models A and B under the flow velocity conditions depicted in Fig. 5. As the flow velocity significantly changed before and after implementing the hooked vane depicted in
Fig. 5, the static pressure inside the mist eliminator tended to significantly decrease after implementing the hooked vane, resulting in the same tendency for both Models A and B. Fig. 7 compares the experimental and simulation values for the pressure drop across the mist eliminators with respect to the air velocity. The pressure was measured between sections where the bends of the mist eliminator were located for both the experimental and simulation applications. Because Models A and B shared the same cross section, there was no significant difference in pressure drop between the two models, similar to the previous results. In the experiment, the pressure drop was 108 Pa for Model A and 103 Pa for Model B at an internal flow velocity of 2 m s$^{-1}$. At 4 m s$^{-1}$, it was 276 Pa for Model A and 243 Pa for Model B. At 8 m s$^{-1}$, it was 882 Pa for Model A and 855 Pa for Model B. The pressure drop predicted in the numerical analysis yielded approximately the same results as that of the experiment. Closer results were observed when the flow velocity was high compared to when it was low.

Table 1 lists the cut-off diameters of Models A and B according to the flow velocity obtained through DPM of steady-state numerical analysis. The cut-off diameter was measured by calculating the collection efficiency based on particle size after injecting 400 to 500 particles in the cross section of the mist eliminator. At 2 m s$^{-1}$, the cut-off diameter was determined as 9.4 μm for Model A and 9.6 μm for Model B.
At 4 m s⁻¹, the cut-off diameters were 6.4 and 6.5 μm for Model A and Model B, respectively.

At 8 m s⁻¹, the cut-off diameters were 4.1 and 4.2 μm for Model A and Model B, respectively, indicating almost identical performance. In the steady-state numerical analysis, re-entrainment that occurs inside the mist eliminator was not considered. Accordingly, the cut-off diameter tended to decrease as the flow velocity increased. The tendency of collection efficiency with respect to the particle diameter can be confirmed through Fig. 8, which shows the particle trajectory of the mist eliminator Model B with respect to the diameter at an air velocity of 4 m s⁻¹. Fig. 8(b) shows the results obtained with 6.5 μm, which is the cut-off diameter. Fig. 8(a) and 8(c) show the results of 3 and 10 μm-particles, which represent cases that are smaller and larger than the cut-off diameter. As shown in Fig. 8(a), particles smaller than the cut-off diameter followed the streamline inside the mist eliminator without leaving it and mostly escaped to the top, resulting in low collection efficiency. As the particle size increased as shown in Fig. 8(b) and 8(c), the effect of inertia increased and tendency to not follow the streamline increased. Therefore, most particles were collected near the hooked vane where the streamline sharply changes. Fig. 9 summarizes the particle collection positions for each particle size at a flow velocity of 4 m s⁻¹ for Models A and B. Bends 1, 2, and 3 depicted in Fig. 9 represent the bends of the mist eliminator presented in Fig. 2. Bends 1, 2, and 3 have lengths of 35, 40, and 35 mm, respectively. During the analysis, they were assigned as different walls to indicate collection
positions. Under the 3 μm-condition, which is much smaller than the cut-off diameter, the amount
of particles collected tended to increase near Bend 3. At Bend 3, the amounts collected
represented 43.6 and 36.1 % of the total amount for Models A and B, respectively. Under the 6.5
μm-condition, which is identical to the cut-off diameter, the largest amount collected was
observed at Bend 2, the middle point. The amounts collected represented 50.8 and 40.4 % of the
total amount for Models A and B, respectively. Finally, under the 10 μm-condition, which is
much larger than the cut-off diameter, most of the particles were collected as soon as they entered
the mist eliminator owing to their high inertia. Accordingly, the largest amount collected was
observed at Bend 1. For 10 μm-particles, the amounts collected at Bend 1 represented 85.0 and
72.9 % of the total amount for Models A and B, respectively. This result indicated that large
particles were collected at the front bend while small particles were collected at the rear bend. In
this instance, the bias of the amount collected at each bend was less for Model B compared to that
of Model A for all particle sizes, indicating that particles were collected relatively evenly across
Bends 1, 2, and 3.

Re-entrainment was more likely to occur as the thickness of the water film formed on the mist
eliminator surface increased. Therefore, we assessed that Model B, which showed relatively
uniform collection, was favorable for inhibiting re-entrainment.
Fig. 10 demonstrates the overall collection efficiency results calculated through the experiment. The results were distinguished according to the air velocity inside the mist eliminator and water flow rate. First, Fig. 10(a) shows the overall collection efficiency according to the water flow rate when the air velocity inside the mist eliminator was 2 m s⁻¹.

Models A and B attained almost identical performance as the collection efficiency difference was less than 2.3 %. As the water flow rate increased, the collection efficiency showed a tendency to slightly decrease. This is because the thickness of the water film formed by the adsorption of droplets to the mist eliminator surface significantly increased, which facilitated re-entrainment even under low air velocity conditions. Fig. 10(b) shows the results obtained when the air velocity inside the mist eliminator was 4 m s⁻¹.

As opposed to the results depicted in Fig. 10(a), there was a significant difference between Models A and B. When the water flow rate increased from 0.2 to 0.8 L min⁻¹, the overall collection efficiency decreased by approximately 4.2 % for Model B and 13.6 % for Model A, indicating a significant performance difference. Fig. 10(c) shows the results obtained when the air velocity inside the mist eliminator was 8 m s⁻¹. Overall, a tendency similar to that of Fig. 10(b) was observed. As the water flow rate increased from 0.2 to 0.8 L min⁻¹, the overall collection efficiency decreased by approximately 12.7 % for Model B and 21.9 % for Model A, indicating that Model B showed higher overall collection efficiency when conditions that facilitate re-
entrainment were applied. The results regarding the water flow rate depicted in Fig. 10 can be
summarized according to the air velocity inside the mist eliminator, as reported in Table 2.

When the water flow rate was 0.2 L min\(^{-1}\), the flow velocity inside the mist eliminator varied
from 2 to 8 m s\(^{-1}\). Accordingly, the overall collection efficiency increased for both Models A and
B, indicating a tendency that generally occurs in inertial particle collectors where collection
efficiency is proportional to the flow velocity. When the water flow rate was 0.4 L min\(^{-1}\), a
tendency different from that observed with 0.2 L min\(^{-1}\) was observed. For both Models A and B,
the overall collection efficiency was proportional to air velocity when the flow velocity varied
from 2 to 4 m s\(^{-1}\). When the air velocity was 8 m s\(^{-1}\), however, slightly lower overall collection
efficiency was observed compared to that observed with 4 m s\(^{-1}\). When the water flow rate was
0.8 L min\(^{-1}\), Model B showed a similar tendency and exhibited the highest overall collection
efficiency at an internal flow velocity of 4 m s\(^{-1}\). However, Model A showed almost constant
overall collection efficiency when the internal flow velocity varied from 2 to 4 m s\(^{-1}\). At 8 m s\(^{-1}\), it
rather exhibited reduced overall collection efficiency.

In the results obtained with DPM thorough the abovementioned steady-state analysis, it was
predicted that Models A and B would exhibit almost identical performance. In the above
experiment that utilized actual droplets, however, the overall collection efficiency varied
depending on the water flow rate and flow velocity. This difference was caused by re-
entrainment, which could not be implemented in DPM of the steady-state analysis. Accordingly, non-steady state analysis was conducted. In the analysis, air and water were simultaneously utilized, including the ejector, unlike the steady-state analysis that utilized only air. The analysis conditions were set to a flow velocity of 8 m s\(^{-1}\) and water flow rate of 0.8 L min\(^{-1}\), which were expected to cause a large difference between the results obtained with Models A and B. The time step size in the non-steady state analysis was 0.01 s, and 360,000 iterations were required for each case to meet the same 180 second condition as in the experiment by conducting 20 analyses per time step. Fig. 11 shows the water volume fraction contour of Models A and B. The volume measurement results showed that 1.21 L out of 2.4 L was collected in the lower water tank for Model A and 1.46 L for Model B when the water flow rate was 0.8 L min\(^{-1}\) and flow velocity was 8 m s\(^{-1}\). Therefore, the overall collection efficiency was 50.4 % for Model A and 60.8 % for Model B. Through Fig. 11, observe that the water volume fraction of Model B was higher than that of Model A below the bend of the mist eliminator. In particular, we found that intensive drainage occurred at the bottom of the 30° slope implemented in Model B. According to experimental results obtained under the same conditions, the overall collection efficiency was 75.6% for Model A and 85.3 % for Model B, indicating that the efficiency calculated through the non-steady state multi-phase fluid analysis was closer to the experimental value than the efficiency calculated through DPM of the steady-state analysis.
Re-entrainment occurs more easily as the thickness of the water film formed on the mist eliminator surface and internal air velocity increase. Therefore, it is necessary to reduce the thickness of the water film to inhibit re-entrainment under the same internal air velocity condition. In Model B, the bias of the amount collected at each bend was found to be less compared to Model A.

Therefore, the amount of droplets collected could be distributed relatively uniformly for each bend, and the thickness of the water film could remain thinner compared to that observed in Model A. In addition, the drainage performance of Model B was higher than that of Model A owing to implementing the 30° slope with respect to the ground. Thus, the growth of the water film formed on the mist eliminator surface could be effectively inhibited. Model A adopts horizontal geometry like conventional mist eliminators, and thus bends are formed in a direction perpendicular to the airflow ascending from the bottom. This makes it difficult to efficiently discharge the droplets adsorbed to the surface. Consequently, when the amount adsorption exceeds a certain level, very large droplets may fall in the air or re-entrainment toward the top of the mist eliminator, due to which the internal airflow may occur. In this process, droplets can be divided into smaller ones through their interactions with each other, which acts as the main cause of deteriorating the collection efficiency of conventional mist eliminators. Conversely, in the case of Model B, water can be guided to the walls on both sides through the 30° slope before the
growth of the water film formed by the droplets adsorbed to the mist eliminator surface. Therefore, the thickness of the water film could be maintained under the critical point even at higher water flow rates. In addition, the collected droplets were guided to the walls on both sides rather than allowing them to fall in the air and collide with newly ascending droplets as in Model A, thereby effectively inhibiting the re-entrainment caused by discharged droplets. Owing to these characteristics, Model B could exhibit higher overall collection efficiency than Model A under conditions that lead to active re-entrainment.

5 CONCLUSIONS

In this study, the collection efficiency of Model A, which has the conventional mist eliminator geometry, and Model B, which has an angle of 30° with the ground while sharing the same cross section as Model A, was evaluated. The pressure drop across the mist eliminator and cut-off diameter predicted through steady-state analysis were found to be almost identical for both models. However, Model B exhibited up to 11.9 % higher performance in the experiment than Model A under the same water flow rate and air velocity conditions. This is because re-entrainment was considered in the experiment and less re-entrainment occurred in Model B compared to Model A owing to their geometrical differences. Therefore, non-steady state simulation was performed under conditions that may lead to active re-entrainment. In the analysis results, the overall collection efficiency of Models A and B was found to be 50.4 and 60.8 %, respectively. For less re-
entrainment under the same internal flow velocity condition, it is necessary to decrease the thickness of the water film formed on the mist eliminator surface. In this respect, Model B performed better than Model A. Through the steady-state simulation, we predicted that the amount collected at each bend would be uniform and water film would be formed relatively evenly for Model B compared to Model A. In addition, through the experiment and non-steady state analysis, we determined that Model B could discharge the droplets collected on the mist eliminator surface more easily than Model A. If these research results are applied to actual mist eliminators for wet flue gas desulfurization equipment, it will be possible to apply higher internal flow velocity and water flow rates owing to the improvements in the droplet discharge structure. Accordingly, it is expected that the treatment amount and overall collection efficiency will be increased simultaneously.

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REFERENCES


Table 1. Numerically attained cut-off diameter of the mist eliminators.

<table>
<thead>
<tr>
<th>Cut-off Diameter (μm)</th>
<th>2 m s⁻¹</th>
<th>4 m s⁻¹</th>
<th>8 m s⁻¹</th>
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<tbody>
<tr>
<td>Model A</td>
<td>9.4</td>
<td>6.4</td>
<td>4.1</td>
</tr>
<tr>
<td>Model B</td>
<td>9.6</td>
<td>6.5</td>
<td>4.2</td>
</tr>
</tbody>
</table>
Table 2. Numerically attained cut-off diameter of the mist eliminators.

<table>
<thead>
<tr>
<th>Water Flow Rate (m s(^{-1}))</th>
<th>Air Velocity (m s(^{-1}))</th>
<th>Model A Collection Efficiency (%)</th>
<th>Model B Collection Efficiency (%)</th>
</tr>
</thead>
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<tr>
<td>0.2</td>
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<td>84.8</td>
<td>84.3</td>
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<tr>
<td></td>
<td>4</td>
<td>92.1</td>
<td>94.6</td>
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<td>8</td>
<td>97.5</td>
<td>98.0</td>
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Fig. 1. Schematics of the mist eliminators: (a) Model A and (b) Model B.
Fig. 2. Geometric parameters of the proposed mist eliminator.
Fig. 3. (a) Photo and (b) schematic of the experimental setup of the mist eliminator.
Fig. 4. Schematic of the computational fluid dynamics domain.
Fig. 5. Velocity magnitude contour of the mist eliminators.
Fig. 6. Static pressure contours of the mist eliminators.
Fig. 7. Pressure drop across the mist eliminators with respect to air velocity.
Fig. 8. Particle trajectory of the mist eliminator Model B.
Fig. 9. Percentage of trapped particles at each bend of mist eliminators.
Fig. 10. Overall water collection efficiency according to water flowrate at air velocities of (a) 2, (b) 4, and (c) 8 m s\(^{-1}\).
Fig. 11. Water volume fraction contours of the mist eliminators.