Notice of Retraction

After careful and considered review of the content of this paper by a duly constituted expert committee, this paper has been found to be in violation of IEEE’s Publication Principles.

We hereby retract the content of this paper. Reasonable effort should be made to remove all past references to this paper.

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Experimental Study on the Performance of Flow & Desulphurization in a Spray Scrubber for Wet Flue Gas Desulfurization

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Abstract—The desulfurization performance of a spray scrubber was experimental study by using two kinds of limestone with different fineness as absorbent. The experimental results show that at a fixed flue gas velocity, increasing the slurry flux give rise of flow resistance and desulphurisation efficiency. And at a high flue gas velocity the rise of the flow resistance and desulfurisation efficiency become more greatly with the liquid-gas ratio increase. The desulfurization efficiency increases with the slurry pH value increases, while it decreases with flue gas SO\(_2\) concentration at entrance increase. Contrast with the two different limestones with different particle size, the one with small size has a better dissolved performance, which induce a higher desulfurization efficiency of the system.

Keywords- spray scrubber; desulphurization performance; flow characteristics; wet flue gas desulfurization (WFGD)

I. INTRODUCTION

Sulfur dioxide has become one of the main pollutants to the environment and human being. The sources of SO\(_2\) mainly come from human being by coal-firing in industry and electric power station [1,2]. The total SO\(_2\) emission amounts in China were 23.46 million tons in 1997, which was the first place in the world. From 2000 to 2007, the SO\(_2\) emission amount of China has kept a high level, about 20 million tons annually. The SO\(_2\) pollution is recognized as an important factor to hinder the sustainable development of the Chinese economy [3,4]. Flue gas desulfurisation (FGD) is useful to decrease the amount of SO\(_2\) emitted from fired-plants. A number of different types of wet scrubbers have been developed in the past 20 years. Date on worldwide applications reflect that wet FGD technologies have been used at most of the installations, 522 out of 668, completed through 1998[5]. Common examples include spray scrubbers, packed towers, jet bubbling reactors, and double-loop towers. The most commonly used and best-studied wet scrubber is the countercurrent spray scrubber employing liquid distribution at different levels in the absorber [6,7]. In China, the technology of wet flue gas desulfurization for controlling the SO\(_2\) emission produced by pulverized-coal-fired electric power plant is basically introduced from abroad, which induces much higher capital cost and operation cost, and too expensive to be accepted by our end consumers. Investigating and exploiting the novel technologies based traditionally ones and master the key of the technology is an important way to control and solve the SO\(_2\) pollution in China [8].

Many effective factors can affect the desulfurisation efficiency, and a main factor is the velocity of the flue gas. The mass transfer ratio will increase at a high flue gas velocity. In tradition spray scrubber, the flue gas velocity is about 2-3 m/s. In our experiments, the velocity of flue gas reaches 4.63m/s. The objective of the paper is to find the performance of the liquid-gas two-phase hydrokinetics and the desulfurisation performance of the spray scrubber high flue gas velocities. The work may give some help for the further research on the mass transfer of the tower and is useful of the design and optimum operation of this absorber type.

II. EXPERIMENTAL

The experimental setup is shown in Figure 1. The experimental system includes five parts, such as the tower, the flue gas simulation system, the flue gas cooling system, slurry circulation system and testing facility. The main components of the experimental setup are the absorber, the holding tank and the oil burner. The height of the tower is about 8.9m, which section is square. The nozzles are set at the height of 4m, 5.5m, 7m, 7.5m above the tank level respectively. The number of the nozzles is 4 in the counter current flow tower. The nozzle is pressure type nozzle, and the type is HHSJ-90210 made in American Sprayer Corp. The area of the square section of the countercurrent tower is 0.49 × 0.49m\(^2\). Static pressures are typically measured along the inlet and outlet planes in the wet scrubber using wall taps equally spaced around the vessel. Average flue gas velocities at each plane can be established from a measurement of the total mass flow through the scrubber by a micromanometer and knowledge of the cross-sectional area and the gas density. Slurry flux is measured by the turbine flowmeter. The liquid flow direction in the tower is defined the droplets fall to the bottom of the tower, and in counter-current tower flue gas has the opposite flow direction with the slurry droplets flow.
direction. In the experiments, the flue gas flow through the water with countercurrent type. The measure points of the flue gas were set at the inlet and outlet of the tower, and the components of the flue gas were got from two gas analyzers respectively. The types of the two gas analyzers are MRU95/3CD and KM9106.

![Figure 1 Schematic illustration of the wet FGD pilot plant](image)

The desulfurization performance of the spray scrubber is experimental studied by using two kinds of limestone with different fineness as absorbent. The particles SMD of two kinds of limestone are 21.37 μm and 6.55 μm. The ingredients of two limestone and particle average diameter are shown in Table 1.

<table>
<thead>
<tr>
<th>The Place of Origin</th>
<th>CaO (%)</th>
<th>MgO (%)</th>
<th>Al₂O₃ (%)</th>
<th>Fe₂O₃ (%)</th>
<th>Insoluble Residua (%)</th>
<th>Particle Average Diameter (μm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guilin</td>
<td>52.76</td>
<td>3.52</td>
<td>8.064</td>
<td>33.44</td>
<td>2.19</td>
<td>6.55</td>
</tr>
<tr>
<td>Chongqing</td>
<td>45.53</td>
<td>20.7</td>
<td>16.03</td>
<td>12.32</td>
<td>5.38</td>
<td>21.37</td>
</tr>
</tbody>
</table>

From the present experiments, the simulant flue gas flux ranged from 2000 to 4000 Nm³/h and the circulating slurry flux ranged from 30 to 50 m³/h. The circulating slurry tank pH is between 5.4 and 6.0, and SO₂ concentration of flue gas at the wet scrubber inlet is between 5140 and 8570 mg/m³. All the experimental conditions are showed in Table 2.

<table>
<thead>
<tr>
<th>Circulatory slurry flux (m³/h)</th>
<th>Flue gas flux (m³/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>2500</td>
</tr>
<tr>
<td>30</td>
<td>PGK1</td>
</tr>
<tr>
<td>35</td>
<td>PGK2</td>
</tr>
<tr>
<td>40</td>
<td>PGK3</td>
</tr>
<tr>
<td>45</td>
<td>PGK4</td>
</tr>
<tr>
<td>50</td>
<td>PGK5</td>
</tr>
</tbody>
</table>

III. RESULTS AND DISCUSSION

A. Flow resistance of the wet scrubber and analyses

In the tower, the flue gas flow resistance is mainly produced by two parts friction. One is the friction of flue gas with tower wall and the other one is the friction of flue gas with disperse phase of the liquid mass and droplets. Comparing with the two parts friction, the experiment data show flow resistance produced by the disperse phase of the liquid mass and droplets is much more than those produced by the tower wall. Then the latter one can be neglected. In the paper, the friction between the disperse phase of liquid mass and droplets and the flue gas mainly brings the flow resistance of the tower.

The flow resistance of the tower is one of the main parameters about the flow performances of absorber. In practice, L/G ratio is usually as a key designing parameter. In the paper, effects of flue gas velocity and L/G ratio on the flow resistance of the counter current tower are studied. The influence of the L/G ratio on the flow resistance of the tower is presented in Figure 2.

![Figure 2 Influence of the L/G ratio on the flow resistance of the tower](image)

In the paper, the effects of flue gas velocity, slurry flux density, L/G ratio, pH value of slurry tank and limestone particle average diameter on the desulfurization efficiency of the pilot scrubber are studied. Figure 3 shows the influence of the L/G ratio and pH value of slurry on the desulfurization efficiency of the pilot scrubber.

B. SO₂ absorption from flue gas and analyses

In the paper, the effects of flue gas velocity, slurry flux density, L/G ratio, pH value of slurry tank and limestone particle average diameter on the desulfurization efficiency of the pilot scrubber are studied. Figure 3 shows the influence of the L/G ratio and pH value of slurry on the desulfurization efficiency of the pilot scrubber.
desulfurization efficiency are showed in Figure 4 and Figure 5.

Influence of the flue gas velocities on the desulfurization efficiency is shown in Figure 3. With the increase of flue gas velocity the desulfurization efficiency will increase. But the increasing trend is slow down especially in high slurry amount. When at the slurry amount is 45m³/h, the flue gas velocity change from 2.31m/s increase to 4.63m/s, and the L/G is from 18 L/m³ drop to 11.25L/m³, the desulfurization efficiency is dropped from 92.3% to 89.7%. The drop extent is only 2.82% which less than the increasing extent of flue gas. From this condition, as the amount of flue gas increases, the per unit volume slurry absorb SO₂ will increase. So the mass transfer of the SO₂ absorb in per unit slurry increase with the flue gas flow rate increased. The main reason is because with the rise of flue gas velocity the drag force of droplet increased, the decline velocity decrease and the residence time in the tower get longer and the slurry amount increase can make the interfacial area increased. Besides this, with the increase of flue gas velocity, the increased flue gas velocity can enhance the turbulence of the gas and liquid flow, the collision between the gas and the flue gas may be fiercer than before and bring much smaller droplets which can enlarge the interfacial area between gas and liquid. At the same time the thickness of static liquid film between gas and liquid which determine the resistant of mass transfer will be decreased [9]. The decrease of the resistance of mass transfer can increase the whole mass transfer coefficient.

When at the flue gas is 2.31m/s and L/G ratio is 20, the desulfurization efficiency is 89.5%. While at the flue gas is 4.63m/s and L/G ratio is 12.86, the desulfurization efficiency is 89.5%. Comparing with the two conditions above, the L/G increasing trend is slow down especially in high slurry amount. The most optimization condition can be got by combining all the factors, such as flow rate increased. The main reason is because with the rise of flue gas velocity the drag force of droplet increased, the decline velocity decrease and the residence time in the tower get longer and the slurry amount increase can make the interfacial area increased. Besides this, with the increase of flue gas velocity, the increased flue gas velocity can enhance the turbulence of the gas and liquid flow, the collision between the gas and the flue gas may be fiercer than before and bring much smaller droplets which can enlarge the interfacial area between gas and liquid. At the same time the thickness of static liquid film between gas and liquid which determine the resistant of mass transfer will be decreased [9]. The decrease of the resistance of mass transfer can increase the whole mass transfer coefficient.

In Figure 3 Influence of the flue gas velocities on the desulfurization efficiency

Figure 4 shows the influence of the slurry flux density on the desulfurisation efficiency. The desulphurisation efficiency increases with an increase of slurry flux density at the same flue gas velocity. The slurry flux density influences the interfacial area and the mass transfer coefficient. So the desulfurization efficiency has increased.

Combined the effects of the flue gas velocity and the slurry flux, the influence of the L/G ratio on the desulphurisation efficiency can be got and shows in Figure 5.

From Figure 5, the desulfurization efficiency increased with an increase of the L/G ratio at the same flue gas velocity. At a high flue gas velocity, the increasing trend of them became more remarkable. To deal with the same flue gas amount, increasing L/G, namely increase the slurry flux, which can enhance the mass transfer area and the whole mass transfer enhancement factor and get high desulfurization efficiency.

As we all known that L/G ratio is one of key parameters in design and operation of a scrubber. Although a high L/G ratio can get high desulfurization efficiency, the high slurry flux can make slurry bump at a high cost which is negative to the whole economic of the power plant. From Figure 5, at a high flue gas velocity the L/G is smaller than a low one. So increasing the flue gas velocity can decrease the L/G ratio. When at the flue gas is 2.31m/s and L/G ratio is 20, the desulfurization efficiency is 89.5%. While at the flue gas is 4.63m/s and L/G ratio is 12.86, the desulfurization efficiency is 89.5%. Comparing with the two conditions above, the L/G ratio decrease 35.7% when they at the same desulfurization efficiency. On the other hand, the flow resistance will increase at a high flue gas velocity. The most optimization condition can be got by combining all the factors, such as flow resistance and desulfurization efficiency of the scrubber.

Figure 6 shows the influence of the pH value of the slurry on the desulphurisation efficiency. With the increase of pH value of slurry desulfurization efficiency increased. The effect is more obvious when the pH value is lower than 5.6. When the slurry pH value has a high value, which will induce a low efficiency of limestone and the desulfurization and operation.
cost will increased. So the suitable pH value is in the range of 5.6~5.8 in considered of all factors.

![Figure 6 Influence of the pH value of the slurry on the desulfurisation efficiency](image)

**Figure 6** Influence of the pH value of the slurry on the desulfurisation efficiency

When using Guilin limestone the desulfurization efficiency is higher than those of Chongqing. This reflects that the small limestone particle has a better dissolve characteristic, which can decrease the liquid side mass transfer resistant and increase the whole mass transfer coefficient between the liquid and solid[10,11]. These make a high limestone utility rate and get high desulfurization efficiency.

IV. CONCLUSION

1) Both the flow resistance and desulfurization efficiency increased with an increase of L/G at a fixed flue gas velocity. At a high flue gas velocity, the increasing trend of them became more remarkable. The flue gas velocity has more influence on the flow resistance than the slurry flux density did.

2) With the increase of flue gas velocity the desulfurization efficiency will increase. But the increasing trend is slow down especially in high slurry amount.

3) The desulfurization efficiency of the pilot scrubber increased with the increase of pH value of the slurry, while it decreased with the rise of the SO₂ concentration of the inlet flue gas. The limestone particle with a small average diameter appears a well dissolve performance which enhances the efficiency of limestone and desulfurisation.

REFERENCES


