Experimental study of influence characteristics of flue gas fly ash on acid dew point

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\textit{Abstract.} The long-term operation experience of a large number of utility boilers shows that the measured value of acid dew point is generally lower than estimated value. This is because the influence of CaO and MgO on acid dew point in flue gas fly ash is not considered in the estimation formula of acid dew point. On the basis of previous studies, the experimental device for acid dew point measurement was designed and constructed, and the acid dew point under different smoke conditions was measured. The results show that the CaO and MgO in the flue gas fly ash have an obvious influence on the acid dew point, and the content of the fly ash is negatively correlated with the temperature of acid dew point. At the same time, the concentration of H\textsubscript{2}SO\textsubscript{4} in flue gas is different, and the acid dew point of flue gas is different, and positively correlated with the acid dew point.

1. Preface
Coal and oil and other sulfur-containing fuel combustion in the boiler generated by the flue gas containing trace SO\textsubscript{3} and about 10\% of the H\textsubscript{2}O vapor, the temperature below 200 \degree C, SO\textsubscript{3} and H\textsubscript{2}O vapor completely combined to generate H\textsubscript{2}SO\textsubscript{4}, due to this trace of H\textsubscript{2}SO\textsubscript{4} vapor The presence of flue gas dew point temperature greatly improved. When the wall temperature of boiler tail device is lower than the flue gas dew point, there will be 80\% concentration of H\textsubscript{2}SO\textsubscript{4} solution condensation in the wall and caused serious corrosion on the equipment, so the dew point is called the acid dew point.

The long-term operation experience of a large number of power plant boilers shows that the measured values of acid dew point are generally lower than the estimated values, and that the former Soviet Union's 1973 acid dew point estimation empirical formula has lower estimates than other formulas due to the influence of fly ash. Shandong University Li Fei et al. studied the problem of acid dew point in flue gas fly ash, and put forward the concept of engineering acid dew point, and speculated that due to the physical adsorption of flue gas particles on the surface of fly ash particles can absorb part of the acid; Fly ash in a small amount of CaO, MgO and other alkaline components can react with sulfuric acid, the consumption of a part of sulfuric acid, so that the sulfuric acid vapor in the sub-pressure reduced, acid dew point temperature. But the researchers did not fly ash CaO, MgO and other alkaline components affect the acid dew point experimental validation. As for the fly ash in the CaO, MgO on the degree of acid dew point, the researchers did not conduct in-depth study. Therefore, this paper explores whether CaO and MgO in flue gas fly will affect the level of acid dew...
point and study the degree of influence on the degree of acid dew point. The flue gas dew point measuring device is designed and constructed. The measurement. By comparing the temperature of the acid dew point before and after changing the experimental conditions, the influence of the alkaline components in the flue gas on the acid dew point was analyzed and the reason was analyzed.

2. Analysis of Acid Dew Point Measurement Method
Smoke dew point measurement began in the 20th century, the late 1920s. In 1929, H.F.Johnstone first proposed the effect of $SO_3$ content in flue gas on flue gas dew point. In 1942, Joylor first formulated flue gas containing different amounts of sulfuric acid and measured acid dew point, but did not have a specific method to evaluate the accuracy of its measurement. The researchers then divided the acid dew point measurement method into indirect and direct measurements. R.J. Jaworowski pointed out that the two methods commonly used in indirect measurement of boiler flue gas dew point are isopropyl alcohol solution absorption method (IPA method) and controlled condensation method (CCD method). These two methods are first measured in the flue gas $SO_3$ or $H_2SO_4$ content, and then by the Muller curve to find acid dew point. They have to use long glass probe and a set of glass equipment, and to strictly abide by the operating procedures, in the field when used very convenient. 1950 British Coal Utilization Association proposed the use of conductive dew point meter direct measurement of acid dew point method, the development of conductive dew point instrument is a well-designed acid dew point instrument. So far, the principle and structure of this dew point instrument is still used by many researchers. Based on the conductive dew point instrument scholars also put forward the characteristics of the measurement methods, there are resistance method, current method, cooling heating average method, the current growth rate of zero and self-current growth rate of zero method. 

The principle of measuring the dew point of the flue gas dew point is to arrange an electrode, an electrode and a power source, a high-precision ammeter in series on a surface of an insulating smooth wall, and to arrange the temperature-controlled cooling liquid to flow through its inner wall surface. The high temperature flue gas flows through the surface of the insulating outer wall which is arranged to keep the outer wall surface temperature higher than the flue gas dew point after a certain period of time, and then adjusts the temperature or flow rate of the cooling liquid flowing through the inner wall surface, Therefore cooling the flue gas flowing through the surface of the smooth outer wall. Thus, the temperature of the outer wall surface in the whole flue gas flow field is the lowest, and when the temperature is reduced to the sulfuric acid vapor condensation temperature in the flue gas, the sulfuric acid vapor in the flue gas near the outer wall surface condenses acid droplets on the outer wall surface. These acid droplets make the circuit in series with the electrode closed, so you can observe and record the circuit ammeter changes to determine whether the sulfuric acid vapor in the flue gas condensation. At the same time, the thermocouple arranged on the surface of the insulating smooth outer wall records the change of the surface temperature of the outer wall. When the current represents the first change, the temperature of the outer wall surface can be regarded as the acid dew point of the flue gas under this condition. In this paper, the design and construction of acid dew point measurement device.

3. Acid dew point measurement experiment
Coal-fired boiler fuel contains a certain amount of sulfur, fuel combustion generated by the flue gas contains a certain amount of $SO_2$, $SO_3$ and water vapor. Under normal circumstances, coal-fired boiler flue gas $SO_3$ volume of about 1~50ppm, when the flue gas temperature below 200 $°C$, $SO_3$ and flue gas in the water vapor condensation $H_2SO_4$ steam, trace $H_2SO_4$ steam makes the flue dew point temperature significantly increased. As the fly ash contains CaO, MgO and other alkaline oxides, they will be with the flue gas $H_2SO_4$ neutralization, so that the actual temperature of the flue dew point below the estimated value.

3.1 Experimental system of acid dew point measurement
In this paper, an experimental model based on simplified simulation of flue gas is designed. Air-based, sprayed into atomized sulfuric acid to simulate the condensed steam environment. Dust particles are added by means of micro-screw feeder to simulate the smoke and ash environment. An Experimental System for Simulating Flue Gas Temperature Environment by Electric Heating System. The experimental system consists of three subsystems: the constant temperature water system, the experimental section and the auxiliary system (Figure 1).

The water tank is the main equipment of the constant temperature water system, which is connected with the supply water, the constant temperature water supply and the backwater connection respectively. The baffle in the tank divides it into two areas: the mixing zone and the temperature zone. Backwater and make-up water flow in the mixed water area after the flow to the temperature control area. Electric heating wire and power supply, contactor connected; thermocouple connected with the digital temperature controller; digital temperature controller connected with the power supply. Set the temperature on the control panel of the digital temperature controller. When the temperature of the digital thermometer display shows that the water temperature measured by the thermocouple is lower than the set value, the contactor will close and heat the heating wire; When the real-time water temperature of the display is higher than the set value, the contactor will be disconnected and the power supply will stop feeding the electric wire. The outlet water temperature is controlled by electric heating wire, thermocouple, digital temperature controller and contactor.

The experimental section consists of L-type flue. Since the length of the flue is designed to be 16m in order to allow the atomized sulfuric acid to be fully mixed with the fly ash. As sulfuric acid has a strong corrosive, so the use of square stainless steel pipe production flue. In the flue at 3.5m at the upper and lower surface openings in the upper surface of the hole in the installation of bolts, the experiment can open the bolt to observe the phenomenon; the lower surface of the hole to install the cross-shaped heat exchange copper, cross-shaped heat exchange copper Tube at both ends of the tube with nylon tube and constant temperature water tank outlet, backwater and booster pump connected. The inlet and outlet of the flue are connected to the auxiliary system[3].

The auxiliary system consists of a vortex pump, a rotor flow meter, an air heating box, a sulfuric acid injection system, a micro screw feeder and an exhaust gas collection system. The air flowing into the air heating box is heated by a dry heating wire and flows into the flue, and the hot air temperature is measured by a thermometer installed in a heating box. The sulfuric acid injection system consists of a sulfuric acid solution bottle, an infusion set and an atomizing nozzle, and the flow is controlled by the knob on the infusion set. The micro screw feeder is controlled by the motor and the frequency converter.
type heat exchange brass, 14—Industrial thermometer, 15—Pressurized water pump, 16—Cooling device, 17—valve, 18—Constant temperature water tank

Fig. 1 experimental system diagram of acid dew point measurement

3.2 Experimental process

Open the whirlpool pump, adjust the valve so that the rotor flow meter count reached the set value, due to power plant economizer, air preheater near the flue gas flow rate of 9~12m/s, according to similar principles and the same number of Reynolds calculated smoke Road air flow rate of 3.3m/s. After the air flow rate is stable, open the air heating box, heating the air to the experimental set temperature. When the temperature of the thermometer measuring the hot air reaches the set value and is stable, open the micro screw feeder and the infusion knob to add fogged sulfuric acid to the flue and the fly ash collected by the power station and mix well with hot air. Simulate the flue gas to set the flow through the flue and scour the cruciform heat transfer brass located at different locations in the flue. After a period of operation, turn on the power to open the constant temperature water tank, heating the cold water tank. When the water temperature reaches the set value, open the booster pump, so that hot water through the cross-shaped heat transfer copper tube, to be stable temperature, the copper wall temperature is approximately equal to the circulating water temperature. Change the circulating water temperature, when the cross-shaped heat exchange copper pipe condensation when the water temperature is acid dew point temperature.

Table 1 Composition and content of some fly ash in power station

|       | CaO  | MgO  | MnO  | SiO₂ | Al₂O₃ | Fe₂O₃ | SO₃  | K₂O  | Na₂O  | P₂O₅ |
|-------|------|------|------|------|-------|-------|------|------|-------|------|
| Value | 1.23%| 0.13%| 0.04%| 16.78%| 11.9% | 6.26% | 0.48%| 0.47%| 0.18% | 0.04%|

4. experimental results

4.1 Effects of CaO on Acid Dew Point in Fly Ash

In order to investigate the effect of CaO on acid dew point, the control experiment was carried out in this experiment, that is, the acid dew point before and after the change of CaO content was measured. In order to further study the effect of CaO on the acid dew point temperature, a certain amount of CaO was added to the original addition of a certain amount of fly ash (CaO content of 1.23%), which changed the percentage of CaO in fly ash and measured the Different conditions of acid dew point value, record the data and draw a curve (Figure 2).

Fig.2 Effect of CaO percentage on fly ash in fly ash
It can be seen from Fig. 2 that there is a negative correlation between the increase in the percentage of CaO in the fly ash. By comparing the results of the second and third points in the curve, that is, only the temperature of the acid dew point before and after changing the CaO content, the presence of CaO in the fly ash does have an effect on the acid dew point. As the CaO can be neutralized with $\text{H}_2\text{SO}_4$ in the flue gas, the $\text{H}_2\text{SO}_4$ concentration in the flue gas is reduced and the dew point of the flue gas is also reduced. At the same time, it can be seen from the figure that with the increase of the percentage of CaO in fly ash, the temperature of acid dew point decreases. This is due to the increase in the percentage of calcium oxide in the fly ash\[4\]. Compared with the CaO content of 0, the acid dew point temperature The maximum drop of 8℃.

4.2 Effect of MgO on Acid Dew Point in Fly Ash

In order to investigate the effect of MgO on the acid dew point, a controlled experiment was carried out in this experiment, that is, the acid dew point before and after adding MgO in fly ash was measured. In order to further study the effect of MgO on the temperature of acid dew point, different amounts of MgO were added on the basis of adding a certain amount of fly ash (0.13% MgO), which changed the mass percentage of MgO in fly ash Measure the acid dew point value under different working conditions, record the data and draw the curve (Figure 3).

As can be seen from Fig. 3, there is a negative correlation between the increase in the percentage of MgO in the fly ash. Through the comparison of the second and third points in the curve, that is, when the MgO content is changed, the presence of MgO in fly ash does affect the acid dew point. As the MgO can neutralize the $\text{H}_2\text{SO}_4$ in the flue gas, the $\text{H}_2\text{SO}_4$ concentration in the flue gas is reduced and the dew point of the flue gas is also reduced. When the percentage of MgO in fly ash is less than 0.5%, with the increase of the percentage of magnesium oxide, the acid dew point decreases greatly. When the percentage of MgO in fly ash is more than 0.5%, the decrease of acid dew point decreases with the increase of MgO content\[5\].

4.3 Effects of $\text{H}_2\text{SO}_4$ Concentration on Acid Dew Point in Flue Gas

In the $\text{H}_2\text{SO}_4$ concentration on the impact of acid dew point experiments to take a certain amount of power station collection of fly ash (which CaO, MgO content percentages were 1.23%, 0.13%) by the micro screw feeder into the flue and hot air mixed and take the concentration 40%, 50%, 60%, 70%, 80% $\text{H}_2\text{SO}_4$ 18ml and fly ash fully mixed reaction. The temperature of the acid dew point under each condition is measured and plotted as a curve (Fig. 4).
As can be seen from Fig. 4, the acid dew point is positively correlated with the increase of H$_2$SO$_4$ concentration. This is due to the fact that the content of CaO and MgO reacted with H$_2$SO$_4$ in certain operating conditions is constant. The content of solute in H$_2$SO$_4$ solution increases with the increase of H$_2$SO$_4$ concentration. After the reaction, the concentration of H$_2$SO$_4$ in the simulated flue gas also increases, so that the acid dew point temperature increases. When the H$_2$SO$_4$ concentration increased from 3.3 ppm to 4.1 ppm, the acid dew point temperature increased rapidly. When the H$_2$SO$_4$ concentration is greater than 4.1 ppm, the acid dew point temperature increases slowly with the increase of H$_2$SO$_4$ concentration. Since sulfuric acid concentration is greater than 65% when the concentration of sulfuric acid, concentrated sulfuric acid has a strong water absorption, the absorption of air moisture and fly ash in the alkaline oxide reaction after the flue gas sulfuric acid concentration decreased more, so the acid Dew point temperature increases slowly.

5. Conclusion

In this paper, the flue gas dew point measurement system was established. The influence of the basic components in the flue gas on the acid dew point was studied from the viewpoint of sulfuric acid concentration, the content of calcium oxide in fly ash and the content of magnesium oxide in fly ash. The following conclusions were drawn:

1. H$_2$SO$_4$ concentration in flue gas will affect the acid dew point. It can be seen from the experiment that the concentration of H$_2$SO$_4$ decreases negatively with the acid dew point and decreases with the increase of H$_2$SO$_4$ concentration.

2. CaO in flue gas will affect the acid dew point. It can be seen from the experiment that the CaO content in the fly ash is negatively correlated with the acid dew point temperature and the temperature decreases with the increase of CaO content.

3. The MgO in flue gas will have an effect on acid dew point. It can be seen from the experiment that the MgO content in the fly ash is negatively correlated with the acid dew point temperature and the temperature decreases with the increase of MgO content.

Acknowledgements

This paper is one of the phased results of the research and development of low temperature and low temperature heat and dust control of supercritical boiler (GDKJXM0000004)in China Southern Power Grid Co., Ltd.

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