Experiments on the Removal of Fine Particles with Flue Gas Conditioning

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ABSTRACT

The removals of fine particles from coal combustion by electrostatic precipitator (ESP) with flue gas conditioning were investigated experimentally based on coal-fired thermal system. The experimental results show that the performance of ESP can be improved significantly by adding atomized water, and the fine particles concentration of ESP outlet can decrease 34% under typical flue gas conditions. The conditioning effects of large particle sizes are better than that of small particle sizes, and the atomized water conditioning effect has been remarkably improved with the increase of dust concentration.1

INTRODUCTION

Haze weather is currently one of the major environmental problem in China, and its main reason is that a large amount of fine particles (PM2.5) derived from human emission reduce the atmospheric visibility. Coal-fired power stations are one of the main sources of fine particles discharged into the atmospheric environment. At present, more than 80% coal-fired power station equip with electrostatic precipitators (ESPs), and the total dust removal efficiency by ESPs can reach more than 99%, but the removal performance of fine particles is still not very effective. In terms of number concentration, more than 90 percent of fine particles escape from the treatment system (1-2).

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A poor ESP performance on fine particles is always related to back corona, or insufficient particle charging, or re-entrainment of dust, or both of them (3). Retrofitting of ESP usually includes resizing ESP itself, replacing power sources, fine particles agglomeration technologies, or flue gas conditioning. Many literatures are available for those individual studies (4-6). Among them, flue gas conditioning is one of the relative cost effective techniques.

The flue gas conditioning (FGC) is a technique that involves addition of chemical additives to the flue gas in order to increase ash collection efficiency of ESPs (7). The chemical additives include sulphur trioxide, ammonia, salts of sodium, or vapor/atomized water. Sulphur trioxide conditioning reduces the resistivity of dust, and ammonia conditioning improves the surface charge density and cohesive properties of the particles (8). But these conditioning agents may form pollutants and discharge into the atmosphere. Atomizing water flue gas conditioning can decrease the specific resistance of fly ash, reduce the flue gas temperature, and enhance the humidity of flue gas, thereby improving the performance of ESPs. It is important that the atomizing water would not produce pollution substances, so it is a kind of economic and environmental friendly conditioning technology.

Based on the flue gas generated by coal-fired boiler, experiments are conducted by spraying atomized water into flue before ESP. The removal of PM2.5 by electrostatic precipitator (ESP) with flue gas conditioning is investigated and the influence of dust concentration was tested.

EXPERIMENTAL SECTION

Experimental Facility

By simulating the process of the coal-fired flue gas pollutants control system in the actual power plant, the 350 Nm3/h experimental platform for flue gas conditioning is established. The experimental system, as shown in Figure 1, consists of flue gas generating system, pollutants addition control system, flue gas conditioning system and dust removal system.

![Figure 1. Schematic diagram of experimental facility.](image)
Many types of equipment are involved in the platform, including a coal-fired boiler, a buffer vessel, a fine particles adding device, a flue gas conditioning room, a spray nozzle, an ESP, etc. Flue gas is generated by a coal-fired boiler with volume flux 350Nm3/h. A buffer vessel fitted with some pollutants adding valves and a stirrer is located to ensure added particles well scattered. Buffer vessel followed by flue gas conditioning room, and the conditioning room set two-stage spray, in which water and compressed air mixed using double-liquid atomizing nozzle and formed into tiny atomized droplets. The ESP adopts wire-plate type with single electric field, two channels. Some flue gas analysis sampling ports is provided at the pipes of the system. The buffer vessel, flue gas conditioning room and related pipes are all covered with insulated cotton.

The flue gas conditioning system consisted of water atomized system and the conditioning room. The atomized system mainly includes a water storage tank, a metering pump, some atomizing nozzles, and an air compressor. The water are injected through the atomizing nozzles into the flue gas in form of droplets with meter diameter less than 30μm. The atomizing nozzles are produced by American BETE Corporation.

Measurement Method

The distribution of particle size and particle concentration in flue gas are measured online with an Electrical Low Pressure Impactor (ELPI) produced by Finland Dekati company, and the measuring median size range of is 0.026~7.651μm. Because the fine particles concentration is high, a diluter was used to decrease the measuring errors.

RESULTS AND DISCUSSION

Fine Particles Removal Efficiency Under Typical Conditions

The typical experimental conditions are as follows: volume flux of 350 Nm3/h, the flue gas temperature of 150℃ at the point of spraying atomized water, the dust concentration of 20 g/Nm3, the ESP operating voltage of -40 kV. The dust concentration is adjusted by aerosol generator, and the additional added fly ashes take from the three stage of ESP in coal-fired power plant, which has the characteristics of small size and high specific resistance.

The experimental results are shown in Figure 2. In the typical flue gas conditions, the number concentration of fine particles in the outlet of ESP reduces from 9.29 x 106 /cm3 to 6.13 by 106 / cm3, and the fine particles concentration decreases by 34 percent. The mass concentration reduces from 120 mg/m3 to 80.4 mg/m3, and the mass concentration decreases by 33%. The experimental results indicate that the performance of ESP can be improved significantly by adding atomized water.
The main reason is that the droplets of atomized water are vaporized in the flue gas, which increases the humidity in the flue gas, then alters the dust specific resistance. At the same time, spraying water can lower the temperature of the flue gas, then the volume and flow rate of the flue gas is decreased, and the retention time stayed in ESP is increased, which can improve the removal capability of fine particles. Due to the increase of water vapor content in flue gas, the operating voltage of ESP can be raised. During the spraying process, the fog droplets in the turbulent flow field formed by the spray can be benefit for the agglomeration of fine particles. These effects indicate that the atomized water flue gas conditioning is benefit for the removal efficiency of the ESP.

Fractional Removal Efficiency of Fine Particles

Figure 2. Particle removal efficiency under typical conditions.

Figure 3. Fractional removal efficiency.
Fractional removal efficiency of fine particles is shown in Figure 3. Overall, the conditioning effects of large particle sizes are better than that of small particle sizes. The number concentration removal efficiencies of low size particles are higher than that of mass concentration, while the high size particles removal efficiencies are just the opposite.

After atomized water conditioning, due to the lower specific resistance, large size fine particles are more likely to be captured by ESP. As the mass ratio sharply rise with the particle size increase, so the removal efficiency of large size fine particles mass concentration is obviously higher than that of the number concentration. When the particle size less than 1μm, fine particles are agglomerated with each other due to turbulence or the water droplets capture, but only part of the aggregates are removed by ESP, so the number concentration removal efficiency is superior to the mass concentration.

**Influence of Dust Concentration**

The typical experimental conditions are as follows: volume flux 350 Nm3/h, the flue gas temperature of 150°C at the point of spraying atomized water, atomizing water spraying flow rate of 15 L/h, the operating voltage of ESP -40 kV, the dust concentration change with 10 g/Nm3, 15 g/Nm3, 20 g/Nm3. Experiments concerning the dust concentration influence on flue gas conditioning effect are conducted, and the test results are shown in Figure 4. When the dust concentration increases from 10 g/Nm3 to 20 g/Nm3, the decrease percentage of fine particles concentration in the outlet of ESP is increased from 6.3 percent to 24.2 percent. This indicates that the atomized water conditioning effect has been remarkably improved with the increase of dust concentration.

![Figure 4. The influence of dust concentration.](image-url)
When the dust concentration is low, the corona current and electric field intensity are enough higher to removal the fine particles, and the decrease of dust specific resistance caused by atomized water conditioning is not obvious to promote the performance of ESP. With the increase of dust concentration, the fine particles concentration raises in the outlet of ESP. At the same time, the removal efficiency of fine particles has been obviously improved due to the changes of dust specific resistance and flue gas properties by the flue gas conditioning, and the effect will enhance with the dust concentration raise.

CONCLUSIONS

(1) Under typical conditions, the atomized water flue gas conditioning is benefit for the removal efficiency of the ESP. The fine particles number concentration decreases by 34 percent, and the mass concentration decreases by 33%.

(2) With the increase of dust concentration, the effect of atomized water conditioning is significantly improved.

REFERENCES