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The experimental study of a water-saving wet electrostatic precipitator for removing fine particles

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A water-saving wet electrostatic precipitator was designed and tested to study fine particles emission. A Venturi nozzle was added to the front of electrostatic precipitator, which replaced the spray washing in the electric field. The experimental results indicated that the performance of spray-type ESP was superior to that of film-type ESP and other treatment processes. It was worth noticing that the lowest collection efficiency for spray-type ESP varied under different parameters, which distinguished from other types. Furthermore, the efficiency difference of spray-type ESP during given experimental time only had a slight fluctuation in range of ±2.8%.

1. Introduction

Coal burning can generate many pollutants, particularly fine particles that are highly hazardous substances can cause stronger negative effects than large particles [1–7]. These pernicious fine particles can penetrate into the lung [8]. Previous studies showed that approximately 8000 death/year occurred due to exposing in $PM_{2.5}$ chronically [9] and several pathological investigations had also confirmed the relationship between death rate and chronic exposure to $PM_{2.5}$ [10].

Electrostatic precipitators (ESPs) are used broadly in the industrial boilers and coal-fired power plants to remove particles due to low pressure drop and high flow rate. However, the dust accumulating on collection plates can decrease dramatically the electrical field strength [11–13]. Furthermore, the particle reentrainment resulted from back corona and rapping can also cause a large decrease of collection efficiency [14–17]. Wet electrostatic precipitator (WESP) can resolve these problems through water cleaning on collection plates [18]. In addition, it can also remove sticky particles and some harmful soluble gases.

Two types of traditional WESPs can be distinguished with regard to collection electrodes cleaning. One type is overflowing water cleaning which can wash away dust accumulated on collection electrodes through a continuous flow [19]. The main disadvantage of this type is high water consumption. The other type is spray cleaning that the nozzles located at the top of precipitator spray tiny droplets to the collection plates. However, unstable spray conditions can restrict the running voltage seriously for this type [19].

Heterogeneous condensation and agglomeration by spray charging were applied to many exhaust gas pollution control devices. Tsai et al. [20] added water mist to hot flue gas in front of Venturi nozzle. The results showed that fine particles can grow up and the collection efficiency of particles from 50 to 100 nm can increase from 40% to 80%. Huang [21] also added water mist to the front of Venturi nozzle at room temperature and the results demonstrated that the collection efficiency of SiO_2 particles from 70 to 500 nm in diameter was increased significantly from 50% to 90%. Meanwhile, Geng's research also pointed out that fine particles can grow up by adding water mist to exhaust gas and thus the particle collection efficiency can increase [22]. All these investigations had indicated that the particle collection efficiency can be improved through condensation and agglomeration. However, the investigations of improving collection efficiency by condensation and agglomeration growth in WESP are relatively less than other dust collectors. Tzu-ming Chen et al. [23] sprayed water mist in front of WESP to enhance the collection efficiency of nanoparticles and submicron particles. Their experimental studies demonstrated that the collection efficiency of nanoparticles can be increased from 67.9%–92.9% to 99.2–99.7% in case of water mist. Nevertheless, their research was not comprehensive and mainly focused on small-scale manufacturing industry, therefore the

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conclusions were not completely appropriate for coal-fired power plant and industrial boilers.

In this study, based on coal-fired power plant and industrial boilers, a tubular ESP combined with a Venturi nozzle was designed and tested. The performance of dry ESP, WESP with overflow water cleaning (film-type ESP) and the integrated system (spray-type ESP) developed in this study are compared and analyzed under different parameters. It is worth noting that the water consumption in this integrated system is significantly reduced.

2. Experimental setup and method

Fig. 1 shows the experimental setup used in this study. The whole experimental system includes feeding apparatus, atomization humidification device, heating apparatus, hot air blowing device, high-voltage system, the ESP body and measuring system. The ESP body was a rectangular tube and the flue gas passed through it from top to bottom. The discharge electrode in the form of spiked band was made of carbon steel and connected to a high-voltage power supply, whilst it was located at the center of the channel. The length and width of the discharge electrode were 3000 mm and 13 mm, respectively, as shown in Fig. 2. The collection plate was made of fiber membrane (terylene, 3927) that had a thickness of 0.5 mm. The width and height of the collection electrode were 400 mm and 3000 mm, respectively, with the arrangement of rectangular cross section. With regarding to Venturi nozzle section, the overall length was 1720 mm and a twin-fluid nozzle was installed in its throat position. Compressed air which was characterized by 0.4 Mpa was introduced to the gas side of spray nozzle and atomized water (15 L/h~40 L/h) was sprayed from the tip of spray nozzle. The water after atomization was evenly dispersed through Venturi nozzzle section and introduced to the electrostatic field.

The Micro screw feeder (TWLX15) which can adjust feeding quantity by varying the feeding frequency was adapted in this study. The dust used during the experiment was originally from the

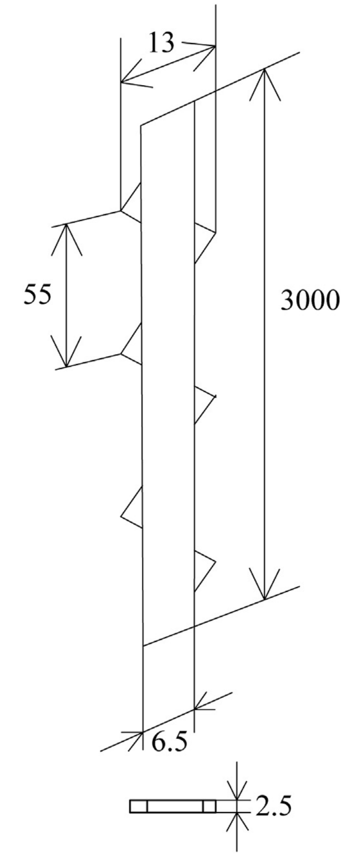

Fig. 2. View of the experimental discharge electrode used in this study.

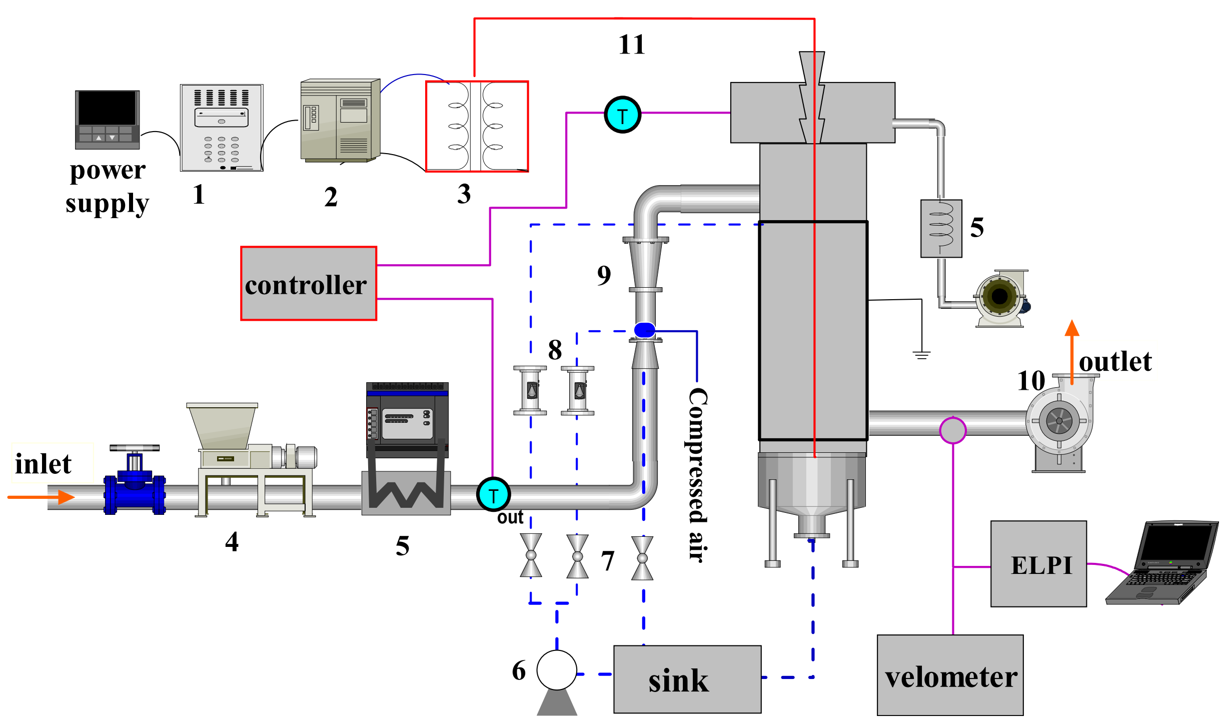

Fig. 1. Scheme of the set-up used for the WESP experiments. 1. low-voltage controller. 2. high-voltage controller. 3. transformer. 4. dust generator 5. gas heater. 6. pump. 7. water adapter. 8. flowmeter. 9. short venturi tube. 10. draft fan. 11. high voltage cable.