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Deposition characteristics of dust on wet membrane electrodes

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ABSTRACT

The wet electrostatic precipitator (ESP) with a membrane collecting electrode is widely used to remove fine particles from a flowing gas. To study the characteristics of the deposition of dust on a wet membrane electrode, a test bench was built in this study, and the efficiency of fractional collection, the microstructure of the membrane, and the size distribution and morphology of the dust layer collecting on the wet membrane electrode were studied and compared with those on a dry metal electrode. Using this information, a migration pathway and a deposition mechanism for charged particles in the wet membrane-based ESP is proposed. The results of experiments showed that charged particles deposited on the wet membrane electrode in a shorter time than on the dry electrode, and the dust collecting on was smaller in volume at the same positions. Patterns of the dust layer on the dry metal electrode were strongly correlated with the distribution of discharge current density on the collecting electrode. In the membrane-based wet ESP, the charged particles deposited on the surface of convex fibers and formed the center of the deposition. The collected particles eventually gathered and formed dispersed distributed spherical aggregates, significantly different from patterns of the dust layer on the dry metal electrode. The morphology of the dust layer supported the proposed deposition mechanism.

1. Introduction

The electrostatic precipitator (ESP) is widely used to reduce the emission of particles because of its low pressure drop and energy consumption, and high collection efficiency and long service life [1–3]. In a dry ESP, the resistivity to dust is in the range $10^4 \sim 10^{11}$ Ω cm or higher, a remarkable voltage drop across the dust layer that results in a low corona and electric field intensity [4]. Moreover, the dry ESP exhibits poor collection efficiency for particles with diameters in the range 0.1–1 μm [5,6] because of its charging mechanism [7,8] and the re-entrainment of particles [9]. To solve these problems, the wet ESP has been developed and applied primarily to the simultaneous removal of fine particles and other gas contaminants from wet flue gases, such as sulfuric acid aerosols, water droplets, and heavy metals [10,11]. In a wet ESP, the dust layer is infiltrated by flowing water and dust resistivity decreases significantly [12]. Compared with the dry ESP, the wet ESP continuously operates at a high corona intensity. In recent years, membrane-based wet ESPs have been widely used [13,14], because of their high efficiency and corrosion resistance, light weight, lack of alkali and water consumption, and uniform water distribution [15].

The characteristics of deposition of dust on the dry metal electrode have been extensively studied. Miller et al. [16] investigated the particle size distribution and porosity of dust in compressed and lightly packed regions of dust layers on a dry metal electrode, and found that electric wind supported the formation of a low-porosity layer, and fine particles were deposited in regions of compressed, packed dust layers. Jedrusik et al. [17] correlated patterns of the collected dust layer with the distribution of the discharge current density, and showed that the former was strongly correlated with the later, and particle re-entrainment mainly occurred in zones of low discharge current density. Didier et al. [18] studied the particle size distribution in a microscopic view of the dust layer on an electrode, and proposed a deposition mechanism based on it. They also claimed that the electrostatic pressure on the surface of the dust layer may lead to particle re-entrainment. The above studies have shown that the deposition characteristics of dust on a dry metal electrode can be considerably influenced by the distribution of discharge current density and properties of the dust layer on the collecting electrode. However, water flowing over the membrane electrode has a significant influence on these two aspects [19]. The deposition characteristics of particles collecting on the wet membrane electrode are thus not well understood.

In this study, a laboratory ESP model with a barbed discharge electrode was used, and the collecting electrode could be alternated

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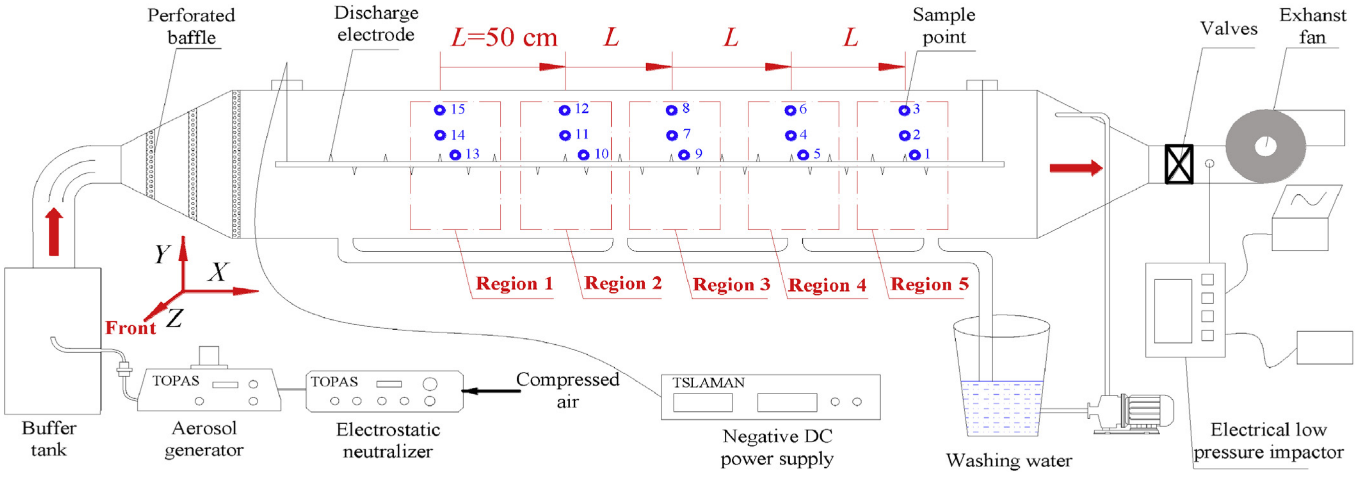

Fig. 1. The experimental setup.

between dry metal and wet membrane. The particles fractional collection efficiency in the membrane-based wet ESP and dry ESP were first studied. The deposition characteristics of collected dust (size distribution) and the morphology of dust layer on the membrane electrode were then investigated. Finally, a mechanism for the deposition of particles on the wet membrane electrode was proposed based on electron transfer and the directional migration of ions in the electrical field, where the mechanism was supported by the morphology of the dust layer on the wet membrane electrode.

2. Experiment

2.1. Experimental setup

Fig. 1 shows the experimental system setup consisting of a particle feeding system, a laboratory scale ESP model, and a particle analysis system.

Compressed air was introduced to the particle feeding system, composed of an aerosol generator (Topas SAG-410, Germany) and an aerosol electrostatic neutralizer (Topas EAN-581, Germany). The particles were effectively dispersed and controllably neutralized into the compressed air, and a buffer tank between the particles feeding system and ESP model was used to maintain the stability of the particles.

The ESP model is shown in Fig. 2(a) and the discharge electrode in Fig. 2(b). This model consisted of a single horizontal barbed discharge electrode and two flat-plate collecting electrodes, where the inter-electrode distance is 200 mm. The barbed electrode was used mainly because of its high discharge characterizes [16,17]. The collecting electrode was 3000 mm in long and 500 mm in high, and could be changed between the dry metal and the wet membrane. The barbed discharge electrode was energized with a negative DC power supply (Tslaman TRC2020N70-300, China) that could provide high voltage in the range of 0–70 kV. The total discharge current and applied voltage could be acquired directly from the display panel of the high voltage supply. As shown in Fig. 1, the front surface of the collecting electrode was divided into five regions (1–5) with an interval of 500 mm along the direction of gas flow, and three fixed circular sample points (1–15) with a diameter of 20 mm on the collecting electrode were chosen in each region.

2.2. Experimental materials

Two types of collecting electrodes were used in this experiment: a dry metal collecting electrode and a wet membrane collecting electrode (Fig. 3), which was a water penetrating polypropylene terephthalate (PPT). The characteristics of the PPT collecting electrode are shown in Table 1. In a previous study, the water was found to spread and penetrate the membrane electrode quickly at a capillary flow rate of 2.5 L/(m·h)$^{-1}$ per unit length along the direction of gas flow [20]. To prevent the collected particles from being cleaned by the flowing water, the flow was shut down once a stable and uniform water film had formed on the surface of the membrane electrode.

Following treatment with a supersonic wave oscillating screen (625 mesh), fly ash from the final ESP stage ash hopper of a pulverized coal

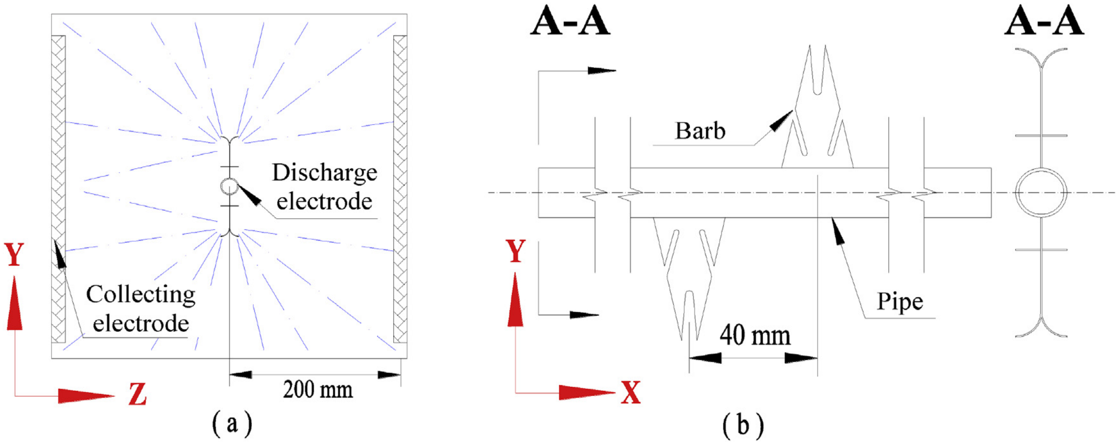

Fig. 2. The wire-plate ESP (a), and discharge electrode (b).