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Experimental study on the impact of electrostatic effect on the movement of charged particles

Wang Jianan[a,b], Wang Xue[a,*], Zhu Tingyu[a], Zhao Yi[b]

[a] Beijing Engineering Research Center of Process Pollution Control, National Engineering Laboratory for Hydrometallurgical Cleaner Production Technology, Institute of Process Engineering, Chinese Academy of Sciences, Beijing, 100190, China
[b] School of Environmental Science and Engineering, North China Electric Power University Baoding, Hebei, 071003, China

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ABSTRACT

In this research, the Electrostatic-bag-precipitator (EBP) platform was made of the fully transparent organic glass materials, and the Particle Image Velocimetry (PIV) device was used to carry out the direct test of the charged particles movement in the precipitator. The Electrical Low Pressure Impactor (ELPI+) was applied to test the charge amounts of the outlet of the electrostatic precipitator (ESP) part and the outlet of EBP simultaneously. It was found that the movement of charged particles was both affected by the electrostatic repulsion among the particles and the charged dust layer on the filter cartridges, and the effect was positively correlated with the charge amounts on the particles and the dust layer. The variation law of cumulative charge amounts of the dust layer under different voltages and during different time phases was analyzed indirectly and the corresponding function model was established, hoping to provide reference for the research on the high-efficient trapping technique of fine particles.

1. Introduction

In recent years, the problem of air pollution in China has deteriorated rapidly, and respirable particulate matters have become the principal air pollutants in major cities [1,2]. Among those respirable particulate matters, fine particles are considered as regional pollutants and can cause pollution in a greater range due to the fact that those fine particles have long residence time in the atmosphere and could be transported for long distances [3]. Among these fine particles, PM2.5 is the major elements affecting the air quality and visibility in cities. In 2010, there was about 6 million tons of dust emission in China, of which more than 4 million tons were PM2.5. The particles which have the least removal efficiency in the dust removal system are the most detrimental to the environment and people's health, thus it has become one of the core pollutants of atmospheric environment in China [2]. Fine particles not only affect the climate environment, but also cause health problems and make a considerable impact on production and development [4,5]. In 2014, the National Development and Reform Commission, the Ministry of Environmental Protection and the State Energy Bureau jointly issued *the Action Plan for the Upgrading and Reconstruction of Coal and Electricity Energy Saving and Upgrading (2014–2020)*, which stipulates that the emission concentration of air pollutants in the new coal-fired generating units in the eastern region should not be higher than 10 mg/m^3, with the aim to strictly control the emission of fine particulate matters.

Electrostatic-bag-precipitator (EBP), as an efficient equipment to capture fine particulate matters, can not only overcome the low efficiency of the ESP for capturing fine particles, but also reduce the pressure loss of the bag filter and increase the endurance of the filter bag. Therefore, EBP is considered to have broad application and development prospects [6,7].

The main reason for the superior performance of EBP is that it has charged the dusts particles [8]. It has been shown through experiments that dusts can form loose and orderly dust layer on the surface of the filter cloth after being charged, so it is able to improve the dust collection efficiency while reducing the filtration pressure [9,10].

Huang Bin [11] conducted a single fiber filtration experiment on pre-charged particles, and found that the charged particles could form a straight chain structure with the capture effect, and the bonding strength was positively correlated with the particle size.

Tu [12] investigated the variation of the dust quantities on the fiber with the pressure drop of the filter under different charge levels of particles. The results showed that the pressure drop caused by charged particles decreased with the increase of the charge amounts.

Lathrache [13] and others studied the character of deposition on the surface of the charged active fiber materials. The results suggested that

* Corresponding author.
E-mail address: 252099111@qq.com (W. Xue).

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the pressure drop and the transmittance of charged active fiber materials were significantly lower than those of ordinary filter media.

Tang [14] studied the accumulation mechanism of charged particles on the surface of the filter bag through applying the electrostatic theory. The results indicated that the charged particles accumulated loosely on the surface of the filter bag due to the role of electrostatic repulsion, thus reducing the resistance of filtration.

Stenhouse [15] explored the effects that particle sizes, charge amounts and other factors may bring on the filtration efficiency of the electrostatic active fiber. The results showed that the smaller particles were easily to prompt the stoppage to reduce the efficiency of dust removal. The larger the charge amounts of particles were, the looser the dust layer on the surface of the filter material was, and the higher the efficiency was.

The motion state of charged particles in the bag filter part of EBP will change due to the impact of the charged dust layer, as well as the mutual repulsion between the particles during movement, and thus have a certain impact on the capture effect [16]. In the past, the study on the motion state of charged particles was almost the indirect study by simulation, which lacks intuition. In this paper, a new research method is proposed with aim to make a direct study on the motion of charged particles through the construction of plexiglass materials EBP platform, and at the same time a theoretical analysis on the cumulative charge amounts of the charged dust layer on the surface of the filter bag will be conducted.

2. Experimental

2.1. Experimental setup

In order to study the movement of the charged particles in EBP, the experimental platform consisting of four parts was built as shown in Fig. 1.

(1) Flue gas generation system.

The core equipment of the flue gas generation system was a dust generator, and the SAG-410L dust generator from TOPAS Company was selected in this experiment. The dust diffusion process was divided into two steps: step 1: the dusts were quantitatively delivered to the diffuser by drive cone belts, and the concentration of dust can be adjusted in accordance with the belt conveyor speed. Step 2: When the dusts were ejected from the nozzle, the agglomerated dust particles could be dispersed by the shearing force formed at the nozzle opening, thus leading to the formation of aerosol particles. The dust concentration could be controlled by the operator interface.

(2) Electrostatic precipitator (ESP) part.

The ESP part comprised a DC high-voltage generating device and an electrode wire-plate part. TYZGF-60KV/5 mA split DC high-voltage generating device made in Shanghai Tai Yi Electric Company was applied to provide voltage for electric filed directly in this experiment. Therefore, the ESP corona voltage in the electric filed and the supply voltage mentioned in results and discussion are same. The volt-ampere characteristic curve is shown in Fig. 2.

Fig. 3 is the schematic diagram of ESP structure, the ESP part was a single channel, which was equipped with two prickly corona electrodes

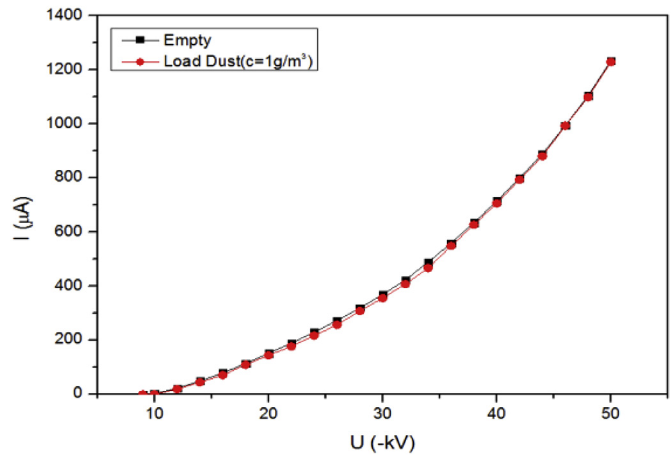

Fig. 2. Volt-ampere characteristic curve.

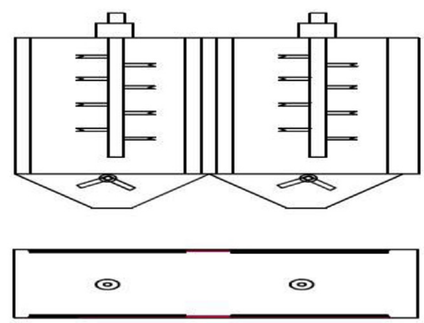

Fig. 3. The schematic diagram of ESP part.

and four dust collecting plates. Two prickly corona electrodes with the line spacing of 400 mm were selected in the platform. There were eight thorns on each corona electrode, and each thorn was 30 mm in length and 100 mm in pitch, and was designed for symmetrical staggering. Dust collector plates made of stainless steel was 200 mm in length and 400 mm in height. The distance between the collector plates was 200 mm, and the entire box were made of plexiglass materials.

(3) Bag filter part.

The bag filter part connected after ESP part was the main part for the collection of fine particles, including glass shell, glass plate, metal skeleton and twelve filter cartridges. The twelve filter cartridges was made of coated PPS filter with the average pore diameter of 0.5–1.0um, resulting in better permeability and stability, and the resistivity of coated PPS filter was big, so there was hardly any charge migration or leakage from filter media in the experimental process.

(4) Analysis and testing system.

Analysis and testing system was composed of two parts: the velocity measured by the Particle Image Velocimetry system (PIV), and the charge amounts measured by the Electrical Low Pressure Impactor (ELPI+).

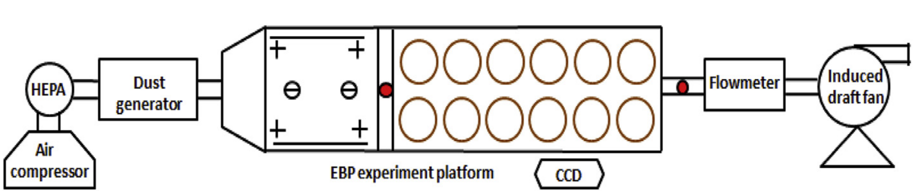

Fig. 1. Experimental platform diagram.