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Electrical properties of fly ash and its decarbonization by electrostatic separation

Tao Youjun [a,*], Ding Qingqing [a], Deng Mingrui [b], Tao Dongping [a], Wang Xu [a], Zhang Jie [a]

[a] School of Chemical Engineering and Technology, China University of Mining & Technology, Xuzhou 221116, China
[b] Tangshan Branch, Tiandi Science & Technology Co., Ltd., Tangshan 063012, China

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ABSTRACT

The basic principle of fly ash triboelectrification is analysed. The mineral electrical index and test method are introduced. The electric difference of different mineral composition of fly ash is discussed by analysis of chemical and mineral composition of fly ash in Xinwen power plant. The dielectric constant and charge–mass ratio of carbon and ash of fly ash are tested. Combined with the experimental study on rotary triboelectrostatic separation, the charged characteristic of fly ash particles with different size is gained. The results show that the dielectric constant of fly ash with different grain size decreased with the decrease of particle size, which lead to the poor electrical conductivity. Thus it can be seen that particle size plays a leading role in conductivity. The charge of carbon and ash with each size increased with the decreased of particle size; and the charge–mass ratio between carbon and ash with the same size larger with the decrease of size, which indicated that the finer particle size, the more favorable for triboelectrification separation. In the same conditions, the best decarburization effect is realized when the particle size ranges from 0.038 to 0.074 mm, whose decarbonization rate and efficiency index reached 38.93% and 120.83% respectively.

1. Introduction

The main methods of fly ash decarbonization at coal combustion power plants are classified as dry and wet, or chemical and physical method. The dry separation process mainly includes the combustion method, electric separation method and fluidization method, etc. While the wet method mainly includes ultrasonic column condensation and flotation method [1]. Flotation method is not widely used because of the high cost and negative impacts on the activity of fly ash, although flotation method is generally considered as the most effective method for fly ash decarbonization. On the contrary, electrostatic separation was a dry process with relatively low investment and operation costs. Therefore, research on fly ash decarbonization using electrostatic separation has gradually become a hot topic. Research and development of triboelectrostatic technologies with low cost and high efficiency for wide application in fly ash decarbonization offers major economic and environmental significance.

Triboelectrostatic separation relies on two electrical properties of minerals, i.e., work function and electrical conductivity. The former decides the sign and intensity of electrostatic charge and the latter mainly affects the electrostatic charge intensity of particles. Commonly, a greater difference of mineral surface work function and the poorer electrical conductivity result in a greater difference in electrostatic charge (including charge sign and magnitude), which is more beneficial for triboelectrostatic separation and improves separation efficiency [2]. Mineral electrical properties directly affect the triboelectrostatic charging characteristics. Therefore it is necessary to carry out an investigation on material electrical properties before triboelectrostatic experiments. Resistance or dielectric constant is used to describe mineral conductivity in general [3] and dielectric constant is used in this study.

2. Experimental

2.1. Test system of permittivity

The testing system of permittivity was composed of incubator chamber which was used for stabilizing measurement environment and reducing the error of measurement, custom-made three electrode plate capacitors for measuring capacitance which was grounded to reduce the electric field edge effect, and micro

* Corresponding author. Tel.: +86 516 83591100.
E-mail address: tyj9000@126.com (Y. Tao).

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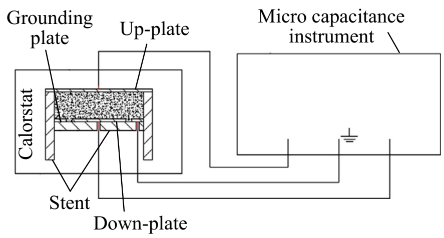

Fig. 1. Test system of permittivity.

capacitance instrument which is used for measuring air capacitance and material capacitance [4], as is shown in Fig. 1.

According to definition of permittivity, permittivity can be expressed as formula (1):

$$\varepsilon = C_k/C_0 \tag{1}$$

where C_0 and C_k represent capacitance of plates with vacuum and capacitance of plates filled with medium respectively.

Basic principle of test system of permittivity is based on the formula (1). The capacitance of plates filled with medium can be received by measuring the self-made three electrode plate capacitance of plates with vacuum and medium respectively and then substituted into formula (1). But it is hard to be completed in the practical measurement when the plates reach to vacuum state but it has accurately measured the air permittivity of only 1.0008 which close to the permittivity in vacuum of 1. Therefore, it used capacitance of plates filled with air *Ca* instead of C_0 in experiments.

2.2. Test system of friction static charge (charge–mass ratio)

Test system of friction static charge (charge–mass ratio) composed of friction charged device, faraday cup and digital charge instrument [5], the system diagram is shown in Fig. 2.

The friction charge usually express as charge–mass ratio for fly ash. The expression is shown in formula (2).

$$q = Q/m \tag{2}$$

where Q is the measured charge and m is the mass of particle. The experimental procedure is described as follows. A 20 g fly ash sample was fed into the charging hopper, and then fell freely along a stainless steel chute to the Faraday cage. During the process, the fly ash became charged by friction. The measured charge value increased as more particles fell into the Faraday cage. At the end of the charge measurement, the maximum reading received from the digital charge measurement instrument was recorded as "Q", which was considered as the friction charge magnitude of particles. The charge–mass ratio of particles was obtained by substituting Q and sample weight (m) into formula (2).

2.3. System of rotary triboelectrostatic separator

As illustrated in Fig. 3 the rotary triboelectrostatic separator used in the present study is mainly composed of a vibratory

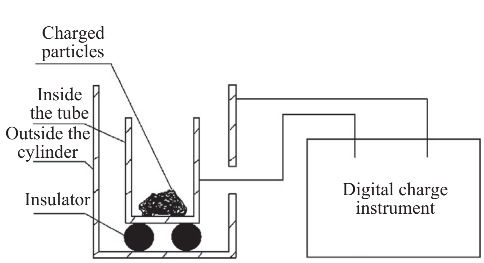

Fig. 2. Test system of friction static charge (charge–mass ratio).

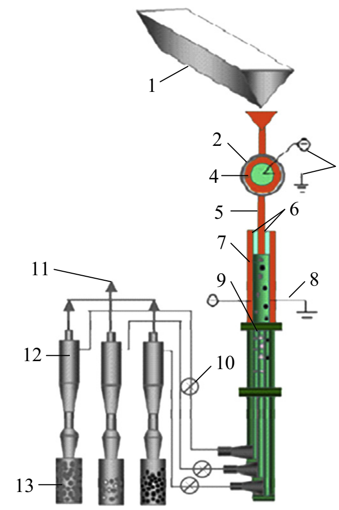

Fig. 3. Structural diagram of rotary triboelectrostatic separator (1 – feeding appliance, 2 – charger shell, 3 – charging DC power supply with high voltage, 4 – rotating friction wheel, 5 – material distributor, 6 – correction flow, 7 – parallel plate, 8 – 3DC power supply with high voltage in sorting area, 9 – separaton plate, 10 – ball valve, 11 – vacuum source, 12 – small cyclone precipitator, 13 – product collecting tank).

sample feeder, a rotary charger or charge exchanger, a separation chamber, an injection gas unit and two high voltage DC supplies. Samples were fed by the feeder into the rotary charger. A relatively small amount of transport gas was injected with the particles. The gas–particle flow interacts with the rotary charger made of copper. Due to particle to charger or particle-to-particle collisions, particles became charged negatively or positively, depending on their work functions. The charged particles then passed through the separation chamber and reported to one of three cyclones attached to the system.

There were two high voltage sources in the rotary separation system: one was for the particle charging, which was attached to the charger and the other was for the separation of the charged particles, which was attached to the separation chamber. The most distinct feature of the rotary separator is that particle charge density and polarity can be controlled by changing the applied voltage. This is an innovative concept that allows separation of multiple components at different stages with different applied voltages, which is analogous to adding different reagents at different stages in the flotation process [6,7].

3. Sample characteristics of fly ash

The fly ash sample employed in this study was collected from the fly ash precipitation system at the Xinwen coal combustion power plant in Shandong province in three different periods of time to ensure the representativeness of the sample. Once the sample was delivered to the lab, the sample was homogenized and representative samples were taken for characterization and analysis.

3.1. Chemical constitution of the fly ash

The chemical composition of fly ash sample was determined by S8 TIGER X-ray fluorescence spectrometer at the Advanced Analysis and Computation Center of China University of Mining and Technology. The instrument is manufactured by Germany Brooke Company. The analysis results are shown in Table 1.

It can be seen that the main components of the fly ash were Al_2O_3, SiO_2, Fe_2O_3, CaO and uncompleted burned carbon from