

Experimental investigation on the particle capture by a single fiber using microscopic image technique

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Abstract

Four kinds of solid particles were captured by a single fiber. The particles included two kinds of fly ash particles and two kinds of ceramic particles under three different types of charging pretreatment. The single fiber was fixed across a square cross-section glass tube. A standard continuous aerosol generator was used to disperse particles to generate a uniform aerosol. The aerosol particles from the generator were tribocharged, polarized or charged, and then passed across the fiber. A microscope and a CCD camera were used to observe the capturing process and the shape distribution of dendrites. The results showed that the deposited particles developed in different ways. In the tribocharged case, dendrite formation can be classified into three distinct stages. In the prepolarized case, straight chains were formed at a uniform spacing interval, and had high binding intensity to support very long chains. Even though the long chains fell over they still had high capturing efficiency. In the precharged case, some straight chains with some branches were formed, but their binding intensity was low and they easily fell over and broke. The results also showed how the particle diameter and shape influenced the formation of dendrites and chains.

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1. Introduction

PM₁₀ is one of the most important atmospheric pollutants in many Chinese cities, especially emits from combustion sources [1]. Fabric filter combined with electrostatics precipitation (ESPs) is promising to meet the strict emission standard [2]. Electrostatic can influence the filtration of fabric filters in three ways: (1) precharging airborne particles, (2) using a charged fiber, such as electret filters and (3) creating an external electric field around the filter [3]. The pre-charging particle technique is the most promising for bag-filter in the power and energy industry.

Numerous experimental and theoretical studies of charged fibers or fibers in external electric fields have been conducted [4–8]. However, the obtained conclusions on the effect of pre-charging particle filtration were inconsistent. Some studies reported that precharging particles increased cake porosity that

enhanced the efficiency and reduced the pressure drop increase rate [9,10]. Other studies showed that the precharging particles had no influence on their capture [11]. There have been few thorough studies on the fundamental principles governing pre-charging particle filtration, so a good understanding of the particle capturing process is necessary for the application of electrostatic forces in the aerosol filtration system. Present studies of electret fibers [12,13] or external electric fields [4,7] just observed the final morphology of the formed dendrites. There is little knowledge about the instantaneous particle deposition process. An in situ microscopic image technique has been developed to investigate the particle deposition pattern. In addition, since the effect of the precharging particles on pressure drop in a practical system containing multiple fibers is too complex to accurately evaluated [11], this study will only focus on the dendrite formation on a single fiber.

This paper presents in situ observations of the morphology, break up and collapse of deposited particles with various pretreatments. The particle capturing process was observed with a microscope and in situ CCD camera. Four kinds of particles with three different pretreatment cases were studied to

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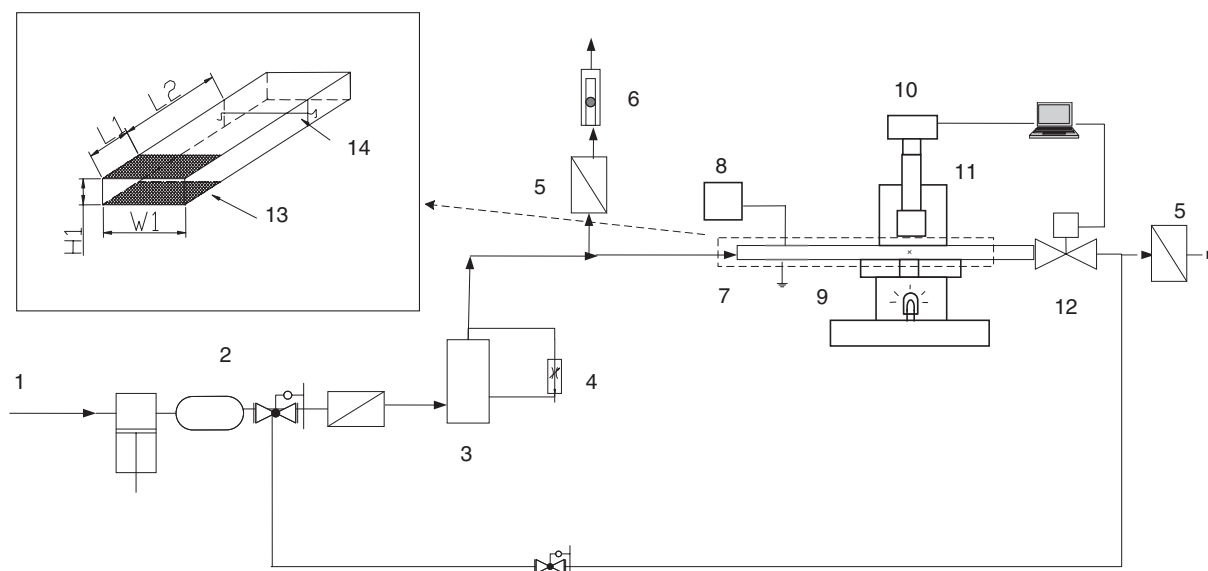


Fig. 1. Experimental set-up: 1—air, 2—pressure tank, 3—dust feeder (RBG-2000@Palas GmbH), 4—mass flow controller, 5—HEPA, 6—flowrator, 7—corona discharge ionizer, 8—high direct current (–2 to –80 kV), 9—glass tube, 10—CCD, 11—plus valve, 12—pulse valve, 13—aluminum foil, 14—fiber. $L_1=50$ mm, $L_2=100$ mm, $H_1=7$ mm, $W_1=25$ mm.

understand the influence of pretreatment on particle captured by a fiber.

2. Experiments

2.1. Lab-scale setup and procedure

Fig. 1 shows a schematic of the experimental setup. The aerosols were continuously generated by a brush particles disperser (Model RBG-2000, Palas, Germany). It was used to feed and disperse particles continuously, and a mass flow controller controlled the steady flow flux to supply the high-speed air to the disperser to maintain constant concentration aerosol. Since the flow volume from the disperser was too large, a bypass was used to separate a part of the aerosol before it entered the 7×25 mm square cross-section glass tube. The flow volume in the bypass was measured by a rotameter, with the flow rate in the experimental tube calculated as the difference between the mass flow controller and the rotameter. Two 25×50 mm sheets of aluminum foil were pasted on the inside walls of the tube as electrodes. One sheet was connected to the ground and the other to a high-voltage power supply, which will pretreat the aerosol. A single fiber was fixed across the glass-tube 100 mm beyond the electrodes. A CCD camera (PL-A662,

Pixie Link capture, China) was mounted on a $200\times$ microscope (ECLIPSE E600 POL, Nikon, Japan) to observe the process. All data were collected by a computer. A pulse valve was installed behind the test region to control compressed air to clean the fiber after the experiment.

At the beginning of each experiment, the microscope was focused on a cleaned fiber fixed in the glass tube. In order to reach a steady constant particle concentration, the disperser was run for 20 min at a constant flow volume and feeder rate through a bypass. The mass flow controller was set at 50 standard liters per minute (SLM) at a disperser feed rate of 10 mm/h for all experiments, and their concentrations are about $1.5\text{--}3\text{ g/Nm}^3$. The velocity in the experimental tube was set at 0.26 m/s by adjusting the bypass. The CCD worked at 0.5 frames per second (fps). The humidity of supplied air was 12–15% for all experiments, so the capillary force can be neglected.

Three aerosol pretreatments were included in this paper: 1) aerosol without pre-treatment flowing through the tube directly, referred as tribocharged case; 2) pre-polarizing the particles with a high DC negative voltage (–6 kV) and zero current, referred as the prepolarized case; 3) pre-charging the particles with a high DC negative voltage (–10 kV) and $20\text{ }\mu\text{A}$ current to the saturated charge state of the particles, referred as precharged case.

Table 1
The percentage composition of particles used in this study

%	Al ₂ O ₃	CaO	TFe ₂ O ₃	K ₂ O	MgO	MnO	Na ₂ O	P ₂ O ₅	SiO ₂	TiO ₂	LOI
P1	31.71	2.90	4.93	2.74	1.60	0.04	0.83	0.68	52.32	1.15	1.11
P2	29.92	4.49	5.32	2.28	1.93	0.05	0.92	1.07	50.60	1.16	2.26
P4	45.61	0.26	0.72	0.14	0.15	0	0.23	0.06	51.14	1.25	0.43
P5	45.83	0.18	0.07	0.11	0.10	0	0.05	0.01	52.50	0.83	0.33

LOI is the ignition loss.

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