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Effects of agglomerates on electrostatic behaviors in gas–solid fluidized beds

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ABSTRACT

This work for the first time shows that both falling polyethylene sheets and small agglomerates significantly affect the electrostatic behaviors in a fluidized bed. By cold model experiments, this work found that V-shaped fluctuations of induced electrostatic potentials were observed as a sheet fell to a certain position, and polarity reversals of induced electrostatic potentials were discovered as some small agglomerates were added and fluidized in the lower part of the bed. Further analysis found that the falling sheet could affect the particle concentration distribution in the bed as well as the surface charges of particles, and these two factors always had opposing effect on the induced electrostatic potential and thus caused V-shaped fluctuations to appear. The reason for the reversal of polarity as small agglomerates were added was the appearance of the positively charged agglomerates in the measuring sensitivity zone. This work opens up new possibilities for agglomerates detection.

1. Introduction

Gas–solid fluidized beds are widely applied in many industrial processes, such as gas–solid catalytic reactions, coating, and drying. During the operation of the fluidized bed, occurrences of agglomerates can affect the hydrodynamic behavior in the bed seriously and incur significant economic losses [1–3]. In general, agglomerates in fluidized bed polymerization reactors exist within the solid bed or adhere to the dome and wall of the reactor. And the larger ones which adhere to the dome and wall of reactors are also termed as sheets [2,4]. Sheets will break away from the wall of the reactor and fall into the bed when they are large enough. Eventually, agglomerates within the bed vary widely in size and weight [5]. Different agglomerates will show different behaviors in the bed under the action of different forces. More specifically, an agglomerate will be deposited on the gas distributor, while gravity on it is larger than the drag force. On the contrary, if the drag force that an agglomerate experiences is larger, it will be fluidized together with other particles. However, since agglomerates are always larger than particles in size, only in the lower bed can they be fluidized due to particles segregation.

The static electricity are known to be one of the main causes for agglomeration in fluidized beds [2,6]. Electrostatic charges are generated and accumulated during the fluidization process due to particle–particle and particle–wall collisions and frictions [7,8]. The high level of electrostatic charges can change the forces on particles [9,10] as well as the hydrodynamics in the bed [11], and then induce particle–wall adhesion, inter-particle cohesion, and finally agglomeration [2,12,13]. Thus, in order to prevent the occurrences of agglomerates, researchers have investigated the measurement and elimination of electrostatic charges in gas–solid fluidized beds. The electrostatic charges in a fluidized bed can be measured by using a Faraday cup or electrostatic probes. The Faraday cup is a device which can be used to measure the charges of particles based on the principle of electrostatic induction [7]. Generally, it is an off-line method, but it can also be improved to measure the charges of particles online for special purposes [14–17]. Signals measured by electrostatic probes can be electrostatic potential or current, depending on the designed circuits. Wang et al. [18] investigated the electrostatic potential distribution in a three-dimension fluidized bed by using a copper bar as probe and drew the contour line of electrostatic potential in a longitudinal cross-section. According to their results, areas with the highest electrostatic potential were close to the wall, which was consistent with Fujino's [19] experiment. Gajewski [20] attached several isolated copper rings inside of a glass column and detected the current from rings to the ground as polypropylene particles were fluidized in the column. Gajewski's results showed that charges were mainly generated near the grid plate and dissipated near the upper of the bed. Essentially, elimination of electrostatic charges in the fluidized bed is to reduce the accumulation of electrostatic charges on particles via different methods. Previous studies have reported that coating the reactor

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inner walls [21], changing the reactor operating conditions [22], adding fines into the reactor [23], increasing the humidity of the fluidizing gas [24,25] and adding antistatic agents [11] all reduce the accumulation of electrostatic charges to a certain extent by reducing the generation rate or increasing the dissipation rate of electrostatic charges. In addition to these methods, neutralizing the electrostatic charges by creating or injecting charges with the opposite polarity can also eliminate the electrostatics in the fluidized bed [10,12,26,27]. However, only antistatic agents and electrostatic charge inducing agents have been used successfully in commercial fluidized bed polymerization reactors.

From the different aforementioned studies, it is clear that former researchers have mostly focused on electrostatic generation, dissipation, distribution and elimination in fluidized beds. Hitherto research on electrostatic behaviors in fluidized beds involving agglomerates is scanty. Previous studies have indeed confirmed that agglomerates affect hydrodynamics in fluidized beds [1,3], thus agglomerates will also affect the electrostatic behaviors, considering the fact that hydrodynamics and electrostatics effects are coupled [2]. Besides, in fluidized bed polymerization reactors, sheets may be as a result of adhesion of catalyst or catalyst-rich fines on the reactor wall [2], and therefore contain more residual catalyst than PE particles. Yu et al. [28] observed that electrostatic potential distribution would be influenced significantly by the differences of catalyst residue in the added granule polymers in a fluidized bed. Thus, as agglomerates appear and collide with other particles, electron transfer can occur and also change the electrostatic charges in the bed. In summary, appearance of agglomerates will likely influence the electrostatic behaviors in gas–solid fluidized beds and the present work is an attempt to investigate this new aspect by using aforementioned experimental method. To be specific, this research work uses induced electrostatic potential signals to characterize the electrostatic charge level in a three-dimension fluidized bed and aims to answer the following questions. Firstly, as a sheet breaks away from the wall of reactor and falls to the gas distributor, which kind of typical variation will appear for the axial electrostatic distribution? Secondly, how do agglomerates fluidized in the lower part of the bed influence the electrostatic charge level of the whole bed? Answers to these two questions will reveal the effects of agglomerates on electrostatic behaviors in a fluidized bed. Moreover, they can also provide the possibility for detecting the positions and dynamic behaviors of agglomerates, as well as making an early warning for occurrences of agglomerates through electrostatic signals.

The whole work is organized as follows. Firstly using a cold model experiment, the influence of a falling sheet on the electrostatic charge level was investigated. By analyzing and measuring the changes of particle concentration and average surface charge of particles in this process, the influence mechanism was revealed too. Secondly changes in the steady value of induced electrostatic potential were analyzed while small agglomerates were fluidized in the lower part of the bed.

2. Experimental setups, materials and methods

2.1. Experimental setups and materials

The experimental setup shown in Fig. 1 consists of two parts: a fluidized bed and a measurement system. The main unit of the fluidized bed is a Plexiglas column, 150 mm in diameter and 1000 mm in height, with a perforated distributor (pore diameter of 2.0 mm and an open area ratio of 2.6%) and a gas mixing chamber installed at the bottom of the column.

The measurement system used in this experiment contains electrostatic potential measurement, pressure measurement and charge-to-mass ratio measurement. In order to detect the electrostatic potential, 24 arched copper electrodes with a central angle of 60° [29] were tightly wrapped around the outside wall of the column at six different floors along the vertical direction. All electrodes are the same in dimension, namely, 6 mm in width and 2 mm in thickness. The layouts of electrodes along the vertical direction and on each floor are given in Figs. 2 and 3. From Fig. 3, there are four electrodes on each floor, which are named as

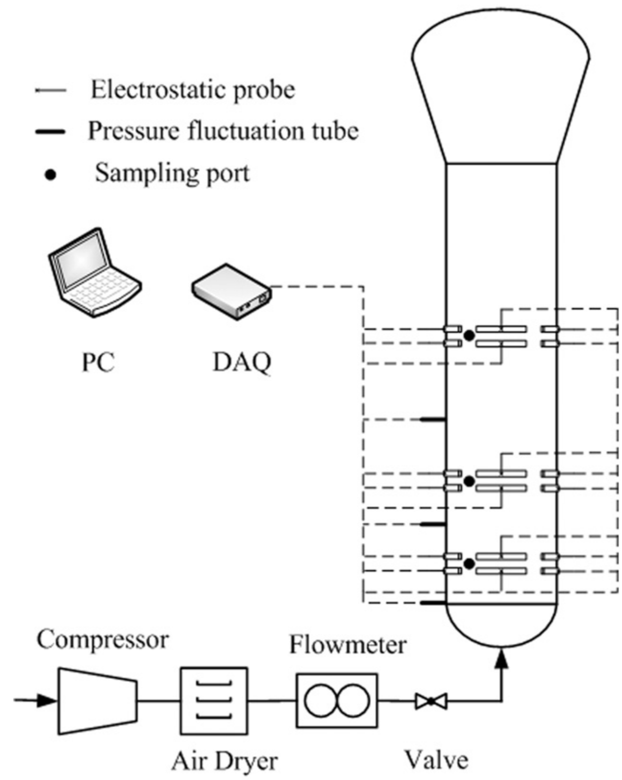

Fig. 1. Schematic diagram of experimental setups.

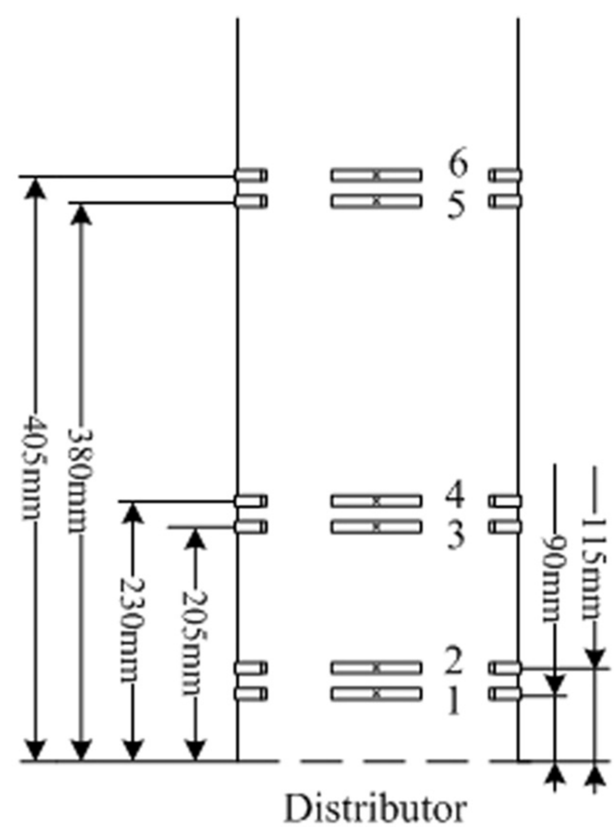

Fig. 2. Layouts of electrodes.