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The effects of granular velocity and shape factors on the generation of polymer-metal electrostatic charge

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ABSTRACT

Electrostatic charge has been observed in many gas-solid two-phase processing systems, which may cause serious industry problems, such as particle clustering, blockage and explosion hazards. However, the fundamental mechanism of electrostatic charge generation has not yet been well studied. The effects of granule velocity, granular shape factors such as front-facing angle, length-ratio and sliding area, as well as charge saturation on electrostatic charge generation were studied in this work, using polyvinyl chloride (PVC) granules (diameter 1.1–4.1 mm, with triangular or trapezoidal sliding faces). The mechanism of electron transfer between polymer and metal was analyzed. It was found that the charge generation on granules is strongly dependent on the sliding velocity. The amount of electrostatic charge generated on a granule increases with the decreasing velocity. Longer contact time is considered to account for this phenomenon. For both triangular and trapezoidal granules, the electrostatic charge generated tends to become saturated after sliding certain times, where accurate charge saturation fitting has been achieved.

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1. Introduction

Electrostatic charge is a very common industrial phenomenon in gas-solid conveying system for the transportation of particulate solids. Granules have frequent contact with each other or the inner surface of a pipe wall. This charging process is called tribo-charging or tribo-electrification [1,2]. The accumulation of charge inside the pipe may lead to electrical hazards and safety problems [3], such as particle segregation [4], sparks [5], solid clustering and even explosions [6,7].

The reasons for these phenomena occurred can be explained by chemical or physical issues. Lots of research about contact charging has been done over many years. Lowell and Rose-Innes [8] investigated three divisions of contact electrification-metals by metals, insulators by metals and insulators by insulators. Masuda et al. [9] successfully calculated powder flow rate by measuring the electric currents in gas-solid pipe flow. Matsusaka et al. [10] introduced a tribo-charging model to analyze electrostatic charge distribution of particles in gas-solid pipe flow. Li et al. [11] studied the tribo-charging properties of plastic granules in tribo-electrostatic separation process by vibration and cyclone. Various kinds of electrostatic measurement methods have been introduced for measuring the electric charge, granule velocity, mass flow rate and so on, such as inductive ring probe [12], twin-plane electrical capacitance tomography (ECT) system [13], and spatial filtering method [14]. The relationship between transport conditions (transport velocity, particle materials, particle shape, humidity, etc.) and electric charge generation has been investigated in recent years. For example, Yao et al. [3] investigated granule flows in pneumatic conveying systems at different flow rates and found typical flow patterns due to electrostatic effect. In 2006, Yao and Wang [15] used the same working system and found that granule shape has significant effect on electrostatic charge generation. In addition, humidity, granule material, flow properties and other factors were considered and an electrostatic equilibrium state was found [16] for the pneumatic system. However the mechanism of the tribo-charging process of single granule is still unclear.

In this study, electron transfer, granule sliding velocity, shape

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factors and saturation properties of a single granule are discussed. PVC granules were used due to its wide usage in industry. It was found that granules generate more charge at lower velocity after sliding the same distance on a plane wall. The saturated charge curve can be described by an exponential fitting equation, which agrees with other works.

2. Experiment

2.1. Granules

Two types of granular sliding-face shapes were studied in the work, triangular and trapezoidal. Fig. 1(a) shows a diagram of the triangular granules and Fig. 1(b) shows that of the trapezoidal. Fig. 1(c) and (d) show the microscope images of sample granule as that in Fig. 1(a),(b). Both Fig. 1(c, I) and Fig. 1(d, I) are the sliding contact faces. The length of triangular granules ranges 2.5–5.0 mm and the sliding area 3.7–7.0 mm^2. The average mass of sampled triangular granules is 13.1 mg. The length of trapezoidal granules ranges 2.0–4.8 mm and the sliding area 4.0–8.0 mm^2. The average mass of sampled trapezoidal granules is 19.44 mg. The length and width of sliding face are defined in Fig. 2. The length-ratio of triangular granule is defined as: length-ratio = length (L)/width (W), where L is larger than W. The length-ratio of trapezoidal granule is defined as: length -ratio = width (W)/length (L), where W is larger than L.

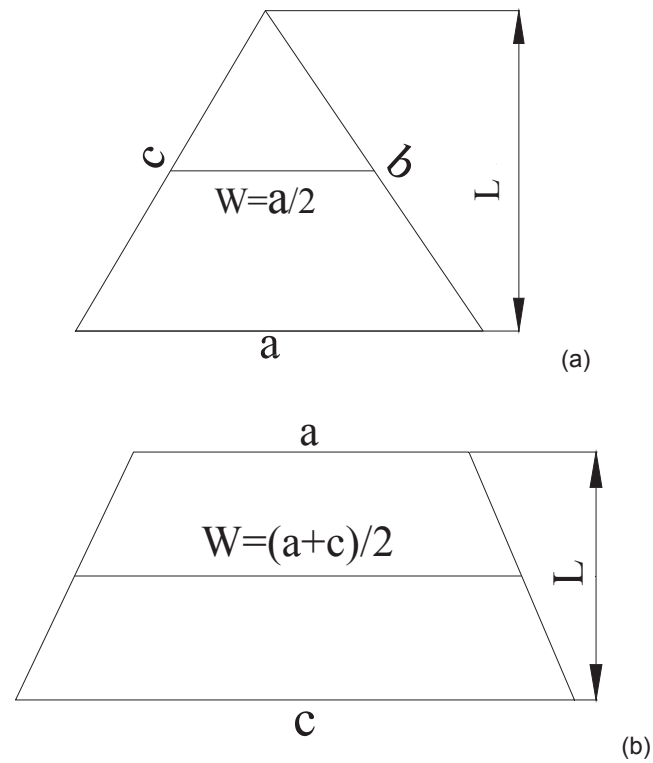

Fig. 2. Granule length-ratio of (a) triangle and (b) trapezium, where a, b, c is the side length of a granule, W is the width of a granule, L is the height of a granule.

3. Specific charge

To compare different results of all the granules, electrostatic charges are given by the following functions:

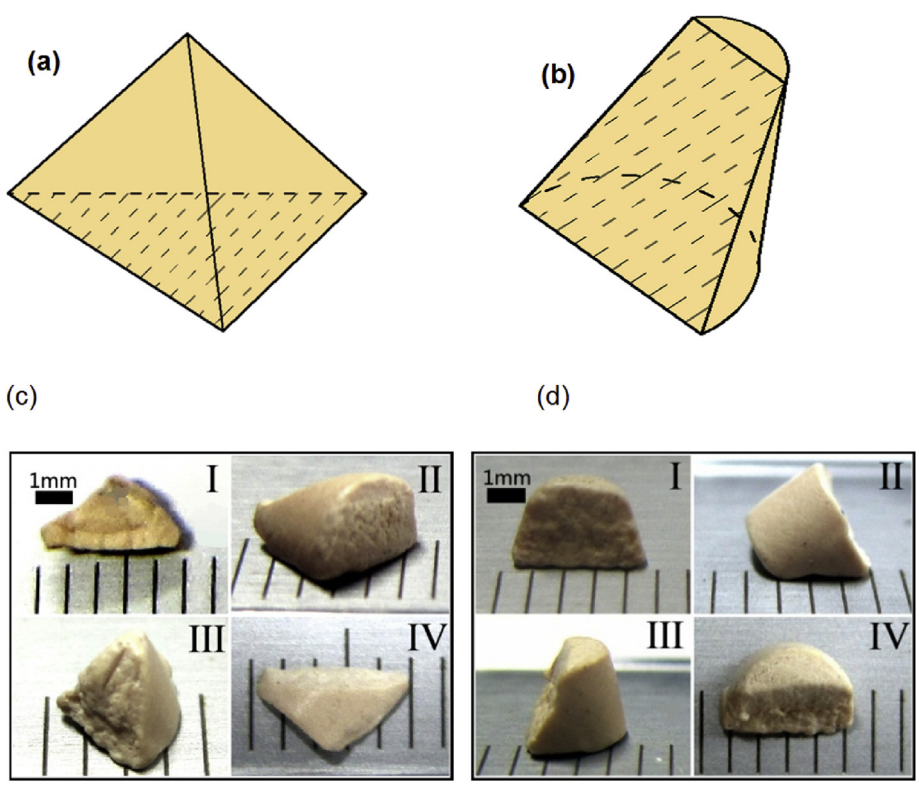

Fig. 1. Granule shape of (a) triangle and (b) trapezium,; microscope images of (c) triangular granule and (d) trapezoidal granule. In (a),(b), the dashed area is granule contact area; in (c) triangular granule I: front face (contact face), II: back face, III: side face, IV over face; (d) trapezoidal granule I: front face (contact face), II: side face, III: side face, IV over face.

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