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Experimental study on the relationship between the charge amount of polypropylene granules and the frequency of electrostatic discharges while silo loading

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ABSTRACT

This paper is a report on the relationship between the charge amount (charge to mass ratio, q/m) of polypropylene (PP, 2–3 mm) granules and the frequency of electrostatic discharges that occur while loading a metal silo. The feedback control system was used in order to control the q/m of PP granules. The electrostatic discharges inside the silo were also observed using a conventional image-intensifier system. The charging control range for PP granules was from 0 to −12 μC/kg in the q/m. The results obtained from the experiments show that (1) two kinds of electrostatic discharges were clearly observed inside a metal silo while loading PP granules, i.e., brush discharges and incendiary bulk surface discharges; (2) the number of brush discharges and incendiary bulk surface discharges increased with the increase in the q/m of PP granules, almost reaching saturation; and (3) brush discharges and incendiary bulk surface discharges began to occur at the −1.16 μC/kg and −2.33 μC/kg points in the q/m, respectively, in this study.

1. Introduction

Dust ignition hazards posed by electrostatic discharges often exist in transporting and loading of polymer powders. There is no risk of ignition by electrostatic discharges with granules that are greater than 500 μm (IEC50404, 2003). However, mixtures of granules and fine powders that are more concentrated than the low explosion limit are potentially hazardous in industrial situations. In fact, our previous studies observed visually the electrostatic discharges generated inside a metal silo while loading polypropylene granules. Some results obtained were noteworthy and, thus, published (Choi, Mogami & Suzuki, 2014; Choi, Mogami, Suzuki, Kim & Yamaguma, 2013). However, the question still remains as to what amount of charged polypropylene granules is generate electrostatic discharges during silo loading. Therefore, the main focus of this present paper is to investigate clearly the relationship between the charge amount of polypropylene granules and the frequency of electrostatic discharges that occur while loading a metal silo (Choi, Mogami, Suzuki, & Yamaguma, 2014). A primary objective of this study is to communicate new information about safety management that will be important to individuals working in the field of industrial accident prevention and mitigation.

2. Experimental

2.1. Pneumatic powder transport facility and sample granules

An actual-sized pneumatic powder transport facility was used in this study (Fig. 1). This facility was used in our previous study (Choi, Mogami, et al., 2013; Choi, Mogami & Suzuki, 2014). It consists of an earthed cylindrical silo (stainless steel; diameter, 1.5 m; body length, 3 m; capacity, 4.8 m^3), a pipeline (stainless steel; diameter, 0.1 m; total length, 23 m), an air blower (11 m^3/min) driven by an inverter motor, and an air conditioning unit controlling the temperature (30 ± 2 °C) and humidity (30 ± 2% RH) of the blowing air. The metal silo had a rotary valve (13 rpm) driven by an inverter motor to discharge sample granules from the bottom of the silo. The discharged sample granules were driven back into the silo from the top through a pipeline with a length of 20 m.

As a sample, 300 kg of polypropylene (PP, Fig. 2) granules was employed in this experiment, since PP has been widely used in chemical industries. The PP granules used in this study were the same used in our previous studies. The PP granules had a typical

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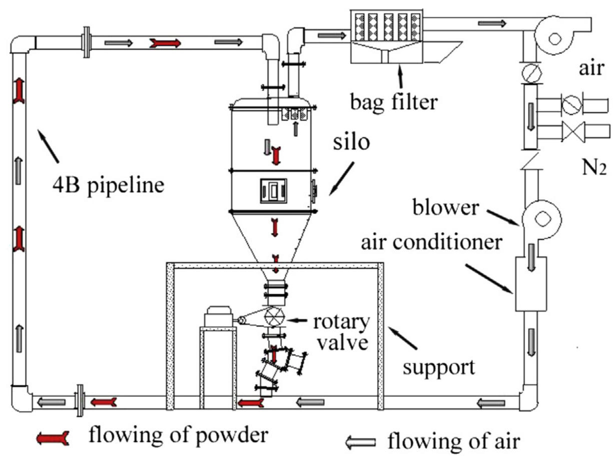

Fig. 1. Pneumatic powder transportation facility used in this experiment.

Fig. 2. Polypropylene (PP) granules used in the experiment.

particle size of 2–3 mm. The apparent volume resistivity, R [Ω•m], of the PP granules was on the order of 10^{15} Ω•m.

2.2. Observation of electrostatic discharges

For observing electrostatic discharges inside the silo, an image-intensifier unit (Hamamatsu Photonics, Ltd.; C9016-02; max. gain, 1,000,000) was set on the windowpane of the silo roof. The unit consists of an image-intensifier head, a remote controller, a CCD camera or a single-lens reflex camera, a wide-angle lens (18–35 mm), a power supply, an AC adapter, a PC, video, and a digital image recorder. The image intensifier was operated and controlled using the remote controller or a PC via the USB interface connector provided on the rear panel of the image-intensifier head. The image-intensifier unit was used with block-out curtains placed around the silo to prevent sunlight from entering.

2.3. Controlling the charge amount of PP granules

The feedback control system was used to control the charge amount (charge-to-mass ratio, q/m) of PP granules. This feedback control system has been developed from our previous study and published (Mogami, Suzuki, Choi, & Ikehata, 2010). The system is composed mainly of an ionizer (NKF10, Kasuga Denki Inc., flange-type, Fig. 3), an electrostatic air-blow field meter (KSF-0201, Kasuga Denki Inc., Fig. 4 (Choi, Kim, & Chung, 2013)), a high-voltage power source, compressed air with zero relative humidity, and

Fig. 3. Flange-type ionizer used in the experiment.

computer control equipment. The ionizer and the electrostatic air-blow field meter were attached to the end of the loading pipe inside the silo. The feedback control system imitates the process whereby the electrostatic air-blow field meter detects and monitors the electrostatic field E_e [kV/m] that occurs as a result of the charged granule particles. In this way, the feedback of the monitored data to the ionizer causes the ionizer to generate ionized air until the charged powders have reached the desired value. The relationship between the E_e and the q/m is shown in the following Equation (1) (Mogami et al., 2010):

$$q/m = \frac{2\varepsilon_0 v \pi r E_e}{u}, \tag{1}$$

where u [kg/s] is the flow rate of granules, v [m/s] is the velocity of granules, r [m] is the radius of the pipe for the electric field, and ε_0 [F/m] is the permittivity of free space (8.854×10^{-12} F/m).

It should be noted that u is 0.42 kg/s, v is 7 m/s, and r is 0.05 m in this study.

3. Results and discussion

Two kinds of electrostatic discharges inside a metal silo while loading PP granules, i.e., brush discharges and incendiary bulk surface discharges known as cone discharges, were clearly observed as shown in Fig. 5. This was taken by an image-intensifier

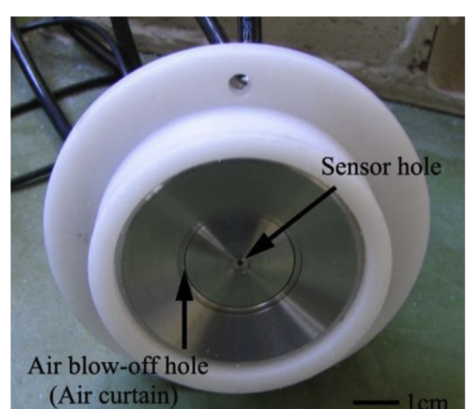

Fig. 4. Electrostatic air-blow field meter used in the experiment.