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Control of electrostatic charge for powder by using feedback control-type ionizer system

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ABSTRACT

As a method to prevent or mitigate cone discharges in a specific section such as a large silo, we have developed a new feedback control-type ionizer system. The feedback control-type system is composed mainly of an ionizer, an electrostatic field strength meter, and computer control equipment. In this study, we evaluated experimentally the practical version of the feedback control-type ionizer system through several tests in a pneumatic powder transport facility. The specific charges of the falling pellets in the silo were also measured for 10 s using a Faraday cage. Polypropylene (PP) pellets with a mean particle size of 3 mm were used in this experiment. The results of the experiment revealed that the feedback control-type ionizer system had the following characteristics: (1) it is possible to control the performance of the ionizer with a supply current; (2) the electrostatic field strength in the loading pipe from the charged powder is reduced and maintained at near zero by using the feedback control-type system; and (3) the performance of the feedback control-type system is superior to that of others, such as the conventional AC- or DC-type ionizers.

1. Introduction

As powder technologies have rapidly been progressing, various new flammable powders have been produced and are used in a variety of industrial processes. Electrostatic charge and/or discharge frequently occur in processes involving powders. Especially, when loading and storing nonconductive pellets within a specific environment, such as a silo, strong electrostatic discharge known as the cone discharge may often occur on the charged pellet heap (Glor, 1984, 1988). Such a discharging phenomenon may cause an explosion or fire when an explosive dust cloud is present simultaneously. From the viewpoint of safety engineering and within the background reported above, experimental studies related to hazardously charged powders have widely been conducted for years (Choi, Yamaguma, Kodama, Suzuki, & Mogami, 2005; Kodama, Suzuki, Nishimura, Yagi, & Watano, 2002; Kodama, Suzuki, & Mogami, 2003; Watano, Saito, & Suzuki, 2003). We developed a nozzle-type electrostatic ionizer with an electrostatic detection meter to reduce the charge of pellets before they enter a silo in a pneumatic transport system (Watano, Saito, & Suzuki, 2002). Testing conducted in previous research indicated that the nozzle-type ionizer generally performed as expected, but several disadvantages were discovered, such as insufficient charge elimination (AC-type) and reverse charging (DC-type). In order to overcome these problems, we have introduced a new feedback control system for a nozzle-type ionizer to reduce and/or manage the charge in powders. The present study is devoted to clarity the performance of a feedback control-type ionizer system through several tests.

2. Development of feedback control-type ionizer system

The feedback control system developed in this study consists of a nozzle-type ionizer (NKF10, Kasuga Denki Inc.), an electrostatic air-blow field meter (KSF-0201, Kasuga Denki Inc.), and computer control equipment. This system imitates the process whereby the electrostatic field strength sensor detects and monitors the electrostatic field strength that occurs as a result of the charged powder particles. In this way, the feedback of the monitored data to the ionizer causes the ionizer to generate ionized air until the charged powders are completely neutralized.

In general, the magnitude of the ions generated by an ionizer is indirectly controlled by adjusting either the voltage applied to the electrode of the ionizer (applied-voltage-control method) or the current applied to the ionizer (applied-current control method). As the first step, we examined and compared the two methods

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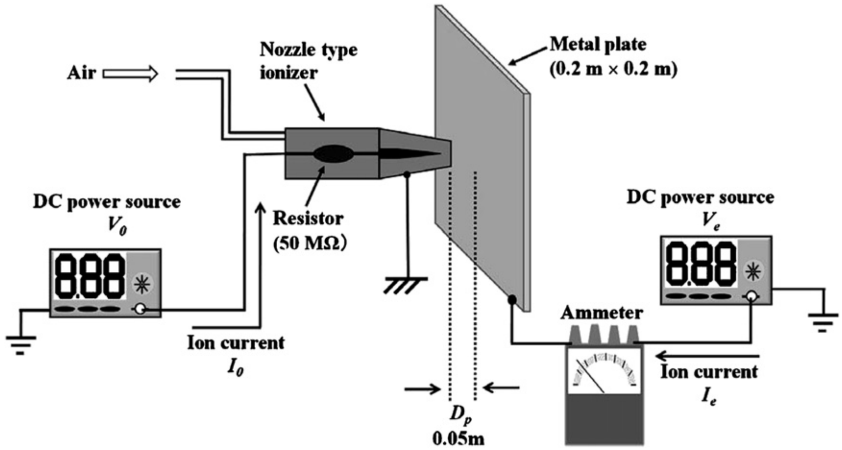

Fig. 1. Schematic of the ion current measurements for the ionizer.

through modeling tests of the control performance of the ions generated by the ionizer. Fig. 1 is a schematic diagram of the modeling test for the ion control performance of the ionizer. It consists of a nozzle-type ionizer, a high-voltage DC power source with an amplifier (Trek, Model No. 664A), an ammeter (Yokogawa, Model No. 2011), an air compressor (Hitachi, 250 ℓ, 10.4 kgf/cm), a fully automatic air dryer (CKD, RD-2008), controllers for the air pressure, and other auxiliary devices.

For the applied-voltage-control method, the voltage, V_o, applied to the electrode of the ionizer and the ion current, I_e, coming from the electrode of the ionizer (i.e., characteristics of V_o–I_e) were experimentally investigated. On the other hand, the current, I_o, applied to the electrode of the ionizer and the ion current, I_e (i.e., characteristics of I_o–I_e), were investigated for the applied-current control method. Both V_o and I_o were controlled and recorded automatically by a computer through GP-IB. The distance, *Dp,* between the opening of the electrostatic eliminator and the metal plate (0.2 m × 0.2 m) was 0.05 m. The I_e was measured with an ammeter connected to a metal plate impressed with a high-voltage dc of 10 kV (in negative polarity). It is noteworthy that the polarity of the high-voltage impressed on the metal plate in the present paper was negative since the charged polypropylene pellets used in this experiment in the pneumatic powder transport facility were negatively charged. The edge of the plate electrode was covered with an insulator film (PTFE) to prevent any current leakage. The test conditions were 30 ± 2 °C and 30 ± 5% RH.

The I_e–V_o and I_e–I_o characteristics are shown in Figs. 2 and 3, respectively. Compressed air at a pressure of 0.1–0.3 MPa was supplied to the nozzle in this study. As a result, the I_e in both models was shown to increase significantly with the air pressure P_a provided to the surrounding region of the needle electrode. We also found that a corona discharge initiated when approximately 3 kV was applied to the electrode of the ionizer in the voltage control method (i.e., corona onset voltage V_{onset}, 3 kV). With 4 kV of applied voltage, the I_e became saturated. In other words, the range of the applied voltage for controlling ions was rather limited (see Fig. 2).

In contrast, the I_e in the current control method, as shown in Fig. 3, increased with an increase in I_o. The range for ion control is clearly wider in this method than in the method using voltage control. These findings suggest the possibility to control the performance of the ionizer by controlling the supplied current.

Taking the experimental results described above into account, we chose the current control method for the performance tests of the feedback control system. Since the output values of I_e are non-linear with I_o, PID (proportional, integral, and derivational) control using practical feedback is not easily introduced (Watano et al., 2002, 2003). As a trial and for stability in tests of long operation, we

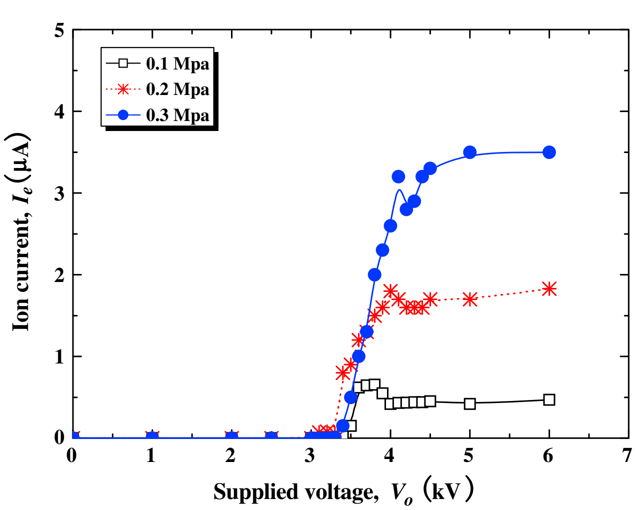

Fig. 2. Relationship between I_e and V_o in the model experiment.

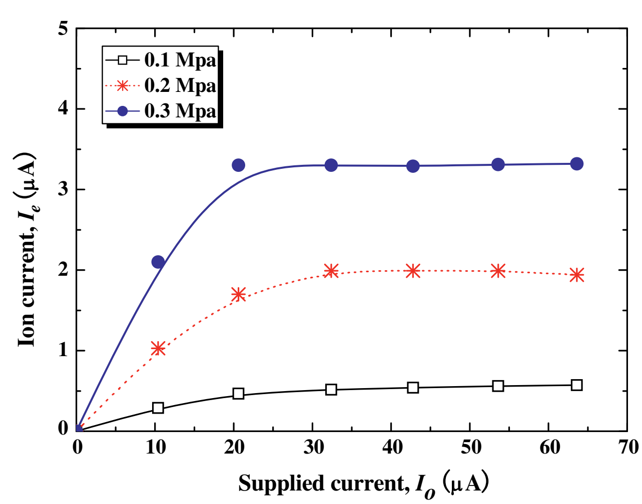

Fig. 3. Relationship between I_e and I_o in the model experiment.