



ELSEVIER

Contents lists available at ScienceDirect

Journal of Electrostatics

journal homepage: www.elsevier.com/locate/elstat

Measuring electrostatic charging of powders on-line during surface adhesion

Janne Peltonen*, Matti Murtomaa, Jarno Salonen

Department of Physics and Astronomy, University of Turku, 20014 Turku, Finland



ARTICLE INFO

Keywords:

Electrostatic charging
Powder adhesion
Powder mixtures
Measurements

ABSTRACT

Electrostatic charging of powders and powder mixtures were measured on-line during surface adhesion by sliding the powders in a pipe. The cumulative charge was monitored as a function of transferred powder mass. The effect of adhesion on the charging was assessed by observing the slope of the measured curve at the very beginning of the measurement. Due to adhesion, the charging decreased exponentially. For mixtures, the powder with higher concentration initially dominated the charging. The sign of the charge changed as the additive powder started to adhere, indicating that contacts between the two dissimilar powders started to govern the charging.

1. Introduction

Electrostatic charging (triboelectrification) is an important phenomenon when insulating powders are transported or handled. Powder particles collide with other particles and with the surfaces of the transportation or handling system. As a result, electrostatic charge is accumulated on the particles. Charging may increase adhesion/cohesion of the particles [1–4], which may hamper, for example, the packing behaviour of the powders or dosing accuracy in pharmaceutical industry, and may lead to unwanted breaks in the production line [5]. On the other hand, adhesion of charged particles is the basis of laser printers [6], and electrostatic powder painting and coating [7–9]. Matsusaka et al. have made a comprehensive review of concepts and mechanisms of triboelectric charging of powders [10].

When mixtures of different powders are handled, the charging process is often more complicated and more unpredictable than with pure materials [11–14]. Moreover, if the contacting surface gets contaminated by adhered particles, the charging becomes dependent on the adhesion [15–18]. The charge generated with a clean surface differs from a charge generated with a contaminated one [15]. As the adhesion increases, the charge of the transported powder eventually reaches a steady-state value [11,12,19]. This saturation value can be close to zero with a one-component powder. On the other hand, it is also known that electrostatic charging is observed also in single-component granular systems so that larger particles tend to charge positive and the smaller ones negative [20,21]. For a powder mixture, the sign of the charge can change as the contact changes from particle–surface contact to particle–adhered particle contacts. At certain concentrations, the net charge of the mixture can be close to zero.

Previously, charging studies by sliding have been performed so that a small amount of powder is fed into the pipe, its charge is measured, it is weighed, and the charge-to-mass ratio is calculated. This is repeated until a certain amount of powder in total is fed [12,14,19]. As a result, charge-to-mass ratio as a function of cumulative mass is observed. If ones aim is to study the effect of surface adhesion on the charging, it is important to feed very small amounts of powder at a time. Therefore, collecting enough data becomes relatively slow with this method. In this study, the charging of powders and powder mixtures with different concentrations was studied by continually measuring the cumulative charge and mass on-line as they made contact with different pipe materials. In this arrangement, cumulative charge as a function of cumulative mass is observed. The charge-to-mass ratio at each point can be obtained by taking a derivative.

The main objectives of this study were: 1) How to measure electrostatic charging of powder in contact with a clean surface, *i.e.* how can the effect of adhesion be evaluated? 2) At the point when particles start to adhere onto the surface, how does the charging change? 3) How does the charging of a powder mixture change with adhesion?

2. Materials and methods

2.1. Materials

Mannitol, dicalcium phosphate, and starch (corn) powders were studied. Microscopic images (Fig. 1) reveal that the particle size of mannitol was some hundreds of micrometres, while the particle size of dicalcium phosphate and starch was tens of micrometres. Stainless steel, polyethylene (PE), polypropylene (PP), and polyvinyl chloride

* Corresponding author.

E-mail address: janne.m.peltonen@utu.fi (J. Peltonen).

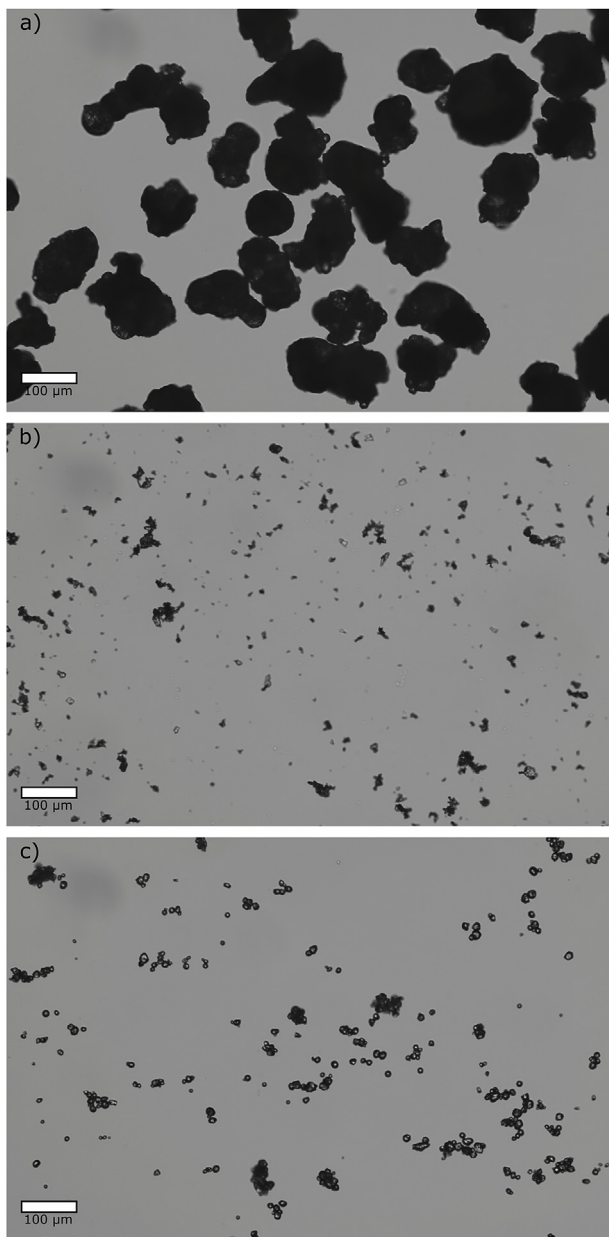


Fig. 1. Microscopic images from a) mannitol b) dicalcium phosphate c) starch.

(PVC) were used as pipe materials. Steel pipe was grounded during the measurements. The lengths of the pipes were 500 mm and inner diameters 25 mm.

2.2. Charging experiments

Powders were charged by sliding in a thin stream in a pipe with an angle of 45° relative to the horizontal level. From the pipe, the powder particles continuously dropped into a lightweight Faraday cup ($m = 180$ g), which was placed on a balance (Ohaus EX225D, resolution 0.0001 g). The cumulative mass and charge of transferred powder were simultaneously measured until the whole sample batch had been fed. The set-up is presented schematically in Fig. 2.

The Faraday cup consisted of two concentric cylindrical cups that were separated from each other with an insulator. The voltage difference between the cups was measured using a non-contacting voltage meter (Trek Model 400 P-S probe). It was placed at the distance of 1 mm from the inner cup through a hole in the outer cup and connected to

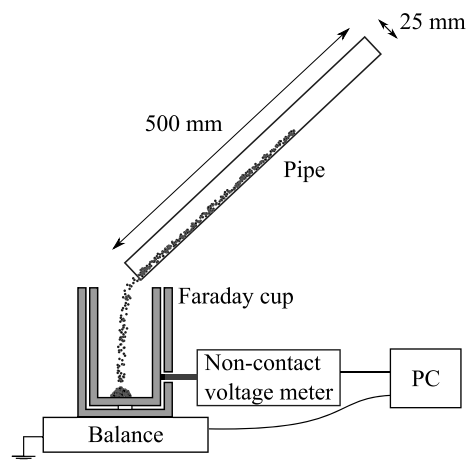


Fig. 2. The measurement set-up (not to scale).

Trek Model 400 voltmeter (resolution 1 V). The voltage reading was transferred to Keithley 6517B electrometer. The voltage difference V between the cups was continuously measured, and the charge Q of the powder was calculated from equation $Q = CV$, where C is the capacitance of the Faraday cup. In order to determine the capacitance, 30 induction charged water droplets with a known positive charge (0.17 nC each) were dropped into the Faraday cup and V was measured (138 V), resulting in $C = 3.7 \cdot 10^{-11}$ F. The cumulative mass and voltage (charge) were simultaneously recorded with a sampling frequency of 10 Hz using a LabVIEW programme. Since the Faraday cup sensed the entering powder slightly before the balance, the powder was fed relatively slowly into the pipe, 1 g per minute at maximum. The measurements were performed at the temperature of 21 C and in relative humidity of 30 ± 5 RH%.

Whenever electrostatic charging is measured, attention needs to be paid to ensure that the samples are neutral before the measurements and that the sampling does not cause significant charging. Before the measurements, the powder samples were neutralized with an AC neutralizer and they were placed on grounded metallic plates in order to allow any possible initial charge to decay to ground. During the measurements, powder was inserted into the pipe with a grounded steel spatula under the neutralizer. Before each measurement, the pipes were cleaned with tap water and ethanol and then blow-dried. They were neutralized with a corona neutralizer equipped with a fan.

Attention was also paid on the insulation of the Faraday cup so that the charge inside the inner cup did not decay to ground during the charge measurements. Test measurements showed that decay was only 0.1 nC in a typical measurement time of 5 min.

According to a previous study [19], the charge-to-mass ratio q of a fed powder batch decreases exponentially as a function of transferred mass m , that is

$$q(m) = q_1 e^{-m/m_0} + q_\infty, \tag{1}$$

where q_1 is amplitude, q_∞ is the saturation value, and m_0 is an adhesion coefficient describing the mass at which the q is decreased to 37% of its initial value. Smaller the m_0 , faster the saturation. In this study, however, the cumulative charge Q_c was measured instead of charge-to-mass ratio. Q_c can be simply expressed as the integral of the previous equation:

$$Q_c(m) = \int q(m) dm = -q_1 m_0 e^{-m/m_0} + q_\infty m + Q_0, \tag{2}$$

where Q_0 is an integration constant. The equation above was fitted to the measured data. The fitted curves were then differentiated in order to obtain the charge-to-mass ratio as a function of cumulative mass. The value $q_{m \rightarrow 0} = q_1 + q_\infty$ is considered as the generated charge-to-mass ratio of the powder particles before adhesion, since it is the slope of the

Download English Version:

<https://daneshyari.com/en/article/7117107>

Download Persian Version:

<https://daneshyari.com/article/7117107>

[Daneshyari.com](https://daneshyari.com)