

Unipolar Charging and Contact Discharging of Insulating Particles on the Surface of a Grounded Electrode

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Abstract - The study of the unipolar charging of insulating particles has been stimulated by the recent development of several important electrostatic technologies: precipitation of dusts, deposition of powders, separation of granular materials. The aim of the present work is to analyse the discharging conditions of insulating disks in contact with an electrode, after having been charged in a unipolar corona field. The experiments were carried out on a roll-type electrostatic separator that simulated the charging/discharging conditions in an industrial unit. The measured data show that the discharge process is a complex phenomenon, depending of at least the following factors: the conductivities of the respective bodies, the aspect of the contact, and the environmental conditions.

1. Introduction

The technological developments in the field of electrostatic processing of particulate matter (precipitation of dusts, deposition of powders, separation of granular materials [1-5]) have always stimulated the research of the physical phenomena related to the ionic charging of conducting and non-conducting particles in D.C. or A.C. electric fields [6-8]. The equations established by Pauthenier and Moreau-Hanot some 70 years ago [9], continue to be confidently used for modeling the unipolar charging of single spherical particles moving freely in a uniform external electric field E_0 , where uniform monopolar space charge with density q exists. This model that is accurate enough for the electrostatic precipitators, as in most industry applications the dust particles are larger than 2 μm in diameter (thermal diffusion could be neglected) and their volume concentration is low.

Numerical techniques can presently be employed for evaluating the ionic charging of particles under different conditions, non-amenable to analytical calculations: single stationary spheres in a uniform electric field [11, 12], single spherical particles moving on the surface of an electrode [13], one or several insulating cylinders evolving in a monoionized electric field [14]. The experiments carried out on the unipolar charging of insulating particles in contact with the rotating roll electrode of a corona-electrostatic separators validated some of these results [15, 16]. They pointed out an additional effect of significant importance for the outcome of the electrostatic separation process: the decay of the charge carried by the particles in contact with an electrode [17].

The aim of the present work is to analyse some of the factors that influence the discharging conditions of insulating disks in contact with an electrode, after having been charged in a unipolar corona field.

2. Materials and method

The study was carried out on of four types of disk-like insulating particles, described in Fig. 1. The samples II to IV were obtained by classification from a genuine polyamide granular material provided by a plastic manufacturer. Type III and IV are cylinders terminated by curved surfaces. In order to obtain type II particles closer in shape to a “standard” disk, glass paper was used to convert the curved bases of genuine granules similar to those of type III and IV into rather smooth planes.

Particle charging/discharging conditions in an industrial unit were simulated by using a laboratory roll-type corona-electrostatic separator (CARPCO, Jacksonville, FL), provided with a wire-type corona electrode, located at a distance $s = 50$ mm from the surface of the grounded roll electrode and brought to a positive potential $U = 25$ kV (Fig. 2). In each experiment, groups of three particles were placed on the surface of the roll electrode, with their centers located in the vertical plane defined by the corona wire and the axis of the roll electrode. They were subjected to a corona field for 10 s. Then the roll drive was turned on, at a speed n high enough to throw off the particles, to be collected in a Faraday pail connected to the electrometer (KEITHLEY INSTRUMENTS, Model 6514). The separator was also provided with a thin metallic wire, the role of which was to remove the particles too tightly “pinned” on the surface of the roll electrode. After turning off the high voltage, the particles were maintained in the same position for intervals of time varying from $t_{\text{disch}} = 0$ s to 4 min.

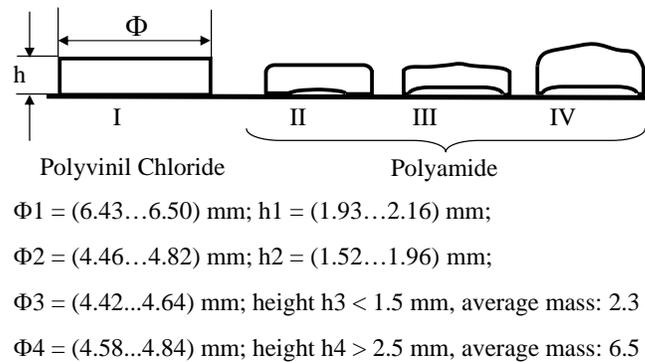


Fig. 1. Schematic representation of the four types of particles employed for this study.

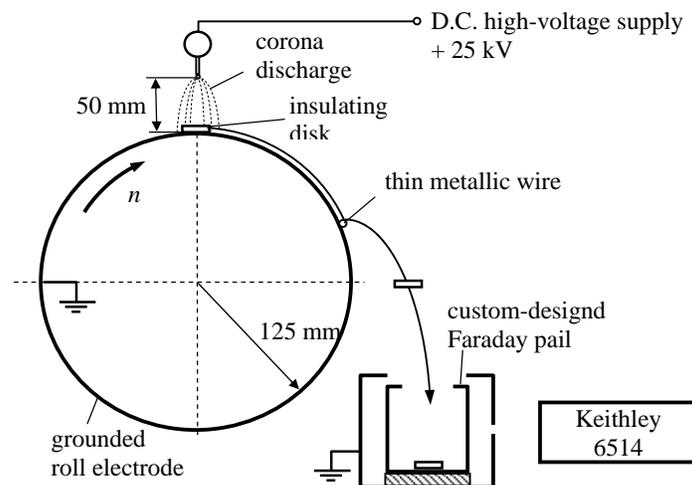


Fig. 2. Schematic representation of the experimental set-up.

3. Results

In the first set of experiments, the discharging of type I particles was carried out for various distances d between adjacent particles. The charge of the particles was found to decrease with the discharging time t_{disch} as shown in Fig. 3, where each point was obtained by dividing the measured charge by the number of new particles collected in the Faraday pail at each experiment.

Type II particles were employed in the similar set of experiments, the results of which can be examined in Fig. 4. The data measured during the other two sets of experiments, involving respectively the particles of types III and IV, are represented in Fig. 5.

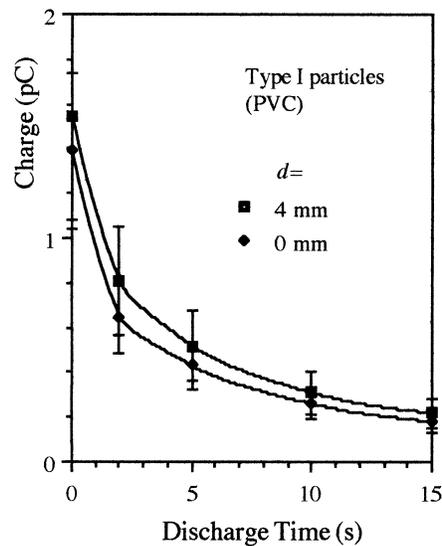


Fig. 3. Charge Q of type I particles as function of discharging time t_{disch} , (the particles were charged at +25 kV, $s = 50$ mm).

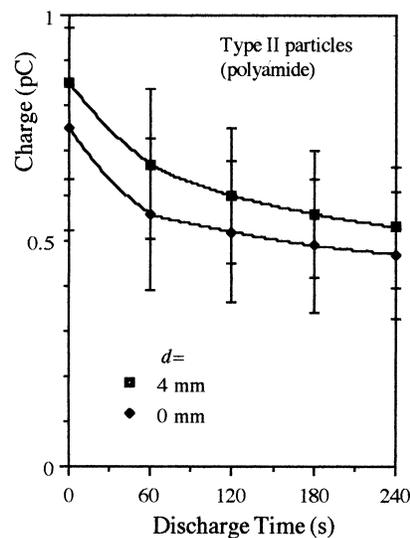


Fig. 4. Charge Q of type II particles as function of discharging time t_{disch} ,

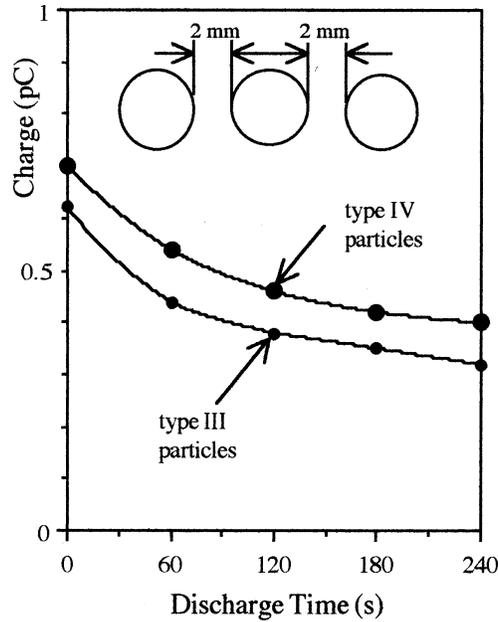


Fig. 5. Charge Q of type III and type IV particles as function of discharging time t_{disch} .

4. Discussion

The study of ionic charging and discharging of particles in contact with an electrode may give clues for the improvement of the efficiency of industrial electrostatic separation processes. Previous studies demonstrated that the proximity of other bodies modifies the distribution of the electric field and hence the conditions of corona charging of insulating particles, as compared with the case when they are single in a uniform electric field. This is why the experiments were conducted for different distances between adjacent particles.

The results in Figs. 3 and 4 confirm previous findings: distanced particles acquire larger amounts of charge than those very close to each other do. This aspect, as well as the dynamics of particle discharging in contact with the carrier electrode, should be taken into account in the development of any new electrostatic separation technology.

The charge decay rate of polyamide, which is a very good insulator, is much lower than that of PVC. The charge of polyamide disks reduces to $\frac{1}{2}$ in more than 4 minutes, against less than 2 seconds for PVC particles. Thus, the difference in charge decay rate might become a mean for selective sorting the constituents of a granular mixture of insulating materials in contact with a grounded electrode. Judging from the dispersion of the measured charge values in the reported experiments, the feasibility of such an application of the electrostatic separation technology depends on the solutions found for reducing the dispersion of particle size, the non-uniformity of the corona generated by the wire electrode, as well as the variation in the state of the surface of the carrier electrode and the aspect of particle-electrode contact.

At roughly same diameter, the disks in sample IV have a larger lateral surface and carry a larger amount of charge than those in sample III, but the dynamics of charge decay seems to be similar (Fig. 6). Nevertheless, more experiments are needed to explore in depth the effect of size, shape and contact surface geometry on particle discharging conditions. Indeed, the charge decay rate of type II particles is slightly different of that measured for the disks of type III and IV, which have a different geometry.

As the sets of experiments were done in different environmental conditions, the control of ambient temperature and relative humidity should be mandatory for any further experiment on this delicate issue.

5. Conclusion

The discharging of insulating particles in contact with a grounded electrode is a complex phenomenon, depending of at least the following factors: the surface/volume conductivities of the respective bodies, the aspect of the contact, and the environmental conditions.

- 1) The good insulators display lower charge decay rates than less insulating particles. This property could be used for separating two sorts of plastics, for instance.
- 2) Particles of same nature but dissimilar with respect to the aspect of their surface (geometry, roughness) behave differently in contact with an electrode. The explanation resides in the relation existing between the charge decay rate and the particle-electrode contact resistance. When one or more of the constituents of a granular mixture are highly non-homogeneous in terms of particle size, shape and surface state, the electrostatic separation is very likely to fail, as particles that are similar in nature will carry different charges and will evolve along totally different trajectories.
- 3) The relative humidity of the ambient air can modify the value of the contact resistivity and hence the discharging conditions. Further investigations are needed to quantify the effect of particle-electrode contact and of the environmental conditions on the charge decay rate of insulating granules in situations similar to those encountered in the various industry applications of the electrostatic separation processes.

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