Journal of Electrostatics 82 (2016) 55–62

Contents lists available at ScienceDirect

Journal of Electrostatics

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

Electric potential distribution at the surface of insulating materials exposed to corona discharges from various electrode configurations

A. Reguig [a], A. Bendaoud [a, *], B. Neagoe [b], Y. Prawatya [b], L. Dascalescu [b]

[a] APELEC Laboratory, Djillali Liabes University of Sidi Bel-Abbes, Algeria
[b] PPRIME Institute, University of Poitiers — IUT, Angoulême, France

ARTICLE INFO

Article history:
Received 21 February 2016
Received in revised form
26 May 2016
Accepted 31 May 2016

Keywords:
Corona discharge
Electric potential
Electrode
Electrostatic separation
Insulating materials

ABSTRACT

Higher and more uniform charging of insulating granules in electrostatic separators increases separation efficiency. The aim of this work is to analyze the effect of a metallic shield in the proximity of "dual-type" or "triode type" corona electrode configurations. The basic idea is to measure the electric potential at the surface of polyvinyl plates exposed to the corona discharge generated by these electrodes. A first set of experimental results clearly show that the presence of the metallic shield enlarges the distribution of charges generated by corona discharge and produces higher electrical potential values on the surface of polymers. A second experiment points out the efficiency of the shielded electrode system for the charging of granular insulating materials in electrostatic separators. These experiments are discussed in relation with the results of the numerical analysis of the electric field generated by the different electrode configurations, taking into account the presence of an insulating material on the surface of the collecting electrode.

1. Introduction

Corona discharge is widely used in a variety of electrostatic process applications [1,2], including dust precipitation [3], separation of granular mixtures [4,5] and the treatment of polyethylene films for cable insulation [6,7]. Several research groups have studied the charging mechanism of insulating materials by corona discharge in various industrial domains, such as xerography, electret production, and electrostatic separation [8–14].

The charging of insulating materials in electrostatic separators can be performed by several types of "dual electrodes" consisting in a corona emitting element (wire, blade, or multi-pins) and a metallic support, connected at the same high voltage [14–18]. Recent works have been done to record the current–voltage characteristics of the various such electrode configurations, the current density distribution at the surface of the collecting electrode and the electric potential decay at the surfaces of insulating materials exposed to corona discharges [19,20]. These studies have been carried out in certain well-defined conditions (distance between the electrodes, level and polarity of the applied high voltage) [10,14].

In a "triode-type electrode system", a metallic grid is interposed between the corona electrode and the grounded plate on which the insulating materials are placed. The authors employed this system for the corona charging of polypropylene non-woven media for air filtration applications [21]. The results of a thorough study of this electrode configuration are reported in [22].

The presence of a metallic shield in the proximity of a corona electrode modifies the intensity and the spatial distribution of the discharge, as the authors have shown in a recent paper [23]. The aim of the present work is to evaluate the effect of such a metallic shield on the corona charging of insulating materials when using either a "dual electrode" or a "triode-type electrode system". The experiments involve the measurement of the electric potential values at the surfaces of polyvinyl chloride (PVC) plates, previously exposed to corona discharges in the two above-mentioned electrode configurations, with and without shields. The measurements are performed using the induction probe of an electrostatic voltmeter [24–26]. These experiments are discussed in relation with the results of the numerical analysis of the electric field generated by the different electrode configurations, taking into account the presence of an insulating material on the surface of the collecting electrode. The conclusions regarding the improvement of the corona charging efficiency in the presence of the metallic shield are

---

* Corresponding author.
E-mail address: abdelber.bendaoud@univ-sba.dz (A. Bendaoud).

http://dx.doi.org/10.1016/j.elstat.2016.05.006
0304-3886/

validated by the results of a corona-electrostatic separation experiment.

2. Experimental procedure

The basic electrode configuration used in this work is shown in Fig. 1(a): the "dual electrode" consisted in a tungsten wire (0.2 mm in diameter) attached to a metallic cylinder (26 mm in diameter) and distanced at 34 mm from its axis [14,16]. The wire and the cylinder are energized from a fully-adjustable high voltage supply −40 kV, 7.5 mA (Model SL40, Spellman Inc).

In a series of experiments, the corona discharge is generated by the "dual electrode" located at a distance h from the grounded plate electrode (250 mm × 160 mm). A grounded metallic shield may be located in its proximity, as shown in Fig. 1b.

Other experiments are conducted on the "triode electrode system" with and without shield as shown in Fig. 2. The grid is connected to the ground through a 40 MΩ resistor. In this way, for an intensity I_g fixed by the constant voltage V_s of the high-voltage supply, a well-defined constant potential $V_g = RI_g$ is imposed between the grid and the grounded plate electrode [21].

A PVC plate (180 mm × 50 mm × 5 mm) is placed on the grounded plate electrode.

In all the experiments, the upper surface of the sample is exposed for 3 s to corona discharge in ambient air (temperature: 18 °C to 20 °C; relative humidity: 30%–40%).

In a first set of experiments, current–voltage characteristics are recorded in all configurations under study (i.e., "dual electrode" and the "triode-type electrode system" with and without presence of the shield), with the PVC sample disposed on the grounded electrode.

In the second set of experiments, the surface potential is measured with an electrostatic voltmeter (Trek Model 341B, equipped with a static probe 3450 model) [24]. The electrical potential measurements are captured by an electrometer (Keithley, model 6514) connected with a personal computer. The acquisition of experimental data is carried out by an ad-hoc virtual instrument, developed in LabView environment (Fig. 2).

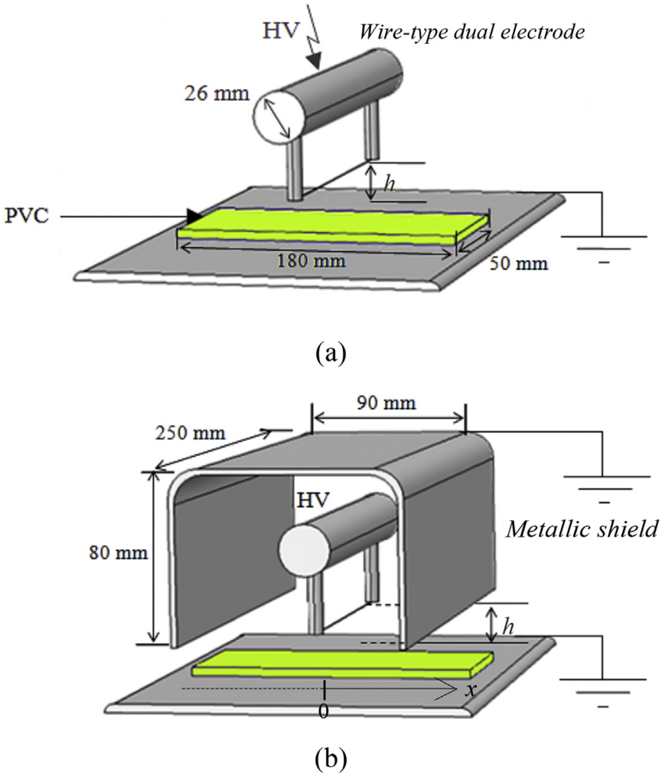

Fig. 1. Wire-type dual electrode used for charging a PVC plate; (a) without shield; (b) with grounded shield.

The mapping of the electric potential distribution at the surface of the samples starts only 200 s after turning off the high-voltage supply of the electrode system, so that to avoid the errors due to the rapid decline of the electric potential during the first 3 min after corona-charging. The total time required for the measurements is about 2 min.

Finally, some experiments are carried out on the Carpco laboratory roll-type electrostatic separator (Fig. 3) with and without a grounded shield in the proximity of the high voltage corona electrode. These experiments are conducted in order to test the efficiency of such electrode configuration on the charging process of insulating granular mixtures in industrial applications [5] and [9]. The control variables are fixed as follows:

1) Inter-electrode spacing: $h = 40$ mm.
2) Roll speed: $n = 40$ r/min, roll radius: $R = 135$ mm.
3) Position angle of the corona electrode: $\alpha_1 = 20°$.
4) Position angle of the electrostatic electrode: $\alpha_2 = 65°$.
5) Feed rate: $m = 40$ kg/h

In these experiments, the separator is equipped with a wire-type "dual electrode", with or without shield. All the tests are conducted on the same sample (Fig. 4) at stable environmental conditions (i.e., 18 °C–20 °C, 49%–52% RH).

The processed materials consist of 100-g samples of a granular electric-wire waste supplied by CITF (Conception Industries Technologies Futures, Charente, France). The quantities of products collected in three bins (conductor, middling, and non-conductor) are weighed separately. Then, the insulating content is evaluated in the two situations, in order to compare the efficiency of corona charging in the electrostatic separation process with and without the presence of the shield.

3. Results and discussion

3.1. Current–voltage characteristics

The I–V characteristics recorded using the wire-type "dual electrode" in the presence of the PVC sample at the surface of the grounded electrode plate are displayed in Fig. 5. They clearly point out an increase of the current I_m generated by corona discharge in presence of the shield.

Similar results are recorded in the triode electrode system by measuring the grid current I_g (Fig. 6). This is due to the electric field intensification at the surface of the corona emitting element [27]. The higher values of the corona current are accompanied by an increase of the electric potentials measured at the surface of polymers exposed to corona discharges by both the wire-type "dual electrode" and the "triode-type electrode system" (due to the increase of grid potential V_g).

3.2. Surface potential decay

Fig. 7 shows the electric potential decay in the central point ($x = 0$) of the sample after been charged for a period of 3 s using a wire-type dual electrode with and without shield. The surface potential decreases quite rapidly during the first 3 min and much more slowly after that. The initial potential at the sample surface is higher for the electrode with the shield and decrease slightly faster