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Experimental study of a modified dual-type high-voltage electrode for electrostatic separation applications

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A B S T R A C T

Several electrode arrangements have been proposed to enhance the efficiency of insulating materials charging by corona discharge. Recent studies pointed out that the presence of metal strips in the proximity of a dual-type high voltage electrode increases the total current measured at the surface of the collecting electrode, decreases the corona onset voltage value and enlarges the reparation of current density as well. The aim of this paper is to evaluate the benefits of using such an electrode arrangement for corona charging of non-conductive particulate materials in belt-type corona-electrostatic separators. The experimental study was carried out with samples of Aluminum and Polystyrene particles in the size class 125–250 µm. The presence of grounded strips reduces the electric wind, which is associated to corona discharge but not tolerated in such processes that involve micronized materials. At the same time, it improves the corona charging conditions of non-conductive materials and as consequence the overall efficiency of the corona-electrostatic separation process. The use of the new electrode configuration is characterized by both high recovery rates and better purities of the separated products.

1. Introduction

Electrostatic separation is defined as the sorting of solid species by means of the electric forces which act on charged or polarized bodies [1]. The range of applications extends from mineral beneficiation and seed conditioning, to food industry and waste recycling [2–10].

In the widely-used roll-type corona-electrostatic separator, a high-intensity electric field is generated between a grounded electrode and one or several electrodes connected to a high-voltage supply, which achieve the corona-charging of non-conductive materials and the trajectories control of the electrostatic-induction-charged conductive particles [11]. These separators are typically employed to process mm-size metal and plastic granules originating from various industrial wastes [12].

However, these separators are inappropriate for processing finely-grinded wastes or powdery materials, because of the difficulty of controlling the trajectories of micrometric-size particles simultaneously subjected to electrical, centrifugal and aerodynamic forces. According to a recent study [13], the belt-type corona-electrostatic separator might be the solution of choice for processing finer particles mixtures, obtained from waste electric and electronic equipment (WEEE) [14].

Many corona electrode arrangements have been developed and extensively studied in relation with such electrostatic applications [15, 16]. In both the roll- and belt-types electrostatic separators, the charging of non-conductive materials is performed by dual-type electrodes consisting in a corona emitting wire associated to a metallic support and connected to the same high voltage [13, 17, 18].

In a recent paper [19], the presence of metallic grounded strips in the proximity of the wire electrode was shown to increase the total current measured at the surface of the collecting electrode, to decrease the corona onset voltage value and to enlarge the reparation of current density. The aim of this work is to analyze the efficiency of such an electrode arrangement when used as corona charging system in a belt-type electrostatic separator.

The ionic wind flow presents an important disadvantage for the micronized particles corona-separation process; it puts them into motion on the belt surface and causes important product mass loss rates [13]. The experimental results obtained in this work prove

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that the electric wind is reduced using the metal-strips electrode arrangement, and that the separation efficiency of fine powdery mixtures is improved.

2. Experimental procedures

The experiments were carried out using a belt-type electrostatic separator (Fig. 1, a) which consists of a metal-belt conveyor, 700 mm in length and 70 mm in width, a vibratory feeder, a rotary cylindrical electrode with a diameter of 50 mm and a length of 70 mm energized from a fully adjustable DC high-voltage power supply (Model SPL 300, 100 kV; 3 mA; SPELLMAN, positive polarity) [13]. The cylindrical electrostatic electrode was fixed at a distance $h = 20$ mm from the conveyor surface with an angular position $\alpha = 15°$ (Fig. 1, b) and connected to an applied high voltage $U = 22$ kV. According to [13], these parameters define the optimal conditions for the processing of micronized mixtures in this belt-type electrostatic separator.

The corona discharge was generated by a wire-type dual electrode consisted in a tungsten wire (0.2 mm of diameter) attached to a metallic cylinder (26 mm of diameter) and distanced at 34 mm from its axis [20], [21]. The wire and the cylinder were energized from the same DC high voltage supply of positive polarity (Model SPL 300, 100 kV; 3 mA; SPELLMAN). Two rectangular parallel strips with 10 mm of height and 120 mm of length were placed, each of them, at a fixed distance $D_b = 40$ mm from the wire, and connected to the ground (Fig. 2). The wire and the lower limits of strips were located at a distance D from the conveyor surface.

The samples used in the experiments were composed of 0.5 g of Aluminum (Al) and 0.5 g of Polystyrene (PS) particles in the size class 125–250 µm.

In a first series of experiments, the effect of the presence of the strips on the ionic wind produced by corona discharge was

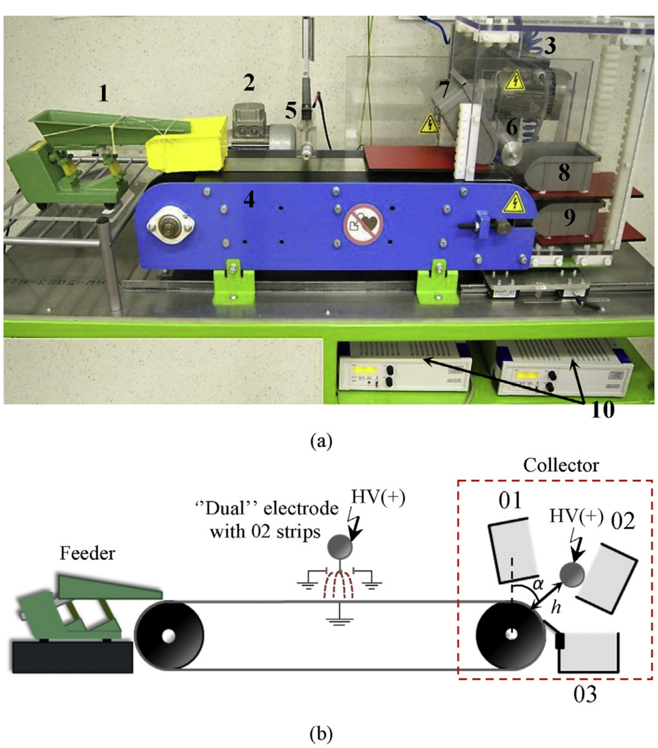

Fig. 1. (a) Photography of the laboratory multi-functional electrostatic separator for fine particles (b) Schematic representation of the separator with the three-boxes collecting system.1: Vibratory feeder; 2 and 3: Electric motors; 4: Metallic conveyor; 5: Corona electrode; 6: Rotary cylindrical electrode; 7: Box n° 1; 8: Box n° 2; 9: Box n°3; 10: High voltage supply.

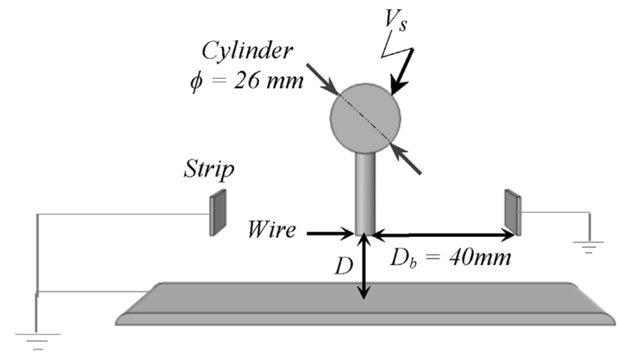

Fig. 2. Wire-type dual arrangement with grounded strips in proximity of the high-voltage "dual electrode".

investigated as function of the discharge gap D and the applied voltage V. The mixture was introduced onto the surface of the conveyor electrode via a vibratory feeder, to be charged by the dual-type corona electrode, in presence and in absence of the grounded strips. The rotary cylindrical electrode of the separator was not energized. This means that no electric field forces were exerted on the particles, which were supposed to be all recovered in box n°3. The mass actually collected in this box (M_{rec}) was subtracted from the total mass introduced onto the separator (M_{int}). In this way, the percentage of losses due to the ionic wind was calculated according the following formula:

$$L = \frac{M_{\text{int}} - M_{rec}}{M_{\text{int}}} \times 100 \tag{1}$$

In the second series of experiments, electrostatic separation tests were performed with and without using corona discharge. The corona-charged non-conductive particles stick to the grounded conveyor surface under the action of the image force. The electric field produced by the roll electrode of same polarity enhances their adhesion to the grounded metallic belt of the conveyor and practically all non-conductive particles are retrieved in box n°3 of the collector. On the other hand, the conductive particles in contact with the grounded belt, charge by electrostatic induction and are attracted to the roll electrode of opposite polarity. Most of them are retrieved in box n° 2 of the collector (Fig. 1, b). Some of the conductive particles impacted the high-voltage electrode and got the same charge polarity with the HV electrode. The electrostatic repulsion force, in conjunction with the centrifugal force (the cylindrical electrode rotated at a variable speed up to 40 rpm), drove them in box n° 01. Boxes 1 and 2 were expected to contain mostly aluminum, and were considered together.

All experiments were performed in stable ambient conditions (relative humidity: 40%–50%; temperature: 24 °C–27 °C).

3. Results and discussion

3.1. Losses rates due to the ionic wind

The two sets of this series of experiments were performed with the aim of evaluating two factors that might affect the mass loss rates caused by the ionic wind that accompany the corona discharge in the belt-type separator.

1) Effect of the discharge gap

In the first set of experiments, the distance between electrodes D was adjusted at various values between 20 and 40 mm, while the