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Continuous operation of a fluidized-bed disk-type electrostatic separator for micronized plastic waste

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ABSTRACT

The objective of this work is to highlight the peculiarities of the continuous operating regime of a new tribo-aero-electrostatic separator for the recycling of plastics contained in micronized waste electrical and electronic equipment. The experiments were carried out with an ABS/PS mixture. The particles are charged by triboelectric effect in a fluidized bed in the presence of an electric field created between two disk electrodes connected to high voltage supplies of opposite polarities. The installation described in this paper has several control variables: the high voltage, the mass of the mixture initially introduced into the fluidized bed, the flow of fluidizing air and the rotation speed of the disk electrodes. The influence of each control variable of the machine on the efficiency of the separation was studied by simultaneously and continuously measuring the mass and the electrical charge of the collected products. The quality of the products obtained and the high hourly rates recommend this type of installation for industrial use.
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1. Introduction

The rapid growth of quantities of electrical and electronic equipment that reach the end of life requires the research and development of new technologies for the recycling of the materials that compose them, in order to reduce their impact on the environment and to conserve resources (UN environmental program, 2007; Ongondo et al., 2011). The methods of recovery of plastics contained in this waste are diverse: by flotation, gravimetric, aerodynamic (Xiuli et al., 2006; Schluept et al., 2009). However, electrostatic separation has become the preferred solution for obtaining high quality recycled plastics (Plastics, 2000; Tilmatine et al., 2009).

During recent years, various devices using the triboelectric effect have been designed and manufactured as means of charging the granules with a view to their separation in an electric field, according to the polarity of the electrode and the sign of the acquired charge. Several publications describe the researches that have been carried out in the field of triboelectric separation, in particular the good results obtained in the case of mm-size granular mixtures (Boukhoulda et al., 2013; Benabboun et al., 2014; Aksa et al., 2015; Li et al., 2015; Miloudi et al., 2015; Iuga et al., 2016; Mekhalef et al., 2017). However, few studies have been aimed at separating mixtures of powdery materials (micrometric particles; i.e. size <1 mm), such as minerals and food products (Hemery et al., 2007; Cangialosi et al., 2008; Sibakov et al., 2014; Wang et al., 2015). A pivotal issue for the research on the tribo-electrostatic separation of sub-mm-size granular mixtures is the appropriate control of particle trajectories, which are strongly affected by the aerodynamic forces (Tilmatine et al., 2014; Mekhalef et al., 2015; Messal et al., 2017; Zeghloul et al., 2017).

An interesting solution is the electrostatic tribo-aero separator with two rotating disk electrodes (Tilmatine et al., 2014; Messal et al., 2017; Zeghloul et al., 2017) (see Fig. 1). The particles are charged by triboelectric effect in a fluidized bed in the presence of an electric field created between the two disk-electrodes connected to high-voltage supplies of opposite polarity and driven by variable speed electric motors.

The objective of this paper is to study the continuous operation regime of such separator, with the development of a system of simultaneous measurements of the electric charge and the mass of the collected products, in order to prepare the transfer of this technology to the recycling industry, for the treatment of plastics mixtures originating from micronized waste electric and electronic equipment.

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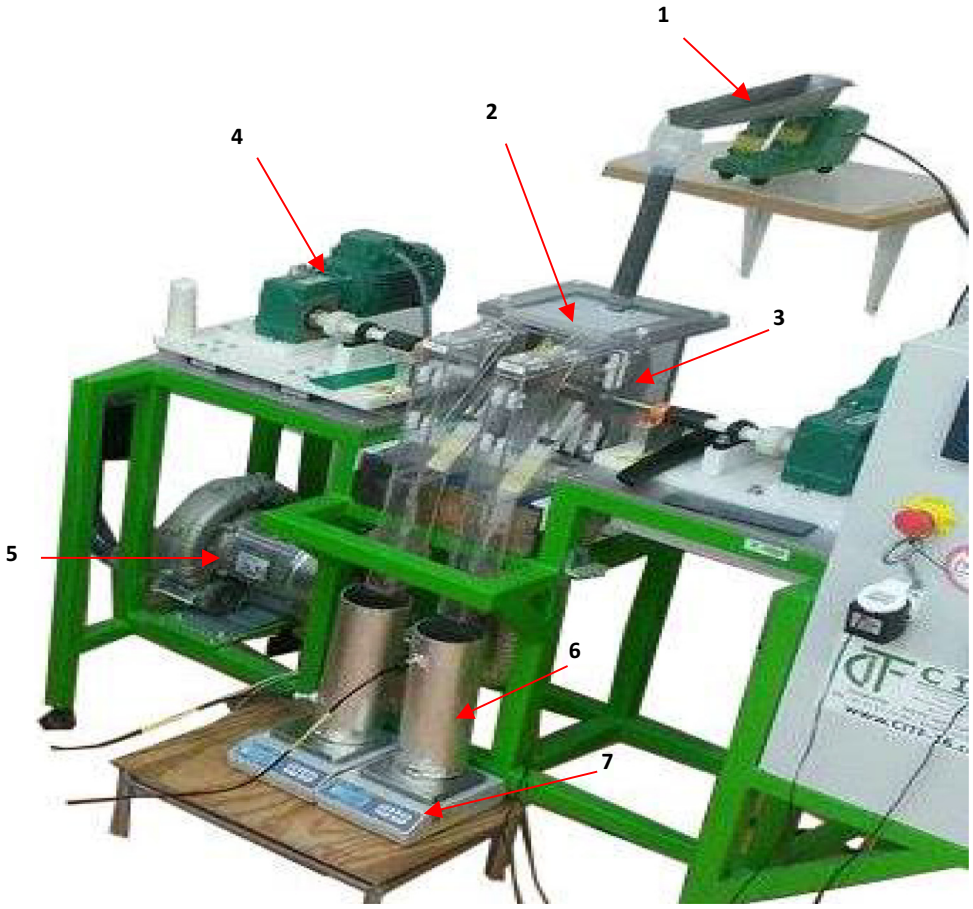

Fig. 1. Tribo-aero-electrostatic separator with two rotating disk electrodes; 1: Vibratory feeder; 2: Fluidization chamber; 3: Disk electrodes; 4: Electric motor for driving the rotating electrodes; 5: Blower; 6: Faraday pails; 7: Scales.

2. Experimental setup

The new tribo-aero-electrostatic separator with two rotating disk electrodes, intended firstly for processing sub-mm-size granular mixtures of insulating materials, was designed by the authors, who also supervised its manufacturing by the CITF Company, Saint Cybardeaux, France.

The powdery mixture is introduced by a vibratory feeder into the fluidization chamber which also serves as a separation chamber and has the following dimensions: 160 mm × 160 mm × 240 mm; its walls are made of transparent PMMA. Variable speed air injection is provided by a blower of 1.5 kW, 4000 rev/min, 166 m^3/h.

The electric field is generated between two stainless steel disks (diameter: 220 mm, thickness: 2 mm) which are distanced by 120 mm from each other and located in the separation chamber. These disk electrodes are fed from two DC high voltage supplies of opposite polarities, and entrained at variable speed by two DC motors.

The separated products are recovered in two Faraday-pail-type collecting tanks connected to two electrometers (KEITHLEY, model 6514) and placed on two electronic scales with a resolution of 0.1 g and an upper limit of 2 kg. The electrometers and the two scales are connected to a PC via GPIB and RS232. The electric charges and masses measured by these instruments are recorded using a data acquisition program supervised by Lab View.

3. Material and method

The powdery mixture used in the present study comprised two types of polymers, brown-colored ABS and white-colored PS, supplied by APR2, France, a company specialized in the recycling of waste electrical and electronic equipment (WEEE). The size of the particles was typically between 500 μm and 1000 μm. Their various shapes can be examined in Fig. 2.

The experiments were carried out under relatively stable climatic conditions: RH = 40–50% and temperature 17–21 °C. It should be noted that, in accordance with their positioning in the triboelectric series, the ABS got positively charged and the PS negatively charged and were therefore collected respectively at the negative and positive electrodes of the separator under the action of the electric forces. The conditions for carrying out the tests in cyclic and continuous mode are described below.

3.1. Effect of voltage and potential in cyclical mode

The tests were carried out with a mixture containing 100 g of ABS and 100 g of PS, at a disk rotation speed of n = 30 rpm, and a fluidization flow rate D = 7 m^3/h. In a first series of experiments, the supply voltages of the two disks were varied between ±4 kV and ±20 kV. The second series of experiments was carried out at constant electric field 2 kV/cm for three variants of supply of the two electrodes (±12 kV, +24 kV-Earth, −24 kV-Earth).

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