Journal of Electrostatics 88 (2017) 2–9

Contents lists available at ScienceDirect

Journal of Electrostatics

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

Numerical simulation of a tribo-aero-electrostatic separation of a ternary plastic granular mixture

Chahinez Mimouni [a], Amar Tilmatine [a, *], Fatima Zohra Rahou [a], Lucian 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 9 October 2016
Received in revised form
13 January 2017
Accepted 23 January 2017
Available online 1 February 2017

Keywords:
Electrostatic separation
Granular materials
Numerical techniques
Triboelectricity

ABSTRACT

Granular materials, when fluidized by air or other gaseous medium, acquire electrostatic charge by particle-particle and particle-wall collisions. The effectiveness of particle tribocharging achieved with such fluidization process is crucial for establishing the feasibility of electrostatic separation of mixed granular solid wastes in the recycling industry. The aim of the present work is to introduce a simple mathematical model for simulating the outcome of a novel tribo-aero-electrostatic separation process involving mixture of three granular materials. The process is characterized by the fact that the charging of the granules is produced in a fluidized bed device, in the presence of an electric field. The mathematical model in this case assumed that the probability of a granule to be separated can be expressed using the normal distribution law, as a function of the number of impacts with granules belonging to the other classes of materials. The effect of the presence of a third species of particles was taken into account. Thus, it was possible to calculate the evolution over time of the mass of granules separated at the electrodes for different compositions of the granular mixture. The calculated results are in good agreement with the experiments.

1. Introduction

The triboelectric separation represents a solution for the sorting of plastics mixtures, whenever the components have a similar size, shape, magnetic permeability and electrical conductivity. The effectiveness of this technique has already been proven both in laboratory and in industry [1–7].

In a triboelectrostatic separator, the plastic granules are charged by triboelectrification and separated by electric field forces. The typical structure of a triboelectric separator consists of a triboelectric charging device [8–12]. The granules are charged by collision and friction with each-other or with the walls of the-tribocharging device. The positively and negatively charge granules are then driven in opposite directions by the forces of the electric field generated by two high voltage electrode sand are collected by appropriate means, as separation fractions (Fig. 1).

The results of the separation are highly dependent on the effectiveness of the triboelectric charging. The fluidized bed systems have proven to be effective charging device for the triboelectric separators [13,14].

Computer simulation could be used to achieve the optimization of triboelectrostatic separation process, as it has already been the case of other applications. In the case of the corona electrostatic separators for recycling metals and insulating materials from cables waste, for example, numerical models have been proposed for the estimation of the charge acquired by the particles and to calculate their trajectories in an electric field [15–17].

Researchers and practitioners need an easier simulation tool to carry out the feasibility studies that precede the development of a new application [18]. Therefore, the aim of this work is to introduce a simple mathematical model to simulate the outcome of a tribo-aero-electrostatic separation process of a ternary plastic granular mixture.

2. Experimental procedure

The electrostatic separation experiments were performed on Polyvinyl Chloride (PVC) and Polypropylene (PP) and High-impact Polystyrene (HIPS) granular materials (Fig. 3**)**. The samples were prepared as mixtures of three products with different

* Corresponding author.
E-mail addresses: mimounichahinez@gmail.com (C. Mimouni), atilmatine@gmail.com (A. Tilmatine), lucian.dascalescu@univ-poitiers.fr (L. Dascalescu).

http://dx.doi.org/10.1016/j.elstat.2017.01.015
0304-3886/

Nomenclature

A, B, C	Materials to be separated
c_A,c_B, c_C	Concentration of materials *A, B, C.*
$c_{air(A,\ B\ or\ C)}$	Percentage of *A, B* or *C* collected under the effect of air
M	Total mass to be separated
M_A, M_B, M_C	Mass of *A, B, C* in the fluidized bed
M_{As},M_{Bs},M_{Cs}	Masses separated of *A, B* and *C*
$M_{A(A)}$	Mass collected of material *A* in the collector *A*
$M_{B(B)}$	Mass collected of material *B* in the Collector *B*
$M_{(A,B,C)sair(A)}$	Separated masses *A, B* and *C* collected in (Collector *A*) under the effect of air
$M_{(A,B,C)s\ air(B)}$	Separated masses of *A, B* and *C* collected in (Collector *B*) under the effect of air
$M_{coll(A)}M_{coll(B)}$	Total mass collected respectively in (collector *A*) and (collector *B*)
λ_{AC},λ_{BC}	Charge exchanged between a granule *A* (or B) and *C*
λ_{CA},λ_{CB}	Charge exchanged between a granule *C* (or *B*) and A
n	Number of computation steps
N	Number of collision per unit time.
P	Probability function
Π	Standard normal distribution function
PP	Polypropylene
PVC	Poly-vinyl chloride
HIPS	High-Impact Polystyrene
X_A, X_B, X_C	Number of collisions
x_A	Normalized number of *A*-(*B* and *C*) collisions
x_B	Normalized number of *B*-(*A* and *C*) collisions
x_C	Normalized number of *C*-(*B* and *A*) collisions
$s_{x(A,B,C)}$	Normalized standard deviation
σ_x	Standard deviation
$t_{50\%}$	Time to the separation of 50% of the *A* granules
P_A	Purity of the product *A*
P_B	Purity of the product *B*

Subscripts

av	Average value
e	Estimated value
exp	Experimental value

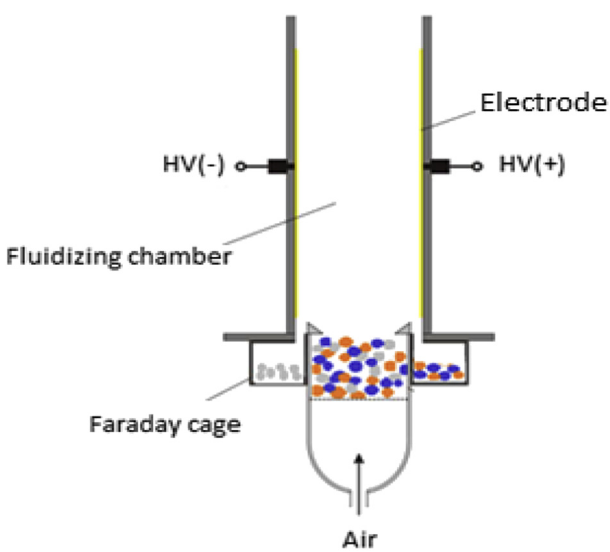

Fig. 1. Schematic representation of a tribo-aero-electrostatic separator in intermittent operation.

compositions. The experiments were performed at a fixed speed of the fluidization air $v = 6$ m/s in relatively stable environmental conditions: temperature $T = 17–22$ °C, the relative humidity $RH = 44–60\%$.

The experimental device (Fig. 1) consists of a rectangular prism chamber (115 mm × 85 mm x 400 mm), with two opposite vertical walls of Poly-carbonate, the other two walls consisting of aluminum plates connected to a high voltage supply (Spellman 40 kV, 9 m A), and a perforated plate at the bottom of it. The granules deposited on this plate are dispersed by the vertically-oriented fluidizing air in the triboelectric room, where multiple granule-granule and some granule-wall collisions occur. The charged particles are attracted by the electrodes of opposite polarity and fall into the two collecting hoppers. The mass of collected goods is measured every $t = 20$s with electronic scales (precision: 0.01 g) [19].

3. Mathematical model

The study focuses on the separation of a mixture of three granular materials noted A, B and C. The three classes of granules have similar sizes and masses, however their triboelectric characteristics are different. The particles do not attain saturation, as they do not spend too much time in the fluidized bed. They are attracted to the electrodes and collected at very low charge levels. The gravitational forces being “balanced” by the aerodynamic forces, the particles move mainly under the action of the electric forces, which will drive them to the electrodes as soon as they got an electric charge. **R₄**

The mathematical model is based on the assumption that the probability of a granule to be separated can be expressed as a function of the number of impacts it has with the other granules. The number of collisions between individual granules depends on the concentration of each class of materials in the granular mixture.

The total mass *M(t)* of the materials located in the fluidized bed at time *t* (Fig. 2) is expressed as follows:

$$M(t) = M_A(t) + M_B(t) + M_C(t) \tag{1}$$

The respective concentrations of materials A, B and C are:

$$c_A(t) = \frac{M_A(t)}{M(t)},\quad c_B(t) = \frac{M_B(t)}{M(t)},\quad c_C(t) = \frac{M_C(t)}{M(t)} \tag{2}$$

At $t = 0$ (i.e., the start of the tribocharging process):$M_A(0) = M_{A1}$, $M_B(0) = M_{B1}$, $M_C(0) = M_{C1}$, $c_A(0) = M_{A1}/M = c_{A1}$, $c_B(0) = M_{B1}/M_1 = c_{B1}$, $c_C(0) = M_{C1}/M_1 = c_{C1}$.

In a fluidized bed of known geometry and a controllable air flow, each granule undergoes *N (t)* collisions per time unit. At $t = 0$, $N(0) = N_1$. It is assumed that the regime of the fluidized bed is not significantly modified by the changes in the mass $M(t)$, which