Study of the Trajectory of Particles in an Electrostatic Separator with a Conveyor Belt

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Abstract - Tribo-electrostatic separation for the purification of granular mixtures occupies a very important place and currently represents an economically viable technology for the preservation of the environment, since it offers high quality recycled plastic and better efficiency for the recovery of metals offered by conventional methods of waste treatment. The behavior of plastic particles in an electrostatic separator depends on the intensity and direction of the force fields which simultaneously act on the particle in the electrostatic separation zone.
In this article, we aim to study and simulate the behavior of particles in a conveyor belt separator. The simulation model used in this study is based on the theoretical models. All the models are implemented in the form of a MATLAB program which allows the simulation of the behavior of the particles according to the electrical and geometric parameters of the installation studied and the parameters of the sorted mixture. This simulation allows the prediction and understanding of the influence of the parameters studied on the special distribution of the particles of the mixture recovered at the level of the collector of the installation studied.

Keywords - High Voltage, Tribo-electrostatic, Separation, Conveyor belt, granular mixtures, simualtion.

I. Introduction

The conveyor belt separator is intended exclusively for separating two plastics. The particles are charged into a triboelectric device and then deposited on a conveyor belt which is grounded. The latter will transport them to the high voltage electrode: the charged particles of sign opposite to that of the electrode are attracted and those of the same charge sign are repelled (Fig. 1).

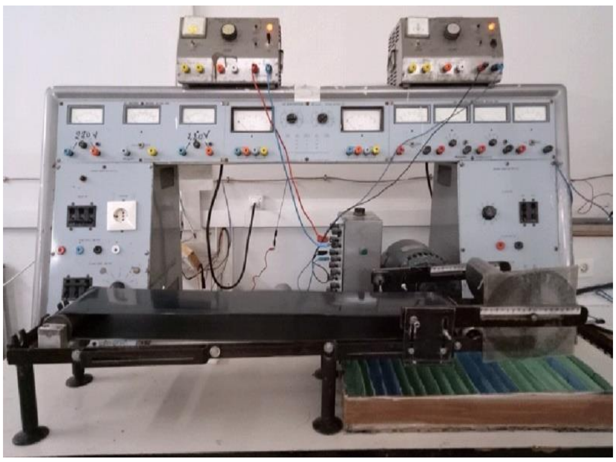

Fig. 1. Photograph of the laboratory conveyor belt

II. Numerical Simulation

In this article we will develop a numerical model of the trajectory of particles in a conveyor belt separator. The model developed uses the geometric and electrical information of the installation and the particles of the product studied to define their position in the collector. The model is used in the study of the distribution of the Q/m ratio of a mixture (ABS/PVC) recovered at the outlet of a laboratory installation (Fig. 2). The results obtained are then used to define the geometric and electrical parameters of the installation which give a maximum difference between the collection points of the two different products characterized Electronic files

III. Simulation Results

After the detachment the particle is projected with a non-zero initial velocity towards the collector. The motion of the particles in this case is considered as much as free motion. During their movements, particles of millimeter size are subjected to several forces. In our study, we took into consideration the influence of gravitational, electrostatic and particle/air friction forces. The movement of the particle in this case is governed by the so-called Newton's equation which takes the following form:

$$m\frac{dv}{dt} = QE_x(x,y) - \frac{1}{2}C_f S_p \rho_{air}\, v(x,y) v_x(x,y) \qquad (1)$$

$$m\frac{dv_y}{dt} = -mg + QE_y(x,y) - \frac{1}{2}C_f S_p \rho_{air}\, v(x,y) v_y(x,y) \qquad (2)$$

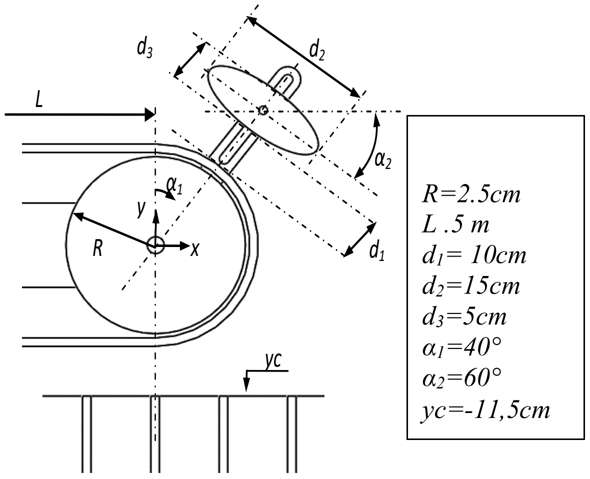

Fig. 2. Geometric parameters of the conveyor belt separator

During the simulation particles can come into impact with the static electrode. Figure 3 shows us a particular case of the particle/electrode type impact problem. During the simulation, the program detects the intersection between the trajectory of the particle (Line formed by the two points P(t_n) P(t_n+1)) and one of the linear segments forming the perimeter of the electrode (Line formed by the two points C_k and C_k+1).

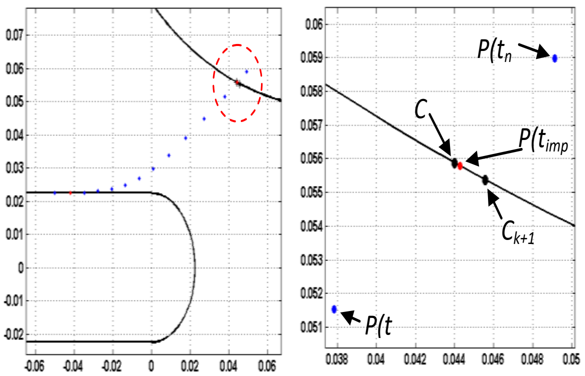

Fig. 3. Simulation of the particle/electrode impact

III-1. Influence of carpet speed

The influence of carpet velocity on particle behavior is examined on two types of particle. The two particles are characterized by a mass charge of ±10nC/g. The results of the simulation are represented in figures 4 and 5. Figure 4 shows us the behavior of a particle characterized by a sufficiently high mass charge (of the order of -10 nC/g).

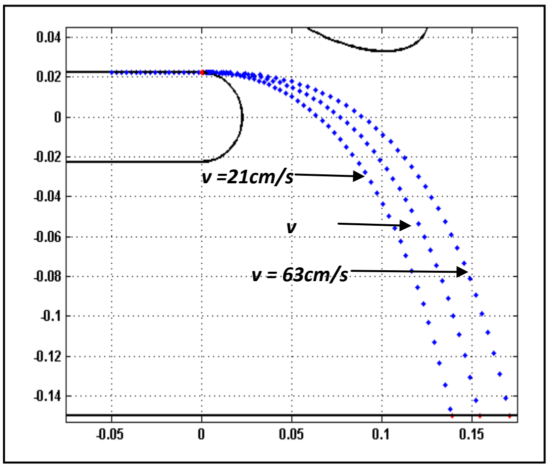

Fig. 4. Influence of carpet speed on negatively charged particles

In this simulation the tangential speed of the carpet v = 21 cm/s ensures the projection of the particle at a distance of 14 cm. The distances of 15.5 cm and 17.2 cm are obtained respectively with a speed of v = 42 cm/s and v = 63 cm/s. So according to the simulation results we can say that an increase in the speed of the carpet is accompanied by an increase in the horizontal distance traveled by the particle. The variation of the distance caused by the variation of the speed of the carpet is of the order of 3.2cm.

The result of simulations presented in Figure 5 shows us the behavior of a positively charged particle obtained for different values of the tangential speed of the conveyor belt. The simulation results show us that the horizontal displacements of the order of -2.3cm; 1.3cm and 5.7cm are respectively associated with the application of speeds of the order of 21 cm/s; v =42 cm/s and v =63cm/s. in this simulation the speed variation range is of the order of 8cm.

One examines the results of this simulation one notices that the variation of the speed of the conveyor belt is accompanied by a variation of the speed of the particle and the direction of this speed at the point of detachment. The results of this simulation show us that the application of a speed of v = 21cm/s causes the detachment of the particle in an angle α = 111.60°.

The same figure shows us that the increase in speed from v = 42 cm/s to v = 63 cm/s is accompanied by a decrease in the angle from α = 72° to α = 13.94°.

In practice, a large dispersion makes it easier for us to select precise ranges of particles. To reduce the overlap of two products of opposite charge the choice of velocity must ensure the detachment of the particle at angles greater than 90°.

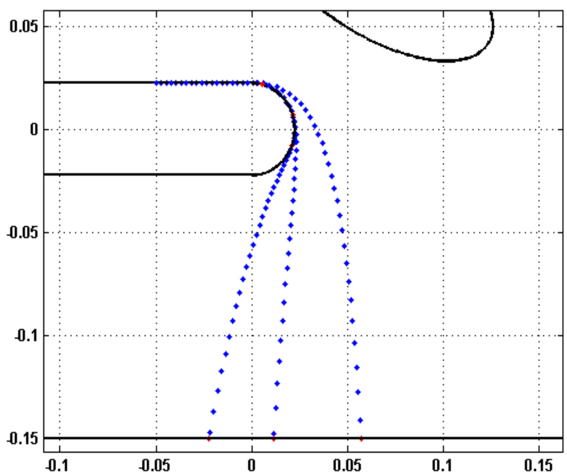

Fig. 5. Influence of carpet speed on positively charged particles

III-2. Influence of the Load/Mass ratio

To simulate the influence of the Load/Mass ratio, we fixed the tangential speed of the belt to the value v = 21 cm/s; the voltage applied to the elliptical electrode over 35 kV and in each simulation the trajectory of a particle is calculated for a fixed value of the Charge/Mass ratio. The values chosen in this simulation are: ±15 nC/g; ±10 nC/g; ±5nC/g.

The simulation result shows the case of an installation equipped with a static electrode supplied by a high voltage source of positive polarity. This simulation shows us that the negatively charged particles can be collected in the right part of the collector. The simulation shows us that the horizontal deviation of the positively charged particles is equal to -3.6 cm for 15 nC/g; -1.9 cm for 10 nC/g and 0.6 cm for 5 nC/g. The horizontal deviation of the negatively charged particles equal to 7.5 cm for -5 nC/g; 12.3 cm for -10 nC/g and 17.9 m for -15 nC/g.

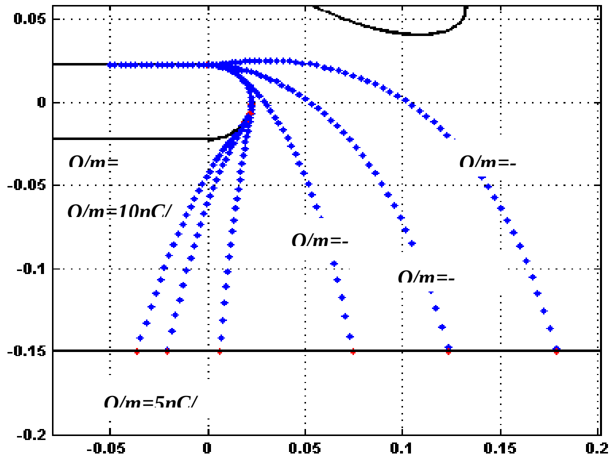

Fig. 6. Influence of mass charge on particle deflection

IV. EXPERIMENTAL STUDY

This study aims at the experimental analysis of the connection which exists between the position of the plastic particles in the collector and the intensity and the direction of the forces acting on the particles during their movements from the point of departure (the point of supply in granular product) to the end point (i.e. the final position of the particle in the collector).

In all the experiments, the particles of the mixture are charged by triboelectrification in an endless screw conveyor. The particles precharged by triboelectrification are continuously deposited on the surface of the conveyor belt. During their movements in the electrostatic separation zone, the negatively charged particles are attracted towards the static electrode fed by a source of positive polarity. The positively charged particles adhere to the surface of the carpet to be then evacuated towards the left part of the collector. (Fig. 7) shows us a typical result of the separation of the PVC/ABS mixture.

Fig. 7. ABS/PVC separation results obtained by a conveyor belt separator

This part of the work aims at the experimental study of the position of the particles in the collector according to the potential difference applied between the electrodes of the installation ΔU (V) and the inclination of these electrodes with respect to the axis. Vertical α (°) and the tangential speed of the conveyor belt n(m/s).

V. DISCUSSION OF EXPÉRIMENTAL RESULTS

In each experiment, a granular mixture of 50% PVC and 50% ABS is introduced into the screw conveyor in order to undergo triboelectric loading. The product recovered at the exit is deposited continuously on the surface of the conveyor belt. After the separation the mass and the total charge of the product recovered in each cell is measured using an electronic balance and a Faraday bucket. The values obtained are then used to calculate the charge/mass ratio of the particles recovered in each cell.

In all the experiments, we used a mixture of two products consisting of 50 (g) of ABS and 50 (g) of PVC.

The charging of the particles of the mixture is carried out by triboelectrification. The charged particles are deposited on the conveyor belt separator. At the outlet of the separator, the particles of the mixture are recovered in a collector with several removable cells. The use of this type of collector gives us the possibility to measure the mass, the size and the charge of the recovered particles at a known deviation characterized by the position of the walls of each cell.

Particles characterized by a high Q/m ratio are attracted towards the ends of the collector, depending on the sign of the charge and the polarity of the electrode. The particles characterized by a low ratio fall vertically into the cells which are in the center of the collector.

After the separation, we measured the mass charge and estimated the radius of the particles in each collector cell. The mass charge of the particles is measured by an indirect method using the Faraday seal connected to an electrometer and a high resolution electronic balance (0.001g).

The results show us that the distribution of the mass and the charge/mass ratio of the particles at the level of the collector varies from one configuration to another.

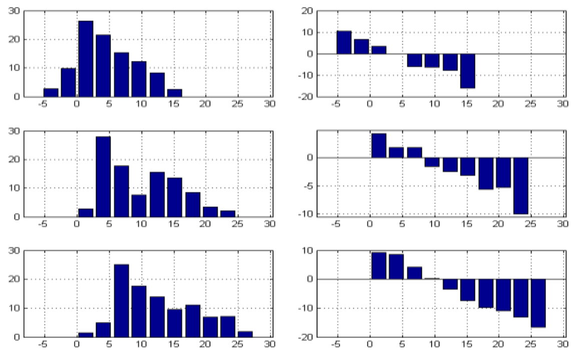

Fig. 8. Spatial distribution of the mass and the Charge/mass ratio of the product recovered at the level of the collector.

This figure shows us a horizontal displacement of the position of the neutral particles according to the three parameters. Theoretically, the intensity and direction of the electrostatic field related to the voltage factor U (kV) and inclination of the static electrode have no influence on the final position of the neutral particles in the collector. On the other hand, this position can be influenced by the tangential speed of the particles at the point of detachment linked to the tangential speed factor of the conveyor belt.

To ensure that the experiments are in agreement with the theoretical notions, we made a study of the effects of the factors: Voltage U; Angle of the static electrode A and the speed of the carpet N on the position of the neutral particles.

To perform this study, we calculated the position of the neutral particles associated with each experiment. This value is obtained from the distribution of the charge/mass ratio of the particles. The calculation method used in this step consists of:

- Identify the two adjacent cells that contain materials of opposite charge.

- To model the variation of the charge/mass ratio as a function of the horizontal position, a linear model of the form Qm(x)= ax+b is used.

- Calculate the position of neutral particles by calculating the solution of the problem Qm(x)=0

Figure 8 shows us a comparison between the results obtained in experiments Nos. 1, 14 and 27 carried out at the low level; average and high of each factor

VI. CONCLUSION

The theoretical and experimental study show that the position of the particles recovered at the level of the collector of an electrostatic separator is strongly linked to the charge/mass ratio of the particles and the intensity of the electrostatic field.

The study of the behavior of the particles in a conveyor belt separator shows that the use of voltages of the order of 60kV generates a dispersion of the particles in a range which varies from -20 cm to 20cm at the level of the collector of the installation. . The charge/mass ratio of the particles recovered at the ends of the collector in this case is of the order of ±5 to ±10 µC/kg. The study also shows that the use of lower voltage levels requires an increase in the performance of the triboelectric charging process to achieve higher charge/mass ratios

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