Recycling of Computer Equipment Debris by Experimental Electrostatic Separation (Continuous Regime)

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RECYCLING OF COMPUTER EQUIPMENT DEBRIS BY EXPERIMENTAL ELECTROSTATIC SEPARATION (CONTINUOUS REGIM

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Abstract: The evolution of the field of plastic waste separation is directly linked, on the one hand, to the awareness of serious environmental concerns. On the other hand, it is linked to the growing scale of various wastes which find no other outlet than landfill. Experimental characterization represents the best way and the most efficient tool to model the phenomenon of electrostatic separation of materials.In this paper, the continuous experimental operation of a tribo-aero-electrostatic separation process for a mixture of three granular materials is achieved through the execution of an experimental device (a prototype) is exposed. The effect of the presence of a third species of particles was taken into account. Thus, it was possible to calculate the change over time of the mass of the granules separated at the electrodes for different compositions of the granular mixture. The experimental results obtained are in agreement with the simulations already carried out as well as with the literature.

Résumé : L'évolution du domaine de la séparation des déchets plastiques est directement liée, d'une part, à la prise de conscience de graves préoccupations environnementales. D'autre part, elle est liée à l'importance croissante des déchets divers qui ne trouvent d'autre débouché que l'enfouissement. La caractérisation expérimentale représente la meilleure voie et l'outil le plus efficace pour modéliser le phénomène de séparation électrostatique des matériauxDans cet article, le fonctionnement expérimental continu d'un procédé de séparation tribo-aéro-électrostatique pour un mélange de trois matériaux granulaires est réalisé grâce à l'exécution d'un dispositif expérimental (un prototype) est exposé. L'effet de la présence d'une troisième espèce de particules a été pris en compte. Ainsi, il a été possible de calculer l'évolution dans le temps de la masse des granulés séparés aux électrodes pour différentes compositions du mélange granulaire. Les résultats expérimentaux obtenus sont en accord avec les simulations déjà réalisées ainsi qu'avec la littérature.

Key words : Electrostatic separation; Granular materials, experimental device; Triboelectricity, empirical tests**.**

Mots-clés : Séparation électrostatique ; Matériaux granulaires, dispositif expérimental ; Triboélectricité, tests empiriques.

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Introduction:

Triboelectric separation represents a solution for the selective sorting of mixtures of plastics, whenever the components have a similar size, shape, density, magnetic permeability and electrical conductivity. The effectiveness of this technique has already been proven .

The experiments aimed to define the range of variation of various factors that influence the flow of separation materials and to estimate the maximum that can be processed in continuous mode. Among these, the potential difference between the two electrodes of the fluidized bed. During the experiments, temperature and relative humidity were monitored. Their values are maintained almost constant respectively in the interval [18-22] C °, [30-40] % RH.

1. Experimental procedure

The electrostatic separation experiments were performed on mixtures of three granular materials: polyvinyl polystyrene (PVC), polypropylene (PP) and A difference arises regarding the material feed, by the use in this case of a vibrating conveyor (Figure 1). Its flow rate varies according to the needs of the users and it is necessary to direct the granules towards the lower triboelectrisation chamber.

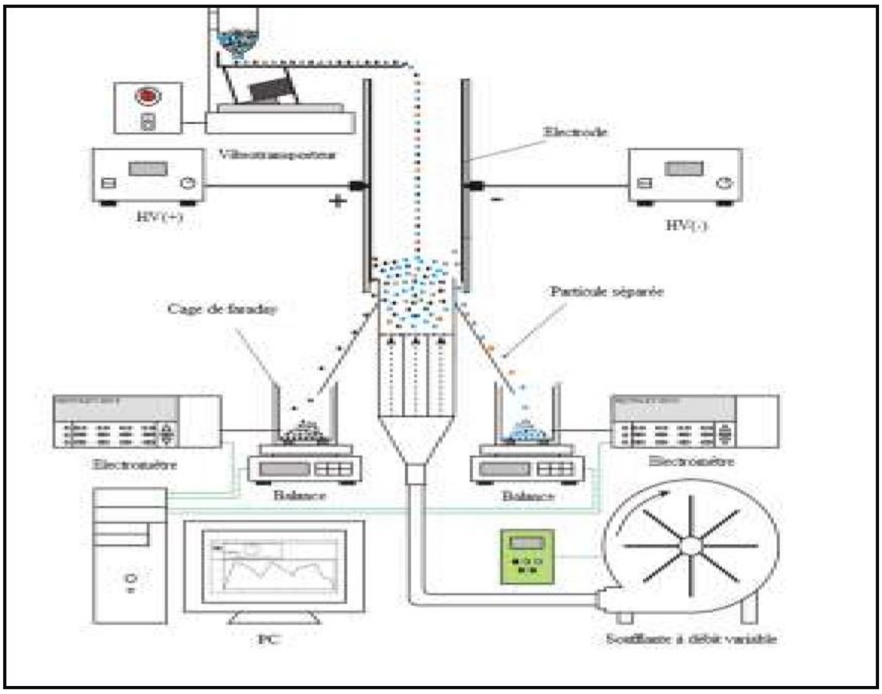

Figure 1 : Tribo-aero-electrostatic separator with electrodes parallel plates

Figure 2 : Apparence of the granules of PA (a), PP (b) and PVC(c) *) belonging to the particle size class 2 to 4 mm*

Table 1 *:* Characteristics of virgin granules used in continuous regime experiments

Granule	PA	PP	PVC
Form	Cylindrical	Cylindrical	Cylindrical
Size [mm]	Ø 2,7 x 3,2	Ø 3 x 3,6	Ø 2,5 x 3,4
Density [kg/m^3]	1,14	0,905	1,38

A difference arises regarding the material feed, by the use in this case of a vibrating conveyor (Figure 1). Its flow rate varies according to the needs of the users and it is necessary to direct the granules towards the lower triboelectrisation chamber.

1.1 Effect of applied high voltage

All the experiments carried out to determine the variation of this factor were carried out with a granular mixture of 33% PA + 33% PVC + 33% PP, for an initial mass of 240 g. All the experiments carried out aim to monitor the process of separating a granular mixture in real time, for three potential difference values. The values chosen are {28; 30; 32} kV. The other parameters are maintained at values: d = 5 g / s for the composition of the granular mixture 33% PA + 33% PVC + 33% PP. The results obtained are shown in the graph in Figure 3.

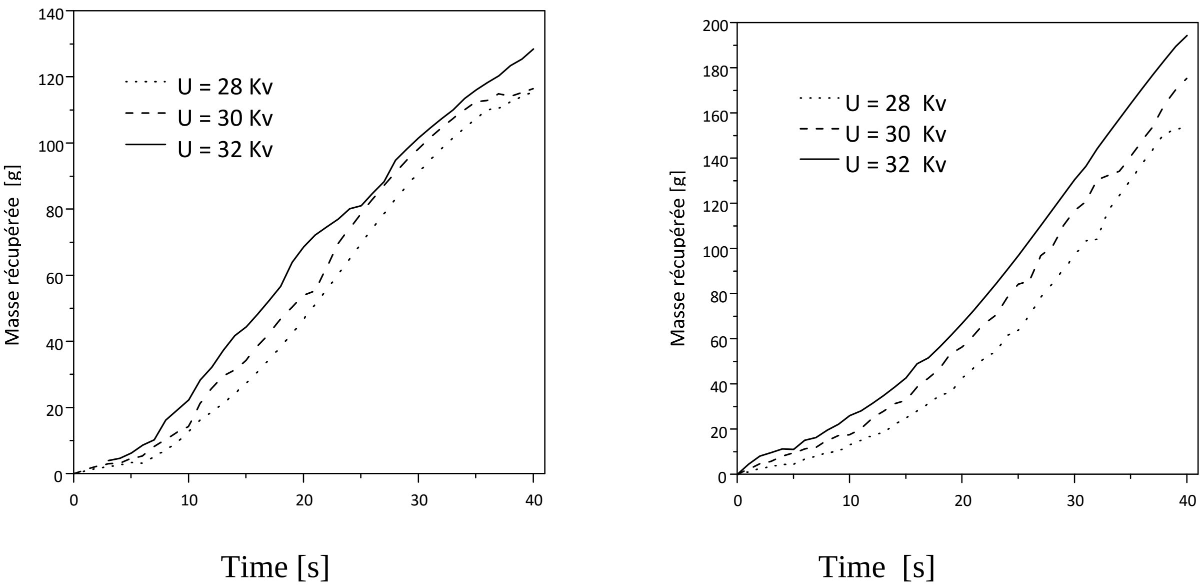

Figure.3. Evolution of the expérimental masses recovered in the two bac of the collector bac (-) (PA) and bac (+) (PP + PVC), for three different values of potential difference

It is noted that the curves which represent the masses separated and recovered in the two tanks of the collector are linear, which indicates a stable treatment time. In addition, increasing the value of the potential difference between the electrodes makes it possible to collect more quantity of material in the collector. Indeed, since the electric field is more intense, the granules are more deflected towards the electrodes. Regarding the purity values obtained at the end of the experiments, Table 3 shows a substantial increase with the increase in the values of the potential difference (28 kV to 32 kV).

Table 2. Purity of the separated materials at different values of the potential difference between the electrodes.

Granule	**Purety [%]**		
	U=28 kV	**U=30 kV**	**U=32 kV**
PA	95,33	97, 36	98, 52
PVC	75,66	81, 36	85, 63

Effect of the granular composition of the mixture

In order to study the influence of the granular composition of the mixture on the separation process, synthetic mixtures of three materials were used: PA, PVC and PP (figure 4.), which weigh 240g with the following proportions: a) 60% PA + 30% PVC + 10% PP ; b) 30% PA + 60% PVC + 10% PP.

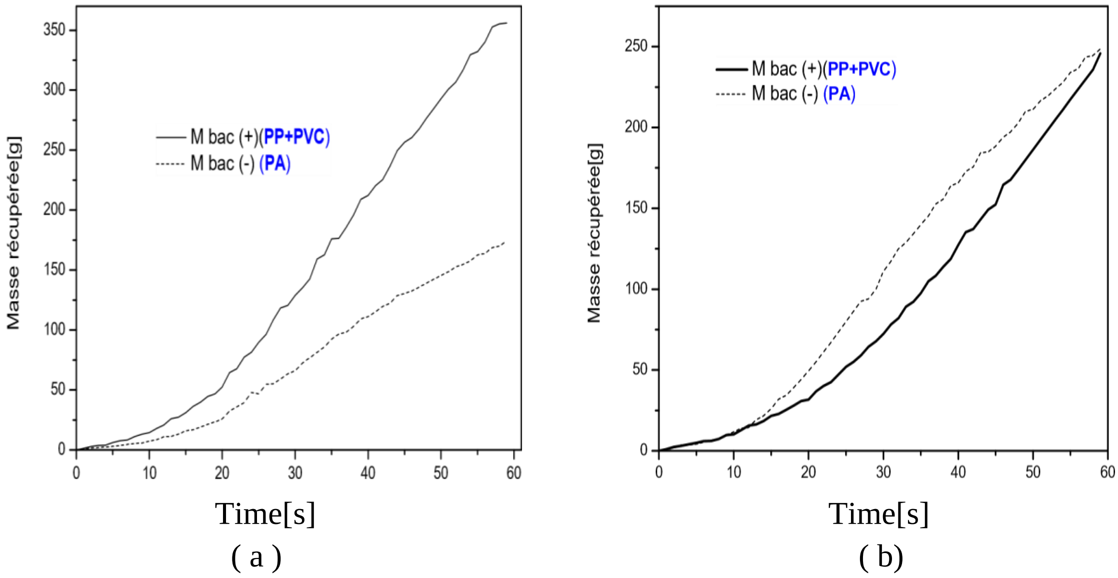

***Figure. 4**: Weights recovered in continuous operation for*
***a**-60% PA + 30% de PVC+10% PP*
***b**- 30% PA + 60% de PVC+10% PP*

The material was fed at a flow rate of 5 g / s, the potential difference between the electrodes was set at the value of 32 kV. The duration of the tests is 60 seconds.

It is also noted that the recovered mass of PVC and PP is large because of its high concentration in the mixture introduced into the separator at the start and during the separation process. The mixture of materials is better collected mainly for a mixture of 60% PA + 30% PVC + 10% PP (Fig. A), since it was considered that the PVC and the PP are charged with the same sign during the separation (c ' is as if we have a single product which will be negatively charged whose concentration is 40% and the PA product which will be positively charged whose concentration is 60%). This is why the difference between the materials collected in the two collector bins decreases.

In the case of unbalanced mixtures (Fig. 4.b.), we notice almost identical quantities of the materials collected in the two bins of the collector: bin (-) reserved for PA particles and bin (+) reserved for PP and PVC particles. . In both cases all the PA particles (minority) are quickly recovered in the tank (-), this is because they have a greater chance of being charged (with the PVC and PP particles) attracted by the electrode (-) then carried to the compartments of the collector.

1.2 Effect of material flow

The material has been introduced into the device in a continuous manner, this defines that the flow of input material remains constant regardless of the amount of material discharged by the device. The figure. 5 represents the evolution of the mass evacuated by the separator of the materials collected in the two tanks of the collector, for concentrations of the granular mixture which weighs 240 g: 33% PA + 33% PVC + 33% PP at different flow rate values of air, for a duration of 60 seconds. In addition, the supply voltage of the electrodes is 28 kV. The experiments were carried out at a temperature T = 22 ° C and a humidity RH = 44,6.

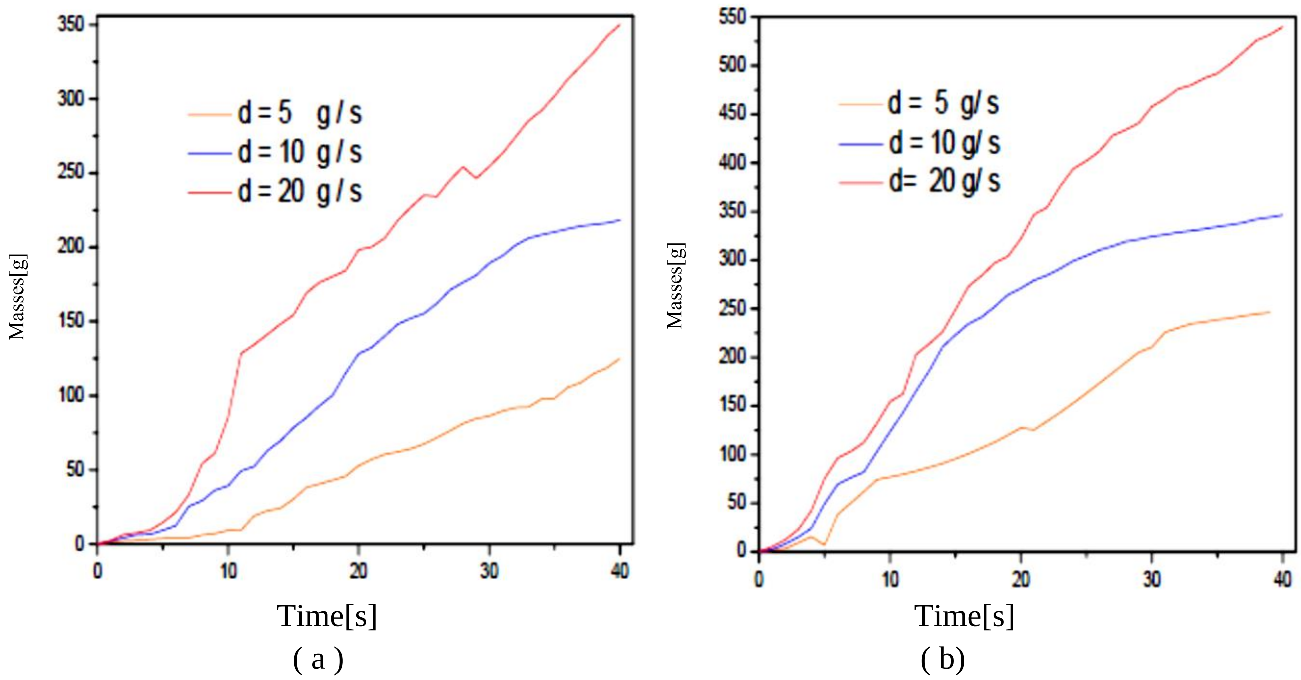

Figure 5 *Weights recovered in continuous operation for* ***d****: 5 [g/s]; 10[g/s]; 20 [g/s]*
a*-bac(+) (PA)* ***b****-bac(-) (PP+PVC)*

Note that by increasing the material flow, the recovered masses increase. The flux at which experiments were carried out for U = 28kV for material flow values equal to 5.10 and 20 [g / s]. For d = 5 g / s, the particles undergo less collisions due to the small mass of material introduced into the triboelectric chamber. By increasing the material flow to 10 [g / s], we notice a slight increase in the mass recovered in the two tanks of the collector.

In the case of a flow rate of 20 [g / s], it is noticed that the maximum limit of the device is not yet reached because, after a certain period of time, the recovered flow begins to decrease although the input flow remains constant.

2.Validation of experimental results

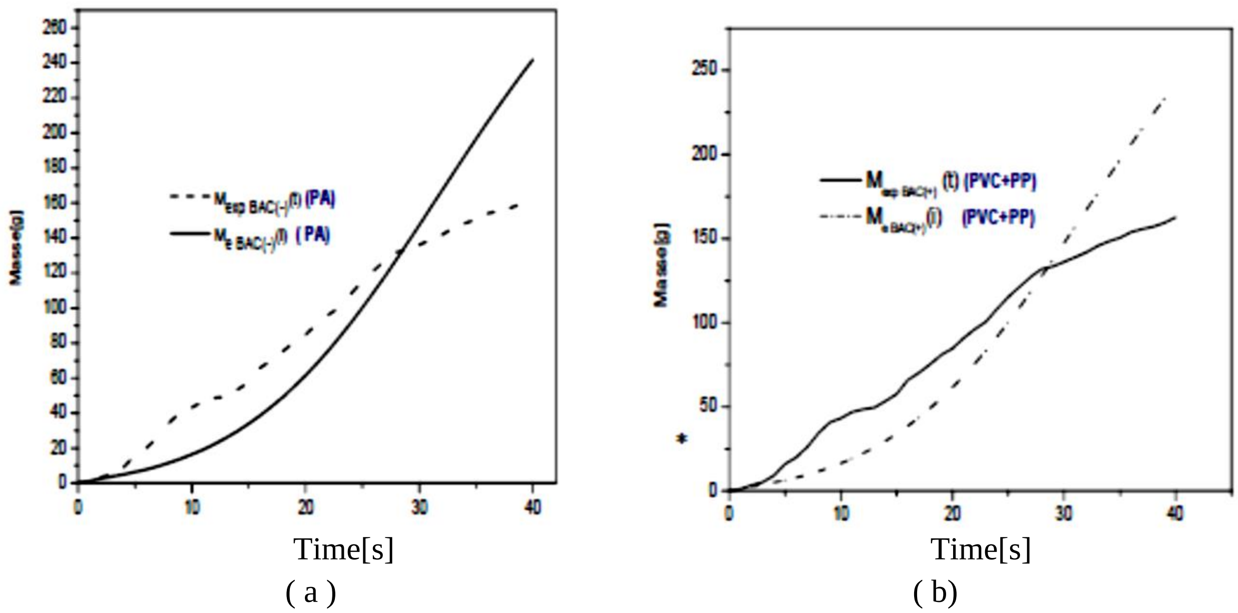

Figure 6 : Experimental and estimated masses recovered cairPA = 0.5%; cairPVC = 0.5%; cairPP = 1%

***a**-bac(+) (PA)* ***b**-bac(-) (PP+PVC)*

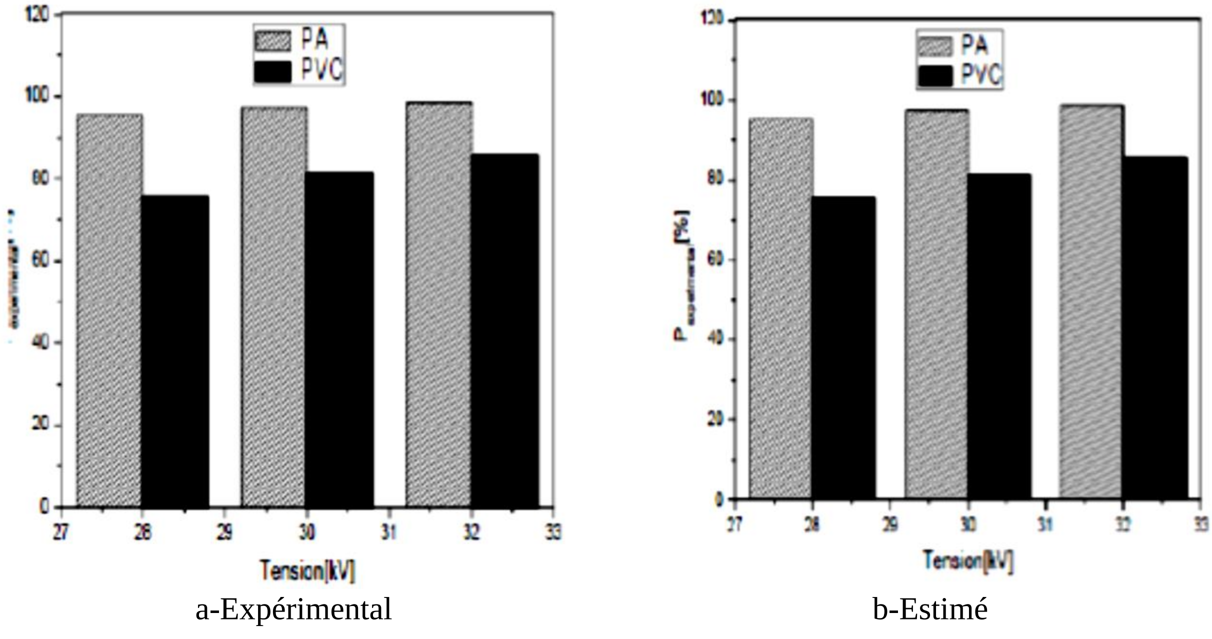

Figure 7 : Purity of PA and PVC in continuous regime cairPA = 0.5%; cairPVC = 0.5%; cairPP = 1% and d = 20 [g / s], initial mass M1 = 240 g, (Mlim = 60 g).

According to the results of Figure 7; 98% of the PA particles are recovered from the side of the positive electrode (the PAs are negatively charged). This is due to the fact that at the start of the separation, a certain amount of PP granules will be accidentally collected under the effect of the aerodynamic force from both sides.
On the other hand, more than 85% of the PVC is recovered from the negative electrode side, because the PP granules are collected with the PVC granules in the negative bin. A very good agreement between the experimental results and those of the simulation. This is corroborated by Figures 6 and 7.

Conclusion:
The present work was devoted to the preliminary experimental study carried out in the case of the continuous operation of a tribo-aero-electrostatic separator which allowed us to define the limits of the operating voltage (U = 28 ÷ 32 kV), the dimensions of the granular materials which vary in the range (2 ÷ 4 mm). At proportions of materials given as follows: 33% PA + 33% PVC + 33% PP, the purity of the separated materials is greater than 90% and in the case of disproportionate mixtures, the purity obtained reaches more than 92% for the material minor if increasing the air flow (maximum value d = 20 g / s).
The continuous operation of this separator can be accurately predicted by the numerical simulation model based on a simple mathematical model, presented in previous articles and validated in the present work.

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