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Review

Electrostatic separators of particles: Application to plastic/metal, metal/metal and plastic/plastic mixtures

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A R T I C L E   I N F O

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A B S T R A C T

Electrostatic separation is a generic term given to a significant class of technologies of industrial waste processing, widely used for the sorting of granular mixtures due to electric forces acting on particles whose average size is approximately 5 mm. The focus of this paper is on three electrostatic processes of separation used for processing of different types of mixtures: (i) role-type electrostatic separator, used to sort mixtures containing metal/plastic particles (copper/PVC for example); (ii) plate-type electrostatic separator, used to sort mixtures containing metal/metal particles (copper/lead for example) and (iii) free-fall electrostatic separator, used to sort mixtures of plastic/plastic particles (PVC/PE for example). Experiments carried out on industrial samples using laboratory electrostatic separators confirm the efficiency of these processes and show that the processes can improve the recovery and purity of products resulting from industrial wastes.

1. Introduction

Electrostatic applications are widely used nowadays in various domains as air filtration, surface coating and electro-photography (Moore, 1973; Bohm, 1982; Hughes, 1985; Crowley, 1986). Electrostatic separation is a generic term given to a significant class of material processing technologies, commonly used for the sorting of granular mixtures by application of electrical forces acting on charged or polarized particles (Ralston, 1961; Brands et al., 2001). Thus, these techniques are mainly used for the dry separation of small particles having a large difference of electrical conductivity (Inculet et al., 1998; Trigwell et al., 2003; Higashiyama and Asano, 1998; Carpco, undated). Further, electrostatic separation of copper, aluminium and insulating materials is a useful technology primarily employed for the preservation of the environment, since it offers recycled plastic of high quality and a better efficiency for the metals recovery rather than conventional methods of waste processing. It represents a modern technology of recycling industrial waste materials.

This paper describes three clean electrostatic processes of granular material separation resulting from industrial wastes such as electric cables.

2. Role-type electrostatic separator

The role-type electrostatic separator, using a high voltage corona discharge, makes possible the separation of insulator–metal granular mixtures, such as PVC–copper particles, with purities that can reach 99.9% (Tilmatine et al., 2003, 2004; Dascalescu et al., 2004a).

2.1. Description of the process

Fig. 1 shows the various elements of this type of separator. Electric charges are created by the air ionization due to the corona discharge generated by an electrode with emitting tips (1) called "corona electrode", connected to a high voltage direct-current supply. Metal/plastic particles are deposited on the rotating cylinder (2) by the vibratory feeder (3) and acquire an electric charge with the same polarity as the potential of the high voltage. The particles behave differently according to whether they are electrically, conducting or insulating.

- Due to the image electric force, insulating granules remain attached to the rotating roll and they adhere to its surface. They fall down into the collector (4) when the gravitational force becomes greater than the image electric force. To make sure that these particles can be removed from the cylinder surface, some separators are equipped by another electrode with emitting tips, called a "neutralization electrode" to eliminate the electric charge acquired by ion bombardment. In addition, a brush (5) is used to detach mechanically the remaining granules from the surface of the cylinder.
- Conducting particles quickly lose the charge, acquired by ion bombardment, through the grounded cylinder. When reaching the zone of the electrostatic field generated by the high voltage

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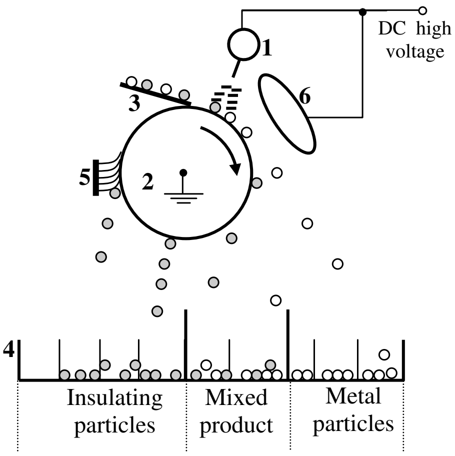

Fig. 1. Descriptive schematic of the role-type electrostatic separator. (1) Corona electrode connected to a direct-current high voltage supply; (2) grounded rotating cylindrical electrode; (3) electromagnetic vibratory feeder; (4) collecting hoppers; (5) brush and (6) static electrode connected to the same high voltage supply.

electrode of elliptic shape (6), called "static electrode", they acquire by electrostatic induction a charge of opposed polarity. They are then attracted and collected in the right side of the collector.

Two charging mechanisms are used simultaneously: ionic bombardment and electrostatic induction. The first is only for the insulating particles when embedded in the corona discharge zone, the second concerns the conducting particles in contact with the grounded cylinder with the presence of the electrostatic field generated by the elliptic electrode.

It is important to mention that many papers have been written on optimization of this electrostatic separation process (Dascalescu et al., 2004b,c,d; Kadous et al., 2004; Medles et al., 2007a,b).

2.2. Application to electric cable wastes

The role-type electrostatic separator can be employed for recycling electric cable wastes; the photos in Fig. 2 show two granular mixtures resulting from this type of wastes. Experiments were carried out on two samples.

- Sample 1: a total mass of 200 g containing 50% of PVC and 50% of fine copper.
- Sample 2: a total mass of 200 g containing 5% of PVC and 95% of massive copper.

The tests were carried out with an electrostatic separator built by one of the authors (Fig. 3) (Tilmatine et al., 2003, 2004). The results obtained are represented in Table 1. Table 1 shows and confirms the efficiency of the role-type electrostatic separator.

2.2.1. Sample 1

More than 94% of the copper introduced into the separator is recovered with purity higher than 99%. More copper can be recovered by reprocessing the collected product in the mixed compartment, since electrostatic processes consume little electrical energy.

2.2.2. Sample 2

The electrostatic separation process increases the purity of the copper up to 99.9% (the purity before separation was equal to 190/200 = 95%). This operation makes it possible to obtain metal with higher purity. Knowing its price which varies accordingly, it is beneficial to use the electrostatic process as "cleaning operation" of the metal product.

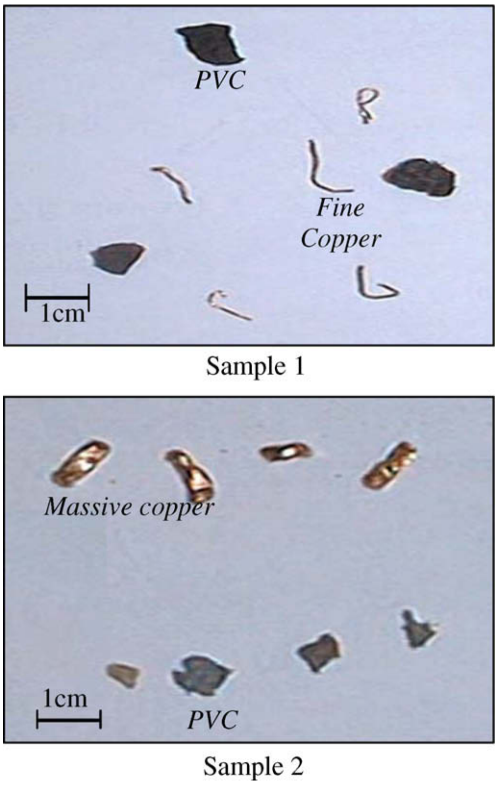

Fig. 2. Size and shape of the particles.

Fig. 3. Laboratory electrostatic separator SELMEG.

3. Plate-type electrostatic separator

The plate-type electrostatic separator is mainly used for the sorting of conducting/conducting particles, such as a granular mixture containing copper and aluminium fine particles.

Table 1
Results after processing of samples 1 and 2

Sample	Insulator compartment		Mixed compartment		Metal compartment		
	Mass of PVC (g)	Mass of copper (g)	Mass of PVC (g)	Mass of copper (g)	Mass of PVC (g)	Mass of copper (g)	[a]Pur (%)
1	92.4	0.5	7.4	5.2	0.2	94.3	99.8
2	8.0	0.2	1.9	4.8	0.1	185.0	99.9

Sample 1: 50% of PVC (100 g) and 50% of fine copper (100 g) and sample 2: 5% of PVC (10 g) and 95% of massive copper (190 g).
[a] Pur: purity of copper = 94.3 (185)/94.5 (185.1).

3.1. Description of the process

The operating principle of this separator can be described as follows (Fig. 4). The granules (more or less good conductors) are deposited by a vibratory electromagnetic feeder on the grounded plate electrode. The particles then "slip" on the surface of the plate and behave differently according to their electric conductivity:

- The granules with good conductivity, reaching the zone of the electric field generated by the high voltage static electrode of elliptical shape, are subject to an attractive electric force exerted by this electrode and thus are collected in the appropriate compartment.
- The granules with poor conductivity do not acquire a sufficiently large charge. They are, however, not attracted by the static electrode and thus drop under the action of their mass and their speed on the left side of the collector.

3.2. Application to salt/sand/glass powders

The experiments were carried out on two different samples having the same granulometric size, where the average size is about 0.1 mm. The tests were carried out using a laboratory electrostatic plate-type separator (Fig. 5):

- Sample 1: 50% of salt (50 g) and 50% of sand (50 g).
- Sample 2: 50% of salt (50 g) and 50% of glass (50 g).

After processing the two samples in the separator, the products are recovered in a collector containing 11 compartments (Fig. 6). The results of the separation tests on samples 1 and 2 are illustrated by histograms in Fig. 7. Results show that it is possible to use the plate-type separator for the sorting of powder mixtures with high purity. The efficiency of this process is shown in Fig. 7, where one can see that the particles are separated, with the resulting products having a higher purity.

The efficiency of this type of electrostatic separator varies and largely depends on the granulometric characteristics of the particles. In addition, let us note that this process can also be used to separate metal particles of larger granulometric size (approximately 5 mm), such as a mixture of copper/lead granules. Tests were carried out on this type of products, not yet published, with good results.

4. Free-fall electrostatic separator

The free-fall electrostatic separator, also called "triboelectric separator", separates granular mixtures containing insulator particles only, such as PVC and PE granules.

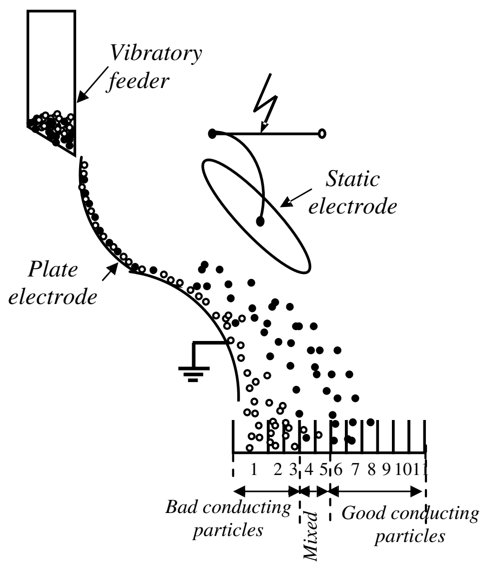

Fig. 4. Descriptive schematic of the plate-type electrostatic separator.

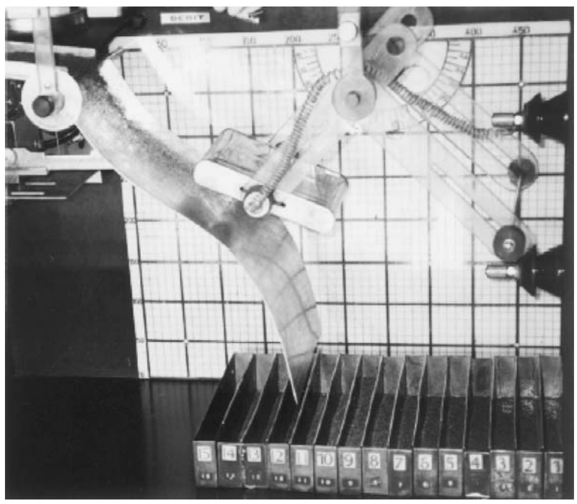

Fig. 5. Photography of a laboratory plate-type electrostatic separator.

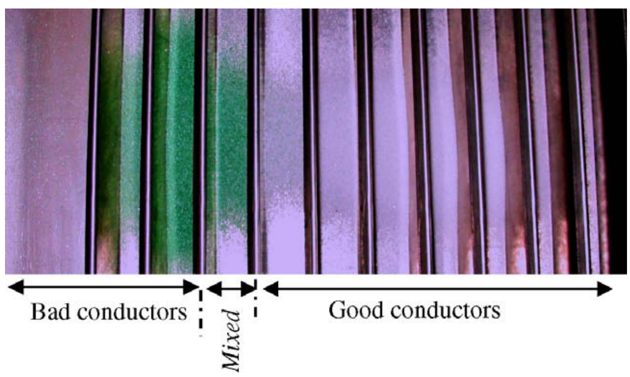

Fig. 6. Compartments of the collector.

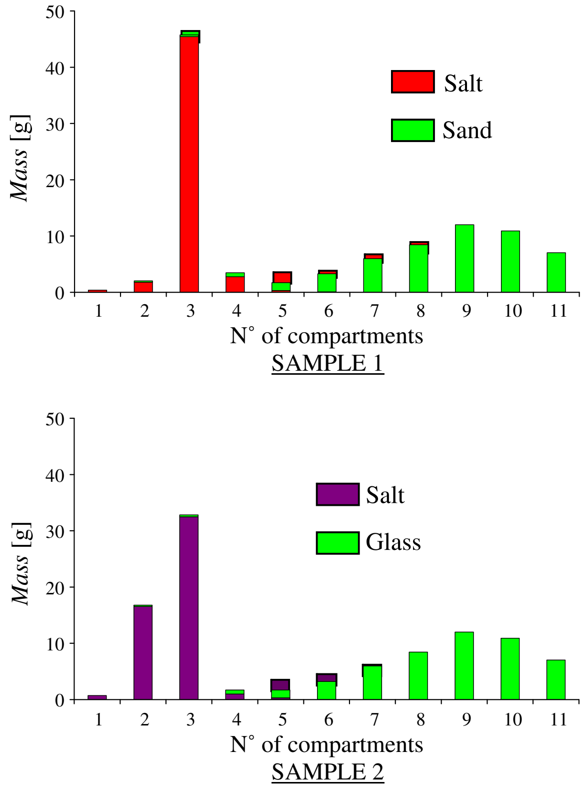

Fig. 7. Histograms of results after separation of samples 1 and 2.

4.1. Description of the process

When two different types of materials are rubbed one against the other, one type acquires a positive electric charge and the other becomes charged negatively. This charging mechanism is based on electrons transfer, not yet well explained, called "triboelectricity".

A descriptive schematic of a triboelectric separator is represented in Fig. 8. First, the particles enter an aluminium cylinder rotating with an adjustable speed. Then, inside the tube, the particles undergo several collisions among themselves (particle–particle collisions) and against the wall of the cylinder (particle–wall collisions). These collisions allow the granules to be charged by triboelectric effect. Thus, the charged particles exit from the rotating cylinder and fall vertically into an intense horizontal electrical field.

This horizontal electrical field is produced by two metal plates of rectangular form, connected to two direct-current high voltage supplies. The particles charged negatively are attracted towards the positive electrode and the ones charged positively are attracted towards the negative electrode. The products are recovered in a collector which contains three compartments (material 1, mixed product, and material 2).

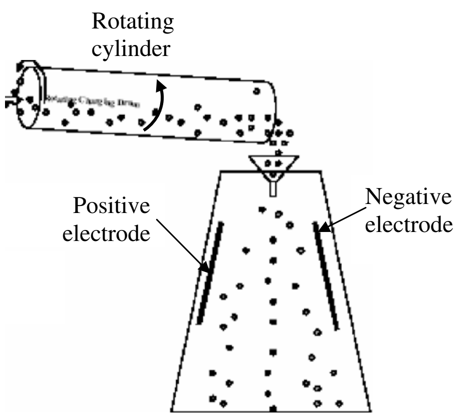

Fig. 8. Descriptive schematic of the free-fall separator.

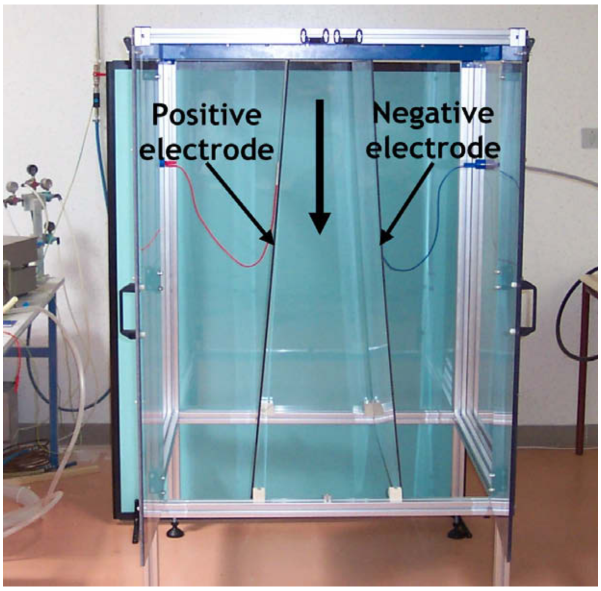

Fig. 9. Photography of a laboratory free-fall electrostatic separator.

Table 2
Results after processing in triboelectric separator

PE compartment			PVC compartment		
Mass of PE (g)	Mass of PVC (g)	Pur (%)	Mass of PVC (g)	Mass of PE (g)	Pur (%)
97.4	1.4	98.6	98.6	2.6	97.4

Sample PVC/PE: 50% of PVC and 50% of PE.

4.2. Application to PE/PVC mixtures

A laboratory free-fall triboelectric separator is shown in Fig. 9. Tests carried out using this laboratory prototype, on samples containing PVC and PE particles resulting from plastic wastes, make it possible to have an idea of the efficiency of this process. The products obtained after triboelectric separation have purities that exceed 95%.

The efficiency of this type of electrostatic separator varies and depends on the granulometric characteristics of the particles. Experiments were carried out on a PVC/PE granular sample of 200 g total mass containing 50% of PVC and 50% of PE. The particle size lies between 1 and 2 mm.

The tests were carried out using the laboratory electrostatic separator (Fig. 9) with an applied high voltage of 30 kV for the positive electrode and −30 kV for the negative electrode. Results presented in Table 2 show and confirm the efficiency of the free-fall electrostatic separator, for the recovery of plastic wastes.

5. Conclusion

The electrostatic separation of granular materials is considered to be an unconventional technology in the recycling industry. It is considered as an efficient and clean way to separate mixtures containing plastic and metal particles, resulting from industrial plastic wastes. Its development has been stimulated by regulations in the field of the environmental protection. The work presented in this paper, carried out on industrial samples, confirms the efficiency of the three types of electrostatic separators and demonstrates that the processes can improve the recovery and purity of products issued from industrial wastes. These processes of electrostatic separation are complementary and can be considered in combination in waste processing, by adding a magnetic separator to eliminate the ferromagnetic particles.

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