Influence of Particle Size after Grinding in Electrostatic Separation of Granular Plastic Mixtures

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Abstract **-**Triboelectrostatic separation is a technology which allows the separation of polymer materials based on their surface charging characteristics. As plastic waste is collected in various large sizes, it is necessary to control the particle size using crushing and shredding units to bring the particles into a proper size before they are subjected to electrostatic separation. The present paper aims to examine the effect of grinding and size reduction on triboelectric charge accumulation and electrostatic separation efficiency. The study was performed on typical pieces of PC-ABS and HIPS originating from waste electric and electronic equipment (WEEE), experiments start by feeding equal quantities of plastic pieces into the grinder. The rotary cutters of the grinder stir the plastic pieces, a charge transfer occur between the plastic particles by repeated rubbing against each other. After a certain time a granular mixture was recovered from the grinder and immediately introduced in a roll type triboelectrostatic separator. The charge of the selectively sorted products was measured using a Faraday cage connected to an electrometer. Four screen mesh diameters were compared (2 mm, 3 mm, 5 mm and 7 mm). It was found that particle size is definitively an important factor influencing the outcome of the triboelectrostatic separation; fine grinding is not favorable, it requires grinding for extended periods and favors the formation of particle agglomeration, high separation efficiency was obtained for relatively coarse particles

***Keywords* -** triboelectric charge, triboelectrostatic separation, particle size.

I. INTRODUCTION

Plastic waste is the most important issue the world has to deal with. Each year, millions of tons of plastic waste are carted off to landfill [1]. A number of studies have been conducted in the last years comparing treatment options for end of life plastic waste; it has been found that recycling is generally the environmentally preferred treatment option when compared to waste incineration and landfill [2].

Different alternatives for the management of plastic wastes were developed: optical sorting [3,4], density separation [5,6], flotation [7,8] and triboelectrostatic separation [9-10] Table I shows, a brief comparison among the main separation methods [11]. Triboelectrostatic separation use triboelectric effect in conjunction with the electric field forces, which consists in the electrification of materials based on their surface charging characteristics followed by their separation in an intense electric field. The main triboelectrostatic separators used for the selective sorting of insulating materials are free fall separators [12,13] and fluidized bed separators [14,15]

In the recycling industry Roll type electrostatic separators are commonly used for the selective sorting of conductive-insulator granular mixture [16,17] and crushed printed circuit boards waste [18], however it is not widely known in the separation of plastic mixtures.

As plastic wastes are collected in various large sizes, it is necessary to control the particle size using crushing and shredding units to bring the particles into a proper size before they are subjected to electrostatic separation; in this paper we present a study on the effect of particle size on the effectiveness of tribocharging and electrostatic separation.

Table I

Comparison of different methods for separation of plastic waste [11]

Method of separation	Separation basis	Wet or dry	Particle size for processing	Features
Optical sorting	Difference between colors and peaks	Dry	>40–60 mm	Low pollution, suitable for drinking bottles.
Density separation	Difference between densities	Wet/dry	It depends on the device	Simple, costly competitive
Flotation	Difference between surface properties	Wet	<500 µm	High efficiency, flexible
Triboelectrostatic Separation	Difference between effective surface work function	Dry	0.1-13mm	Suitable for most plastics, efficient, low pollution

The study was carried out on plastic mixtures obtained after grinding of pieces of plastic waste using different screen mesh diameters, the mixtures tribocharged in the grinder were then selectively sorted using a roll type triboelectrostatic separator.

The ground mixtures were not submitted to a sieving process to point out the effect of broad size distribution mixtures on the efficiency of triboelectrostatic separation.

II. MATERIALS AND METHOD

Two types of plastic were selected from waste electric and electronic equipment, Polycarbonate-Acrylonitrile Butadiene Styrene blend (PC-ABS) and High Impact Polystyrene (HIPS) Fig.1, they were then cut into pieces using a band saw (Metabo BAS 261 Precision band saw), an initial mass of 300 g of plastic pieces containing equal quantities of PC-ABS and HIPS was fed in the grinder (grinder manufactured by CITF company France), the grinding chamber is equipped with three rotary cutters made of stainless steel and a mesh screen placed below the cutters. During the grinding step, the plastic pieces are stirred up by means of the rotary blades, hence a charge transfer occur between the plastic particles by repeated rubbing against each other. After a certain time a mass of 200 g was recovered from the grinder and immediately transferred to the separation unit.

In this study the granular mixtures obtained after grinding (Fig. 2) were not submitted to charge neutralization or extra charging by triboelectric effect after the grinding process, the charge acquired during grinding was sufficient for their electrostatic separation.

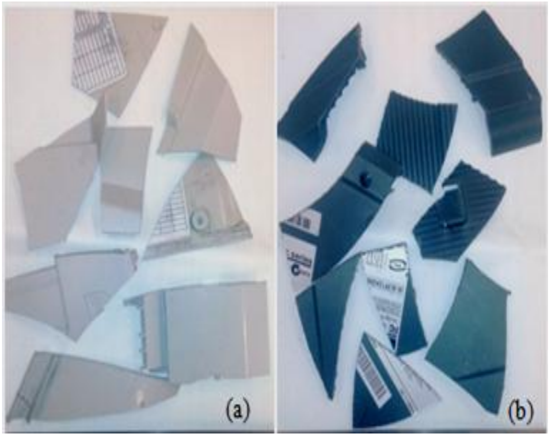


Fig. 1. (a) PC-ABS; (b) HIPS.

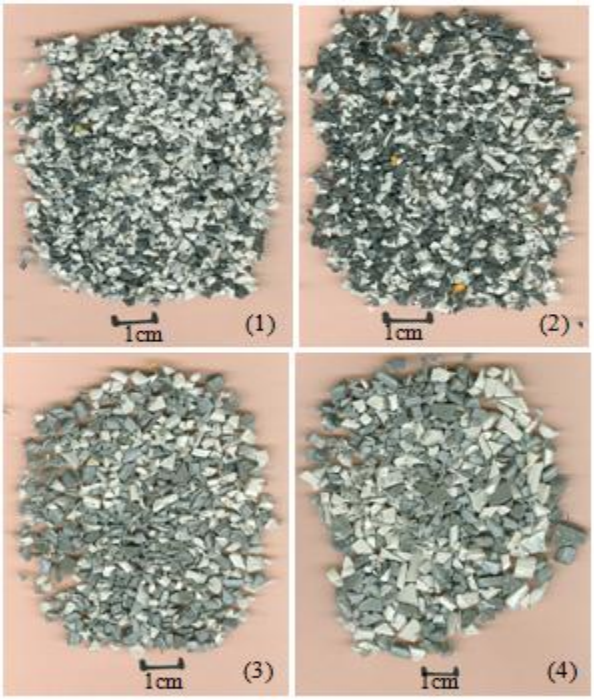


Fig. 2. Particle of PC-ABS and HIPS obtained after grinding : (1) using 2mm grid size; (2) 3mm grid size; (3) 5mm grid size; (4) 7mm grid size.

Four set of experiments were carried out to point out the effect of particle size on the effectiveness of charge accumulation and triboelectrostatic separation, thus four screen mesh diameters were compared (2 mm, 3 mm, 5 mm and 7 mm)

For each experiment, the mass and the charge of the collected products were measured using an electronic balance and a Faraday cage connected to an electrometer (Keithley Instruments model 6514) and then the charge to mass ratio was calculated.

The purity and the recovery of the collected products were calculated as follows:

$$P[\%] = \frac{m_{xBx}}{m_{TBx}} \times 100 \quad (1)$$

$$R[\%] = \frac{m_{xBx}}{m_{xB1} + m_{xB2} + m_{xB3}} \times 100 \quad (2)$$

Where m_{xBx} is the mass of the product *x* collected in the box reserved for it, m_{TBx} is the total mass recovered in B_x (compartment reserved for product *x*) and m_{xBi} is the mass of product *x* collected in the different collectors B1, B2, B3.

After each of the four sets of experiments, a granulometric separation was carried out using a vibrating sieve shaker (Retsch, model AS200 basic) to determine particle size distribution in each collecting box.

The selective sorting of the granular mixture was performed using a roll type electrostatic separator (provided by PRODECOLOGIA Company Ukraine) shown in Fig. 3, in such separators the granular mixture to be sorted is deposited on a vibrating feeder (labeled 1) which introduce them as a monolayer on the surface of a rolling cylinder connected to the ground (labeled 2), the differently charged particles pass through an intense electric field generated by a high-voltage electrode connected to a DC power supply(labeled 3), depending on the polarity of their charge, particles are either deflected towards the high voltage electrode and collected in collecting box 1 or pinned to the surface of the roll electrode and recovered in box 2, the particles that remain attached to the surface of the rotating electrode are detached using a brush and recovered in box 3.

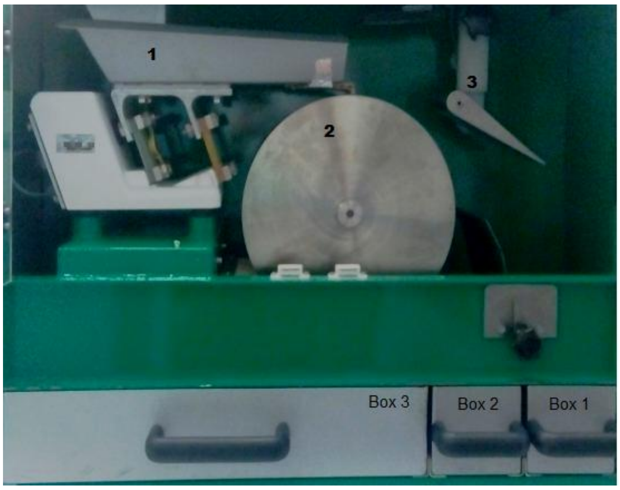


Fig. 3. Photography of roll type electrostatic separator.

In the present study the high voltage electrode was connected to a positive polarity DC power supply, all the experiments were performed at the set point recommended in a previous study [19], the inclination angle of the high voltage electrode α = 35°, the high voltage applied to the electrode U = 25 kV, the splitter position angle β = - 10°, the roll speed n= 40 rpm and the feed rate Q = 2.5 g/s.

III. RESULTS AND DISCUSSION

In all the experiments the HIPS particles acquired a negative charge during grinding and were attracted to the high-voltage electrode connected to a positive polarity DC power supply and collected in compartment B1, while PC-ABS particles got charged positively and were collected in compartment B2. The product collected in compartment B3 was grouped with the granules recovered in B2, as it contains mainly PC-ABS particles.

The experiments were performed at temperature ranging between 15°C and 17°C and ambient relative humidity that varied between 38% and 41.5%.

Figs. 4 and 5 compare the recovery and purity of the PC-ABS and HIPS products obtained in the four sets of experiments. In the case of fine grinding using a screen mesh of 2 mm diameter the recovery of HIPS product did not exceed 89% with purity of 96%, and 97% of PC-ABS product was recovered with purity of 88%, in fact, particles with a size range of 0.25mm-1mm are generated during grinding, the oppositely charged particles combine and form agglomerates destroying the purity of PC-ABS.

The charge to mass ratio recorded for the collected products -2.69 nC/g and 4.18 nC/g for HIPS and PC-ABS respectively.

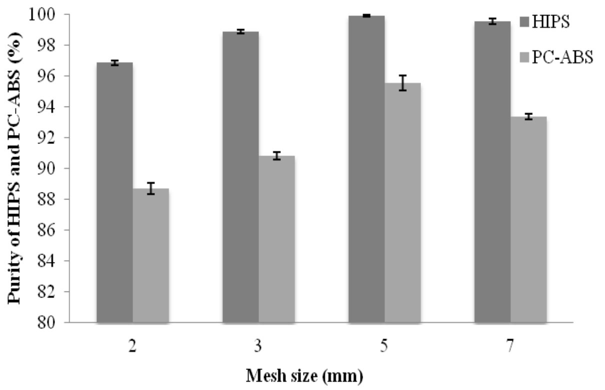


Fig. 4. Purity of HIPS and PC-ABS products

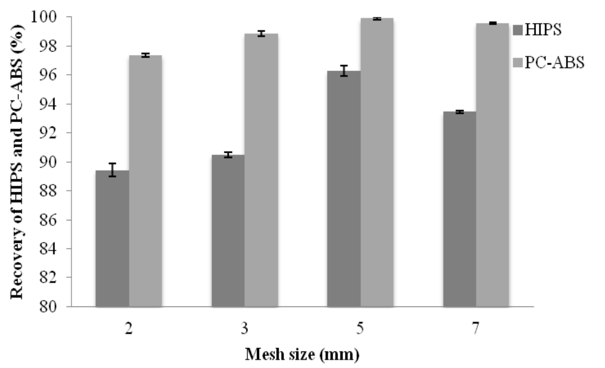


Fig. 5. Recovery of HIPS and PC-ABS products

For the second set of experiments, increasing the mesh screen size lead to a decrease of the presence of fine particles in the mixture this indicates that less particle agglomerates are produced in the mixture. The purity of the products increase to 91% for PC-ABS and 98% for HIPS with recovery rates of 98% and 90% respectively, the charge of the collected products were -2.52 nC/g for HIPS and 3.87 nC/g for PC-ABS.

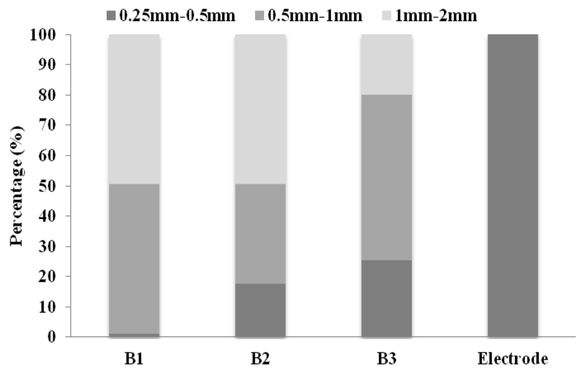
Grinding using 5mm diameter screen mesh gives better results. HIPS particles were sorted with recovery of 96% and purity of 99%, as for the PC-ABS particles the recovery and purity rates were about 99% and 95% respectively. The particles were characterized with a charge to mass ratio of -2.37 nC/g for the HIPS particles and 3.23 nC/g for PC-ABS particles.

In the case of coarse grinding, HIPS particle acquired a charge of -1.97 nC/g and PC-ABS 2.76 nC/g, the electric field generated between the high voltage electrode and the roll grounded electrode was not sufficient to attract the coarse particles of HIPS (typical size > 7mm) so they fall in the box reserved for the PC-ABS product, thus reducing the recovery of HIPS and purity of PC-ABS to 93%.

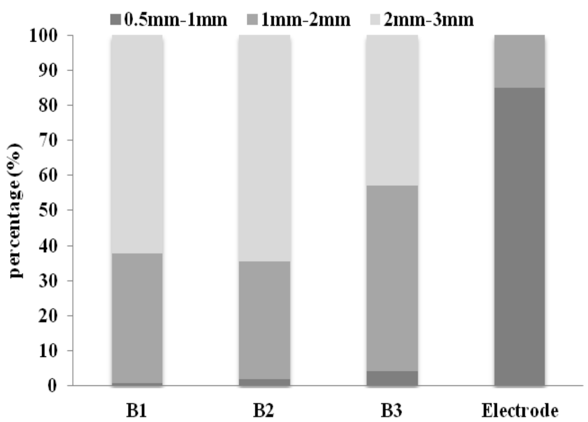
The residence time of the mixture in the grinding chamber decrease with the increase of grid diameter, hence the charge acquired by the particles also decrease gradually.

It was observed during experiments that the high voltage electrode get covered with fine particles of HIPS, in the case of grinding using a screen mesh of 7mm or 5mm about 5% to 6% of the mass of HIPS stick on the surface of the electrode with a charge to mass ratio of about-5.92 nC/g and-6.56 nC/g respectively, while for 3 or 2mm diameter mesh screen 14% to 16% of the total mass of HIPS adhere on the surface of the electrode with a charge of about -12nC/g.

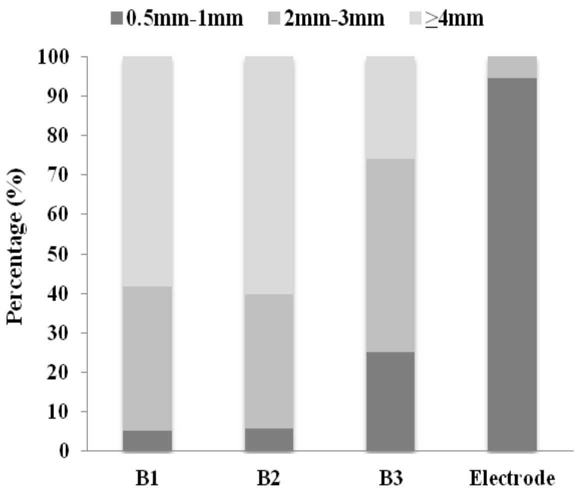
The results of the granulometric separation (Fig. 6) show that grinding generates mixtures with broad size distribution.



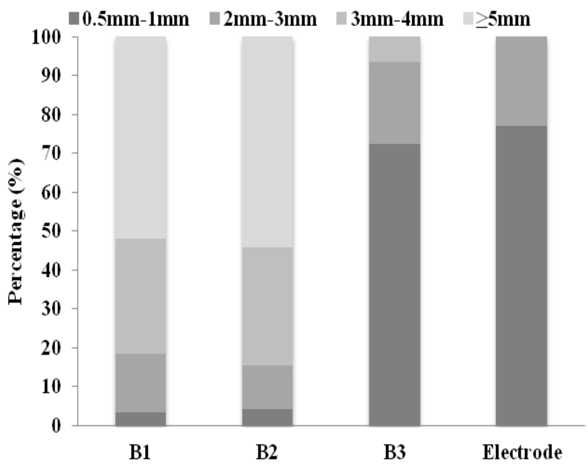
(a)



(b)



(c)



(d)

Fig. 6. Size distribution of particles in the collecting boxes (B1, B2, B3) and the electrode for diffrent screen mesh diameters : (a) 2mm, (b) 3mm, (c) 5mm, (d) 7mm.

In the four cases studied, it was observed that collecting box 1 and 2 have the same size distribution, generally coarse particles were recovered in box 1 or 2 according to the polarity of their charge. Small particles with high charge were pinned to the surface of the roll electrode and were collected in box 3.

IV. CONCLUSION

The study presented in this paper examines the effect of grinding on triboelectrostatic separation of plastic mixtures; the following results can be concluded:

Particle size is definitively an important factor influencing the outcome of the triboelectrostatic separation. Roll type electrostatic separator has proved his efficiency in processing mixtures with broad size distribution, however the presence of fine particles of typical size between 0.25mm and 1mm have a negative effect on electrostatic separation process, it favors the formation of particle agglomeration and adhesion to the surface of the electrode.

The choice of mesh screen diameter can play an important role in grinding process, particles reduction into small sizes requires grinding for extended periods.

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