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Tribocharging of plastics granulates in a fluidized bed device

Alexandru Iuga[a,*], Laur Calin[a], Vasile Neamtu[a], Adrian Mihalcioiu[a,b], Lucian Dascalescu[b]

[a]*The High-Intensity Electric Fields Laboratory, Technical University of Cluj-Napoca, 15 C. Daicoviciu Street, 400020, Cluj-Napoca, Romania*
[b]*Electronics and Electrostatics Research Units, LAII-ESIP, UPRES-EA 1219, Institut Universitaire de Technologie, 4 Avenue de Varsovie, 16021 Angoulême, France*

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Abstract

The paper presents a modular fluidized bed device for the study of plastics tribocharging and electrostatic separation, with application in the field of plastic recycling. Evaluation of the device in *independent* operation for charge-to-mass ratio measurements pointed out the different triboelectric behaviour of six tribocharging chambers made of plastic (PVC, PP, PET, PE, PMMA) and aluminium. The electrostatic separation tests carried out on PET and PVC granulates confirmed the effectiveness of the fluidized bed tribocharging device *integrated* in a free fall separator. They pointed out three charging mechanisms by particle/particle and particle/walls collisions.

Keywords: Tribocharging; Fluidized bed; Electrostatic separation; Plastics granulates

1. Introduction

Triboelectrostatic separation of recyclable plastic materials is an advanced technical solution to an ecological problem. The separation effectiveness relies on

*Corresponding author. Tel.: +40 264401429; fax: +40 264592055.
E-mail address: Alexandru.Iuga@et.utcluj.ro (A. Iuga).

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the ability to control particle tribocharging [1–4], a process which still defies the true test of scientific understanding, i.e., predictability of outcome [5]. The versatility of a newly-designed fluidized bed tribocharging device was validated by several tribocharging and separation experiments carried out on PET and PVC granules.

2. Laboratory fluidized bed tribocharging device

The main features of the newly designed fluidized bed tribocharging device presented in Fig. 1 are the following: (i) *transparent walls* to facilitate the visual observation of the fluidization process and particle motion in the tribocharging chamber; (ii) *replaceable air distributors* correlated with granulates size; (iii) *easily replaceable tribocharging chamber* made of polymethylmethacrylate (PMMA), polyethylene therephtalate (PET), polyethylene (PE), polyvinyl chloride (PVC), polypropylene (PP), aluminium (Al); (iv) *dual operation mode*, namely *independent* for granulates charge measurement and *integrated* with a free-fall electrostatic separator; (v) *modular solution* (air chamber, input–output module, tribocharging chamber). These features allow the use of the tribocharging device for various experimental studies.

3. Tribocharging testing

The first set of experiments was carried out on the *independently-operating* device (Fig. 2), with the aim of finding the adequate tribocharging chamber for the PET/PVC separation. An experimental procedure was put in place and an ad hoc experimental triboelectric series was established.

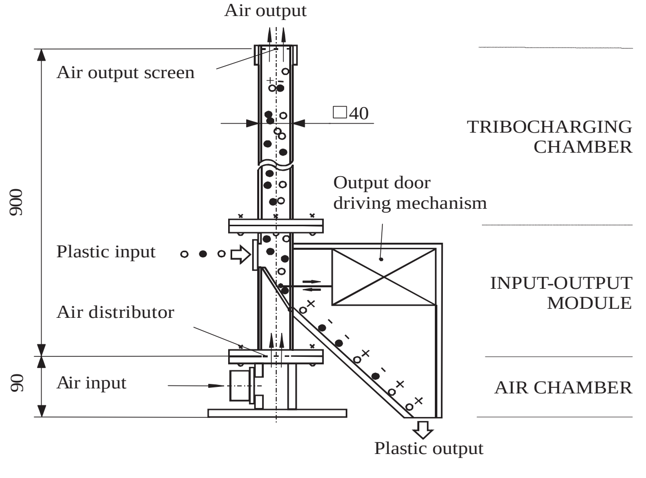


Fig. 1. Fluidized bed tribocharging device for granular plastics.

Fig. 2. Experimental set-up for the study of PET and PVC granulates tribocharging: 1—fluidized bed device with transparent PMMA walls; 2—replaceable PET, PE, PVC, PP, A1 tribocharging chambers; 3—turboblower; 4—air speed regulator; 5—Faraday pail; 6—electrometer; 7—scale; 8—thermo hygrometer.

3.1. Materials and experimental set-up

Materials used in tribocharging and separation experiments were virgin PET and PVC granulates. As these materials have similar densities (1380 kg/m^3 PET and 1350 kg/m^3 PVC), this plastic mixture is difficult to separate by conventional methods [6]. Parallelepiped shape granulates ($3 \times 2 \times 2$ mm PET and $4 \times 2 \times 2$ mm PVC) differ by colour (white PET and grey PVC). Each experiment was performed on 25 g of clean, fresh plastic.

The tribocharging device 1 in Fig. 2 is equipped with a PMMA chamber, which can be replaced with various other chambers 2. "The turbulent" steady-state [7] required for tribocharging is obtained with an adjustable air supply 3 and 4. Charge-to-mass ratio Q/m is determined with a Faraday pail 5 connected to electrometer 6 using the electronic scale 7. The thermo-hygrometer 8 monitors the fluidized air conditions at the exit of the tribocharging chamber. They were maintained at a relative humidity of roughly 23% and a temperature of about 40 °C.

For the first set of experiments, the residence time in the tribocharging device was 3 min for each of the 25 g samples. The charged material was directly transferred to the Faraday pail. Wall contact during the short transfer time proved to be negligible.

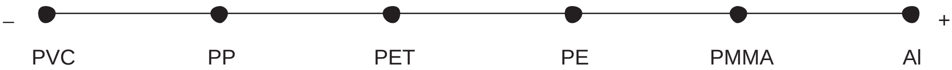
3.2. Selection of adequate tribocharging chambers

The results in Table 1 lead to a preliminary triboelectric series for the chamber materials with respect to PET granules: (*negative*)-PVC-PP-PET-PE-Al-PMMA-(*positive*). Final position of the six materials in the experimental triboelectrical series was established through additional tribocharging testing of each element with its neighbours. As a consequence, Al was finally positioned at the positive end.

Table 1
PET granulates charge in [nC/g] after three minutes of tribocharging in the six chambers

Granulates	Chamber	PVC	PP	PET	PE	PMMA	Al
PET		+18	+3	−5	−6	−18	−11

Experimental triboelectric series



As PP is located between PVC and PET in this series, the use of a PP chamber may be advantageous for the opposite charging of PET and PVC. Consequently, use of PP chamber will be preferred for PET/PVC triboelectrostatic separation.

4. Electrostatic separation tests

Three mechanisms mainly influence the net charge accumulated by particles of a binary plastics mixture: collisions between particles of the same type, collisions between different types of particles, and particles-wall collisions [8]. The tests carried out with the tribocharging device *integrated* in the free-fall electrostatic separator (Fig. 3) prove the presence of these mechanisms.

The operating conditions for electrostatic separation were the following: potentials $V_1 = -50\,\text{kV}$, $V_2 = +50\,\text{kV}$, electrodes equally distanced from the in-feed, distance between the upper ends of the electrodes 150 mm, electrode angle to vertical axis $\alpha = 5^\circ$, electrode length 1000 mm, fluidizing air 23%RH and 40 °C.

Test No. 1. The binary mixture 50%PET-50%PVC was tribocharged in an Al chamber for 1.5 min and then separated in the electrostatic field (Fig. 4a). This experiment reveals that although PET and PVC charge negatively by collisions with aluminium chamber walls (Table 1—Triboelectric series), the resultant charge is produced by collisions between PET and PVC.

Test No. 2. The same mixture PET/PVC charged in a polypropylene chamber for 1.5 min and then passed through the free fall electrostatic separator (Fig. 4b). Better results in this test are due to an excess of charge on the PET and PVC granulates by particles/PP walls collisions (Table 1—Triboelectric series). The duration of tribocharging in Tests 1 and 2 was experimentally established to 1.5 min, when opposite charges on PVC and PET are high enough (diagram in Fig. 3) to allow the best purity.

Test No. 3. This experiment used 50 g of PET granulates only, charged in an aluminium chamber for 5 min, and then fed into the free fall separator. After passing through the electrostatic field, about 80% of granulates, negatively charged (Table 1), were collected on the positive electrode and about 20% were collected to the opposite electrode. This experiment confirmed that particles of the same material

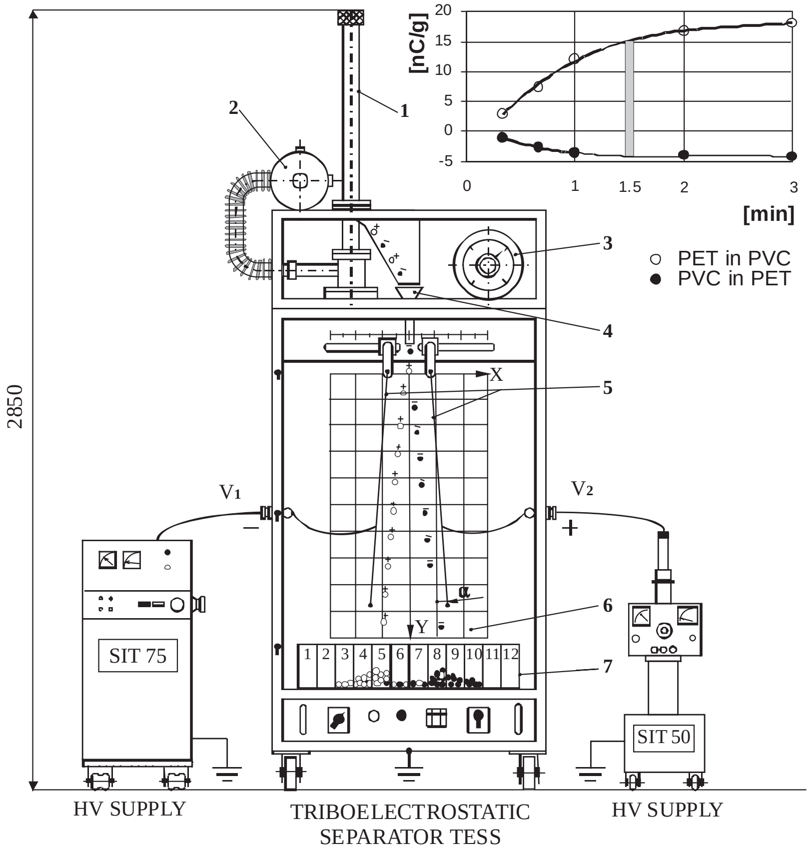


Fig. 3. Fluidized bed device integrated in the free fall electrostatic separator; 1—tribocharging device; 2—turboblower; 3—air speed regulator; 4—entrance; 5—electrodes; 6—positioning panel; 7—boxes.

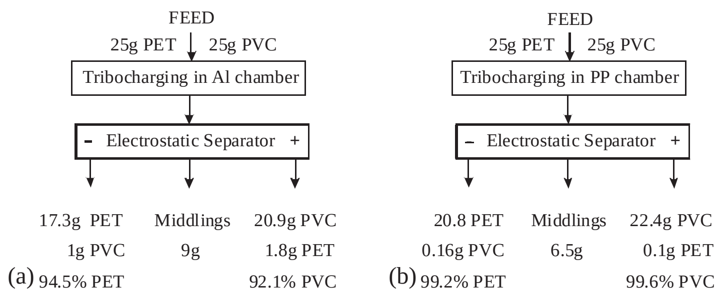


Fig. 4. Experimental results for triboelectrostatic separation of 50% PET, 50% PVC mixture.

charge with opposite signs after collisions between them [8] so the presence of collisions between granulates of the same material represents an impediment to obtain high purity plastic concentrates.

5. Conclusions

The newly designed laboratory fluidized bed device is adequate for the study of the complex tribocharging phenomena and electrostatic separation in the field of plastic recycling.

Tribocharging is a statistical process, so it is of future interest to put more effort into statistical validation and reproducibility of plastic tribocharging studies.

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