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# Triboelectrical charge generated by frictional sliding contact between polymeric materials

T Zeghloul<sup>1</sup>, M B Neagoe<sup>1</sup>, Y E Prawatya<sup>1,2</sup> and L Dascalescu<sup>1</sup>

<sup>1</sup> Institut P', UPR 3346 CNRS - Université de Poitiers - ENSMA  
IUT, 4 avenue de Varsovie, 16021 Angoulême, France

<sup>2</sup> Department of Industrial Engineering, Tanjungpura University  
Jl. Ahmad Yani, 78124 Pontianak, Indonesia

E-mail : thami.zeghloul@univ-poitiers.fr

**Abstract.** The polymers used regularly in mechanical assemblies are brought up in relative sliding. The electrostatic charges generated in these functional conditions are merely known. Many factors are involved in the triboelectric charging process: normal load, the sliding velocity. The aim of this paper is to analyse the influence of these factors in the repartition and evolution of the electric potential at the surface in contact. The tribocharging experiments are carried out with samples cut from three polymers: sample A (5 mm x 15 mm x 100 mm) from Acrylonitrile Butadiene Styrene (ABS) or Polypropylene (PP), and sample B (5 mm x 50 mm x 180 mm) from Polyvinyl Chloride (PVC). The normal load is set to four values in the range 2 to 14 N, and the sliding velocity is varied between 70 and 122 mm/s. The results point out that the variation of relative velocity between samples is not changing the average potential for the sample B. The surface potential has a linear increase with the normal load.

## 1. Introduction

The increasingly use of polymers and polymer composites in numerous industrial applications, such as aerospace, automotive, railway, etc., require their better characterization from different points of view. Compared with other materials, they can provide self-lubricant conditions, high strength/weight ratio, good mechanical and thermal properties, as well as a remarkable ease of manufacturing [1-5]. It is well known that rubbing together two insulators can provide an electrostatic charge generated at the surface of the bodies [6-8]. Studies are made to better control the electrostatic charge with the purposes to minimize it and avoid hazards (i.e. ignition in flammable environments) [9] or to maximize for industrial applications (i.e. electrostatic particle separation) [10].

The tribology theory is not simple, adding electrostatic phenomena increases its complexity. The study of electric charges through contact and friction between insulating materials has been an interest for many researchers. Because of multitude of factors involved, sliding charging is more complicated than simple contact charging [11-12].

The polymers used regularly in mechanical assemblies are brought up in relative sliding. The electrostatic charges generated in these functional conditions are merely knew. Many parameters are involved in this triboelectric charging mechanism: normal load, roughness, sliding velocity, rubbing time, etc. [13-23]. The aim of this study is to evaluate the effect of the normal load and the sliding velocity on the tribocharging of pairs of samples cut from Acrylonitrile butadiene styrene (ABS), Polyvinyl Chloride (PVC), and Polypropylene (PP).



## 2. Methods and materials

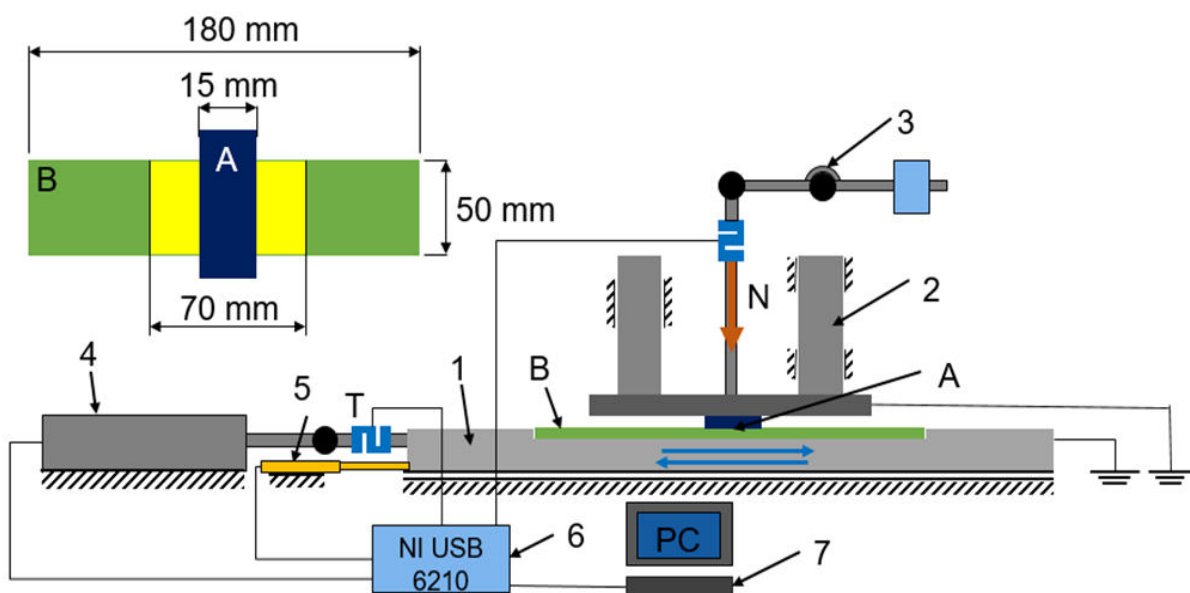
Two types of samples (A): 5 mm x 15 mm x 100 mm, and (B): 5 mm x 50 mm x 180 mm are employed for the electric tribo-charging experiments. They are cut from ABS, PVC, and PP. The samples (A) are cut from ABS or PP, while (B) is made of-PVC. The residual charge at the surface of these samples is neutralized using an ionizing system (electrode ECA 88 BS and high-voltage supply SC 04 B, 5 kV, 7 mA, manufacturer: ELCOWA, Mulhouse, France).

### 2.1. Charge generation

Tribocharging process is carried out using a linear tribometer (figure 1) to generate the electric charge by friction between a pair of samples (A) and (B). The (A)-type sample is connected to a top holder (2) fixed in a vertical guiding system and using an adjustable arm (3) to vary the normal load. The (B)-type sample is placed in a holder attached to a back-and-forth sliding motion system (1), driven by an electric actuator (4). The tangential and normal loads, as well as the relative displacement of the samples are continuously measured. This laboratory bench enables the control of several factors that affect the electrostatic charge generation: relative sliding speed, normal contact load, and number of back-and-forth cycles. Room temperature and relative humidity are important factors in electric surface charging experiments and also for wear generation. The two are constantly read with a thermo-hygrometer and are kept in a certain interval of variation 23-25 C° respectively 35-45% RH, using a dehumidifier- heating system.

The experiments are conducted to show the effect of the relative velocity and normal load for the samples (A) and (B) brought in sliding contact in the tribocharging process. For the first experiment velocity is setup at 70 mm/s, 82 mm/s, 95 mm/s, 110 mm/s and 122 mm/s respectively. The normal load is  $FN = 10$  N and the number of sliding cycles is 10. The stroke used is 55 mm. The contact surface on sample B has the dimensions 50 mm (given by the bottom (B) sample width) and 70 mm (i.e., the stroke plus the width of the top (A) sample A). A second experiment is conducted at four values of the normal load: 2 N, 6 N, 10 N and 14 N. The relative velocity is setup at 82 mm/s, the number of cycles and the stroke are the same as in the previous experiment. Each experiment is repeated three times.

The surface of the sample (B) is investigated with a thermal infrared camera (FLIR E60) to monitor the increasing of temperature on the surface.



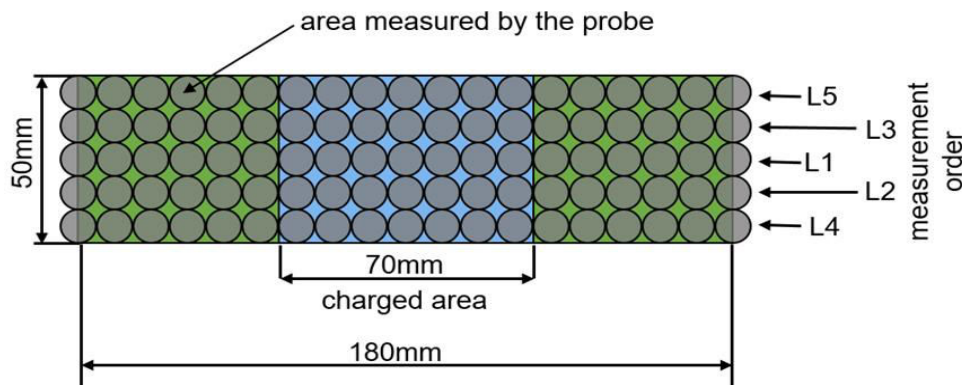
**Figure 1.** Schematic representation of the laboratory bench for triboelectric charging.

## 2.2. Charge measurement

The electric charge generation is monitored by measuring the surface electric potential distribution at the end of rubbing process on sample (B). This method has already been employed in another paper [24]. The measurements are performed with an induction probe (Trek, model 3450) of a 10 kV electrostatic voltmeter (Trek, model P0865). After charging, the sample is transferred in a 2-axis positioning device that facilitates the cartography of the surface potential. The measurement is performed in 5 x 19 grid beginning with line L1 (figure 2). The probe is measuring each 10 mm in a straight line. The distance between the sample and probe is 3 mm.

The probe “sees” the potential on a surface that has a diameter of approximately 10 mm. The surface potential measurements are conducted on the entire surface of the sample (B), including the area that comes not in contact with the sample (A). The data used for the analysis are the values of the average surface potential of the contact area.

Roughness measurements are performed using the roughness meter Mitutoyo SJ210 according to the standard ISO-1997. The measurements are repeated three times, for a sampling length of 15 mm. The roughness tests are made in the same direction as the sliding.



**Figure 2.** Potential measurement mapping.

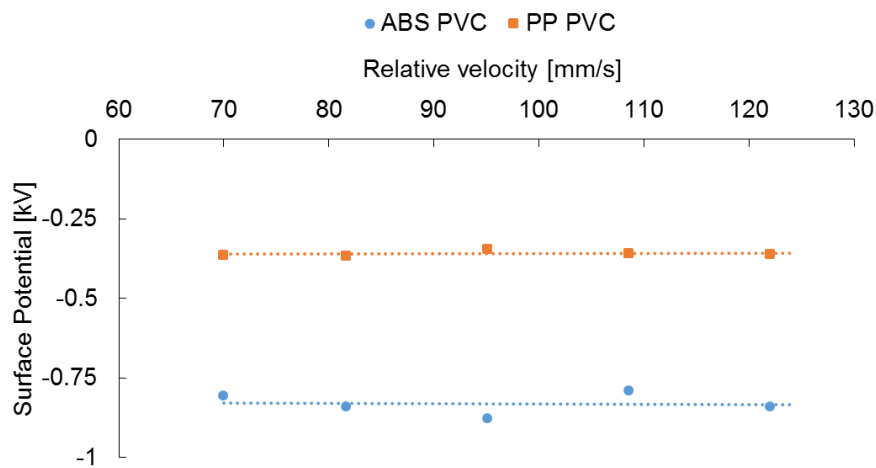
## 3. Results and discussions

Due to the low number of back and forth cycles (ten, in this experiment), the temperature increase on the sample is limited at a maximum of 1.5 °C. The level of temperature is studied to ensure that a secondary charging effect generate by the heating will not appear. The temperature variation on the surface of the sample is lower than that of air temperature. Therefore, it can be considered that sample heating does not significantly affect the charge.

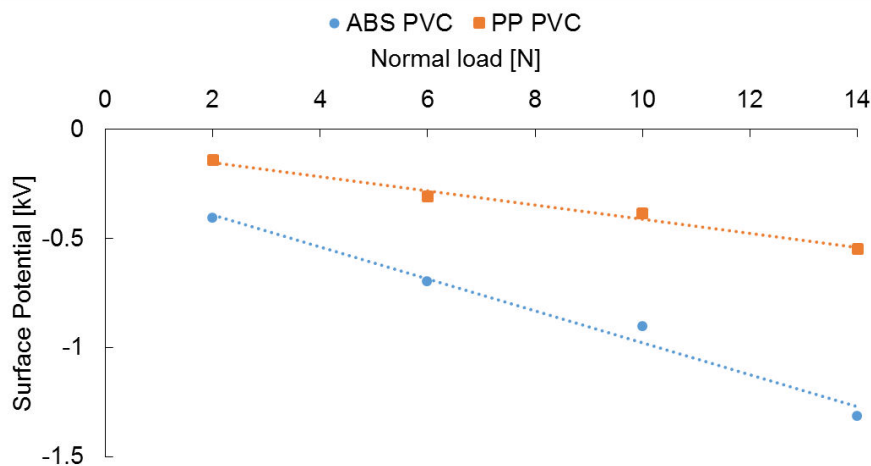
The initial roughness of the three samples is:  $R_{a\text{ ABS}} = 0.5 \pm 0.1 \mu\text{m}$ ,  $R_{a\text{ PP}} = 1.2 \pm 0.1 \mu\text{m}$  and  $R_{a\text{ PP}} = 0.1 \pm 0.02 \mu\text{m}$ . These values are in the same class of roughness (0.1-2  $\mu\text{m}$ ). As a consequence, the effect of initial roughness can be considered as non-significant.

The two pairs of samples under study, ABS-PVC and PP-PVC, are expected to have a different tribocharging behavior. The first experiment points out that the average value of the surface potential is the same, at different sliding speeds (figure 3). The average value of the electric potential measured for the pair ABS-PVC is higher than for PP-PVC, in good agreement with ABS and PP in the triboelectric series [25].

In the second experiment, The increase of the normal load between the two samples produce a linear increase of the average surface potential of sample (B), as shown in figure 4. The tendency slope of the electric potential measured for the ABS-PVC pair is steeper than that obtained with the PP-PVC samples. This means that, in contact with the PVC, the ABS can generate a higher charge than the PP, at a given normal load between the bodies in contact.



**Figure 3.** The average surface potential of contact area on sample (B) vs. the relative velocity between samples.



**Figure 4.** The average surface potential of contact area on sample (B) vs. the normal load between samples.

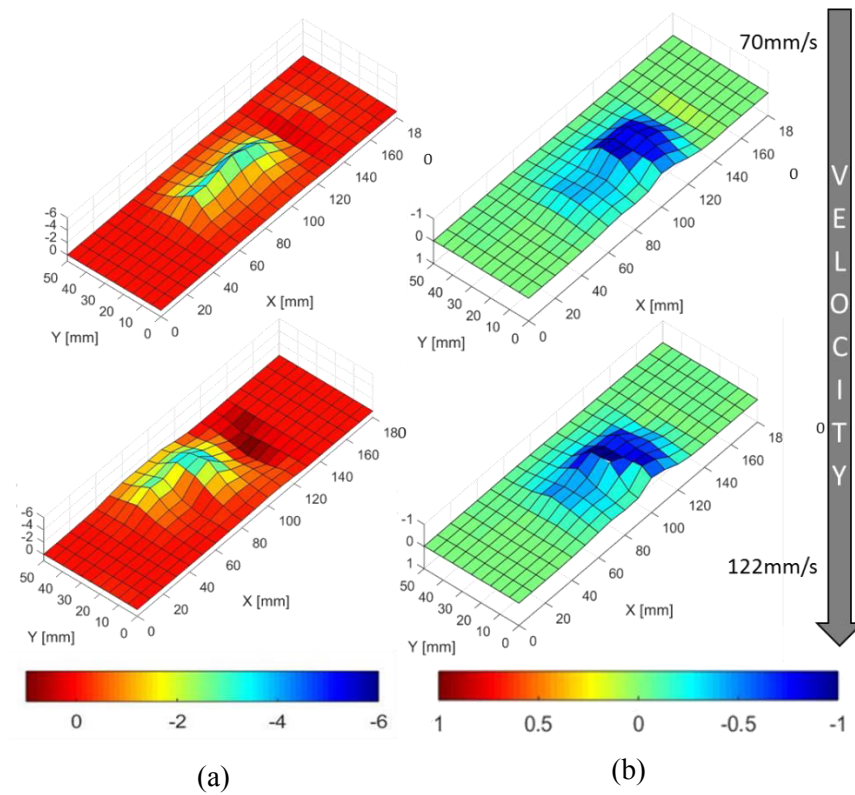
In figures 5 and 6, the repartition of the surface potential on sample (B) is represented for the limit values of the sliding speed, 70 mm/s and 122 mm/s, and of the normal load, 2 N and 14 N, for which the experiments have been conducted. From figure 5 can be seen that with the increase of the sliding speed the charged area is changing the position but the uniformity of potential repartition is similar. Figure 6 indicates that the footprint of the charge is increasing with the normal load. This phenomenon is partly due to the fact that increasing the load causes also the deformation of the samples. The maximum value of the surface potential is increasing from -1.7 kV for the 2 N load, to almost 4 kV for the 14 N load.

#### 4. Conclusions

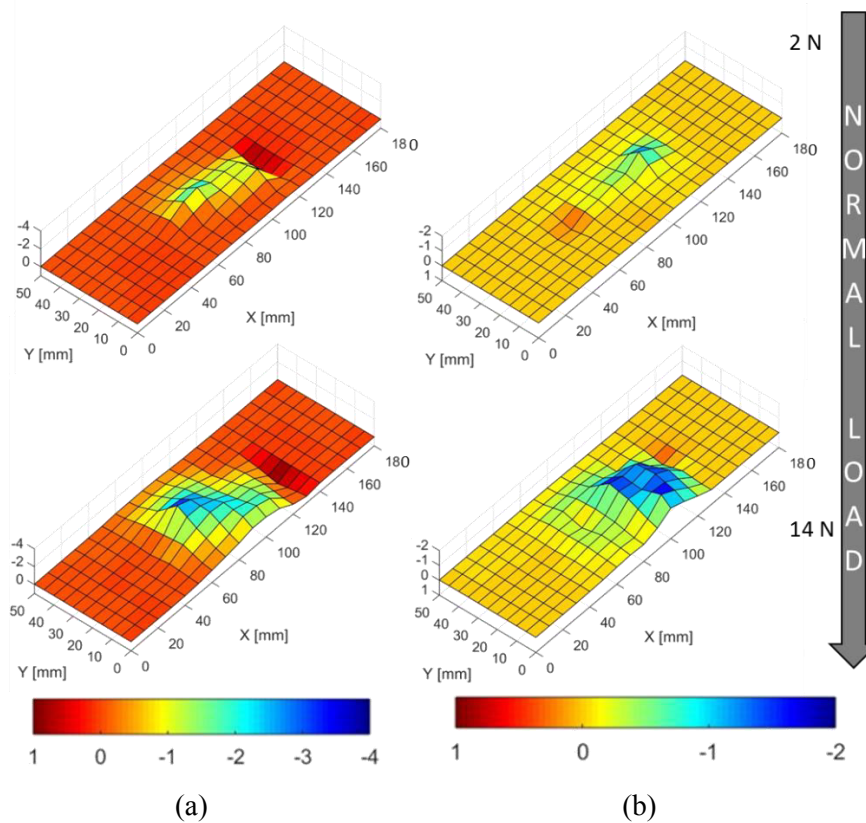
The two sets of experiments conducted to analyze the generation of triboelectric charge by dry rubbing point out the following conclusions:

- (1) The sliding velocity has no influence on the tribocharge generation, either for the rubbing of ABS-PVC or PP-PVC.
- (2) A linear variation exists between the load and the average surface potential measured after rubbing of ABS-PVC and PP-PVC pairs. The ratio between the average potential of the two rubbing pairs is kept constant when increasing the normal load between the bodies in contact.
- (3) The non-zero surface potential area is increasing with the load due to the increase of contact footprint between the two samples.





**Figure 5.** Surface potential mapping for minimum and maximum values of the sliding velocity (70 mm/s and 122 mm/s, respectively); (a) ABS-PVC; (b) PP-PVC.



**Figure 6.** Surface potential mapping for minimum and maximum values of the normal load (2 N and 10 N, respectively); (a) ABS-PVC; (b) PP-PVC.

## Acknowledgement

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