Accelerated Discharge of Corona-charged Non-woven Fabrics

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Abstract— **Fibrous polymers with extremely low electrical conductivity as polypropylene, polycarbonate, polyurethane and polyethylene are commonly employed as air-filter materials. The charge accumulated on such materials due to tribocharging effects inherent to the manufacturing process might be harmful either to the operator or to the electronic equipment of the production line. Whenever charge build-up cannot be avoided, it is important to dispose of effective means to rapidly discharge the materials. The present work aims to evaluate the efficiency of active neutralization of charged non-woven fabrics. The experiments have been carried out on 0.3 mm thick polypropylene (PP) and polyester (PE) fibrous media, the average diameter of the two types of fibers being 28 µm and 19 µm respectively. The non-woven fabrics were charged by exposing them to a negative corona discharge generated by a wire – grid – plate electrode system. The samples, laid on the surface of the grounded electrode or suspended at a small distance (4.6 mm) above it, were then subjected to the action of the bi-polar ions generated by a commercial neutralizer (model 6430, Ion Systems Inc., Berkeley, CA). The monitored variable was the surface potential detected by the probe of an electrostatic voltmeter. The controlled variables were the potential of the grid electrode, the neutralisation time, and the distance between the neutralizer and the media. The results of the experiments enabled a crude evaluation of each factor effect. Research should continue, using the experimental design methodology, in order to establish the optimum conditions for charge neutralization.**

Index Terms— **surface potential decay, corona discharge, charge neutralization, fibrous dielectrics.**

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I. INTRODUCTION

CHARGING and discharging characteristics of non-woven fabrics have been most often investigated in relation to one particular class of applications: the electret filters for dust collection [1-3]. When used for the filtration of submicron particles from polluted gases, the fibers of the fabrics are electrostatically charged, in order to enhance the collection efficiency in comparison with that of mechanical filters. A good air-filter should be able to preserve a high level of electric charge for as long a time as possible.

Polypropylene (PP), polycarbonate, polyurethane and polyethylene (PE) are fibrous polymers with extremely low electrical conductivity, commonly employed as air-filter materials. Electrostatic charging of such fibrous non-woven dielectric media is typically performed using a corona discharge and is one of the last steps in the air filter manufacturing process. The challenge appears when the electrostatic charge accumulates on the media at a different location on the production line, due to tribocharging effects inherent to dielectric material handling. In the case of such occurrence, the charge accumulated on these media can be harmful to either the operator or to the electronic equipment that the media might come in contact with. As the manufacturing process cannot always be modified to avoid charge build-up on the fabric, it is important to dispose of effective means of a rapid discharge of the materials.

The investigation of charging and discharging of dielectric surfaces has been stimulated by industry demand related to adjustment of Xerox-photography processes, evaluation of electrostatic risks, assessment of polyethylene films for cable insulation, or determination of the very low frequency characteristics of dielectric materials [4-10]. In all these situations, surface potential decay (SPD) measurement techniques [11-15] have been considered as the most appropriate, because of their reliability and low cost.

Most of the literature on SPD deals with thin insulating films [16]. Atmospheric neutralization, surface conduction, polarization, intrinsic conduction, piezoelectricity and inter-facial charge injection are the main physical phenomena affecting the SPD of such materials. The few available technical reports on charging and discharging of fibrous dielectrics are focused on the investigation of two physical mechanisms that might influence the dust collection efficiency of these media: the partial discharges that occur inside the porous sheet; and the surface conductivity as affected by the relative humidity of ambient air [17-21].

In two previous papers [22, 23], the authors addressed the problem of improving the corona charging conditions of non-woven filter media The aim of the present work is to

evaluate the efficiency of active neutralization of such materials.

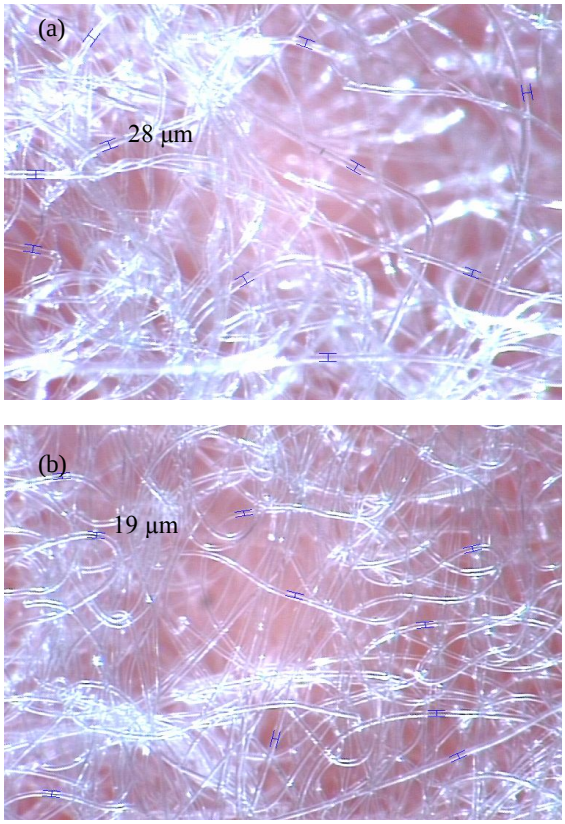

Fig. 1. Photograph of the non-woven (a) polypropylene and (b) polyester media.

II. Materials and Methods

The experiments were performed on 165 x 117 mm^2 samples of non-weaved sheets of PP and PE, at ambient air temperature (19°C to 22.5°C) and relative humidity (35% to 43%). The sheet thickness for both samples was 400 µm; the average fiber diameter was 28 µm for PP and 19 µm for PE, as shown in Fig. 1.

The samples were charged for 10 seconds using a triode electrode system (Fig. 2) that consists of a high-voltage wire-type dual electrode [24], facing a grounded plate electrode (aluminium; 250 mm x 130 mm), and a grid electrode.

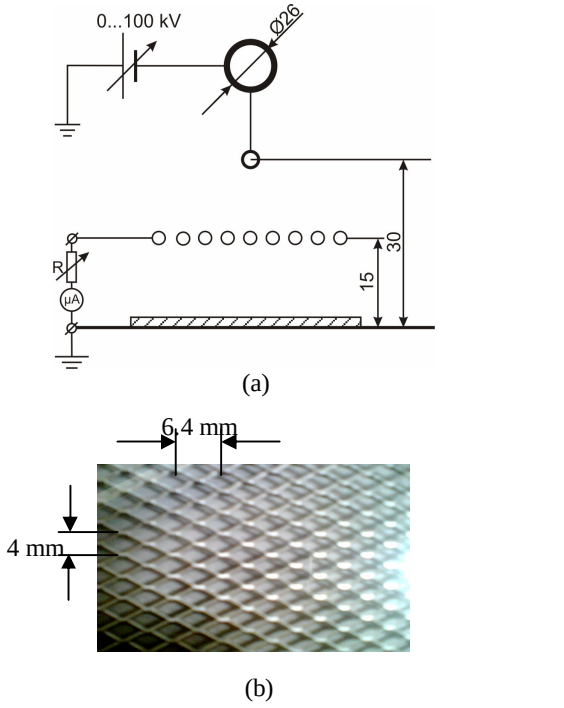

Fig. 2. Electrode systems employed for the corona-charging of non-woven media (all dimensions are in millimeters); (a) triode-type arrangement; (b) aspect of the grid electrode (grid wire diameter: 1.18 mm).

The high-voltage electrode consists of a tungsten wire (diameter 0.2 mm) suspended by a metallic cylinder (diameter 26 mm) at 34 mm distance from the axis. The wire and the cylinder were energized from the same adjustable high-voltage supply, 100 kV, 3 mA (model SL 300 Spellman, Hauppauge, NY), as shown in Fig. 3. Unless otherwise specified, the distance between the wire and the surface of the plate electrode was 30 mm.

The grid is connected to the ground through a series of callibrated resistors of a total resistance R. In this way, for a current intensity I, a well-defined potential $V_g = RI$ is imposed between the grid and the grounded plate on which the samples are deposed. Part of the charge carriers generated by the corona electrode pass through the grid and are driven by this potential to the surface of the non-woven media, which retains them.

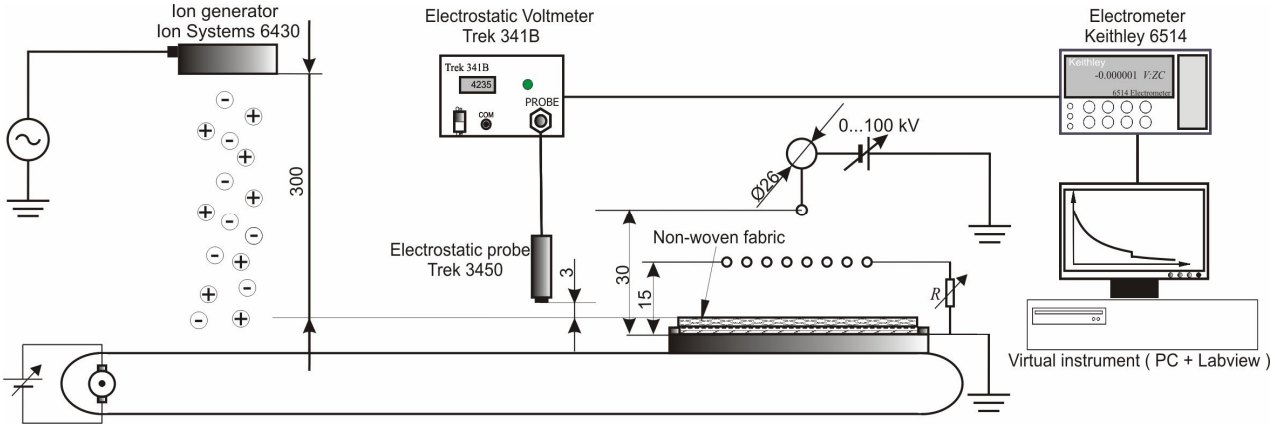

Fig. 3. Experimental set-up.

The surface potential on the charged media was then measured for 10 minutes with an electrostatic voltmeter (model 341B), equiped with an electrostatic probe (model 3450, Trek Inc., Medina, NY). The measured potential was monitored via an electrometer (model 6514, Keitheley Instruments, Cleveland, OH), connected to a PC. The acquisition and processing of the experimental data was performed using an ad-hoc virtual instrument, developped in LabView environment. After 10 minutes, the media was moved beneath the neutralizer (model 6430, Ion Systems, Berkeley, CA) and it was exposed to both negative and positive ions, for either 4 or 10 seconds. Finally, the potential at the surface of the sample after neutralisation was measured using the previously-described method.

III. Results and Discussion

A. *Discharging of polypropylene (PP) samples*

In a first set of experiments, the PP samples, laid on the grounded electrode, were charged using several values of the grid potential V_g, then neutralized using the operating conditions recommended by the manufacturer of the ion generator: neutralization time t_N = 4 s, and neutralizer – sample spacing d_N = 300 mm (Fig. 4). When the sample was charged using a grid potential V_g = 0.6 kV, the potential at the surface of the media V_m measured after 10 min was of about 670 V, and decreased to about 540 V after neutralization. In all the other cases, i.e. V_g = 0.8 kV, 1 kV, and 2 kV, the surface potential remained relatively high: V_m ~ 700 V.

During the first 60 s after neutralization turn-off, the potential V_m at the surface of the PP sample increases with several volts (Fig. 5). Then V_m decreases at roughly the same rate (i.e., 0.01 V/s) as before neutralization. A possible explanation is the following: after the media was exposed for t_N = 4 s to both negative and positive ions generated by the neutralizer, part of the charge that was initially at the surface of the sample was eliminated. This created a possibility for the charges trapped deeper in the structure of the fibrous media to climb up to the surface and increase the potential measured by the electrostatic probe. Another explanation may be formulated in relation to the compression exerted on the fibrous media by the air flow generated by the fan of the neutralizer. When the action of the air flow ceases, the fibrous material decompresses; the distance between the charges at the surface of the media and the grounded electrode increases, and the electrostatic probe measures a higher potential at the surface of the sample.

By increasing the duration t_N of the neutralization process, and hence the amount of charge provided by the ion generator, it is possible to reduce the potential at the surface of the sample (Fig. 6). However, neutralization durations t_N > 10 s are likely to be considered unacceptable for most situations of practical interest.

Decreasing the spacing d_N between the ion generator and the samples quite significantly improves the discharge effect of the neutralizer. As a matter of fact, by reducing d_N, more ions generated by the neutralizer will be able to cross the spacing to the sample without recombination, and contribute to the discharge of the non-woven PP media.

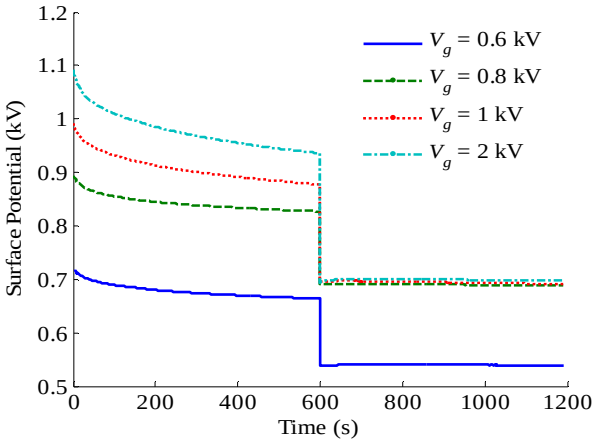

Fig. 4. Typical surface potential decay curves, obtained for PP samples in contact with the ground electrode and corona-charged at various potentials of the grid electrode V_g. The neutralization was performed 600 s after corona-charging turn-off, for a duration t_N = 4 s.

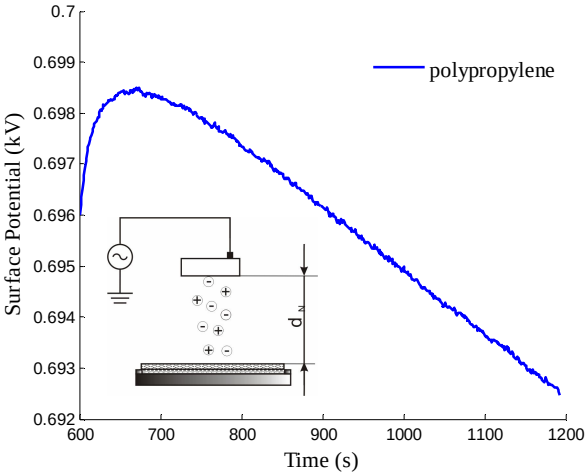

Fig. 5. Zoom on the surface potential decay curve obtained after neutralization in the case of a PP sample in contact with the ground electrode, corona-charged using a grid potential V_g= 1 kV. The neutralization was performed 600 s after corona –charging turn-off, for a duration t_N = 4 s.

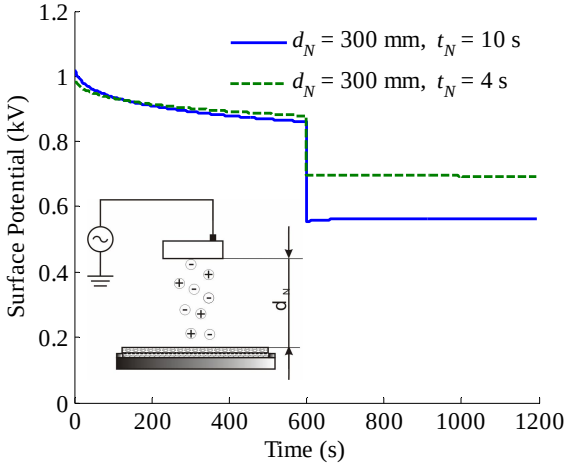

Fig. 6. Typical surface potential decay curves obtained for two neutralization durations t_N in the case of PP samples in contact with the ground electrode and corona-charged using V_g = 1 kV. The neutralization was performed 600 s after corona-charging turn-off.

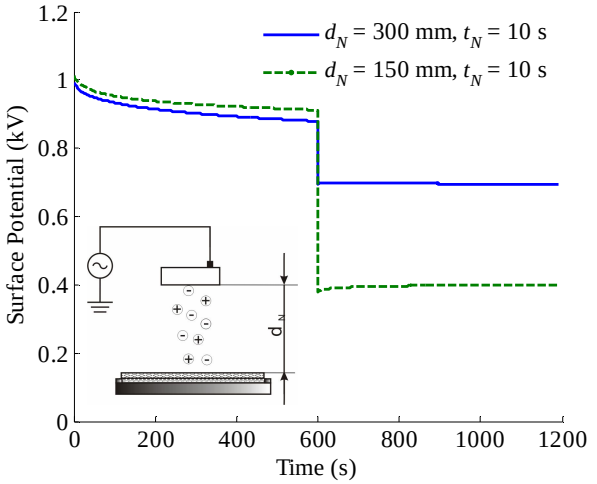

Fig. 7. Typical surface potential decay curves obtained for two values of the spacing d_N between the neutralizer and the non-woven media, in the case of PP samples in contact with the ground electrode and corona-charged using V_g = 1 kV. The neutralization was performed 600 s after corona-charging turn-off, for a duration t_N = 10 s.

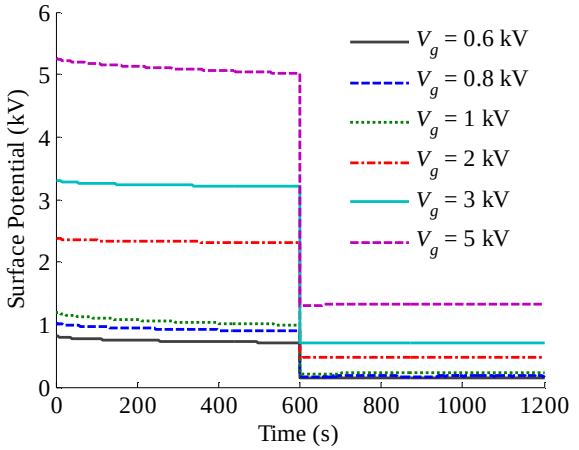

Fig. 8. Typical surface potential decay curves obtained for PP samples suspended at a distance d_N = 4.6 mm from the grounded electrode, and corona-charged at various potentials of the grid electrode V_g. The neutralization was performed 600 s after corona-charging turn-off, for a duration t_N = 4 s.

The neutralization is more effective when the sample is suspended on an insulating grid located at d_N = 4.6 mm above the grounded plate (Fig. 8). This result can be explained by the fact that the air flow generated by the fan of the neutralizer can pass through the sample, which was not the case when the non-woven fabric was laid directly on the grounded electrode. The ions can penetrate much deeper and neutralize a larger number of charges accumulated in the texture of the fibrous media.

This hypothesis might be confirmed by the following observation (Fig. 9): after neutralization, the potential at the surface of the samples located at d_N = 4.6 mm increases for a much longer time (600 s and more) than in the case when the non-woven media were in contact with the grounded electrode (about 60 s). Indeed, the redistribution of the charges needs a longer time in case when the neutralization affected the whole depth of the non-woven media, than in the case when the ion penetration was limited to a thin sheath at the surface of the samples.

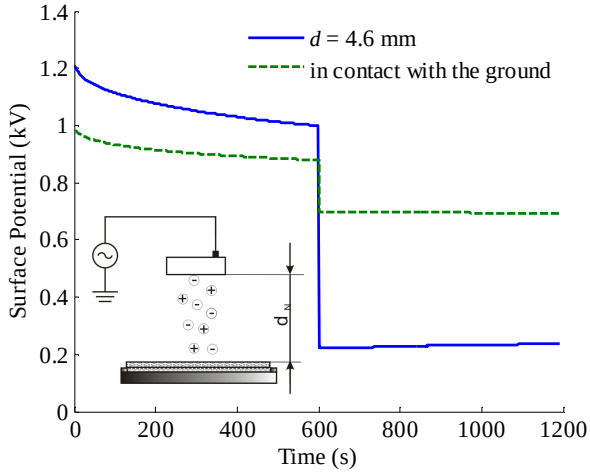

Fig. 9. Typical surface potential decay curves obtained for PP samples at a distance d_N = 4.6 mm or in contact with the ground electrode. The samples were corona-charged using V_g = 1 kV. The neutralization was performed 600 s after corona-charging turn-off, for a duration t_N = 4 s.

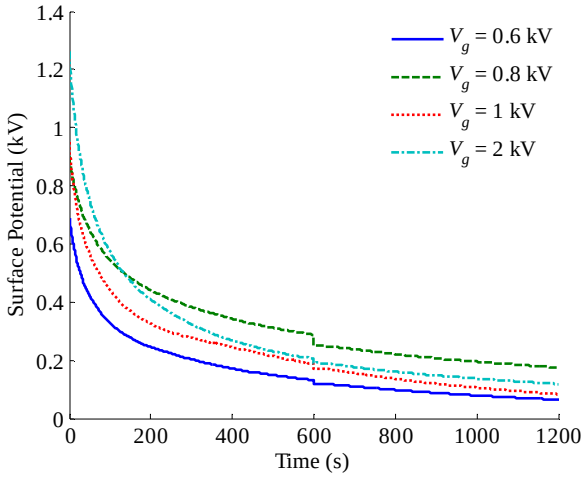

Fig. 10. Typical surface potential decay curves obtained for PE samples in contact with the ground electrode, and corona charged at various potentials of the grid electrode V_g. The neutralization was performed 600 s after corona-charging turn-off, for a duration t_N = 4 s.

B. Discharging of polyester (PE) samples

The ability of polyester to preserve the charge acquired by corona discharge is poor (Fig. 10). Thus, the surface potential decays to about 200 V in 600 s after the corona-charging of the sample using a grid potential V_g = 1 kV. The neutralization applied at that moment has a rather small effect: it reduces the surface potential by less than 15%.

Same as for the PP samples (Fig. 5), a slight potential increase is observed at the surface of PE samples after neutralization turn-off, but only for less than 10 s (Fig. 11). After that, the potential continued to decay rather steeply.

When the PE samples are suspended at a distance at d_N = 4.6 mm above the grounded plate, their surface potential decreases much slower and the effect of the neutralization is much more significant (Fig. 12), though less important than with PP samples. The comparison between the surface potential decay curves obtained for PE and PP samples clearly point out the different behavior of these two non-woven media (Fig. 13).

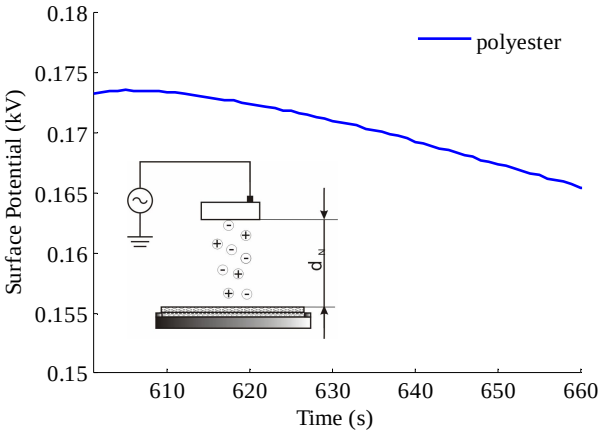

Fig. 11. Zoom on the surface potential decay curve obtained after neutralization in the case of a PE sample in contact with the ground electrode, corona-charged using a grid potential V_g= 1 kV. The neutralization was performed 600 s after corona – charging turn-off, for a duration t_N = 4 s.

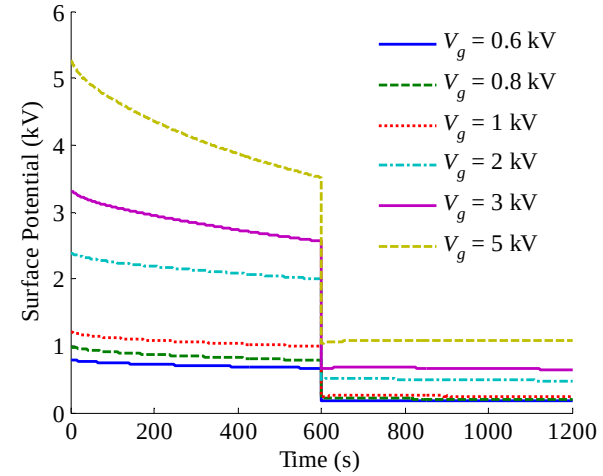

Fig. 12. Typical surface potential decay curves obtained for PE samples suspended at a distance d = 4.6 mm from the grounded electrode, and corona-charged at various potentials of the grid electrode V_g. The neutralization was performed 600 s after corona-charging turn-off, for a duration t_N = 4 s.

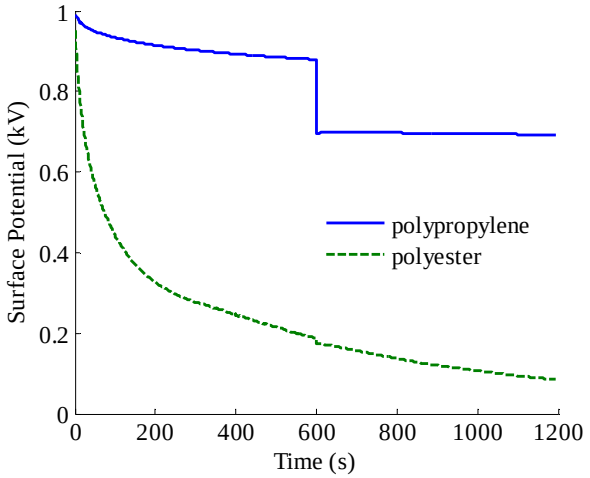

Fig. 13. Comparison between two typical surface potential decay curves obtained for PP and PE samples in contact with the ground electrode, and corona charged using a grid electrode potential V_g = 1 kV. The neutralization was performed 600 s after corona-charging turn-off, for a duration t_N = 4 s.

IV. Conclusion

Surface potential decay measurement is an effective technique for assessing the neutralization of corona-charged non-woven media. The efficiency of the neutralization achieved with a commercial ion generator depends on the nature of the processed materials, the distance between the neutralizer and the substrate, the duration of exposure and the position of the sample with respect to the grounded electrode.

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