Electric Charge Distribution on the Surface of Insulating Materials Subjected to Corona Discharge

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Abstract **-** The configuration of the wire-grid-plane electrodes is used to generate the corona discharge necessary for the electrostatic charge of nonwoven fibrous media used for air filtration. This article analyzes experimentally the distribution of the voltage generated by this class of corona electrodes whose ionizing element is a fine tungsten wire (diameter 200 μm) attached to a cylinder by means of two metal rods. The grid, inserted between the wire-cylinder corona electrode and a metal plate connected to the ground, is brought to a well-defined potential. This allows the control of the electrical charge of the filter media in contact with the grounded electrode. The voltage distribution and potential decline at the media surface, therefore the charge deposition is uniform and it stops once the potential on the media surface is equal to the potential of the .The electrical charge produced by this type of configuration is analyzed for different types of samples in order to make some recommendations concerning the design and its use The inter-electrode spacing has a very significant influence on the current–voltage characteristics of the triode system and on the extension of the corona discharge generated by it.

Keywords **-** Corona discharge, Triode, Grid, Experimental Analysis, Potential Distribution, Potential Decay, Filter Media.

I. INTRODUCTION

The development of air filtration systems on electret non-woven fibrous media for automobile interiors is one of the challenges of sustainable transport. The automotive industry is booming and it has significant know-how in the development and manufacture of air filters for vehicle cabins. The technology behind our study is based on the use of polypropylene fibers [1] for the production of a non-woven filter media [2], sprinkled with activated carbon and charged by corona discharge. Activated carbon, which absorbs organic molecules in the air, is used to eliminate odors. The electrical charge of the material enhances the collection of submicron particles by electrostatic mechanisms.

In recent publications [3-4], our research team published the results of several studies aimed at characterizing the charge state of nonwoven fibrous materials. We have pointed out that the non-homogeneity of the filler is partly related to the very structure of the nonwoven materials. The results also show that the surface potential of these materials is limited by the appearance of partial discharges, due to local intensifications of the electric field produced by the charges themselves. Relative humidity and ambient temperature accelerate the decay of potential.

The literature teaches us that several physical mechanisms are at the origin of the decline in surface potential, such as: the migration of charges towards the interior of the medium under the action of the electric field, surface conduction, the piezoelectric effect or the injection phenomena at the media-air and media-electrode interfaces [5-6]. Among the physical factors having a significant influence on the decay of surface potential, the most important are the relative humidity, the ambient temperature and the local electric field [7-8].

In order to achieve this goal, it was necessary to implement and improve the characterization of electret filters [9–10]. First, a device for forming an electret by corona discharge was developed

[11-12] in order to control the initial deposition of the electrical charges generated in a configuration of “triode” type electrodes [13-14]. . Although the characterization carried out is essentially based on the measurement of the surface potential and the monitoring of its decline over time.

In this work, we are going to be interested in other factors which could influence the distribution of the electric charge on the surface of the media and on the DPS, in the case of the use of a system of electrodes of the type "triode": the "static" or "sweeping" charging mode (the non-woven medium is stationary or moving at variable speed relative to the crown electrode).

II. EXPERIMENTAL REALIZATION

The corona discharge was provided by using a dual-type electrode, consisting of a thin tungsten wire, 198 mm long, with a diameter of 0.16 mm, attached to a copper cylinder, with a diameter of 26mm, as shown in Fig. 2. The ionizing wire and the cylinder are powered by the same reversible high voltage direct current power source (model SL300, SPELLMAN, Hauppauge, NY). The two elements are parallel and the plane defined by their axis is perpendicular to the electrode connected to earth. The grid, sandwiched between the wire-cylinder crown electrode and a grounded metal plate, is brought to a well-defined potential as shown in Fig. 2. This allows control of the electrical charge of the filter media located in contact with the grounded electrode.

Given that the characterization of the nonwoven media charged by corona discharge, carried out within the framework of this work, is mainly based on the non-contact measurement of the surface potential, we have designed and produced for this purpose the device of Figure 1 at the University Institute of Technology of Angoulême.

This is a very common configuration in potential decay studies where one of the surfaces of the insulator is charged and then left free. The non-woven medium, in contact or not with a metal plate linked to the ground, is carried by a carriage attached to a conveyor belt and which moves to transfer the sample, once it is subjected to a corona discharge towards the measuring station. A DC electric motor drives the belt at an adjustable speed. The positioning of the sample under the crown electrode and under the probe is carried out using an electromechanical control.

The experimental installation, on which all the electrostatic measurements are carried out, consists of three stations. Figure 1 illustrates all of these stations as well as the instruments used. On the first station, the charge of the free surface of the material is obtained by exposing it, for ten seconds, to a corona discharge generated in a so-called “triode” electrode configuration.

The main advantage of this configuration is due to the presence of the grid (Fig. 2) connected to the ground via a resistor. This gate electrode makes it possible to control the initial potential of the surface, and consequently, the initial deposition of the electric charges, on which the evolution of its state of charge depends on it. After being loaded, the material is transferred, using the bung conveyor, to the two stations for non-contact surface potential measurements. The transfer time, between the end of the corona discharge and the start of the measurement, is 2 to 3 seconds.

The use of the electrometer, in the measuring stations, allowed the interfacing of the measuring devices with the computer to carry out the data acquisition using a virtual instrument developed under the LabView environment.

II-1. Potential distribution

In a first series of experiments we changed the loading time (1 s, 5s, 10s, 30s and 60s) and the sample size. In these series of experiments we used two flat tissue samples (Fig. 3) of geometric dimensions (95 mm x 110 mm and 95 mm x 175 mm). For the second series of experiments, it was deemed useful to see the distribution of the potential and its spreading over the surface of another type of sample, Plexiglas (Fig. 4) of size (160 mm x 140 mm x 2 mm). The ambient temperature is 16.6°C and the humidity 54%.

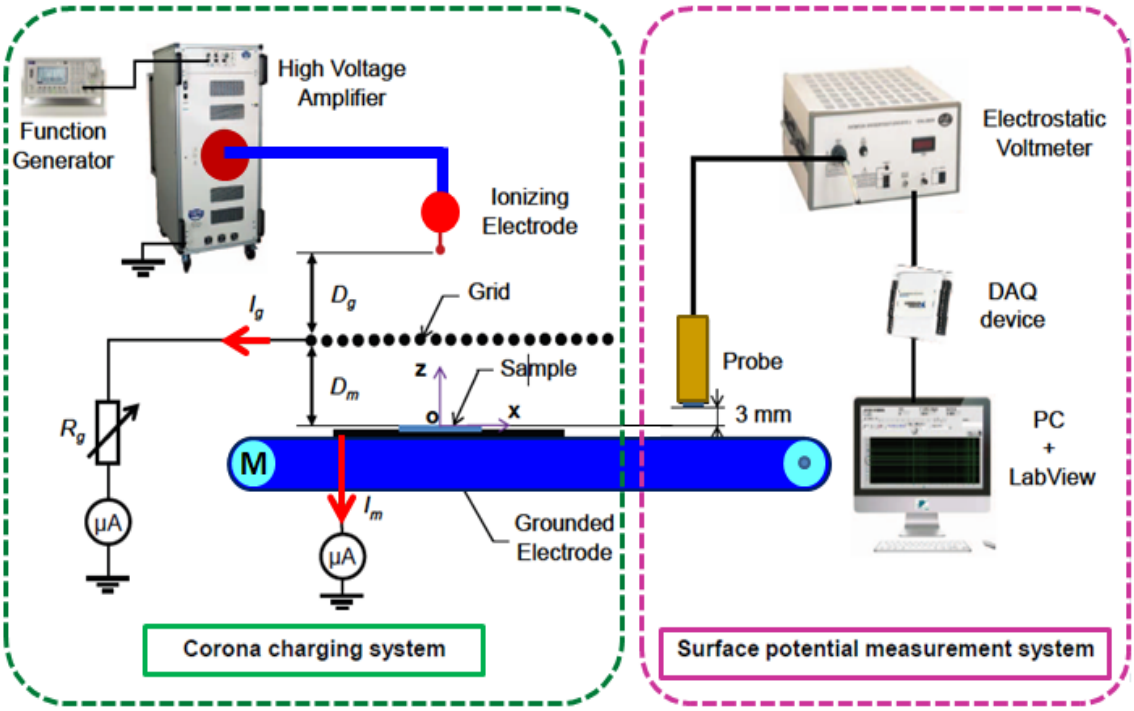

Fig. 1. Experimental procedure for charge generation and surface potential measurement.

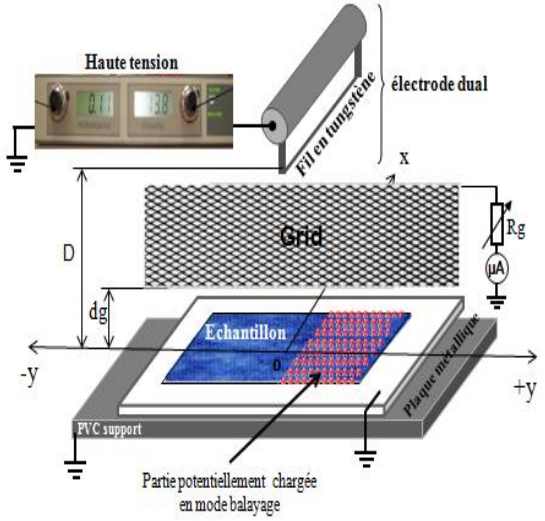

Fig. 2. Initial loading position (static and scan mode).

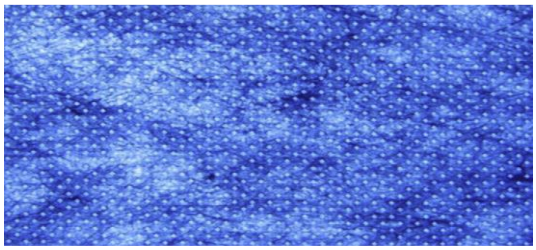

Fig. 3. Photograph of a nonwoven fabric sample polypropylene

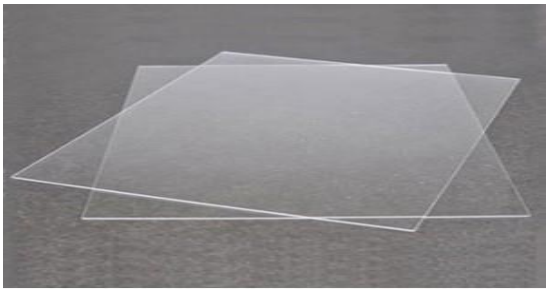

Fig. 4. Photograph of a Plexiglas plate

The belt is set for a speed equivalent to a voltage of 4.5 V to make the measurement by scanning. The voltage used to charge the sample is 1 kV (the resistance Rg = 20 MΩ and the measured current Ig = 50 µA).

II-2. Decline of potential

For these series of experiments, two samples of Plexiglas (Fig. 4) of thickness (3.93 mm "Ep_1" and 2.93 mm "Ep_2") of initial charge respectively f_1 = 72 V and f_2 = -2 V were used. Superimposed one on the other to increase the thickness and keep the homogeneity of the sample, a high voltage generator set at V_{pp} = 24 kV and a frequency of 50 Hz. The ambient temperature is

91.1 °C and humidity of 58%. The treadmill was set for a speed equivalent to a voltage of 9.8 V. Three cycles of charging and neutralization were carried out in order to confirm the results.

III. RESULTS AND DISCUSSION

Potential distribution: The potential distribution results for deferent charging times are given by the curves in Figures 5 and 6. These presented results show that with a higher charging time the spreading of the charge is significant; the spreading is greater for a larger sample.

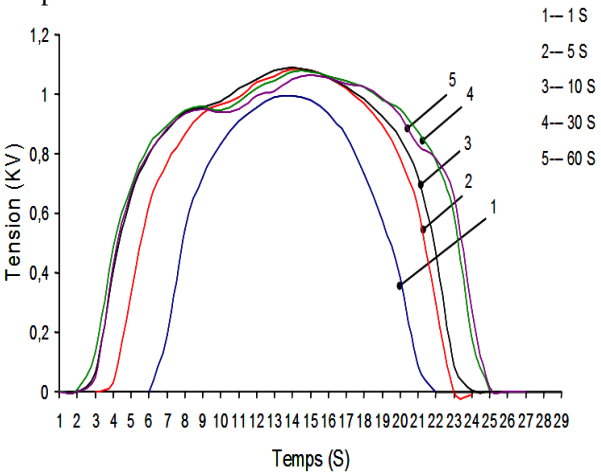

Fig. 5. Potential distribution for a tissue of the dimensions (95mmx110mm)

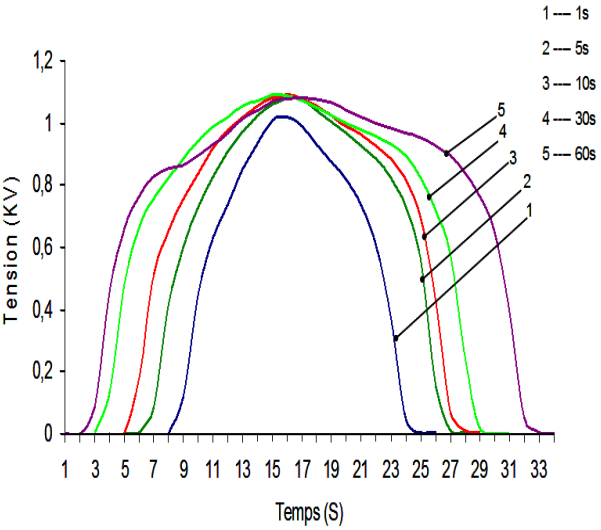

Fig. 6. Potential distribution for a tissue of the dimensions (95 mm x 175 mm)

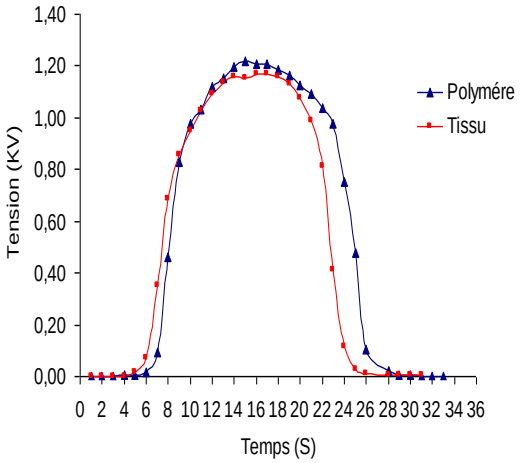

Fig. 7. Potential distribution on the tissue and the polymer

The charge area increases with the charge time and the dimensions of the sample. The corona discharge is more extensive for a higher charge time. So the increase in the charging time and the dimensions of the sample cause a more extensive corona discharge.

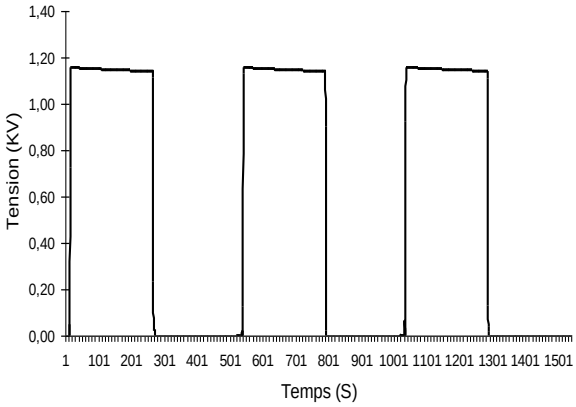

Fig. 8. Decline of the potential on the polymer plate of dimension 110 mm x 90 mm x 3.93 mm.

The charge increases with the potential of the grid, then remains practically at a constant passing through a maximum. The difference in trend between the initial average surface charge density and the initial surface potential occurs at fairly high levels of the gate potential, which makes it quite difficult to explain.

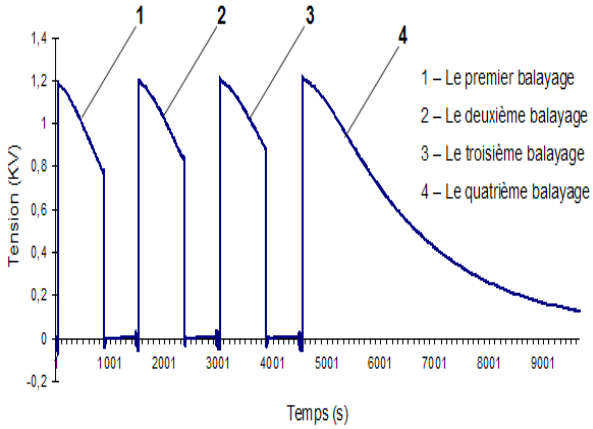

Fig. 9. Potential decay on a polymer plate

The results of the potential decline obtained for a sample of PMMA, thickness 3.93 mm, are presented in Figure 9. And to better see the influence of the scanning (loading) we have superimposed the quad curves which are presented by the figure above.

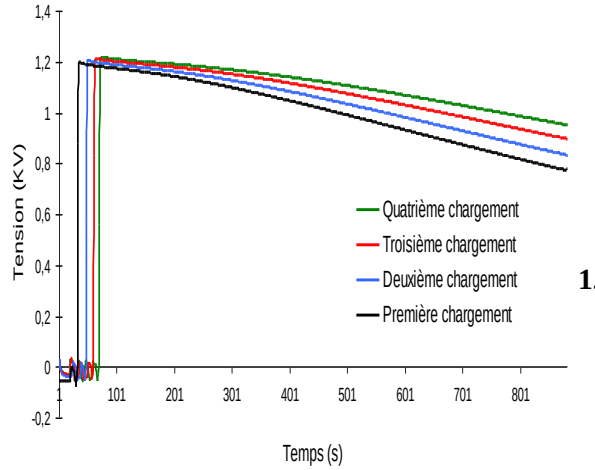

Fig. 10. Potential decay on a polymer plate

By observing these curves, it can be seen that the load increases with the increase in the number of scans.

The response of the nonwoven fibrous media to charge deposition as excitation, which is represented by the supply voltage of the crown electrode, depends profoundly on this excitation and not only on its intrinsic properties. Thus, the characterization of the material by a network of curves to see these differences, we plotted the distributions of the potential in the form of a histogram.

IV. CONCLUSION

The measurement bench produced allows the monitoring and recording of surface potential decline using a vibrating capacitor probe (Kelvin probe), for several situations and by varying experimental parameters. It was concluded that:
In the presence of the media, characterized by its own resistance, reduces the current Im, also the charge of the media leads to the reduction of the gradient of the potential between the gate and the ground plane, in fact the surface potential of the dielectric tends to closer to that of the grid.
Beyond these results that helped us to better understand the phenomena, we did tests with other types of samples to observe how the charge spreads over the different surfaces.

The presence of electrical charges on the surface of insulating materials can cause electrostatic risks in industrial processes, as it can endanger the operator and the electrical and electronic equipment used. In many applications, such as the handling of textiles, sheets of paper or polymeric films, the electrical forces associated with these charges can stick the materials to each other or to build on metal surfaces. Electric discharges from charged elements represent a major source of danger in the manufacturing process of electronic devices.

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