Estimation of static dissipation through corona discharges in protective garments using core conductive fibres

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Abstract

Effectiveness of protective garments using core conductive fibres is difficult to assess using the methods described in the current standards. However, in the framework of the European project ESTAT-Garments, it has been shown that some corona discharges can occur in this type of garments, allowing for charge redistribution and so preventing damages except to the most demanding Electronic Sensitive Devices.

The measuring technique developed by **Centexbel** is an indirect method. Increasing potential differences are applied across a sample to stress the material globally and locally under higher and higher electric fields. The results are presented as the "Resistive Signature" of the material. This signature is a coloured plot of the sample resistance in

function of the applied voltage where the colouring scheme discloses the chronological progress of the measurement.

For fabrics using core conductive fibres, this method shows that under high electric fields some conduction develops inside the sample that can explain the antistatic effect of the material. Corona discharge is the most likely origin of this conduction phenomenon.

This measurement technique is also effective for the evaluation of the electrical conductivity of seams.

Keywords :

Charge redistribution **Antistatic textiles**
Conductive fibres **Indirect measurement method**
Seam conductivity

1. Introduction

Prevention of electrical discharges occurring from garments are of concern both for the risk of explosion in potentially explosive atmospheres and for the risk of damaging electronic components during handling and mounting.

In the former case, the project group 2 of **CEN TC162 WG1** *"Antistatic properties of protective clothing"*, which emanates from **CEN TC 162** *"Protective clothing including hand and arm protection and life jackets"*, is in charge of revising **EN 1149** *"Protective clothing - Electrostatic properties"*.

In the latter case, the project team 2 of **IEC TC101 WG5** *"Tests methods for garments"* deals with the revision of standard **IEC 61340-5-1** *"Protection of electronic devices from electrostatic phenomena – general requirements"*.

The methods currently included in these standards present problems for new types of antistatic garments as they fail to recognise some of them as such, unfortunately, sometimes in a contradictory way. Problems with existing methods are of different types :

- use of charging methods of non frictional nature (can an equivalence of propensity to charge using different methods be proved ?)
- decay curves where the starting (highest) voltage is missing (short time constant are lost)
- measure of voltages as if the fabric/garment was a conductor (although the charge density is a more enlightening value since the fabric/garment is not always a conductor) and comparing this voltage with a HBM maximum voltage (although the fabric/garment capacitance can be far lower than that of a human body).

A more detailed description can be found in [1].

Garments made of fabrics using core conductive fibres are difficult to analyse with standard methods. The proposed measuring technique, developed by **Centexbel**, implements an indirect method for the evaluation of the charge dissipation in such fabrics.

This method aims at checking this antistatic behaviour in a rather “easy” way, without resorting to frictional triboelectrification or other artificial charge generations.

The point (to be validated) would be that, if some conduction can be induced by our method, no high local charge density on a fabric/garment can occur, for, as soon as some threshold is reached, charge flows to some conducting fibre (from where it cannot come back unless a new conduction channel is built in the opposite direction).

In such a case, on the one hand, the voltage (charge density) is smoothed (so, implying a lower maximum value) AND, on the other hand, the capacitance is maintained low, for no galvanic path exists between fibres.

As such fabrics consist of around 65% of air with fibres mostly in bundles of 6 (Figure 1 and 2), we think that the conduction arises between a conductive fibre tip and another one through corona discharge. Possibly, some treeing also occurs in the skin of trilobal fibres.

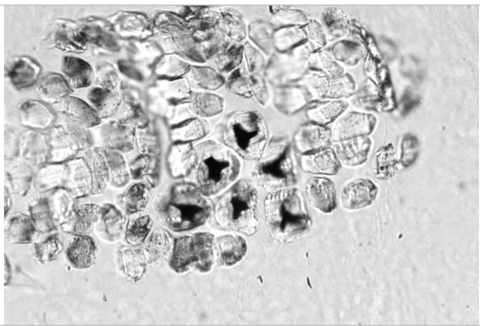

Fig. 1 : Thread : white PES + 6 Conductive fibres.

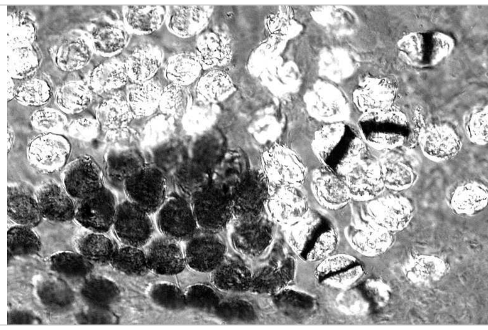

Fig. 2 : Thread made of 3 yarns : white PES, black PES, white PES + 6 Conductive fibres.

2. Method description

The basic idea is to apply increasing potential differences to the sample to stress the material globally and locally under higher and higher electric fields. Electrodes are used at two extremities of the sample to impose a high voltage difference between two fabric regions, for example across the diagonal of a A4-size sample.

In our method, the potential difference is increased stepwise under control of a PC driven software that allows for choosing the voltage steps and their timing; moreover, the program records the resulting current through the sample. The software also monitors the climate inside the enclosure (Relative Humidity and Temperature).

The climatic conditions as well as the maximum voltage, the number of steps, the delay between steps and the maximum allowed current can be chosen in function of the nature of the material.

During the whole measurement, the instantaneous values of all the parameters can be displayed as well as graphical representation of either **V** (voltage) and **I** (current) in function of time, **R** (i.e. V/I) in function of time or **R** in function of **V**.

The measurement can proceed with the potential difference reverting to 0 V or not. Moreover, the software stops of increasing the voltage as soon as a maximum current is reached, in a tentative way not to modify the material under test.

The results most interesting presentation is the "Resistive Signature" of the sample. This is a coloured plot of **R** in function of **V** where the colouring scheme allows to recover the chronological aspect of the measurement (Figure 3) :

- *a* ***R*** *value recorded at time* ***0*** *will get a green colour and a value recorded at the end time (normally back to a* ***0*** *potential difference) will get a yellow colour*
- ***R*** *values in between go through a cyan, blue, magenta, red and orange gamut.*

For example, when a measure takes a total time of **600s**, the resistance value for the voltage at time **0s** is displayed in light green, **100s** in green, **200s** in cyan, **300s** in blue, **400s** in magenta, **500s** in red and **600s** in yellow (Figure 4).

The Resistive Signature shows that under high electric fields some special conduction mechanism develops inside some samples, confirming the antistatic effect of the materials.

For fabric samples, the measurement uses two 5 lbs. electrodes with 2.5 in. (∅) carbon conducting pads, placed diagonally across A4-size rectangles. In this way, we prevent direct conduction between electrodes due to lone conductive fibres, a phenomenon that is not representative of the global behaviour of the material, and that excludes the use of classical concentric electrodes for resistivity measurement of this type of material.

The measurements are done in a climatic room where temperature is chosen between 20°C and 25°C; the relative humidity can vary from 10% to 50%. Furthermore, the room is shielded against electrostatic perturbations.

3. Results

The measurements of Resistive Signatures hereafter were made at a temperature of 23°C and a relative humidity of 25% RH.

In Figure 3, one can see that, when voltage is increased, nearly no conduction exists until about 2 kV where the resistance drops around 100 MΩ. The voltage decrease phase of the signature shows that some conducting paths were damaged, for the resistance reverts to its initial higher value as soon as the voltage drops below about 12 kV.

In Figure 4, on the contrary, the low resistance appears at 250V and persists when the voltage is lowered (but shall revert to its initial value after manipulating the fabric).

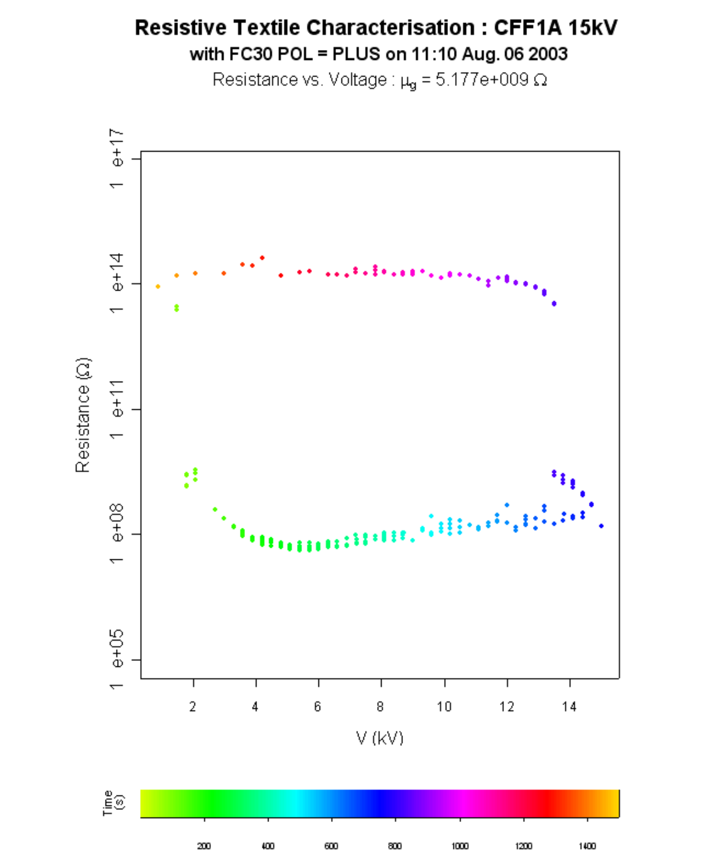

Fig. 3 : Effect of voltage on a sample showing increased conductivity above a given threshold with damages along the conduction path caused by high voltage.

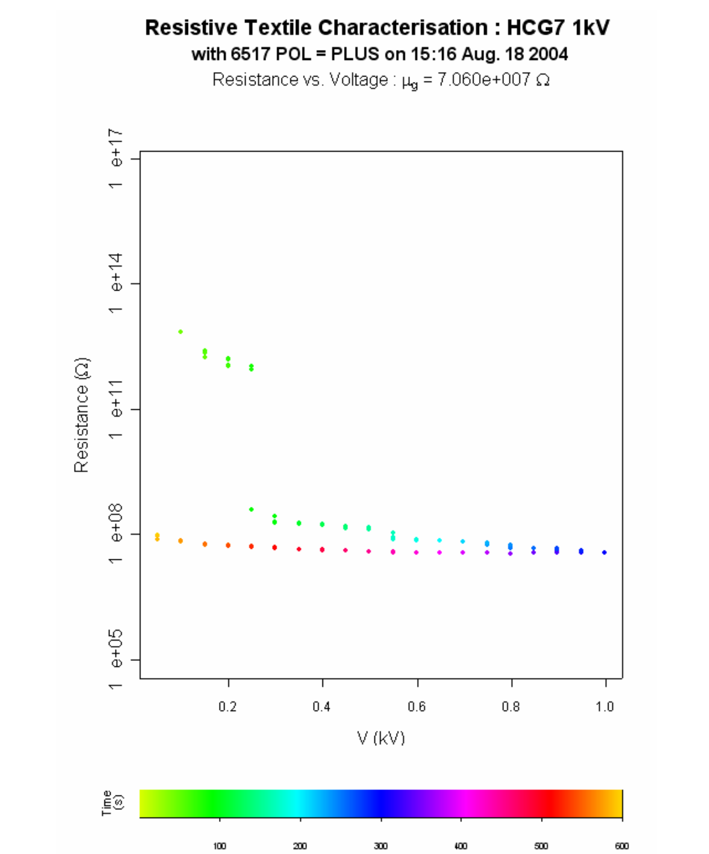

Fig. 4 : Effect of voltage on a sample showing increased conductivity above a given threshold with a conduction path still effective at the end of the measurement cycle.

In Figure 5 (b), we can see the effect of a bad seam on garment conductivity; only very high potential differences were able to produce conduction between the two sewn fabrics. Two conduction paths were consecutively built one at 4 kV and the other at about 7 kV; at 13 kV, a very high conduction arose damaging the sample.

The sample without seam (a) shows a quite lower resistance at even the lowest voltage level.

The purpose here is not to make evaluation of different garments, but to show that the Resistive Signature method gives far more information that standard resistive methods using fixed potential differences as EN 1149-1 [2] or ESD STM2.1 [3]. For some materials, a drop in resistance at some voltage shows that the material prevents the build-up of high local charge concentrations.

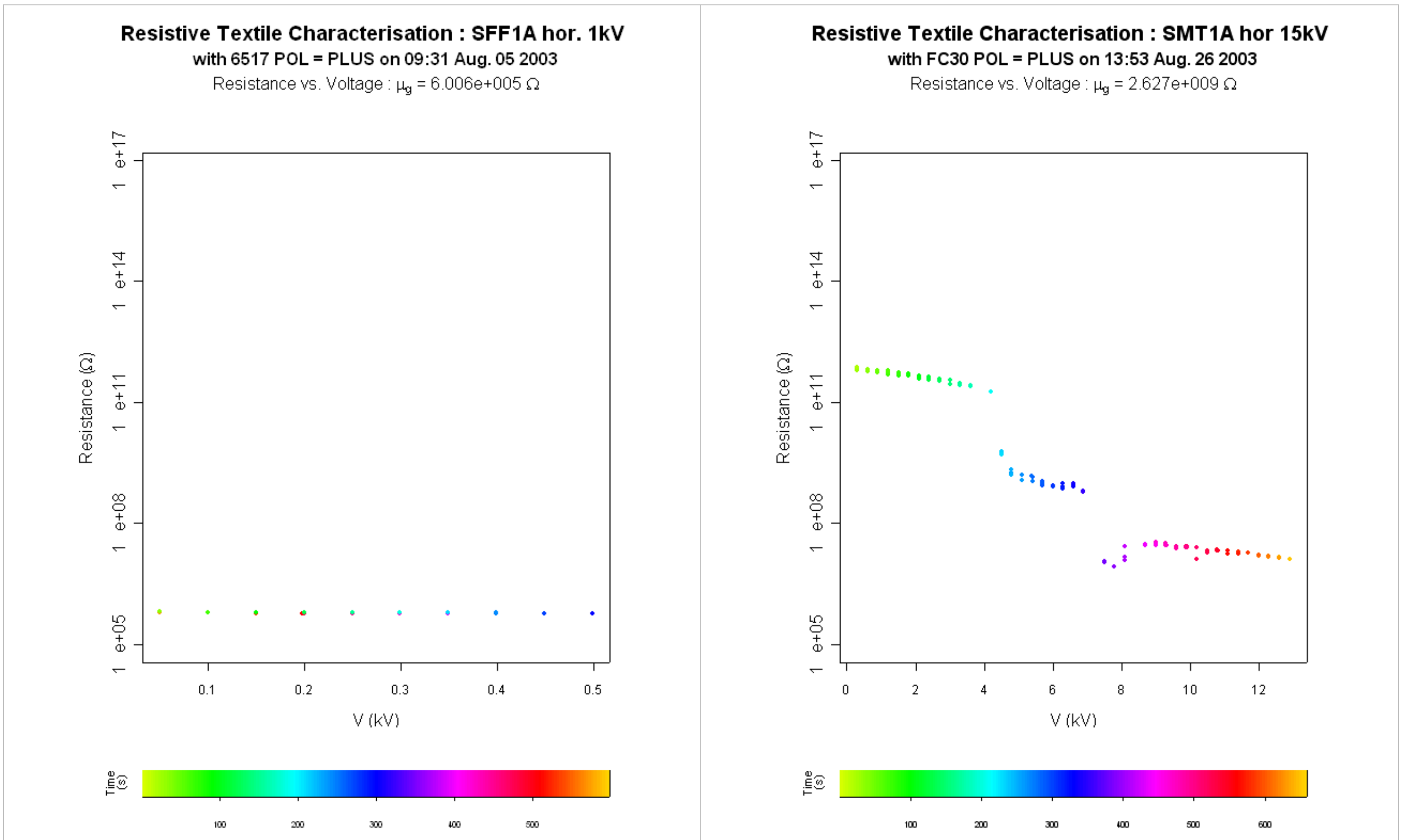

Fig. 5 : Two samples of the same fabric, (a) without seam, (b) with a bad seam reducing the otherwise good conductivity of the fabric.

Furthermore we showed that the Resistive Signature is useful for characterising seams, at least to detect how far from conductive they are. The signature let us know whether contacts at seams are of the same quality as those at grid crossings or, on the contrary, present a quite higher resistance.

When the method is used for seams conductivity evaluation, the sample includes a seam parallel to the small edge of the A4-size sample, roughly dividing it into two A5-size fabric pieces (Figure 6).

In case of less than perfect seams, the resistive signature starts at high resistance values for suddenly dropping to lower values at some threshold voltage (Figure 7).

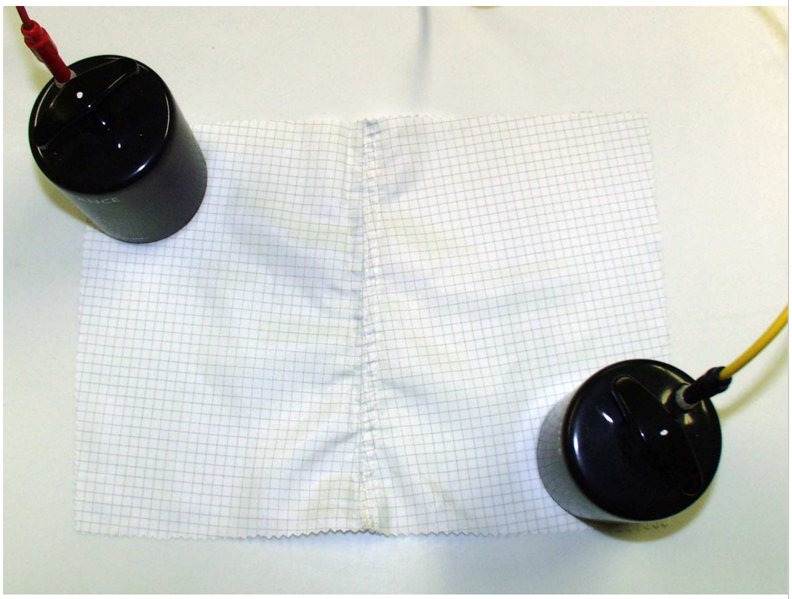

Fig. 6 : Seam characterisation set-up.

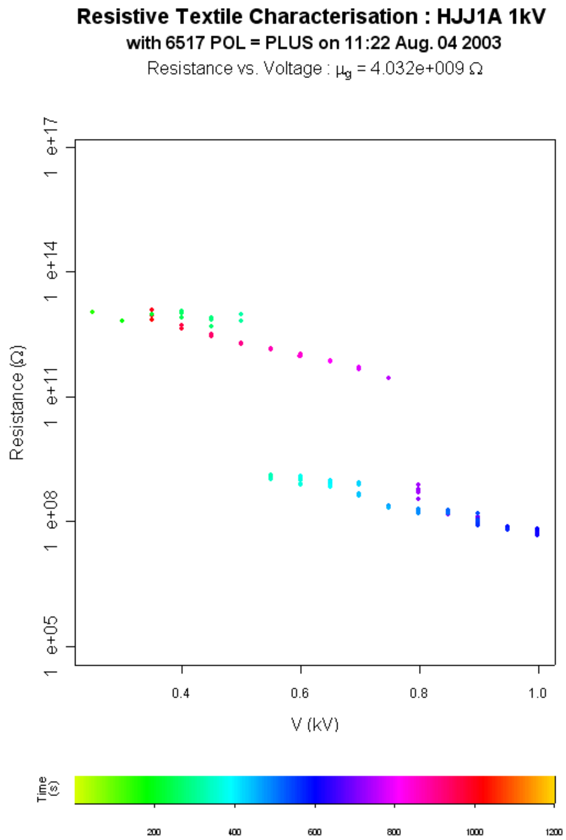

Fig. 7 : Seam signature.

Acknowledgements

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References

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