Some experiments about the triboelectric performances of composite textiles

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Abstract: ESD protective garments performances depend also on the characteristics of the composite textiles they are made of (grids and squares, type of conductive threads, fabric, etc). A tribocharging automated system has been rigged to perform charge retention tests on samples of such composites. Special testing procedures, based on a suitable definition of Surface Voltage (or tribocharge) have been devised and implemented to investigate the charge release capability of three different textiles. The discharge process, represented by the SV(t) plots measured via a non-contact probe system, has been experimentally studied via a 3 synthetic parameters approach. The analysis of the tests output allowed to focus the role of the square dimensions, of the r.h. (relative humidity) factor and of the type of conductive threads

Introduction

Special textiles are adopted to prepare ESD garments, i.e. clothing to be worn over usual clothes in electronic industries for protective reasons. Particularly in especially electrostatic protected areas (EPA) , the operator body could be carrying an important electric charge, which is "generated" substantially as tribocharge or via a contact process. Such a charge would give rise to an electric field (on the garment or inside an electronic device) which could overcome, locally, the dielectric strength of air. This way an electrostatic discharge could affect, catastrophically or not (ref. problems of latent defects), the functionality of an assembly or of an electronic device. The textiles of such protective garments are named "composite" because they can host a conducting grid of different types.

Both the fabric basic material (or mix of materials) and the features of the "conductive" grid can have an influence on the ESD performances of the textile, therefore of the garment. Such performances are referred to the chargeability (charge "generation" attitude) and to the charge retention capability of the textile. Both factors are influenced by the textile composition, by the grid features, by their interaction and by other effects.

While the ESD "protection" level depends on the system 'grounded-operator/garment/object', an investigation about the discharging process (after tribocharging) of composite textile specimens was deemed useful to focus information about the charge retention mechanism/s of a textile in itself.

Experimental set up and investigated materials

A special automatic apparatus has been used to define charge decay (i.e. surface voltage, SV, decay) curves obtained by means of a non-contact voltmeter (TREK 347) : a general view is reported in Figure 1. The relevant probe (TREK 600B-5C) was set, at 1 mm distance, in view of fabric/textile surfaces. In pre-set environmental conditions (23 °C +/- 2 °C; 12 % or 50 % +/- 3 % r.h.), 120 x 120 mm specimens were 48 h preconditioned at the same environmental conditions adopted for the tests. Then a special stick (similar to a flat rod, made by PTFE and copper, as visible in Figure 2) was rubbed (in automatic and controlled – pressure and velocity - way) five times, by means of an electronic driven motor [1, 2, 3] and of a PTFE coated rubbing stick.. This way the tribocharge present over the textile surface could be controlled better than in other ways.

A calibration was performed in order to check the repeatability of the test system

The outputs of the results for 3 runs, same sample, same force between stick and sample (= 65 g), same pulling force (= 500 g) is shown in figure 3.

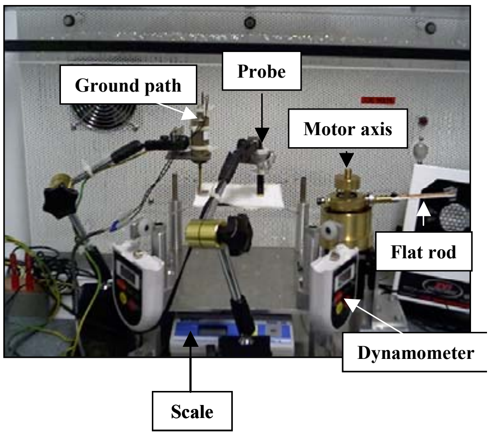

Figure 1: A view of the test cell

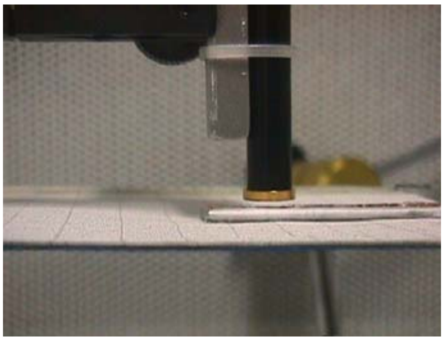

Figure 2: Probe, stick and textile sample.

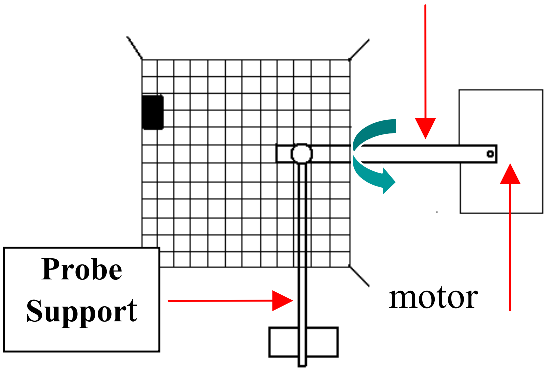

Figure 4: An upper view sketch of the test set-up

The latter data can be compared to [4, 5]: the present system appears potentially much more accurate.Besides, an view-from-the-top of the test set-up is offered in Figure 4 , where it is visible that a side area of the specimen was clipped by a copper strip and by a conductive rubber plate, so to decrease the contact resistance of the path to ground.Then, after the tribocharging process, this side electrode was quickly (through a solenoid driven metallic cylinder, holding a metallic needle) grounded, i.e. it was put in contact with the above grounded needle. Off course the capacitive effects (due to the ground electrode that was approaching the side electrode) had to be minimised; in fact the remote ground effect was controlled by setting a suitable metallic plane "below" the specimen. The (V,t) data-points, which formed the SV(t) curves obtained after grounding the above described side electrode were stored by means of a non contact voltmeter, of a sampling digitizer and of a suitable PC (by means of an ad hoc written software). The initial conditions were reset after each data acquisition, exposing both the specimen surface and the special stick to the ionised air flow from two suitably positioned ionisers, so that no residual charge remained on the rubbed surfaces after an acquisition.

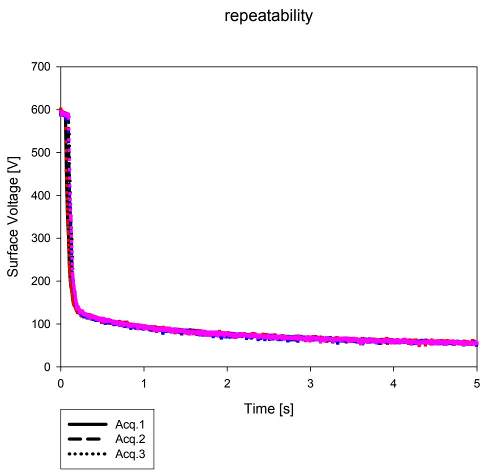

Figure 3: A check of the repeatability

Side

electrode

Rubbing stick

Also this operation was computer driven, by means of the above named computer software.
The overall software and hardware had been introduced so to minimise the influence of operator dependent factors on the measured SV values and on the charge dynamics.

In order to explore the influence of the conductive grids, two fabrics (polyester and polyester/cotton) were tested, while 3 different conductive grids were considered (stainless steel, surface conducting and hybrid conductive); such grids were made by 5 x 5 mm or by 10 x 10 mm squares.

Furthermore, the plain (no grids) fabrics have been tested as reference.

Summarising, the following materials have been selected for the planned tests:

1) P100: a plain 100% polyester fabric
2) P65: a mixed 65% polyester + 35% cotton plain fabric
3) SS 5 and SS 10: stainless steel 5 and 10 mm squares grids, within a mixed 65% polyester + 35% cotton fabric
4) SC 5 and SC 10: surface conductive 5 and 10 mm squares grids, within a mixed 60% polyester + 40% cotton fabric
5) SCB 5: surface conductive 5 mm squares grid, within a mixed 70% polyester + 30% cotton fabric
6) CCB 10: hybrid core conductive (Beltron 31) 10 mm squares grid, within a mixed 70% polyester + 30% cotton fabric

The measurements of surface voltage vs time [SV(t)] were carried out through a non-contact probe which was set over a swept area (where tribo-charge was formed) either over the <center> of a square or over the <cross> position among 4 squares.

Each sample experienced 3 separate "center" acquisitions and 3 separate "cross" acquisitions, so to check , at each instance, the repeatability of results.
These procedures were repeated for each investigated composite textile at the two selected relative humidity

(rh%) values of 50 ± 3% and 12 ± 3%. After each measuring cycle, the data were suitably post-processed.

Results

A preliminary set of tests were carried out on P100 and P65 types of fabrics. The relevant data, obtained after a special rubbing stage, both at 12 and at 50% u.r. are reported in Table 1.

Table 1 has been outlined introducing a group of three descriptive parameters: V(0) = initial surface voltage, V(2) = surface voltage after 2 s since the initial grounding and d/dt V(0) = initial derivative of SV(t). Such parameters allow to easily compare the various SV(t) curves. Therefore, each obtained SV(t) curve has been described in terms of the above parameters and its information, both for 10 and for 5 mm squares textiles, has been summarised in Table 1 (as "dry" tests are concerned) or in Table 2 (in the case of high humidity tests).

Table 1 Synthetic parameters (12% r.h. conditions)

Material		V(0)	V(2)	d/dt V(0)
P100		480	≅ 480	≅ 0
P65		2900	≅ 2900	≅ 0
SS10	*center*	1041	469	10260
	cross	1172	233	47762
SS5	*center*	589	120	13921
	cross	565	106	14235
SC10	*center*	1708	237	33753
	cross	1730	151	69405
SC5	*center*	614	64	16820
	cross	721	72	20931
CCB10	*center*	1082	237	7633
	cross	1348	151	30978
SCB5	*center*	662	102	17262
	cross	667	88	19479

All the dry SV(t) plots and the Table 1 results allow to list the following comments:

a) for the 5 mm square grid textiles the center and the cross data appear more similar than they do for the 10 mm square grid cases. This fact is consistent with the different ratio between square area and probe integration area.
b) the SC10 textile offers the highest V(0) value, but the V(2) is medium-low and the derivative is quite high
c) the V(2) of SS is higher than the ones in the other cases: it means that in this case the SV plot purports still a "high" value after a long term, from the start.
d) the highest SV initial derivative belongs to the SC material
e) in general the initial derivative of cross conditions is higher than the one for center conditions. The latter observation suggests that the interface between conductor and insulating fabric cross dominate the fast (ms) charge transients.

As to the actual plots, it is worth to recall the Figure 5 SV(t) curves, which regards the 3 composite textiles at 12% r.h. and 21-25 °C conditions: in this case the probe was set facing the center of a square.

Similarly, the Figure 6 reports the 3 composites SV(t) data plot obtained at 50% r.h. and 21-25 °C conditions. Figure 6 evidences the influence of the relative humidity on the SV(t) plots, therefore on the charge decay in the textile: as expected, in this case the charge decay is substantially more important.

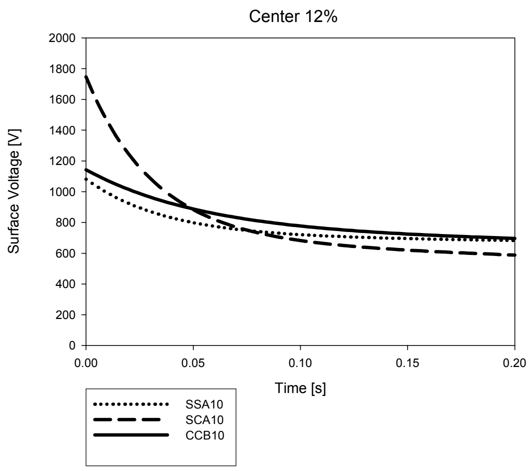

Figure 5: SV (t) for 3 composites, grid 10 mm, center, at 12% r.h.

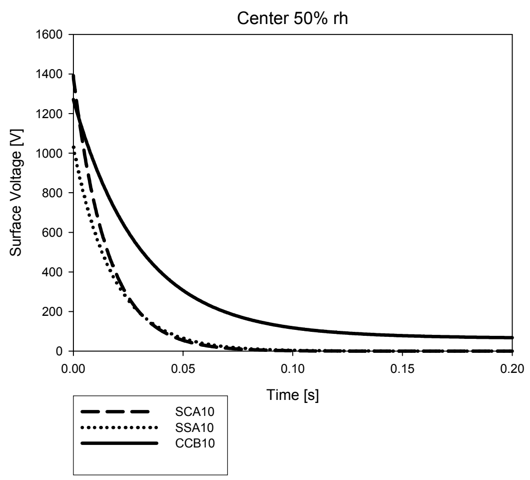

Figure 6: SV (t) for 3 composites, grid 10 mm, center, at 50% r.h.

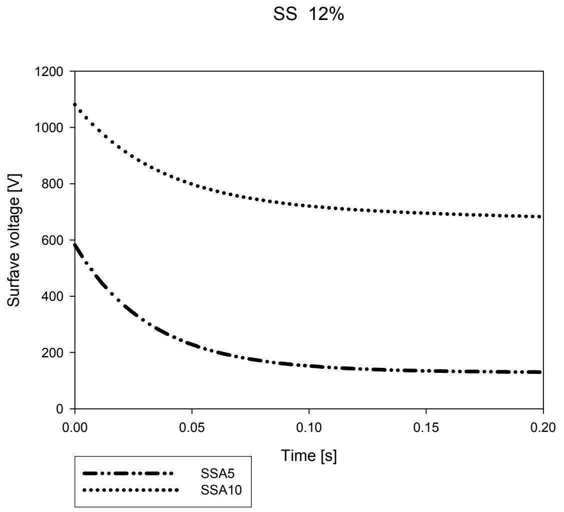

Figure 7: Example of a comparison between SV (t) plots,for textile with different square dimensions (center)

The many data obtained changing textiles, grid dimensions, test conditions (center or cross) and relative humidity allow to sort and to evidence a particular output.

For instance:

- at dry conditions the center data SV vs time plots , for 5 mm grid textiles are very similar
- the 10 mm squares center SV(t) curves, for SS and SC tested materials, are high almost twice than the same curves for 5 mm same textiles. An example, for the materials with a stainless steel grid, is illustrated in Figure 7. The latter effect was expected, owing to capacitive reasons..

As far as 50% r.h. tests are concerned, in all the tested materials the SV(t) plots did show a fast initial decrease and the V(2) was null in all the tested cases.

Table 2 Synthetic parameters (50% r.h. conditions).

Material		V(0)	V(2)	d/dt V(0)
P100		1050	≅ 900	≅ 100
P65		2400	≅ 2400	≅ 0
SS10	*center*	1030	0	57230
	cross	963	0	60180
SS5	*center*	955	0	46140
	cross	894	0	37350
SC10	*center*	1392	0	92790
	cross	1344	0	89590
SC5	*center*	1439	0	82650
	cross	1413	0	96750
CCB10	*center*	1234	0	39240
	cross	1157	00	40830
SCB5	*center*	1212	0	54650
	cross	1158	0	53430

The above reported data (50% r.h.) would support the assertion that the SC textiles can offer a possibility for single discharge inceptions (ESD) to happen during the initial times (period between 0 and 2 s) of the charge decay curves: the potential is the highest, although the duration is the shortest.

Similarly the 12% r.h. data (Table 1) appear consistent with the remotely possible formation of ESD discharges in the periods longer than 2 s.

Conclusions

The starting point of this work hinged on the possibility of realising a testing "machine" very flexible. But, overall, the above system had to be capable of offering reliable SV(t) data after a rubbing process, i.e. the charge (equivalent to Surface Voltage) variation vs time.

Once obtained the latter goal, the point became testing the charge decay of various samples with the same accuracy and repeatability and with the aim of studying the behaviour of each sample, changing several factors of influence. This way it made sense to establish just 3 simple parameters [V(0); d/dt V(0); V(2)] which could synthetically describe the SV(t) plots obtained varying different conditions (r.h., temperature, pressure and velocity during rubbing etc).

Essentially, the above reported data represent a set of charge decay measurements indicative of the factor "squares amplitude" and of the factor "fabric" on the behaviour of a textile adopted for composite garments (just of the textile, as the inhabited garment behaviour would depend also on other factors).

Acknowledgements

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References

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