Understanding core conductor fabrics

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Abstract. ESD Association standard test method ANSI/ESD STM2.1 – Garments (STM2.1), provides electrical resistance test procedures that are applicable for materials and garments that have surface conductive or surface dissipative properties. As has been reported in other papers over the past several years, fabrics are now used in many industries for electrostatic control purposes that do not have surface conductive properties and therefore cannot be evaluated using the procedures in STM2.1. A study was conducted to compare surface conductive fabrics with samples of core conductor fibre based fabrics in order to determine differences and similarities with regards to various electrostatic properties. This work will be used to establish a new work item proposal within WG-2, Garments, in the ESD Association Standards Committee in the USA.

1. Introduction
Core conductor fibres are being used in a wide variety of clothing applications, particularly where there is a need to control static electricity but surface conductive properties are viewed as being an electrostatic discharge (ESD) risk. The present industry test procedures that rely on surface or volume resistance or resistivity measurements do not provide appropriate or sufficient information when applied to fabrics with core conductors or other buried layer conductors. Work is underway within the ESD Association Standards Committee working group on garments in the USA to attempt to develop appropriate test methods for non-surface conductive materials used in garments.

Numerous fabrics were involved in this study including: plain cotton, polyester, conductive grid pattern on polyester base (conventional cleanroom garment), Chinese silk, and three (3) levels of core conductor fabrics (varying weights).

Several aspects of electrostatics were evaluated including: surface resistance, shielding/suppression of samples in free space with and without grounding; triboelectric charging with an inclined plane with quartz, PTFE and hard brass rollers; and a rotating drum triboelectric charging test using the various fabrics mentioned above.

2. Surface Resistance
The surface resistance of the samples was measured according to ANSI/ESD STM11.11. The core conductor fabrics were in excess of $3 \times 10^{10}$ ohms and the conductive grid pattern materials measured $3.6 \times 10^6$ ohms. The conventional cloth samples were greater than $1 \times 10^{11}$ ohms.
3. Shielding/Suppression Test

Fabric samples were supported in wood rings that were suspended by monofilament fishing line within another wooden ring. A small Van de Graaf generator placed 30 cm (12 inches) away from the samples under test was used as the electrical field source. A field mill (3M Model 711 Voltage Analyzer) was connected to a computer through a data acquisition system (Prostat Model PGA710 Auto Analysis system). Figure 1 shows a photograph of the test set-up. Figure 2 compares the grounded and ungrounded voltage allowed through the conventional cloth samples. Figure 3 shows the results for the core conductor and grid pattern cleanroom garment materials. Note the change in voltage level on the y-axis of the charts. Also note that “GRD” means attached to ground and “no GRD” means the ground lead is removed which electrically isolates the sample under test.

![Figure 1. Shielding/Suppression Test Set-up](image1)

![Figure 2. Voltage allowed –standard cloth](image2)

![Figure 3. Voltage allowed – Core Conductors (AP, AX and B) and Grid cloth samples](image3)

None of the fabrics in Figure 2 provided much in the way of electrical field suppression although cotton seemed to perform better when the ground lead was not attached. This observation probably is a result of the electrical field actually interacting with the ground lead even though it was connected on the field mill side of the fabric. When a grounding clamp was attached to the fabric, all of the samples shown in Figure 3 were able to suppress the electrical field substantially. The core conductor suppression level varied according to the fabric weight – AP being the lightest weight and Sample B the heaviest. The grid pattern material had very good suppression ability when bonded to ground but when in a non-grounded state, sample B performed at a similar if not superior level.
4. Inclined Plane Triboelectric Test
Evaluation of the triboelectric properties of materials involves selecting the two (or more) interacting materials. The inclined plane test is highlighted in ESD ADV 11.2 – Triboelectric Charge Accumulation Testing. A steel plate incline of 15° is used to support a sample under test. Cylinders made from quartz glass and PTFE are used as they represent the generally accepted extremes on a Triboelectric Series. Hard brass cylinders also provide significant information and insight into the charge generation characteristics of materials. The cylinders roll down the inclined plane and are captured in a Faraday Cup and the charge in nanocoulombs recorded. The test is repeated with six (6) cylinders of each type and the charge averaged. Two of the core conductor samples, cleanroom grid material, cotton and silk were evaluated using the inclined plane method. Tests were conducted with the metal incline grounded and also with the metal incline insulated (base still grounded) to look for differences in the charge generation and accumulation properties. Figure 4 shows the summary results of the inclined plane tests.

Figure 4. Charge in nanoCoulombs for rollers on grounded and insulated inclined plane supporting the fabric samples. Note: samples AX and B show only grounded metal plate values.

The charging level of the hard brass is negligible except against the ungrounded silk sample. All three of the core conductor materials had similar charge generation properties and were lower than the cleanroom grid sample for quartz and brass.

5. Rotating Drum Triboelectric Test
The conventional inclined plane test did not provide the differentiation needed to verify the performance properties of fabrics. Another procedure was developed whereby fabrics could be contacted in a controlled manner to a fabric sample under evaluation. The same wooden hoop arrangement used in the suppression test shown in Figure 1 was used to support the sample under test. A rotating drum from a rock tumbler ball-mill was prepared to hold a contacting fabric sample. Figure 5 shows the test set-up. Figure 6 shows the results of the triboelectric testing using the rotating drum. An additional grid pattern fabric was added to the test (Red Grid). Voltage recorded is for the peak value after approximately 60 seconds of contact time between the roller fabric and the test sample.

Figure 5. Rotating drum set-up
Figure 6. Core conductor and grid pattern peak voltage
When the fabrics were grounded, the charging levels were quite low and controlled and there is only
minor difference between core conductor materials and the grid pattern fabrics. In an ungrounded
condition, the core conductor fabrics actually charge less than the grid pattern fabrics. This property
would lend itself for use in garments in environments where specific and intentional grounding was
not possible or only incidental. Figure 7 and 8 show the actual data acquisition graphs for sample B in
the grounded and ungrounded conditions with natural wool as the contacting fabric. Figures 9 and 10
show the grounded and ungrounded grid pattern fabric against natural wool.

As can be observed, grounded sample B maintains a very low steady voltage while the ungrounded
sample increases over time before eventually levelling out due to charge saturation.

The grid pattern cleanroom fabric shows opposite polarity and significantly higher overall charging
levels against the wool roller than the core conductor sample B fabric shown above. At the end of
each graph, the natural decay pattern is shown after the contacting drum rotation was stopped.

6. Conclusions
If taken at face value, the surface resistance of the core conductor fabrics would limit their application
in some areas due to not meeting the arbitrary specifications established in some industry accepted
garment standards. This study shows that the core conductor fabrics have lower charge generation
propensity overall than conventional conductive grid fabrics. Especially important is the observation
that when the core conductor fabrics are not bonded to ground, the charging characteristics are
considerably lower than the conductive grid pattern materials. This feature would lend itself well to
garments made for special applications, especially for flammable or other ignition hazard
environments where exposed conductors may be considered a risk for ESD.

References
[1] Holdstock, P: September 7, 2009, Proceedings, EOS/ESD Symposium, “Limitations of using Resistance Measurements
to Qualify Garments for use in an EPA”, 2B.4-1 to 2B4-6
[2] ANSI/ESD STM2.1, Garments, ESD Association, www.esda.org USA
[3] ESD ADV11.2 – Triboelectric Charge Accumulation Testing, ESD Association, 7900 Turin Road, Building 3, Rome,
New York, USA 13440, www.esda.org
[4] Huntsman, J R, Proceedings, 1984 EOS/ESD Symposium, “Triboelectric Charge: Its ESD Ability and a Measurement
Method for its Propensity on Packaging Materials”