RESEARCH REGARDING ESD GARMENTS DEVELOPMENT

RAZVAN SCARLAT[1], EFTALEA CARPUS[1], DETLEF BONFERT[2], ALEXANDRA ENE[1], CARMEN MIHAI[1], EMILIA VISILEANU[1], ALEXANDRU POPA[3]

[1] *National Research and Development Institute for Textiles and Leather, Bucharest*

[2] *Fraunhofer Research Institution for Modular Solid-State Technologies, Munich, Germany*

[3] *"Aurel Vlaicu" University of Arad*

The electrostatic discharge (ESD) can be defined as a sudden transfer of electrostatic charge between two objects of different potentials. In terms of ESD characteristics, fabrics will quickly dissipate the accumulated charge, but will present a potential risk for electrostatic charging and energy transfer during an accidental discharge; these issues are solved by the fabrics that contain surface conductive fibres. To obtain an ESD garment with superior qualities, the present paper proposes the study of a double layered knitted structure. The fabric were manufacture on a electronic flatbed knitting machine, and tested from the functional characteristics point of view (electrical resistance, shielding factor, discharge time) and from the comfort characteristics point of view (thermal conductivity, thermal resistance, air and vapour permeability).

Keywords: electrical discharge, knitting, protective clothing

INTRODUCTION

The electrostatic discharge (ESD) can be defined as a sudden transfer of electrostatic charge between two objects of different potentials. An electrostatic discharge appears when the charged object comes near to an uncharged object. This is accompanied by a high energy transfer and may cause malfunctions or irreparable damages of sensitive devices. To overcome these issues, ESD protective solutions are developed, which reduce the risk of an electrostatic discharge (Carpus *et al.,* 2014).

In terms of ESD characteristics, fabrics will quickly dissipate the accumulated charge, but will present a potential risk for electrostatic charging and energy transfer during an accidental discharge; these issues are solved by the fabrics that contain surface conductive fibres.

Functional characteristics are defined as follows:

- resistivity 10^4-10^5 Ohm·m;
- distribution of electrostatic charges (EN 1149-1/Protective clothing - Electrostatic properties-Part 1: Test methods for the measurement of surface resistivity);
- provision of instantaneous discharge (EN 1149-3/Protective clothing - Electrostatic properties-Part 3: Test methods for the measurement of charge decay);
- anti-static properties are preserved even after 100 wash cycles.

An ESD protective garment should ideally have the following functions:

• The protective garment should effectively shield the electric field originating from the insulating parts of the operators' normal clothing;

• The protective garment should prevent direct discharges from the operators' normal clothing;

• The protective garment should not itself cause similar problems. That is, it should not generate electrostatic field external to the garment and it should not be a potential source of direct electrostatic discharges.

To ensure the performance of a maximum safety and comfort activity, a two-layer structure with different electrostatic behaviour has been chosen. The outer layer is mainly dissipative, providing protection against short circuit and limiting the amount of electrostatic energy that can be dissipated to the work environment, while the inner layer is mainly conductive, ensuring controlled drainage of static electricity. An additional requirement for the inner layer is to ensure the user's comfort (Carpus *et al.*, 2014).

In this paper, has been selected a configuration of a bilayer ESD fabric and analyzed by various testing methods.

EXPERIMENTAL PART

Two-layer knit variants were made with plaited structures, with parallel evolution of two or more yarns with strictly determined relative position as a result of their submission at different angles (plaiting yarn V at an angle smaller than ground yarn F). The most used knitted structures are jersey and rib structure. In case of jersey structure, the plaiting yarn V appears on the foreground on the front and the ground yarn F, on the foreground on the back of the fabric. In case of rib structure due to alternating of front-back wales - both the plaiting yarn (at front aspect stitches) and the ground yarn (at rear aspect stitches) will be present on the foreground, on each side of the fabric.

Nega-Stat® is introduced into textile materials to provide protection against a range of risks and hazards caused by static electricity in industrial end-use situations.

Knitting is made on electronic flatbed knitting machines having yarn thread guides with special construction that provide the yarns with different deposition angles under needle head, so that in the stitch forming stage the plaiting yarn (V), in our case a conductive yarn, remains on the front of fabric, while the ground yarn (F), in our case the fabric yarn will stay on the back of the fabric (Carpus *et al.*, 2014).

Within the present paper, from the 21 knitted variants, the variant number 7 has been selected, as it can be seen in Table no. 1.

Table 1. The structure chosen

Structure	F1/Front	F2/Rear	Conductive yarn percentage
plaited jersey	one yarn Nm 50/3, 100% cotton + one yarn 75% cotton + 25% epitropic yarn (Nm 34/1 carbon coated polyester)	one yarn Nm 50/3, 100% cotton + one yarn Nega-Stat P190, 155 dtex, 24f, polyester filament with trilobal carbon inner core	5%

Functional and Comfort Characteristics Measurements

In order to characterize the sample were conducted the following parameters: weight [g/m^2], density (wales/10cm, rows/10cm), thickness (mm), air permeability (l/m^2/s), water vapour permeability (%), thermal conductivity (mW/mK), thermal resistance (m^{2}KW) (Table 2).

Table 2. The results of measurements

Weight [g/m^2]	Density Do	Density Dv	Thickness, [mm]	Air permeability, l/m^2/ s	Water vapour permeability, %	Thermal resistance m^{2}K/W
487	44	86	1.63	484.6	42.5	0.03354

Considerations:

- the figures for weight and density are suitable for this kind of knitted articles considering that the proposed garment are designed for spring-automn season;

- the value for water vapor permeability is placed into optimal zone, due to the presence of the cotton yarn in the structure.

- air permeability causes sensations of warm and cool of clothing products, the value obtained beeing characterized by the presence of cotton yarn and conductive yarn element from nylon filament surface saturated with carbon particles (Scarlat *et al.*, 2014).

Electrical Measurements

Electrical Measurements on Fabrics. Charge Decay Time Measurements

To determine the charge decay time for the knitted samples, a measuring stand using a Charge Plate Monitor (CPM) type 268A-1T manufactured by Monroe Electronics, a discharge electrode, an ESD switch normally open, an oscilloscope and a set of electrostatic insulators was used. CPM has an internal 5 kV power source and an electric field sensor. Through the high voltage power source, the CPM's plate is charged up to a certain potential in regards with the ground. Being in contact with the charged plate, the tested material will also be charged at the same potential. After disconnecting the power supply, the discharge stage is started by connecting the electrode to the ground. The discharge signal is viewed and recorded via oscilloscope and will be used to determine the charge decay time. All insulator items used within the measuring stand were made of polycarbonate. It was intended to separate the charging area from the discharging area for the tested samples.

The charge voltage used for every sample was set to 5 kV. Determinations were made in two different conditions:

- the discharge electrode connected to the sample's dissipative surface (CD);
- the discharge electrode connected to the fibre's conductive core (CC).

Determined parameters which define the discharge process have the following meanings:

- $t_{1/2}$ represents the time after which the 5 kV voltage at which the samples were initially charged decreases by half as result to the discharge (half-time);

- $t_{1/e}$ represents the time after which the 5 kV voltage at which the samples were initially charged decreases to 1/e of its value as result to the discharge (37% time);

- U_{125} represents the voltage recorded at the sample's surface after a period of 125 ms has passed from the beginning of the discharge (residual voltage after 125 ms);

- r_{125} represents the ratio between the residual voltage after 125 ms and the initial charge voltage (Donciu *et al.*, 2013).

The results regarding the charge decay time are presented for the chosen sample in figure 1 and represents the evolution of the discharge voltage. Centralization of data and parameters that characterize the discharge process are presented in table 3.

Table 3. Measured parameters characterising the discharge process

$t_{1/2}$([s]		$t_{1/e}$([s]		U_{125}([V]		r_{125}([%]	
CD	CC	CD	CC	CD	CC	CD	CC
0.0451	0.0278	0.0804	0.0412	1520	480	30.4	9.6

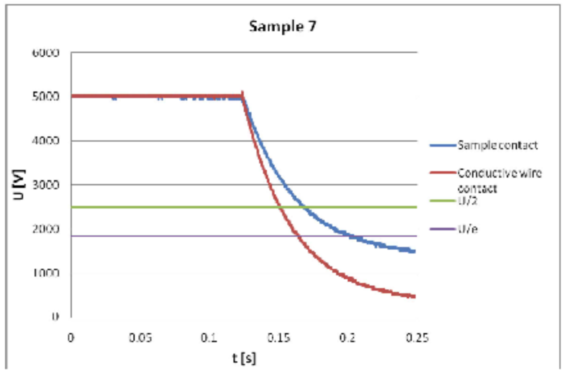

Figure 1. Charge decay times for bilayer sample

Analysing the results it can be noticed that the sample presents good ESD properties. These are strongly enhanced if the conductive core is electrically connected to the discharge electrode.

To determine the fabric resistance, a different applied voltages, V_{appl} = 1-200V was performed to the fabric.

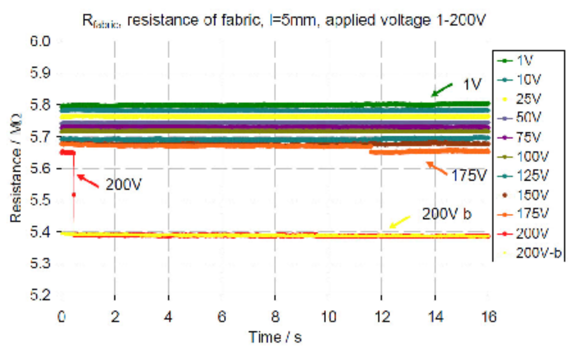

Figure 4. Resistance of the fabric during different applied voltages, V_{appl} = 1-200V

The results of measurements reveal the good electrical behaviour of the fabric of the tested samples. The measured resistances are in the MΩ, the range is sufficient to avoid electrical charge build-up in the fabric.

Electrical Measurements on Yarns

To determine the yarn resistance, a different applied voltages, V_{appl} = 1-200V was performed to a yarn extracted from the fabric.

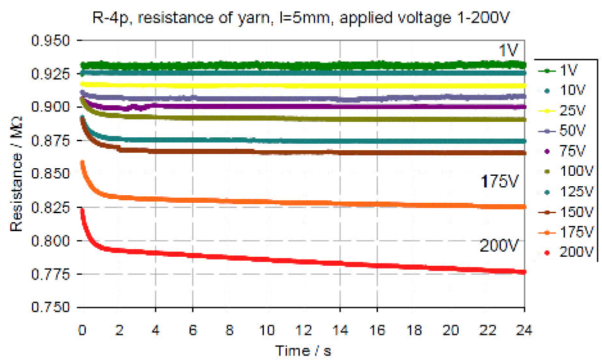

Figure 3. Resistance of yarn

The results of measurements reveal the good electrical behaviour of the yarn from the tested samples, when containing carbon covered fibers. The measured resistances are in the MΩ, the range is sufficient to avoid electrical charge build-up in the fabric that contain the yarn.

CONCLUSIONS

Within this paper, the properties of a knitted fabric with bilayer structure were investigated using various methods. The parameters which were investigated are:

- functional and comfort characteristics: weight, density of the fabric, thickness, air permeability, water vapour permeability, thermal conductivity, thermal resistance.
- electrical measurement on the fabric: discharge time and electrical resistance;
- electrical measurements on the yarns: electrical resistance.

The results of measurements reveal the good electrical behaviour of the yarn and fabric of the tested samples. The measured resistances are in the MΩ, the range is sufficient to avoid electrical charge build-up in the fabric.

- the figures for weight and density are suitable for this kind of knitted articles considering that the proposed garment are designed for spring-automn season;
- the values for water vapor permeability air permeability are placed into optimal zone, due to the presence of the cotton yarn in the structure.

Acknowledgement

The work was supported by the a grant of the Romanian National Authority for Scientific Research, CNDI- UEFISCDI, project PCCA 179/2012, “ESD garments made of two-layer knitted fibres with conductive core”.

REFERENCES

Carpus, E., Scarlat, R., Bonfert, D.A., Visileanu, E., Donciu, C., Popa, A., Enache, Gh. (2014), “ESD protective equipment. Investigation of two-layer knitted structures with conductive fibres content”, *Industria Textila*, 3, ISSN 1222 – 5347, 121-178.

Donciu, C. (2013), “Core Conductive Yarn Based Integral Knitted ESD Garments Part I. Metallic Core Conductive Yarns Investigation”, *Advanced Materials Research*, 772, 467-473.

Research Regarding ESD Garments Development

Scarlat, R., Carpus, E., Ene, A., Mihai, C., Visileanu, E., Donciu, C. (2014), "ESD Garments", in: Proceedings, *Annals of the Oradea University. Fascicle of Textiles*, ISSN 1843-813X, vol. XV, 95-100.