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ESD - FUNCTIONAL CLOTHING

SCARLAT Razvan[1], CARPUS Eftalea[2], DONCIU Codrin[3], POPA Alexandru[4], BARBU Ionel[5]

[1, 2]The National Research and Development Institute for Textile and Leather Bucharest, 16, Lucretiu Patrascanu str., sector 3, Bucharest, Romania, razvan.scarlat@certex.ro

[3]"Gheorghe Asachi" Technical University of Iasi, 76, Bd. Prof. Dimitrie Mangeron, Iasi, Romania, cdonciu@tuiasi.ro

[4,5]"Aurel Vlaicu" University of Arad, 77, Bd. Revolutiei, Arad, Romania, alexpopaarad@yahoo.com

Correspomding author: Scarlat Razvan, e-mail: razvan.scarlat@certex.ro

Abstract: *The functional clothing represents a sustainable development direction of in the field of technical textiles, a bridge between various activity domains, a solution to user's complex requirements. The research and development potential in the field is supported by the new fibers/ yarns generation, the new technologies and the market niches, as well. Protective clothing is now a major part of textile classified under technical textile. Protective clothing refers to the garment and other fabric related items designed to protect the wearer from harsh environmental effects that results in injuries or death. The innovation, as a result of convergence processing technologies, consumer demands and what is viable on the market, defines the personal protective equipment field.*
In this article, we present the work of an ESD protective clothing development. Therefore, it has been applied a modern knitting technology, on 7E and 12E STOLL machines, using cotton and wool yarns as base yarn and conductive yarns for plaiting structures. Also, the optimal parameters establishment and the functional requirements are aspects of the research activity performed. The experimental models have been conducted in order to demonstrate the design concept used and choosing the optimal variant.
The characterization of the developed experimental variants took into account the evaluation of physico-mechanical and electrical characteristics. From the electrical point of view, the variants have been mainly evaluated through "point to point" method in terms of electrical isolation efficiency dimensional changes analysis.

Keywords*: textile, knitted structures, electrostatic discharge, conductive yarn*

1. INTRODUCTION

The EU's priorities are outlined in the Europe 2020 Strategy: focusing on Europe becoming a smart, sustainable and inclusive economy by 2020.

The clothing and textiles sector is a significant part of the world's economy. Textiles and clothing is a diverse sector that plays an important role in the European manufacturing industry, employing 1.7 million people and generating a turnover of EUR 166 billion. The sector has undergone radical change recently to maintain its competitiveness with a move towards products with higher value added [1]. The textile and clothing industry (T/C industry) is a very diverse and heterogeneous industry, covering a wide range of important activities regarding the transforming of fibers into yarns and yarn into fabrics used for textile products/ systems development meant for all activity domains [2,3]. Years ago, technical textiles were defined as textiles that are other than clothing or home textiles. Advances in the field of textile fibres as well as in the flexible processing systems have assigned to the technical textiles a new definition, namely: “Technical textiles are materials meeting high technical and quality requirements (mechanical, thermal, electrical, durability etc.) giving them the ability to offer technical functions” [4].

The value chain of technical textiles is influenced by political, economical, sociological, tehnological, legal, ecological, cultural and historical factors with environmental and social effects [5].

Functional apparel can therefore be defined as a generic term that include all such types of clothing or assemblies that are specifically engineered to deliver a pre-defined performance or functionality to the user, over above its normal function [6]

Technical textiles represents a multi-disciplinary field with numerous end use applications.

Types of technical textiles [7]:

- mechanical functions: mechanical resistance, reinforcement of materials, elasticity, tenacity;
- exchange functions: filtration, insulation and conductivity, drainage, impermeability, absorption;
- functionalities for living beings: antibacterial, anti dust mites, biocompatibility, (hypoallergenic textiles), biodegradability/ bioresorption;
- protective functions: thermal, fire, mechanical, chemicals, impermeable – breathable, antistatic, particles antirelease, electrical insulation, IR and UV rays, NBC (nuclear, biological and chemical), high visibility, electromagnetic fields etc.

Protective clothing is now a major part of textile classified under technical textile. Protective clothing refers to the garment and other fabric related items designed to protect the wearer from harsh environmental effects that results in injuries or death.

The innovation, as a result of convergence processing technologies, consumer demands and what is viable on the market, defines the personal protective equipment field (fig. 1).

Fig. 1: *The factors convergence influencing the innovation process (http://www.textiletoday.com.bd/transformation-of-the-textile-and-apparel-industry-of-bangladesh-through-innovation/)*

The studies regarding the essential performances of ESD protective garments lead to a number of contradictory requirements when defining the ideal ESD garments: (i) high conductivity to facilitate the dissipation process and to avoid charge accumulation and (ii) high resistivity to prevent fast dissipation and to limit the energy transfer during discharging [8]. They also must have good shielding properties to reduce the intensity of the electrostatic fields generated under the garment [9] and anti-static properties to not generate electric charge when come in contact with other materials [10]. These requirements can't be met at the same time by a garment, thus a compromise will be considered. In general is aimed to obtain a garment with dissipative properties that, according to Standard EN 1149-5:2008, must possess a half decay time of the electric field strengthunder 4 seconds, shielding factor greater than 0.2 or surface resistance less than 2.5 × 109 Ω [11].

2. EXPERIMENTAL PART

For ESD equipment development was chosen a knitted bilayer structure that can assure good protection from accidental electrical discharges on the dielectric layer and a drainage of accumulated electric loads through conductive layer. In these conditions, the bilayer type approaching allows the delimitation of accidental discharge path from the controlled discharge path of the electrification material.

The knitting was made at SC TANEX SRL on the 7E and 12E STOLL knitting machines, with the possibility of yarn tension adjusting in order to obtain a correct yarn plating.

The experimental matrix comprise the following yarns:

- base yarn: - Nm 50/3, 100% cotton;
  - Nm 30/2, 100% wool;
- plaiting yarn: - conductive yarn 75% cotton + 25% epitropic yarn (Nm 34/1carbon coated polyester);
  - conductive yarn multifilament bi-component core-sheath structure, Nega-Stat P210, 112 dtex 12 f, polyester filament with trilobal core and carbon outer layer;
  - conductive yarn Nega-Stat P190, 155 dtex, 24f, polyester filament with carbon trilobal inner core;
  - conductive yarn filament nylon surface saturated with carbon particles.

Reduced elasticity of the used yarns imposed low speed knitting to 0.65 m/ sec, and the plaiting of knitted fabric was performed in two textures of fabric.

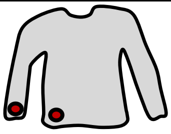
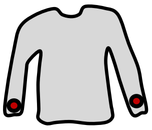
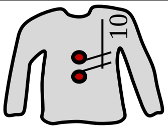
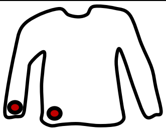
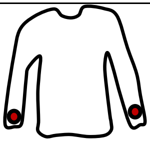
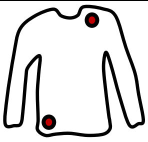
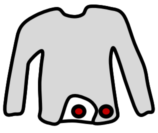
The characterization of experimental variants took into account the evaluation of the physico-mechanical and electrical characteristics. The main tested characteristics are presented in tab. 1:

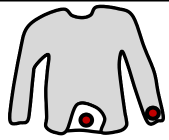
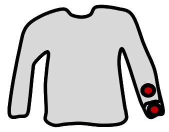
Tab. 1: *The main physico-mechanical and electrical characteristics*

Variant no.	Bilayer structure	Weight [g/m²]	Density		Thichness, [mm]	Discharging time $t_{1/2}$ (F1)	Discharging time $t_{1/2}$ (F2)	Conductive yarn percentage
			rows/10cm	wales/10cm				
5		470	43	92	1,58	0,0227	0,0228	5
7		487	44	86	1,63	0,0274	0,0246	7
21		521	47	71	1,65	0,0253	0,0282	21
8		705	37	61	3,52	0,026	0,0268	4.5%

The variants have been evaluated through "point to point" method in terms of electrical isolation efficiency according to directions graphically displayed. All samples presents good electrical isolation properties at the surface. Especially, with very good properties, it stands out the following variants: V7 and V8.

Tab. 2: *Point to point resistance*

Measurement points location	**Variant**	**Point to point resistance**	**Observations**
	V5	96.3 MΩ	Front measurement
	V7	1.5GΩ	
	V8	1.7GΩ	
	V21	23.2MΩ	
	V5	183MΩ	Front measurement
	V7	2GΩ	
	V8	2GΩ	
	V21	36.6MΩ	
	V5	22.5MΩ	Front measurement
	V7	1.2GΩ	
	V8	49MΩ	
	V21	5.35MΩ	
	V5	11.4MΩ	Front measurement
	V7	0.4GΩ	
	V8	0.38GΩ	
	V21	7.7MΩ	
	V5	120MΩ	Back measurement
	V7	1.9GΩ	
	V8	2GΩ	
	V21	20.2MΩ	
	V5	134MΩ	Back measurement
	V7	2GΩ	
	V8	2GΩ	
	V21	37MΩ	
	V5	20.9MΩ	Back measurement
	V7	0.97GΩ	
	V8	0.7GΩ	
	V21	6MΩ	
	V5	8.3MΩ	Back measurement
	V7	0.6GΩ	
	V8	0.5GΩ	
	V21	2.7MΩ	
	V5	2.4MΩ	Measurement from front to back
	V7	0.18GΩ	
	V8	39MΩ	
	V21	0.8MΩ	

	V5	109MΩ	Measurement from front to back
	V7	2GΩ	
	V8	1.85MΩ	
	V21	25MΩ	
	V5	40MΩ	Measurement from front to back
	V7	0.6GΩ	
	V8	1.1GΩ	
	V21	9.1MΩ	
	V5	157MΩ	Measurement from front to back
	V7	2GΩ	
	V8	2GΩ	
	V21	39MΩ	
	V5	99.2MΩ	Measurement from front to back
	V7	1.38GΩ	
	V8	2GΩ	
	V21	23MΩ	

The results of dimensional changes analysis after 1, 5, 10, 15 and 20 washes are presented in tab. 3.

Tab. 3: *Dimensional changes*

Variant no.		**Washing and drying dimensional changes (%)**				
	No. of washes	**1 wash**	**5 washes**	**10 washes**	**15 washes**	**20 washes**
5	Sleeve length	-0.76	-0.91	-1.36	-1.67	-1.97
	Equipment length	-0.90	-1.06	-1.66	-2.04	-1.59
7	Sleeve length	-0.45	-0.75	-1.35	-1.66	-1.66
	Equipment length	-0.38	-0.61	-1.61	-1.92	-1.92
21	Sleeve length	-0.44	-0.74	-1.04	-1.34	-1.34
	Equipment length	-0.38	-0.54	-0.77	-1.23	-1.23
8	Sleeve length	-0.28	-0.57	-0.86	-1.00	-1.29
	Equipment length	-0.52	-0.74	-1.11	-1.34	-1.34

Regression equations representing dimensional change tendency define the interdependence or the link between observed variables in statistic data (tab. 4).

Tab. 4 *Regression equations*

Variant no.	**Dimensional changess**	**Dimensional change tendency equations**	**Dependancy grade, R^2**
5	Equipment length Sleeve length	$y = 0{,}0258x^3 - 0{,}2439x^2 + 0{,}3602x - 0{,}894$ $y = 0{,}0008x^3 + 0{,}0054x^2 - 0{,}3555x - 0{,}852$	0,9955 0,9901
7	Equipment length Sleeve length	$y = 0{,}0508x^3 - 0{,}3939x^2 + 0{,}4852x - 0{,}584$ $y = 0{,}0817x^3 - 0{,}6793x^2 + 1{,}009x - 0{,}826$	0,9962 0,9779
21	Equipment length Sleeve length	$y = 0{,}025x^3 - 0{,}1821x^2 + 0{,}0929x - 0{,}38$ $y = -0{,}4x - 0{,}39$	0,9979 1
8	Equipment length Sleeve length	$y = 0{,}0317x^3 - 0{,}2436x^2 + 0{,}2748x - 0{,}58$ $y = 0{,}0175x^3 - 0{,}2039x^2 + 0{,}2086x - 0{,}538$	0,9989 0,9995

3. CONCLUSIONS

- To satisfy the two conditions for the ESD garments (high resistivity and high conductivity) it was opted for a bilayer structure:

• internal layer: best charge dissipation properties;

• external layer: good charge dissipation properties and high surface resistivity.

- When using a rib structure, voluminousness of the fabric will be higher due to the spatial arrangement of the stitch elements, due to an increased amount of incorporated air into the knitted structure. These aspects favour on the one hand a very high thermal comfort and on the other hand an effective air flow, respectively perspiration vapours between body and environment.

- Simple electrical measurements, like two point and four point DC- measurements reveal the good electrical behaviour of the yarn and fabric of the tested samples, when containing carbon covered fibers. The measured resistances are in the MΩ - range and are sufficient to avoid electrical charge build-up in the fabric.

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