



Research Article

Developing a Heating Panel for Protective Garment

Eryuruk SH*, Bahadir SK and Kalaoglu F

Abstract

Heating panels can be used in protective clothing when the employee works in cold weather conditions. One possible option is to use conductive yarns inside the fabric structure to develop electrical circuit in the fabric for fabric heating. For the performance of the heating structures, uniform distribution and dissipation of heat are important characteristics that should be well controlled by the location of heating elements in a close proximity to the heated area. In this study the design of heating panels based on e-textile design concepts is aimed. The e-textile architecture of the heating panels was formed using stainless steel conductive yarn that was successfully embedded via sewing technique on the textile structure. Different kinds of fabrics were combined in order to obtain functional protective clothing system.

Keywords:

E-textiles; Protective clothing; Heating panels; Stainless steel

Introduction

Protective clothing is a kind of clothing which is specifically designed, treated or fabricated to protect the wearer's body or other items of clothing from any hazards such as heat, chemicals and infection. The purpose of the protective clothing is to protect user to hazards or effective to decrease potential risks to acceptable levels. Today there are many studies with the aim of developing new textile products with sensing properties may be defined as smart textiles, intelligent textiles, or functional textiles. Electronic textiles (e-textiles) are produced combining textile materials with electronics and specific technological materials [1-3].

When people work in cold weather conditions, they need to protect themselves from the negative effects of weather. They generally wear multi-layered protective clothing but they may still need more reliability, performance and comfort, therefore there has been a strong push towards other solutions that can achieve better properties. This new functionality can be achieved by the integration of textiles and electronics to the textile structures. Heating panels can be a useful tool in protective clothing when the employee works in cold weather conditions. One possible option is to use conductive yarns inside the fabric structure to develop electrical circuit in the fabric. On the other hand, uniform distribution and dissipation of heat are important characteristics for performance of the heating structures and should be well controlled by the location of heating elements in

a close proximity to the heated area. When electric current is passed through a conductive material, the resistance leads the material to heat up. The heating capacity of the fabric changes depending on the fabric structure, the used materials as well as power source and system configuration. Moreover, the selection of the appropriate conductive yarn with a base yarn is a crucial issue since the voltage applied on the conductive yarn causes fabric to be heated.

In the literature, there are many studies about e-textiles particularly dealing with the usage of conductive yarns [4,5]. In some studies, conductive yarns presenting electrical function for heating purposes have been presented. Hamdani et al. [6] investigated the thermo-mechanical properties of knitted structures designed by using silver-coated Nylon 6,6 filaments. Kayacan et al. studied the functionality of heating panels using stainless steel yarns [7]. Sezgin et al. applied silver conductive threads through woven structures to analyze heating behavior of the developed structures [8]. Li et al. used silver-coated yarn to produce conductive knitted fabric with specific stitches that can be used for intelligent applications such as monitoring and heat generation [9]. Kursun et al. studied the electrical resistance heating of knitted e-fabric structures including silver plated conductive yarns. They investigated the application of ultrasonic welding technology on these knitted e-fabrics in order to see their effect on heating performance and thermal analysis was carried out under different voltage values to observe temperature variations over the knitted e-fabrics [10].

This study aimed at the design of heating panels based on electrical resistance heating approach. Stainless steel conductive yarn is used to obtain the e-textile circuit of the heating panels. Different kinds of fabrics were combined to obtain different types of layered fabric systems for functional heating panels. The layered fabric system was tested for thermal resistance, water vapour resistance, air permeability properties as well as for heating function.

Experimental Work

Materials

In this study, fabric system consisting of five layers was used: first layer is outer fabric made from PBI fiber, second layer is moisture barrier fabric from hydrophilic polyester membrane laminated on to a polyester raschel knitted fabric, third layer is conductive yarn embedded thermal barrier fabric, the fourth layer is again moisture barrier fabric from hydrophilic polyester membrane and the fifth layer is thermal barrier fabric. The characteristic of fabrics are given in Tables 1 and 2.

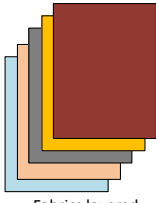
The electrical circuit in the structure was formed over the 3rd layer using silver coated with a linear resistance of <25 ohm/m and <10 ohm/m. The linear resistance of the conductive yarn was measured in ohm per meter (ohm/m) using a TTi 1906 computing multimeter. Flat sewing machine was used in order to integrate conductive yarn into textile structure. The 3rd layer with conductive yarn is shown in Figure 1.

Measurements

The samples were tested for thermal comfort properties as well as

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Received: November 27, 2017 Accepted: January 11, 2018 Published: January 16, 2018



Layer	Fabrics Used
1st layer	Outer Fabric-PBI Matrix and Nomex
2nd layer	Moisture Barrier- PU Membrane which is laminated to knitted fabric
3rd layer	Heat barrier laminated with conductive yarn- Aramid Viscose FR inner lining quilted to nonwoven
4th layer	Mosture Barrier- PU Membrane which is laminated to knitted fabric
5th layer	Heat Barrier- Aramid Viscose inner lining quilted to Aramid felt

Table 1: Layers of Fabric.

CODE	OUTER FABRIC
A1	PBI Matrix 200 g/m ²
	MOISTURE BARRIER
B1	PU Membrane which is laminated to knitted fabric (85 g/ m ²)
	HEAT BARRIER LAMINATED WITH CONDUCTIVE YARN
C1	Aramid Viscose FR inner lining quilted to nonwoven (55 g/ m ²)
C2	Aramid Viscose FR inner lining quilted to nonwoven (85 g/ m ²)
	HEAT BARRIER
D	Aramid Viscose inner lining quilted to Aramid felt

Table 2: Characteristics of fabrics.

Yarn Number	Linear Resistance (ohm/m)	Yarn Count (Nm)	Fiber Type
1	<25	2.97	Stainless-Steel
2	<10	3	Stainless-Steel

Table 3: Characteristics of the conductive yarn.

Fabric Layers	Temperature (°C)		
	5V	10 V	15 V
A1B1C1Y1B1D1	22	23	33
A1B1C1Y2B1D1	25	38	56
A1B1C2Y1B1D1	27	28	34
A1B1C2Y2B1D1	26	33	49

Table 4: Thermal camera results.

for heating function. All the fabric samples were conditioned for at least 24 hours prior to testing under standard atmospheric conditions (65% ± 2% RH, 20°C ± 2°C). Thermal resistance of samples was determined using Permetest machine and water vapour resistance of samples was also determined with permetest machine with adding pure water to the machine. Prowhite Air Permeability Tester Machine was used to test air permeability of the samples. Tests were done according to ISO Standarts (under 400 kPa). To carry out thermal analysis, thermal camera (from Testo Inc., Thermal Imager Testo 885) and DC power supply were used. The required energy to e-fabric samples was provided from DC power supply. Voltage supplied from DC power supply was increased starting from 5V to 15V with an increment of 5V.

Results

Multimeter was used to calculate conductivity measurements using the sewed fabric with conductive yarn. Electrical conductivity tests were done with conductive yarns sewed to heat barrier fabric. Length of conductive yarn on design was 173.5 cm for the design. Characteristics of the selected conductive yarn was shown in Table 3.

Thermal resistance, water vapour resistance and air permeability tests were shown in Figures 2-4. It was observed that layered e-textile samples have high thermal and water vapour resistance and air permeability values. Yarn type C2 (Aramid Viscose FR inner lining

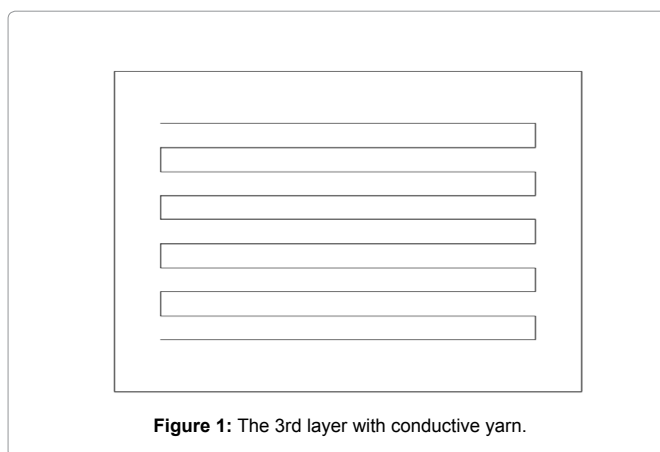


Figure 1: The 3rd layer with conductive yarn.

quilted to nonwoven (85 g/ m²) had higher thermal resistance. High thermal resistance is required to meet the thermal isolation after the heating panels are activated. Because fabric system consists of five layers, high water vapour resistance values were obtained. Moreover, acceptable air permeability results were obtained considering PU Membrane moisture barrier which was used in the second and fourth layers inside the five layered structure.

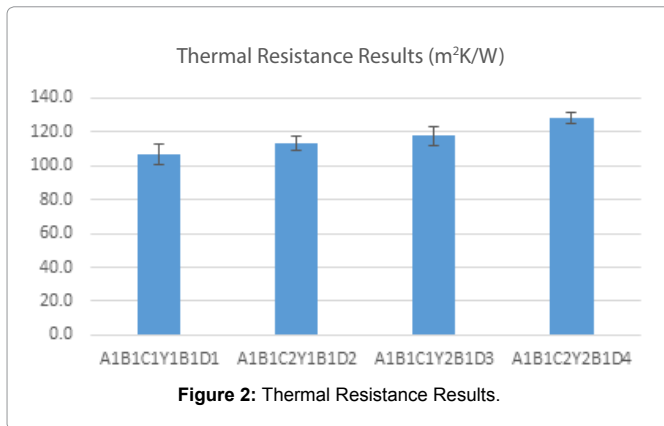


Figure 2: Thermal Resistance Results.

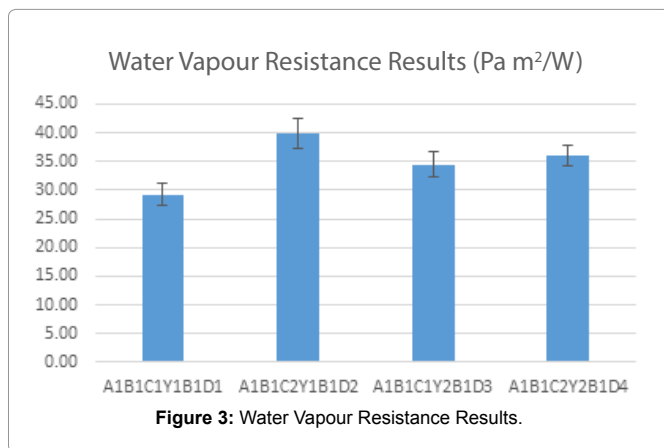


Figure 3: Water Vapour Resistance Results.

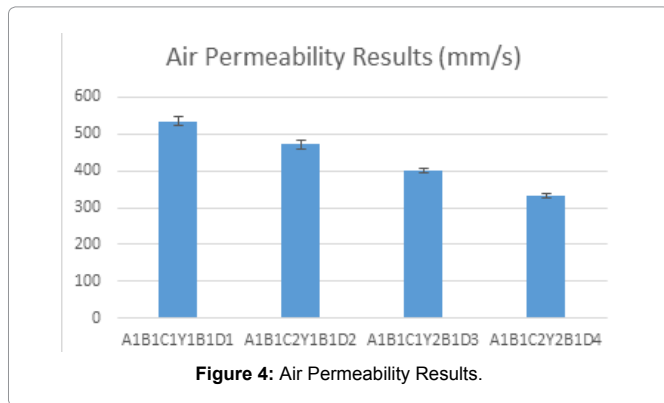


Figure 4: Air Permeability Results.

Thermal Imager Testo 885 was used to measure temperature distribution at three different voltages 5-10-15 V respectively. Results are presented in Table 4. When 5 V voltage was applied, temperature values between 22 °C and 27 °C were obtained for all fabric combinations. When 10 V voltage was applied, we get higher temperatures which are 33 and 38 °C for yarn type 2. When 15 V voltage was applied, 56 and 49 °C temperatures were obtained for yarn 2. As a result it was concluded that, 10 V voltage and yarn type 2 is adequate to use for the textile structure.

Conclusions

This study aimed at designing of a heating panel on the protective clothing with e-textile infrastructure. Firstly, protective clothing type

and fabric layers were specified then conductive yarn type and the identification of circuit design of conductive yarn into the fabric layers were specified. Electrical conductivity, thermal resistance, air permeability, water vapour permeability and thermal camera tests were applied for functional requirements of produced e-textile structures. As a result of the study it was observed that designed e-textile structure meet the functional requirements adequately.

Acknowledgements

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 644268. The article describes the part of the project which was realized by the Department of Textile Engineering of ITU and Kivanc Group.

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