EFFECT OF DIFFERENT CONDUCTIVE YARNS ON HEATING BEHAVIOUR OF FABRICS

Hande Sezgin[1],Senem Kursun Bahadir[1]; Y. Erhan Boke[2] & Fatma Kalaoglu[1]

[1] *Istanbul Technical University, Faculty of Textile Technologies and Design, Department of Textile Engineering, Istanbul,Turkey*
[2] *Istanbul Technical University, Faculty of Mechanical Engineering, Department of Mechanical Engineering, Istanbul, Turkey.*
kalaoglu@itu.edu.tr

Abstract: In recent years, various novel and practical products have been emerged by the rapid development in science and technology in order to meet human demands. By textile science incorporating with electronic industry, developed textile products start to take part in different areas such as industry, military, space, medical etc. for health, protection, defense, communication and automation. In this study, conductive yarns used as transmission lines of e-textile structures were examined due to increase in voltage. To do this, five different conductive yarns with different linear resistance values were used in order to form e-textile structure. Then, voltage was applied through the textile circuit from the end of the conductive yarns and their thermal images were captured by thermal camera. Results showed that the amount of temperature along the conductive yarn due to an increase in voltage value differs according to type of conductive yarns and the base yarn of the fabric.

1. Introduction

With developing technology and increasing demand of people, conventional textiles become insufficient. The need for clothes which have properties that support vital activities such as feeling, movement, communication, adaptation to environmental aspects increases day by day and it leads to occurrence of the term " Smart Textiles" [1].
Smart textiles is a kind of area in the technical textiles which the advanced technologies are used and nowadays they are becoming more and more popular with having highest added value characteristics [2]. With advances in textile technology and the fiber synthetic material science, smart textiles has emerged as a result of an interdisciplinary areas including design, electronics and computer engineering, medicine [3,4].
The latest trends in smart textiles bring the electronics together with fabrics. By this way, these are called as "e-textiles". The integration of electronics onto fabrics has led to an entirely new field of application [5, 6, 7].
In this project, heat manner of conductive yarns which constitute the basis of electronic textiles (e-textiles) were examined. An amount of energy is needed for e-textiles to perform the expected functions. Energy is mostly provided by the batteries which integrated to clothes. This batteries apply voltage to conductive yarns and enable passing of the current through yarn. At this point, heat factor arises with the energy on the fabric. Temperature of the conductive yarn that current is passing through increases and by this way, spreads out heat. This heat is so important for e-textile structures. E-textile fabrics are generally composed of base textile yarns and conductive yarns which are placed at certain intervals according to construction. The heat that is released from conductive yarns should not give any damage to other yarns, this is an important issue. Besides this, since clothes are in contact with skin, they should not affect comfort of the wearer while they are performing their functions.

When literature analyzed, it is seen that there are many studies about e-textiles. In those studies, conductive yarns presenting electrical function in an e-textile structure are generally studied.

However, in those studies heat released from the conductive yarns of the fabric has not been analyzed yet. Therefore, in this study, heat release of the conductive yarns was investigated due to conductive and base yarn type.

2. Experimental

2.1. Material

In this study, ten different plain fabric samples were produced. Two samples of these fabrics are shown in Figure 2.1. For the base textile yarn of the e-textile structures, Ne 20/2 cotton (100%) and cotton-acrylic (50%-50%) yarns were used.

Figure 2.1 *Fabric samples.*

As for conductive yarn, three different silver yarns and two different steel yarns with different linear resistance values were used. The average linear resistance values of yarns and yarn numbers are shown in Table 2.1.

Table 2.1: *Yarn average lineer resistivities and yarn numbers.*

Yarn Name	Yarn Number (Tex)	Average Linear Resistance (Ω/m)
Silver 1	1134	50
Silver 2	3	1350
Silver 3	8	377
Steel 1	130	130
Steel 2	526	17

Fabric samples were produced using hand weaving looms. Energy was provided by DC power supply. Testo 880 thermal camera and TestoIRSoft software program were used to obtain and examine the thermal images of the fabric structures.

2.2. Method

Firstly, fabric samples were placed on a plate. After that, positive and negative poles of DC power supply were clamped to two parallel conductive yarns of the samples as shown in Figure 2.2. Distance between these parallel yarns were adjusted to 1 cm.

Figure 2.2 *Connection of the power supply to fabric.*

Voltage supplied to conductive yarns was increased step by step starting from 1 Volt to the point where yarn started to break or fabric started to burn (with an interval of 1 Volt). The amount of current passing through conductive yarns was taken from the screen of DC power supply.
After setting the voltage value with the power supply, we waited for 30 seconds to ensure the temperature to become stable. Then, with the help of a button on the thermal camera, instant thermal images of fabric were recorded. A schematic diagram of experimental set up and the thermal image of one sample are shown in Figure 2.3 and Figure 2.4, respectively.

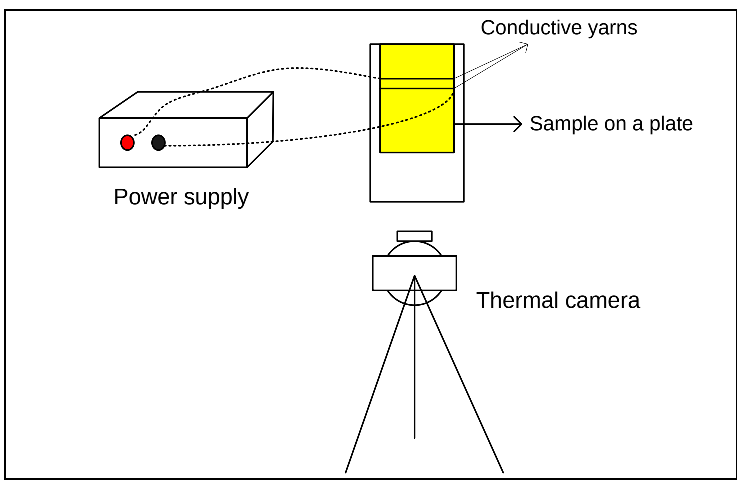

Figure 2.3: *Experimental set up.*

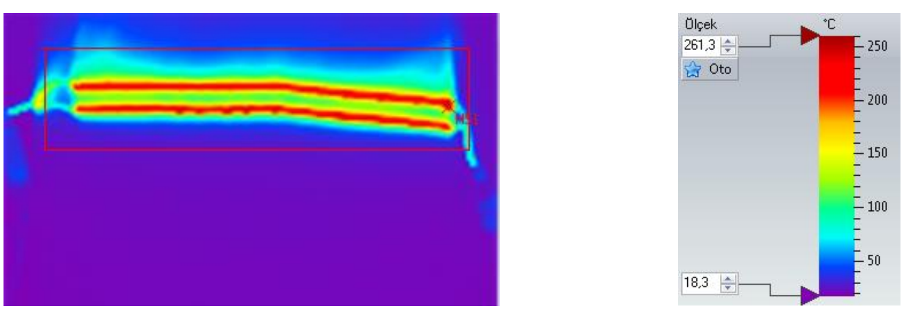

Figure 2.4 *Thermal image of a sample at 17V.*

3. Results

The physical properties of the ten fabric samples are shown in Table 3.1.

Table 3.1: *Properties of fabric samples.*

Sample Number	Weave	Conductive Yarn	Base Yarn	Resistance (Ω/m)
1	Plain	Steel 1	Cotton	130
2	Plain	Steel 1	Cotton/Acrylic	130
3	Plain	Silver 1	Cotton	50
4	Plain	Silver 1	Cotton/Acrylic	50
5	Plain	Steel 2	Cotton	17
6	Plain	Steel 2	Cotton/Acrylic	17
7	Plain	Silver 2	Cotton	1350
8	Plain	Silver 2	Cotton/Acrylic	1350
9	Plain	Silver 3	Cotton	377
10	Plain	Silver 3	Cotton/Acrylic	377

First of all, we made an assessment according to base yarns of the fabric samples. It is seen that at the same voltages the heat of cotton fabrics is higher than that of the cotton-acrylic fabrics for samples steel 2 and silver 2 yarns (see Fig.3.1). In these comparisons only variable is base yarn, other parameters are identical. As shown in this figure, samples 5 and 7 (100% cotton) approach to higher temperatures than samples 6 and 8 (50% cotton- 50% acrylic) at same voltage value.

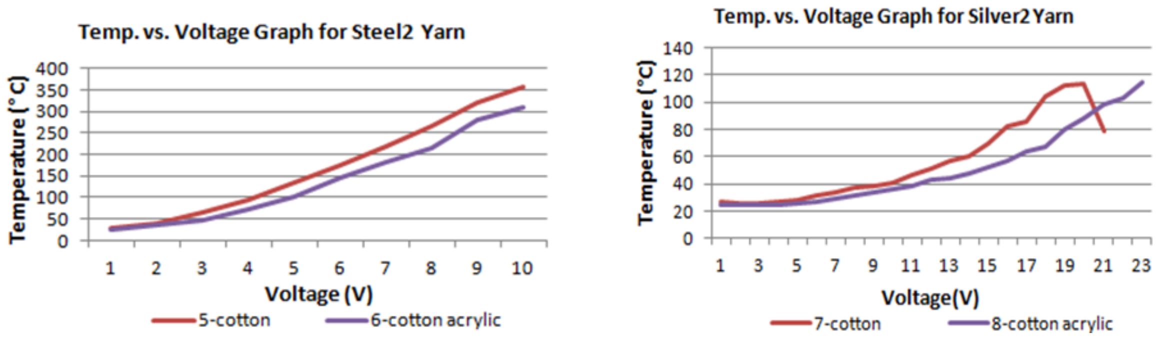

Figure 3.1: *Temperature vs. voltage graph of samples: steel 2 (a) and silver 2 (b) yarns.*

Secondly, we made an assessment according to type of conductive yarns. In these comparisons the only variable is conductive yarn, other parameters are identical. Figure 3.2 shows the variation of temperature-voltage of samples 1, 3, 5, 7 and 9 (only samples with 100% cotton).

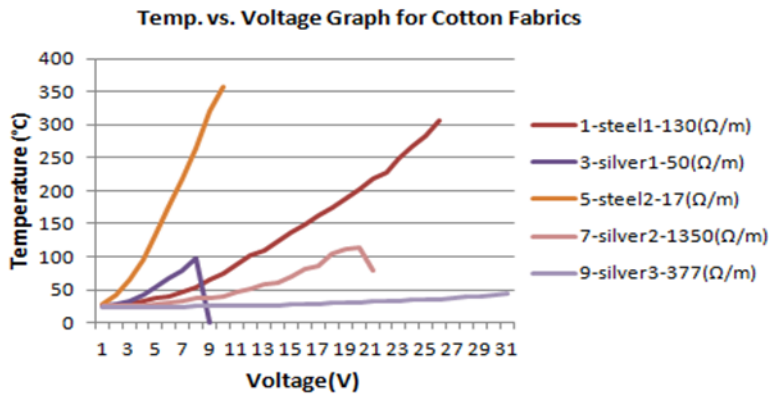

Figure 3.2 *Variation of temperature-voltage of samples 1, 3, 5, 7 and 9 (only samples with 100% cotton).*

When we examined the Figure 3.2, it is easily seen that sample 9 which is woven with 8 tex (70 denier) silver yarn endures to maximum voltage. After sample 9, sample 1, 7, 5 and, 3 endures to 26V, 21V, 10V and 9V without any damage, respectively. If we look a certain voltage value, at the maximum temperature of sample 5, sample 9 approaches the minimum.

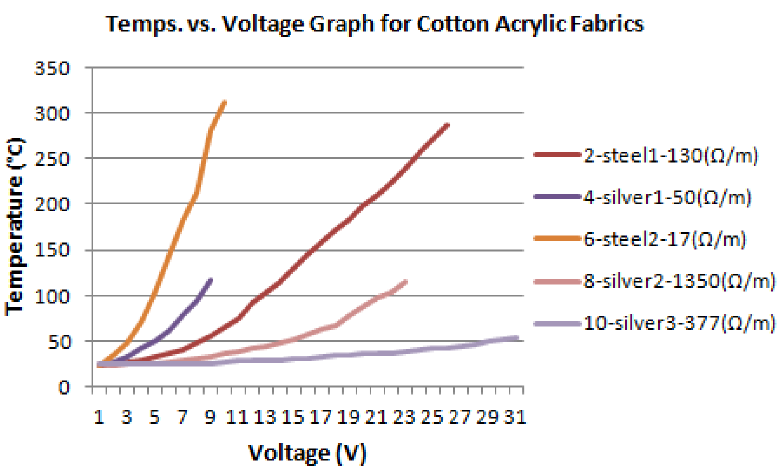

Figure 3.3 *Variation of temperature-voltage of samples 2,4,6,8 and 10.*

Figure 3.3 shows the variation of temperature-voltage of samples 2,4,6,8 and 10 (cotton-acrylic). Due to Fig.3.3, it is seen that sample 10 which is woven with 70 denier silver yarn endures to maximum voltage once more. After sample 10, sample 2, 8, 6, 4 endures to 26V, 23V, 10V, 9V without any damage, respectively. When temperatures examined, at the same voltage, sample 6 approaches the maximum temperature while sample 10 approaches the minimum. These results may be attributed to the linear resistance values of conductive yarns.

Additionally, from the results it was observed that 100% cotton samples reach higher temperatures than the 50% cotton- 50% acrylic samples. This can be related to thermal conductivity coefficients of fibers. Mostly, cotton conducts heat well. Among conventional fibers, cotton has the highest thermal conductivity coefficient (0,461 W/mK) whereas acrylic has lesser (0,2 W/mK). According to this information, it is appeared that using 50% cotton- 50% acrylic yarn is more convenient than 100% cotton yarn since it approaches lower degrees of temperature values at same voltage.

4. Conclusion

In this project, five different conductive yarns with different linear resistance values and two different base yarns (100% cotton and 50% cotton- 50% acrylic) were used in order to produce e-textile structures. The temperature distributions along the conductive yarns on the samples were examined according to increased voltage values.

Our results show that the maximum voltage was obtained with the 70 denier silver yarn which has a linear resistance of 377 Ω/m. On the other hand, the minimum voltage was obtained with 526 tex steel yarn which has a linear resistance of 17 Ω/m.

Additionally, due to thermal conductivity coefficients of fibers it was found that 100% cotton samples reach higher temperatures than the 50% cotton- 50% acrylic samples. Thus, it is apparent that instead of fabrics composed of 100% cotton yarns, using fabrics composed of 50% cotton- 50% acrylic yarns is more convenient for e-textile structures.

Finally, as mentioned above using 70 denier silver plated nylon yarns with 50% cotton- 50% acrylic yarns are more suitable for e-textile applications since they present better (lower) temperature values due to an increase in voltage value.

References

[1] Kayacan, O., Bulgun, E., Metalik Tekstil Yapılarının Isınma Davranışları, *Proceedings of 3.International Technical Textile Conference*, Istanbul, (2007).

[2] Huang, C., Shen, C., Tang, C., Chang, S., A wearable yarn-based piezo-resistive sensor, *Sensors and Actuators*, **Vol. 141** (2008), pp. 396-403.

[3] Balcı, H., *Akıllı(Fonksiyonel) Tekstiller, Seçilmiş Kumaşlar Antibakteriyel Apre ve Performans Özellikleri* (master thesis), Çukurova University Instıtute of Science and Technology, Adana, (2006).

[4] Cherenack, K., Zysset, C., Kinkeldei, T., Münzenrieder, N., Tröster G., Woven Electronic Fibers with Sensing and Display Functions for Smart Textiles, *Advanced Materials*, **Vol. 22** (2010), pp. 5178-5182.

[5] Locher, I., Tröster, G., Enabling Technologies for Electrical Circuits on a WovenMonofilament Hybrid Fabric, *Textile Research Journal*, **Vol. 78** (2008), pp. 583-594.

[6] Kohler, A. R., Hilty, L. M., Bakker, C., Prospective Impacts of Electronic Textiles on Recycling and Disposal, *Journal of Industrial Ecology*, **Vol. 15** (2011), pp. 496-511.

[7] Dhawan, A., Seyam, A. M., Ghosh, T. K., Muth, J. F., Woven Fabric-Based Electrical Circuits: Part I: Evaluating Interconnect Methods, *Textile Research Journal*, **Vol. 74** (2004), pp. 913-919.