Investigation of Heating Behaviour of E-textile Structures

H. Sezgin, S. Kursun Bahadır, Y. E. Boke, F. Kalaoğlu

Abstract**—**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. Electronic textiles (e-textiles) are fabrics that contain electronics and interconnections with them. In this study, two types of base yarns (cotton and acrylic) and three types of conductive steel yarns with different linear resistance values (14Ω/m, 30Ω/m, 70Ω/m) were used to investigate the effect of base yarn type and linear resistance of conductive yarns on thermal behavior of e-textile structures. Thermal behavior of samples was examined by thermal camera.

Keywords**—**Conductive yarn, e-textiles, smart textiles, thermal analysis.

I. INTRODUCTION

THE development in textile industry brings out integration of electronics onto fabrics. These products are called “E-textiles” [1]-[3]. Textile structures are most suitable materials for electronic integration due to their property that they are fundamental and transformational component of human beings’ lives [4].

E-textiles are structures that have properties like sensing, actuating, communicating, generating and storing power. E-textiles are wearable structures which enable continuous interaction between device, user and environment. They have usage in many application areas such as; military, healthcare, sports and fashion [5], [6].

In an e-textile circuit, mostly conductive threads are used to transmit energy. Metal, carbon and optical fibers are the most well-known textile conductive yarns [7]. They can be directly woven, knitted, embroidered, or sewn into the fabrics for designing e-textile transmission lines [8].

In the literature, there are many studies dealing with the issue of conductive yarns’ usage. In one of these studies, Li et al. designed an intelligent wearable garment with transcutaneous electrical nerve stimulation (TENS) function for the treatment of various types of diseases and pains of the body by using silver-coated conductive yarns [9]. Hertleer et al. used a thin copper-plated high-quality nylon rip stop fabric, a copper, and tin-plated woven nylon fabric to design wearable microstrip patch antennas working in 2.45GHz frequency [10]. Senol et al. used 100% stainless-steel filaments to design a fully integrated functional active T-shirt structure [11]. Bahadir et al. used silver-plated nylon conductive yarns to develop a smart clothing prototype enabling detection of obstacles called ‘‘Wearable Obstacle Detection System’’ for visually impaired people [12].

Conductive yarns in the fabric spread out some heat according to rising voltage. The given out heat must not affect the comfort of the people who wear these clothes in their daily lives and also must not give any damage to the other yarns that are used. The amount of heat differs according to type of conductive yarn and the base yarn of the fabric. The purpose of this study is to examine the effect of base yarn type and linear resistivity of conductive yarns on thermal behavior of e-textile structures.

II. MATERIALS AND METHODS

Six different plain weave fabric samples were produced using hand looms.

Fig. 1 Conductive yarns

In this study, cotton (100%) and acrylic (100%) yarns used as base yarn, three steel yarns with different linear resistance values were used as conductive yarns (Fig. 1).

The linear resistance values of conductive yarns was measured in ohm per meter (V/m) using a TTi 1906 computing multimeter. Yarn characteristics (average linear resistance values of yarns and yarn numbers) are given in Table I.

DC power supply was used to acquire the required amount

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of energy. Testo880 thermal camera and Testo IR Soft software program were used to obtain and examine the thermal images of the e-textile fabric samples.

TABLE I
YARN CHARACTERISTICS

Yarn type	Yarn number	Linear Resistance (Ω/m)
Cotton	Ne 20/2	-
Acrylic	Ne 20/2	-
100% Stainless Steel	505 tex	14
100% Stainless Steel	235 tex	30
100% Stainless Steel	110 tex	70

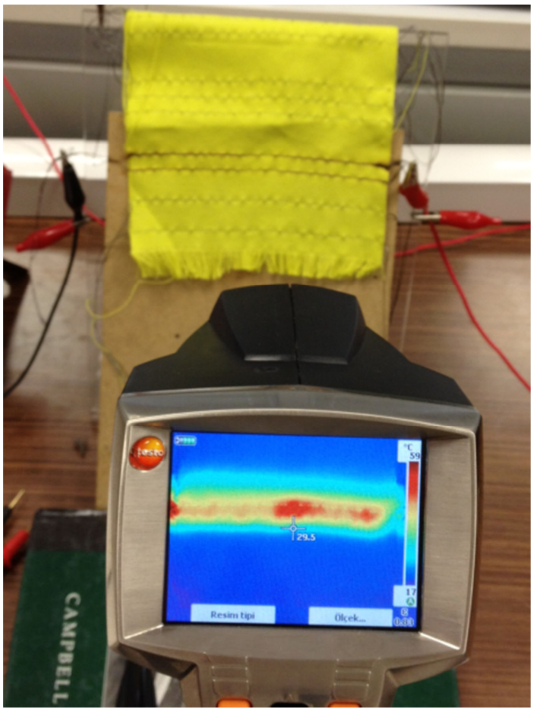

Fig. 2 Experimental set up

Samples conditioned at least 24 hours at standard atmospheric conditions (65%±2% RH, 20ºC±2ºC). Before starting thermal analyzing, samples were placed on a flat surface to satisfy stable measurement. Fig. 2 shows the experimental set-up.

Then, the positive and negative poles of DC power supply attached to the two parallel conductive yarns. After that, voltage increased one by one to the point where the conductive yarn started to burn. Also the amount of current passing through conductive yarns was obtained from DC power supply.

After setting the voltage value with the power supply, it is waited for 30 seconds to stabilize the temperature and then took the thermal image by using thermal camera.

Maximum temperature values of samples were obtained from thermal images. Thermal image of sample 5 is given in Fig. 3. The point which is referred as “HS 1” represents the hottest point of the fabric sample.

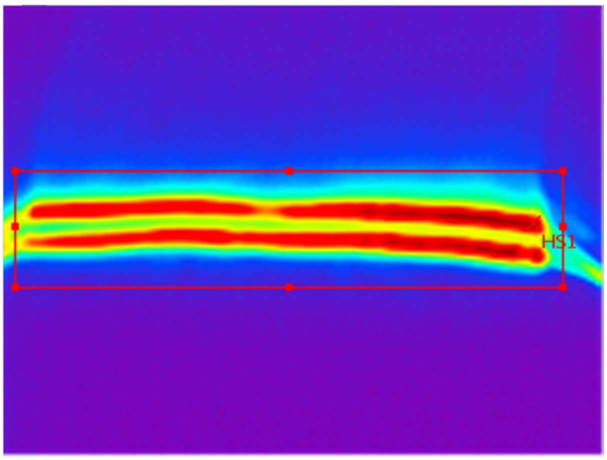

Fig. 3 Thermal image of sample 5

Red lines show the conductive yarns on the fabric. The hottest point on the fabric was acquired by selecting the area as shown in Fig. 2.

III. RESULTS

The characteristics of six fabric samples are given in Table II.

TABLE II
SAMPLE CHARACTERISTICS

Sample No	Weave Type	Base Yarn	Conductive yarn
1	Plain	Cotton	Steel (14 Ω/m)
2	Plain	Cotton	Steel (30 Ω/m)
3	Plain	Cotton	Steel (70 Ω/m)
4	Plain	Acrylic	Steel (14 Ω/m)
5	Plain	Acrylic	Steel (30 Ω/m)
6	Plain	Acrylic	Steel (70 Ω/m)

Results were examined in two categories. These are; analysis based on linear resistivity of conductive yarns and analysis based on base yarn type.

A. Analysis Based On Base Yarn

Firstly, analysis was done according to the base yarn type. As it was mentioned before, cotton and acrylic yarns were used as base yarns.

When the samples that are produced with 14 Ω/m steel yarn are examined, it is easily realized that cotton fabric reached higher temperature than acrylic fabric at the same voltage value (Fig. 4 (a)). Although there is not a considerable difference between temperature values of cotton and acrylic fabric samples in which 30 Ω/m and 70 Ω/m steel yarns are used, cotton fabric reached a bit higher temperature values than acrylic fabricsat the same voltage values (Figs. 4 (b), (c)).

B. Analysis Based On Linear Resistances of Conductive Yarns

Then, the effect of linear resistance values of conductive yarns on heat manner of e-textile samples was examined.

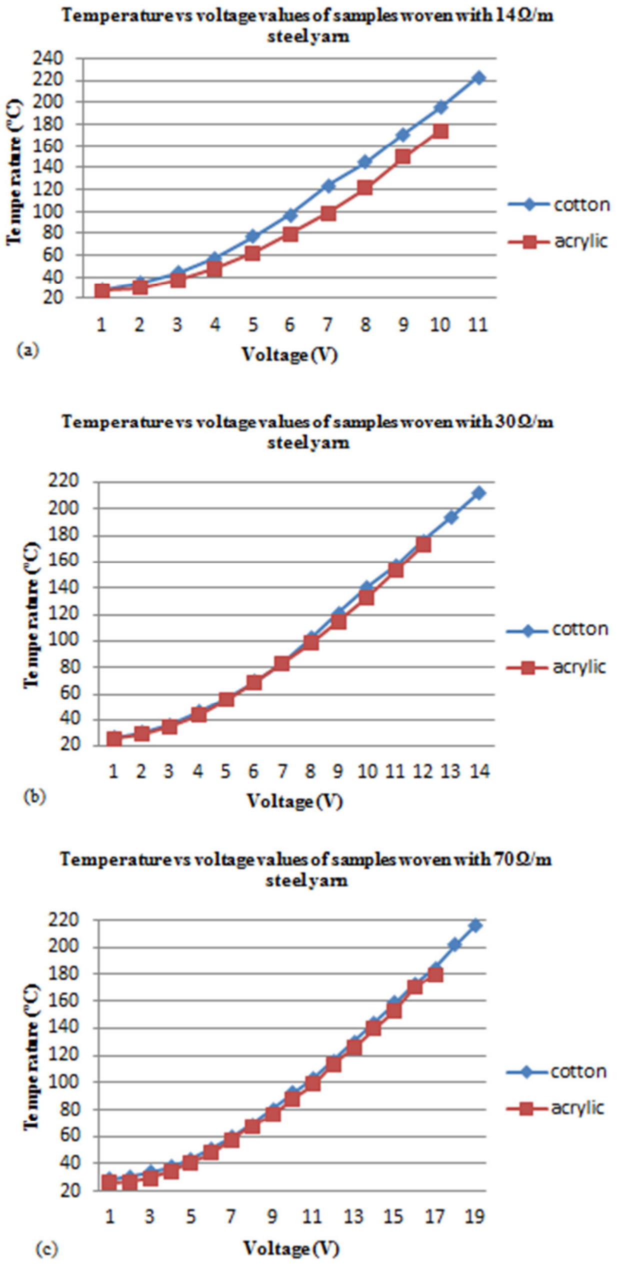

Fig. 4 Temperature vs voltage values of samples woven with (a) 14 Ω/m, (b) 30 Ω/m, (c) 70 Ω/m steel yarn

It is seen from Fig. 5 that, samples woven with steel yarn which has a linear resistance value of 14 Ω/m reaches the maximum temperature values than other samples at the same voltage values. Also, samples that are woven with steel yarn which has a linear resistance value of 70 Ω/m reaches the lowest at both cotton and acrylic fabrics samples.

So it can be concluded that, average linear resistance value of conductive yarn is inversely proportional to temperature of e-textile fabrics obtained when they are connected with power supply.

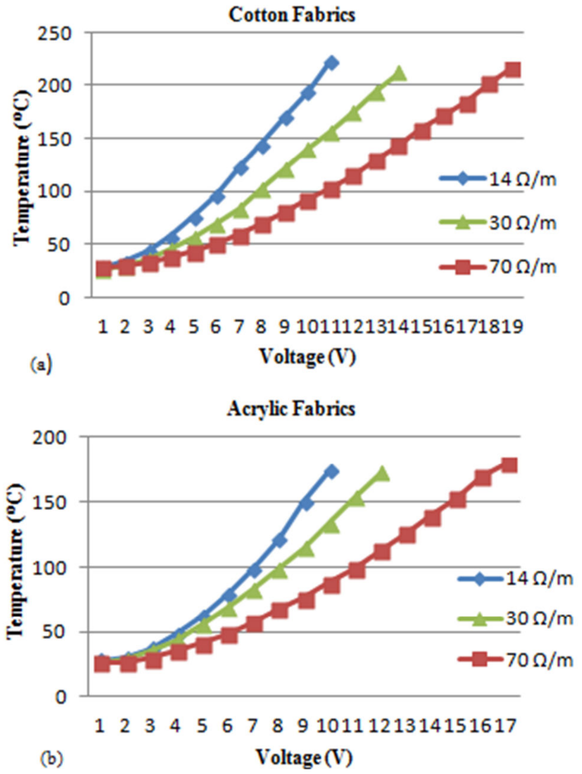

Fig. 5 Temperature vs voltage values of (a) cotton and (b) acrylic fabric samples

IV. CONCLUSION

As it is mentioned above, since e-textile structures may be in contact with skin, it is essential to have low temperatures when they are functioning. With regard to the end use, the heat generated by the circuitry over the e-textile is becoming critical issue for reliability and health security concepts.

Results show that although there is not a significant effect of base yarn type on thermal behavior of samples, lower temperatures can be achieved by integrating conductive yarns that have higher linear resistance on to the fabrics due to flow of current

Achieved results will guide incoming e-textile applications and mostly will help to ignore the problems that may develop afterwards like; melting of based yarn of the construction of fabric and damaging the regional parts of the body because of heat given out.

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