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INVESTIGATION THE ELECTRICAL RESISTANCE AND THERMAL BEHAVIOUR OF SURFACE MOUNT DEVICE INTEGRATED STAINLESS STEEL ELECTRONIC YARN

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ABSTRACT

The emergence of intelligent textiles in recent years has highlighted the importance of e-textiles (electronic textiles). Electrically conductive textiles can be found in the form of fabrics, yarns, or fibres textile structures. The electronic yarn (E-yarn) was manufacturing by incorporated tinny surface mount electronic device (SMD) into textile conductive yarn. This paper deals with the electrical resistance and thermal properties of SMD LED embedded stainless steel (SS) E-yarn. The relationship between the current voltage curve and total electrical resistance of the electronic yarn was investigated experimentally. In addition, the analytical finding shows that, as the supply voltage increase, the electrical resistance of conductive yarn significantly increased and the surface temperature of both the SS conductive yarn and E-yarn had increased. Furthermore, From the test result, it can be confirmed that, this electronic yarn was suitable to be used for resistive heating elements and use for possible application in wearable e-textiles heating and a new way of energy saving.

KEYWORDS

E- yarn, electrical resistance, resistive heating, wearable electronics, temperature.

INTRODUCTION

Conductive fabrics and electrically heated clothing have been extensively explored and implemented in many sectors as a consequence of rapid development of wearable electronic textiles and smart textiles. In recent years, a lot of research is going on in the field of electro conductive textile materials for a wide range of heating applications.

Several researchers had conducted studies on the heating properties of conductive materials using different techniques by highlighting there advantage and dis advantages. These methods includes by printing of conductive inks such as carbon [1] and Graphene coated on multi-layer fabric insulation [2].

An aligned carbon nanotube sheet and a thermochroic silicone elastomer were combined to create a novel type of flexible and stretchable strip-shaped thermos chromicresistive heater (TRH) [3]. That have been expected to be combined with the human body for wearable heating and thermal therapy [4].

In addition to printing of conductive ink on to textile fabric, by incorporating of conductive material on to textile fabric, heating of textile was developed. A study by Kayacan et al. [5] conductive steel yarn integrated textiles with a specific 12 Voltage source electronic circuit was developed and used as effective heating garments. However, the average heating value of the heating pad was depend on the length of conductive yarn and the amount of power supply. A wearable heating system with controllable textile based conductive yarn was developed. Kurşun [6], Shahzad et al. [7], Hertleer et al. [8] developed and studied a conductive resistor yarn has been inserted into textile in order to generate heat use for medical applications. Poboroniuc [9] also develop and studied a Bekitex conductive yarn he knitted of sewed structures for heating sole.

In addition, Warska [10] studied inserting different conductive textile yarn in to spacer fabric for cars seat to improve user's driving comfort. The result showed that, the heating capacity was depend on the types of conductive yarn and the shape design of different trajectories. Talha et al. [11] was investigated the thermos mechanical properties of textile heating element based on silver coated polymeric yarn can generate sufficient heat to warm up the body and the analytical result finding showed that the mechanical stretching had not a significant effect on the amount of heat generated. However, high input battery can be used depending upon the heating requirement.

The majority of these heating textiles, as mentioned above, were manufactured by using incorporating conductive wires and yarns such as copper, stainless steel, silver coated polymers, and carbon black. To generate huge amounts of heat, it needs high amounts of conductive yarns and high space utilization also. In addition, the surface heating capacity of the conductive yarns was limited. Furthermore, the heating capacity was more likely depends on the types of conductive yarn, types of the fabric constriction (i.e. knitting, weaving, nonwoven or spacer fabric), also types of fabric types (i.e. polyester, cotton, wool) and types of the shapes conductive strands on the fabrics (i.e. either zigzag, ladder, or horseshoe shapes). Moreover, to the best of the authors' knowledge, no studies that examine the thermal behavior of small electronic integrated E-yarns.

The aim of this research work was the possibility to design a flexible, SMD LED embedded E-yarn based heating systems is to provide necessary warmth to the user in a cooler environment at specified point of human body. In addition, the electrical resistance and thermal behaviour of surface mount device integrated stainless steel E- yarn investigated.

MATERIALS AND METHODS

Materials

In the experimental part of the paper, two 5 cm, BEKINOX,VN.12.2.2.2.175 stainless steel multi filament 4/1 ply 555 Tex, 7 Ω/m resistance electrically conductive yarns were purchased from BEKAERT (Belgium). According to the supplier information, this yarn has a property of corrosion free, flexible and halogen free. In addition, 0603 thin film white SMD 800 K super bright LED (Light Emitting Diodes) which has 1% tolerance was purchased from Digi electronics key Belgium.

Methods

This study used a two-phase methodological technique. The initial method was embedding an SMD LED inside SS conductive thread via using 1 mm silver cylindrical crimp beads to create functioning E-yarn. After construction of the E-yarn, the electro mechanical and thermal character tics of the E-yarn was examined.

Developments of SMD LED embedded E-yarn

The integration of 68-ohm SMD LED into SS conductive yarn was performed using 2 in 1 hot air gun-soldering machine. This methods was simple and performed by hand and hot air was applied to transfer the heat through the machine to assemble the SMD LED and the SS conductive thread. However, direct soldering of stainless thread was difficult due to excess of a thick oxide (Cr_2O_3) has on its surface. To overcome this, surface preparation of SS conductive yarn was needed. (I.e. the tips of SS conductive yarn was heated via 50°F hot air for 2 min and then polish by a small drop of phosphoric acid based paste). Here after the tips of the SS thread inserted into silver crimp beads and applied pressure by pliers. Once the physical connection between the tips of SS conductive yarn and crimp beads performed the integration of SMD LED into SS conductive yarn was done by applying a solder paste on the connection point and applied hot air to melt this solder paste at 173°C.Then the mechanical bond between them was performed. Hence the SMD LED embedded E-yarn was developed as shown Figure 1.

Figure 1. SMD LED embedded Steeliness steel E-yarn.

Sample Preparation

The trajectory line of the SMD LED embedded SS conductive electronic yarn were made by using stitching on cotton fabric. After stitching, was made, encapsulation of the electronic yarn using TPU were performed as shown in Figure 2 A and the equivalent circuit illustrated in Figure 2 B.

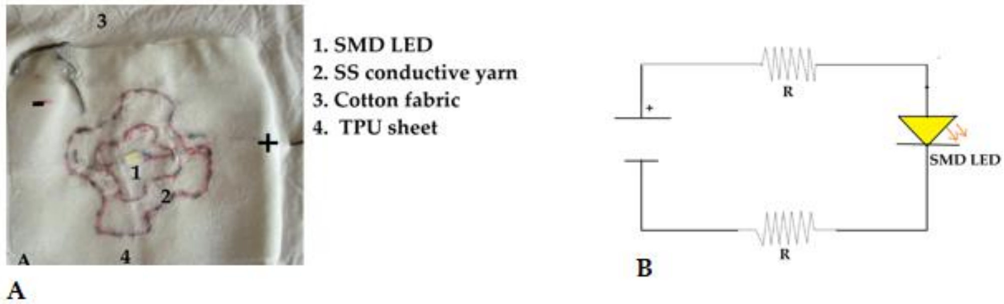

Figure 2. Heating sample of SMD LED E-yarn (A) and its equivalent circuit (B).

Experimental setup

Measurements of electrical resistance and power of E-yarn

The electrical resistance of the E-yarn was conducted by using four point probe methods with multi meters. The experimental setup is shown in Figure 3. The tips of the SMD embedded SS E-yarn were clamped by two jaws (one fixed and one movable). A power supply source with an adjustable voltage regulator with variable voltage was applied on the samples and the resistance of the E-yarn was examined by using the integration of multi meters. Based on the ohmic law, the contact resistance of the SMD LED was calculated as in Eq. [1]:

$$R_{LED} = \frac{V_{LED}}{I_{LED}} \quad [1]$$

where, R_{LED} represents resistance of LED, V_{LED}, is voltage drop across in the LED and I_{LED} denotes current flow in the SMD LED.

When a voltage (V) is applied, across the SMD embedded E-yarn, power (P) is dissipated both at conductive SS yarn and at the SMD LED in the form of thermal energy due to the finite resistance which governed by Ohm's law. The power dissipated calculated by Eq. [2]:

$$P = VI \quad \text{or} \quad P = RI^2 \quad [2]$$

where, *P* (W) is power, *V* is Voltage drop across the circuit, *I* denotes current flow in the circuit, and *R* represents the electrical resistance of heating element.

Measurements of thermal behavior of E-yarn

The measurements of thermal temperature of the SMD resister embedded SS E-yarn was performed by using thermos couple and IR thermograph camera as shown Figure 3.

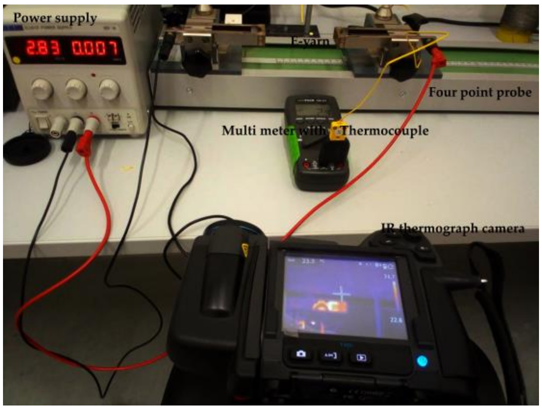

Figure 3. Thermal measurement setup of SMD LED embedded E yarn.

In addition, to investigate, the thermographic image of the het generate SMD LED embedded e-yarn, infrared thermographic camera was used. The IR thermographic camera was set around 50 cm away from the heated materials, and the tests were conducted at a temperature of 20+/- 2°C.

RESULTS AND DISCUSSION

Measurements of electrical resistance and power of E-yarn

The change in the electrical resistance of the SMD LED embedded SS E-yarn during the increase in applied voltages was shown in Figure 4. Frome the figure it can be shown that the resistance of the E-yarn changes with changing applied voltage over time. A variable change in the resistance value was observed with even a very small increase in applied voltage.

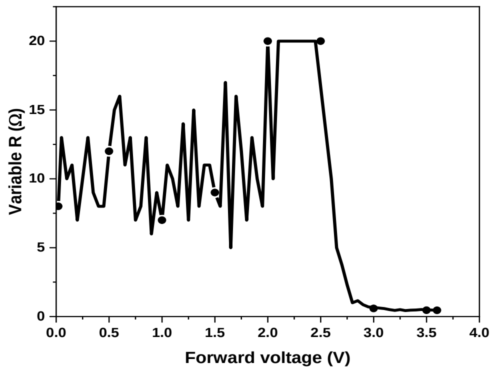

Figure 4. Change electrical resistance due to increasing voltage.

Measurements of thermal behavior of E-yarn

The outcomes of measuring the temperature of the heated zone on a specific points of the conductive yarn and at the SMD LED of the E-yarn sample at variable supply voltages of between (0.012 V to 3.32 V). The surface temperature and IR image of SS conductive yarn and SMD integrated E- yarn shown in Figure 5. It was confirmed that, as the supply voltage increased, the surface temperature of the SS conductive yarn and SMD LED embedded E-yarn proportionally increased. compared to the samples that, when 3.0 V was applied, the surface temperature of the SS conductive yarn was 23.2 °C, and the surface temperature of SMD LED embedded E-yarn were about 83.0 °C. This is due to there was more heat dissipation occurs on the tinny SMD LED by electrical loss (Joule effect), resulting in a temperature rise.

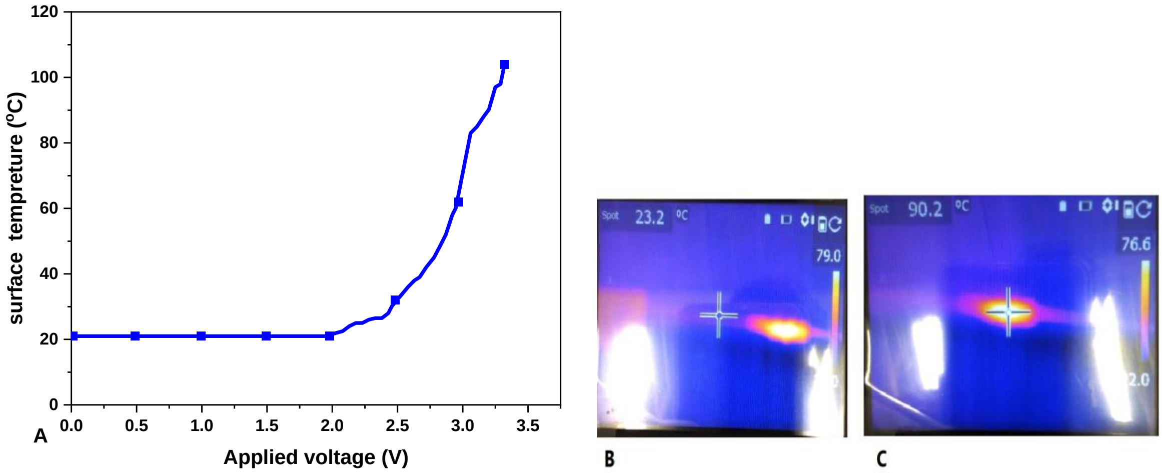

Figure 5. Surface temperature (A), IR thermographic images of SS conductive yarn (B) and SMD LED embedded e-yarn (C).

In addition, the temperature measurements against a specific voltage applied with a given time showed in Figure 6. It was shown that, a rapid increase in temperature in the first minute of the heating process, and a slower increase in temperature was acquired in the next 3 min of the process. Furthermore, it can be observed that the temperature reaches its constant values only after 3 min of the heating process. The diagram also shows the influence of the supply voltage because a separate temperature rise curve is shown for each applied voltage. As expected, the lowest voltage (2.43 V) gives the smallest increase in temperature as well as the lowest and fastest constant temperature was reached. The highest voltage (3.4 V) causes a strong and rapid initial rise in temperature as well as the highest temperature, but to achieve constant temperature values takes significantly longer, even 10 min.

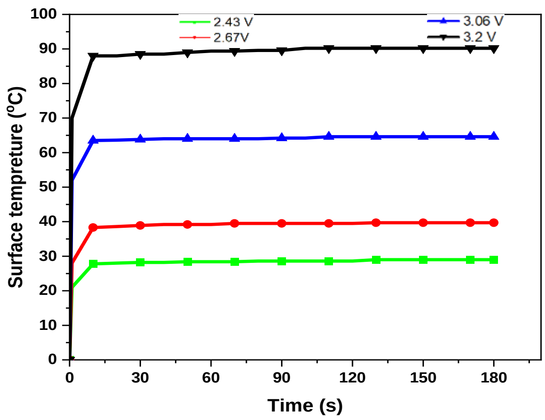

Figure 6. Temperature measurements of SMD LED embedded SS E-yarn with specified voltage applied with time.

CONCLUSION

In this study, an E-yarn composed of tiny SMD LED electronic components, which, embedded into stillness steel conductive multifilament yarn, was developed. After the development of the E-yarn, the electrical resistance and thermal behavior of the e-yarn were examined. The main interest is to design the SMD resistance embedded E-yarn in such a way that the wearable heating system can be operated at a low voltage, typically less than 5 volts. The analytical finding confirmed that the developed E-yarn generates heat for wearable heating textile and the E-yarn was heated up to approximately 27.5-90.2°C with a limited amount of electric voltage between around 2.43 V to 3.2 V. In addition, the electro thermal response was verified concerning response time and the input voltage. From the above result, it can be concluded that the SMD LED E-yarn can be used for an alternative methods for heat generated wearable textile at the specified point in the medical, technical textile application. Furthermore, it can be used for a new way of energy saving without compromising the final design and characteristics of textile fabric.

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