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HEATING PROFILE OF ELECTRO-CONDUCTIVE WEFT-KNITTED COMPOSITE FABRICS DURING CYCLIC DEFORMATION

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ABSTRACT

The goal of this research was to learn more about how heat is generated during cyclic deformation of highly conductive knitted composite fabric. The heating materials in this investigation were silver (Ag) coated polyamide (PA) yarn knitted into a pattern. At various time intervals, the temperature generated on the fabric surface was measured. An Instron tensile testing machine was used to perform the cyclic stress strain in the course direction of the developed fabric. The temperature on the conductive fabric surface increased rapidly for the first two minutes, then slowly afterward, eventually levelled off at a specific point. Heat generation is negatively influenced by stretching and cyclic deformation. Heat generation was also affected by the amount of conductive yarn used in the knitting design. The materials developed in this work could be employed in orthopaedic compression support to offer sufficient heating.

KEYWORDS

Electro-conductivity, Heat generation, Knitted fabrics, Orthopaedic compression support.

INTRODUCTION

Medical applications such as orthopaedic supports, electrotherapy, clinical covers to maintain patient internal heat level, strain sensors, movement tracking gadgets; technical products such as motorbike gloves, household use such as heating pads, leisure and sport wears, and so on are constructed using heating textiles [1–3]. Many studies have been conducted on the design, characteristics, and behaviour of knitted compression structures used in orthopaedic supports. The bulk of orthopaedic compressions are prepared, then integrated structures with elastomeric inlay-yarns are made. Furthermore, any extra stiff elements used in orthopaedic supports for medical or wear comfort purposes are known to have a significant impact on the compression imposed by the support [4–6]. Few studies have been published on the topic of electro-conductive knitted fabrics.

Heat treatment actively works to relieve pain and stiffness in the joints. Heat reduces body pain by regulating the release of pain metabolites, as well as improving blood flow, muscle and connective tissue pliability, joint flexibility, and stiffness. Knee therapy should take place at a temperature of 40-45°C [7,8]. There are, however, flaws in the research on heated compression supports used for orthopaedic therapy during cyclic deformation that has been published.

The goal of this study was to create a knitted compression support structure with integrated metal (Ag) coated polyamide yarns and explore the influence of cyclic deformation on heat production characteristics. To assess the feasibility, the temperature changes over time and the applied voltage function were evaluated. The effect of yarn linear density, conductive yarn amount, and metal coated yarn distribution in the knitting pattern on the heating profile was also investigated.

MATERIALS AND METHODS

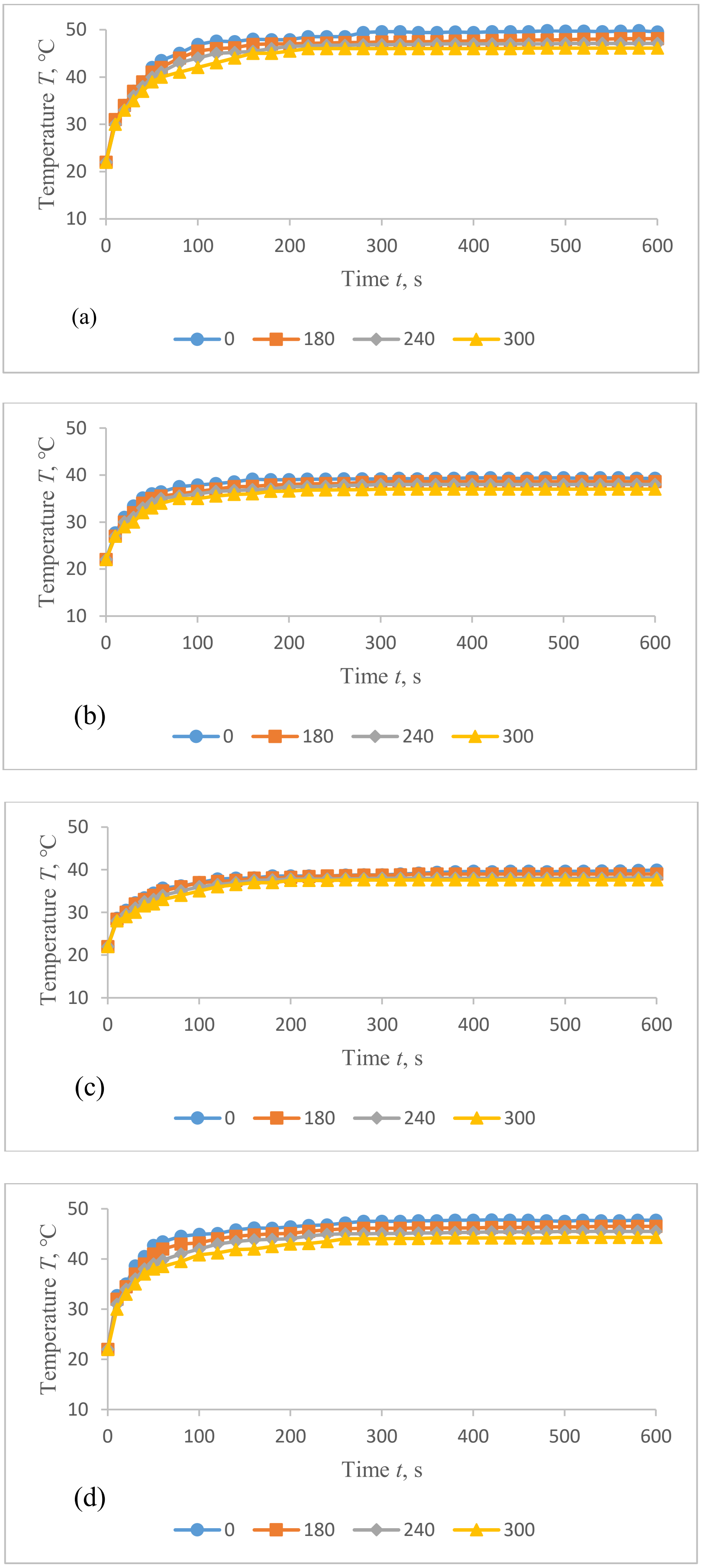
Six different specimens depending on the amount and distribution of electro-conductive yarn in the knitted structure along with two types of linear density of electro-conductive yarn were developed. The ELITEX (Imbut GmbH, Germany) yarns of 66 tex and 235 tex linear density were used as conductive yarns. The specimens were knitted on a flat double needle-bed 14E gauge knitting machine CMS 340TC-L (STOLL, Germany) in combined half-Milano rib structure with elastomeric inlay-yarn inserted into every course of the knitted structure. Two copper plates were tied to a DC power source and positioned on the opposing sides of the knitted composite. An Instron (model 2519-107) tensile testing machine was used for stretching the specimens in transversal (along courses) direction. The fluke 561 HVACPro infrared thermometer was used to determine the surface temperature by measuring the amount of infrared energy radiated by target's surface. Infrared specifications of this thermometer are stated as like as temperature measurement range: -40°C to 550°C; spectral range: 8 to 14 microns; accuracy: ± 1% or ±1°C; response time (95%): 500 ms. The single point laser was used on the thermometer and wavelength was 630 to 670 nm. The properties of conductive fibres, their inter-connection within a fabric and to external circuitry, and the geometry of the fabric collectively contribute to the electrical resistance of a fabric piece. Surface resistance of the fabric specimens were measured by using signstek UNI-T UT71D True RMS multimeter. The amount of yarn used in the pattern and structure are mentioned in previous work [3]. Temperature was measured after each 10 s during the first minute of observation, and after each 20 s starting from the first minute till the end of experiment, i.e. till 600 s. 2.5 V is sufficient to reach the goal temperature for CF_LY group specimens, while 1.5 V is sufficient for CF_HY group specimens. All experiments were carried out in a standard atmosphere for testing according to Standard LST EN ISO 139:2005.

Table 1: Main characteristics and resistance of electro-conductive knitted fabrics.

Sample code	Area density, g/m^2	Wale P_v and course P_h density (cm^{-1})				Resistance, Ω
		Technical face side		Technical back side		
		P_v	P_h	P_v	P_h	
CF_LY1	336±2	6.7±0.2	12.7±0.3	6.7±0.2	6.7±0.2	0.64
CF_LY2	323±2	6.9±0.2	12.7±0.3	6.7±0.2	6.7±0.2	1.04
CF_LY3	325±2	6.7±0.2	12.9±0.2	6.9±0.2	6.7±0.2	1.24
CF_HY1	357±2	6.7±0.2	13.3±0.3	6.9±0.2	6.3±0.2	0.14
CF_HY2	340±2	6.9±0.2	13.3±0.3	6.9±0.2	6.3±0.2	0.34
CF_HY3	340±2	6.5±0.2	13.0±0.3	6.7±0.2	6.2±0.2	0.34

RESULTS AND DISCUSSION

An electric current is transmitted across the conductive substances when electrodes are connected to the power source and heat is produced. For orthopedic supports, at least 40°C temperature has to be reached. The cyclic deformation of the compressive composite knitted fabric has a negative effect on the heat generation. The highest temperature is obtained on the surface of CF_LY1 and CF_HY1, which are knitted with metal coated yarns in each second course of the knit, as seen by thermal pictures. Due to the greater distance between courses with and without metal coated yarn, the temperature unevenness on the surface of the composite knitted constructions was shown for CF_LY2, CF_LY3, CF_HY2 and CF_HY3. And this unevenness is more pronounced in fabrics with lower conductive yarn linear density. The investigation results also revealed a temperature differential between the edges of the heating surface and the center. Significant heat loss by radiation and air convection on the edge compared to the central position caused this scenario.


Temperature T, °C
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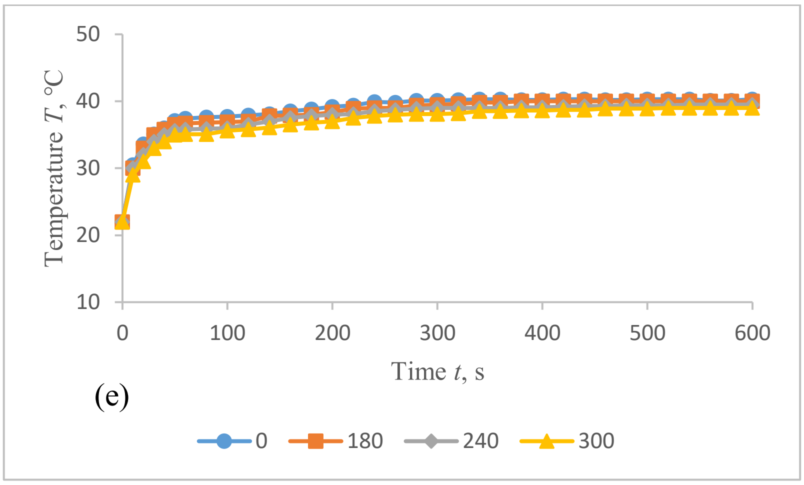

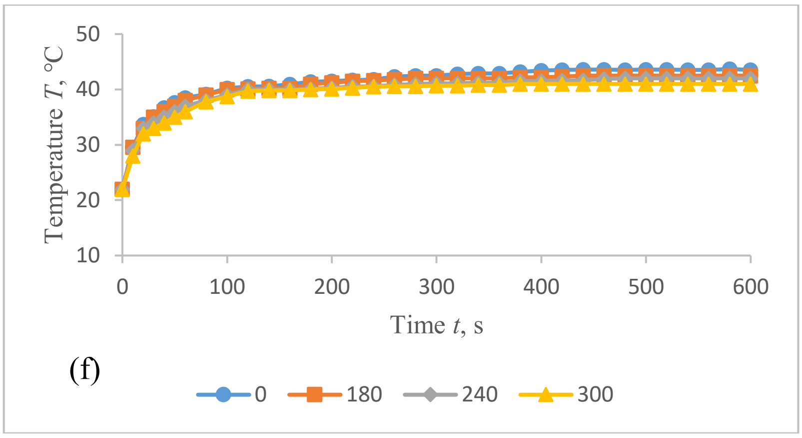

Figure 2. Temperature changes of (a) CF_LY1, (b) CF_LY2, (c) CF_LY3, (d) CF_HY1, (e) CF_HY2 and (f) CF_HY3 structured electro-conductive composite weft-knitted fabric during the 600 s period by applying 2.5 V on a-c and 1.5 V on d-e samples in different cyclic deformation (0-300 times) at 20% stretch level.

CONCLUSION

The reported work revealed the possibility of using knitted composite textile structures with metal coated yarn inserted for heat generation in orthopaedic compression supports. Silver coated polyamide yarns were inserted into a combined half-Milano rib structure plated by the PA6.6 yarn to protect the structure from mechanical destruction. The temperature of the heated specimens rises rapidly for the first two minutes and then gradually decreases until it reaches a steady state. The general stable heating temperature of 40°C was achieved in around 2-3 minutes, depending on the structure and voltage supplied. The stretch of the specimen has been observed to have a negative impact on heat generation as a result of the increased surface area. The proposed composite structure produced in this work can be used to deliver appropriate heat to orthopaedic compression supports; however, due to the higher linear density of the metal coated yarn, a lower voltage energy source is required to achieve the desired 40°C. Both the temperature and the time it takes to attain the required temperature are affected by the cyclic stretching. The deformation stretch has a slightly smaller effect on the CF_LY group made with 66 tex/12 filaments than it does on the CF_HY group made with 235 tex/34 filaments. As a result, when designing a system, the influence of cyclic stretch on the reduction in heat generation must be considered.

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