APPLICATION OF HYBRID HEATING TEXTILE STRUCTURES IN CLOTHING FOR SENIORS

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Abstract: *Active integral electronic elements in smart clothes can increase the utility value of the garment and the user's comfort. This article is primarily focuses on the comfort of clothing designed especially for the elderly, or people with impaired thermoregulatory capabilities. The research part is focuses on the possibilities of increasing clothing comfort of application a smart electronic textile element into garments. It deals especially with the possibilities of application of electric heating built directly into clothing for seniors, especially for clothes designed for cold environment. The proposed heating system based on embroidery with using hybrid threads can be use especially in winter clothing, but can also be used for home-use clothing or everywhere it is disadvantageous or inappropriately to increase the ambient temperature. The main goal is to improve physiological comfort and ensure thermal comfort in the winter months. From the textile point of view, it is important to ensure that the integration of the heating structure into the garment in order to fulfil its function as best as possible and allow the normal maintenance of the garment by the user and have no impair to the physiological comfort and other utility properties which are also important for the garment. In the case of seniors, the electronics must contain safety features to prevent tampering and avoid the risk of injury to the user. The textile part must therefore comply with both the textile and maintenance requirements as well as the electrical properties. When using active elements in clothing, we need to address the issue of safety, routine clothing maintenance, battery placement, electronics interconnection, durability and other aspects of textile and electronic character. This paper describes the possibilities of creating heating elements using an embroidery machine and the possibility of their integration into selected types of clothing. A practical example then demonstrates the use of hybrid threads that are applied by embroidering the heating structure directly onto a suitable textile backing, demonstrating their potential for increasing the utility properties of the garment.*

Keywords: *thermoregulation, clothing, comfort, heating, smart textiles.*

1 INTRODUCTION

With an influence of various factors on the human organism, it is a crucial ensures that a human body should be in a thermal optimum, called thermal comfort [1]. The determination of thermal comfort and its optimization is given considerable attention form a researchers, sellers and companies especially for the younger and middle generation, which is more active than older population. Research is also focused on the relaxing athletes and especially to the top athletes. Scientific research is focuses than mainly on a medical, military and sports. Interest of a clothing manufacturers and their research has less focusing an older population at this area, because the older people are not for them their typically customers. This group of people is enough big but has a different clothing requirements and also expectation from a clothing comfort.

2 SUBJECT OF RESEARCH

The research part described in this article focuses on the area of a comfort of clothing designed especially for the elderly with the possibility to increasing of garment comfort by using a hybrid textile structure integrated into garment.

2.1 Comfort of clothing for seniors

Thermal comfort, or a thermal well-being, it is the achievement of such thermal ratios, when is a person in balance without any unpleasant feelings as cold, or warm feelings [1-2]. The properties of clothing significantly affect heat transfer and feelings of user. We can conclude that for a good thermal comfort is the most important characteristic the thermal resistance of the garment. The heat resistance of the garment is based on the layering of the material and the air layers between them.

Other properties important for clothing include air permeability, water-vapor permeability, type of a textile structure, resistance to water penetration, resistance to surface wetting, sweating management, etc. and they has to be also consider in a design of clothes [3].

2.2 Specifics of clothing comfort in the age group of seniors - utility of clothing

Elderly and consumers with diseases prefer to buy clothes with high levels of comfort that can meet their physiological, hygienic and health needs. Clothing requirements for seniors are based on physico-mechanical properties of garment comfort. Utility value is a set of utility features that meet the demands of clothing in terms of appearance, durability, easy maintenance and user-friendliness. The process of aging affects every living creature. It affects all the tissues of the organism and is characterized by a different speed. This also applies to human skin, which is an extremely important organ that provides contact with the external environment and represents a mirror, respectively is a monitor of both physiological and pathological phenomena outside and within the body. Therefore, it is important to keep the skin at optimum temperature.

3 EXPERIMENT – PREPARING OF SAMPLES EMBROIDERED BY USING A SPECIAL HYBRID THREADS FOR HEATING

Next text is describing simplified procedure of preparing and embroidering of samples and their basic characteristics.

3.1 A simplified procedure for a creating a draft of embroidery

On the beginning it was necessary to design embroidery pattern suitable for their purpose of use. Proposed embroidery topology was after that transferred to a vector by using SW AutoCAD. Subsequently, these vectors were imported into Tajima program. In this program was carried out their optimization and was prepared program for an automatic embroidery machine TEJT-C1501, on which specimens were have been made.

For embroidering we have used two types of conductive hybrid threads, which were made for this purpose in company VÚB a.s. First hybrid thread contains a Cu/Ag wires a second contains a brass wires (Msx), see Table 1 for detailed specification of hybrid thread. Hybrid thread for embroidering was used on the top and on the bottom of embroidery. Sewing speed of embroidery machine was set to 350 stitches per minute. For a sewing had been tested different types of needles which have been chosen from two companies. One was Groz-Beckert® and second one Schmetz® company. A needle which had been used for sewing was from the Schmetz® company type DBxK5 TN, size 14. Threads were for eliminating a friction and getting the right tension for sewing were lubricated by using a silicon spray.

3.2 Preparing, modification and embroidering textile hybrid heating structures

For a real testing were prepare four different type of textile hybrid heating pad. Differences and their basic properties are in the Table 2. As a underlying fabric for embroidering was used a canvas and for a special embroidery sample model with knitted fabric with a reflecting coating which should be able to reflect a heat flow to a human body.

As is it evident from the Table 2 a different type of hybrid thread and different length and shapes of embroidery lead to a variety electrical resistance of embroideries. All these changes lead to on the basis of that to the different heating performance of pads. It has to be consider before next step a proposal of power supply and electronic parts and conductive textile wires which have to be able to manage lead an electric current till 2 amperes. Samples of embroidery A, B, C are showing on the Figure 1. Sample A is at the end of the embroidery terminated by a sewing spots, which are ready to application a metal connectors or textile poppers. Samples B, C are connected with metal poppers and wired via textile conductive wire called “Ribbon”. It is a conductive textile ribbon, which combines thin metal wires (30 strands) made from Cu with Ag coating with a textile braiding with resistance 0.30 [Ω/m].

Table 1 Basic characteristics of hybrid threads used for embroidering

Type	Yarn fineness [tex]	Composition	Resistance [Ω/m]
Hybrid thread no. 53	50	47% PESh / 53% Cu/Ag wire	6.50
Hybrid thread no. 25A	72	31% PESh / 69% Msx brass wire	8.90

Table 2 Realized embroidered textile heating samples and their basic characteristics

Sample (type)	Dimensions of embroidery [mm]	Thread consumption top + bottom [m]	Electrical resistance of embroideries R [Ω]	Type of used hybrid thread	Underlying material
A1 (Meander)	125 x 283	9.2 + 3.1	5.36	Hybrid thread no. 53	Canvas (PES/Co)
A2 (Meander)	125 x 283	9.2 + 3.1	6.53	Hybrid thread no. 25A	Canvas (PES/Co)
B (Kidney)	190 x 186	12.2 + 4.1	23.56	Hybrid thread no. 53	Canvas (PES/Co)
C (Kidney)	190 x 186	12.2 + 4.1	20.86	Hybrid thread no. 53	Special knitted fabric with a reflecting coating

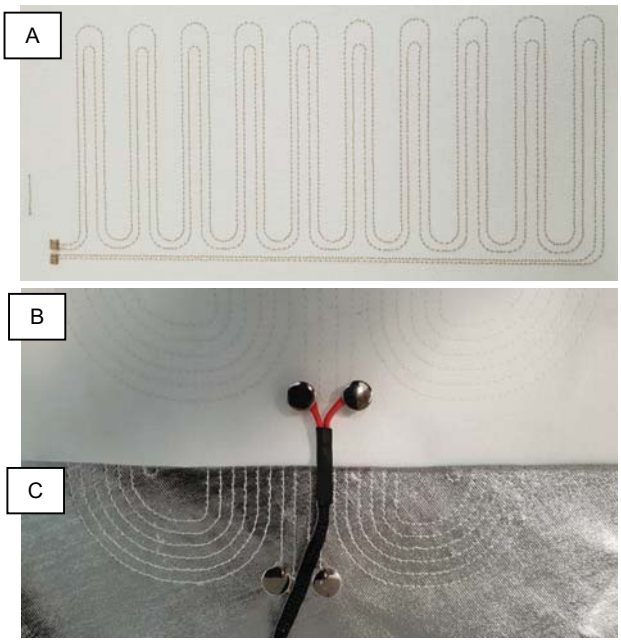

Figure 1 Textile hybrid heating pads, samples B, C are connected with metal poppers and wired via textile conductive wire called “Ribbon”

One of the most important and a difficult part of preparing hybrid textile heating pads was made an improving of automatic embroidery machine which consist with several steps. Basic machine for embroidering is not ready for using a hybrid threads with metal components. List of adaptations which have to be done to reach reasonable quality of embroidery: right size of a needle with titanium or ceramic surface finishing with bigger eye, reduction and normalization friction of a sewing thread, removing the jump change of friction in the sewing thread, adjustment of leading the sewing thread in the machine (reduction of bends), using removable oil to improving a friction.

Inappropriate machine settings or using a wrong type of needle leads to a poor quality of the embroidery, or to violation of sewing thread see Figure 2. This leads to a malfunction of the electrical circuit and it is necessary to repeat the process of embroidering.

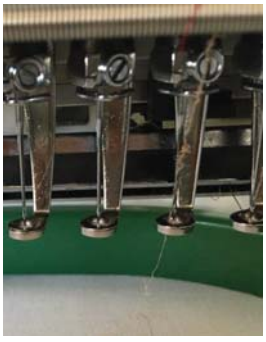

Figure 2 Violation of sewing hybrid thread in the middle of embroidering process

4 THEORY – ELECTRICAL POWER IN RESISTIVE CIRCUITS

In physics, power is the rate of doing work, the amount of energy transferred per unit time. The SI unit of power *P* is the watt [W], which is equal to one joule per second [J/s].

In the case of resistive (linear) loads as our textile heating structure, Joule's law can be combined with Ohm's law (see equation 1) to produce alternative expressions for the amount of power that is dissipated and can be expressed by equation 2:

$$U\,[V] = I\,[A]*R\,[\Omega] \quad (1)$$

$$P = dW/dt = U.I = R.I^2 = U^2/R\,[W] \quad (2)$$

For each type of textile heating structure (heating pad A1, A2, B, C) was according equation 2 calculated theoretical electrical power *P** in watt from known resistance and expectation of voltage on input to circuit. Changes in the internal energy of the wires, caused by the passage of the current, lead to an increase of their temperature and exchange heat flow between the wires and the surroundings [4].

4.1 Experiment – measuring electrical power in closed resistive circuits based on textile heating structures

Methodology

All types of samples were placed into climate room with standards textile condition where is a temperature 21±1°C, relative humidity 60±10%. After acclimatization a heating pad was connected via textiles metal poppers with the laboratory power supply EA-PS 3016-10 B, which is able to precisely set and measure current and voltage at the power source output. Voltage was set step by step (5, 10, 12 and 16 V) and after 5 minutes of stabilization for every step was taken a thermogram and data of a current in the electrical circuit.

4.2 Results

Results with theoretical calculated power and based on the measurement of electrical power from experiment are shown in the Table 3.

4.3 Evaluation of an embroidered heating pads made by using a hybrid threads

For a qualitatively evaluation of embroidering process is a good to use a thermography. The following thermograms were taking by using a thermocamera system Flir S60 in a room with climate control where is a temperature 21±1°C, relative humidity 60±10%, wind circulate 1 m/s. Pads were set to a maximum heating power see Table 3. On the thermogram (see Figure 3) is easily to recognize o spot where is a temperature extreme, which can lead in o long time to make circuit breaks and a dysfunction of heating pad.

Table 3 Measured electrical properties and calculated electrical power P in a comparison with theoretical electrical power P*

Sample (type)	Power P [W] (measured value)	Electric current I [A]	Electrical voltage U [V]	Power P* [W] (calculated value)
A1 (Meander)	4.0	0.8	5.0	4.7
A1 (Meander)	16.0	1.6	10.0	18.7
A1 (Meander)	22.8	1.9	12.0	26.9
A2 (Meander)	3.5	0.7	5.0	3.8
A2 (Meander)	15.0	1.5	10.0	15.3
A2 (Meander)	21.6	1.8	12.0	22.1
B (Kidney)	3.0	0.3	10.0	4.2
B (Kidney)	4.8	0.4	12.0	6.1
B (Kidney)	9.6	0.6	16.0	10.9
C (Kidney)	4.0	0.4	10.0	4.8
C (Kidney)	6.0	0.5	12.0	6.9
C (Kidney)	9.6	0.6	16.0	12.3

Places with lower resistance, which better lead of electric current, can be identify on thermograms as points with a higher local temperature. These locations may indicate a problem with the quality of the embroidering. From the look of functionality and durability of heating pad, this local overheat can leads to malfunction of heating pad in long term of use.

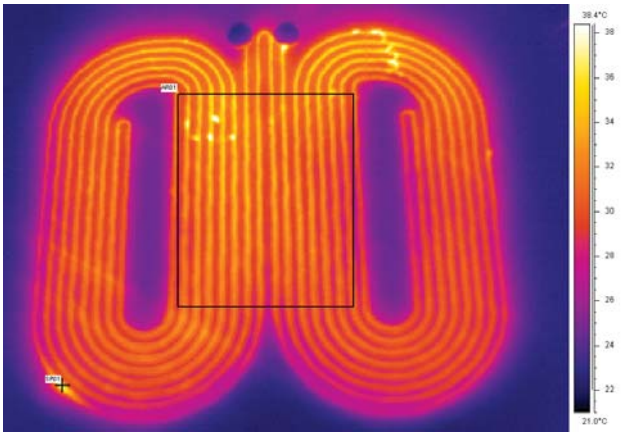

Figure 3 Thermogram of a sample C with an analysis of temperature: Area - AR01: Min. 27.5°C, Max. 40.3°C, Avg. 31.1°C, Spot - SP01: 38.1°C

Thermograms can be also used for a detailed analysis of linking stitch and analysis of flowing of heat direction and spreading in a background material and to the other layers of clothing see Figure 4. The heating pad should to be near to the human skin, but also we need to be ensuring that the temperature in contact points does not to exceed 40°C. Temperature higher than 40°C in a bigger heating area could be unpleasant for a sensitive people and it can leads to bad feelings from a wearing garment.

Whit this technique we can also visualization of the most critical spots for each part of embroider which are place for connectors to join a power supply or other electronics like a logic board. In this case we used textile poppers for a connection to power supply. This article is not focused on other important parts as electronic parts and power wires or durability.

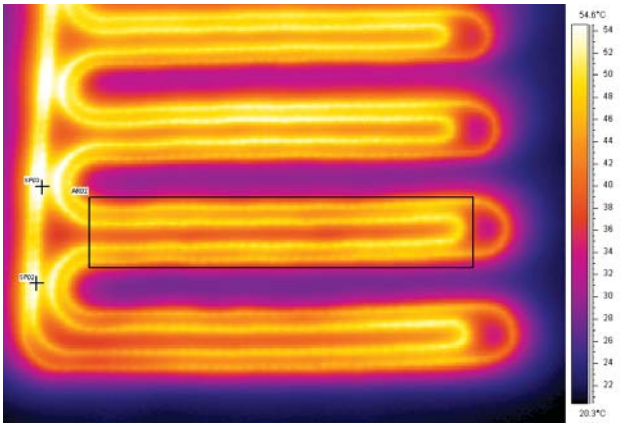

Figure 4 Thermogram of a sample A1 in detail with an analysis of temperature: Area - AR02: Min. 34.0°C, Max. 52.2°C, Avg. 45.1°C, Spots - SP02: 55.0°C, SP03: 57.1°C. (e = 0.95 [-], Temp. refl. = 20°C)

5 DISCUSSION AND CONCLUSION

Improving of thermal comfort of garment and ensuring a good thermal comfort is important for the older people and for people with an impaired thermoregulation. This can be achieved by using a textile hybrid structure like is a heating pad made by embroidering directly on the surface of a clothing, or as a separated par of textile, which can be inserted into a clothing. This article describes in two parts the procedure for the preparing of embroideries with a special hybrid threads and the evaluation of embroidered heating pads. For a using special hybrid threads with a metal parts to embroidering it is important to make some changes in setting of automatic sewing machine to achieve a good quality of embroidery. It is also important to use a lubricant to reach a right tension of sewing threads. If there is a possible to use for yours embroidery system a special needles, which has been designed

for sewing with hybrid threads it is recommended to use them. These special needles for sewing with hybrid threads have improved shape, coating and bigger eye of needle. For an analysis of results it is also is important to use a thermography to discover problematic spots and improve a technology of sewing means change a needle, speed of sewing, lubricate, improve of friction of a thread and so on, or also improve a topology of embroidery. Results from experimental part are promising and mainly hybrid thread with Cu/Ag wires which have better sewing properties than hybrid thread with brass wires is suitable for next research and application as a heating textile structure in smart clothing. The use a technology of embroidering of a heating structure in the garment allows us to make a design of an optimal shape according to the location and type of clothing where will be used. Second option how to create a heating area integrated in textile is insert a hybrid threads directly into fabric to the desired area. This area of using a special hybrid heating fabric made by weaving fabric with a special hybrid threads will be close described in our next contribution.

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