American Journal of Polymer Science & Engineering
http://www.ivyunion.org/index.php/ajpse/

Research Article

Development of Weft Knitted Heating Pads on V-bed Hand Flat Knitting Machine by Using Conductive Yarns

Abdul Rehman Akbar[1*], Md. Kamruzzaman[2],
Weilin Xu[1], Sayyam Gull[3], Waqas Ahmed[3], Junaid Khalid[1]

[1] School of Textile Science & Engineering, Wuhan Textile University, Wuhan, China
[2] School Chemistry & Chemical Engineering, Wuhan Textile University, Wuhan, China
3 Department of Textile Engineering, National Textile University, Faisalabad, Pakistan

Abstract

In this investigation weft knitted heating pad was developed on V-bed hand flat knitting machine by using acrylic, polyester as a main yarns and three different copernic, thermotech –N, thermaram as conductive yarns with both all knit and inlaid insertion. Moreover time period for heating of yarn, recovery time of yarn for making weft knitted heating pad, structural comparison of different conductive yarn as copernic, thermaram ,thermotech –N and main yarn as acrylic yarn, polyester yarn was studied. Through analysis conductive yarn that inlaid in the acrylic yarn showed satisfactory heating performance for different time periods and retained more heat rather than polyester yarn. Copernic conductive yarn and thermotech-N conductive yarn had high resistance when compared with thermaram conductive yarn that generated more heat. Acrylic yarn when used as main yarn having conductive thermotech-N yarn inlaid in its structure had produced better heating and retaining properties for the weft knitted heating pad.

Keywords: Heating pad; conductive yarn; acrylic yarn; polyester yarn; knit fabric; thermal comfort
Received: October 23, 2016; **Accepted**: November 24, 2016; **Published**: December 28, 2016
Competing Interests: The authors have declared that no competing interests exist.

***Correspondence to:** Abdul Rehman Akbar, Sunshine Campus, Wuhan Textile University, Wuhan, Hubei, China
E-mail: ntuwtu@yahoo.com

Introduction

The smart textile structures that integrate electronics and textile materials have realized their great potential in recent years. The garments, which can heat the body, will possibly be one of the most widely used products as Electro textiles for future use in daily life [1].Heat and blood flow has direct relation with each other. When the skin temperature is increased blood vessels has become dilate. Dilation of blood vessels provides easiness to blood flow. If temperature becomes low in any section of body, blood vessels become contracted. Contraction of blood vessel create problem for the regulation of blood. Low blood pressure is caused in the result of low body temperature. Vessel contraction causes pain in the different sections of body where the heat is very important. For example in the joints, low blood cause pain when they move and require more energy. Smart fabric that uses for certain functions and falls in electro-textile and also in medical field. Smart textile gaining wide importance in medical application, one of the examples is heating pad. The main function of heating pad is to provide thermal comfort to maintain human metabolism and to cure diseases against cold climate. It provides heat by the phase change material, conductive yarn, or chemicals. Portable power supply and rechargeable batteries use to operate the garment. A user interface is used to control the system. The main part of heating pad can be consist of heating element, power source, and User interface and temperature sensor. The main objective of heating pad is to provide Heating, heal the diseases. It is a smart garment which helps a man to control its body temperature. It protects against very cold climate.

A heating pad is used for warming of parts of the body in order to manage pain. Localized application of heat causes the blood vessels in that area to dilate, enhancing perfusion to the targeted tissue [2].Temperature and heat has a vital role in the blood regulation. Heat increases the metabolism of body. By increasing the metabolism, sweat gland activity occurs and causes an increase in blood pressure that enhances healing processes .The main function of heating pad is to provide thermal comfort to maintain human metabolism and to cure diseases against cold climate. Low blood pressure is caused as a result of low body temperature. Vessel contraction may occur which causes pain in the different sections of body where the heat is very important. By heating the skin artificially, diseases of skin can reduce. For this purpose by a heating pad generates heat the skin to gain an optimum temperature, blood flow will be better and reduce these problems. Heating pads can be used over joints of body so that proper working of body parts can be regulated and pain in muscles and joints can be relieved. In 2003 Scott F. Nadler and all, found that in the 20th century lower back pain is the main issue to all over the world. People do a lot of exercises to reduce this pain. By conducting surveys and investigating, they concluded that lower back pain can be reduced by heat therapy. Electrical heating pads are used for this therapy [3].

The production of heating pads depends upon the type of yarn to be used during knitting process. Two sets of yarn used as one is considered as main yarn while other type of yarn include conductive properties so that the voltage can be provided and heating can be produced. Knitting is the process of forming fabric by interloping yarn in a series of connected loops by means of needles. Knit fabrics provide outstanding comfort qualities due to their inherent softness and flexibility and have long been preferred in many types of clothing. The loops are also held together by the yarn passing from one to the next. These loops intermesh with each other to form knitted structure[4].Electrically heating garments are most common type of heating pads that can provide heat to an optimum level [5]. By the integration of electro-conductive properties in the fabric structure, a flexible textile can be obtained that does not reduce the quality of comfort, maintenance and wear ability of clothing [6]. Generally, electrical heating products use embedded heating elements to generate heat. Commonly steel based conductive wires are used to heat the fabric for heat control. A suitable temperature is set to keep our body comfortable according to the climate. Electrically heating pads are produced using this technique [7] . Carbon fiber heating elements are also popular in EHGs. The carbon fiber heating element has good heat efficiency and can generate heat uniformly and rapidly [8].A chemical heating pad uses a reaction of chemical substances to generate heat e.g. chemical energy can be turned into heat energy by oxidization the reagents are kept in separate compartments within the pad. When the user squeezes the pad, a barrier ruptures and the reagents mix, producing heat. There are three main methods to incorporate PCMs in garments as packaging, micro-encapsulating and spinning, coating and laminating [8].

Different conductive yarns as copernic, thermotech-N and thermaram are used as conductive yarns due to their resistive properties. These yarns can produce a heating effect with the other type of main yarn which has ability to store heat. As nylon and acrylic yarns have ability to store heat. Hence the combination of conductive yarn with main yarn is the key to produce a heating pad [9].In the Thermo-Mechanical Behavior of Textile Heating Fabric Based on Silver Coated Polymeric Yarn, the study investigates the rate of heating and cooling of the knitted structures. The work also presents the decay of heating properties of the yarn due to overheating. The interlock structure knitted with silver yarn has better heating performance, to plain and rib structures. The reason for this is that the interlock structure allowed more current to pass through it at relatively lower voltages. In all the cases for rib, interlock and single jersey, the distribution of heat over the entire fabric was observed to be uniform and devoid of hot spots [10].

The prevailing work become undertaken to produce a fabric structure by use of conductive yarns in order to produce a weft knitted heating pad. Furthermore evaluation of time period for heating of yarn ,recovery time of yarn for making weft knitted heating pad, structural comparison of different conductive yarn as Copernic ,Thermaram ,thermotech –N and main yarn as acrylic yarn ,polyester yarn become studied.

Materials and methods

Materials

Copernic non insulated conductive yarn (9Ω), Thermaram hybrid conductive yarn (5.8Ω), Thermotech-N non insulated conductive yarn (9.6Ω) were sourced from National Textile University, Faisalabad, Pakistan .Polyester yarn (2/30 ́s) supplied by Gatron industries Limited, Karachi, Pakistan and Acrylic yarn (2/30 ́s) was obtained from Masters wool spinners, Gujranwala, Pakistan for making weft knitted heating pad.

Equipment

1.Hand flat knitting machine.

2.Battery

3.Thermocouples

4.Multimeter

Method

The experimental work contained many steps involved in the manufacturing of knitted heated structure. This was done in several steps with which the main step was to produce fabric structures by use of conductive yarns in order to produce a weft knitted heating structure. Conductive yarns were used with ordinary yarns to produce conductive patches. Three conductive yarns were selected to make a knitted structure. Acrylic and polyester were selected to produce a base structure while conductive threads were induced as inlaid and all knit category. Twelve samples were produced by using two different main yarns and three different conductive yarns with both all knit and inlaid insertion. Acrylic used as main yarn having 30 single but 2 ply so that 15 single acrylic was first knitted with all three conductive yarns as 15 cm length of each conductive yarn was knitted in each patch as half course of 5cm conductive yarn inserted consecutively after two courses of main yarn used. Hence insertion of 15 cm conductive yarn was carried out in one and a half course. In the same way, inlaid structure was used as conductive yarn was inlaid in all knit acrylic structure. Polyester used as main yarn having 30 single but 2 ply so that 15single was first knitted with the conductive yarn as one and a half course of all three conductive threads was induced in the knitted structure of polyester respectively and then inlaying of all three conductive yarns was occur to produce conductive patches. Hence twelve patches of both acrylic and polyester used as main yarn were produced on the hand flat knitting machine by using 3 different conductive threads, induced as inlaid and knitted structures. Weft knitting heating pad was shown in Figure 1.

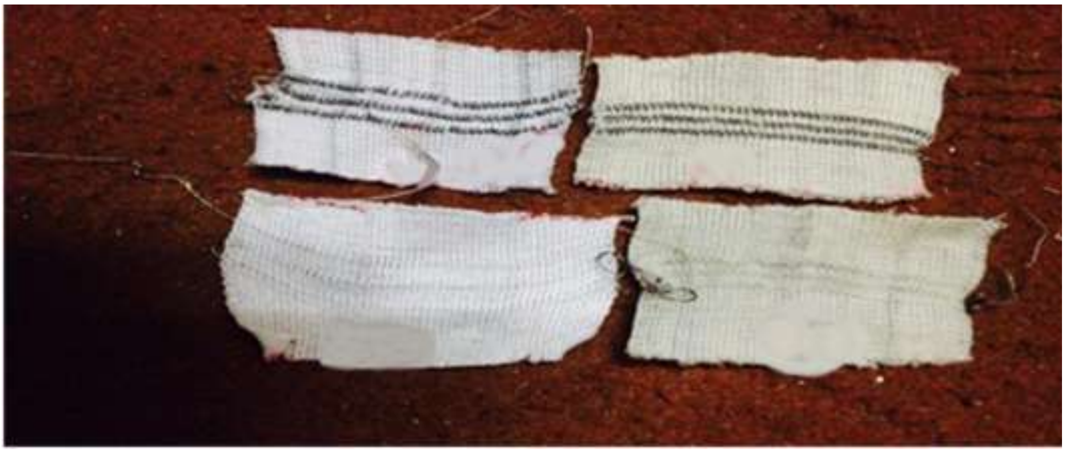

Figure 1 Weft knitted heating pads

Patches length

Patches used in order to produce heating pad were of 2×2 inches, as conductive threads were induced at a length of 15cm respectively so that every half course of conductive thread was of 5cm length and induced after every 2 courses of main yarn knitting. In order to achieve certain length of 2inches width patch, 53 working needles were active so that desired length was achieved. These 53 working needles induced 15cm of yarn in every half course on a simple hand flat knitting machine.

Assembling of test experiment

Patches made at hand flat weft knitting machine were tested in a conditioned environment where 26^{0}C of temperature was maintained. All equipment connected in a series, both ends of conductive yarn were connected with the terminals of battery and thermocouple connected with the multimeter in order to measure the temperature. DC battery provided 9v charge and sensor of thermocouple touched with the patch to determine the temperature .Assembling of test equipment was seen in Figure 2.

Figure 2

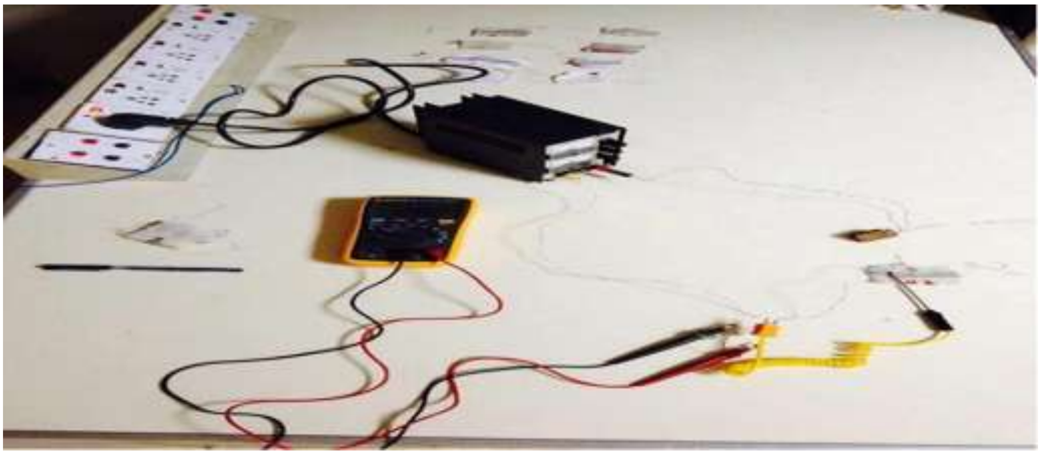

Figure 2 Apparatus of test during assembling

Results and Discussions

Heating for different time periods analysis

For analysis time period for heating of all twelve patches of acrylic and polyester yarns were heated for 30 sec and 1min time respectively at 9 V. The results in **Table 1** reveal that yarn show various temperature at different time period.

The **Table 1** showed that 44^{0}C temperature after one min for acrylic yarn (all knit) when copernic conductive yarn used which was less than the acrylic yarn (in lay) that gave 48.8^{0}C temperature after one min by using copernic conductive yarn. At 30 sec Polyester (all knit) provided 37.2^{0}C temperature which was increased after one min in case of copernic conductive yarn. For polyester (inlay) yarn temperature was elevated after one min when copernic conductive yarn used .Thermaram conductive yarn and Thermotech-N conductive yarn demonstrated same rising phenomenon after one min for all acrylic(knit) and polyster (in lay) yarn .This was due to inverse relationship of resistance with current flow(V=I/R) and direct proportional relationship of current flow with generation of heat . When less current was passed by the influence of more resistance , as a result more heat was produced .

Table 1 Time period for heating of yarn

	Yarn type	Temperature (^{0}C) at 30 sec	Temperature (^{0}C) after 1 min	Voltage (V)
Conductive yarn	Main yarn			
Copernic yarn	Acrylic yarn (all knit)	37	44	9
	Acrylic yarn (in lay)	40.6	48.8	9
	Polyester (all knit)	37.2	44.6	9
	Polyester (inlay)	35.2	42.6	9
Thermaram yarn	Acrylic yarn (all knit)	45.9	57.5	9
	Acrylic yarn (in lay)	46.7	60.2	9
	Polyester (all knit)	33.4	39.2	9
	Polyester (inlay)	35.5	43.7	9
Thermotech-N yarn	Acrylic yarn (all knit)	35.4	43	9
	Acrylic yarn (in lay)	38.2	48.4	9
	Polyester (all knit)	40.1	48.2	9
	Polyester (inlay)	36.4	43.5	9

Structural comparison

As shown in Figure 3, it is clear that inlay structures performs better heating than knitted structures for 30sec and 1min time limit. This is due to the reason that inlay structure consists of no interloping and yarns passes straights in the course so that voltage applied can easily pass through the structures and conductive yarn was heated according to its resistance.

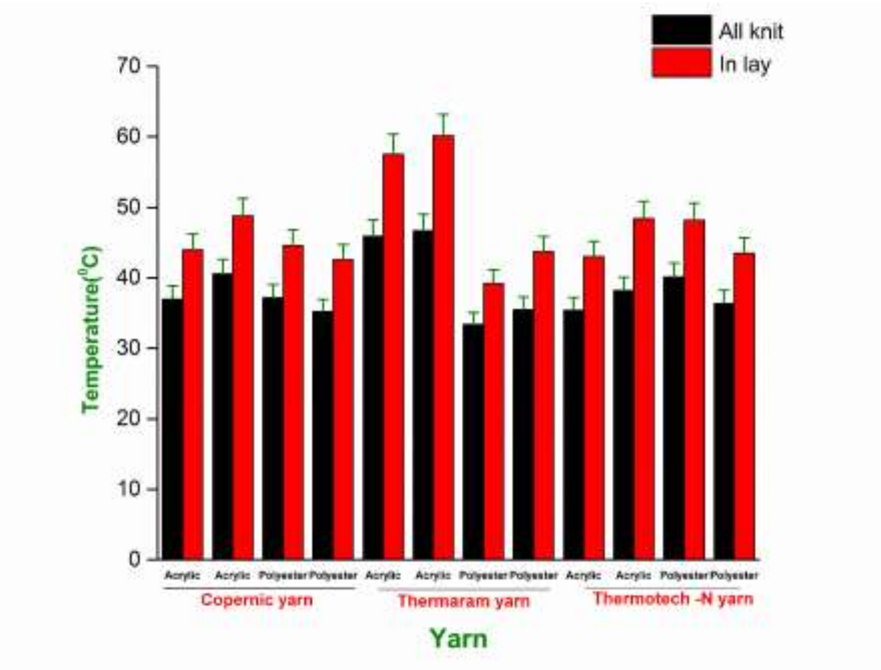

Figure 3 Structural comparison of yarn for heating pad

Recovery time

Recovery time for heated pads after one minute and then overall recovery time at 26^0C was shown in **Table 2**.

Table 2 Recovery time of different yarn for heating pad

	Yarn type	Recovery time after 1 min	Overall recovery time(min)	Voltage (V)
Conductive yarn	Main yarn			
Copernic yarn	Acrylic yarn (all knit)	31.6	4.09	9
	Acrylic yarn (in lay)	35.6	4.22	9
	Polyester (all knit)	31.4	3.35	9
	Polyester (inlay)	36.3	3.45	9
Thermaram yarn	Acrylic yarn (all knit)	34.4	2.57	9
	Acrylic yarn (in lay)	42.3	4.3	9
	Polyester (all knit)	30.7	2.15	9
	Polyester (inlay)	34.4	3.13	9
Thermotech-N yarn	Acrylic yarn (all knit)	30.3	2.27	9
	Acrylic yarn (in lay)	38.2	4.32	9
	Polyester (all knit)	33	3.32	9
	Polyester (inlay)	33.4	3.58	9

Overall recovery time of acrylic yarn (all knit) was 4.09 min when Copernic yarn was used whereas recovery time of acrylic yarn (in lay) with Copernic yarn was 4.22 min that was seen in table .When polyester yarn (all knit) and Copernic yarn was used for making heating pad the recovery time was 3.35 min that was not higher than the recovery time of in lay polyester yarn with copernic yarn. For thermaram yarn and thermotech –N yarn recovery time of both in lay polyester and acrylic yarn was more than the recovery time of both knit polyester and acrylic yarn. This is due to, thermal behavior, physical properties, structure of acrylic, polyester yarn and conductive yarn.

Recovery time comparison

As shown in

Figure 4 it is clear that acrylic yarn made up for inlaid conductive thread can retain heat in it for the longer period of time. Retaining time for acrylics is more than that of polyester yarn. Acrylics are synthetic fibers made from cellulose, and polyester is a synthetic made from petrochemicals. Acrylic is better to hold heat as it acts as a wool fiber and trap the heat exhaled by the body. Polyester has a high wicking property and wicks out all the sweat on the outer layer of the clothing. Hence acrylic is better in retaining heat in it resists most acids, oxidants, and solvents.

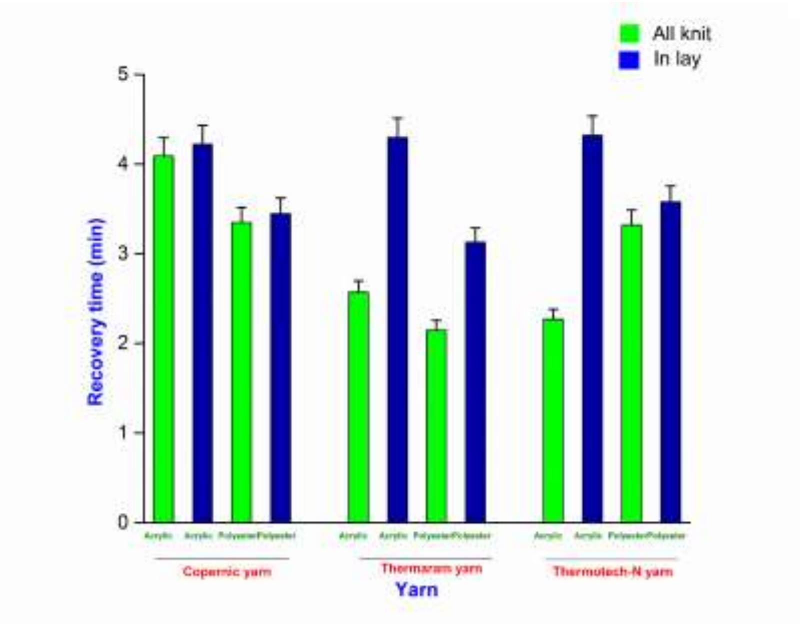

Figure 4 Recovery time comparison of different yarn for heating pad

Conclusion

Conductive yarn which is inlaid in the acrylic yarn structure has much better properties regarding heating for different time periods and can retain heat for more time than that of polyester. Copernic conductive yarn and thermotech-N conductive yarn which have high resistance as compared to the thermaram conductive yarn that can produce more heat. Moreover thermotech-N conductive yarn has better properties in retaining and heating at different time periods. So, Acrylic yarn used as main yarn having conductive thermotech-N yarn inlaid in its structure has better properties for the weft knitted heating pad as it can produce better heating and retaining properties.

Acknowledgements

During research work research materials and equipments were provided from National Textile University ,Pakistan and Wuhan Textile University, China that helped us to finish research work at steady and effective way .Heartiest gratitude to Professor Dr.Weilin Xu and Professor Dr.Sheraz Ahmad to supervise and spur our research work.

References

1. O K, BE Y. Heating behaviors of metallic textile structures. ***International Journal of Clothing Science and Technology***. 2009, 21:127-136
2. Edwards D. Physicians' reference heat therapy. *Evidence for Use of Heat Therapy as a Clinical Modality*.

3. SF N, DJ S, GN E, DA H, SB A, KW W. Continuous low-level heatwrap therapy for treating acute nonspecific low back pain. ***Archives of physical medicine and rehabilitation***. 2003, 84:329-334
4. IS Č, Z S. *Geometry of weft knitted structures-influence on heat resistance*. Prague, Czech Republic; 2014:1-4
5. P T, A D, R A. Heat and mass transfer through thermal protective clothing–a review. ***International Journal of Thermal Sciences***. 2016, 106:32-56
6. I Š, I B, J B, N T. *Conductive yarns application potentialities for smart textile*. Croatia; **AUTEX**; 2012:587-592
7. G DM, M Ö, A S, I K, C H, L VL, NÇ G. Designing of conductive yarn knitted thermal comfortable shirt using battery operated heating system. ***Journal of Textile & Apparel/Tekstil ve Konfeksiyon***. 2014, 24
8. F W, C G, K K, I H. A review of technology of personal heating garments. ***.International journal of occupational safety and ergonomics***. 2010, 16:387-404
9. I Š, I B, N T, J B, E D. Selection of conductive yarns for knitting an electrical heating element. ***WIT Transactions on The Built Environment***. 2014, 137:91-102
10. ST H, P P, A F. Thermo-mechanical behavior of textile heating fabric based on silver coated polymeric yarn. ***Materials***. 2013, 6:1072-1089