Seam Strength and Washability of Silver Coated Polyamide Yarns

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Abstract Seam strength has a huge impact on the durability of the garment. Conductive yarn usage in a stitching while development the e-textile structures is often used to connect electronic modules to sensors and actuators. Most common conductive yarn, used for the joining of e-textile products, is silver coated polyamide yarn. In this standpoint, chosen woven fabric stitched with silver coated polyamide yarn and seam strength was measured in both directions, weft, and warp and seam efficiency was calculated. Moreover, washing procedure was applied to the stitched samples to investigate the changing behavior of mechanical strength and electrical conductivity through the washing. Durability of the e-textiles is one of the key factors of maintaining the product through the washing. In this perspective, mechanical performances of the seam were tested together with the washing and electrical resistance values of the seam were recorded. After the washing procedure, seam elongation was decreased for both warp and weft directions. As expected, washing cycle has a negative effect on the silver coated yarns thus, some signal damage was recorded. However, electrical conductivity of the silver coated yarns is not totally destroyed after the gentle washing cycle.

***Keywords*— Conductive thread, Conductive yarn, E-textiles, Silver coated yarn, Washing of e-textiles**

I. Introduction

Textile industry gains different forms due to the emerging fields such as e-textiles. Conventional textile products are combined with the smart solutions to obtain an electronic feature on the wearable textile products. E-textiles mainly consist of two parts; one is textile and other is an electronic part. To interconnect the electronic parts among them and with power supplies, conductive threads are used. These conductive threads are the backbone of the smart textile system. Efficient smart textile products should be strong enough to bear the strength and also electrically conductive enough to guaranty a good signal quality and proper power supply.

To transmit data from textile sensors or towards flexible actuators, in the field of medical, sports or leisure applications, conductive threads should be able to transmit all information [1]. E-textile prototypes are often developed in research laboratory worldwide, but they exhibit poor washability and reliability limiting their access to the market. Consequently, conductive threads together with sensors actuators and electronic modules should withstand numerous laundering cycles. They are used for instance to supply LED arrays, ECG monitoring systems embedded to underwear etc. Interconnection of conductive threads with sensors actuators and electronic modulus is also a major problem. They are used to draw conductive patterns, in order to make textile flexible circuit boards. For pattern making, usually embroidery and stitching techniques are used [2], [3].

Different types of conductive threads are available on the market. Mainly, conductive yarns are produced by spinning and coating processes. For spinning processes, raw material can be in melt or wet form, made of conductive polymer solution, used to obtain conductive fibers [4], [5]. For coating processes; electrically conductive materials or metal powders are used as coating compounds to cover the yarns and provide the electrical conductivity [6], [7]. For instance; silver coated polyamide yarns or PEDOT:PSS coated yarns. However, the most common and the easiest threads to stitch are silver coated polyamide yarns. They are available on the market with different diameters and different number of plies. These threads are stitched or embroidered on the fabric. In both cases, stitch efficiency is one of the major factors responsible for durability and reliability of these structures.

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Stitching has a key role on the e-textile designs as a joining element [8] thus, seams should be robust enough to withstand everyday use and laundering.

Stitching processes should also be conducted gently to prevent the thread damages during it. If conductive threads are damaged through the stitching process, their electrical resistance may become high or even infinitive provoking the loss of electrical conductivity. Another possible damaging factor is a washing of e-textile samples. Gentle washing cycles should be applied [9], in washing standard ISO 6330, different washing times are discussed depending on type of washing materials. For instance, maximum washing time is for cotton and minimum for silk.

A lot of research works have been done on smart textile products. Only few of them focus on the seam importance of conductive threads. Seam is one of the major key factors in joining of e-textiles. If conductive yarn used as a seam is damaged, all prototypes fail. Signals generated by sensors or sent to actuators within smart textile structures are conducted through these conductive threads. In our study, linear electrical conductivity and mechanical strength of conductive threads are discussed and effects of washing on these parameters are examined.

Mechanical performance of seam was measured by taking into account the effect of washing performance of the basic joining unit. Also, electrical conductivity is recorded for both directions (weft and warp) before and after washing samples in order to examine and establish the relationship between stitching direction and electrical conductivity of silver coated polyamide yarns.

II. Procedures

Cotton/Polyester woven fabric, 127.4 g/cm^2 is selected for the experimental studies. Shildtex f117/17 silver coated polyamide yarn was used as a conductive yarn. This is two ply yarn with 17 fibers in each ply. Its linear resistance before stitching is 300 ohm/m. Linear resistance was measure by Keithley 8009 device. Basic sewing machine from SINGER was used to produce the stitched samples. Plain stitching type was followed and stitch steps are about 4.7 stitches per cm as mentioned in the standard. For measuring the seam strength, ASTMD 1683 standard was followed for preparing the samples. Fabric strength and seam strength are separately measured to calculate the seam efficiency. MTS Criterion Model 43 device was used to measure the tensile strength of fabric and seams.

$$E = Ss/Fs \times 100 \qquad (1)$$

All samples (warp and weft direction stitched) are washed in the domestic type of laundering machine and parameters were set to 40 rpm washing speed, 600 rpm spin speed and 30°C water temperature. Tumble dryer was not used for drying of the samples. After the washing process resistance values of stitched yarns and seam strength were measured and analyzed.

III. Results and discussion

Mechanical performance of unstitched fabrics was examined to calculate the seam strength. Accordingly, mechanical test was applied in both warp and weft direction fabrics. Elongation percentage of fabric without seam and with seam in warp and weft direction is shown in Figure 1 and error bars represents the fluctuating value range. Elongation in warp direction was relatively higher comparing to weft direction.

Afterwards, seam stress was measured for the unwashed samples. Linear resistance of these samples was determined in kohm per 5 cm. These samples are then washed and dried at room temperature. For seeking the washing effect on the stitched samples, seam strength and conductivity measurements were realized. Resistance values of stitched samples before and after washing are given in Table 1 with distance between the probes set to 5cm for all the samples. Five samples were tested for warp and five for weft direction and calculated average values are presented together with their standard deviations. Figure 2 gives the comparison of resistance values for warp and weft directions. After washing procedure, a warp direction seams show more important variations in resistance values.

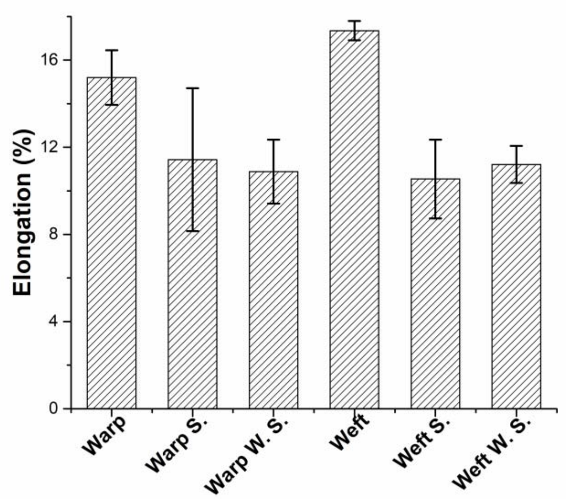

Fig. 1. Elongation at break values for both directions of fabric, S. refers to seam and W. refers to washed sample.

Seam has a key role on the serviceability of the apparel thus, it should be robust enough [10]. Silver coated polyamide yarns are one of the most common conductive yarns. In this study the seam strength of the yarns before and after washing for the aim of its usage in e-textiles as a joining element is analyzed.

Stretchable electronic textile modules have an importance to maintain the comfort and wearability of textile based electronic materials [9]. Due to that reason, conductive threads should exhibit flexibility. Silver coated polyamide yarns are stitched on the both directions and elongation at break values of weft direction seam represents more extension than for the warp direction. However, elongation values decreased after the washing cycle for both directions and values approached.

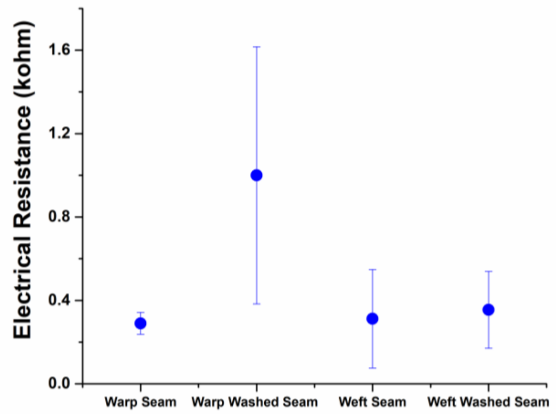

Fig. 2. Compression of resistance values before and after washing for both directions.

Average electrical resistance value for warp direction seam increased dramatically after the first washing process, when compared with the weft direction seam. Moreover, the standard deviation of the washed seam on warp direction became higher due to the effects of the washing process. Increased standard deviation on the electrical resistance points the poor reliability of the joining element. Mechanical performance values should be evaluated together with the electrical resistance values before choosing the stitching direction of conductive yarn.

TABLE I
ELECTRICAL RESISTANCE VALUES OF STITCHED SILVER COATED YARNS, BOTH WEFT AND WARP DIRECTIONS BEFORE AND AFTER WASHING.

	Electrical Resistance (KΩ)			
	Before Washing		After 1st Washing	
	Warp	Weft	Warp	Weft
	0.21	1.04	1.10	0.52
	0.35	0.22	0.34	0.11
	0.28	0.34	1.56	0.32
	0.29	0.71	-	0.47
	0.32	0.73	-	-
Average	0.29	0.608	1.00	0.35
STDEV	0.05	0.33	0.62	0.18
CV (%)	18	54	62	52

Table 2 and table 3 show the seam strength, seam efficiency and breaking force for fabric and conductive seams before and after washing. Seam efficiency for warp direction washed samples was highest in all cases. Seam efficiency increased after washing in both warp and weft direction. Figure 3 show the tensile strengths of seam in warp and weft directions after washing. These values are almost in the same range.

TABLE II
Tensile test results for warp and weft directions.

Direction	Fabric Breaking Force (N)	Seam Strength
Warp	405.61±61.12	
Weft	430.96±57.70	
Warp Seam		281.47±147
Weft Seam		246.63±61
Warp Washed Seam		305.88±71
Weft Washed Seam		295.46±60

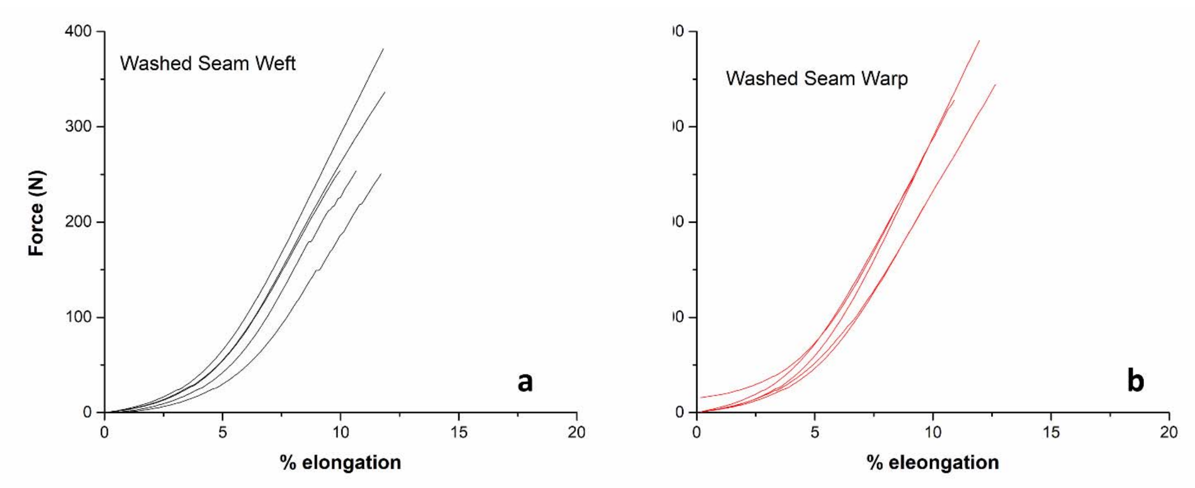

Fig. 3. Tensile test results of the stitched fabrics in (a) weft direction, after washing, (b) warp direction, after washing.

Strength of the seams slightly increased after the washing cycle, while average elongation at break values decreased for the washed samples, on the other side breaking force increased for both warp and weft directions.

TABLE III
SEAM EFFICIENCY CALCULATION RESULTS.

Direction	Seam Efficiency (%)
Warp Seam	69.39
Weft Seam	57.23
Warp Washed Seam	75.41
Weft Washed Seam	68.56

IV. CONCLUSION

Mechanical and electrical resistance have been measured and it was seen that: first cycle of gentle washing cycle has not a huge impact on the seam strength of silver coated polyamide yarns. Results point out that; silver coated polyamide yarn can resist the gentle washing cycle. However, the electrical resistance is affected inversely due to the damage of coating layer. It means that coated silver layer has not any effect on the mechanical performance of the polyamide yarn, and silver coating only supports the electrical conductivity of the polyamide yarn. Weft direction stitching is more flexible for unwashed samples, as expected. After, the washing cycle, elongation values decreased for both weft and warp directions. Silver coated polyamide yarns are strong enough to stitch and wash for both directions of the fabric.

Silver coated yarns can be a good alternative as a joining element for flexible electronics, they exhibit a certain elongation, but they preserve their electrical conductivity feature.

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REFERENCES

[1] K. A. Asanovic, T. A. Mihajlidi, S. V. Milosavljevic, D. D. Cerovic, and J. R. Dojcilovic, “Investigation of the electrical behavior of some textile materials,” J. Electrost., vol. 65, no. 3, pp. 162–167, Mar. 2007.
[2] M. Stoppa and A. Chiolerio, “Wearable Electronics and Smart Textiles: A Critical Review,” Sensors, vol. 14, no. 7, pp. 11957–11992, Jul. 2014.
[3] I. Kazani et al., “Washable screen printed textile antennas,” in Advances in Science and Technology, 2013, vol. 80, pp. 118–122.
[4] S. J. Pomfret, P. N. Adams, N. P. Comfort, and A. P. Monkman, “Advances in processing routes for conductive polyaniline fibres,” Synth. Met., vol. 101, no. 1, pp. 724–725, May 1999.
[5] C. Cochrane, V. Koncar, M. Lewandowski, and C. Dufour, “Design and Development of a Flexible Strain Sensor for Textile Structures Based on a Conductive Polymer Composite,” Sensors, vol. 7, no. 4, pp. 473–492, Apr. 2007.
[6] B. Kim, V. Koncar, E. Devaux, C. Dufour, and P. Viallier, “Electrical and morphological properties of PP and PET conductive polymer fibers,” Synth. Met., vol. 146, no. 2, pp. 167–174, Oct. 2004.
[7] Z. Hua, Y. Liu, G. Yao, L. Wang, J. Ma, and L. Liang, “Preparation and Characterization of Nickel-Coated Carbon Fibers by Electroplating,” J. Mater. Eng. Perform., vol. 21, no. 3, pp. 324–330, Mar. 2012.
[8] F. K. Ko, “Seaming and joining methods,” Geotext. Geomembr., vol. 6, no. 1, pp. 93–107, Jan. 1987.
[9] T. Vervust, G. Buyle, F. Bossuyt, and J. Vanfleteren, “Integration of stretchable and washable electronic modules for smart textile applications,” J. Text. Inst., vol. 103, no. 10, pp. 1127–1138, Oct. 2012.
[10] A. K. Choudhary and A. Goel, “Effect of Some Fabric and Sewing Conditions on Apparel Seam Characteristics,” Journal of Textiles, 2013. [Online]. Available: https://www.hindawi.com/journals/jtex/2013/157034/. [Accessed: 16-Apr-2018].
[11] U. Chowdhary and D. Poynor, “Impact of stitch density on seam strength, seam elongation, and seam efficiency,” Int. J. Consum. Stud., vol. 30, no. 6, pp. 561–568, Nov. 2006.
[12] M. Akter and M. R. Khan, “The effect of stitch types and sewing thread types on seam strength for cotton apparel,” Int. J. Sci. Eng. Res., vol. 6, no. 7, pp. 198–205, 2015.