ISSN 2229-5518

Improving the Crease Recovery Property of Cotton Fabrics by Using Shape Memory Alloy Wires

Sevda Altaş, Elif Yılmaz

Abstract—Shape memory alloy (SMA) is a material that "remembers" its original shape and when deformed, returns to its pre-deformed shape by heating. Shape memory alloys have applications in industries including automotive, aerospace, biomedical and robotics; also they are used in the production of smart textiles. In the study, it was aimed to develop a shape memory cotton woven fabric which needs only a heat treatment instead of ironing after creasing. For this purpose, shape memory alloy wires (SMA) were embedded in the cotton fabrics. Five different embedding methods; (1) sewing the wire to the fabric with hand, (2) fastening the wire to the fabric with sewing machine, (3) bonding the wire to the fabric with silicon along the wire, (4) intermittent bonding the wire along with the fabric with silicon and (5) fastening the wire to the interlining with sewing machine were used. In order to observe the effect of the SMA wire on crease recovery, also one reference fabric without SMA wire was used for comparison. In experimental part of the study, firstly each sample was creased under load and then subjected to the hairdryer for 3 minutes and the improvement of the creases after heat treatment was assessed, secondly each sample was washed and dried according to ISO 6330 standard and subjected to heat again. The crease recovery properties of the fabrics before and after heat treatment were evaluated with ISO 9867 standard. According to the test results, SMA wires have a positive effect on crease recovery properties of cotton woven fabrics. Best results were obtained with (3) and (5) methods. The bonding and fastening of the SMA wire could be a valuable alternative method to solve the creasing problem of the fabrics.

Index Terms— cotton woven fabrics, crease recovery, shape memory alloy (SMA), woven fabrics

1 Introduction

Cellulosic fibers have been used for ages because they are comfortable, biodegradable, natural and healthy. Cotton is one of the most common used natural fibers in the world. But when the cotton fabrics subjected to creasing, shearing, compressing, bending, bulging during wear, after washing and drying, they crease generally [1],[2],[3].

Creasing is a bending deformation of the fabric and causes an undesirable appearance on the fabric's surface [4]. Also creasing cause damages on fabric, because abrasion occurred along the crease. Creasing recovery is the ability of a fabric to recover from folding deformations [2],[5] and return to original appearance as much as possible. This ability also improves the aesthetic view and easy-care properties of the fabrics and also affects the performance of end product [2],[4],[5]. Physical properties; especially bending properties of fibers, fabric construction and finishing processes are three main parameters which affect the crease recovery of fabrics [4],[5],[6]. Apart from these parameters; twist coefficient, fabric weft and warp yarn densities, fabric thickness are also important parameters related to crease recovery property [4].

- *Sevda Altaş is currently pursuing Assoc. Prof. Dr. in Emel Akın Vocational School, in Ege University, Turkey, E-mail: sevda.altas@ege.edu.tr*
- *Elif Yılmaz is currently pursuing PhD program in Textile Engineering in Ege University, Turkey, E-mail: elif.yilmaz@ege.edu.tr*

Today by applying crease-resistance treatment to the fabrics, wrinkle-free fabrics can be produced. But chemicals used for crease-resistance treatments can cause ecologic and health problems [1]. In that case, the requirement to the new methods for improving the crease recovery properties of fabrics made by natural fibers is seen clearly.

In the study, it was aimed to develop a shape memory cotton woven fabric which needs only a heat treatment instead of ironing after creasing. For this purpose, shape memory alloy wire (SMA) was used for embedding to the cotton fabrics. SMA is a material that has special characteristics such as shape memory effect, super elasticity and reversing tensile elongation. It was first discovered in 1932 by Arne Ölander and now has a wide range of usage in industry [7],[8],[9],[10]. The most interested alloy in practice is nickel-titanium and copper based alloys [11]. In the study, nickel-titanium based alloy was used.

The samples were prepared with different embedding methods and a reference fabric without SMA wire was used for the comparison.

2 Materials and Methods

2.1 Materials

The fabric used in this study is plain and 100% cotton, having areal density of 173g/ m². The weft yarn is Ne 34 having twist coefficient αe=3.9, warp yarn is Ne 33 having twist coefficient αe=3.8. Fabric's warp density is 54 picks/cm and weft density is 30 ends/cm. Fabric thickness is 0.3 mm and measured with SDL ATLAS Digital Thickness Gauge M034A according to the ASTM 1777 standard.

ISSN 2229-5518

The NiTi shape memory alloy wire used in the study. The main characteristics of this wire are 55.5% Ni- 44.5 % Ti, density 6.5 g/cm³, the melting point of 1300 ºC and 0.2mm in diameter. The SMA wire which purchased as in fully annealed condition has an ability to return to its original flat form at body temperature and transition temperatures are As: +49°C, Af: +50°C, Ms= -18°C and Mf=-19°C.

In the study, to develop a shape memory cotton woven fabric which needs only a heat treatment instead of ironing after creasing, shape memory alloy wires (SMA) were embedded with the cotton fabrics in the warp direction with five different embedding methods. These methods are (1) sewing the wire to the fabric with hand, (2) fastening the wire to the fabric with sewing machine, (3) bonding the wire to the fabric with silicon along the wire, (4) intermittent bonding the wire along with the fabric with silicon and (5) fastening the wire to the interlining with sewing machine. The distance between the wires were 5 cm for all samples. On the other hand, in order to observe the effect of the SMA wire on crease recovery, also one reference fabric without SMA wire was used for the comparison. Sample preparation methods are given in Table 1.

TABLE 1
PREPARATION METHODS OF COTTON FABRIC SAMPLES

Sample No	Sample Preparation Methods
1	Sewing the wire to the fabric with hand
2	Fastening the wire to the fabric with sewing machine
3	Bonding the wire to the fabric with silicon along the wire
4	Intermittent bonding the wire along with the fabric with silicon
5	Fastening the wire to the interlining with sewing machine
6	Reference fabric

2.2 Methods

All the measurements in the study were performed under standard atmospheric conditions (20 ± 2 °C, 65 ± 2% Rh). The crease recovery properties and the appearance of fabrics were measured with Wrinkle Recovery Tester 155 according to the ISO 9867 standard. Wrinkle Recovery Tester 155 is shown in Fig. 1.

In the first part of the study, the fabric samples with dimensions 150mmx280mm were wrapped cylindrically, then compressed and rotated under constants of axial load (3.5kg) and rotational angle [12].

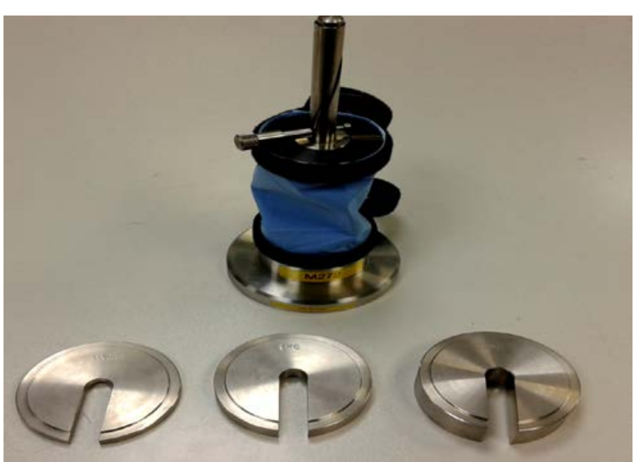

Fig. 1. Wrinkle Recovery Tester 155

Later on, each sample was subjected to heat at temperature approximately 60°C by hairdryers medium heat setting for 3 minutes to observe the improvement of the creases by heat treatment and the crease recovery properties of all samples were evaluated with ISO 9867 standard again for comparing the results obtained before and after heat treatment.

In the second part of the study, all fabric samples were subjected to one laundry cycle using a washing machine [13]. The washing temperature was 40ºC and 20 gr of detergent was used, laundry cycle continued nearly an hour and samples were line dried. After all fabric samples dried, they were subjected to heat again and appearances of creases after washing and improvement in crease recovery after heat treatment were compared.

3 Results and Discussion

In the study appearances of the fabric samples after creasing with Wrinkle Recovery Tester 155 and after one washing cycle were evaluated by rating according to the photographic standards. Score 1 refers the more creased fabric appearance and Score 5 refers the less creased fabric appearance. The test results obtained before and after heat treatment for both cases are given in Table 2.

ISSN 2229-5518

TABLE 2
EVALUATING THE APPEARANCE OF FABRICS BEFORE AND AFTER HEAT TREATMENT

Sample No	Wrinkle Recovery Tester 155		Washing Cycle	
	Before Heat Treatment	After Heat Treatment	Before Heat Treatment	After Heat Treatment
1	1	2	2	3
2	1	2	1	2
3	2	3	2	3
4	1	2	1	2
5	2	3	2	3
6	1	1	1	1

According to the test results, it is observed one-degree recovery after heat treatment for all fabric samples with SMA wires. It indicates that SMA wires have a positive effect on crease recovery properties of cotton woven fabrics with only a heat treatment for 3 minutes. As it is seen in Table 2, for the first part of the study best results were obtained with samples (3) bonding the wire to the fabric with silicon along the wire and (5) fastening the wire to the interlining with sewing machine methods; and for the second part of the study in addition to the samples (3) and (5), sample (1) sewing the wire to the fabric with hand gives the other best result.

Furthermore, the heat treatment applied by hairdryer influenced the appearance of fabrics and the fabrics recovered to their flat shape within a few seconds and became smoother. Appearances of fabrics before and after heat treatment are shown in Fig. 2-7. In order to show the SMA embedding methods, only back sides of the fabrics were photographed. According to Fig. 2-7, the improvement in the crease recovery of the fabrics for samples (3) and (5) is clearly seen in Fig. 4 and 6.

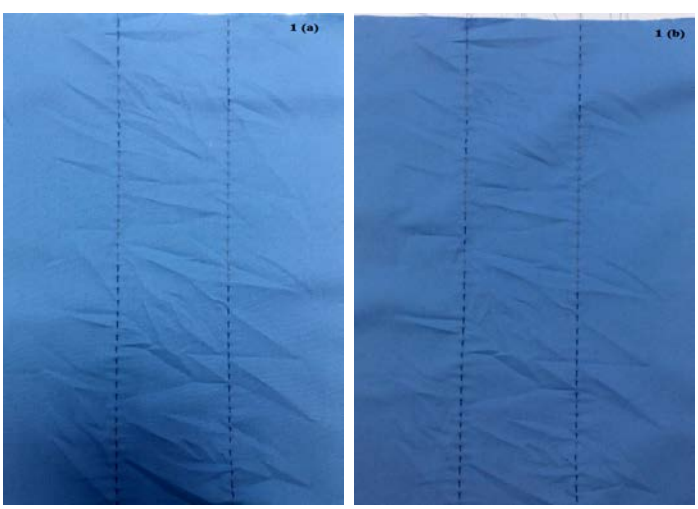

Fig. 2 (a). Sample (1) sewing the wire to the fabric with hand, and appearances (a)before and (b)after heat treatment by creasing with Wrinkle Recovery Tester 155,

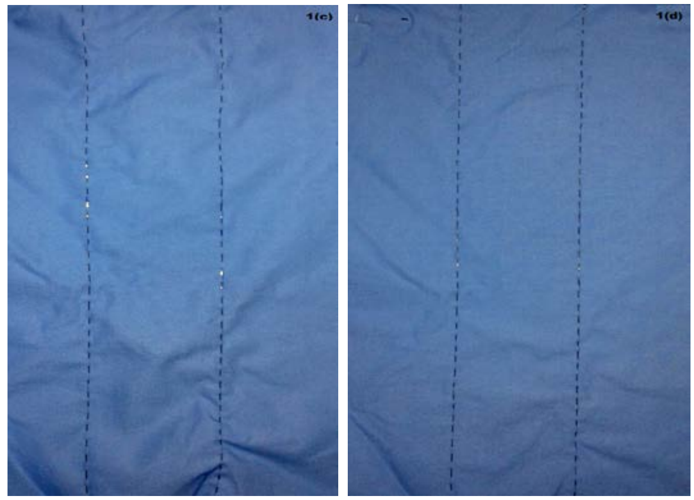

Fig. 2 (b). Sample (1) sewing the wire to the fabric with hand, and appearances (c) before and (d) after heat treatment after a washing cycle.

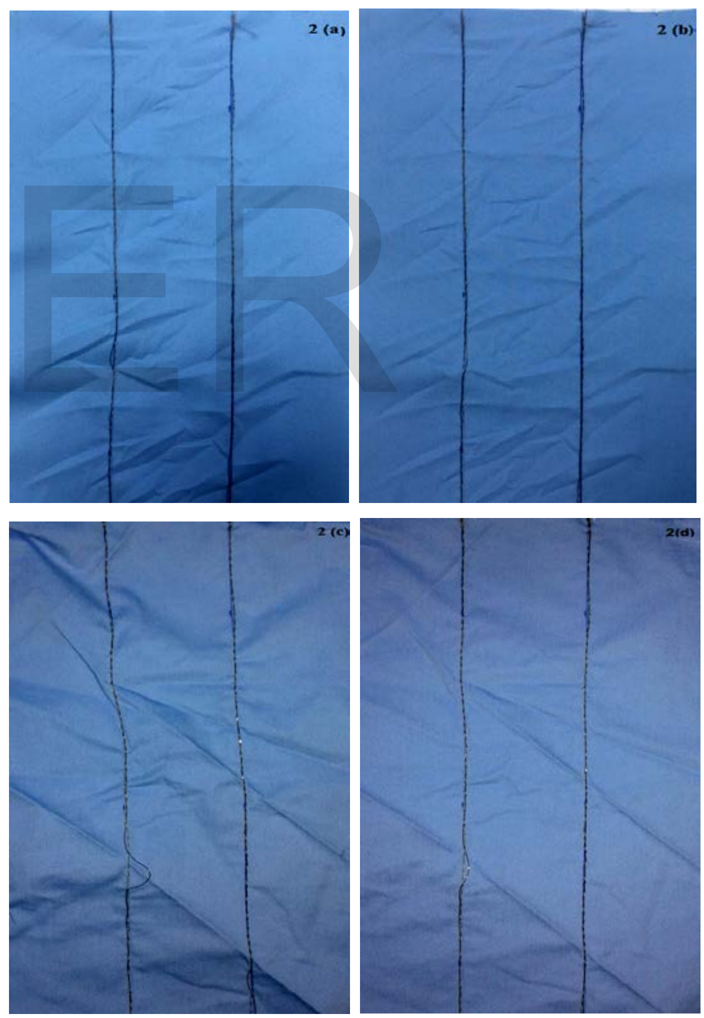

Fig. 3. Sample (2) fastening the wire to the fabric with sewing machine, and appearances (a)before and (b)after heat treatment by creasing with Wrinkle Recovery Tester 155, (c) before and (d) after heat treatment after a washing cycle.

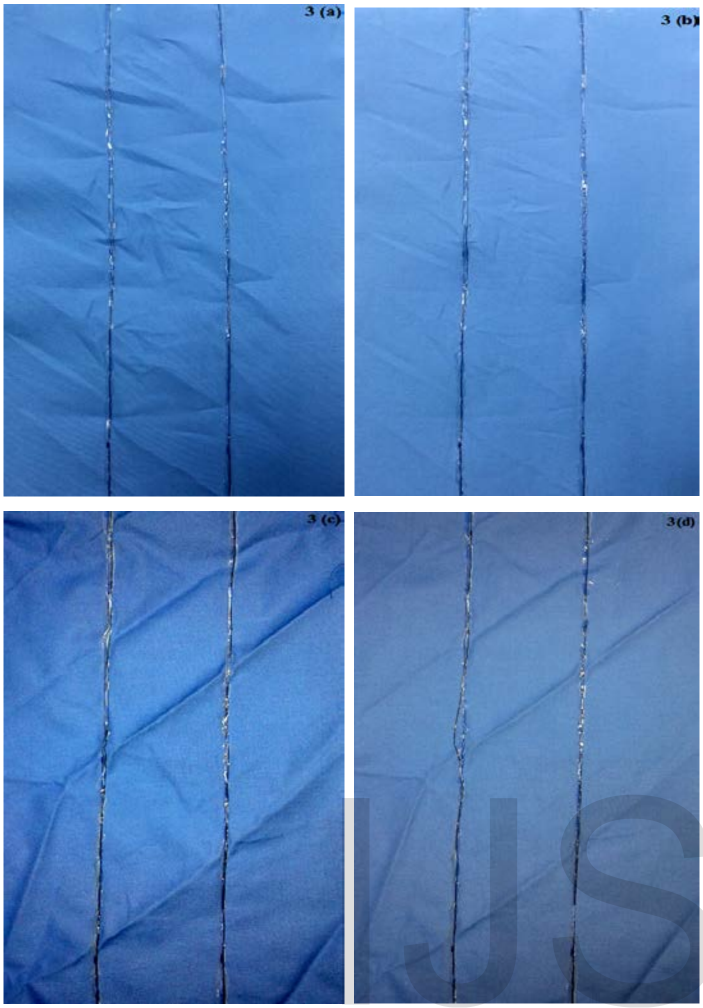

Fig. 4. Sample (3) bonding the wire to the fabric with silicon along the wire, and appearances (a)before and (b)after heat treatment by creasing with Wrinkle Recovery Tester 155,(c) before and (d) after heat treatment after a washing cycle.

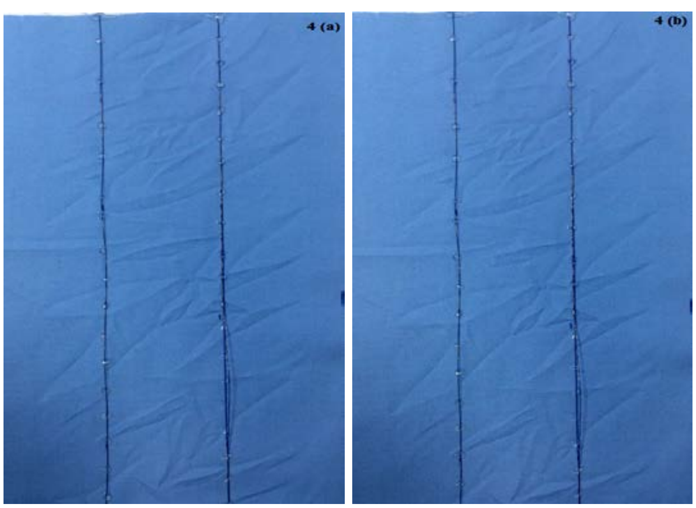

Fig. 5(a). Sample (4) intermittent bonding the wire along with the fabric with silicon, and appearances (a)before and (b)after heat treatment by creasing with Wrinkle Recovery Tester 155

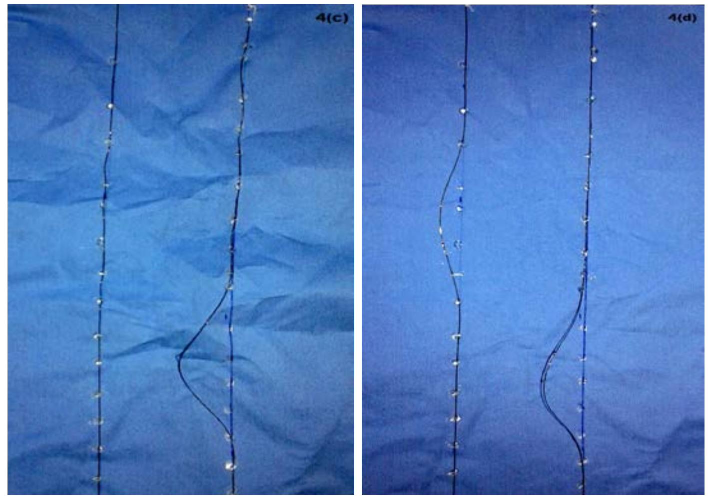

Fig. 5(b). Sample (4) intermittent bonding the wire along with the fabric with silicon, and appearances, (c) before and (d) after heat treatment after a washing cycle.

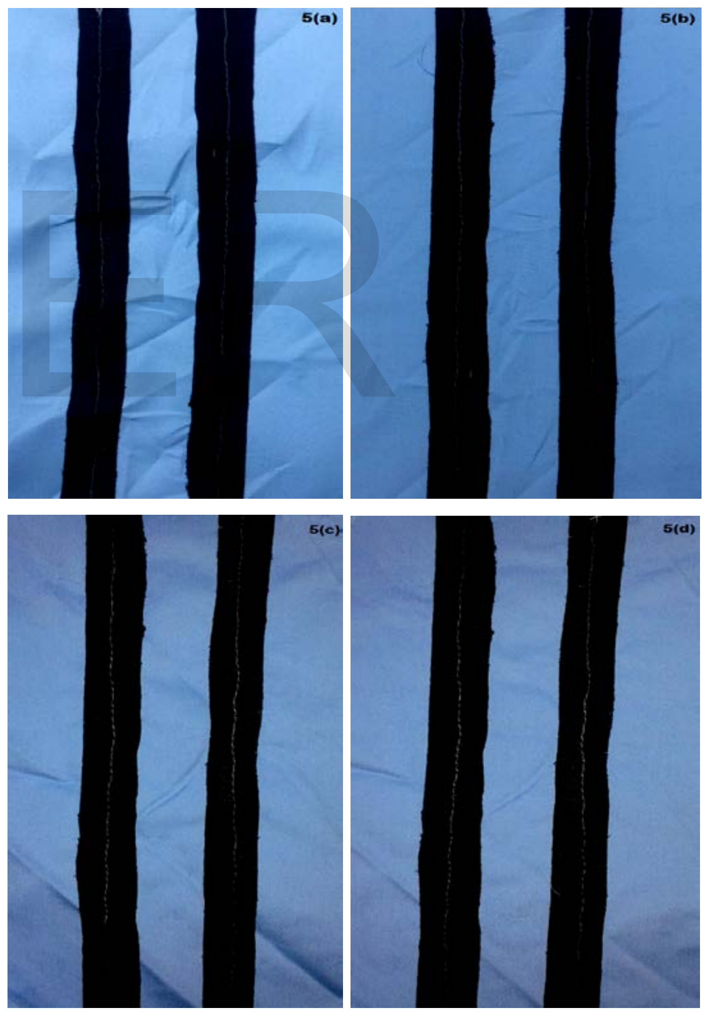

Fig. 6. Sample (5) fastening the wire to the interlining with sewing machine, and appearances (a)before and (b)after heat treatment by creasing with Wrinkle Recovery Tester 155, (c) before and (d) after heat treatment after a washing cycle.

ISSN 2229-5518

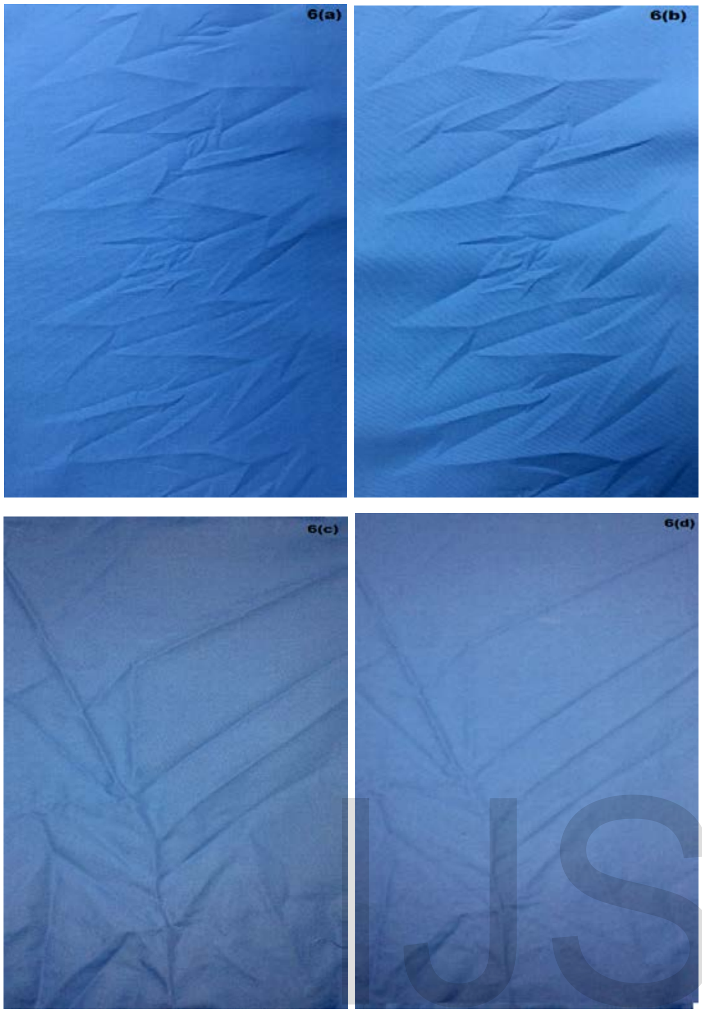

Fig. 7. Sample (6) reference fabric and appearances (a)before and (b)after heat treatment by creasing with Wrinkle Recovery Tester 155, (c) before and (d) after heat treatment after a washing cycle.

In the study we used silicon for bonding the wire to the fabric for samples (3) and (4). Based on the observations it is determined that it is not a proper way in practice. Because due to heat treatment silicon gets warmer and separates from the fabric, this causes the wire tends to separate from the fabric too. Also same problem occurred after washing. The separation problem of wires occurred after heat treatment and washing for samples (3) and (4) are given in Fig. 8.

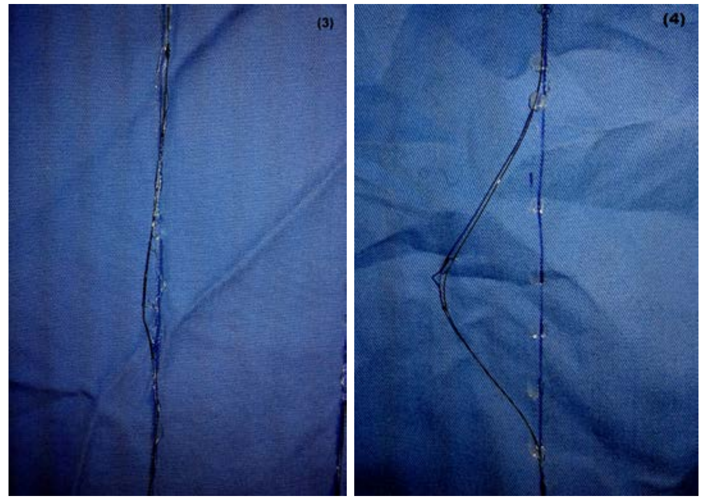

Fig. 8. Problems occurred after heat treatment and washing for sample; (3) on the left side, and (4) on the right side

In the second part of the study, we got another best result from sample (1). However, this method is thought for only investigation, because the sample prepared by sewing the wire to the fabric with hand and it is not suitable for mass production. Also after washing, it is determined that the SMA wire tends to bend and slip among the stitches. This problem is shown in Fig. 9.

Fig. 9. SMA Wire tends to bend and slip among the stitches after washing

4 Conclusions

A shape memory alloy wire was embedded to cotton woven fabrics with five different embedding methods to improve the crease recovery property. The appearance of fabrics with SMA wires and the reference fabric were compared after creasing with Wrinkle Recovery Tester 155 and also fabric samples were subjected to a washing cycle. The appearances of the fabrics were evaluated before and after heat treatment and best SMA embedding methods were tried to be determined. Furthermore, the performance of these methods during wear, after washing and drying processes were investigated. According to the obtained results, it is observed that SMA wires improve the creased appearance of fabrics for one degree with only heat treatment applied for a few minutes.

Based on the results, it can be said that without applying crease resistance treatment or ironing, it is possible to improve the creasing problem of the fabrics made by natural fibres by bonding and fastening of the SMA wires to the fabrics. These will be a valuable alternative way to produce wrinkle free fabrics. But it is so important to use heat-tolerant bonding materials. Because bonding materials such as silicon can leave the fabric during the heat treatment or washing and drying processes. This affects the wire performance and the desired results may not be got. For this reason, we recommend fastening the wire to the interlining with sewing machine and then bonding it to the fabric at ready-made stage.

For further studies SMA wires can be embedded in weft, warp and both directions to the fabrics which made of different raw materials and different fabric constructions and the results can be compared.

ACKNOWLEDGMENT

This study was supported by "2015 EAMYO 001" numbered Scientific Research Project of Ege University.

REFERENCES

[1] B. Arık, "Latest Developments on Crease Resistance Processes for Cellulosic Fabrics", *Pamukkale University Journal of Engineering Sciences*, vol. 21, no. 7, pp. 296-305, 2015.

[2] F. Shi and Y. Wang, "Modelling Crease Recovery Behaviour of Woven Fabrics", *The Journal of The Textile Institute*, vol.100, no. 3, pp. 218-222, 2009.

[3] B.K. Behera and P.K. Hari, "*Woven Textile Structure*", B.K. Behera and P.K. Hari, eds., Cambridge: Woodhead Publishing Limited, pp.197-204, 2010.

[4] N. Özdil, *The Physical Quality Control Methods of Fabrics*, Izmir: Ege University Textile and Apparel Research-Application Center, pp.105-107 2003.

[5] T. Hussain, M. Tanveer, A. Zulfiqar, Z. Arshad and A. Nazır, "Comparison of Artificial Neural Network and Adaptive Neuro-Fuzzy İnference System for Predicting the Wrinkle Recovery of Woven Fabrics", *Journal of Textile Institute*, vol. 106, no. 9, pp. 934-938, 2015.

[6] J.F. Krasny and A.M. Sookne, "Crease Recovery of Fabrics Part I: Some Tensile Properties of Wool, Vicara, and Rayon Fibers and Their Relationship to Fabric Crease Recovery", *Textile Research Journal*, vol. 25, no. 6, pp. 493-498, 1955.

[7] S. Vasile, J. Githaiga and I.L. Ciesielska-Wrobel, "Comparative Analysis of the Mechanical Properties of Hybrid Yarns with Superelastic Shape Memory Alloys (SMA) Wires Embedded", *Fibres&Textiles in Eastern Europe*, vol. 6, no. 89, pp. 41-46, 2011.

[8] J. Hu, Jinlian, "*Shape Memory Polymers and Textiles*", J. Hu, eds., Cambridge: Woodhead Publishing Limited, pp. 3-25, 2007.

[9] A. Bedeloğlu, "Şekil Hafızalı Alaşımlar ve Tekstil Malzemelerindeki Uygulamaları", *The Journal of Textiles and Engineer*, vol. 18, no. 83, pp. 27-37, 2011.

[10] J. M. Jani, M. Leary, A. Subic and M.A. Gibson, "A Review of Shape Memory Alloy Research, Applications and Opportunities", *Materials and Design*, vol. 56., pp. 1078-1113, 2014.

[11] A. Akdoğan and K. Nurveren, "Shape Memory Alloys", *Engineer and Machinery*, vol. 44, no. 521, pp. 35-44, 2003.

[12] Textile-Evaluation of the wrinkle recovery of fabrics-Appearance method, ISO 9867: 2009.

[13] Textiles-Domestic washing and drying procedures for textile testing, ISO Test Method 6330: 2012.