ISSN 1392–1320 MATERIALS SCIENCE (MEDŽIAGOTYRA). Vol. 20, No. 1. 2014

# Analysis of Shape Nonconformity between Embroidered Element and Its Digital Image

**Svetlana RADAVIČIENĖ [1] *, Milda JUCIENĖ [1], Žaneta JUCHNEVIČIENĖ [1], Lina ČEPUKONĖ [1], Ausma VILUMSONE [2], Ugis BRIEDIS [2], Ilzė BALTINA [2]**

[1] *Department of Clothing and Polymeric Products Technology, Kaunas University of Technology, Kaunas, Lithuania*
[2] *Institute of Technology and Design of Textile Materials, Riga Technical University, Riga, Latvia*

crossref http://dx.doi.org/10.5755/j01.ms.20.1.2911

*Received 21 November 2012; accepted 12 May 2013*

Embroidery technologies are widely applied for developing decorative elements of original design in garments, for integrating threads intended for protection into garments and other articles. Nonconformity of the shape and dimensions of the embroidered element with the designed digital image is influenced by properties of embroidery threads and fibres, by the filling type, density of stitches and other technological parameters. The objective of the paper is to explore the influence made by properties of fabrics and by the direction of stitches of the actual embroidered element on conformity of the shape with one of the designed digital image. For the research, embroidery threads of different purpose as well as three woven fabrics have been selected. For preparation of test samples, round digital images have been designed filling the embroidery area in different stitch directions. Analysis of the results of the investigations has demonstrated that the shape and dimensions of the embroidered element failed to conform to the shape and dimensions of the designed digital image in most cases. In certain cases, e.g. when the stitch direction goes towards the middle of the embroidered element, a defect, i. e. hole, is observed due to considerable concentration of stitches in the centre of the element.

*Keywords*: fabrics, embroidery threads, embroidered element.

## 1. INTRODUCTION

An embroidery process is one of the ways to assemble textiles into a system. Embroidery technologies are widely applied both for developing decorative elements of original design in garments and for integrating threads intended for protection into garments and other articles. Embroidery with electric conductive threads allows manufacturing conductive textile structures on a fabric, joining the embroidered outlines with electronic modules [1]. For the time being, wearable electronic textile systems are widely applied in health care [2], for human protection against electromagnetic waves [3], etc. The manufacturing process of smart garments and other similar articles employs the multilayered embroidery method that requires especially high accuracy, i.e. the embroidered elements shall meet the dimensions of the programmed digital images precisely. Therefore, it is necessary to know how the materials used in the embroidery process will behave in the system. Accurate dimensions and shape of the embroidered element are influenced by a stable stitch. Analysis of change in stitch length during the sewing process has been carried out. Technological parameters of the sewing process, friction forces occurring between the fabric and material of sewing machine gears during transportation as well as technical parameters and technical condition of the sewing machine have been established to influence stable length of the stitch [4, 5]. Quality of the embroidered element may also be influenced both by properties of textiles, the filling type of the embroidered element and the stitch formation direction with respect of fabric direction. Investigations have illustrated that quality and appearance of the embroidered element depend both on the embroidery threads selected, stitch formation direction and length thereof, whereas behaviour of the embroidered element relies on anisotropic properties of the fabric [6]. Anisotropy is determined by structure of the textiles chosen, performances of threads, the type of weave, density and nature of deformation. Former investigations have demonstrated that the embroidery direction makes influence on elongation of the embroidered element [7]. Nonconformity of the dimensions and shape of the embroidered element with the digital image may be caused by shifting of warp and weft threads in the fabric. The aforesaid defect results from the force acting perpendicularly to the embroidered element direction. Textile weave and final finishing have been established to make influence on slippage of threads at the seam [8]. Within the stitch of the embroidered element, the textile is compressed and due to anisotropy, under the impact of certain forces, it gets deformed. Nonconformity of the shape and dimensions of the embroidered element may be caused by textile structure, fibre composition, mechanical properties [9]. Behaviour of stretch fabrics may be influenced by the elastane filaments contained by these fabrics in the directions of warp and/or weft [10, 11]. Assembling of textiles by a sewing process and embroidery process is carried out employing the same type of a lockstitch. However, the purpose of assembling, requirements for quality and properties of the final assembling are different. Plenty of research studies are devoted to seam puckering. Investigations have illustrated that interaction of the fabric and sewing thread with sewing machine gears and sewing machine parameters make a direct influence on occurrence of seam puckering [12]. The

* Corresponding author. Tel.: +370-37-300205; fax: +370-37-353989.
E-mail address: *svetlana.radaviciene@stud.ktu.lt* (S.Radavičienė)

developed methods for seam puckering examination enable to assess seam waviness by changes in the initial length of the test sample after sewing, through analysis of the scanned image of the seam wave and via testing of fabric thickness change in the place of the seam [13].

Although being important and used on a large scale, the embroidery process has not been widely investigated thus far. More detailed surveys as for nonconformity of the shape and dimensions of the embroidered element with the designed digital image, for puckering of the embroidered element are not readily available.

The objective of the paper is to explore the influence made by properties of fabrics and by the direction of stitches of the actual embroidered element on conformity of the shape with one of the designed digital image.

## 2. MATERIALS AND TESTING METHODS

For the investigations embroidery threads of different linear density and fibre composition were selected. In respect of their application embroidery threads can be grouped into upper (UT) and lower (LT) embroidery threads. The characteristics of investigated threads are listed in Table 1.

**Table 1.** Characteristics of embroidery threads

| Legend | Raw material | Purpose | Structure | Linear density, tex |
|---|---|---|---|---|
| UT | 100 % PES | Upper thread | Two-ply multifilament yarn | 30.2 |
| LT | 100 % PES | Lower thread | Two-ply spun yarn | 24.7 |

Fabrics having different composition, similar thickness and usually used in the embroidery process were selected for the research (Table 2).

Thread density ($P_{warp}$, $P_{weft}$ ) and linear density ($T_{warp}$, $T_{weft}$) of the fabrics were defined in compliance with LST EN 1049-2, whereas surface density ($W$) was defined in compliance with LST ISO 3801 [14, 15]. Calculated diameters of warp and weft yarns $d_{warp}$ and $d_{weft}$ were calculated after evaluating on fabric fibers density and mass of volume. Peirce linear filling factors $e_{warp}$ and $e_{weft}$ and fabric cover factor $e_s$ were estimated using the least fabric thread density ($P_{warp}$, $P_{weft}$) and calculated yarn diameter $d_{warp}$ and $d_{weft}$. Thickness $h$ of fabrics was measured by thickness gauge "SCHMIDT DPT 60 Digital". Pressure and pressing plane of thickness gauge was 1.0 kPa and 20 cm$^2$ respectively. Ten measurements of of each fabric sample were carried out. The computed averages of the measured thickness values demonstrated that a relative error of measurement results did not exceed the limit of 5.0 %.

For the investigations the image of round shape was selected due to the reason that it enables the most accurate assessment of the influence made by textiles properties and by filling type on embroidered samples shape stability in all directions. Round digital images were generated applying "Brothers PE-Design 8" Software Package (Fig. 1). Diameter of the generated circle of embroidered element was 50 mm (radius $r_s$ = 25 mm). Test specimens were prepared using embroidery machine "Brothers PR-600 II" with 1 head and 6 needles. For the experiment, test samples (21.0 cm × 21.0 cm) of selected fabrics were placed in a 16.0 cm × 13.0 cm embroidery hoop. Applying a correctly balanced embroidery stitch, when a possibility for a lower thread to be visible on the front side of the embroidery area is eliminated, by 6 test samples of each selected fabric were embroidered. Embroidery speed of 600 stitches per minute was applied, whereas stitch density of all filling types was the same (4.0 line/mm). The following three different filling types of the embroidery area were chosen: Concentric Circle Stitch (CCS) (Fig. 1, a), Radial Stitch (RS) (Fig. 1, b), Fill Stitch (FS) (Fig. 1, c).

Sequence of the digital image embroidered with Filling Type CCS was composed in the way as to embroider the round element in two stages. In the first stage, the primary (middle) portion was embroidered from the origin point of the outer outline spirally to the centre of the element. In the second stage, the last row of stitches was made around the already embroidered primary portion of the element in order to avoid an uneven edge of the embroidered element. Filling Type CCS of the embroidery area consists of 5342 stitches. When Filling Type RS is applied, the element is embroidered from the origin point to the centre, from the centre to the edge of the element, thereby in a circle, as long as the entire embroidery area is filled. The aforementioned filling type consists of 6598 stitches. When the embroidery area is filled with Filling Type FS, rows of stitches are made from on edge of the embroidered element to other one in the horizontal direction from the origin point of the embroidered element to the end point of the embroidered element. Filling Type FS consists of 2187 stitches.

When the embroidery process is finished, a test sspecimen is removed from the embroidery hoop; test samples are scanned and measured not earlier than 24 hours after the embroidery process when a test sample is relaxed in standard conditions. The aforementioned relaxation time is sufficient for appropriate assessment of embroidered element quality [16].

For measurement of geometrical parameters, test

**Table 2.** Characteristics of tested fabrics

| Legend | Material composition | Weave | Area density ($W$), g/m$^2$ | Thickness ($h$), mm | Thread density, cm$^{-1}$ | | Linear density, tex | | Fabric cover factor ($e_s$) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | $P_{warp}$ | $P_{weft}$ | $T_{warp}$ | $T_{weft}$ | |
| F1 | 100 % Linen | Plain | 150 | 0.34 | 19.9 | 18.4 | 26.3 | 26.3 | 0.590 |
| F2 | 100 % Cotton | Plain | 144 | 0.26 | 52.0 | 40.0 | 13.6 | 14.3 | 0.893 |
| F3 | 98 % PES; 2 % EL* | Satin | 210 | 0.38 | 80.2 | 28.1 | 18.9 | 17.8 | 1.000 |

* – with elastane yarn in the weft direction.

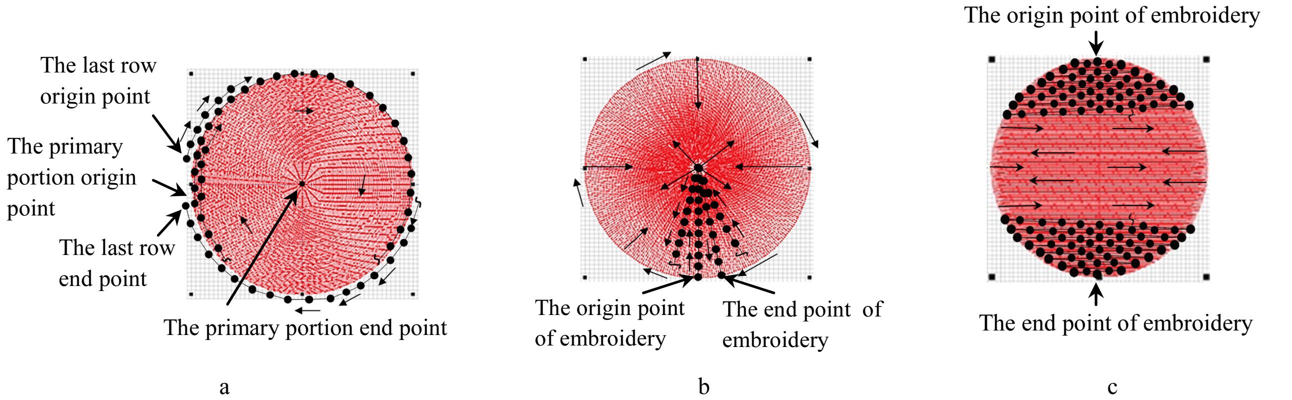



**Fig. 1.** Filling types of the embroidery areas in designed digital round images: a – "Concentric Circle Stitch" (CCS); b – "Radial Stitch (RS); c – "Fill Stitch" (FS); legend: —— – embroidery thread; ● – needle insertion place, ➞ – formation direction of embroidery stitches

samples were scanned by a scanner "Canon PIXMA MP 140", with resolution of 600 dpi, placing a ruler beside in order to evaluate the scanning scale. For editing captured images and measuring geometrical performances of the embroidery pattern, "COREL DRAW X5" Software Package was applied.

For measurement of radius $r_r$ (an actual embroidered element) of the round embroidered element, a reference-starting point is placed on a vertical axis corresponding to Y in the coordinate system, i. e. to the direction of weft (of weft or warp for the embroidered elements of Fabric F3). Radius $r_r$ is measured every 22.5º from center to the edge of embroidered element, the direction of measurement tallies with the clockwise direction (Fig. 2).

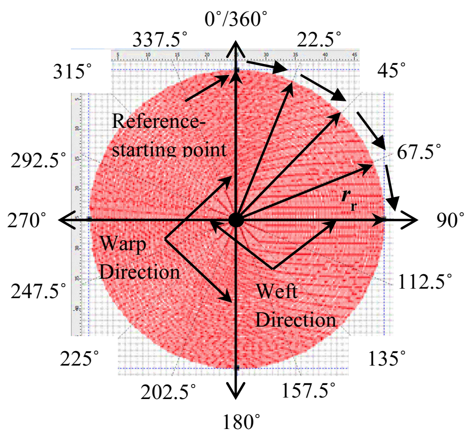



**Fig. 2.** Measurement diagram of the round embroidered element

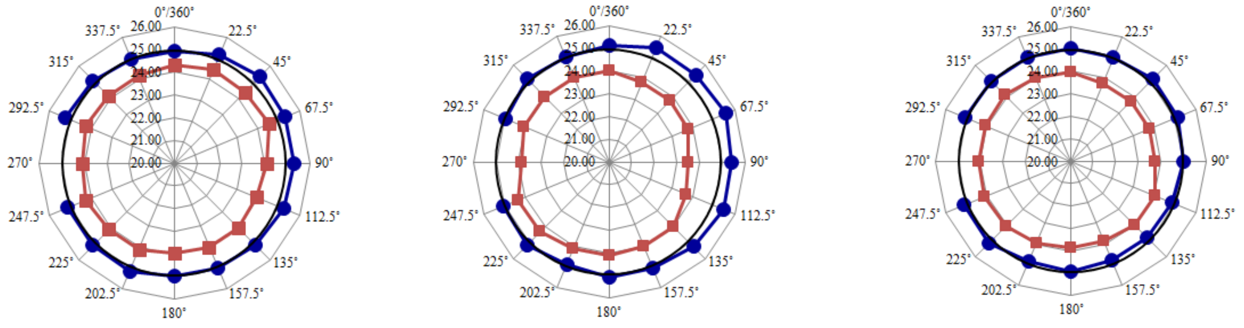
When for filling of the embroidery area Filling Types CCS and RS are applied, stitches in the process of embroidery are formed in all directions of the fabric, therefore, test samples were embroidered just in the direction of warp. In the case of Filling Type FS, the embroidery area is filled through formation of stitches in one direction, i. e. in the horizontal direction in the test samples under investigation. Therefore, test specimens of Fabric F3 the thread density ($P_{warp}$, $P_{weft}$) whereof differs almost three times and contains elastane in the direction of weft, were embroidered in the directions of warp and weft.

Averages of values of research results as well as variation coefficients were computed fluctuating from 0.2 % to 8.6 %.

## 3. EXPERIMENTAL RESULTS AND DISCUSSION

Carried-out analysis of the results has demonstrated that the embroidered element shape obtained in all the cases under investigation failed to comply with the shape of the designed digital image. Taking into account the filling type, other defects of the embroidered elements have also been identified. According to investigations, the elements embroidered with Filling Type CCS have demonstrated a gap between the primary portion of the embroidered element and the last row of stitches the function whereof was to ensure a top-quality edge of the embroidered element (Fig. 1, a). The aforementioned defect was caused by deformation of the fabrics of the embroidered element [7]. Between embroidery stitches, the fabric is compressed, dimensions of the primary portion of the embroidered element decrease and segments of the embroidered element shift. The aforesaid leads to decrease in the primary portion of the embroidered element, whereas the last row of the element is embroidered with the radius the value whereof is designed by the programme. Due to this reason, radius of the outer round and of the primary round of the embroidered elements have been measured. In all cases, the outline of the last row of stitches of the embroidered element has been established to be uneven, with a gap. Programme of the digital image embroidered with Filling Type CCS is composed in the way as to locate the end point of the outline of the last row of stitches beside the origin point of the primary portion (Diagram in Fig. 1, a) in order to obtain the embroidered element of the correctly shaped round. Due to deformation of the primary portion of the embroidered element, however, a gap has occurred and the broken outline has shown up.

In measurement directions, radius $r_r$ of the outer outline of the embroidered element has demonstrated the greatest values among all the cases investigated ranging from 24.9 mm to 25.6 mm, whereas the values of the primary outline have varied from 23.5 mm to 24.4 mm. Values of the gap between the primary portion of the embroidered element and the last row of stitches have extended from 0.4 mm to 0.9 mm in different measurement places implying a significant defect easily identified by a human eye.




a b c

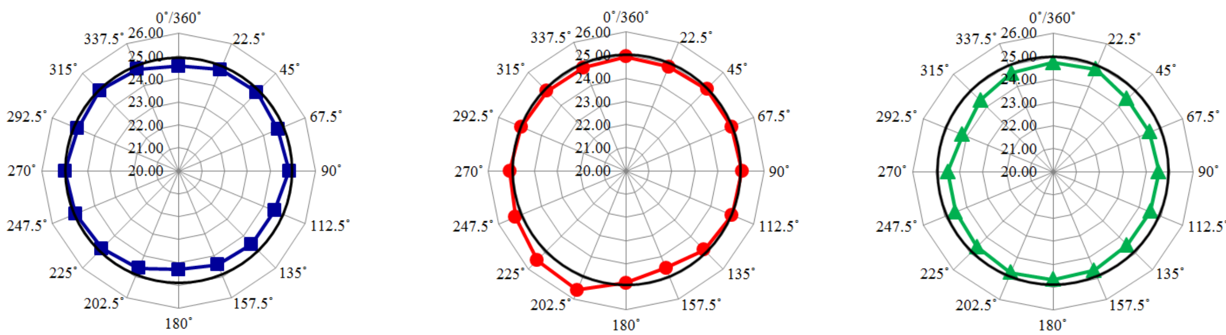
**Fig. 3.** Shapes of the embroidered element formed with filling type CCS, when: a – fabric F1, b – fabric F2, c – fabric F3; when: – radius $r_r$ of the outer outline, – radius $r_r$ of the primary portion, – radius $r_s$ of designed digital element

Analysis of investigation results has demonstrated that the smallest nonconformities of radius $r_s$ of the programmed digital image with one of the actual embroidered image was observed by Fabric F3. In this situation, values of radius r have fluctuated from 25.2 mm at 45º to 24.8 mm at 157.5º measurement angles for the outer outline.

In the test specimens embroidered with Filling Type RS, an unwanted defect, i. e. hole, formed inside the embroidered element (Fig. 6, b). According to the technology required to fill the round element with Filling Type RS, the greatest concentration of stitches is observed in the middle of the embroidered element. Concentration of stitches and multiple cutting through of textiles with a needle in one place have influenced formation of the hole in the central portion of the embroidered element. Due to this reason, threads of the fabric have been damaged, whereas the force action and relaxation processes occurring in embroidery threads have led to breakup of threads at the moment of stitch tightening. In the centre of embroidered elements of Fabrics F1 and F2, a round hole of greater dimensions has formed. It shall be pointed out that the greatest decrease values have been demonstrated by radius $r_r$ of the actual embroidered element round of Fabric F3, i. e. they ranged from 24.19 mm (292.5º) to 24.82 mm (22.5º). Fabric F3 is of satin weave and contains high floats of threads shifting easily. In Fabrics F1 and F2 of plain weave, values of radius $r_r$ of the embroidered elements have been closer to radius $r_s$ of the programmed digital image (Fig. 4). Embroidery with Filling Type FS has demonstrated no such defects as absence of continuous filling of the embroidered element or fabric damage. In the process of research, round elements have been embroidered in the direction of warp. In the embroidery process, the area is filled with stitches just in the horizontal direction, whereas Fabric F3 contains elastane in the direction of weft and thread density ($P_{warp}$, $P_{weft}$) thereof differs almost 3 times, therefore, test specimens have been embroidered in the directions of warp and weft. According to the analysis of the results of investigations, all cases with the aforesaid filling type have demonstrated compression of the actual embroidered element in the direction of stitch formation. In all cases, the greatest nonconformities in test specimens have been observed in the direction of stitch formation; in the direction of warp in the situation under investigation (Fig. 5, a). Formation of an unwanted defect, i. e. uneven outline of the embroidered element, has also been established. The outline of the element embroidered with a filling type gets the shape of an ellipse (oval).

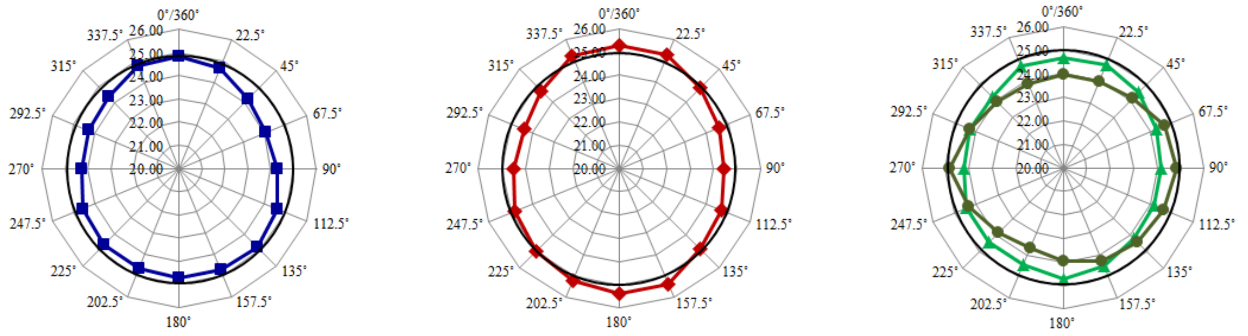
In case of Fabric F3, measurement of radius of the embroidered element has illustrated that values of radius $r_r$ of the element embroidered in the direction of warp were lower (24.2 mm) compared to values of radius $r_r$ of the element embroidered in the direction of weft (24.8 mm). This difference has amounted to 0.6 mm. Measurement in the direction of weft has demonstrated slightly greater inconformity, i. e. 0.7 mm. Nonconformities of values of radius $r_s$ of the designed digital image with the embroidered element have ranged from 1.0 % to 3.4 % and from 0.7 % to 4.6 % embroidering in the directions of warp and weft respectively. Due to the relaxation processes occurring in embroidery threads, the fabric within the stitch is compressed, whereas fabric threads undergo shifting.

Research paper [8] of other authors illustrates that slippage of the seam formed by the sewing process is usually observed in fabrics containing higher floats of threads.




a b c

**Fig. 4.** Shapes of the embroidered element formed with filling type RS, when: a – fabric F1; b – fabric F2; c – fabric F3

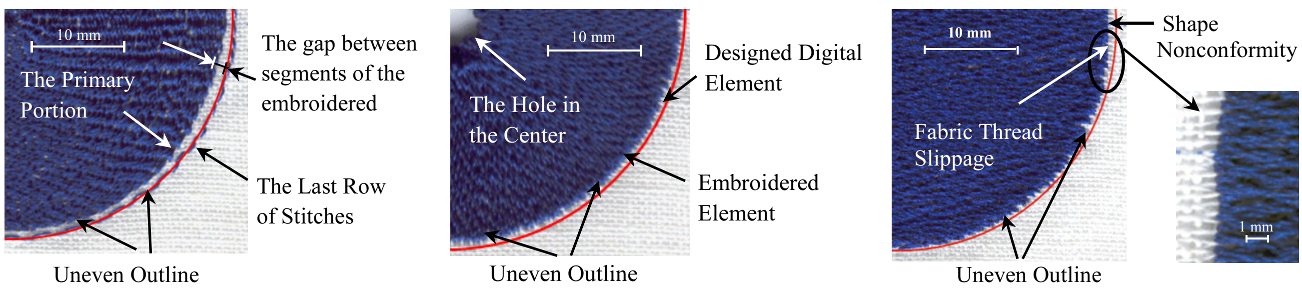



a b c

**Fig. 5.** Shapes of the embroidered element formed with filling type FS, when: a – fabric F1; b – fabric F2; c – fabric F3: – $r_r$ embroidered in the directions of warp; – $r_r$ embroidered in the directions of weft

Slippage of fabric threads at the seam may be defined by shifting of fabric threads due to the force applied. It shall be pointed out that the greatest decrease has been demonstrated by radius $r_r$ of the embroidered element of Fabric F3. In this situation, values of actual radius $r_r$ have varied from 24.2 mm at 90º to 24.7 mm at 0°/360° and 180º measurement angles. The aforementioned behaviour of the embroidered element has been influenced by the weave type of the fabric and by the direction of stitch formation during the embroidery process. Analysis of the results of the investigations has shown that the lowest decrease was demonstrated by radius $r_r$ of the embroidered element of plain weave Fabric F2. The present situation has been influenced by great thread density ($P_{warp} = 52$ cm$^{-1}$, $P_{weft} = 40$ cm$^{-1}$) and high cover factor ($e_s = 0.893$) of the fabric. In certain cases, measurement in the direction of weft shall be pointed out to demonstrate greater radius $r_r$ of the actual embroidered element compared to radius $r_s$ of the designed round (Fig. 6, a, b). Greater values of the embroidered element in respect of the values of the designed round have also been established for the embroidered elements of Fabric F2 (25.2 ±0.21). Besides, the same fabric has demonstrated the lowest nonconformity of the geometric parameter values between the generated digital image and actual embroidered element. In this case, decrease in values of radius $r_r$ of the actual embroidered element has varied from 0.6 % to 2.6 %. The present situation could be influenced by structural distinctions of the aforesaid fabric and the great surface filling indicator characteristic of the fabric. During formation of the stitch, a needle penetrates through the fabric, moves aside threads of the fabric, therefore, the system of fabric threads gets deformed. Due to an embroidery thread introduced additionally into the fabric, threads of the fabric are unable to return to their original position, therefore, the fabric is extended perpendicularly to the embroidery direction. In the fabric of great density, threads of the fabric are compressed tightly. After introduction of an additional embroidery thread, threads of the fabric push and overtake each other, thereby deforming in a greater area. During formation of the stitch, embroidery threads compress the fabric. In this situation, the direction of stitch formation has also been perpendicular to the system of fabric threads. Hence, relaxation of threads and slippage of fabric threads at the outline of the embroidered element result in narrowing of the embroidered element in this direction. Therefore, values of actual radius rr of the element embroidered with Filling Type FS has demonstrated greater decrease almost in all cases. Although being closer to the designed digital image by the shape thereof (Figs. 3 and 4), the elements embroidered with Filling Types CCS and RS have demonstrated other unwanted defects (Fig. 6, a, b), therefore, the aforesaid filling types should not be used for the fabrics under investigation. Analysis of the results of the investigations has illustrated that the elements embroidered with Filling Type FS feature the greatest nonconformity in respect of the shape, however, the present filling type is recommended for usage taking into account properties of the fabric in the direction selected.

The analysis of the obtained results in the context of other authors [6, 17, 18] has revealed that assessment of embroidered element properties and embroidery thread deformation plays a crucial role. During the investigations of anisotropic properties of embroidered elements, the author [6] has found that these properties reiterate anisotropic properties of fabrics. The results of the present research has also shown that subject to the stitch forming direction in respect of the fabric threads system the shape of embroidered element changes unevenly. The minimum




a b c

**Fig. 6.** Defects of the embroidered elements: a – filling type CCS; b – filling type RS; c – filling type FS

filling deformations are generated when the stitch forming direction is close to the direction of the fabric threads system. In the studies by D. A. Chernenko [6], relative deformation in the warp direction was higher than one in the weft direction in all situations, similarly to the case under investigation when relative deformation in the warp direction and in the weft direction varied from 2.1 % to 3.4 % and from 0.5 % to 1.4 % respectively. Evaluation of fabric thread slippage at the seam should be considered. Other authors [17] emphasize that the present defect is highly dependent on the fabric direction orientation. The research has also demonstrated that fabric thread slippage was observed when the stitch forming direction tallied with the fabric warp direction. Returning to the original length, the sewing threads deformed after the sewing process shrink the fabric along the seam line [18]. This fact could also explain the dimensional nonconformities of embroidered element observed during the research.

## 4. CONCLUSIONS

The shape and dimensions of the actual embroidered element have been investigated to fail to conform to the shape and dimensions of the designed digital image. The elements embroidered with Filling Type FS have demonstrated the most significant mismatch of the shape and dimensions between the embroidered elements and the programmed digital image. The greatest nonconformities have been observed in the stitch formation direction of the embroidered element ranging from 0.7 % to 4.6 %.

The elements embroidered with Filling Types CCS and RS have been established to be the closest to the designed digital image by the shape thereof. Considering the filling technology and properties of the fabric, however, embroidered elements demonstrate unwanted defects. The elements embroidered with Filling Type CCS have been established to show a gap between the central portion of the element and the last row of stitches due to shifting of individual segments of the element. In the centre of the actual element embroidered with Filling Type RS, formation of a hole is observed. Occurrence of the aforesaid defects has been influenced by structural distinctions of fabrics, density in the direction of weft and warp, filling indicators.


### *Acknowledgments*

R. S. Acknowledge support by project "Promotion of Student Scientific Activities" (VP1-3.1-ŠMM-01-V-02-003) from the Research Council of Lithuania. This project is funded by the Republic of Lithuania and European Social Fund under the 2007 – 2013 Human Resources Development Operational Programme’s priority 3.


### REFERENCES


1. **Taelman, J., Adriaensen, T., Spaepen, A., Langereis, G. R., Gourmelon, L., Van Huffel, S.** Contactless EMG Sensors For Continuous Monitoring of Muscle Activity to Prevent Musculoskeletal Disorders *Belgian Day on Biomedical Engineering, December 7–8, IEEE Benelux EMBS Symposium,* 2006.
2. **Merritt, C.** Electronic Textile-Based Sensors and Systems for Long-Term Health Monitoring *Raleigh North Carolina, PhD Thesis* 2008: 175 p.
3. **Michalak, M., Kazakevičius, V., Dudzinska, S., Krucinska, I., Brazis, R.** Textiles Embroidered with Split-Rings as Barriers Against Microwave Radiation *Fibers & Textiles in Eastern Europe* 17 (1/72) 2009: pp. 66 – 70.
4. **Jucienė, M., Vobolis, J.** Correlation between the Seam Stitch Length of the Sewing Garment and Friction Forces *Materials Science* (*Medžiagotyra*) 13 (14) 2007: pp. 74 – 78.
5. **Jucienė, M., Vobolis, J.** Investigation of the Influence of Defects of Sewing Machine V-belt Drive on the Stitch Length *Tekstil* 53 (5) 2004: pp. 219 – 225.
6. **Chernenko, D. A.** Systematization of Design Parameters for Automated Embroidery and Modeling of Deformation System of "Fabric-Embroidery“ *Ph. D. Thesis* Orel, Russia, 2006: 132 p.
7. **Radavičienė, S., Jucienė, M.** Influence of Embroidery Threads on the Accuracy of Embroidery Pattern Dimensions *Fibers & Textiles in Eastern Europe* 20 (3/92) 2012: pp. 92 – 97.
8. **Bačkauskaitė, D., Daukantienė, V.** Investigation of Wear Behaviour of Sewn Assemblies of Viscose Linings with Different Treatment *Materials Science* (*Medžiagotyra*) 17 (2) 2011: pp. 155 – 159.
9. **Domskienė, J., Strazdienė, E.** The Effect of Bending Rigidity upon Fabric Behaviour In-Plane Compression *Tekstil* 54 (6) 2005: pp. 255 – 259.
10. **Klevaitytė, R., Masteikaitė, V.** Anisotropy of Woven Fabric Deformation after Stretching *Fibers & Textiles in Eastern Europe* 16 (4/69) 2008: p. 52 – 56.
11. **Klevaitytė, R., Sacevičienė, V., Masteikaitė, V.** Investigation of Fabrics Tensile Deformations *Materials Science* (*Medžiagotyra*) 12 (2) 2006: pp. 152 – 157.
12. **Dobilaitė, V., Jucienė, M.** Influence of Sewing Machine Parameters on Seam Pucker *Tekstil* 56 (5) 2007: pp. 286 – 292.
13. **Park, C. K., Lee, D. H., Kang, T. J.** A New Evaluation of Seam Pucker and its Applications *International Journal of Clothing Science and Technology* 9 (1/3) 1997: pp. 252 – 255. http://dx.doi.org/10.1108/09556229710168405
14. LST ISO 3801:1998. Textiles. Woven Fabrics. Determination of Mass per Unit Length and Mass per Unit Area.
15. LST EN 1049-2:1998. Textiles – Woven Fabrics – Construction – Methods of Analysis – Part 2: Determination of Number of Threads per Unit Length.
16. **Amirbayat, J., McLaren Miller, J.** Order of Magnitude of Compressive Energy of Seams and Its Effect on Seam Pucker *International Journal of Clothing Science and Technology* 3 (3) 1991: pp. 12 – 17.
17. **Daukantienė, V., Lapinskienė, M.** Influence of the Deformation Mode on Seam Slippage in Woven Fabrics *Fibers and Polymers* 13 (8) 2012: pp. 1086 – 1093.
18. **Dobilaitė, V., Jucienė, M.** The Influence of Mechanical Properties of Sewing Threads on Seam Pucker *International Journal of Clothing Science and Technology* 18 (5) 2006: pp. 335 – 345. http://dx.doi.org/10.1108/09556220610685276



*Presented at the National Conference “Materials Engineering’ 2012” (Kaunas, Lithuania, November 16, 2012)*