Svetlana Radavičienė,
Milda Jucienė

Kaunas University of Technology, Faculty of Design and Technologies, Department of Clothing and Polymeric Products Technology,
Studentų g. 56, LT – 51424, Kaunas, Lithuania
E-mail.: svetlana.radaviciene@stud.ktu.lt; milda.juciene@ktu.lt

Influence of Embroidery Threads on the Accuracy of Embroidery Pattern Dimensions

Abstract
In the production of garments, embroidery carries out decorative, informative, data transfer and other functions. The features of textiles, stitch density, filling type, area and other factors have a direct influence on embroidery quality. The objective of the paper was to investigate the influence of embroidery threads on the accuracy of embroidery pattern dimensions. For the investigations, embroidery threads with a different linear density, fibre composition, structure, and purpose were selected. Test samples were embroidered by two different filling types, with an embroidery width of 7, 6, 4, 3 and 2 mm, in warp and weft directions and in the bias direction. In all the cases analysed, the width and area of the embroidery pattern was established to decrease the width and area of the digital design. The greatest elongation values were observed during the embroidery process in the bias direction of the fabric.

Key words: *embroidery threads, embroidery process, embroidery pattern, textile.*

Introduction

In the production of garments, embroidery carries out decorative, informative, data transfer and other functions.

The main and common embroidery defects are the following: shifting of the embroidery portions compared to the digital design, the compression of filling along the stitch direction (***Figure 1.a***), the concavity or convexity of the embroidery patterns, filling quality, i.e. visible spaces between stitches, an uneven edge (***Figure 1.b***), the slippage of fabric yarns at the sides of the embroidered element (***Figure 1.c***), defects affecting the programme process ability during the embroidery process i.e. the responsiveness of embroidery equipment to shorten stitches, the concentration of many stitches in one place, the breaking of embroidery threads, cutting through of the textile with a needle, etc.

Embroidery quality is influenced by the embroidery process speed, stitch density, filling type, embroidery area, features of fabrics, lower and upper embroidery threads, etc. The assembling of textiles into a system by the sewing and embroidery processes has some similarities. In both cases threads are affected by factors of a similar character, i.e. the dynamic load, bending, friction, abrasion, etc. The textile is anisotropic and deformation thereof under the impact of certain forces varies depending on the fibre composition and mechanical properties of the fabric. The mismatch of embroidery pattern dimensions can cause the slippage of warp or weft threads affected by a force perpendicular to the direction of the embroidery pattern. It was found that the weaving and finishing of fabrics have an influence on the slippage of yarns at a seam [1 - 3]. Investigations showed that the new weave factor, *NPR* (calculated directly from the weave matrix), better describes the influence of the weave on slippage than other known weave factors (V. Milašius factor *P* or Ashenhurst factor *F*) [4]. The smallest yarns slippage is shown by fabrics with small repeats and short interlacements of warp and weft made by the following weaves: plain, twill, and sateen, as well as by weaves of short interlacements (in general) in one of the systems [5]. Investigations have illustrated that the mechanical properties of a fabric, and the formability, strength and stability thereof may be changed by employing different embroidery/stitching patterns [6, 7].

Fabric shrinkage after the sewing process may be affected by the relaxation processes observed in threads, resulting in their shrinkage, thereby creasing the fabric [8, 9]. Investigations have demonstrated that technological parameters of the sewing process such as the sewing speed, thickness of the sewing needle used, fabric rigidity, the number of layers of assembling fabrics, dynamic and thermal loads have a direct influence on changes in the mechanical properties of sewing threads of different fibre composition. The fibre composition of threads determines the different response of sewing threads to an external impact [10 – 17].

The accurate dimensions of an embroidery pattern are influenced by a stable stitch. Changes in the stitch length have been analysed during the sewing process. Friction forces occurring between the fabric and material of sewing machine gears during transportation as well as the technical parameters and technical condition of a sewing machine [18 - 21] were established to influence the stable length of the stitch.

Investigations have also illustrated that interaction of the fabric and sewing thread with sewing machine gears and sewing machine parameters have a direct influence on the occurrence of seam puckering [22, 23]. In the embroidery process, embroidery threads undergo deformations of multiple tensile, bend-

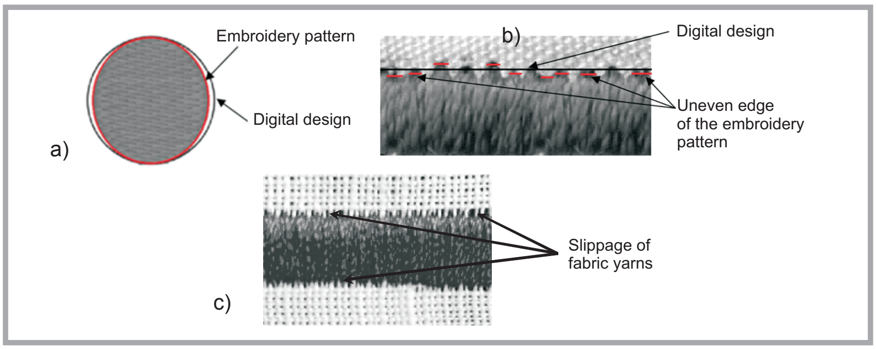

Figure 1. *Examples of embroidery defects: a) filling compression along the stitches, b) uneven edge of the embroidery pattern, c) slippage of fabric yarns.*

ing and friction. Embroidery threads of different structure, different fibre composition and linear density feature different mechanical properties. An analysis demonstrated that embroidery threads of different fibre composition experience different relaxation processes after the embroidery process, i.e. different values of residual elongation are observed [24].

The occurrence of embroidery defects is influenced by properties of both embroidery threads and textiles such as surface texture, stretch, surface density, flexibility, etc. [25].

The influence of the properties of fabrics and sewing threads, caused by technological parameters of the sewing machine, on seam quality and puckering is an issue widely investigated by researchers of various countries [8, 9, 16, 22]. The influence of the stitching pattern direction, place and density on the deformation behaviour of fabrics has also been analysed [6]. However, reports exploring the embroidery process and factors having an influence on embroidery quality are very few. The Russian scientist D. Chernenko investigated the assembling of textiles by the embroidery process; however, no detailed analysis of the influence of fabrics and technological factors on embroidery quality has been carried out [24]. Researchers of Alexandria University investigated the behaviour of embroidery articles in the process of wear in order to optimise the embroidery area size, types of threads and the type of the needle according to fabric thickness [26].

The assembling of textiles by the sewing and embroidery processes is carried out by employing the same type of a lockstitch. However, the purpose of assembling, requirements for the quality and properties of the final assembling are different. The analysis carried out demonstrated that the embroidery process, despite being important and popular, has not been widely investigated thus far.

The aim of this paper is to explore the influence of different embroidery threads on the accuracy of embroidery pattern dimensions.

Materials and methods

A diagram that illustrates the assembling of textiles into a system by by the embroidery process is presented in *Figure 2*. The system is made up of the following: fabric, upper embroidery thread, and lower embroidery thread. An appropriate balance of the tension of embroidery threads within a stitch (when a lower thread occupies 1/3 to 2/3) eliminates the possibility of the lower thread being visible on the front side of the embroidery area.

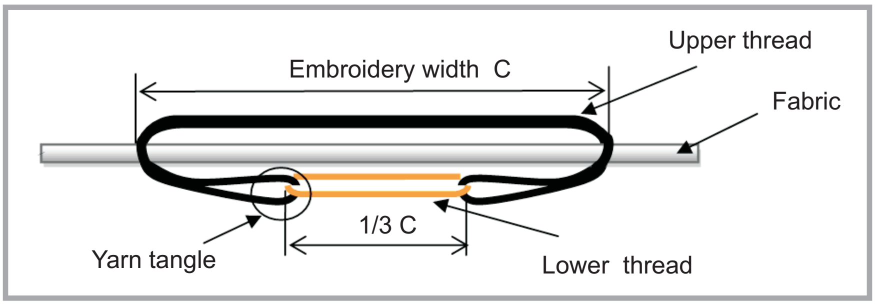

Figure 2. *Diagram of a portion of assembling textiles into a system by the embroidery process.*

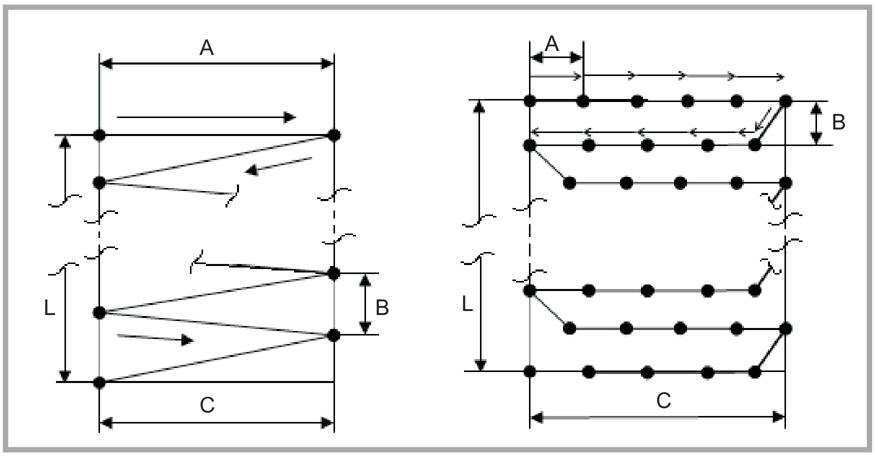

Figure 3. *Embroidery area formation diagram: a – filling type Z, b – filling type T, here, A – stitch length, B – distance between stitches, C – embroidery width, L – embroidery lentgh, legend: ▪▪▪▪▪▪▪ – embroidery contour; ▬▬ – embroidery thread, – needle insertion place, – formation direction of embroidery stitches.*

For analysis of the influence of embroidery threads on the accuracy of embroidery pattern dimensions, different threads of various linear density, fibre composition and structure were selected. For this purpose, embroidery threads were grouped into upper and lower embroidery threads. Along the length, the upper and lower embroidery threads featured the same thickness and met the quality requirements. The performances of the embroidery threads used for the investigations are listed in ***Table 1.***

For analysis, a plain weave linen fabric with the following performances was selected: surface density - 150 g/m^2, thickness - 0.32 mm, density in the warp direction - 19.9 cm^{-1}, density in the weft direction - 18.4 cm^{-1}, and with same linear density of warp and weft threads - 26.3 tex.

To carry out investigations, two different types of filling threads of the embroidery area were chosen:

1. **Z** – where each stitch is formed from one edge of the embroidery pattern to another (***Figure 3.a***). In this case, embroidery width C tallies with stitch length A.
2. **T** – when a row of stitches is formed from one edge of the embroidery pattern to another . At the end of the row, a short stitch in the direction of embroidery is made in order to preserve the rows of stitches parallel. Hereby rows of stitches do not overlap (***Figure 3.b***).

For embroidery pattern filling types Z and T, a width of the digital design C = 7, 6, 4, 3 and 2 mm and length thereof L = 60 mm were selected (***Table 2***). The digital design was generated by applying the Wilcom ES (Embroidery Software) 2006 Software Package. To carry out the investigations, a Barudan BEVT –

Table 1. Performances of embroidery threads.

Legend	Raw material	Purpose	Composition	Linear density, tex
ET1	100% PES	Upper thread	Two-ply yarn, multifilament	30.2
ET2	40% metallic, 60% CV		Combined, two-ply yarn, monofilament thread and multifilament thread	26.4
ET3	100% CV		Two-ply yarn, multifilament	27.8
ET4	100% cotton		Two-ply yarn	40.0
ET5	100% PES	Lower thread		24.7

Table 2. Plan of the experiment.

Embroidery thread legend	Filling type	Direction	Digital design width C, mm					Digital design length, mm
ET1	Z	Warp	7	6	4	3	2	60
ET2		Weft						
ET3		Bias						
ET4	T	Warp						
		Weft						
		Bias						

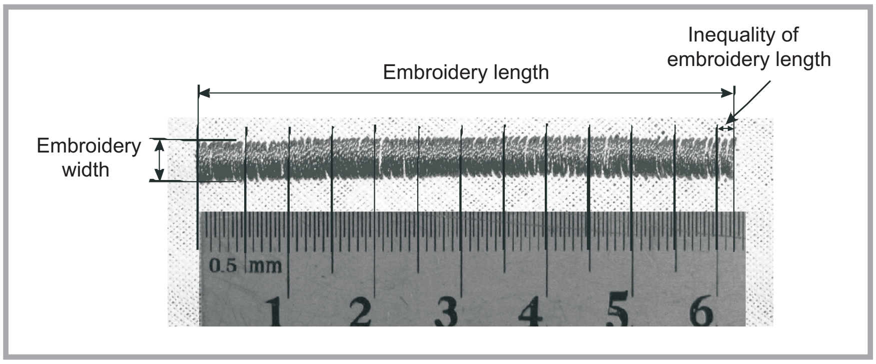

Figure 4. Diagram of the measure of geometrical performances (length and width) of the embroidery pattern.

Z901CA Single head 9 needles automated embroidery machine was used. A sewing process speed of 700 stitches per minute and stitch density B = 0.42 mm were applied. Applying a correctly balanced embroidery stitch (***Figure 2***), 6 test samples were embroidered in the warp and weft directions and in the bias direction of 45°.

The test samples were scanned by a Canon PIXMA MP 140 scanner, at a resolution of 600 dpi, placing a ruler beside in order to measure the scanning scale. For editing images and measuring the geometrical performances (length and width) of the embroidery pattern, the COREL DRAW X5 Software Package was applied. The embroidery pattern length was measured from the beginning to the end of the embroidery pattern. The embroidery pattern width was measured at the beginning, at the end and every 5 mm from the point where the embroidery pattern starts (***Figure 4***). The embroidery pattern area was measured by the Auto Cad 2007 Software Package. An accurate shape of the area contour was obtained via manual marking-out.

Averages of values of the research results as well as variation factors fluctuating from 0.19 to 8.99% were computed.

Analysis of results

An analysis of variation of the embroidery pattern width illustrated that the embroidery pattern width decreases in all cases. Embroidery with filling threads of type Z, when the embroidery width C = 7 mm, showed that embroidery with upper polyester embroidery threads ET1 in the warp and weft directions and in the bias direction results in the greatest narrowing value of the embroidery pattern width in respect of the digital design as compared to embroidery with the other threads analysed . In the warp direction, the greatest narrowing value of the embroidery pattern width, i.e. 21.4%, is demonstrated by embroidery with embroidery threads ET1, whereas in the weft and bias directions this value ranges around 18.6%, respectively. It should be pointed out that in the embroidery process with polyester and viscose embroidery threads, the embroidery pattern contour in the warp and weft directions is broader at the beginning and at the end compared to the middle portion (***Figures 5.a, 5.b***). Such behaviour could also be influenced by the shifting of fabric threads at the seam. Seam slippage is usually observed in fabrics, particularly in plain weave fabrics, twill weave fabrics, sateen, etc. Former investigations have demonstrated that the slippage of fabric threads at the seam is defined by the shifting of fabric threads due to the force applied perpendicular to the seam [1]. Narrowing of the embroidery pattern contour in the bias direction is also observed not to be as great as in the warp and weft directions . Compared to the digital design width, the lowest narrowing value of the embroidery pattern width, i.e. 11.4%, is demonstrated by embroidery with metallised embroidery threads containing viscose ET2 and cotton embroidery threads ET4, with filling type Z, when C = 7 mm (***Figure 5.a***).

The analysis illustrated that embroidery with filling threads of type T results in greater narrowing values of the embroidery pattern width in the case of embroidery with polyester embroidery threads ET1, when C = 7 mm. The greatest narrowing value of the embroidery pattern width in respect of the digital design width was observed for embroidery in the weft direction, i.e. 11.4%. In the warp direction, embroidery with viscose embroidery threads and cotton embroidery threads demonstrated the narrowing value of the embroidery pattern width to be 0.5 mm (7.1%), whereas embroidery with metallised embroidery threads containing viscose showed a narrowing value of the embroidery pattern width of 0.6 mm (8.6%) (***Figure 5.b***).

Such an uneven behaviour of embroidery threads could be influenced by different fibre compositions, structures and linear densities. Former investigations have illustrated that significant elastic elongations (with a reversible nature) are typical of polyester embroidery threads ET1. Reversible deformation is characteristic of polymeric bodies and has a relaxation nature. Reversible deformation disappears gradually after the removal of external forces. Embroidery threads featuring significant reversible elongation will shrink after a certain time from embroidery due to the relaxation processes occurring in threads, thereby decreasing the area and width of the embroidery pattern. It should be noted that the reversible elongation of viscose embroidery threads ET3 was not great, i.e. 3.2% [25].

It should also be pointed out that in most cases embroidery with filling types Z and T in the weft direction demonstrated the greatest narrowing values of the embroidery pattern width, which could be influenced by the lower fabric density observed in this direction.

Embroidery with filling type Z shows that a decrease in the digital design width leads, in many cases, to an increase in the percentage of the narrowing value of the embroidery pattern (***Figure 6***).

Embroidery with filling type T, all embroidery threads and all embroidery widths demonstrate lower narrowing values of the embroidery pattern compared to embroidery with filling type Z. This situation may be explained by the course of the embroidery type: in this case, a row consists of not one but a few stitches, and a needle and thread are inserted in the same place of the fabric repeatedly, therefore the fabric is slightly extended by the embroidery process. Thus, embroidery with filling type T results in a lower narrowing value of the pattern compared to embroidery with filling type Z.

It should be noted that almost all cases show an elongation of the embroidery pattern compared to the digital design. The greatest elongation values of the embroidery pattern were observed during the embroidery process in the bias direction of the fabric (***Figures 7.a, 7.b***, see page 96). This fact may be related to the uneven mechanical properties of textiles in different directions, i.e. the anisotropy . The anisotropy is determined by the structure of the textiles under consideration, the performances of threads, type of weave, density and nature of deformation.

It should be pointed out that no significant dependence of elongation values of the embroidery pattern on the fibre composition of threads was observed. However, embroidery in the bias direction of the fabric demonstrated the greatest elongation values of the embroidery pattern in all cases. The greatest elongation values were observed for the embroidery pattern embroidered in the bias direction of the fabric with threads ET1 and ET4 featuring a greater linear density compared to other embroidery threads.

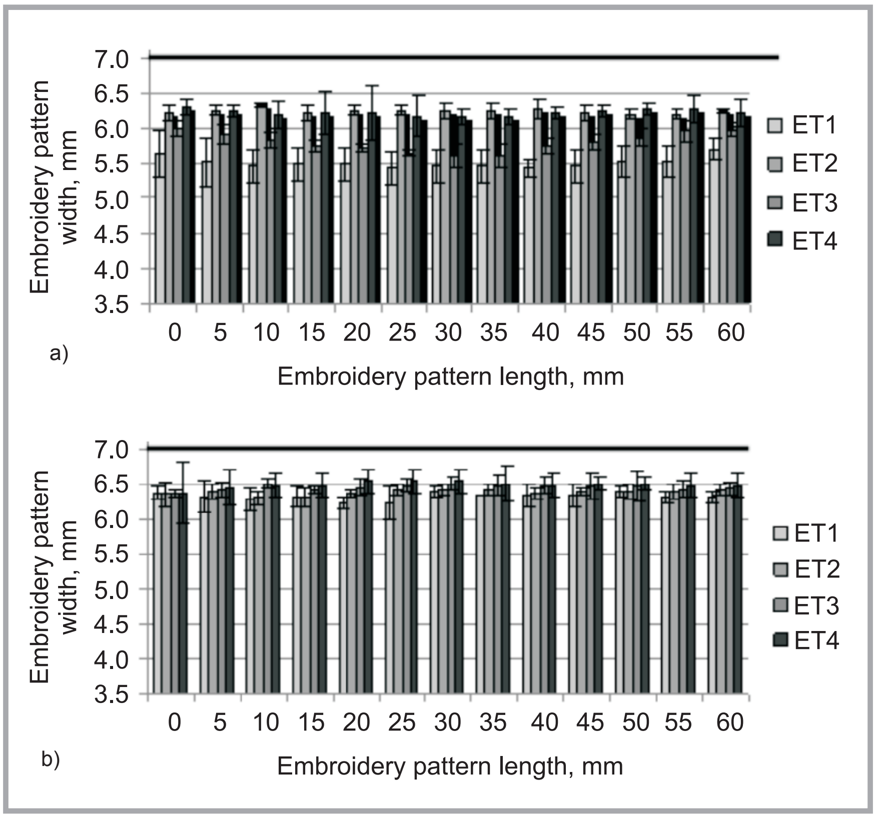

Figure 5. Embroidery pattern width in the warp direction: a) with filling type Z, b) with filling type T, when C= 7 mm.

An analysis of the investigation results shows that embroidery with filling type Z demonstrated in all cases a greater decrease in values of the embroidery pattern area in respect of the digital design area compared to embroidery with the same threads, the same embroidery widths and filling type T (***Figure 8***, see page 96).

In this situation, the greatest nonconformity of the embroidery pattern area with the programmed area was demonstrated by the embroidery with polyester embroidery threads. In some cases, the present nonconformity amounted to 27%.

Hence, the analysis of results with respect to the investigation of the influence of the properties of embroidery threads on the accuracy of embroidery pattern dimensions has illustrated that assessment of the influence of the properties of threads on final embroidery quality is very important, as well as the correct selection and combination of the lower and upper embroidery threads, forecasting the progress of the embroidery process, and anticipation of embroidery article behaviour after a certain time from the

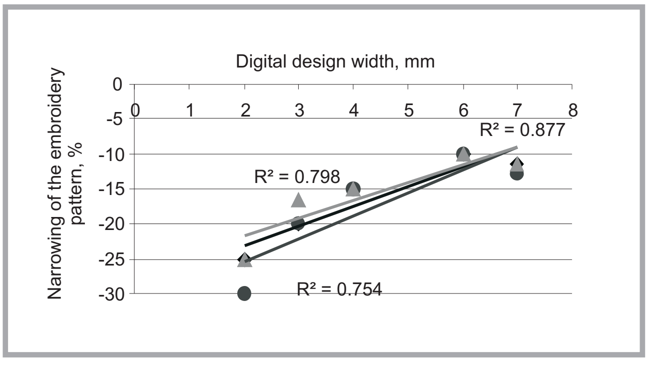

Figure 6. *Narrowing of the embroidery pattern during embroidery with threads ET2, filling type Z: ◆– in the warp direction ● – in the weft direction, ▲ – in the bias direction.*

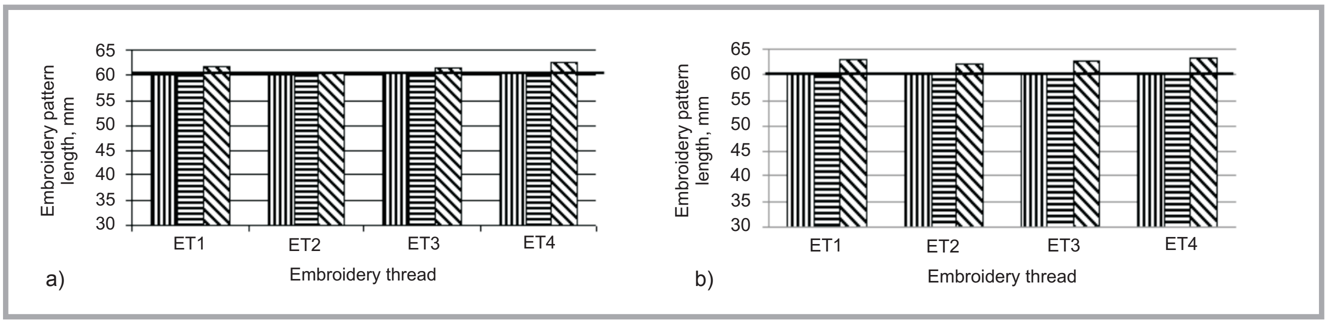

Figure 7. Embroidery pattern length: a) with filling type T, when embroidery width C = 7 mm; b) with filling type Z, when embroidery width C = 7 mm, ▥ *– in the warp direction ,* ▤ *– in the weft direction,* ▧ *– in the bias direction/*

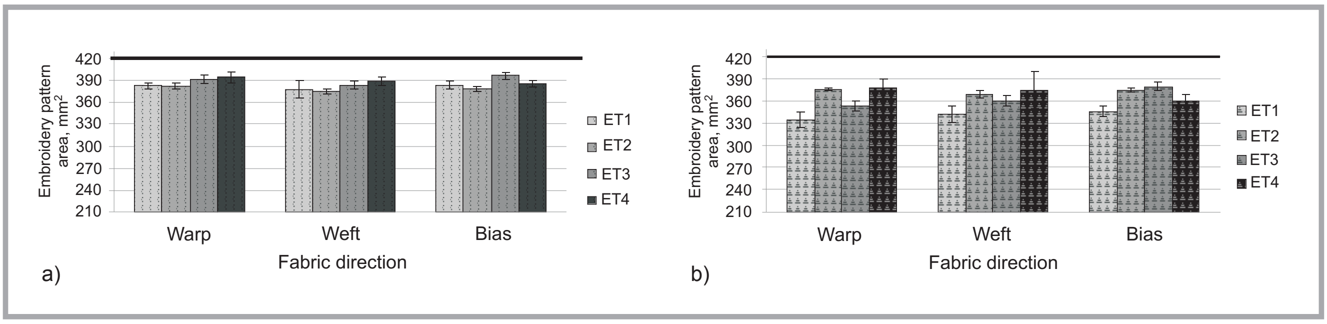

Figure 8. Variation in the embroidery pattern area during the embroidery of patterns types, when C = 7 mm: a – with filling threads of type Z, b – with filling threads of type T , ▒ *– filling type Z,* ▦ *– filling type T.*

embroidery as well as during final finishing and usage.

Conclusions

1. In all the cases analysed, the embroidery pattern width decreases compared to that of the digital design. Embroidery with polyester embroidery threads demonstrates a greater decrease in embroidery pattern width values compared to embroidery with the other embroidery threads.
2. In almost all cases, embroidery with the embroidery threads selected shows an elongation of the embroidery pattern compared to the length of the digital design. The greater linear density of embroidery threads results in a longer embroidery pattern.
3. The embroidery pattern area decreases compared to the digital design area. It should also be pointed out that embroidery with polyester embroidery threads demonstrates greater decrease values.
4. For embroidery, viscose embroidery threads are recommended as the non-conformity of the embroidery pattern dimensions with those of the digital design during embroidery with different filling types and applying different embroidery widths demonstrates the lowest percentage compared to embroidery with other embroidery threads. The correction of digital design dimensions considering the changes in values of embroidery pattern dimensions is advisable.

Reference

1. Bačkauskaitė D, Daukantienė V. Tensional Behaviour of Seamed Lining Fabrics. Book of Proceeding of the 4th International Textile. In: *Clothing & Design Conference*, October 05th to 08th 2008, Dubrovnik, Croatija, pp. 519 – 523.
2. Malčiauskienė E, Milašius A, Laureckienė G, Milašius R. Influence of Weave into Slippage of Yarns in Woven Fabric. *Materials Science (Medžiagotyra* 2011; 17, 1: 47 – 51.
3. Bačkauskaitė D, Daukantienė V. Investigation of Wear Behaviour of Sewn Assemblies of Viscose Linings with Different Treatment. *Materials Science (Medžiagotyra)*. 2011; 17, 2: 155 – 159.
4. Malčiauskienė E, Milašius A, Milašius R. Weave Factor for Seam Slippage Prediction of Unbalance Fabrics. *Fibers & Textiles in Eastern Europe* 2011; 19, 4(87): 101 – 104.
5. Frontczak-Wasiak I, Snycerski M, Cybulska M. Influence of Woven Fabric's Weave on Thread Slippage. *Fibers & Textiles in Eastern Europe*. 2002; 10, 3(38): 43 – 46.
6. Bekampienė P, Domskienė J. Influence of Stitching Pattern on Deformation Behaviour of Woven Fabric during Forming. *Material Science (Medžiagotyra)* 2010; 6, 3: 226 – 230.
7. Warrior NA, Rudd CD, Gardner SP. Experimental Studies of Embroidery for the Local Reinforcement of Composites Structures: 1. Stress Concentrations. *Composites: Science and Technology* 1999; 59, 14: 2125 – 2137.
8. Dobilaitė V, Jucienė M. The Influence of Mechanical properties of Sewing Threads on Seam pucker. *International Journal of Clothing Science and Technology* 2006; 18, 5: 335 – 345.
9. Dobilaitė V, Petrauskas A. The Method of Seam Pucker Evaluation. *Material Science (Medžiagotyra)* 2002; 9, 1: 209 – 212.
10. Rudolf A, Geršak J, Ujhelyiova A, Sfiligoj Smole M. Study of PES Sewing Thread Properties. *Fibers and Polymers* 2007; 8, 2: 212 – 217.
11. Midha VK, Kothari VK, Chatopadhyay R, Mukhopadhyay A. Effect of high-speed sewing on the tensile properties of sewing threads at different stages of sewing. *International Journal of Clothing Science and Technology* 2009; 21, 4: 217 – 238.
12. Geršak J. Rheological Properties of Threads – Their Influence on Dinamic Loads in the Sewing Process. *International Journal of Clothing Science and Technology* 1995; 7: 71 – 80.
13. Sundresan G, Salhotra KR, Hari PK. Strength Reduction in Sewing Threads During High Speed Sewing in Industrial Lockstitch Machine – Part I. Effect of Thread and Fabric Properties. *International Journal of Clothing Science and Technology* 1998; 10: 64 – 79.
14. Ajiki I, Postle R. Viscoelastic properties of Threads Before and After Sewing. *In-*

ternational Journal of Clothing Science and Technology* 2003; 15: 16 – 27.
15. Rudolf A, Geršak J. Influence of Sewing Speed on the Changes of Mechanical Properties of Differently Twisted and Lubricated Threads During The Process of Sewing. *Tekstil* 2007; 56, 5: 271 – 277.
16. Pogorelova M, Kamilatova O. The Influence of Deformation Pecularities of Sewing Threads on Seam Properties. *Tekhnologiya Tekstil'noy Promyshlennosti (Technology of Textile Industry)*, State Technological University of Kostroma, 2007; 304, 6: 19 – 22 (In Russian).
17. Midha VK, Kothari VK, Chatopadhyay R, Mukhopadhyay A. Studies on the Changes in Tensile Properties of Sewing Thread at Different Sewing Stages. *Textile Research Journal* 2009; 79 (13): 1155 – 1167.
18. Jucienė M, Vobolis J. Correlation between the Seam Stitch Length of the Sewing Garment and Friction Forces. *Material Science (Medžiagotyra)* 2007; 13, 14: 74 – 78.
19. Jucienė M, Vobolis J. Investigation of the influence of defects of sewing machine V-belt drive on the stitch length. *Tekstil* 2004; 53, 5: 219 – 225.
20. Jucienė M, Vobolis J. Dependence of Stitch Length along the Seam on External Friction Force Theoretical Anglysis. *Materials Science* (*Medžiagotyra*) 2009; 15, 3: 273 – 276.
21. Vobolis J, Jucienė M, Punys J, Vaitkevičius V. Influence of Selected Machine and Material Parameters on the Stitch Length and Its Irregularity. *Fibers & Textiles in Eastern Europe* 2003; 11, 3 (42): 50 – 55.
22. Dobilaitė V, Jucienė M. Influence of Sewing Machine Parameters on Seam Pucker. *Tekstil* 2007; 56, 5: 286 – 292.
23. Dobilaitė V, Jucienė M. Seam pucker Indicators and Their Dependence upon the Parameters of sewing machine. *International Journal of Clothing Science and Technology* 2008; 20, 4: 231 – 239.
24. Chernenko DA. *Systematization of design parameters for automated embroidery and modeling of deformation system of „fabric-embroidery".* Doctoral Disertation, State Technological University of Orel, Orel, 2006, p. 132.
25. Radavičienė S, Jucienė M. Investigation of Mechanical Properties of Embroidery threads. In: *5th International Textile, Clothing & Design Conference*, Dubrovnik, Croatija, 3 - 6 October 2010, pp. 494 – 499.
26. El Gholmy S, Bondok N, El Geiheini A. Optimization of embroidery design on denim fabrics. In: *5th International Textile, Clothing & Design Conference*, Dubrovnik, Croatija, 3 - 6 October 2010, pp. 821 – 826.

Received 25.02.2011 Reviewed 05.10.2011