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The Influence of the Properties of Embroidery Threads on Buckling of Fabric Inside of the Embroidered Element

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In production of garments, embroidery carries out a variety of functions, one of which is the aesthetic appearance of the product improvement. The resulting defects, are seen as a negative indicator of the product quality. The discrepancy of the embroidered element to the digital design in size is a defect, which is influenced by the embroidery threads, embroidery materials properties and process parameters. The fabric surrounded by the embroidery threads between adjancent needle penetrations inside of the embroidered element is compressed, buckling. The aim of this paper is to investigate the influence of the properties of embroidery threads on buckling of fabric inside of the embroidered element. For investigations specimens were prepared using different fibre composition, density and linear structure of the embroidery threads. Specimens were cut and photo-captured at the beginning, middle and end of the embroidered element. It was found, that different properties of the embroidery threads affecting on the different behavior of fabric inside of the embroidered element. The results of the investigations showed that the fabric inside of the embroidered element formed larger waves of buckling using the maximum elongation of the feedback exhibiting embroidery thread.
Keywords: embroidery threads, embroidered element, fabric, buckling.

1. INTRODUCTION

Improvement of aesthetical garment appearance, communication of informational content and assurance of safety represent the functions carried out by embroidery in production of garments. Assembling of textiles into a system by an embroidery process is similar to assembling by a sewing process. In both cases, assembling of textiles is carried out employing a stitch. In the course of embroidery and sewing processes, threads are affected by dynamic loads, multiple bending, friction, abrasion, etc. This results in damage of threads, decrease of strength of threads and deformation thereof. The results of the investigations showed that different response of sewing threads to an external impact is determined by fibre composition of threads [1–8]. Fabric shrinkage after the sewing process may be caused by the relaxation processes [9, 10] observed in threads and by properties of textiles [11]. Investigations showed that thread shrinkage after the sewing process, thus seam puckering may also be influenced by the parameters of the sewing machine, interaction of the sewing thread and fabric with sewing machine [12, 13]. Quality of the embroidered element may also be related to the stability problem of stitch length. Investigations of changes in stitch length during the sewing process have shown that technical condition of the sewing machine and technical parameters, friction forces occurring between the fabric and material of sewing machine during transportation have an influence on stable stitch length [14–16].

Occurrence of embroidery defects may be related to the properties of both embroidery threads and textiles. The results of the investigations showed, that different embroidery/stitching patterns may be employed to change mechanical properties of the fabric, strength, stability and formability thereof [17, 18]. Formability has been determined to define seam tendency to puckering [19]. Tension of threads during sewing compresses the fabric in the place of stitching. As soon as balance between tension of threads and compression of the fabric is achieved, force stress is decreased [19]. Inside of the embroidered element, the textile is compressed and buckled. Analysis of the results of the investigations with respect to buckling and compression of textiles has served as a basis for determining that a great influence on deformation behaviour is made by fabric structure, direction and mechanical properties [20–23].

The factors having an influence on the quality of the seam, i. e. properties of textiles and sewing threads, technological parameters of the sewing machine, etc., represent the issues widely investigated by researchers of various countries [7, 9, 10, 12]. An influence of stitching pattern direction, place and density on deformation behaviour of fabrics has been analysed [17]. However, sewing and embroidery process has several essential differences such as: the stitch balance, the stitch density, the transportation mechanism of fabric, usage of interlinings (backing materials), needles and etc. Assembling of textiles by an embroidery process has been

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investigated by the Russian scientist A. Chernenko [24]. In order to optimise embroidery process parameters, behaviour of embroidery articles during usage has been studied [25]. However, assembling of textiles into a system by an embroidery process and factors influencing the quality of the embroidered element has not been studied broadly.

The aim of the paper is to investigate the influence of the properties of embroidery threads on buckling of fabrics inside the embroidered element.

2. MATERIALS AND METHODS

For investigation of the influence of the properties of embroidery threads on buckling of fabrics inside the embroidered element, embroidery threads of different fibre composition, various linear density and structure were selected. By purpose, embroidery threads are grouped into upper and lower embroidery threads. Characteristics of embroidery threads are presented in Table 1.

Tensile testings of embroidery threads have been carried out in standard testing environment under the conditions established by standard ISO 139. Tensile characteristics of embroidery threads have been determined on the basis of Standard ISO 2062. Tensile testings have been carried out by the tensile machine "Zwick/Z005". Initial gauge length of the test sample was 250 mm, movement speed of clamps was 250 mm/min and initial pretension was 0.25 cN/tex. Analysis of mechanical hysteresis of sewing threads has been carried out by the tensile machine "Zwick/Z005". In the course of analysis, load of 2 N was suddenly applied to specimens and eliminated immediately, returning the lower clamp to the initial position. Distance between clamps was 250 mm, movement speed of clamps was 250 mm/min, 1 load cycle was performed. Against the obtained curves of mechanical hysteresis, parameters of embroidery threads such as total strain, elastic strain and remaining strain were determined. During analysis, by 10 specimens of embroidery threads of each sort have been tested, averages of values of research results as well as variation factors have been calculated. In all cases, variation factor did not exceed 7.7 %.

For analysis, a plain weave linen fabric was selected. Characteristics of the fabric were the following: fabric thickness was equal 0.3 mm, surface density was equal 150 g/m^2, density in the direction of warp was equal 19.9 cm^{-1}, density in the direction of weft was equal 18.4 cm^{-1}. Linear density of warp and weft threads was equal 26.3 tex.

During analysis, an embroidery area was filled forming each stitch from one edge of the embroidery pattern to another. An embroidered element with width C_t = 7; 6; 4 and 3 mm, and with length of 60 mm was used. The digital image was generated applying "Wilcom ES (Embroidery Software) 2006 Software Package". For investigations, automated embroidery machine "Barudan BEVT-Z901CA" was used and embroidery process speed of 700 stitches per minute was applied. For investigation by six specimens in the directions of warp and weft were embroidered (using different embroidery threads).

Specimens were photo-captured at the beginning, in the middle and at the end of the element. Specimen 3 (Fig. 1, a) was cut around the embroidered element leaving the cut edges of the fabric of ≈ 15 mm. At the beginning, in the middle and at the end, the element was cut just before fastening into clamps. The prepared specimen was fastened into clamps 5 and 6 of original structure, at distance $A \approx 2$ mm from the embroidered element to clamps (Fig. 1, a).

Specimens were photo-captured by digital camera "Olympus E620 1" with resolution of 4032 × 3024 pixels. For photography, lens "Sigma AF-MF Zoom Lens 105 mm F2.8 EX DG Macro" was used. Scheme of the embroidered element image is presented in Fig. 1, b. Camera 1 was fastened on the support, whereas the centre of the camera lens was located at the same level as the central line of specimen 3. Clamps 5 and 6 with specimen 3 were put to a special box in order to avoid the influence of external light sources. For photography, a background of contrasting colour, i. e. black in this case, was applied. Distance between specimen 3 and camera 1 is X ≈ 0.35 m. For illumination of the sample, two light sources 2 (power of a light source is 20 W) were used. Distance from light source $X_1' = X_1'' \approx 0.1$ m. Angle between the specimen and light propagation direction $\Phi' = \Phi'' = 45°$.

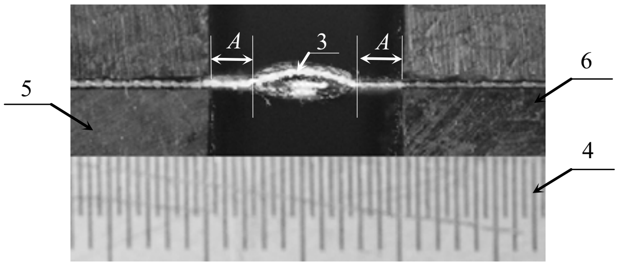
For measuring actual geometric parameters (embroidery width C_f, embroidery height D_f, wave height inside the embroidered element E_f, wave length inside the embroidered element F_f) of the embroidered element, "ImageJ Software Package" was used. The shape of the wave inside the embroidered element was obtained via manual marking-out applying "Corel Draw X5 Software Package".

Data obtained during investigations was processed statistically. The coefficient of variation of test results ranged from 0.40 % to 9.80 %.

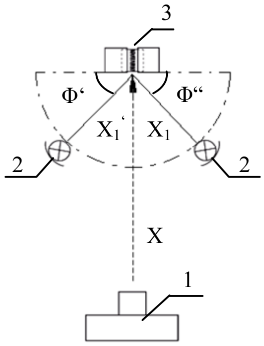
Table 1. Characteristics of embroidery threads

Mark	Raw material	Structure	Linear density, tex	Elongation, %	Total strain ε_b, %	Reversible strain ε_t, %	Remaining strain ε_l, %
SV1*	100 % PES	Two-ply yarn, multifilament	30.2	38.55	3.44	2.86	0.58
SV2*	40 % metallic, 60 % CV	Combined, two-ply yarn, monofilament thread and multifilament thread	26.4	30.73	3.98	3.16	0.82
SV3*	100 % CV	Two-ply yarn, multifilament	27.8	22.16	12.31	3.19	9.13
SV4*	100 % cotton	Two-ply yarn	40.0	5.07	1.36	0.79	0.57
SA1**	100 % PES	Two-ply yarn	24.7	20.77	7.32	2.95	4.37

* – is upper embroidery thread; ** – is lower embroidery thread.



a



b

Fig. 1. Illustration of fixing of the embroidered specimen (a) and photo-captured of the embroidered specimen by a digital camera (b): A – distance from the clamp to the embroidered element; 1 – digital camera; 2 – light source; 3 –specimen; 4 – ruler for image calibration; 5 – stationary clamp; 6 – mobile clamp

3. EXPERIMENTAL RESULTS AND DISCUSSION

To carry out analysis of geometric parameters of the embroidered element, the following distinctions with respect to measurement of the parameters shall be discussed.

An assumption is made that:

- theoretical width of the embroidered element C_t is equal to designed width of the digital image C_d;
- theoretical height of the embroidered element D_t is equal to thickness of the embroidery fabric and thickness of embroidery threads; theoretically, the fabric inside the embroidered element is straight;

theoretical amount of the fabric inside the embroidered element F_t is equal to theoretical width of the embroidered element C_t.

Analysis of the investigation results has demonstrated that actual parameters of the embroidered element are different from theoretical parameters in all cases. Theoretical and actual geometric characteristics of the embroidered element and measurement scheme thereof are presented in Figure 2.

Analysis of investigation results shows that actual height of the embroidered element D_f (Table 2) is greater than theoretical height of the embroidered element D_t.

Table 2. Height of embroidered element

Direction of fabric	Theoretical width of embroidery element C_t, mm	Embroidery thread			
		SV1	SV2	SV3	SV4
Warp	7	3.1 ±0.11	1.8 ±0.06	2.0 ±0.09	2.3 ±0.08
	6	3.1 ±0.04	1.7 ±0.06	1.8 ±0.01	1.9 ±0.01
	4	1.8 ±0.01	1.4 ±0.02	1.4 ±0.02	1.6 ±0.01
	3	1.4 ±0.13	1.3 ±0.06	1.3 ±0.05	1.5 ±0.14
Weft	7	2.9 ±0.06	1.7 ±0.06	1.6 ±0.03	1.9 ±0.02
	6	1.9 ±0.02	1.6 ±0.01	1.4 ±0.02	1.8 ±0.07
	4	1.3 ±0.02	1.2 ±0.01	1.2 ±0.01	1.6 ±0.05
	3	1.3 ±0.03	1.3 ±0.03	1.1 ±0.02	1.4 ±0.11

It shall be noted that height values of the elements embroidered with different embroidery threads demonstrate uneven distribution. In almost all cases, i.e. during embroidery of test samples in the directions of warp or weft of the fabric, the greatest height values D_f of the embroidered element were typical of the specimens embroidered with polyester threads SV1 and applying almost all embroidery widths, i. e. when width C_d of the designed digital image is equal to 7, 6, 4 mm.

Investigations demonstrated that great height values of the embroidered element were characteristic of the specimens embroidered in the directions of warp and weft with embroidery threads SV4. This fact may be related to linear density of cotton embroidery threads that is the greatest among all the threads selected for analysis, i. e. 40.0 tex. During embroidery in the direction of warp, the lowest height values of the embroidered element were demonstrated by the test samples embroidered with metallised embroidery threads SV2. Unevenness of height values D_f of embroidered elements may be determined by different structure of embroidery threads, different linear density, different fibre composition, etc. Former investigations have illustrated that significant elastic elongations with a reversible nature are typical of polyester embroidery threads SV1 [8]. Reversible deformation is characteristic of polymeric bodies. The deformation disappears gradually after removal of external forces. Due to the relaxation processes occurring in threads, embroidery threads featuring significant reversible elongation will shrink after certain time from embroidery, thereby causing buckling of the fabric inside the embroidered element.

Between embroidery stitches, being covered with embroidery threads, the textile is compressed and buckled inside the embroidered element. Inside the element embroidered with different embroidery threads, formation of waves with different height and different shape was observed. Formation of the waves (Fig. 3) with the greatest height values inside the embroidered elements embroidered with polyester embroidery was observed for almost all cases applying width C_t = 7, 6, 4 and 3 mm of the designed digital image. Formation of the waves with the lowest height values inside the embroidered element was demonstrated by the specimens embroidered with metallised embroidery threads containing viscose SV2. It

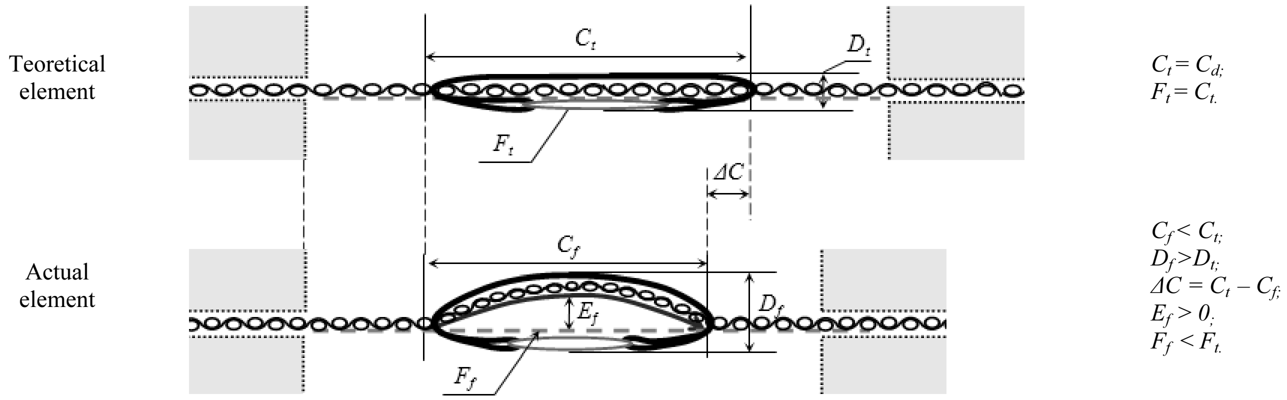


Fig. 2. Geometric parameters of the embroidered element and measurement scheme thereof

shall be pointed out that the actual wave height inside the embroidered element E_f was also influenced by the direction of the fabric embroidered (warp or weft). In all the cases analysed, the waves having formed inside the elements embroidered in the direction of weft were established to be lower compared to ones inside the elements embroidered in the direction of warp. The present situation is influenced by lower bending rigidity value in the direction of weft of the fabric. Formation of the wavewith certain shape and height may be caused by shifting (slippage) of fabric threads at the sides of the embroidered element and by different fabric density in the directions of warp and weft.

Analysis of the shapes of the curves presented (Fig. 4) has demonstrated that formation of the waves with the greatest height values E_f was characteristic of the elements embroidered with polyester embroidery threads in all cases. This fact may be explained by the great value of reversible strain of embroidery threads SV1. Investigations have demonstrated significant difference of the wave shape during embroidery with different embroidery threads and applying digital image width $C_d = 7$ mm. It should be noted that flat S-shaped waves have formed inside the embroidered elements embroidered with metallised embroidery threads containing viscose SV2 and with viscose embroidery threads SV3.

Pictures representing the shapes of the waves inside the embroidered elements under investigation are presented in Fig. 4 and Fig. 5.

It shall be noted, that decrease of digital image width in all cases, i. e. embroidery with all selected embroidery threads, leads to formation of low waves inside the embroidered element, whereas threads of the fabric are compressed forming an uneven contour of the wave (Fig. 5). The aforesaid situation was influenced by lower height values D_f of the embroidered element. Application of the lowest embroidery width C_t = 3 mm and embroidery with all selected embroidery threads in the direction of weft have demonstrated the same actual height values of the wave of the embroidered element, i. e. 0.1 mm. Analysis of actual height values E_f of the specimens embroidered in the direction of warp has shown that the greatest value was characteristic of the specimens embroidered with embroidery threads SV1.

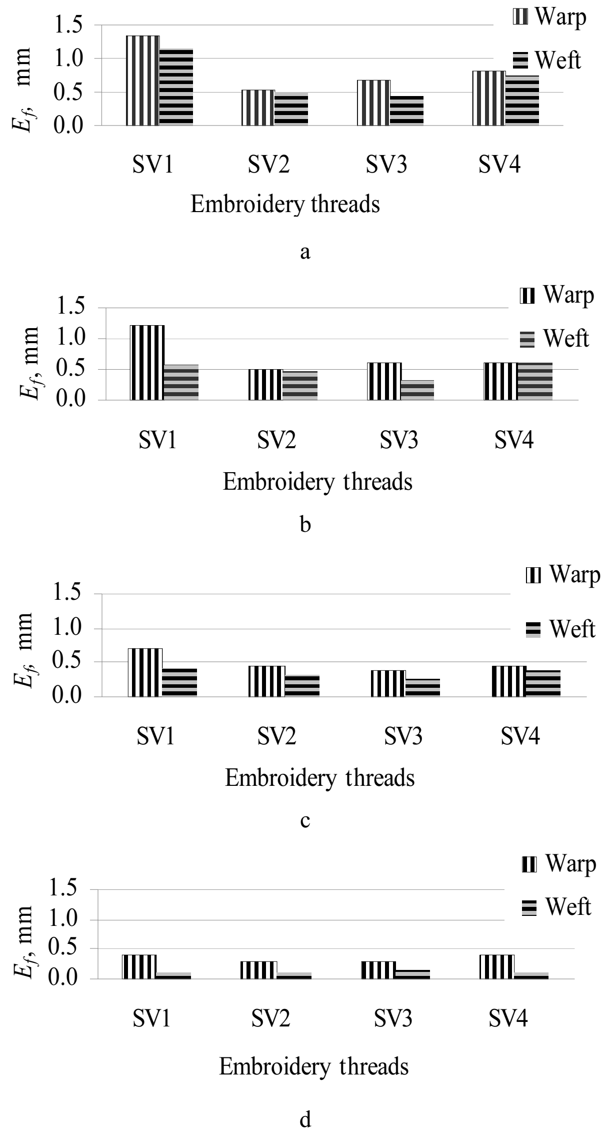


Fig. 3. Height of the wave inside the embroidered element: a – digital image width of 7 mm; b – digital image width of 6 mm; c – digital image width of 4 mm; d – digital image width of 3 mm

Buckling of the fabric inside the embroidered element has resulted in narrowing of the embroidered element. It

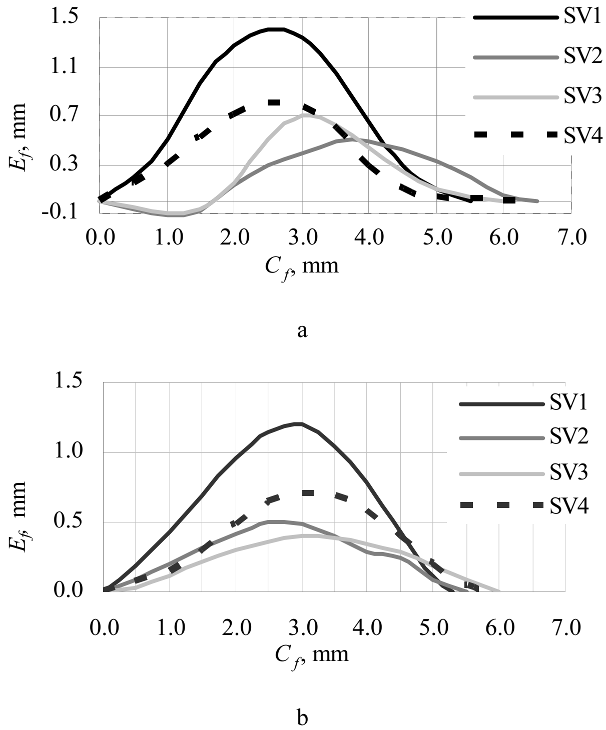


Fig. 4. The buckling wave curves, when C_d = 7 mm : a – in the direction of warp; b – in the direction of weft

shall be pointed out that actual width of the embroidered element C_f in all cases is lower than width of the designed digital image embroidered element C_t. Application of designed width of the digital image C_d = 7 mm has demonstrated the greatest difference, i. e. amounting to 24 %, between width values C_f of the embroidered element embroidered with embroidery threads SV1 in the direction of warp. The lowest difference between the aforesaid values has been shown by the embroidered elements embroidered with metallised embroidery threads containing viscose SV2 in the direction of warp, and it amounted to 12 %. It shall be noted that the greatest narrowing value, i. e. 25 %, with respect to width of the embroidered element embroidered with polyester threads has also been demonstrated by the element embroidered in the direction of weft, when digital image width C_d = 7 mm. Decrease of the actual width values C_f of the embroidered element could be influenced both by relaxation behaviour of embroidery threads and shifting of fabric threads at the seam. The present situation could be caused by different fabric density in the directions of warp and weft. Usually, seam slippage is observed in fabrics, particularly in twill weave fabrics, sateen, plain weave fabrics, etc. Previous investigations have demonstrated that slippage of fabric threads at the seam may be defined by shifting of fabric threads due to the force applied perpendicular to the seam [26].

Theoretical amount of the fabric inside the embroidered element F_t has been assumed to be equal to theoretical designed width of the embroidered element C_t. In the ideal case, actual width of the embroidered element C_f shall also be equal to C_t. Analysis of the results of the investigations, however, has demonstrated that C_f features lower values in all cases. The present behaviour of the embroidered element was influenced by a range of factors

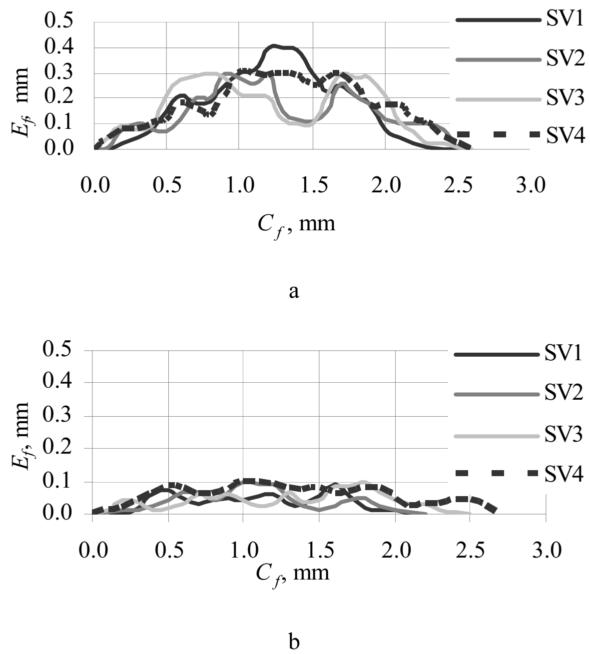


Fig. 5. The buckling wave curves, when C_d = 3 mm: a – in the direction of warp; b – in the direction of weft

such as relaxation processes in embroidery threads after the embroidery process, fabric density, bending rigidity, formability, etc. In all cases, actual amount of the fabric inside the embroidered element F_f has been established to feature greater values compared to actual width of the embroidered element C_f, and this difference amounted to 2 % – 12 %. It shall be emphasised that application of greater width of the embroidered element has demonstrated that the greatest shift of fabric threads inside the embroidered element is observed at needle insertion places, whereas the wave contour is almost even, i. e. no considerable compression of fabric threads has been noticed. Decrease of width of the embroidered element leads to significant increase of compression of fabric threads and to formation of the wave with complex configuration. Slippage of fabric threads at the edges of the embroidered element and compression of fabric threads (uneven wave contour) inside the embroidered element make accurate measurement of fabric amount inside the embroidered element very complicated.

4. CONCLUSIONS

In almost all cases, i. e. during embroidery with all embroidery threads selected for investigation in the direction of warp and weft, the greatest height values of the embroidered element have been demonstrated by the test samples embroidered with polyester threads SV1.

Application of the greatest width of the digital image (7 mm) has been established to demonstrate the greatest difference between width values C_f of the embroidered element embroidered with polyester embroidery threads in the direction of warp and weft and width values C_d of the digital image. Decrease of width values C_f of the embroidered element could be influenced both by relaxation behaviour of embroidery threads and shifting of fabric threads at the seam.

Waves with different height and different shape have been noticed to form inside the embroidery element embroidered with different embroidery threads. Formation of the waves with the lowest height values inside the embroidered element has been demonstrated by the specimens embroidered with metallised embroidery threads containing viscose.

The shape of the wave inside the embroidered element has also been influenced by cut direction of the fabric. In all the cases analysed, the waves having formed inside the elements embroidered in the direction of weft have been established to be lower compared to ones inside the elements embroidered in the direction of warp.

REFERENCES

1. **Rudolf, A., Geršak, J., Ujhelyiova, A., Sfiligoj Smole, M.** Study of PES Sewing Thread Properties *Fibers and Polymers* 8 (2) 2007: pp. 212 – 217.
2. **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* 56 (5) 2007: pp. 271 – 277.
3. **Ajiki, I., Postle, R.** Viscoelastic Properties of Threads before and after Sewing *International Journal of Clothing Science and Technology* 15 (1) 2003: pp. 16 – 27. http://dx.doi.org/10.1108/09556220310461132
4. **Geršak, J., Knez, B.** Reduction in Thread Strength as a Cause of Loading in the Sewing Process *International Journal of Clothing Science and Technology* 3 1991: pp. 6 – 12.
5. **Midha, V. K., Kothari, V. K., 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* 21 (4) 2009: pp. 217 – 238.
6. **Sundresan, G., Salhotra, K. R., Hari**, **P. K.** 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* 10 (1) 1998: pp. 64 – 79. http://dx.doi.org/10.1108/09556229810205303
7. **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* 304 (6 C) 2007: pp. 19 – 22 (in Russian).
8. **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.
9. **Dobilaitė, V., Petrauskas, A.** The Method of Seam Pucker Evaluation *Materials Science* (*Medžiagotyra*) 9 (1) 2002: pp. 209 – 212.
10. **Jucienė, M., Dobilaitė, V.** The Effect of Fabric Properties on Seam Pucker Indicator *Book of Proceeding of the 5th International Textile, Clothing & Design Conference, 03 – 06. 10*, Dubrovnik, Croatija, 2010: pp. 464 – 469.
11. **Dobilaitė, V., Jucienė, M.** Influence of Sewing Machine Parameters on Seam Pucker *Tekstil* 56 (5) 2007: pp. 286 – 292.
12. **Dobilaitė, V., Jucienė, M.** Seam Pucker Indicators and Their Dependence upon the Parameters of Sewing Machine *International Journal of Clothing Science and Technology* 20 (4) 2008: pp. 231 – 239.
13. **Jucienė, M., Vobolis, J.** Investigation of Stitch Length Change under the Conditions of Sewing Garment Inertia Motion *Tekstil* 55 (5) 2006: pp. 244 – 248.
14. **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.
15. **Jucienė, M., Vobolis, J.** Dependence of Stitch Length along the Seam on External Friction Force Theoretical Anglysis *Materials Science* (*Medžiagotyra*) 15 (3) 2009: pp. 273 – 276.
16. **Radavičienė, S., Jucienė, M.** Investigation of Mechanical Properties of Embroidery Threads *Book of Proceeding of the 5th International Textile, Clothing & Design Conference 03 – 06. 10*, Dubrovnik, Croatija, 2010: pp. 494 – 499.
17. **Bekampienė, P., Domskienė, J.** Influence of Stitching Pattern on Deformation Behaviour of Woven Fabric during Forming *Materials Science* (*Medžiagotyra*) 6 (3) 2010: pp. 226 – 230.
18. **Warrior, N. A., Rudd, C. D., Gardner, S. P.** Experimental Studies of Embroidery for the Local Reinforcement of Composites Structures: 1. Stress Concentrations *Composites Science and Technology* 59 (14) 1999: pp. 2125 – 2137.
19. **Kawabata, S., Niwa, M.** Clothing Engineering Based on Objective Measurement Technology *International Journal of Clothing Science and Technology* 10 (3/4) 1998: pp. 263 – 272.
20. **Domskienė, J., Strazdienė, E., Maladauskaitė, D.** The Peculiarities of Textile Behavioue Under In-Plane Compression *Proceedings of the International Conference Baltic Textile & Leather, Kaunas, Lithuania,* 2003: pp. 76 – 80.
21. **Domskienė, J., Strazdienė, E.** The Effect of Bending Rigidity upon Fabric Behaviour In-Plane Compression *Textil* 54 (6) 2005: pp. 255 – 259.
22. **Alamdar–Yazdi, A., Amirbayat, J.** Evaluation of the Basic Low Stress Mechanical Properties (Bending, Shearing and Tensile) *International Journal of Clothing Science and Technology* 12 (5) 2000: pp. 311 – 330. http://dx.doi.org/10.1108/09556220010377850
23. **Pavlinič, D. Z., Geršak, J.** Investigations of the Relation Between Fabric Mechanical Properties and Behaviour *International Journal of Clothing Science and Technology* 15 (3/4) 2003: pp. 231 – 240.
24. **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.
25. **El Gholmy, S., Bondok, N, El Geiheini, A.** Optimization of Embroidery Design on Denim Fabrics *Book of Proceeding of the 5th International Textile, Clothing & Design Conference, 03 – 06. 10*, Dubrovnik, Croatija, 2010: pp. 821 – 826.
26. **Bačkauskaitė, D., Daukantienė, V.** Tensional Behaviour of Seamed Lining Fabrics *Book of Proceeding of the 4th International Textile, Clothing & Design Conference,* 05 – 08. 10 Dubrovnik, Croatija, 2008: pp. 519 – 523.

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