The influence of weft density in fabric on the mechanical characteristics of sewn seams

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ABSTRACT – REZUMAT

The influence of weft density in fabric on the mechanical characteristics of sewn seams

The goal of this paper was to examine the influence of three different densities of fabric threads per weft (10, 17 and 25 m^{-1}) as well as three different yarn counts of weft yarn (20, 30 and 50 Tex) on the mechanical characteristics of sewn seams. To test the strength of seams, fabric samples were prepared according to the regulations of the ISO 13935-1 standard. The patterns were then sewn in the direction of the weft with the selected type of sewing seam, mark 1.01.01/301 according to the ISO 4916 standard. Using a video camera, it was determined that at one point the value of the force drops sharply, but then again it begins to grow to the point of breaking the seam, in all samples. This more precisely determines the point where the seam structure is significantly damaged. This phenomenon is analysed in detail in this paper, because in the available literature, only the end point of the break is taken as the strength of the seams. The obtained results show that the stitch strength values, for all samples, increase with the increase of: stitch density, thread density per weft and yarn per weft. The precise determination of these parameters, which affect the strength of the sewn seams, is a significant contribution for manufacturers of quality clothing because it gives them the opportunity to project the necessary production parameters in advance.

Keywords: *mechanical characteristics of seams, damage to sewn seams, structure and density of fabrics, yield point of the seam, breaking point of the seam*

Influența desimii firelor de bătătură din țesătură asupra caracteristicilor mecanice ale cusăturilor realizate

Scopul acestei lucrări a fost de a examina influența a trei desimi diferite ale firelor de bătătură (10, 17 și 25 cm^{-1}), precum și a trei tipuri diferite de finețe a firelor de bătătură (20, 30 și 50 Tex) asupra caracteristicilor mecanice ale cusăturilor. Pentru a testa rezistența cusăturilor, au fost pregătite probe de țesătură conform reglementărilor standardului ISO 13935-1. Modelele au fost apoi cusute în direcția bătăturii cu tipul de cusătură selectat, marca 1.01.01/301 conform standardului ISO 4916. Folosind o cameră video, s-a stabilit că la un moment dat valoarea forței scade brusc, dar apoi începe din nou să crească până la punctul de rupere a cusăturii, pentru toate probele. Acest lucru determină mai precis punctul în care structura cusăturii este deteriorată semnificativ. Acest fenomen este analizat în detaliu în această lucrare, deoarece în literatura disponibilă doar punctul final de rupere este considerat ca limita de rezistență a cusăturilor. Rezultatele obținute arată că valorile rezistenței cusăturilor, pentru toate probele, cresc odată cu creșterea: desimii cusăturii, desimii firelor de bătătură și finețea firului de bătătură. Determinarea precisă a acestor parametri, care afectează rezistența cusăturilor, reprezintă o contribuție semnificativă pentru producătorii de îmbrăcăminte de calitate, deoarece le oferă posibilitatea de a proiecta în avans parametrii de producție necesari.

Cuvinte-cheie: *caracteristicile mecanice ale cusăturilor, deteriorarea cusăturilor, structura și densitatea țesăturilor, limita de elasticitate a cusăturii, limita de rupere a cusăturii*

INTRODUCTION

When designing new high-quality clothing products, it is especially important to know the properties of textile materials and production conditions in order to obtain high-quality products in industrial conditions. The seam is one of the most important parameters of garments, because it joins pieces of fabric and gives the garment its final shape. The correct selection of fabric, sewing thread, and the type of seams greatly affects the comfort of the user and the aesthetic and functional requirements of the garment [1]. This area is extensively researched, providing a new approach for predicting weld quality and strength [2].

If the clothes are made of fabrics, it must be taken into account that each fabric is a complex material and that its structure affects its own properties. Therefore, many researchers are engaged in the analysis of fabric structure, which is considered one of the basic parameters that contribute to the dominant physical and qualitative properties of woven material [3]. In research, methods of evaluating the structure of woven material are given, weaving factors and factors of the integrated structure of fabrics are presented, and the differences and advantages of the mentioned factors are analysed [4]. Before fabric production, it is necessary to know how the

structure of the fabric affects the quality of the seam, i.e. the yielding of the threads in the seam [5].
The performance of seams and the quality of textile materials are critical factors that affect the end product and the end user. Therefore, it is of great importance to examine the effect of seam types, seam density and sewing direction on the quality of seams in terms of seam strength and seam yielding, as this determines the optimal sewing conditions [6]. Thus, this area attracts a lot of attention from researchers. For example, the influence of fabric thread density and seam structure on linen fabrics on seam yielding characteristics and seam strength is investigated [7, 8]; influence of seam properties by evaluating seam characteristics such as seam compression, seam thickness, seam bending behavior and seam surface friction [1]; complex dynamic interactions between fabric performance, sewing process parameters and seam puckering [9]; efficiency, strength and elongation of seams on cotton fabrics [10]; the influence of different sewing parameters, such as: type of sewing thread, type of seam, direction of the seam as well as stitch density on the strength of the seams [11]; influence of stitch density and seam class on moisture management properties in seams [12]; the influence of the yarn count of the sewing thread on the performance of different types of stitches, the strength of the stitches, etc. [13]; durability of clothing depending on the strength of seams, density of stitches, aesthetic appearance and puckering of seams on different fabric structures [14]; the influence of different stitch densities on achieving proper and adequate seam quality, which ultimately determines the overall quality of any garment [15]; the influence of the relationship between the types of fabrics, the fineness of the sewing thread, and the parameters of the sewing needle on the strength, efficiency and puckering of seams [16]; the influence of seam parameters, such as: seam strength, seam yielding, seam puckering and sewing thread breakage on the life of clothing [17]; the influence of deformation method, sample elongation, type of fabrics, direction of warp and weft of fabric and position of seams on yielding of seams [18]; resistance to yarn yielding in the seam in fabrics as an important factor for designing fabrics before their industrial production [19]; the influence of the raw material composition of fabrics, the fineness of the sewing thread and the parameters of the sewing needle on the characteristics of the clothing seam, i.e. seam strength, seam strength efficiency, seam puckering, seam stiffness, etc. [20]; reasons that lead to poor seam quality such as sewing thread breakage, fabric tearing, excessive seam yielding, or their combinations [21]; yield resistance of seams of unbalanced fabrics [22]; the appearance of the seam depending on the types used: sewing threads, fabrics and stitches [23].
From the available literature, it can be seen that the problems of sewing damage do not have a single solution that could eliminate all the damage on the seams found on the fabric. All established parameters affecting fibres, yarns, fabric construction, sewing thread, stitch types and sewing machines must be tested [24].
In all these studies, a large number of parameters affecting the quality of seams were examined. In all tests, breaking strength is taken as one of the key indicators of seam quality. The research in this paper led to the knowledge that the quality of seams is impaired even before their tearing, which is shown on the device for testing breaking strength.

MATERIAL AND METHODS

The paper examined the influence of different weft densities and yarn count on the mechanical characteristics of sewn seams. For the purposes of researching the mechanical characteristics of seams, which are used to join woven textile materials, different samples of cotton fabrics were made in industrial conditions on a “Vamatex” loom with a weft feeding system with grippers and an electronic threading machine. Loom specifications are stated in table 1.

Table 1

LOOM SPECIFICATIONS	
Characteristic	**Value**
Manufacturer	VAMATEX
Category	Vamatex Rapier Looms
Type	P1001ES
Nominal width (mm)	2100
Weaving speed (wefts/min)	330
Serial number	27664
Year of manufacture	1997

The samples were made on the same loom to avoid the influence of different machines on the production of the samples. From the company’s production program, an article with a raw material composition of 100% cotton in a 1/1 plain weave was selected for the production of samples for research, on which the existing fineness of the yarn for the warp of Tt 30 Tex and the density of the yarn for the warp of 23.3 cm^{-1} were kept for all samples. The yarn density per warp and weft was determined according to the EN 14971 standard. The yarn density per weft was changed in three values: 10, 17 and 25 cm^{-1}. For each of these weft densities, three finenesses of weft yarn were used: Tt 20 Tex, Tt 30 Tex and Tt 50 Tex. The fineness of the warp and weft yarn is determined according to SRPS ISO 7211-5 and SRPS F.S2.511 standards. The surface mass of the fabrics was determined according to the SRPS EN 12127:2014 standard for nine different samples of woven fabrics for testing.
To test the strength of seams, fabric samples were prepared according to the regulations of the ISO 13935-1 standard. In the direction of the warp, laboratory samples for all nine fabrics with dimensions of 350 x 700 mm were cut. Then, each of the samples is individually folded in half so that the longer side is parallel to the folded part. The patterns were then

Table 2

STITCH MACHINE PARAMETERS	
Parameter	**Value**
Manufacturer	Juki
Type	DDL-5550
Stitch type	301
Stitch density (stitches/cm)	2, 3, 3.5, 4 and 5
Sewing speed (stitches/min)	3,000
Needle fineness	Nm 90
Presser foot pressure (N)	2.8
Thread tension (N)	0.50

stitched in the direction of the weft with the selected type of sewing stitch mark 1.01.01/301 according to the international standard ISO 4916. The patterns were sewn on a universal sewing machine manufactured by Juki mark DDL-5550 with stitch type 301. Parameters that were set on the stitch machine are shown in table 2.

The same type of thread was used for sewing the tested samples with fineness od Tt 47.7 Tex, strength of 23.37N and breaking elongation of 19.17%. The thread is made of 100% polyester fibre, and the composition is specified by the manufacturer. The measurement of seam strength was performed on a dynamometer Tenso Lab 3, series 2512A of the Italian manufacturer Mesdan S.p.A. The dynamometer gives numerous values and draws the curve F-Ɛ (force-elongation). These measurement results were further analysed using appropriate software for data processing. In this way, at each point of the diagram, changes in the force values depending on the stretching were determined. Table 3 shows different samples of tested fabrics that were sewn with the type of sewing seam marked 1.01.01/301. In table 3, marking d_{wa} indicates the density of threads in the warp direction per 1 longitudinal centimetre, while d_{we} indicates the same but in the weft direction.

RESULTS AND DISCUSSION

The strength of fabric samples was measured in the warp direction. The seams are sewn parallel to the direction of the weft. This was done to determine the effect of different weft thread thicknesses on the yielding of those weft threads in the seam. The seams are sewn with different stitch densities. This was done to determine the effect of seam density on its strength. Based on the measurements and research on the influence of different fabric densities on the mechanical characteristics of seams, the obtained results are presented. Tables 4, 5 and 6 show the results of measuring fabric samples with weft densities of 25 cm^{-1}, 17 cm^{-1} and 10 cm^{-1}.

Figures 1 to 3 show force-elongation curves, which represent the comparative results of seam strength measurements of all samples sewn with stitch densities of 2 cm^{-1} and 5 cm^{-1}. The curves show the force values at the yielding points of the seam.

Figure 4 shows the correlation between the force at the yield point of the seam and the total breaking force of the seam for samples with thread density per weft of 25 cm^{-1}, 17 cm^{-1} and 10 cm^{-1}.

Difficulties in seam strength testing arise from various seam tear failures that can be classified as: fabric break, fabric break at clamp, fabric break at seam, sewing thread break, thread pull, or any combination of the above. The relevant test results are only those samples where a break occurred at the seam itself. Breaks in other places were not considered for analysis in this research. For an easier analysis of the test results, a video camera that recorded the sample during the test was used. By analysing the videos, it can be seen that at one point the value of the force drops sharply, but then starts to increase again to the point of breaking the seam. This phenomenon is registered by the sample testing instrument and plotted on the force-elongation diagram. This phenomenon is analysed in detail in this paper, because in the available literature, only the end point of the break is taken as the strength of the seams. However, when assessing the quality of a seam on a garment, it is

Table 3

DIFFERENT SAMPLES OF FABRICS SEWN WITH THE TYPE OF SEWING SEAM MARKED 1.01.01/301

Sample code	Weave structure	Yarn count, T_t (Tex)		Yarn type		Density		Mass ($g \times m^{-2}$)
		warp	weft	warp	weft	warp d_{wa} (cm^{-1})	weft d_{we} (cm^{-1})	
A	Plain 1/1	30	50	100 Co		23.3	25	207.36
B			30					165.16
C			20					128.24
D			50				17	150.61
E			30					129.29
F			20					107.14
G			50				10	128.24
H			30					111.36
I			20					96.59

Table 4

MEASUREMENT RESULTS OF FABRIC SAMPLES WITH A WEFT DENSITY OF 25 cm^{-1}					
Sample marking	Stitch density (cm^{-1})	Seam yielding		Breaking point	
		Elongation (%)	Force (N)	Elongation (%)	Force (N)
A	2	5.973	119	8.96	205
	3	7.284	168	8.622	221
	3.5	7.753	175	9.245	230
	4	7.604	188	8.201	239
	5	7.719	197	8.313	248
B	2	6.551	116	8.337	180
	3	6.392	121	7.879	197
	3.5	6.68	132	8.906	208
	4	6.838	156	8.176	215
	5	6.828	164	7.422	222
C	2	7.571	100	9.797	168
	3	6.113	100	8.052	175
	3.5	5.509	102	6.7	180
	4	5.658	132	6.998	187
	5	5.789	146	6.531	195

Table 5

MEASUREMENT RESULTS OF FABRIC SAMPLES WITH A WEFT DENSITY OF 17 cm^{-1}					
Sample marking	Stitch density (cm^{-1})	Seam yielding		Breaking point	
		Elongation (%)	Force (N)	Elongation (%)	Force (N)
D	2	6.522	124	8.152	182
	3	5.525	150	7.317	190
	3.5	6.67	160	7.856	202
	4	6.17	172	6.905	210
	5	7.136	197	8.474	220
E	2	5.352	88	8.028	165
	3	5.781	105	7.411	168
	3.5	6.392	123	7.73	172
	4	5.211	156	6.253	183
	5	6.551	157	7.146	191
F	2	5.525	80	6.869	138
	3	4.786	89	7.178	142
	3.5	6.65	102	8.867	150
	4	6.838	116	9.812	164
	5	6.7	121	7.891	171

important to determine that the seam is damaged to the extent that its appearance impairs the quality of the garment. This is exactly what happens at the point where the value of the forces drops sharply. Therefore, values of the F-Ɛ curve were followed in this paper. A uniform increase in force was observed in all samples up to a point where the force suddenly starts to decrease, and then the force increases again. That part of the curve, in this paper, for all samples, is defined as seam yielding. By reviewing the video footage, it can be seen that there is a significant disruption of the seam structure, but the tearing device continues to tear until the seam is completely torn. At the place of a sudden drop in the force value, seam damage occurs, which is mainly caused by the yielding of the fabric threads on the warp or on the weft in the seam itself, where these threads are held by the sewing thread.

The obtained results show that the values of the force at the point of yielding of the seam and the breaking force of the seam are affected by the stitch density. Namely, if we look at the values shown in table 4, for sample A, it can be seen that the force values increase during the yielding of the seam with an increase in stitch density. This happens because denser stitches strengthen the seam structure itself. This makes the seam more resistant to external forces. The values of the force at the point of yielding of the seam increase in samples B and C as well.

Also, in all samples, the breaking forces of the stitches increase with increasing stitch density. This happens because denser stitches, despite the damage to the seam at the point of seam yielding, still retain, to a certain extent, the remaining strength of the seam structure.

Table 6

MEASUREMENT RESULTS OF FABRIC SAMPLES WITH A WEFT DENSITY OF 10 cm^{-1}					
Sample marking	Stitch density (cm^{-1})	Seam yielding		Breaking point	
		Elongation (%)	Force (N)	Elongation (%)	Force (N)
G	2	5.352	98	8.028	169
	3	5.946	112	8.474	177
	3.5	5.658	117	7.891	185
	4	5.815	145	7.604	191
	5	6.59	161	7.938	196
H	2	4.906	67	8.176	142
	3	5.047	84	7.422	146
	3.5	5.955	114	7.742	152
	4	5.781	129	7.263	160
	5	6.104	132	7.295	168
I	2	4.473	69	6.859	117
	3	5.368	99	6.71	122
	3.5	5.674	96	7.765	131
	4	5.824	103	6.869	137
	5	5.195	119	6.828	147

In tables 5 and 6, the values for samples D, E, F, G, H and I are shown. For all these samples, the values of the force at the yield point of the seam and the values of the breaking force of the seam can be explained in the same way as for samples A, B and C. The obtained results show that the values of the force at the yield point of the seam and the breaking force of the seam are affected by the thread density per weft. Namely, for the same yarn count of the weft, which amounts to Tt = 50 Tex, sample A has a

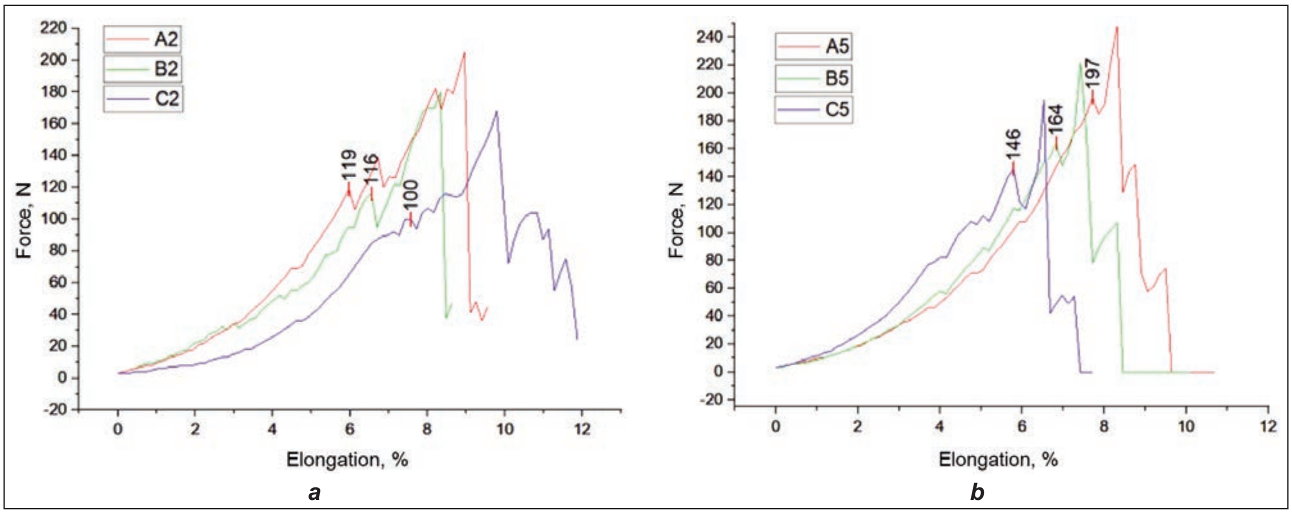

Fig. 1. Comparative results of the influence of different yarn counts of weft yarns at densities of 25 cm^{-1} and the number of stitches: *a* – 2 cm^{-1}; *b* – 5 cm^{-1} on the strength of the seam

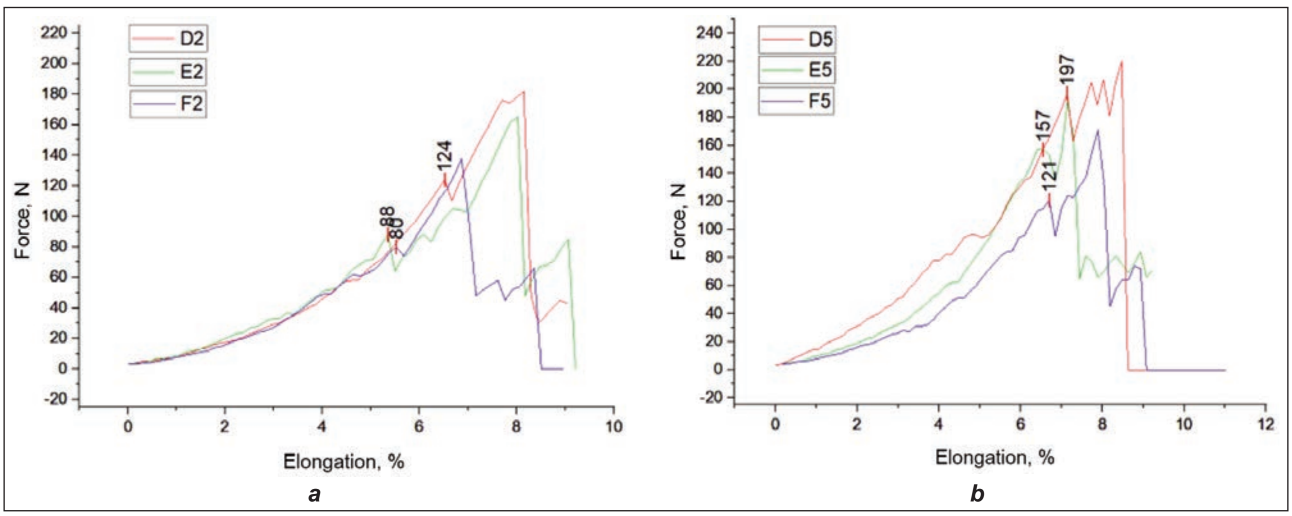

Fig. 2. Comparative results of the influence of different yarn counts of weft yarns at densities of 17 cm^{-1} and the number of stitches: *a* – 2 cm^{-1}; *b* – 5 cm^{-1} on the strength of the seam

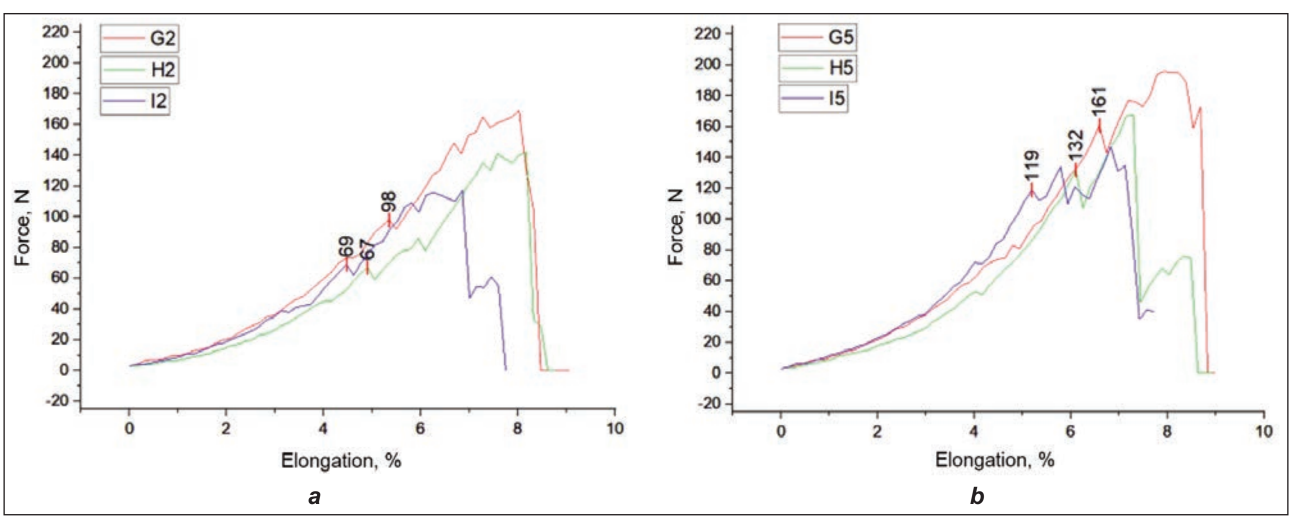

Fig. 3. Comparative results of the influence of different yarn counts of weft yarns at densities of 10 cm^{-1} and the number of stitches: *a* – 2 cm^{-1}; *b* – 5 cm^{-1} on the strength of the seam

density per weft of 25 cm^{-1}, sample D has a density per weft of 17 cm^{-1}, and sample G has a density per weft of 10 cm^{-1}. In terms of seam yielding and seam breaking force, it can be seen that the force values are the highest for all stitches in sample A. Then they decrease in sample D and are the least in sample G.

Deviation, in seam yielding, is seen only in sample A for stitch density of 2 cm^{-1}, where the force value is lower than the value for sample D. Also, for 5 cm^{-1}, the seam yield force values are the same for these two samples.

For a yarn count of Tt = 30 Tex, sample B has a weft density of 25 cm^{-1}, sample E has a weft density of 17 cm^{-1}, and sample H has a weft density of 10 cm^{-1}. In terms of seam yielding and seam breaking force, it can be seen that the force values are the highest for all stitches in sample B. Then they decrease in sample E and are the least in sample H. The deviation in seam yielding is seen only in sample B for a stitch density of 4 cm^{-1}, where the force value is the same as for sample E.

For yarn count of Tt = 20 Tex, sample C has a weft density of 25 cm^{-1}, sample F has a weft density of 17 cm^{-1} and sample I has a weft density of 10 cm^{-1}. In terms of seam yielding and seam breaking force, it can be seen that the force values are the highest for all stitches in sample C. Then they decrease in sample F and are the least in sample I. The deviation in seam yielding is seen only in sample C for a stitch density of 3.5 cm^{-1}, where the force value is the same as for sample F.

The obtained results show that the values of the seam yielding force and the breaking force are affected by the yarn count of the threads per weft. Namely, the yarn count of threads per weft is Tt = 50 Tex for sample A, Tt = 30 Tex for sample B and Tt = 20 Tex for sample C. In the case of seam yielding and seam breaking force, it can be seen that the force values are the highest for all stitches of sample A. Then they decrease in sample B, and they are the least in sample C. The same is true for samples D, E and F, as well as for samples G, H and I. From the obtained results, it can be seen that the weft with a larger cross-section more intensively resists thread yielding in the seam.

Figure 4 shows the correlation between the force at the yield point and the breaking force of the seam for samples with weft densities of 25 cm^{-1}, 17 cm^{-1} and 10 cm^{-1}. The results show that the correlation coefficient between the analysed parameters is the lowest for fabrics with the lowest weft thread density.

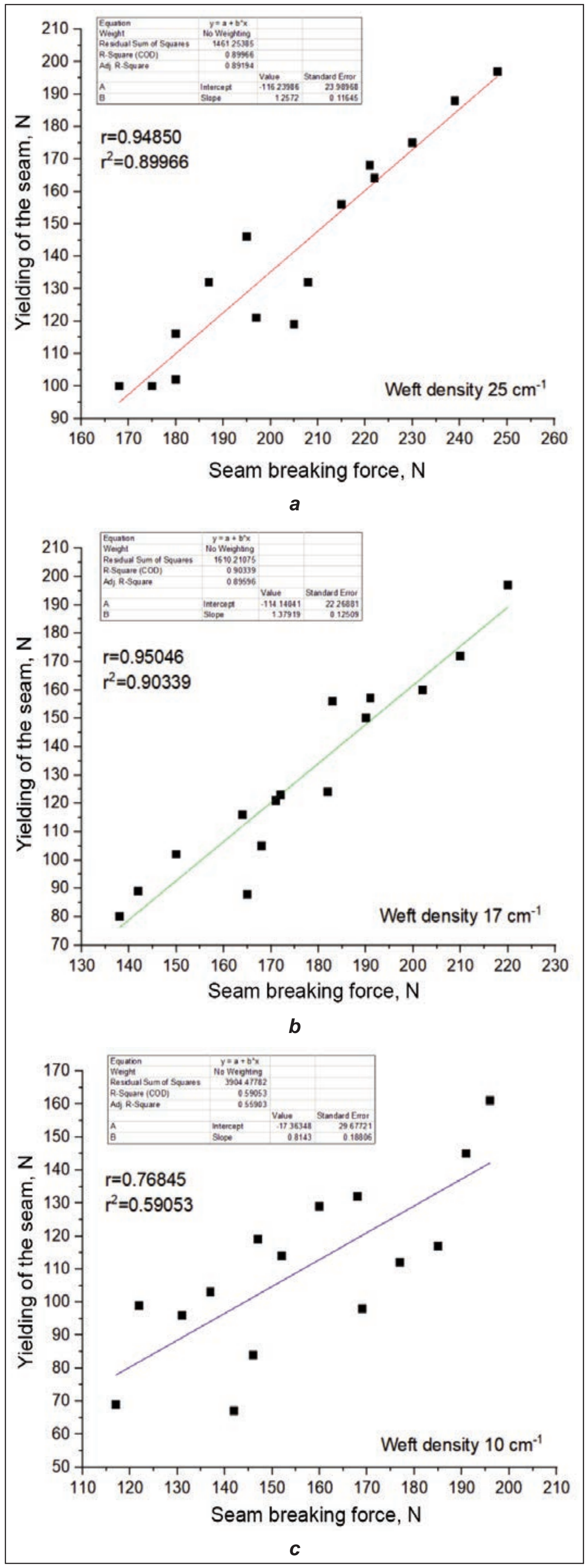

Fig. 4. Representation of the correlation between the strength at the yield point and the breaking force of the seam in fabrics with the density of weft wires: *a* – 25 cm^{-1}; *b* – 17 cm^{-1}; *c* – 10 cm^{-1}

CONCLUSION

This research elucidates the influence of different weft yarn counts and different weft densities on the mechanical characteristics of seams in 100% cotton raw material fabrics woven in plain weave. This paper aimed to investigate the influence of three different fabric densities per weft (10, 17 and 25 cm^{-1}) as well as three different weft yarn counts (20, 30 and 50 Tex) on the mechanical characteristics of sewn seams.

Using a video camera, it was determined that, in all samples, at one point, the force value drops sharply, but then starts to rise again to the point of breaking the seam. This more precisely determines the point where the seam structure is significantly damaged. With further seam loading, after this point of uniform increase in force, the force values decrease, and in most cases then increase. In this part, damage to the seams most often occurs in the form of dislocation of the warp and weft threads in the fabric in the area of the seams. This phenomenon is analysed in detail in this paper because, in the available literature, only the end point of the break is taken as the strength of the seams.

The obtained results show that the seam strength values, for all samples, increase with the increase of: stitch density, thread density per weft and yarn count of threads per weft. The precise determination of these parameters, which affect the strength of the sewn seams, is a significant contribution for manufacturers of quality clothing because it gives them the opportunity to project the necessary production parameters in advance. By knowing this data, it is possible to project in advance the intensity of the forces to which the seams can be subjected in clothing without impairing their quality.

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