The Influence of Stitch Density and of the Type of Sewing Thread on Seam Strength

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Abstract – **Having in mind the complex problems of technological process of sewing, as well as general demands for seams produced in garment production, this research should contribute the development of sewed seams breaking forces. Thus, many measurements of seam breaking forces have been conducted. These measurements enable us to define optimal strength of seam strength that improves the compliance of sewed seams parameters. This paper deals with the influence of the thread type and stitch density on the seam strength. The breaking forces and elongations at break were determined by the standardized method (SRPS 2062) and fabric (tape method) according to SRPS EN ISO 13934-1. Fabric samples used for seam testing were sewed by seam (1.01.01) and stitch type 301 with stitch densities 3, 4 and 5 cm^{-1}. Optimal seam strength (130.9 Ncm^{-1}) on the fabric T71, and at the same time the highest strength, has been noticed at the samples with seam line in weft direction with stitch density 5 cm^{-1}, sewed with polyester thread 20x2 tex count, while on fabric T71 that value is 115.9 Ncm^{-1}. According to obtained results, it can be concluded that stitch density (3 cm^{-1} ÷ 5 cm^{-1}) and the type of sewing thread (cotton and polyester, K1 ÷ K5) have great influence on defining seam sttrength, their inconsistency may lead to great differences in seam behavior.**

Keywords – Seam Strength, Seam Breaking Force

1. Introduction

The seam characteristics include: strength, elasticity, durability, safety, and appearance. Inconsistency of these characteristics can lead to significant differences in seam behavior and it also affects their deformation characteristics. During the process of clothes exploitation, sewed seams and materials are subjected to different loads, which are usually very variable, leading to different deformations. Seam strength should correspond to material strength in order to obtain product uniformity which will be capable to endure all forces which is that product subjected to [1,2]. During wearing, stitch bonded parts of clothing are subjected to different stresses. In order to improve seam endurance, seam elasticity should be a little stronger than material elasticity. Thus, the material would also mitigate the effect of the forces that affect clothing product during wearing. The seam elasticity depends on material that is stitch bonded, stitch type, seam type, stitch density, etc. Seam durability depends on its strength and on relationship between seam and material elasticity [3,4]. Seam safety depends mainly on sewing width, slippage of fabric wires as well as on stitch type. It is crucial to prevent its slitting and breaking during the wearing process.

2. Defining seam strength

One of the most important indicators of the sewed products quality is seam strength, which depends on different technical-technological parameters, such as: fabric type, type and sewing thread count, sewing needle count, stitch type, stitch density, seam type, etc. According to definition, strength and elasticity of sewed seam should be made in such a way that they do not allow seam breakage upon normal stresses of garment products, but also it cannot allow the fabric deformation [1,4]. The seam strength can be determined experimentally (by defining the force which the seam can withstand). Defining breaking force, the point when deformation, seam breakage and elongation at break occur, i.e. when the sewed sample changes its length, is based on measurements related to force and elongations under constant direct stress.

On the dynamometer, during the testing fabric samples with seam in transverse direction in relation to the seam, the stress (loading) q at mobile pirn clamp is evenly applied (Figure 1a). Furthermore, we can notice q′ reaction at fixed pirn clamp which is also evenly applied stress even to q (N/cm), i.e. q = q′.

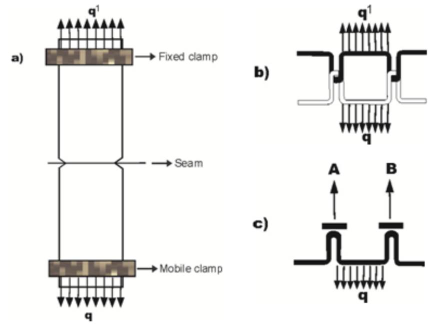


Figure 1. Seam stress at transverse tension a) sample on dynamometer, b) and c) application of the stress in a stitch

For the value of the applied force on the lower mobile pirn clamp, the loading *q* will be:

$$q = q' = \frac{F}{b} \text{ [N/cm]} \quad (1)$$

Where:
q – stress of the sample at mobile clamp (N/cm),
q' – the reaction to the stress q (N/cm),
F – drawing off force of lower mobile clamp (N),
b - the sample's width on the dynamometer(cm).

If we observe the application of the force in one stitch, 301 type, (Figure 1b), it is obvious that, ideally, threads will be stressed at elongation in each stitch. Due to the fact that q = q′, stitch stress will not cause the thread migration at entangle points. Because of that, we must define reactions that occur at side stitches (Figure 1c). In that case, if we apply the force of lower clamp movement and the theory of material resistance, we can find values of reaction forces A(N) and B(N), which would refer to the strength of thread built in the seam:

$$F_P = A = B = \frac{q \cdot d}{2} = \frac{F \cdot d}{2 \cdot b} \text{ [N]} \quad (2)$$

Where: d-stitch length (cm).

If we change the values for the stitch length that is d= b/n, in the last formula, the seam breaking force F, which is bonded with stitch type 301, can be expressed as follows:

$$F = 2 \cdot F_P \cdot n = 2 \cdot \frac{F_P \cdot b}{d} \text{ (N).} \quad (3)$$

Where:

F_P – thread breaking force (N),
n – number of stitches in sewed material sample

If we know the initial thread breaking force and the coefficient of strength loss of thread in the process of stitch making η, the previous formula is changed into:

$$F = 2 \cdot F_{P1} \cdot \eta \cdot n \text{ (N),} \quad (4)$$

Where: F_{P1} - initial thread breaking force (N),
η - Coefficient of strength loss of thread.

If we want to use this formula, it is necessary to determine the value of coefficient of strength loss of thread experimentally under the different conditions of stitch formation. On the basis of these experimental data relating to different fabrics sewed by lockstitch of different densities, the value of this coefficient is between 0,8 and 1,2.

Methods used for testing seam strength are based on testing thread slippage or thread breakage in the seam area. According to tt.Coats method, the seam breaking force is defined at one cm of seam length, i.e. by defining relative breaking force, in transverse direction in relation to seam line. The relative seam breaking force is calculated on the basis of average value of breaking force and seam length (the width of test tube used for testing) according to the expression [3,5]:

$$F_r = \frac{F}{b} \quad \left[Ncm^{-1}\right] \quad (5)$$

Where: F_r – relative seam breaking force (Ncm^{-1})
F – breaking force of test tube seam (N),
b – the width of sewed sample test tube (cm).

As the stitch density and breaking force of used thread have great influence on breaking characteristics if seams, it is necessary for this paper to introduce parameter called "seam strength factor", which is calculated according to the following equation:

$$f_k = F_P \cdot g_u \quad \left[Ncm^{-1}\right] \quad (6)$$

Where: f_k – seam strength factor (Ncm^{-1})
F_P – thread breaking force (N)
g_u – stitch density (cm^{-1})

Havin in mind the analysis of seam breaking forces testing and the instability of wire system of the fabric and thread system in the seam (due to the stress), it is necessary, for projecting sewed seams breeaking forces, introduce appropriate correction coefficients that would take this fact into consideration. In this case, correction coefficient k is defined throug the relationship between seam breaking force (F_r) and seam strength factor (f_k).

3. Experiments

Two types of fabrics were used for sample seam bonding (Figure 1), which were bonded by sewing machine (PFAFF company), class 461 (sewing speed 2500 min^{-1}), stitch type 301 (Figure 2) [6].

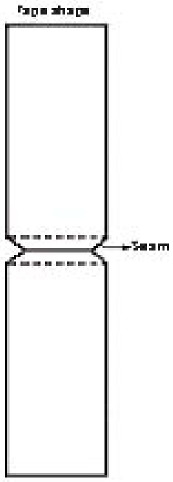


Figure 2. The shape of seam sample used for testing breaking characteristics

The machine is equiped with upper and lower transport, pedal and needle positioning and automatic thread cutting. Fabric samples, tape shape (two pieces), dimensions 185 mm x 50 mm, were sewed by the seam mark 1.01.01 (Figure 3) [7], at the distance of 10mm from the edge, with the needle 90 (normal needle point), and stitch density 3 cm^{-1}, 4 cm^{-1} and 5 cm^{-1}.

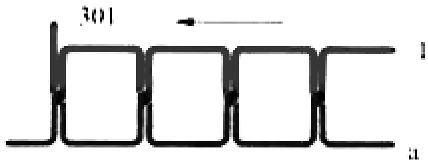


Figure 3. Lockstich type 301 (1- upper needle thread, a- lower thread-shuttle thread)

Breaking characteristics of threads were tested on dynamometer USTER TENSORAPID 4, according to standardized method SRPS 2062 [8], while breaking characteristics of fabrics were tested on dynamometer ZWICK, according to SRPS EN ISO 13934-1 [9]. The processing of research data was carried out by mathematical statistics.

4. Results and discussion

Table 1 presents basic fabric characteristics that were used for making seam samples, while table 2 presents the characteristics of used sewing threads.

Table 1. Basic characteristics of fabrics used for making seam sample.

Fabric characteristics	T21	T71
Weave	Five wired sateen weave	Five wired sateen weave
Raw material content (%)	50/50; PES/Co	50/50; PES/Co
Surface mass (gm^{-2})	280	315
Warp yarn count (tex)	25x2	25x2
Weft yarn count (tex)	25x2	25x2
Warp density (cm^{-1})	30	37
Weft density (cm^{-1})	22	26
Breaking force in warp direction (N)	1672	1727
Breaking force in weft direction (N)	1305	1298
Elongation at break in warp direction (%)	19	19
Elongation at break in weft direction (%)	15	15

Table 2. Characteristics of used threads for sample seams sewing.

Thread characteristics	K1	K2	K5	K3	K4
Raw material content (%)	100; Co	100; PES	60/40; PES/Co	100; Co	100;PES
Count (tex)	8.9x3	8.3x2	12.5x3	19.4x3	20x2
Number of twists for single wired yarn (m^{-1})	S 1267	S 1039	S 1026	S 845	S 681
Number of twists at plying (m^{-1})	Z 875	Z 1010	Z 780	Z 690	Z 727
Breaking force (cN)	787	1204	1264	2051	2091
Elongation at break (%)	4.74	14.22	22.95	6.11	13.94
Breaking force at loop (cN)	1072.2	1646.1	1805.3	2546.7	3080.3

Table 3 shows the results of testing breaking characteristics of sewed seams.

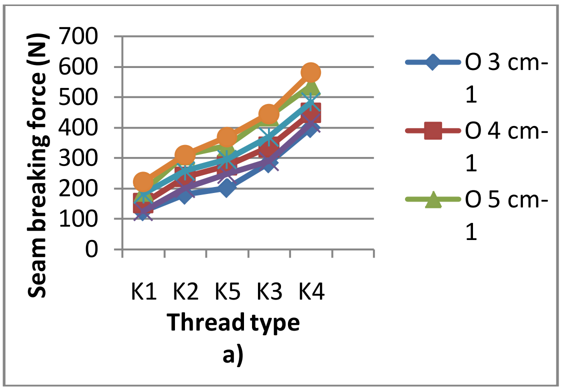
Table 3. Results of testing seam breaking forces on fabric T21:

Stitch density	Thread	Fabric T21							
		Seam line in warp direction				Seam line in weft direction			
		Seam breaking force	Relative seam breaking force	Seam strength factor	Correction coefficient	Seam breaking force	Relative seam breaking force	Seam strength factor	Correction coefficient
		F (N)	F_r (Ncm^{-1})	f_k (Ncm^{-1})	k	F (N)	F_r (Ncm^{-1})	f_k (Ncm^{-1})	k
3 cm^{-1}	K1	124.9	24.9	23.58	1.0559	125.1	25.0	23.58	1.0602
	K2	179.1	35.8	36.12	0.9911	199.9	39.9	36.12	1.1046
	K5	201.2	40.2	37.90	1.0607	246.7	49.3	37.90	1.3008
	K3	282.4	56.4	61.53	0.9166	288.3	57.7	61.53	0.9377
	K4	398.2	79.6	62.79	1.2677	413.4	82.7	62.79	1.3171
4 cm^{-1}	K1	150.8	30.2	31.44	0.9605	181.9	36.4	31.44	1.1578
	K2	236.8	47.4	48.16	0.9842	257.4	51.5	48.16	1.0693
	K5	274.2	54.8	50.56	1.0838	295.1	59.0	50.56	1.1669
	K3	334.8	66.9	82.04	0.8154	368.7	73.7	82.04	0.8983
	K4	447.2	89.4	83.64	1.0688	483.2	96.6	83.64	1.1549
5 cm^{-1}	K1	190.1	38.0	39.30	0.9699	221.8	44.4	39.30	1.1297
	K2	309.1	61.8	60.20	1.0265	310.1	62.0	60.20	1.0299
	K5	338.9	67.8	63.20	1.0727	368.3	73.7	63.20	1.1661
	K3	436.9	87.4	102.55	0.8522	444.2	88.8	102.55	0.8659
	K4	537.5	107.4	104.55	1.0272	579.4	115.9	104.55	1.1085

Table 4. Results of testing seam breaking forces on fabricT71:

Stitch density	Thread	Fabric T71							
		Seam line in warp direction				Seam line in weft direction			
		Seam breaking force	Relative seam breaking force	Seam strength factor	Correction coefficient	Seam breaking force	Relative seam breaking force	Seam strength factor	Correction coefficient
		F (N)	F_r (Ncm^{-1})	f_k (Ncm^{-1})	k	F (N)	F_r (Ncm^{-1})	f_k (Ncm^{-1})	k
3 cm^{-1}	K1	138.6	27.7	23.58	1.1747	156	31.2	23.58	1.3231
	K2	194.0	38.8	36.12	1.0741	203.8	40.7	36.12	1.1267
	K5	212.3	42.5	37.90	1.1213	254.5	50.9	37.90	1.3430
	K3	295.8	59.2	61.53	0.9621	325.9	65.2	61.53	1.0596
	K4	405.1	81.0	62.79	1.2900	416.9	83.4	62.79	1.3279
4 cm^{-1}	K1	160.0	32.0	31.44	1.0178	184	36.8	31.44	1.1704
	K2	247.3	49.5	48.16	1.0278	272.1	54.4	48.16	1.1295
	K5	265.8	53.2	50.56	1.0522	301.7	60.3	50.56	1.1926
	K3	353.9	70.8	82.04	0.8592	377.7	75.5	82.04	0.9202
	K4	538.8	107.7	83.64	1.2876	563.0	112.6	83.64	1.3462
5 cm^{-1}	K1	212.0	42.4	39.30	1.0788	234.3	46.8	39.30	1.1908
	K2	311.8	62.4	60.20	1.0365	334.0	66.8	60.20	1.1096
	K5	314.3	62.9	63.20	0.9952	371.3	74.3	63.20	1.1756
	K3	438.9	87.8	102.55	0.8561	464.8	93	102.55	0.9068
	K4	570.2	114	104.55	1.0903	654.7	130.9	104.55	1.2520

The graph shows the results of testing seam breaking forces according tables 3 and 4. These results are presented in figure 5.



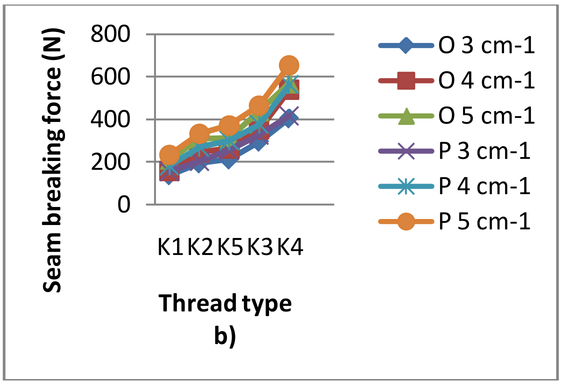


Figure 5. Changes of seam breaking forces depending on thread type and stitch density, a) for fabric T21 and b) for fabric T71 (O – seam line in warp direction, P – seam line in weft direction)

The analysis of obtained results of breaking forces shows:

- Increased stitch number improves the strength of analyzed seams, i.e. their breaking and relative breaking force. This improvement can be noticed for all samples, regardless to the type of used thread.
- Comparing fabrics T71 and T21, the bigger breaking force can be noticed at fabric T71, which is caused by fabric construction itself. As these fabrics are in the same weave and of the same raw material content, the seam breaking force is influenced by the density of weft and warp wires in the fabric (Table 1). The seams in weft direction have bigger breaking force comparing to seams in warp direction, which can be explained as a result of structural solution of woven fabric and its bigger breaking force in warp direction.
- Seam samples were sewed by PES threads (K2, K4) that, thanks to better mechanical characteristics, have bigger values of breaking forces in relation to samples sewed by cotton threads (K1, K3).

Statistic data processing proves the validity of results obtained by the influence of stitch density and sewing thread type on seam strength. This also confirms mutual dependance of seam relative breaking force, as dependance variable, and stitch density and sewing thread type, as independant variable, during which correlation coefficient R is determined.

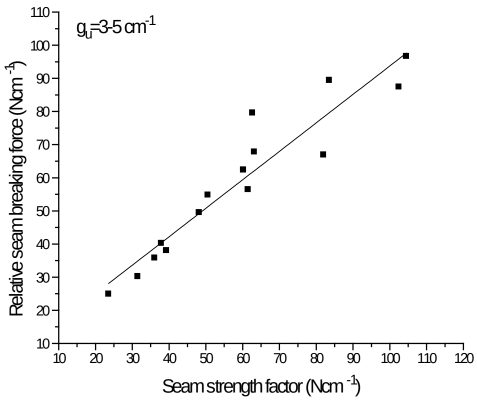
Table 5 shows correlative and regression analysis of results, which are obtained by testing relative breaking force of seam and stitch density for seam samples with used stitch 301 type.

Table 5. Correlation and regression analysis of results obtained by testing the influence of seam strength factors on relative seam breakin force.

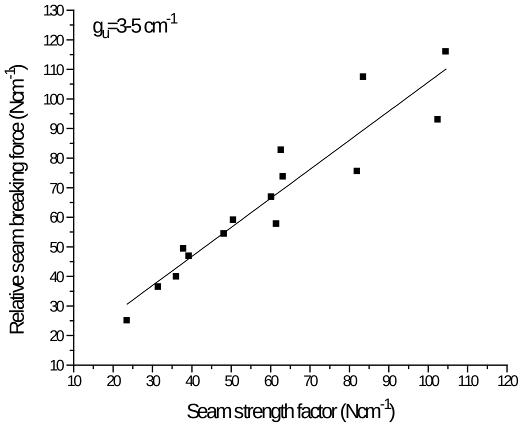
Seam sample	F_r (Ncm^{-1})	Statistical data of correlation and regression analysis (Y = A + B · X)				
		R	A	B	SD	$F_r = A + B \cdot f_k$
In warp direction of fabric T21	59.20	0.94927	4.93548	0.91715	7.86325	$4.93548 + 0.91715 \cdot f_k$
In weft direction of fabric T21	63.77	0.93973	8.52728	0.93374	8.79279	$8.52728 + 0.93374 \cdot f_k$
In warp direction of fabric T71	62.13	0.93021	4.58683	0.9725	9.93144	$4.58683 + 0.9725 \cdot f_k$
In weft direction of fabric T71	68.18	0.91797	6.87083	1.04624	11.70005	$6.87083 + 1.04624 \cdot f_k$

Note: F_r –average value of relative breaking force of seam force, R – correlative coefficient, A and B – coefficients of regression (linear) equation, f_k –seam strength factor (Ncm^{-1})

Linear regression of dependence between relative breaking force and seam strength factor is shown in figures 6 and 7. These regressions are valid for stitch density interval from 3 cm^{-1} to 5 cm^{-1}.

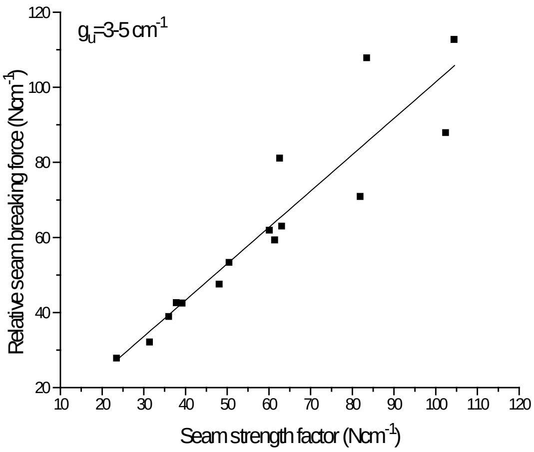


(a) seam in warp direction

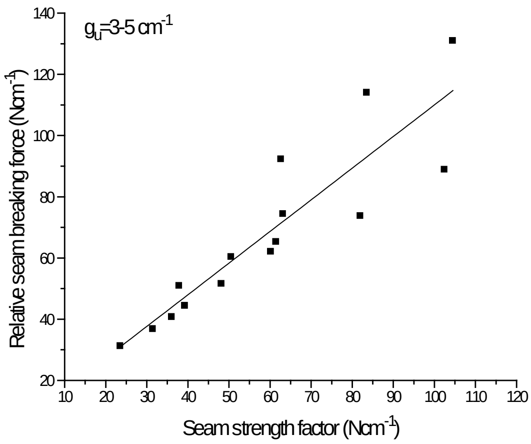


(b) seam in weft direction

Figure 6. Linear regression between relative breaking force and seam strength factor for samples used on fabric T21, a) seam in warp direction and b) seam in weft direction.



(a) seam in warp direction



b) seam in weft direction

Figure 7. Linear regression between relative breaking force and seam strength factor used for samples on fabric T71, a) seam in warp direction and b) seam in weft direction

On the basis of results shown in tables and graphs, it can be noticed that optimal seam strength on fabric T71 with 4 cm^{-1} has the value 70.8 Ncm^{-1} for the seam in the warp direction, and 75.5 Ncm^{-1} for seam in weft direction, with 5 cm^{-1} , it is 114 Ncm^{-1} for the seam in warp direction and 130.9 Ncm^{-1} for the seam in weft direction.

It acan also be concluded that change of seam breaking force (results referring to stitch densities in itnterval from 3-5 cm^{-1}) gains aproximative functional dependance. Higher values of stitch density cause damaging of above mention dependance.

Dependence correlation between parameters, in an interval, besides information on the type of dependence, can also be used for calculating values of one parameter for appropriate value of other one. Understanding dependence between some parameters of sewing process is of great importance in quality control and in the process of textile processing.

5. Conclusion

According to the results from this experiment, it can be concluded that seam strength depends on used fabric (structural and construction parameters), type of used thread (raw material content, count), as well as on stitch density per cm of the seam. Optimal seam strength (130.9 Ncm^{-1}) on fabric T71, which is at the same time the highest strength value, was seen at samples with seam line in weft direction with stitch density 5 cm^{-1}, sewed by poliester thread 20x2 tex count, while, for fabric T21, that value is 115.9 Ncm^{-1}.

Having analyzed dependency of relative breaking force and seam strength factor on stitch density, as well as having applied given correlative relationships, it can be concluded that there is connectivity between parameters. It is approved by the values of correlation coefficient. On the basis of this analysis, it is possible to predict seam-breaking force for stitch density interval from 3 cm^{-1} to 5 cm^{-1} for all above mentioned sewing threads.

Taking into consideration numerous parameters influencing the seam quality (type of material, type and thread count, seam type, stitch type, stitch denstiy, etc.) , there are many possibilities for combining them with different final characteristics of seams. The main purpose of these combinations is defining the appropriate technical-technological parameters of sewing process in order to improve productivity and seam quality.

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