PERFORMANCE OF GARMENT SEAMS STRENGTHENED WITH THERMOPLASTIC STITCHED RAINFORCED TAPE

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Abstract: *The purpose of this study was to evaluate the possibility of increasing seam performance by insertion of thermoplastic stitched reinforced tape in seam construction. The seam quality was evaluated by seam slippage, seam strength and seam efficiency. Two groups of specimens were investigated to determine the effect of thermoplastic stitched reinforced tape on seam quality. Specimens sewn according the standard were in the first group and specimens sewn by the industrial practice were in the second group. The obtained results show that with the insertion of thermoplastic stitched reinforced tape in the seam construction seam slippage strength increases in both groups of specimens, but the percentage of seam slippage increasing is higher for the group of specimens sewn according to the industrial practice. Seam efficiency is increased in the group of specimens sewn according to the industrial practice.*
Key words: SEAM STRENGTH, SEAM SLIPPAGE, SEAM EFFICIENCY

1. *Introduction*

Seam slippage, seam strength and seam efficiency are the seam quality criteria which define a seam stability. There are various factors that can affect seam strength and seam efficiency. Many previous studies [1, 2] showed that seam strength and seam efficiency depend on the interrelationship of fabrics, threads, stitch and seam selection, and sewing conditions, which include: needle size, stitch density, appropriate operation, sewing machine setup etc. [3-10].

Many researchers have investigated seam slippage in order to determine the causes of this phenomenon and to find techniques to reduce or eliminate it. The obtained results show that, higher weft density, cover factor, yarn count of fabric yarns and lower weave factor lead to seam slippage decreasing [11-13]. Seam slippage may also be affected by stitch type, stitch density, width of seam allowance, fabric's sewing direction, seam type and size, type of sewing thread and thread tension.

In most of previous studies, researchers in their experiments were focused on increasing fabric resistance on seam slippage and seam breaking by fabric structure modification. A lesser number of studies were focused on seam slippage and seam breaking decreasing in garment production process by sewing parameters optimization and seam characteristics adaptation.

Investigation of techniques to reduce seam slippage and increase seam strength and seam efficiency in the garment during production process is very important for the development of high quality textile products. For this purpose, we used stitched reinforced tapes for fabric structure strengthening in the sewing area. These tapes are support materials from the group of thermoplastic interlining, which are used to increase the stability of textile materials and support the form of garment. Also, they can be used to improve the garment seam performance. The purpose of this paper is to examine the impact of thermoplastic stitched reinforced tapes on the performance of the seams.

2. *Experimental part*

In this study, 3 lightweight woven fabrics were investigated. The characteristics of fabrics used are given in Table 1.

Table 1. *Characteristics of fabrics used in tests*

Fabric		F1	F2	F3
Composition		silk	pes	cot
Weave		plain	plain	plain
Yarn count (tex)	Tt_w	4	4	14
	Tt_{wf}	4	4	14
Yarn density (cm^{-1})	n_w	47	35	54
	n_{wf}	40	29	26
Yarn thickness (cm)	d_w	0.0075	0.0070	0.0135
	d_{wf}	0.0075	0.0070	0.0135
Cover factor		0.54	0.40	0.82
Surface density (g/m^2)		28	47	114

The surface density was measured according to the standard MKS BS EN 12127: 1998 yarn count according to the standard ISO 7211-5:1984 and MKS EN 1049-2: 2007 was used to determine yarn density. In the test, three thermoplastic stitched reinforced tapes produced by "Vantela"- Turkey were used, Figure 1. The first tape T1is a lockstitch reinforced tape in sewing direction, and the other two tapes have lockstitches in bias direction. The tape T2 is additionally reinforced with a chain stitch and the tape T3 is additionally reinforced with a weaving tape.

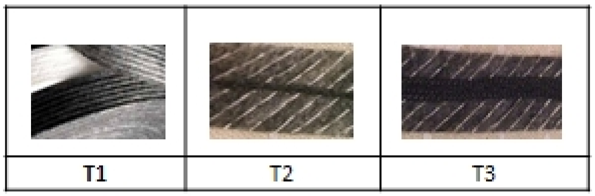


Fig. 1 *Types of thermoplastic stitched reinforced tapes*

The characteristics of the tapes are shown in Table 2. The fusing process was performed on a "Gygli" TPR8M751R machine at the temperature of 135^0C, 3 bar pressure for 13 seconds.

Table 2. *Characteristics of thermoplastic stitched reinforced tapes used in the tests*

	Tape T_1	Tape T_2	Tape T_3
Composition	100% PES	100% PES	100% PES
Surface density of thermoplastic interlining	45 g/m^2	45 g/m^2	45 g/m^2
Substrate	Non-woven fabric	Non-woven fabric	Non-woven fabric
Reinforcement	Stitches parallel to seam	Stitches in bias direction	Stitches in bias direction
Additional reinforcement	None	Chain stitch	Woven tape

Seam slippage strength was determined using fixed opening method according to the standard ISO 13936-1:2004 for 3mm seam opening. Seam strength was measured according to the standard ISO 13935-2:2004 and fabric strength was measured according to the standard ISO 13934-2:2004. The test procedure involves extension of two specimens, one without seam and one with seam, and the results are two force/extension curves, Figure 2. The horizontal distance between force/extension curves is seam opening as the result of seam slippage. The ISO 13936-1 standard measures seam slippage strength for fixed seam opening from 2-6mm. The measurement of seam slippage strength for 3mm seam opening was chosen as more rigorous criteria for high quality garment. If seam slippage strength is higher than 200N, then the result is reported as “no seam slippage”. All measurements were made with the tensile testing machine “Tinious Olsen” H5KT.

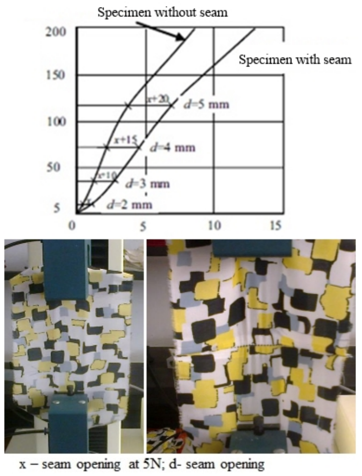


Fig.2 *Force/Extension curves for specimen without seam and specimen with seam*

Because the sewing parameters from the standard ISO 13936-1 do not correspond with the sewing parameters used in industrial practice, the seam slippage and the seam strength in two groups of test specimens were measured. In the first group, specimens were sewn according the standard, and in the second group specimens were sewn according the industrial experts instructions. According to standard, all type of fabrics were sewn together using the same sewing parameters, but according to the expert’s instructions, pieces of the testing fabric were sewn with different thread size and needle size number, in coordination to the weight and the composition of the fabrics, as shown in Table 3.

Table 3. *Sewing parameters for specimens from the two test groups*

	Fabric	F1	F2	F3
Sewing parameters according to ISO standard	Yarn count, tex	45±5	45±5	45±5
	Needle size, metric	90	90	90
	Stitch density, stitches/100 mm	50±2	50±2	50±2
Sewing parameters according to industrial practice	Yarn count, tex (Tkt)	18 (180)	21 (150)	30 (100)
	Needle size, metric	60	65	75
	Stitch density, stitches/100 mm	50	50	50

Legend: Tkt- thread ticket number

The only common parameter for these two groups was stitch density. Specimens were sewn in warp direction with a high speed sewing machine Juki DDL 9000b-s using polyester core-spun sewing threads.

3. *Results and discussion*

Thermoplastic stitched reinforced tapes were fused onto the seam area of testing specimens. Under the same conditions, specimens without thermoplastic tapes were prepared and tested. Obtained results for seam slippage strength, fabric strength, and seam strength and calculated results for seam efficiency are shown in Table 4 and Table 5, for two test groups of specimens. The results shown in Table 4 and Table 5 are mean values calculated from five specimens.

Table 4*. Fabric strength, seam slippage strength, seam strength and seam efficiency for specimens sewn according to standard*

Fabric	Fabric strength, N	Seam slippage strength, N	Cv, %	Seam strength, N	Cv, %	Seam efficiency, %
F1	88.7	28.46	25.0	65.54	3.98	73.93
F1/T1		34.39	43.0	61.78	13.5	69.65
F1/T2		30.75	18.9	57.02	3.60	64.28
F1/T3		30.24	11.5	48.32	9.25	54.47
F2	343	16.08	9.03	37.68	67.7	10.98
F2/T1		24.64	8.00	51.36	5.84	14.97
F2/T2		24.96	10.2	50.80	16.7	14.81
F2/T3		27.68	7.80	42.32	10.5	12.34
F3	182.4	83.8	19.3	167.28	4.82	91.71
F3/T1		94.76	23.3	171.04	0.05	93.77
F3/T2		95.16	11.9	167.64	5.07	91.91
F3/T3		91.72	22.9	161.88	5.55	88.75

Legend: F-fabric, T1, T2, T3- thermoplastic stitched reinforced tape

Table 5. *Fabric strength, seam slippage strength, seam strength and seam efficiency for specimens sewn according to industrial practice*

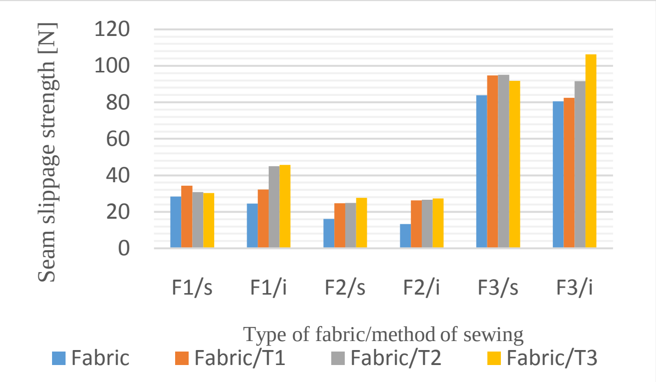
Fabric	Fabric strength, N	Seam slippage strength, N	Cv, %	Seam strength, N	Cv, %	Seam efficiency, %
F1	88.7	24.54	11.4	60.32	8.22	68.00
F1/T1		32.24	6.73	61.12	4.56	68.90
F1/T2		44.97	13.1	61.77	2.12	69.64
F1/T3		45.65	6.98	61.17	5.23	68.96
F2	343	13.28	5.34	20.96	2.17	6.11
F2/T1		26.24	9.18	87.83	11.5	25.61
F2/T2		26.60	8.00	94.2	11.1	27.46
F2/T3		27.28	12.2	102.9	10.4	30.00
F3	182.4	80.60	14.8	163.2	3.54	89.47
F3/T1		82.4	2.05	168.2	4.76	92.21
F3/T2		91.64	5.9	175.4	5.41	96.18
F3/T3		106.2	4.97	177.4	2.27	97.26

Legend: F-fabric, T1, T2, T3- thermoplastic stitched reinforced tape

According to the results obtained for fabrics specimens, there is seam slippage at all three fabrics in both groups of specimens. The group of specimens sewn according to standard has higher seam slippage strength, seam strength and seam efficiency compared to the group of specimens sewn according to the industrial practice, for all three fabrics.

When the seam is under transversal load the seam deformation occurs, in fact, the stitch and the fabric are deformed and seam slippage occurs due to fabric deformation. In a standardized group of specimens, the sewing thread has higher yarn count and it needs higher extension force for seam deformation.

With insertion of thermoplastic stitched reinforced tape in seam construction seam slippage strength increases in both groups of specimens (Fig. 3).



Legend: F1, F2, F3- fabrics; iI-specimens sewn according to industrial practice; s- specimens sewn according to standard; T1, T2, T3- tapes.

Figure 3. *Seam slippage strength of the fabrics with and without tape*

In the fusing process, substrate of interlining is fused onto the fabric by thermoplastic polymer. One part of the polymer remains on the fabric surface, fuses the substrate and the fabric, and the other part of polymer migrates into the internal fabric structure through the interspaces of warp and weft yarns. The result of the fusing process is a fabric with higher bending rigidity, thickness and more closed structure. Warp and weft fabric yarns are fused together, the fabric structure consolidated and yarn slippage resistance increases. On the other hand, from the literature review we have knowledge that higher bending rigidity and thickness have positive impact on seam slippage reduction [14].

Generally, fused specimens sewn according to the industrial practice have higher seam slippage strength. In order to make a comparison between the two test groups, we calculated the percentage of seam slippage strength increasing of fused specimens, Table 6. Results in Table 5 show that the percentage of seam slippage strength increasing is higher for fabrics of lower cover factor. The fabric F2 has the lowest cover factor $C_f= 0.40$ and the highest percentage of seam slippage strength increasing, *53.23 – 72.14%* in the standard test group of specimens and 97.59 - 105.42% in the group of specimens sewn according to industrial practice.

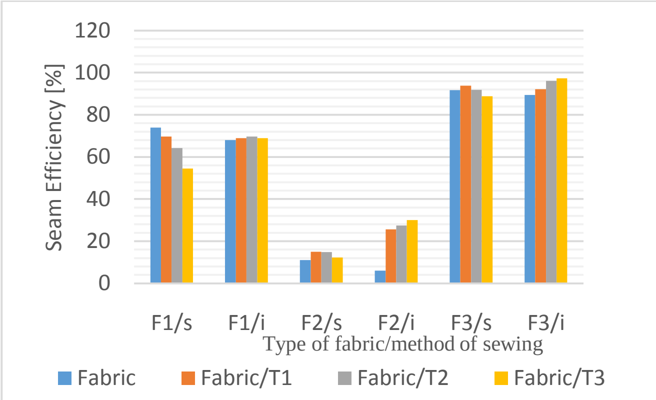
Table 6. *Percentage of seam slippage strength increasing*

Fabric	C_f	Method	Seam slippage strength increasing (%) Seam with tape T1	Seam with tape T2	Seam with tape T3
F1	0.54	S	20.8	8.04	6.25
		I	31.38	83.62	86.02
F2	0.40	S	53.23	55.22	72.14
		I	97.59	100.30	105.42
F3	0.82	S	13.07	13.55	9.3
		I	2.23	13.69	31.76

Legend: s- specimens sewn according to standard; i-specimens sewn according to industrial practice

The percentage of seam slippage strength increasing of fabric F1 with cover factor $C_f= 0.54$ is 6.25- 20.8% in the standard group of specimens, and 31.38 - 86.02% in the group of specimens sewn according to industrial practice. The fabric F3 has the highest cover factor $C_f= 0.82$ and the percentage of seam slippage strength increasing is 9.3-13.55% in the standard group of specimens, and 2.23-31.76% in the group of specimens sewn according to industrial practice. Fabrics with higher cover factor have greater coverage of the total fabric area with yarns [15], so a bigger part of thermoplastic polymer stays on the fabric surface and a smaller part migrates into the internal structure of fabrics. As the result of this, there is smaller mutual weft and warp yarns fusing and they have a greater ability to slip, while fabrics with smaller cover factor have a more open structure and gaps between warp and weft fabrics yarns through which the thermoplastic polymer migrates into the internal structure of fabrics and fuses weft and warp yarns together. Therefore, the effect of thermoplastic stitched reinforced tape is higher for fabrics with a lower cover factor.

With the insertion of thermoplastic tapes in the seam structure, results show that seam efficiency is increased in the group of specimens sewn according to industrial practice. In the standard group of specimens there is seam efficiency increasing for fabric F2 and fabric F3 fused with tapes T1 and T2 and seam efficiency decreasing for fabrics F1 and F3 fused with the tape T1. The results of seam efficiency are shown in Figure 4.



Legend: F1, F2, F3- fabrics; i-specimens sewn according to industrial practice; s- specimens sewn according to standard; T1, T2, T3- tapes.

Figure 4. *Seam efficiency of fabric with and without thermoplastic tape*

The increase in seam efficiency is due to the strengthening of the fabric structure in the seam area. The percentage of seam efficiency increasing is shown in Table 7. The group of specimens sewn according to industrial practice has a higher percentage of seam efficiency increasing compared with the group of standardized specimens.

Table 7. Percentage of seam efficiency increasing

Fabric specimen	Seam efficiency increasing (%) Seam with tape T1	Seam with tape T2	Seam with tape T3
F1 s	/	/	/
F1i	1.32	2.40	1.41
F2 s	36.34	34.88	12.39
F2 i	319.14	349.42	391.00
F3 s	2.25	0.22	/
F3i	3.06	7.5	8.7

Legend: s- specimens sewn according to standard; i-specimens sewn according to industrial practice

By increasing the fabric thickness and bending rigidity by fusing a thermoplastic tape, the needle penetration force (NPF) also increases during sewing. Also the needle penetration force increases proportionally with the needle size. A fabric with high needle penetration force and low fabric yarn mobility is more susceptible to damage during the sewing process. Because of the high fabric thickness and high needle penetration force, higher sewing thread size in the standardized group is subjected to greater friction during stitches formation, which conditionally reduces its strength. Fabric damage during the sewing process and lower thread strength causes seam efficiency decreasing of the fabric F1 in the standardized group. F1 is silk, lightweight fabric with lowest strength and in sewing it is susceptible to damage. Another indicator that the fabric F1 is subject to damage during the sewing process is a very low percentage 1.32-2.40% of seam efficiency increasing in the group of industrial practice.

From aforementioned explanation we can conclude that thermoplastic stitched reinforced tapes has greater effect for the seam slippage strength increasing than for the seam efficiency.

The influence of the thickness on the seam quality of fused specimens can be seen from the lower percentage of seam slippage strength increasing in the group of specimens sewn according to standard practice compared with the group of specimens sewn according to industrial practice.

4. *Conclusion*

In this study the effect of three types of thermoplastic stitched reinforced tapes on seam slippage and seam strength/seam efficiency were investigated. Three woven fabrics were tested and two test groups of specimens were prepared. In the first group specimens were sewn according to the standard, and in the second group specimens were sewn according the industrial practice.

According to the results obtained for fabrics specimens, seam slippage occurs at all three fabrics in both groups of specimens. The group of specimens sewn according to the standard has higher seam slippage strength, seam strength and seam efficiency compared with the group of specimens sewn according to the industrial practice, for all three fabrics. With the insertion of thermoplastic stitched reinforced tape in the seam construction seam slippage strength increases in both groups of specimens, but the percentage of seam slippage increasing is higher for the group of specimens sewn according to the industrial practice. The effect of thermoplastic stitched reinforce tapes on seam slippage is higher for fabrics with lower cover factor.

With the insertion of thermoplastic tapes in the seam structure, seam efficiency is increased in the group of specimens sewn according to the industrial practice. The percentage of seam efficiency increasing is from 1.32- 2.40 % for fabric F1, 319.14-391 % for fabric F2 and from 3.06-8.7% for F3, depending from type of tape used. In the standard group of specimens there is increasing of seam efficiency 12.39- 36.34% for fabric F2 and 2.25% and 0.22 % for fabric F3 fused with tapes T1 and T2, while seam efficiency was decreased for fabrics F1 and F3 fused with the tape T1. The effect of thermoplastic stitched reinforced tapes on the seam quality increasing is higher for the group of specimen sewn according to the industrial practice due to the selection of correct sewing parameters, seam thread and needle size. Generally, the results of measured properties for the group of specimens sewn according to the industrial practice have lower coefficients of variation, which means that these seams are more homogeneous and have higher quality.

All three tapes have the same effect, increase the resistance of fabrics to seam slippage, but the percentage of seam slippage strength increasing is different due to the different structure of the tapes. This will be the subject of further research.

5. *References:*

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