Sukran Kara*
Sevil Yeşilpınar

Comparative Study on the Properties of Taped Seams with Different Constructions

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Dokuz Eylul University,
Textile Engineering Department
Buca, Izmir, Turkey,
* e-mail: sukran.kara@deu.edu.tr,
e-mail: sevil.yesilpinar@deu.edu.tr

Abstract
Ready to wear end-products may be obtained by different assembling methods such as sewing, bonding, seam taping, welding and pressing fabrics. Currently, sewing is the most common method, but other techniques are improving day by day in accordance with the new application areas and new requirements from seamlines. Seam taping is an innovative alternative method that can improve the properties of seams. In this study, some essential properties such as the strength, elongation, thickness and air permeability of sealed samples with different constructions were compared. As taping constructions, ultrasonic bonding plus taping, sewing plus taping, and only taping methods were used. These methods were varied according to the taping temperature and speed. Also, only sewn and ultrasonically bonded samples were prepared as reference samples. In total, 20 different kinds of seam sealed samples were obtained as test materials. According to the results, taped samples were advantageous in terms of seam thickness and seam strength properties when compared to only sewn and ultrasonically bonded references. Especially, "only taped" samples were one step ahead among the all constructions. The air permeability of the taped seams decreased by a certain amount, but it is thought to be tolerable in a full garment.

Key words: *seam sealing methods, taped seams, seam strength, thickness, air permeability, seam constructions.*

Introduction

Sewing is the most common method to assemble ready-to-wear garment pieces which are cut in certain dimensions and shapes. With the improving technology, alternative assembling methods have been developed in order to fulfil the new requirements of seamlines and new application areas, such as technical textiles [1-5].

New assembling methods include different types of welding, adhesive bonding and pressing techniques [1, 2]. These techniques also contain their own sub-methods. For example, welding has 5 types: hot air welding, hot wedge welding, ultrasonic welding, radio frequency welding and laser welding. In the welding techniques, materials to be joined are heated somehow and thermoplastic materials melt. Heat may be obtained by the blowing of hot air, by contacting with a hot wedge [2], by application of a high frequency voltage [6] or laser [3], and by creating ultrasonic waves [5] for different welding methods. After heating, partly melted materials are compressed together, which causes an intermingling of polymers. A seam is formed as the materials cool and solidify [3]. All the welding methods have their own advantages and disadvantages in terms of strength, appearance, wearing comfort, flatness, stiffness, thickness, lightness and functionality [7-12]. The quality of a welded or bonded seam is dependent on the process parameters, such as temperature, pressure and the process speed [4, 7, 11-13].

For the welded seams; the fabric material itself may contain thermoplastic fibres or any additional materials such as tapes, powders, coatings, films, nets and coated threads may be used [7, 14]. Within the context of this study, we focused on seam tapes applied by the use of the hot air welding method.

Seam taping can be constructed differently according to the materials and application areas of the end-products. For some application areas, double-sided tapes may be used to make overlapped seams. In other techniques, tape can be sealed to a presewn fabric. This kind of sealing process can be especially preferred for waterproof seamlines. According to the taping method, the sealing process may cover one or more steps. Taping parameters such as the taping temperature, pressure and speed should be carefully selected in order to produce useful taped seams.

In the literature; the properties of sewn classical fabrics have been widely studied, and the effects of stitching parameters such as the stitch density, seam direction, sewing thread properties, sewing thread tensions, sewing needle fineness, fabric type, washing etc. on the seam strength and seam slippage of sewn fabrics have been evaluated in detail [15-29]. Also, there have been some studies which subjected alternative assembling methods, such as taping, bonding, ultrasonic welding and other welding techniques to analysis. For example, Kuo et al. used hot-melt, pressure-sensitive adhesives to bond nylon fabrics without sewing and investigated the adhesion of the bonded systems [8, 30]. Beaudette and Park compared the thermal properties of garments containing taped seams (using double sided adhesive film), overlock seams and flatlock seams [9]. Bahadir and Jevsnik optimised the hot air welding process parameters for the formation and electro-conductive properties of textile transmission lines [13]. Golomeova and Demboski found that the insertion of a thermoplastic reinforcing tape in the seam generally increased the seam strength and efficiency, and decreased seam slippage [31]. Korycki and Szafranska studied the theoretical optimisation of material thickness for the coupled heat and mass transport problem of seams sealed with tapes [32]. Mikalauskaite and Daukantiene researched the bonding strengths of laminated knitted and woven fabrics which were seamed via adhesive tape [33]. Shi et al. studied the effect of ultrasonic welding parameters on the waterproofness, tear force and shrinkage of ultrasonic welded hot air taped waterproof samples [34]. Irzmanska et al. evaluated the mechanical properties of ultrasonically spot welded textile composites to be used for protective footwear [35]. Grineviciute et al. investigated the seam strength and waterproofness of sewn

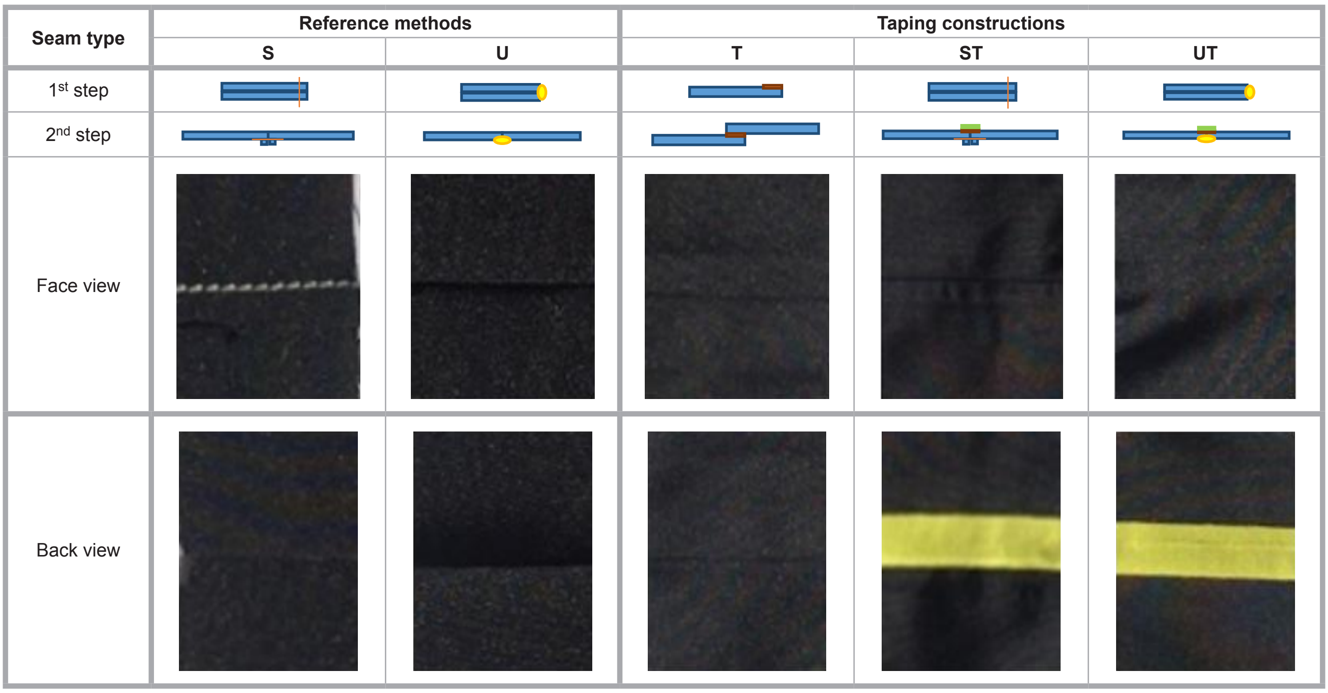

__Figure 1.__ Photographs and preparation schematics of samples (( ) = fabric, ( )= sewing, ( )= ultrasonic cutting and bonding, ( ) = sealing tape, ( ) = supreme fabric on the sealing tape).

and sealed nonwoven fireproof laminated samples [4]. Belforte et al. compared the tensile strengths, fatigue properties and air-tightness of textiles used in pneumatic devices joined with different assembling methods (sewing, sewing and taping, laser welding, ultrasonic welding, bonding etc.) [36]. Jakubcioniene et al. applied taping with different seam constructions to selected woven, knitted and laminated fabrics and investigated the peeling strength and seam strengths of the specimens [7]. Ujevic, Kovacevic and Horvat-Varga employed high-frequency welding to artificial leather and tested its breaking force and water impermeability [6]. Hustedt et al. used the laser welding technique to assemble airbag parts and compared the seam strengths of samples with different process conditions [14]. Jeong and An investigated the tensile-shear properties and seam pucker of taped coated and laminated fabrics and analysed the results according to finishing methods [10, 37]. Kara and Yesilpinar researched the strength and waterproofness of tape sealed laminated fabrics [11, 12].

From the literature review, it can be concluded that tape welding technologies are mostly examined for waterproof and other technical applications. In this study, different from the literature, it was examined in depth whether the tape containing welding methods could be useful and beneficial for daily applications of classical woven fabrics. Also, an extensive study was conducted for different constructions of seams containing tape. The comparability of taped seams with sewn ones was interpreted via strength, thickness (flatness of the seam) and air permeability performances. In the study, it was aimed to broaden the usage of taped seams to replace the sewn seams of daily garments and casual sportswear.

Materials and methods

Materials

Materials of this study consisted of woven base fabric, sewing thread and seam sealing tapes. A woven polyester (PET) fabric was used as the base fabric for sealing. Properties of the fabric are given in ***Table 1***.

2 ply 50 tex core-spun polyester sewing thread was used for the sewn samples. For sealing the seams, Bemis 3415 (USA) seam sealing tape was used, the width of which was 1 cm. For the upper applications of the tape, the sealing tape was bonded with a 100 % PET (130 g/m^2) supreme fabric in order to support the tape and improve the appearance.

__Table 1.__ Properties of PET fabric.

Raw material	Yarn type	Weave	Unit mass	Warp density	Weft density	Warp strength	Weft strength
100% PET	Multifil.	Plain	92 g/m^2	60 warp/cm	35 weft/cm	953.6 N	502.8 N

Methods

Sample preparation

Samples were prepared according to 5 different sealing methods: two reference methods (only sewing and only ultrasonic bonding) and 3 taping constructions. These methods are schematised in ***Figure 1***. Also, pictures of the real seams can be found in the figure. Overall, 20 different types of sealed samples were prepared. The experimental design and codes of the taped samples are given in ***Figure 2***.

S and U samples were prepared as reference in order to compare the seam strength, thickness and air permeability of the taped samples. The S reference sample was the “only-sewn” sample. For sewing, a Juki DDL-8500-7 model electronic lockstitch machine was used. The stitch density was 5 stitches/cm and the seam allowance – 4 mm. An SSa superimposed seam was created for this sample type [38]. A metric 90 sewing needle was used for sewing. The U reference sample was the “only-ultrasonic bonded” sample. In this method, samples were bonded together along one edge using a circular ultrasonic horn. The ul-

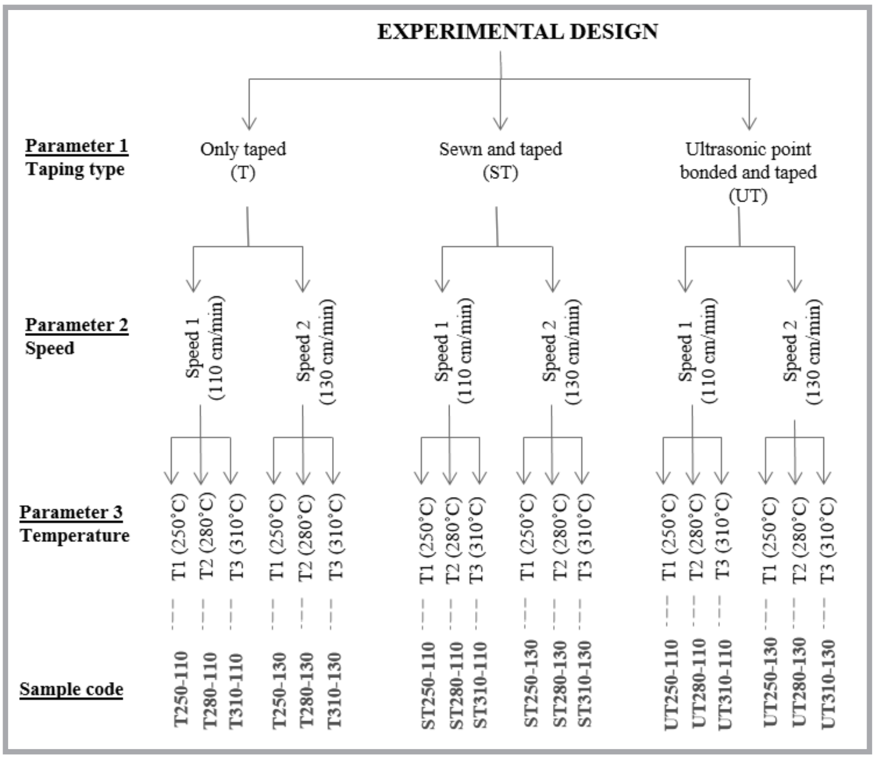

Figure 2. *Experimental design and sample codes of taped samples.*

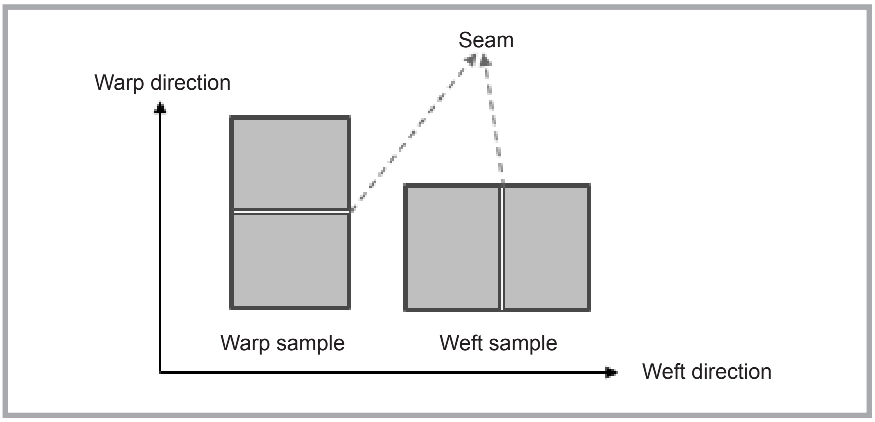

Figure 3. *Orientation of warp and weft samples.*

trasonic horn cut and weakly bonded the fabrics together in the same step, along a 1-dimensional line. This bonding is normally used as a preparation step for additional seam sealing methods. Ultrasonic bonding was made using a KTK Cutting and Edge Trimming Machine (Guangzhou J.D.Q. Machinery Co. Ltd., China). Bonding parameters for the ultrasonic bonding were 19800 Hz frequency, a 5.5 cm/s speed of the upper and lower cylinders, and 0.4 MPa pressure.

"Only-taped" T samples were taped between two fabric layers. This tape was double sided. Firstly, the tape was applied to one of the fabric's edge using a KTK Adhesive Film Fusing and Trimming Machine with an ultrasonic cutter (KTU-336CU model), as shown in ***Figure 1***. Afterwards, this preform was overlapped with the second fabric and bonded together by a KTK Sew Free Felt Seam Machine (KT-886B9800 Model).

ST samples were "sewn-and-taped". These were firstly sewn as S samples. After sewing, they were taped using the KTK Sew Free Felt Seam Machine (KT-886B9800 Model). In this method, the tape was preliminary laminated to a supreme fabric on one side, see Materials section.

UT – "ultrasonically bonded-and-taped" samples were firstly ultrasonically bonded as U reference samples. After bonding, they were taped using the KTK Sew Free Felt Seam Machine (KT-886B9800 Model). Tape laminated with a supreme fabric was used for this method.

Taped (T), sewn-and-taped (ST) and ultrasonically bonded-and-taped (UT) samples were varied according to the operation temperature and operation speed of the KTK Sew Free Felt Seam Machine. Taping temperatures were 250, 280 and 310 °C for the upper cylinder and 150 °C for the lower cylinder. Feeding speeds were 110 and 130 cm/min.

Warp and weft samples were organized as shown in ***Figure 3***.

Seam strength test

Seam strength tests were performed on an Instron 4411 Tensile Tester according to the TS EN ISO 13935-2: 2014 standard [39]. Seam strengths and elongation values of the samples were recorded. Tests were repeated 5 times for each type of sample.

Air permeability

The air permeability of the samples was determined according to TS 391 EN ISO 9237 using a Textest FX3300 air permeability tester [40]. The air pressure was 100 Pa during the tests, and the test area was 20 cm^2. 10 measurements were taken for each type of sample.

Thickness measurement

The thickness of the samples' seamed parts was determined according to the TS 7128 EN ISO 5084 standard using a James Heal RxB Cloth Thickness Tester [41]. The pressure during measurements was 5 gf/cm^2. 5 measurements were taken for each sample type, and average values were calculated.

Statistical analysis

Statistical analysis was performed using the SPSS 22.0 and Minitab 16.0.1 programmes. SPPS two-way variance analysis was used to compare the effects of the sealing types (S, U, T, UT and ST) on the sealed fabric properties. Also, Minitab was used to compare the effects of the taping type (T, UT, and ST), taping temperature and taping speed on the properties of the taped fabrics. SIDAK analysis was used to make pairwise comparisons as it is a strong test among Post-Hoc applications.

An ANOVA table was made only for the seam strength results. Similar tables were obtained for other fabric properties, but they were not added to the paper.

Results

Seam strength results

Seam strengths of the samples are given in ***Table 2***, with standard deviation values (st. dev.).

The only-sewn sample S had a seam strength of 417.5 and 281.3 N in the warp and weft directions, respectively. The only-ultrasonically bonded sample U showed a very low seam strength (lower than 60 N). All the taping methods yielded higher seam strengths when compared to sample U. The highest values were obtained from only-taped T samples in both the warp and weft directions, followed by ST samples and UT samples, respectively. For T samples, seam strengths were between 725-753 N in the warp direction and 370-490 N in the weft direction. Seam strengths of T samples were 1.5-2 times higher than for S samples. Moreover, the seam strengths of ST samples were at least 22% higher than for S samples. In the weft direction, the contribution to the seam strength increased by up to 60%. Among the taped samples, UT samples gave lower values when compared to S samples. They managed 50% of the seam strength of S samples at most.

Seam strength values were visualised according to the taping temperature and taping speed, shown in ***Figure 4***. From ***Figure 4*** and ***Table 3***, seam strength differences can be clearly observed for different taping constructions: T, ST and UT ($p < 0.05$). The seam strength of the taped samples were also affected by the taping temperature and taping speed ($p < 0.05$). For the warp samples, the seam strength increased at the higher taping temperatures. The highest seam strengths were obtained at a taping temperature of 310 °C for all types. Furthermore, according to the SIDAK results, taping at 310 °C had a significant contribution to the seam strengths of T and ST samples ($p < 0.05$). The effect of the taping speed was less prominent ($p = 0.022$). Significant effects of the taping speed were obtained only in the weft direction of T and ST samples. For UT samples, the taping temperature and taping speed did not cause statistically significant changes in seam strengths in both the warp and weft directions ($p > 0.05$).

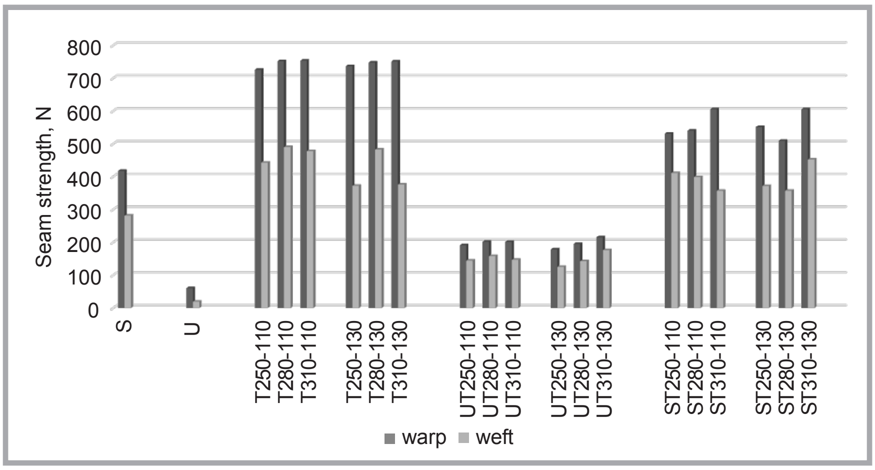

Figure 4. *Seam strength of samples.*

Table 2. *Seam strength of samples.*

Sample code		Seam strength, N			
		Warp		Weft	
		Mean	St. Dev.	Mean	St. Dev.
S		417.5	12.1	281.3	12.3
U		60.5	8.2	19.2	5.0
T	T250-110	725.8	12.1	442.9	35.9
	T250-130	736.5	15.1	371.9	40.2
	T280-110	751.9	16.8	490.0	7.1
	T280-130	747.7	15.2	482.4	41.4
	T310-110	753.4	16.8	477.6	19.8
	T310-130	751.0	18.0	376.1	16.4
UT	UT250-110	191.1	15.3	144.0	28.2
	UT250-130	178.4	14.6	125.4	18.9
	UT280-110	201.9	12.0	158.2	9.2
	UT280-130	195.1	15.3	142.4	19.9
	UT310-110	201.6	7.6	146.6	19.9
	UT310-130	215.2	10.3	176.3	12.7
ST	ST250-110	530.8	51.5	410.9	44.2
	ST250-130	551.4	42.0	371.8	27.5
	ST280-110	540.5	57.3	399.1	30.6
	ST280-130	509.4	69.7	357.2	25.8
	ST310-110	605.7	45.9	356.6	39.8
	ST310-130	605.5	31.9	452.2	37.3

During the tests, for S, U, UT and ST samples, mostly the seams broke. For T samples, mostly the fabrics broke. This was valid for both the warp and weft directions.

Elongation (%) results of samples are given in ***Table 4*** and visualised in ***Figure 5***. The lowest elongation value was obtained from reference sample U – around 7%. In the seam strength tests, U samples broke under small loads, so that this sample exhibited very low elongation results when compared to sewn and taped counterparts. The elongation values of S samples were 33 and 24.5% in the warp and weft directions, respectively. For T and ST samples, elongation values were very close to those of S samples . Pairwise comparisons showed that elongation differences between S and ST samples were not statistically significant ($p > 0.05$). UT samples had lower elongation values than ST samples. According to ***Table 4***, elongation in the weft direc-

Table 3. *ANOVA results for strength values of taped samples.*

Source	Sig. value
Taping method (T, UT, ST)	0.000
Temperature	0.000
Taping speed	0.022
Taping type*Temperature	0.000
Taping type*Taping speed	0.010
Temperature*Taping speed	0.040
Taping type*Temperature *Taping speed	0.000

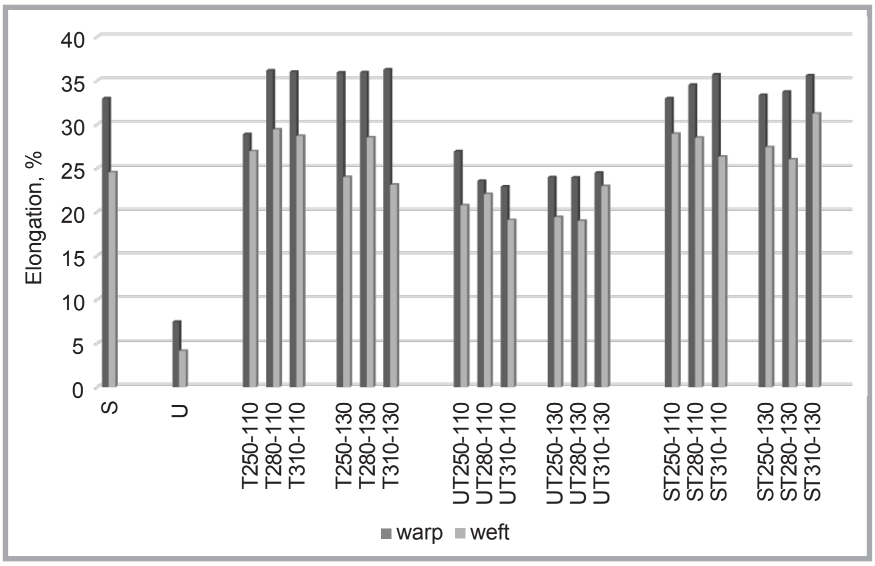

Figure 5. *Elongation results of samples.*

tion is lower than that in the warp direction for all sample types.

According to statistical analysis results, the taping method had a statistically significant effect on the elongation values ($p < 0.05$). In contrast, the temperature and speed did not have a statistically significant effect on the elongation of the samples ($p > 0.05$).

Overall, the seam strength and elongation values increased after the taping process, which may be due to the additional adhesive force between the textile and adhesive tape [12, 37].

Table 4. *Elongation results of samples.*

Sample code		Elongation, %			
		Warp		Weft	
		Mean	St. Dev.	Mean	St. Dev.
S		33.0	0.9	24.5	0.4
U		7.5	0.6	4.1	0.4
T	T250-110	28.9	13.9	26.9	1.9
	T250-130	35.9	0.8	24.0	2.5
	T280-110	36.2	0.9	29.4	0.5
	T280-130	35.9	0.8	28.5	1.7
	T310-110	36.0	0.9	28.7	1.3
	T310-130	36.3	1.0	23.1	0.6
UT	UT250-110	26.9	3.3	20.8	3.8
	UT250-130	24.0	1.7	19.4	1.8
	UT280-110	23.6	1.7	22.0	1.2
	UT280-130	23.9	1.6	19.0	3.9
	UT310-110	22.9	1.3	19.1	1.9
	UT310-130	24.5	1.7	23.0	2.2
ST	ST250-110	33.0	1.2	28.9	2.1
	ST250-130	33.4	1.8	27.4	1.5
	ST280-110	34.5	1.6	28.5	2.0
	ST280-130	33.7	2.0	26.0	1.5
	ST310-110	35.7	2.0	26.3	2.4
	ST310-130	35.6	1.7	31.2	2.2

Air permeability results

Air permeability results of the samples are given in ***Table 5***. For all types of samples, air permeability changed between 29 and 43 l/m^2/s. According to the variance analysis results, air permeability differences between the main sealing types (S, U, T, UT and ST) were statistically significant ($p < 0.05$).

The highest air permeability results were obtained for S samples. Also, U samples showed higher air permeability values when compared to taped samples. Higher air permeability values were expected from S and U samples, as their seams only had one dimension along the seam line.

For the taped samples (T, UT and ST), air permeability values decreased by up to 33% when compared to the reference S sample. This was due to covering the seam with the 1 cm width tape along the seamlines. In a related research in the literature, the air permeability of a taped knitted fabric was found to be lower when compared to an overlock sewn counterpart [9].

Air permeability values of all taped samples were similar, changing in a narrow band around 30-37 l/m^2/s for all taped samples. But they can be ordered as ST, UT and T from the highest to lowest air permeability. For the identical taping parameters, the maximum difference between the air permeability of T and ST samples was 16%. The effect of the taping direction was not statistically significant for the air permeability properties of taped samples ($p > 0.05$). Moreover, changing the taping temperature and speed did not affect the air permeability results systematically. According to SIDAK comparisons, air permeability, only differences between ST250-110, ST250-130 and ST310-110, ST310-130 in the weft direction were statistically significant ($p < 0.05$).

Thickness results

Thickness results of the samples are given in ***Table 6***. According to the variance analysis test and pairwise comparisons, the thickness differences between all sealing types (S, U, T, UT and ST) were statistically significant ($p < 0.05$). Applying the tape in the warp or weft direction slightly affected the thickness results.

The thickness of sewn parts of samples S was 1.4 and 1.3 mm in the warp and weft directions, respectively. U samples had a lower thickness of 0.8 mm. Among all the samples, only-taped samples T exhibited the lowest thickness along the seamline of 0.4 mm, which was 67% lower than that of only-sewn samples S. This yielded a flat seamline when compared to sewn samples. This result is in accordance with Beaudette and Park's study (2017) [9].

For UT and ST samples, taping reduced the thickness of seamlines in the amount of 0.1 mm to 0.3 mm when compared to only-sewn and only-ultrasonically bonded reference samples. This corresponded to 7-25% thickness decrements. These decreases after taping are due to the compression force during taping.

Thickness differences due to the taping method (T, UT, ST) were statistically significant ($p < 0.05$). In contrast, the taping temperature and taping speed did not cause a statistically significant change in the thickness of taped samples ($p > 0.05$).

Discussion

In this study; the strength, thickness and air permeability properties of sealed samples with different constructions were determined and compared. Sewing, ultrasonic bonding, ultrasonic bonding-and-taping, sewing-and-taping and only-taping methods were used as the seam sealing techniques. Tape involving methods were varied according to the taping temperature and taping speed.

According to thickness test results, the thinnest seam lines were obtained from only-taped T samples. Also, after taping, the thickness of ultrasonically bonded and sewn samples decreased too. Therefore, it can be inferred that taping results in flatter seams, which can contributes to the smoothness of seamlines. It can help to increase the sensorial comfort of casual wear by reducing the frictional forces between the body and seamlines [9].

Seam strength results showed that higher seam strengths can be obtained by taping methods when compared to the sewn reference sample. Taped (T) and sewn-and-taped (ST) samples succeeded in giving better results than the sewn counterpart. This shows that taping can successfully replace sewing in terms of seam strength. When the seam strength results were evaluated together with thickness results, it is obvious that only-taped T samples are more advantageous when compared to other constructions of taped and only-sewn samples. They provided flatter and thinner seams with very high seam strength values. Also, as it did not require an additional sewing process, it could help to save on the cost of assembling casual wear with tapes. This puts T type taping one step ahead among the all taping structures in this study.

According to air permeability results, taping decreased the air permeability of samples by up to 33%. However, it must be kept in mind that the air permeability test is applied to a 20 cm^2 area according to the test standard. A tape of 10 mm width covers a big area in this 20 cm^2 test area. In real garment conditions, the coverage of the tape on the total garment is significantly lower. Thus, it is expected to have smaller decrements in air permeability in real wearing conditions of taped garments. Hence, taped samples can maintain the physiological comfort requirements of casual garments.

Overall, the fabric used in this study was suitable for daily wear and casual sportswear. As it was a woven polyester fabric, it was more suitable to be used in loose garments such as lightweight tops, pants and shorts, which are not in tight contact with the body. T type taped samples are proposed to be used especially in the straight edge seams of these garments like side seams. Even the taped places contact with the body, but it is expected

Table 5. *Air permeability results of samples.*

Sample code		Air permeablity results, l/m^2/s			
		Warp		Weft	
		Mean	St. Dev.	Mean	St. Dev.
S		43	1.08	43	1.23
U		37	1.19	41	1.17
T	T250-110	32	0.96	29	0.55
	T250-130	31	0.78	30	0.75
	T280-110	32	0.74	30	0.51
	T280-130	31	1.62	30	0.61
	T310-110	31	0.74	31	0.64
	T310-130	30	0.50	30	1.26
UT	UT250-110	33	1.28	33	1.72
	UT250-130	32	1.06	32	1.28
	UT280-110	32	0.82	32	2.09
	UT280-130	32	0.59	32	1.51
	UT310-110	34	1.47	33	2.85
	UT310-130	33	0.61	32	1.85
ST	ST250-110	34	1.29	34	1.72
	ST250-130	34	1.36	34	1.28
	ST280-110	34	1.12	35	2.09
	ST280-130	33	1.72	34	1.51
	ST310-110	34	0.68	37	2.85
	ST310-130	33	0.66	36	1.85

Table 6. *Thickness results of samples.*

Sample code		Thickness results, mm			
		Warp		Weft	
		Mean	St. Dev.	Mean	St. Dev.
S		1.4	0.10	1.3	0.04
U		0.8	0.02	0.8	0.06
T	T250-110	0.4	0.01	0.4	0.02
	T250-130	0.4	0.01	0.4	0.02
	T280-110	0.4	0.02	0.4	0.04
	T280-130	0.4	0.02	0.4	0.04
	T310-110	0.4	0.01	0.4	0.03
	T310-130	0.4	0.02	0.4	0.03
UT	UT250-110	0.7	0.02	0.7	0.04
	UT250-130	0.7	0.02	0.7	0.04
	UT280-110	0.6	0.07	0.7	0.02
	UT280-130	0.7	0.05	0.6	0.03
	UT310-110	0.7	0.04	0.7	0.02
	UT310-130	0.7	0.04	0.7	0.01
ST	ST250-110	1.2	0.01	1.1	0.02
	ST250-130	1.2	0.17	1.2	0.09
	ST280-110	1.3	0.08	1.2	0.03
	ST280-130	1.1	0.04	1.2	0.08
	ST310-110	1.1	0.01	1.1	0.03
	ST310-130	1.1	0.03	1.1	0.03

to improve the sensorial comfort as it has lower thickness when compared to sewn seams and has no free seam allowances. The sensorial comfort of taped seams can be explored in future studies by designing and manufacturing garments with different seam types and conducting wear trials. As it would be a very detailed study, it is planned as a continuing work in the future.

References

1. Kurumer G. *Konfeksiyon uretimi ve teknolojisi 2nd Press*, Printer Ofset Matbaacılık, Izmir. 2012.
2. Jana P. Assembling Technologies for Functional Garments – An Overview. *Indian Journal of Fibre & Textile Research* 2011; 36: 380-387.
3. Boles K. Examination of Alternative Fabric Joining Techniques Compared to Traditional Sewing. *McNair Scholars Research Journal* 2012; 5, 1: 1-17.
4. Grineviciute D, Valaseviciute L, Narviliene V, Dubinskaite K, Abelkiene R. Investigation of Sealed Seams Properties of Moisture Barrier Layer in Firefighters Clothing. *Materials Science* 2014; 20, 2: 198-204.
5. Shi W, Little T. Mechanisms of Ultrasonic Joining of Textile Materials. *International Journal of Clothing Science and Technology* 2000; 12, 5: 331-350.
6. Ujević D, Kovačević S, Horvat-Varga S. Analysis of High-Frequency Artificial Leather Welding as a Function of Seam Quality. *FIBRES & TEXTILES in Eastern Europe* 2011; 19, 4(87): 94-100.
7. Jakubcioniene Z, Masteikaite V, Kleveckas T, Jakubcionis M, Kelesova U. Investigation of the Strength of Textile Bonded Seams. *Materials Science* 2012; 18, 2: 172-176.
8. Kuo CFJ, Chen JB, Lin PH, Yen HT. Hot -Melt Pressure-Sensitive Adhesive for Seamless Bonding of Nylon Fabric Part I: Effect of a Functional Monomer. *Textile Research Journal* 2019, 89, 6: 926-935.
9. Beaudette E, Park H. Impact of Seam Types on Thermal Properties of Athletic Bodywear. *Textile Research Journal* 2017; 87, 9: 1052-1059.
10. Jeong WY, An SK. Mechanical Properties of Breathable Waterproof Fabrics with Seaming and Sealing Processes. *Fibers and Polymers* 2004; 5, 4: 316-320.
11. Kara S, Yesilpinar S. A Research on the Waterproofness of Seam Lines of Protective Clothes. Paper presented at the *5th European Conference on Protective Clothing and NOKOBETEF 10, Future of Protective Clothing: Intelligent or not 2012-a*, 29-31 May, Valencia, Spain.
12. Kara S, Yesilpinar S. A Research on the Sewing Problems of Protective Clothes. Paper Presented at the *5th International Technical Textiles Congress 2012-B*, 7-9 November, Izmir, Turkey.
13. Bahadir SK, Jevsnik S. Optimization of Hot Air Welding Process Parameters for Manufacturing Textile Transmission Lines for E-Textiles Applications: Part I: Electro-Conductive Properties. *Textile Research Journal* 2017; *87,* 2: 232-243.
14. Hustedt M, Stein J, Herzog D, Meier O. Laser-Based Joining of Technical Textiles for Airbag Production. Paper presented at the *Third World Automotive Congress Plastics-in-Motion* 2008, 14-16 May, Czech Republic, Prague.
15. Namiranian R, Shaikhzadeh Najar S, Etrati SM, Manich AM. Seam Slippage and Seam Strength Behavior of Elastic Woven Fabrics Under Static Loading. *Indian Journal of Fibre & Textile Research* 2014; 39, 3: 221-229.
16. Choudhary AK, Goel A. Effect of Some Fabric and Sewing Conditions on Apparel Seam Characteristics. *Journal of Textiles* 2013, 1-7.
17. Gurarda A. Investigation of the Seam Performance of PET/Nylon-Elastane Woven Fabrics. *Textile Research Journal* 2008; 78, 1: 21-27.
18. Bharani M, Shiyamaladevi PSS, Mahendra Gowda RV. Characterization of Seam Strength and Seam Slippage on Cotton Fabric with Woven Structures and Finish. *Research Journal of Engineering Sciences* 2012; 1, 2: 41-50.
19. Sular V, Mesegul C, Kefsiz H, Seki Y. A Comparative Study on Seam Performance of Cotton and Polyester Woven Fabrics. *The Journal of the Textile Institute* 2015; 106, 1: 19-30.
20. Citoglu F, Kaya G. Dikiş iplik özelliklerinin ve dikiş sıklıklarının farklı dikiş açılarında dikiş mukavemeti üzerine etkileri. *Tekstil ve Konfeksiyon* 2011; 21, 2: 182-188.
21. Xin LU. Effect of Sewing Form and Parameters on Seam Strength of Silk Fabric. *Shanghai Textile Science & Technology* 2010; 5: 17.
22. Ozdemir H, Yavuzkasap D. The Effects of Yarn and Fabric Structural Parameters on the Seam Slippage, Abrasion and Pilling Properties of Double Woven Upholstery Fabrics. *Industria Textila* 2012; 63, 6: 307-314.
23. Yeşilpınar S, Bahar S. The Effect of Sewing and Washing Processes on the Seam Strength of Denim Trousers. *AATCC review* 2007; 7, 10: 27-31.
24. Yeşilpınar S. Analysis of the Performance of Sewing Threads Manufactured from Conventional and Compact Ring-spun Yarns. *FIBRES & TEXTILES in Eastern Europe* 2006; 14, 2(56): 20-23.
25. Gribaa S, Ben, Amar S, Dogui A. Influence of Sewing Parameters Upon the Tensile Behavior of Textile Assembly. *International Journal of Clothing Science and Technology* 2006; 18, 4: 235-246.
26. Chowdhary U, Poynor D. Impact of Stitch Density on Seam Strength, Seam Elongation, and Seam Efficiency. *International Journal of Consumer Studies* 2006; 30, 6: 561-568.
27. Tarafder N, Karmakar R, Mondal M. The Effect of Stitch Density on Seam Performance of Garments Stitched from Plain and Twill Fabrics. *Man-Made Textiles in India* 2007; 50, 8: 298-302.
28. Mukhopadhyay A, Sikka M, Karmakar AK. Impact of Laundering on the Seam Tensile Properties of Suiting Fabric. *International Journal of Clothing Science and Technology* 2004; 16, 4: 394-403.
29. Brain DH. The Prediction of Strengths of Lock Stitch Seams in Woven Fabrics. *Journal of the Textile Institute* 1970; 61, 10: 493-505.
30. Kuo CFJ, Lan WL, Wang JW, Chen JB, Lin PH. Hot-Melt Pressure-Sensitive Adhesive for Seamless Bonding of Nylon Fabric Part II: Process Parameter Optimization for Seamless Bonding of Nylon Fabric. *Textile Research Journal* 2018; 0040517518790970.
31. Golomeova S, Demboski G. The Influence of the Thermoplastic Reinforcement Tape Location on the Seam Performance. *Advanced Technologies* 2017; 6, 1: 93-95.
32. Korycki R, Szafranska H. Thickness Optimisation of Sealed Seams in Respect of Insulating Properties. *FIBRES & TEXTILES in Eastern Europe* 2017; 25, 2(122): 68-75. DOI: 10.5604/12303666.1228185.
33. Mikalauskaite G, Daukantiene V. Influence of the Delamination Loading Velocity on Textile Bonds and Sewn Seams Strength. *International Journal of Clothing Science and Technology* 2017; 29, 6: 768-775.
34. Shi H, Wang J, Chen X, Luo S, Zhang L. Research on the Seam Performance of Waterproof Clothing Based on Continuous Ultrasonic Welding Technology. *International Journal of Clothing Science and Technology* 2016; 28, 2: 171-190.
35. Irzmańska E, Majchrzycka K, Adamus-Włodarczyk A, Brochocka A. Evaluation of the Mechanical Parameters of Ultrasonically Welded Textile Composite Structures for Protective Footwear. *FIBRES & TEXTILES in Eastern Europe* 2019; 27, 3(135): 99-105. DOI: 10.5604/01.3001.0013.0821.
36. Belforte G, Eula G, Ivanov A, Grassi R, Askri H, Appendino S. Comparison of Assembly Techniques for Textiles Used in Pneumatic Devices. *The Journal of the Textile Institute* 2014; 105, 7: 717-728.
37. Jeong WY, An SK. Seam Characteristics of Breathable Waterproof Fabrics with Various Finishing Methods. *Fibers and Polymers* 2003; 4, 2: 71-76.
38. ASTM D 6193.Standard Practice for Stitches and Seams.
39. TS EN ISO 13935-2:2014. Textiles – Seam Tensile Properties of Fabrics and Made-Up Textile Articles – Part 2: Determination of Maximum Force to Seam Rupture Using the Grab Method.
40. TS 391 EN ISO 9237: 1999. Textiles-Determination of Permeability of Fabrics to Air.
41. TS 7128 EN ISO 5084: 1998. Textiles-Determination of Thickness of Textiles and Textile Products.

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