Comparison of the physical properties of cut-and-seal ultrasonic welding vs cut-and-sew overedge stitch

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ABSTRACT – REZUMAT

Comparison of the physical properties of cut-and-seal ultrasonic welding vs cut-and-sew overedge stitch

The usage area of ultrasonic welding, which is one of the trending methods of today, continues to increase daily. Ultrasonic welding is one of the methods used to transform textile surfaces into the final product. Thanks to the modifications made to this method, it is also possible to obtain joining systems similar to conventional methods. The joint obtained by cut-and-seal ultrasonic welding is identical to the cut-and-sew overedge stitch method, one of the traditional methods. For this reason, this study compared physical properties, including air permeability, water impermeability, seam strength, and thickness, of untreated and tape-coated joints produced by the two methods. Four functional fabrics commonly used in outerwear and outdoor products were examined. The results show that ultrasonic welding combined with tape significantly improves seam strength (up to 3–4 times higher compared to ultrasonic welding alone) while maintaining adequate air permeability and water impermeability. These findings suggest that ultrasonic welding can be considered a viable alternative to overedge stitching for high-performance applications.

Keywords: *cut & seal ultrasonic welding, overedge stitch, comparison, joining methods*

Comparație între proprietățile fizice ale lipirii ultrasonice de tip „tăiere și sigilare” și ale cusăturii de tip tăiere și surfilare

Domeniul de aplicare al lipirii ultrasonice, una dintre metodele la modă în prezent, continuă să se extindă pe zi ce trece. Lipirea ultrasonică este una dintre metodele utilizate pentru transformarea suprafețelor textile în produsul final. Datorită modificărilor aduse acestei metode, este posibilă obținerea unor sisteme de îmbinare similare cu cele obținute prin metodele convenționale. Îmbinarea obținută prin metoda de lipire ultrasonică de tip „tăiere și sigilare” este identică cu cea obținută prin metoda tradițională „coasere cu tăiere și surfilare”. Din acest motiv, în cadrul acestui studiu au fost comparate proprietățile fizice, inclusiv permeabilitatea la aer, impermeabilitatea la apă, rezistența cusăturii și grosimea îmbinărilor netratate și a celor acoperite cu bandă, obținute prin cele două metode. Au fost examinate patru țesături funcționale utilizate frecvent în confecționarea îmbrăcămintei de exterior și a produselor pentru activități în aer liber. Rezultatele arată că lipirea ultrasonică combinată cu aplicarea unei benzi îmbunătățește semnificativ rezistența cusăturii (de până la 3-4 ori mai mare comparativ cu lipirea ultrasonică utilizată singură), menținând în același timp o permeabilitate la aer și o impermeabilitate la apă adecvate. Aceste constatări sugerează că lipirea ultrasonică poate fi considerată o alternativă viabilă la cusătura de surfilare pentru aplicații de înaltă performanță.

Cuvinte-cheie*: lipire ultrasonică prin tăiere și sigilare, cusătură de surfilare, comparație, metode de îmbinare*

INTRODUCTION

In the clothing industry, the transformation of fabrics with a two-dimensional structure into a three-dimensional final product can only be possible by cutting and sewing these fabrics in a certain order. In this context, there are a wide variety of methods for joining fabrics.

In the process of sewing fabrics together, traditional sewing types, which are performed with needle and thread, are the most commonly used. However, in recent years, different types of joining methods apart from traditional sewing types have often found a place in the sector. The usage area of ultrasonic welding, which is one of the trending methods today, continues to increase daily. In this direction, the preferred joining methods are shown below:

- Traditional
  - Lockstitch
  - Overedge stitch
  - Cover stitch
- Unconventional
  - Ultrasonic welding
  - Hot air taping
  - Glueing sealing
  - Laser [1].

In joining fabric surfaces, the choice of the method is extremely important. The method affects the properties of the joint line to be obtained [2, 3]. In this direction, the following points should be considered when choosing a method: aesthetic image, strength, comfort of use and cost [4].

Ultrasonic welding technology is rapidly gaining popularity in the textile and apparel industry. Furthermore, it is increasingly becoming a subject of research as an alternative joining technique when compared to traditional methods. The following studies have been identified in the literature review on the subject of the study.

In 2018, Macit and Tiber examined three types of polyurethane-coated woven fabrics to examine the seam strength, burst strength, and bending properties of fabrics combined with ultrasonic welding. The fabrics were combined using ultrasonic and conventional methods with various parameters. The fabrics combined with both methods were washed, and the mentioned properties of the fabrics were tested before and after washing [5]. In 2022, the same authors evaluated the seam burst strength, bending properties, and water impermeability values of fabrics on which the ultrasonic welding process was applied under different parameters [6]. In 2017, Jevsnik et al. evaluated the waterproofing performance of the ultrasonic welding process by considering the joint strength, thickness, and hardness of the joint site. Since the joint performance was evaluated for use in shoes in the study, the fabrics were examined in a 4-layer form [7]. In a study conducted by Seram and Nandasiri in 2015, both traditional sewing types and ultrasonic welding techniques were used in the production of sportswear products. In this study, the products were divided into two groups, and only the joint strengths of the products were evaluated [8]. In 2016, Shi et al. evaluated the effect of the ultrasonic welding and tape system on the waterproofing performance at the joints of fabrics [9]. In 2022, Hussen et al. evaluated the performance of the joints obtained by combining woven polyester fabrics with ultrasonic welding processes at different parameters [10]. In 2013, Seram and Cabon investigated the feasibility of producing different joining methods using ultrasonic joining techniques. They reported that while this technique was insufficient in terms of joining performance due to factors such as the thickness of the joining area, it was sufficiently suitable for decorative use [11]. In a study by Eryuruk et al. (2017), nonwoven fabrics used in many fields were joined using both ultrasonic and traditional methods, and their performance was evaluated [12].

Balasaraswathi and Bajpai (2024) investigated the effects of ultrasonic welding parameters on seam performance and stated that while ultrasonic seams had good comfort properties, their strength values were more limited [13]. Furthermore, previous studies on nonwoven and woven fabrics highlight that ultrasonic bonding is highly dependent on fabric type, number of layers, and process parameters, and that performance results vary significantly depending on fabric properties (Boz and Küçük, 2021).

In this context, in this study, 4 different fabrics with different properties and materials, which are frequently preferred due to their waterproof properties, were combined with overedge seam, overedge seam and tape bonding, ultrasonic welding, and ultrasonic welding and tape bonding techniques to determine the most appropriate joining method/methods. Afterwards, the physical properties of these joint lines, such as air permeability, water impermeability, joint point thickness, and seam strength, were determined and evaluated.

The most important difference of this study from other studies in the literature is that while ultrasonic welding was performed with patterned rollers in other studies, in this study, the welding process was carried out with cut-and-seal rollers with the principle of an overedge seam to reduce the seam thickness caused by the number of fabric layers. Accordingly, the comfort of use has also been taken into account. As the joint area (joint thickness) per unit area in the seamed region increases in ultrasonic seam, the seam strength value increases in parallel [15]. In this study, although the combined unit area amount is quite low due to the cut-and-seal system, it was also checked whether the expected strength values were achieved or not. In this way, it is thought that this gap in the literature will be closed with this study. Ultrasonic welding technology is mostly evaluated on single types or a limited number of fabrics; studies systematically comparing the performance of cut and seal systems on multilayer laminated fabrics are limited in the literature. Furthermore, studies that compare traditional sewing methods and cut and seal systems under the same experimental conditions, considering different fabric types and multiple performance criteria, are insufficient in the literature. In this context, this study aims to fill this research gap. This study is also one of the first in the literature to experimentally investigate the performance of cut and seal systems on multilayer laminated fabrics.

MATERIAL AND METHOD

Materials

The materials of the study consist of 4 different fabric types, which are frequently preferred in areas where functionality is kept at the forefront, suitability for purpose, and expected to provide high protection (such as military, extreme sports, and protection from natural conditions). These fabrics and their properties are shown in the table below (table 1).

The fabrics, the details of which are shown in table 1, were combined using 4 different joining techniques: overedge, overedge + tape, ultrasonic welding, and ultrasonic welding + tape, in order to determine the

Table 1

THE FABRICS' PROPERTIES

Fabric	Raw material	Lamination material	Mass per unit area (g/m^2)
Fabric-1	Polyester	Polyurethane	174.40
Fabric-2	Polyester	Polyester	166.00
Fabric-3	Polyamide	Polyurethane	144.50
Fabric-4	Polyester	Polyurethane	140.20

most appropriate joining method for the purpose of functionality. The details of these joining techniques are shown in table 2.
Within the scope of the study, overedge sewing was applied on 4-thread overedge sewing machines with Juki MO6714 model number. 150 dtex*2 core-spun 100% polyester thread is preferred as sewing thread. The stitch density was set to 2.5 mm.
Ultrasonic cut and seal application was performed on the Nucleus dx1 machine using the "cut and seal roller" (Cut angle: Left 00, Right 100, Joint width: 0.2 mm) shown in figure 1.

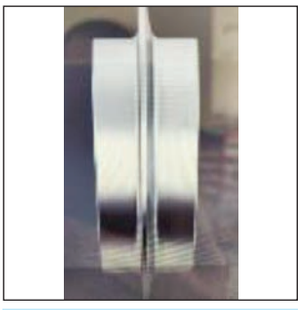


Fig. 1. Cut and seal roller

Ardmel hot air seam sealing machine was used for tape welding on overedge seam and ultrasonic welding applications. The tape used is 100% PUR, 220 g/m^2, 12 mm wide and 0.19 mm thick.
The fabric types shown in table 1 were combined with the techniques specified in table 2, and the seam areas were subjected to the tests specified in the method section.

Method

The fabrics, the details of which are shown in table 1, were combined using 4 different combination techniques in order to determine the most suitable joining method for the purpose of functionality. Details of these joining techniques are shown in table 2.
The four alternative joining techniques included in the experimental plan differ from each other in terms of their structures, application systems, and equipment used. In the traditional 4-thread overedge stitch, fabrics are joined mechanically with needles and threads. In the 4-thread overedge + tape technique, the stitch line is covered with an additional tape. In the ultrasonic welding (cut and seal) method, fabrics are welded together without needles and threads using ultrasonic energy and simultaneously cut and joined. In the ultrasonic cut and seal + tape technique, the resulting weld line is covered with an additional tape application. The comparison of the four different techniques was carried out by evaluating the performance of the techniques on the fabric.
The performance of the fabrics in the experimental plan and the seam areas obtained by combining them with different techniques was evaluated by air permeability, water impermeability, joint area thickness, fabric breaking strength, and seam strength tests.

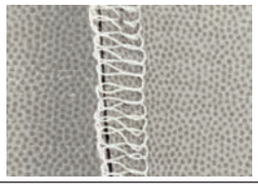
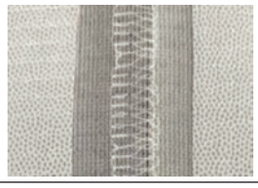
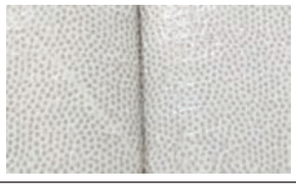
Air permeability test

Air permeability, which is one of the important indicators of the thermal comfort feeling of fabric surfaces, can be measured in accordance with the ASTM D 1776 standard with the "Textest FX 3300 Air Permeability Tester". In the experiments, the air permeability properties of both the fabrics and the seam areas were tested. The tests were repeated 5 times for each sample [16].

Water impermeability test

The water impermeability tests were carried out in accordance with the TS EN ISO 811 standard. The tests were repeated five times for each sample. The concept of water resistance of the fabric is defined as

Table 2

<table>
<tr><td colspan="4">THE TECHNIQUES</td></tr>
<tr><td colspan="2">Traditional</td><td colspan="2">Ultrasonic Welding</td></tr>
<tr><td>Technique-1</td><td>Technique-2</td><td>Technique-3</td><td>Technique-4</td></tr>
<tr><td>Overedge</td><td>Overedge + tape</td><td>Ultrasonic welding
(cut and seal)</td><td>Ultrasonic welding + tape</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">– 4-thread overedge
– Stitch density: 2.5 mm
– Thread: 150 dtex*2 corespun</td><td colspan="2">– Ultrasonic power: 60 Watt
– Roller pressure: 50 Newton
– Speed: 3 m/min
– Roller: 0.2 mm (cutting wheel)</td></tr>
<tr><td colspan="4">Tape: 100% polyester
Tape width: 12 mm
Tape bonding temperature: 525ºC
Band roller pressure: 7 bar
Speed: 2.5 m/min</td></tr>
</table>

the ability to resist being wetted by water and the ingress of water [17]. In the study, the data obtained as a result of the tests performed on both the fabrics and the seam areas are presented in the findings section.

The fabric and the joint areas' thickness

The thickness tests were carried out with the "Wira Digital Thickness Gauge" in accordance with the TS 7128 EN ISO 5084 standard [18]. In the experiments, both the thickness of the fabric itself and the thickness of the seam areas were measured in 5 repetitions.

The fabric breaking strength and the seam strength

In the study, the seam strength measurement was made using the Zwick Roell Z010 test device in accordance with the ISO 13935-2 (2014) standard [19]. Five consecutive tests were performed in the direction of warp and weft for each sample. In the tests, only the maximum forces determined by rupture of the sewing threads or the opening of the joint line were recorded. In order to be able to compare the seam strengths, the fabric breaking strengths of 4 different fabrics were applied with 5 repetitions according to the TS 2008 method.

FINDINGS

After the fabrics and joint areas in the experiment plan were conditioned under appropriate conditions, they were subjected to tests in accordance with the standards specified in the method section. The data obtained as a result of these tests are shown in the tables below (tables 3–6).

The values obtained as a result of all the tests applied to all fabrics in the experiment plan, and the standard deviations of these values, are shown in tables 3–6. These results were analysed statistically in the continuation of the study.

RESULTS AND DISCUSSIONS

In this study, four different functional fabrics were joined using four different (including combinations) joining techniques, and the joining areas were evaluated in terms of air permeability, water resistance, thickness, and seam strength. The findings showed significant differences not only depending on the joining technique but also on the structural properties of the fabric, such as raw material, lamination type, and mass per unit area.

Fabric-based evaluation of air permeability results

According to the air permeability test results, the highest values for all fabric types were obtained from samples with the overedge + tape technique. This result is thought to be due to the partial thinning of the lamination layer on the fabric surface and the

Table 3

THE AIR PERMEABILITY RESULTS					
Samples	**Air permeability (100 Pa – l/m²/s – 5 cm²)**				
	Fabric surface	**Technique-1**	**Technique-2**	**Technique-3**	**Technique-4**
Fabric-1 Avg.	0.31	50.82	143.20	0.43	10.32
Std. Deviation	0.01	5.05	18.78	0.02	0.36
Fabric-2 Avg.	0.35	55.14	150.20	0.46	20.68
Std. Deviation	0.02	19.09	18.22	0.17	0.45
Fabric-3 Avg.	0.37	58.02	157.80	0.71	30.37
Std. Deviation	0.01	0.85	2.59	0.03	0.98
Fabric-4 Avg.	0.39	59.38	161.40	0.74	29.90
Std. Deviation	0.01	2.78	1.14	0.04	1.44

Table 4

THE WATER IMPERMEABILITY RESULTS					
Samples	**Water impermeability (mm H_2O column) (water increase rate 600±30 mm/min for fabric surfaces, 100±30 mm/min for seam areas)**				
	Fabric surface	**Technique-1**	**Technique-2**	**Technique-3**	**Technique-4**
Fabric-1 Avg.	15200.00	117.00	269.00	450.00	536.67
Std. Deviation	200.00	2.00	7.94	13.23	44.81
Fabric-2 Avg.	14700.00	103.00	260.00	425.00	470.00
Std. Deviation	264.58	2.65	15.00	5.00	5.00
Fabric-3 Avg.	12300.00	93.33	225.00	285.00	448.33
Std. Deviation	100.00	2.08	20.00	5.00	7.64
Fabric-4 Avg.	11800.00	87.00	206.67	281.67	426.67
Std. Deviation	200.00	1.00	2.89	7.64	5.77

Table 5

THICKNESS RESULTS					
Samples	**Thickness (mm)**				
	Fabric surface	**Technique-1**	**Technique-2**	**Technique-3**	**Technique-4**
Fabric-1 Avg.	0.28	1.33	1.46	0.93	1.03
Std. Deviation	0.00	0.03	0.04	0.02	0.01
Fabric-2 Avg.	0.23	1.28	1.38	0.86	0.94
Std. Deviation	0.01	0.03	0.02	0.02	0.02
Fabric-3 Avg.	0.21	1.15	1.30	0.69	0.79
Std. Deviation	0.01	0.02	0.03	0.01	0.03
Fabric-4 Avg.	0.20	1.13	1.22	0.66	0.75
Std. Deviation	0.00	0.02	0.01	0.01	0.02

Table 6

THE FABRIC BREAKING STRENGTH AND THE SEAM STRENGTH					
Samples	**Seam strength TS EN ISO 13935-2 Grab method**				
	Fabric surface	**Technique-1**	**Technique-2**	**Technique-3**	**Technique-4**
Fabric-1 Avg.	1222.58	418.49	438.94	96.24	271.13
Std. Deviation	35.65	14.37	15.10	0.94	18.54
Fabric-2 Avg.	1090.97	340.45	435.15	86.51	253.89
Std. Deviation	85.63	5.54	2.82	1.38	34.23
Fabric-3 Avg.	648.24	319.80	429.44	67.03	187.07
Std. Deviation	13.33	6.40	47.86	2.25	7.48
Fabric-4 Avg.	591.46	297.55	428.51	44.21	182.42
Std. Deviation	4.82	7.93	30.54	1.64	3.61

increase in porosity at the seam during hot air tape application. In the analyses, air permeability values increased in Polyester-PU coated Fabric-1 and Fabric-4 after tape application. In contrast, this increase was relatively more limited in the polyester-polyester coated Fabric-2 sample. This can be attributed to the polyester coating exhibiting a more heat-stable structure.

In samples joined with the ultrasonic cut and seal technique, low air permeability values were observed for all fabric types. This is thought to be due to the melting and fusing of fibres at the ultrasonic weld line, largely closing the gaps that allow air passage. This effect was observed more clearly, especially in Fabric-3 and Fabric-4 samples with lower grammage.

Fabric-based evaluation of water impermeability results

According to the water impermeability test results, high values were obtained on the fabric surfaces, while these values decreased significantly in the joining areas. The water impermeability performance of samples with overedge stitching was severely reduced due to the presence of needle holes. This effect was particularly pronounced in the thinner and lower grammage Fabric-3 and Fabric-4 samples.

It was determined that tape application significantly improved waterproofing performance in both traditional and ultrasonic welding methods.

The waterproofing values of samples treated with ultrasonic + tape were higher than those treated with overedge + tape. This is thought to be due to ultrasonic joining without creating needle holes. When evaluated on a fabric basis, PU laminated fabrics (Fabric-1, Fabric-3, and Fabric-4) were found to have higher waterproofing performance compared to polyester laminated Fabric-2.

Interpretation of thickness results

According to table 5, the highest joint thickness for all fabric types is observed in samples with traditional overedge + tape application. This is thought to be primarily due to the high volume of yarn used in the overedge seam structure and the additional layer created by the tape application in the joint area.

In the ultrasonic cut & seal technique, the fact that the weld line is only approximately 0.2 mm wide and no yarn is used results in a lower joint thickness. This is particularly advantageous in thinner and lighter fabrics (Fabric-3 and Fabric-4).

Although the thickness values in the ultrasonic + tape application increased compared to the ultrasonic welding method, this increase was more limited compared to the overedge + tape application. This finding indicates that the ultrasonic joining technique, even with tape application, offers a thinner and more compact joint structure. The results show that the

ultrasonic cut and seal method has significant potential in terms of garment comfort and volume reduction.

Fabric-based evaluation of seam strength results

According to the seam strength results, the highest values were obtained in samples with overedge stitching for all four fabric types. This can be attributed to the fact that overedge stitching creates a seam line approximately 7 mm wide, thus allowing the load to be distributed over a wider area. In contrast, when evaluated similarly, the ultrasonic cut and seal joining method creates a seam line 0.2 mm wide. This resulted in lower strength values.

However, it was observed that the seam strength increased 3–4 times in all fabric types with the ultrasonic + tape technique. This increase can be explained by the tape expanding the load-bearing area and ensuring a more homogeneous distribution of tension.

Overall, the ultrasonic cut and seal joining method, when supported by tape application, offers strength values close to those of traditional overedge stitching.

In order to reveal the behaviour of all fabric types and joint areas obtained by different joining techniques, all data obtained from the tests were statistically handled using the IBM SPSS 25 statistics program. All the data obtained from the tests applied to all fabrics and the joint areas were analysed statistically. A homogeneity test was performed to analyse the results. For this purpose, One-Way ANOVA (Levene Test test was conducted to determine whether the values obtained were statistically significant at the 95% confidence level ($p<0.05$). The test results are as follows (table 7).

Table 7

TEST OF HOMOGENEITY OF VARIANCES				
Air permeability				
Item	**Levene statistic**	**df1**	**df2**	**Sig.**
Techn.1	23.784	3	16	0.000
Techn.2	3.793	3	16	0.031
Techn.3	3.855	3	16	0.030
Techn.4	3.434	3	16	0.042
Water impermeability				
Techn.1	1.099	3	16	0.404
Techn.2	1.279	3	16	0.346
Techn.3	2.207	3	16	0.165
Techn.4	0.988	3	16	0.446
Seam strength				
Techn.1	4.542	3	16	0.017
Techn.2	14.591	3	16	0.000
Techn.3	2.081	3	16	0.025
Techn.4	5.764	3	16	0.007
Fabric results				
Air permeability	6.277	3	16	0.005
Water permeability	0.485	3	16	0.698
Seam strength	9.093	3	16	0.001

According to the air permeability and seam strength values of the techniques, it was determined that there was a statistically significant difference between the joining techniques ($p<0.05$) (table 7). However, when examined in terms of water impermeability, the difference between joining techniques was not statistically significant ($p>0.05$) (table 7). Table 7 shows that there are statistically significant differences ($p<0.05$) in terms of air permeability and seam strength among fabric types. However, the obtained water impermeability values did not yield statistically significant results in terms of fabric types ($p>0.05$). Accordingly, it is thought that the bonding technique applied has a greater effect on water impermeability performance than the fabric type (figure 2).

When figure 2, *a* and *b* were examined, it was observed that the air permeability value increased interestingly when the tape was adhered with the hot air blower. When the test samples are examined, it is seen that the coating material thins during the heat treatment. For this reason, it is seen that the micropores in the joint area increase, which correspondingly increases the air permeability value. This agrees with Havlova [16], who linked porosity to higher permeability. However, it was observed that the tape bonding technique contributed positively to the water impermeability values, consistent with Shi et al. [9].

The thickness results in figure 2, *c*, as explained above, show that the ultrasonic cut and seal method, due to its threadless nature and narrow structure, provides a thinner seam compared to the traditional overlock technique on all fabric types. The tape application further enhanced this value, resulting in a more compact structure compared to the overlock + tape method.

When figure 2, *d* is examined, the overedge seam strengths are higher, but the ultrasonic welding strengths are sufficient. It is thought that the reason for this is that the seam width is 7 mm for the overedge seam and 0.2 mm for the ultrasonic welding. For ultrasonic welding, if it is necessary to increase seam strength according to where the product is intended to be used, rollers that provide a wider joint can be preferred. As can be understood in figure 2, *d*, another method of increasing strength is tape bonding to the surface on which overedge stitching or ultrasonic welding is made. The other interference is that tape bonding on the overedge seam showed a smaller increment in strength than ultrasonic welding proportionally. Another point is seen in table 8, *d*: tape bonding on ultrasonic welding increases the seam strength value 3–4 times. This confirms the findings of Jevsnik et al. [7], but introduces the novel advantage of cut and seal rollers in reducing seam thickness.

The fabrics used in the study are mainly used in outerwear and outdoor products. In line with the results of the study, it has been observed that the expected seam strength, air permeability, and water impermeability properties of these products are also provided by ultrasonic welding and ultrasonic + tape methods.

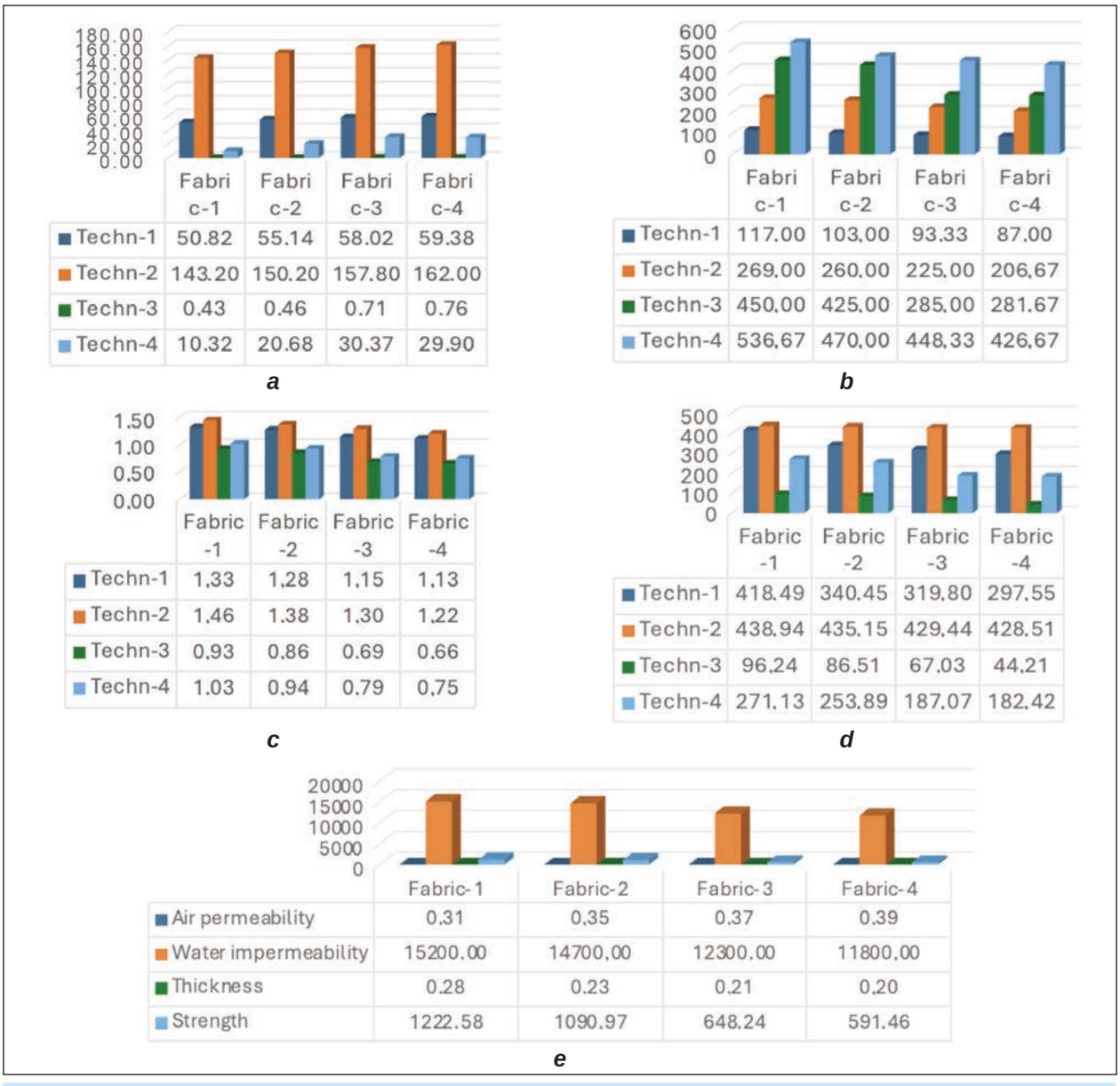


Fig. 2. Comparison of test results: *a* – air permeability (100 Pa – l/m^2/s – 5 cm^2); *b* – water impermeability (mm H_2O column); *c* – thickness (mm); *d* – seam strength (kPa); *e* – fabric results

CONCLUSION

The most significant contribution of this study to the literature is the evaluation of the experimental performance of the ultrasonic cut and seal system on multilayer laminated fabrics, both with and without tape. Furthermore, comparison with traditional systems under the same conditions enhances the originality of the study.

Key findings are the following:

- Ultrasonic welding with tape improved seam strength up to 3–4 times compared to ultrasonic welding alone.
- Seam strength of ultrasonic welding + tape was comparable to overedge seams, despite a narrower seam width.
- Tape bonding enhanced water impermeability in both joining methods.
- Ultrasonic welding produced thinner seams, potentially improving comfort.

These results confirm that cut and seal ultrasonic welding is a viable alternative to overedge stitching, particularly in outdoor and protective clothing where strength, waterproofing, and comfort are critical. Future studies may explore durability under washing, abrasion resistance, and large-scale industrial applications.

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