Süleyman Demirel Üniversitesi
Fen Bilimleri Enstitüsü Dergisi
Cilt 26, Sayı 2, 314-320, 2022

Süleyman Demirel University
Journal of Natural and Applied Sciences
Volume 26, Issue 2, 314-320, 2022

DOI: 10.19113/sdufenbed.1063823

Seam Performance of Nonwoven Apparel Fabrics

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(Alınış / Received: 27.01.2022, Kabul / Accepted: 24.05.2022, Online Yayınlanma / Published Online: 20.08.2022)

Keywords
Nonwoven,
Apparel,
Seam strength,
Sewn seam,
Lock stitch,
Seam efficiency

Abstract: Nonwoven fabrics have limited usage as durable apparel fabrics. Their relatively lower drape, mechanical properties and flexibility decrease their chance to be used as apparel fabrics. However, in the last decades, there are attempts to improve the nonwoven fabric properties in order to seize an opportunity for their use in durable apparel applications. At this point, usage of bicomponent fiber technology together with hydro-entanglement fixation method was found beneficial. In addition to the fabric properties, the suitability of nonwoven fabric for durable seams are quite important for their usability as apparel fabrics. Therefore, in this study, seam performance of nonwoven apparel fabrics made up of polyester: polyamide bicomponent fibers have been determined in order to reveal their usability for durable applications. For this purpose, nonwoven fabrics with 3 different unit masses were utilized. In order to mimic the seams of woven garments, nonwoven samples were sewn with lock stitch with 3 different stitch lengths. Results of the study showed that, unit mass was not a determinative factor for the seam performance of selected nonwoven samples. Also, it was inferred from the study that, sufficient seam strength and seam efficiency values could be obtained by using lower stitch lengths.

Dokusuz Yüzey Giysilik Kumaşların Dikim Performansları

Anahtar Kelimeler
Dokusuz yüzey kumaş,
Giysi,
Dikiş mukavemeti,
Dikiş yeri,
Çift baskı dikişi,
Dikim verimliliği

Öz: Dokusuz yüzey kumaşların dayanıklı giysilerde kullanımı kısıtlıdır. Bu kumaşların görece düşük dökümlülüğe, mekanik özelliklere ve esnekliğe sahip olması, onların giysiliklerde kullanılması şansını azaltmaktadır. Buna karşılık son yıllarda, dokusuz yüzey kumaşların giysilerde kullanım olanaklarının artırılması amacıyla, kumaş özelliklerini geliştirmek üzere çalışmalar yapılmaktadır. Bu noktada, bikomponent lif çekim teknolojisi ile su jetli fiksasyon metotlarının birlikte kullanılması faydalı olmuştur. Kumaş özelliklerine ek olarak, dokusuz yüzey kumaşların dayanıklı dikimler oluşturabilmesi de giysilik olarak kullanılabilirlikleri açısından oldukça önemlidir. Bu nedenle, bu çalışma kapsamında, poliester:poliamid bikomponent lifleri kullanılarak üretilmiş dokusuz yüzey kumaşların dikim performansları incelenmiştir. Bu amaçla, 3 farklı gramaja sahip kumaş kullanılmıştır. Dokuma giysilere benzetilmesi amacıyla dokusuz yüzey kumaşlar çift baskı dikişi ile 3 farklı dikiş uzunluğunda dikilmiştir. Çalışmanın sonuçlarına göre; seçilmiş dokusuz yüzey kumaşların dikiş mukavemetinde gramajın belirleyici bir faktör olmadığı görülmüştür. Ayrıca, daha düşük dikiş uzunluğu ile yeterli seviyede dikiş mukavemeti ve dikim verimliliği elde edildiği belirlenmiştir.

1. Introduction

Nonwoven fabrics are defined as sheet or web structures bonded together by entangling staple fibers or filaments (and by perforating films) mechanically, thermally or chemically [1]. In nonwoven fabric production, yarn production is generally eliminated and fabric structure is obtained by several methods, excluding weaving and knitting [1, 2]. Thanks to their diversity in structure and properties, nonwoven fabrics can be used for different application areas such as automotive textiles, geotextiles, medical/surgical textiles, hygiene textiles, industrial textiles, upholsteries, insulation and apparel applications [1-3].

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Usage of nonwoven fabrics in apparel production can be advantageous as they are low cost, lightweight and soft [4, 5]. However, due to their relatively lower drape, flexibility and mechanical properties, nonwoven fabrics find limited applications in durable/reusable apparel industry [3]. In the apparel industry, nonwoven fabrics are extensively used in the production of disposable apparels [5]. Also, they find usage in the production of interlinings and underwears [1, 2]. Here, the point is to develop the nonwoven fabric properties in order to make them usable for durable apparels. By the way, low cost and other advantages of nonwoven fabrics can be combined with required fabric properties for apparels. In recent years, some companies have attempts to produce more suitable nonwoven fabrics to be used for durable apparel applications. Combining bicomponent fiber spinning and hydro-entanglement is one of the key solutions to develop nonwoven fabric properties those can be suitable for durable apparels [3, 6, 7].

In addition to the fabric properties, seam properties of nonwoven fabrics should be examined, too. Some of the required seam properties of apparels can be summarized as seam strength, seam elasticity, seam slippage, drape, bending, seam puckering and etc. [8, 9]. Besides the hand and appearance related drape, bending and seam puckering properties, seam strength has a vital role for the durability of an apparel. In the literature, seam properties of nonwoven fabrics have been tested for different application areas. For example; Seif and Nasir compared the effects of traditional sewing and ultrasonic welding on some seam properties of nonwoven shopping bags [10]. Eryuruk, Kayaoglu and Kalaoglu studied the effects of ultrasonic welding and 5-yarn overlock stitch on the seam strength and some functional properties of disposable surgical gowns [11]. Grineviciute et al. investigated the seam properties of nonwoven fabrics which included taped seams. They used moisture barriers of firefighter clothes as nonwoven fabrics. [12]. In some other studies, usability of ultrasonic welding for assembling the nonwoven fabrics were investigated [5, 13-15]. According to the literature search, sewn seam performance of nonwoven apparel fabrics have not been studied in details, yet. Existing literature are highly focused on the ultrasonic welding of nonwoven fabrics for different applications. According to the results of these studies, seam efficiencies of the ultrasonically welded nonwovens achieved to a level and were adequate for disposable apparel applications.

Therefore, different than the literature, seam performance of durable/reusable nonwoven apparel fabrics was investigated in this study. For this purpose, sewn seams were formed on the fabrics instead of other assembling methods, in order to obtain high ratios of seam efficiency. According to preliminary trials, lock stitch with 3 stitch length levels were selected to sew the samples. The nonwoven fabrics of this study were suitable for upperwear, and can be applied for shirt production.

2. Material and Method

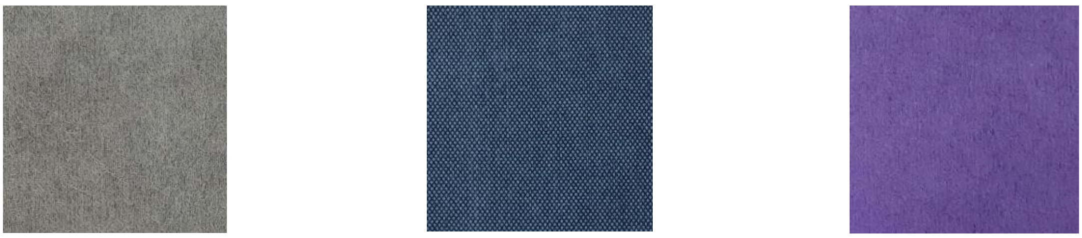
2.1. Materials

Materials of this study were nonwoven fabrics and sewing thread. Nonwoven apparel fabrics with 3 unit masses were supplied from a Turkish manufacturer. The fabrics were made of bicomponent microfilaments composed of 70:30 PET:PA6 (polyester: polyamide 6) raw materials. They were hydro-entangled via high pressure water jets. In addition to the apparel (sportswear, leisure wear, uniforms and workwear), these fabrics can be used in several end-use areas such as home textiles, mattress covers, dry wipes and towels [6]. Properties of nonwoven fabrics are given in Table 1. Also, photographs of nonwoven fabrics are given in Figure 1.

Table 1. Physical properties of fabrics

Sample code	Unit mass (g/m^2)	Thickness (mm)
L (Low)	110	0.50
M (Medium)	138	0.59
H (High)	165	0.58

Sewing thread used in this study was a 2 ply 100% polyester spun sewing thread (Coats Astra). Thread fineness was 40 tex. Breaking strength and strain of the sewing thread was determined as 14.55 N and 56.53 %, respectively. Metric 90 sewing needle with light ball point (SES) was used.



L M H

Figure 1. Face view of nonwoven fabrics

2.2. Methods

2.2.1. Sample preparation

Samples of the study were prepared by sewing the L, M and H fabrics with lock stitch. Samples were varied by changing the stitch lengths. Stitch lengths were determined as 2.5, 3 and 4 mm according to preliminary trials. Stitch lengths of 2.5 mm, 3 mm and 4 mm corresponded to 4, 3.3 and 2.5 stitches/cm densities, respectively. Sample design of the study and sample codes are given in Figure 2.

Seam allowance was kept as 10 mm for all samples.

Seam and sample placements according to the nonwoven fabric directions are shown in Figure 3.

2.2.2. Seam strength and strain measurement

Seam strength and strain of samples were determined using an Instron 4411 Model Universal Test Machine, according to TS EN ISO 13935-2 standard [16]. For the test, gauge length was used as 100 mm and test speed was 50 mm/min. For sewn samples; seam strength, strain and failure type were recorded. As reference samples, non-sewn fabrics were also tested with the same test machine and test parameters, and their strength and strain results were recorded. The test was repeated 5 times for each sample type in machine direction and cross direction.

Before testing, all the samples were conditioned under standard atmosphere conditions (20±2ºC, 65±4 % relative humidity) for at least 24h.

Seam efficiencies of samples were calculated by using reference sample strengths and seam strengths, according to Equation 1 [17].

$$Seam\ efficiency\ (\%) = \frac{Seam\ strength}{Fabric\ strength} * 100 \qquad (1)$$

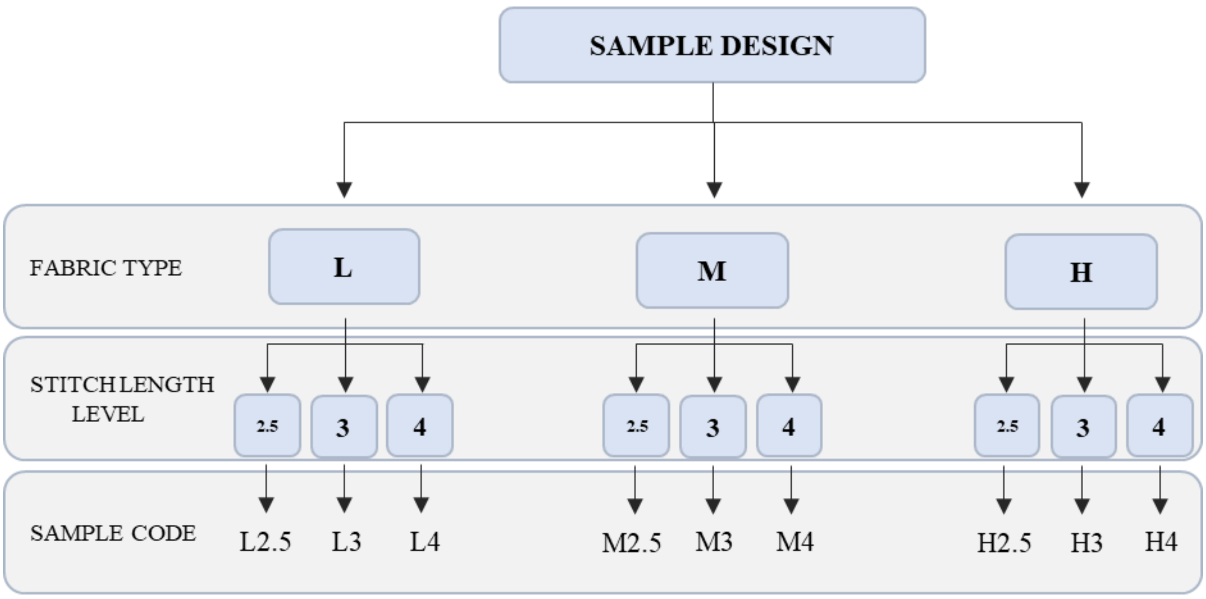


Figure 2. Sample design of the study

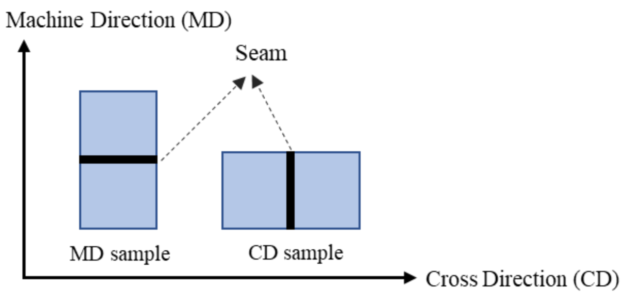


Figure 3. Seam and sample placements according to the fabric directions

2.2.3. Statistical analysis

Statistical evaluations were performed by using SPSS Package Program version 24. At the first step, normality and homogeneity of variance of samples were examined. For normality decision; Shapiro-Wilk test, histograms, variation coefficients (%), Skewness/Kurtosis values and Q-Q plots were evaluated. For homogeneity of variances, Levene's tests were considered. As all the data showed normality and homogeneity of variances, one-way ANOVA and Tukey (Post-Hoc test) tests were used to make comparisons.

3. Results and Discussion

Strength of non-sewn reference samples and seam strengths of sewn samples are given in Table 2 and visualized in Figure 4. Strength of reference samples, namely L-R, M-R and H-R, are between 341 and 411 N in machine direction and, 190 and 252 N in cross direction. According to statistical analysis, strengths of

L-R, M-R and H-R samples in machine direction did not have any significant differences (p values > 0.05). Also, in cross direction, only the strength difference between L-R and H-R was statistically significant and H-R exhibited lower strength ($p < 0.05$). It shows that the unit mass increment did not enhance the tensile properties of the nonwoven fabrics used in this study. Lower strength of H fabric was not expected as it had higher mass. It can be due to any additional processes that could be done until the production of fabric. For all the non-sewn reference samples, strength values in machine direction were higher than the strength values in cross direction. It can be due to fiber orientation differences of the fabrics in machine and cross directions [18]. Similar anisotropic results were obtained for bicomponent fiber containing hydro-entangled nonwovens, in the literature [19].

When we focus on the failure type of samples in machine direction, we see that all L and M samples exhibited seam breakages. In contrary, only H4 sample exhibited seam breakage among all sewn H samples (H2.5, H3 and H4). It can be due to relatively lower strength of H reference fabric when compared to L and M reference fabrics. So that, before the seam breakages, H fabric itself broke during the tests. Similar behavior was also detected for L3 and M2.5 samples in cross direction. Because of the fabric breakages of sewn H samples, in general, seam performance of L and M samples were compared.

According to the seam strength results of L and M samples, it was clearly seen that, seam strength decreased with the increasing stitch lengths, as expected [20]. However, according to statistical analysis, only 4 mm stitch lengths gave statistically significant lower seam strengths when compared to reference samples and other stitch lengths. It was valid for both machine direction and cross direction (only p values between L4 vs. L-R, L2.5, L3; and M4 vs. M-R, M2.5, M3 <0.05).

For the same stitch lengths, any significant differences were not detected for L and M competitors in both test directions (all p values for the same stitch lengths >0.05).

Table 2. Strength and seam strength results of samples

Fabric Type	Stitch Length (mm)	Sample Code	Strength/ Seam strength (N)					
			Machine Direction			Cross Direction		
			Mean	St. Dev.	Failure Type	Mean	St. Dev.	Failure Type
L	No stitch	L-R	411.3	23.4	-	252.2	23.9	-
	2.5	L2.5	381.6	27.2	Seam breakage	260.3	15.3	Mix
	3	L3	345.1	32.9	Seam breakage	252.9	30.7	Fabric breakage
	4	L4	278.9	17.9	Seam breakage	186.5	27.4	Seam breakage
M	No stitch	M-R	411.4	64.0	-	241.7	20.3	-
	2.5	M2.5	391.1	42.6	Seam breakage	257.4	21.9	Fabric breakage
	3	M3	363.2	26.5	Seam breakage	249.8	13.4	Mix
	4	M4	295.8	16.0	Seam breakage	187.6	17.4	Seam breakage
H	No stitch	H-R	341.7	37.7	-	190.6	16.4	-
	2.5	H2.5	299.0	51.0	Fabric breakage	180.2	24.0	Fabric breakage
	3	H3	324.9	21.2	Fabric breakage	150.2	18.6	Fabric breakage
	4	H4	282.4	11.2	Seam breakage	177.0	16.1	Seam breakage

When L4, M4 and H4 samples were compared, any statistically significant seam strength differences were not obtained for any fabric types in both machine and cross-directions (p values > 0.05). So that, the fabric unit mass was not considered as a determinative parameter on the seam strength of selected nonwoven fabrics.

Seam efficiency results of samples are given in Table 3. According to the results, samples exhibited fairly high seam efficiency results. The lowest seam efficiency value was 67.8 % for L4 sample in machine direction. Normally, seam efficiencies around 60-80 % are common and it is hard to obtain seam efficiencies around 80-90 % [21, 22]. For this study, quite high seam efficiency values were obtained for nonwoven apparel fabrics.

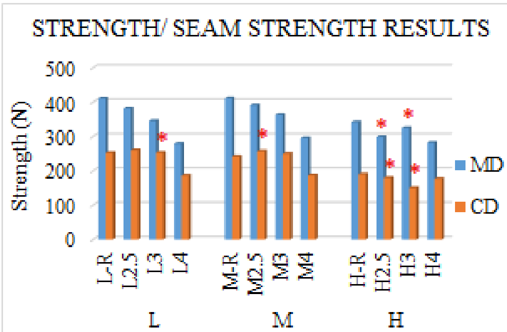


Figure 4. Strength/ seam strength results of samples

(The columns with a * show that fabric breakage was observed instead of seam breakage)

When the statistical analysis results of strength values are considered together with seam efficiency values, it can be concluded that, 2.5 and 3 mm stitch lengths almost did not result any decrements in strengths of samples.

Table 3. Seam efficiency results of samples

Fabric type	Stitch length (mm)	Sample code	Seam efficiency (%)	
			Machine Direction	Cross Direction
L	No stitch	L-R	-	-
	2.5	L2.5	92.8	103.2
	3	L3	83.9	-*
	4	L4	67.8	73.9
M	No stitch	M-R	-	-
	2.5	M2.5	95.1	-*
	3	M3	88.3	103.4
	4	M4	71.9	77.6
H	No stitch	H-R	-	-
	2.5	H2.5	-*	-*
	3	H3	-*	-*
	4	H4	82.7	92.8

(The * shows that fabric breakage was observed instead of seam breakages. Therefore, seam efficiencies could not be calculated for these samples)

Strain (%) values of samples are given in Table 4 with standard deviations. Also, strain results are visualized in Figure 5. When the strain results of non-sewn reference samples were compared, it was seen that strain values decreased as the unit mass increased. For machine direction, L-R exhibited the highest strain value and it was statistically significant (p values < 0.05). Similarly, for cross direction, L-R and M-R gave similar and higher strain values when compared to H-R (p values between L-R vs. H-R and M-R vs. H-R were <0.05).

According to results, stitch length did not have a statistically significant effect on the strain values of L and H samples of machine direction and also, it was valid for strain values of H samples of cross direction (all p values were >0.05 for these samples). As fabric breakages were observed for H2.5 and H3 samples, it was an expected result. In contrast, M4 generally gave statistically significant lower strain values when compared to other M samples, for both machine direction and cross direction (p values <0.05, in general). Similarly, in cross direction, L4 gave statistically significant lower values when compared to L2.5 and L3 (p values<0.05). L4 and M4 samples with the lowest seam strengths, exhibited the lowest strain values among the all stitch lengths. When L4, M4 and H4 were compared, it can be concluded that, lower unit mass samples showed higher strain values. This is partly supported by the statistical analysis results. For all samples, strain values in cross direction were higher than in machine direction.

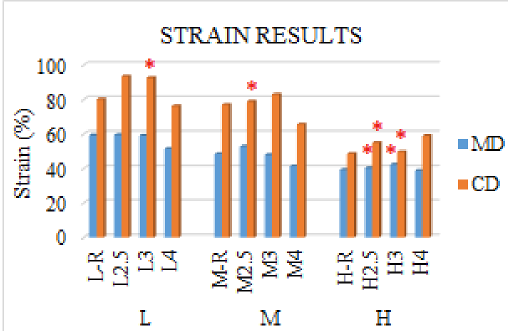


Figure 5. Strain results of samples

(The columns with a * show that fabric breakage was observed instead of seam breakage)

Table 4. Strain results of samples

Fabric Type	Stitch Length (mm)	Sample Code	Strain (%)			
			Machine Direction		Cross Direction	
			Mean	St. Dev.	Mean	St. Dev.
L	No stitch	L-R	59.3	4.5	80.0	4.7
	2.5	L2.5	59.5	7.6	93.4	6.0
	3	L3	59.0	6.3	92.6	5.5
	4	L4	51.3	3.0	76.1	5.6
M	No stitch	M-R	48.2	4.8	77.0	3.8
	2.5	M2.5	52.6	6.0	78.8	7.0
	3	M3	47.8	4.7	82.8	3.8
	4	M4	41.4	1.5	65.5	2.8
H	No stitch	H-R	39.2	1.8	48.5	3.6
	2.5	H2.5	40.2	3.6	54.8	5.9
	3	H3	42.3	1.8	49.6	6.2
	4	H4	38.7	1.3	58.9	2.9

4. Conclusions

In this study, seam performance of nonwoven fabrics for durable apparel applications were examined. For this purpose, hydro-entangled nonwoven fabrics of bicomponent fibers with 3 different unit masses were utilized. They were sewn with lock stitch with 3 different stitch lengths, and examined for their seam performance. According to test results, quite high seam efficiencies were obtained for nonwoven samples. For most of the samples, seam breakages were observed instead of fabric breakages. It was found advantageous as the sewing thread broke instead of fabric damage. It gives the wearer the opportunity to repair the apparel after daily seam breakages.

For the selected samples, unit mass of the nonwoven fabric was not detected as an important criterion for the seam strengths of samples. It should be mentioned that, the average unit mass differences of the samples of this study were about 27 g/m^2. Effects of higher unit mass differences can be found significant on seam performances, in a different sample design. In addition, thickness values of nonwoven samples were similar around 0.51-0.59 mm. This can be another reason for the non-significant seam performances of samples having different unit masses.

For most of the end-use areas of durable apparels, higher fabric strengths when compared to seam strengths are desirable. Otherwise, fabric breakages before seam breakages makes the apparel unrepairable [9]. Therefore, using higher stitch densities for H fabric was found unnecessary, as the fabric breakages were observed before seam breakages for this fabric type.

In the further studies, effects of different seam types and stitch types can be examined for the seam performance of nonwoven apparel fabrics. For these studies, it should be kept in mind that, a higher seam strength is not always preferred for apparel fabrics as it does not allow the repairability of the apparel. Instead of that, sewing can be optimized in order to achieve 80-100 % seam efficiencies.

Acknowledgement
Nonwoven fabrics of the study were kindly supplied from Mogul Tekstil San. Tic. A.S. (Gaziantep, Turkey). Sewing yarn was supplied kindly from Coats Turkiye Iplik San. A.S. (Bursa, Turkey). The author thanks the companies for their supports.

Declaration of Ethical Code

In this study, we undertake that all the rules required to be followed within the scope of the "Higher Education Institutions Scientific Research and Publication Ethics Directive" are complied with, and that none of the actions stated under the heading "Actions Against Scientific Research and Publication Ethics" are not carried out.

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