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Effect of Sewing Thread Properties on Seam Performance of Woven Fabrics

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ABSTRACT

This paper investigates the influence of sewing thread properties, sewing process and repeated washing on strength reduction of sewing threads and the seam strength of sewn samples. For this purpose, 24 different sewing threads were selected. The specimens were sewn with specific sewing parameters and subjected to 10 washing cycles. After each sample preparation part, the tensile properties of needle threads were measured. Also, the seam strength was measured. It was found that the breaking force of each parent thread was significantly higher than the corresponding sewn and washed-sewn thread strength. Considering the strength loss after sewing and washing, the samples sewn with core-spun threads have a lower loss of strength, while the samples sewn with cotton threads have the highest loss. Moreover, the seam strength values after washing are higher for cotton-containing threads than before washing. Conversely, an opposite trend was observed for the samples sewn with polyester-containing threads.

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KEYWORDS

Sewing thread, strength reduction, seam strength, parent thread, sewn thread, repeated washing cycle

1. INTRODUCTION

In the apparel industry, sewing is the most common way of assembling fabric to achieve the required seam strength and flexibility in manufacture and use. In sewing, thread is one of the most important elements and there is still no substitute for it [1]. A sewing thread is a strong, smooth, evenly spun, hard-twisted and elastic, ply or cabled yarn that is treated by a special finishing process to resist abrasion as it passes through the eye of the needle and materials during sewing. It can be made from staple yarns, continuous filaments or core- spun yarns and plays an important role, although it usually accounts for much less than 1% of the mass of a garment [2].

The range of sewing threads on the market has recently increased significantly due to the development of new fibers, the development and improvement of new processes for the production of sewing threads, and the ever-increasing demand from the industry for a variety of sewing threads suitable for sewing a wide range of articles [3].

The mechanical properties of sewing thread play an important role in sewing. The study of tensile properties of sewing thread is essential to understand and predict the thread behavior during sewing and seam failure while the sewn product is in use [4, 5]. In a high-speed sewing machine, the sewing thread, especially the needle thread, is subjected to complex kinematic and dynamic conditions that adversely affect both its processing and functionality. Under these conditions, the thread is subjected to frictional, tensile, bending, compressive, shear, and surface loads caused by guides, tension disks, tension springs, take-up levers, needle eye, and sewing material. These forces repeatedly act on the sewing thread. Such severe sewing conditions can reduce the initial strength of the sewing thread by up to 60%, which

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in turn reduces the serviceability of the seam [6-9].

The performance of sewing threads is generally evaluated by examining the strength reduction of sewing threads after sewing. The extent of strength reduction is a function of the level of stresses acting on the threads and their ability to resist the degrading effect of the stresses [6, 10]. If the thread becomes weaker after getting incorporated into the seam, the seam strength will also be lower than expected. Therefore, it becomes very important to know how much the loss of tensile properties is during sewing [11].

Both the fabric and the seam are washed numerous times during the life of a garment, as this is the most common care process. During washing, the fabric is subjected to complex thermal, mechanical, and physical forces in both the wet and dry states. Repeated washing can alter the quality and performance of sewn products [12-16]. Therefore, in terms of customer satisfaction, it is very important to assess the performance of the garment after the washing processes.

The effects of sewing thread properties and sewing process on seam performance of fabrics have been studied by several researchers. Rengasamy and Wesley (2011) studied the simple, loop, and knot tensile properties of 29 sewing threads [5]. Trivedi et al. (2018) investigated the effect of different sewing methods on the tensile behaviour of sewing threads in denim garments. The tensile behavior of all sewing threads was compared in terms of tenacity, initial modulus, and breaking energy for the lockstitch and chain stitch processes. For all types of sewing threads, a reduction in tensile properties was observed for both sewing methods [17]. Khanna et al. (2015) studied the effect of various interactions between the sewing variables on the sewing thread strength properties during use [18]. Mori and Niwa (1994) used 53 commercially available sewing threads to investigate which sewing thread is suitable for producing visually good seams and how the thread properties are related to the seam quality [4]. Rudolf et al. (2007) investigated the properties of 100% PES core spun threads before and after the sewing process by determining the threads' tensile force during the sewing process and by changes in the mechanical and thermomechanical properties after the sewing process [19]. Zervent Unal and Duru Baykal (2018) determined the effects of different sewing threads and washing methods (rinse, enzyme, and stone with enzyme) on fabric tensile and sewing thread properties [20]. Akcagun et al. (2017) investigated the effects of different washing techniques on the strength of sewing threads. For this purpose, two different sewing threads were sewn to the trouser legs using lockstitch and chain stitch. After this procedure, the trouser legs were subjected to five special washing processes. The washing techniques used in this study were random washing (rag bleaching) and mesh washing (bad washing). The strength properties of the sewing threads before and after washing were statistically investigated [21].

Based on this review of the existing literature, to our knowledge, there are no previous studies that have calculated the effects of repeated washing cycles on sewing thread properties. Therefore, this study investigates the effects of sewing thread type, sewing thread count, sewing process, and repeated washing cycles on the seam performance of woven fabrics. For this purpose, the breaking strength of different sewing threads unraveled from the seams was compared with that of the parent sewing thread. In addition, the seam strength of samples sewn with different sewing threads was analyzed.

2. MATERIAL AND METHOD

2.1 Material

In this study, 24 commercial sewing threads commonly used in the ready-made garment industry are examined, and these threads are classified into 7 groups based on their thread construction. Within each group, there are sewing threads with different thread counts and numbers of plies. The physical properties of the selected sewing threads are analyzed and presented in Table 1.

A plain-weave cotton fabric was used for the sewing trials with selected sewing threads. The properties of the fabric are given in Table 2.

2.2 Method

Yarn twist (TS EN ISO 2061), yarn breaking strength and elongation at break (TS EN ISO 2062), mass per unit area (TS 251), and thickness (TS 7128) values were measured according to the appropriate standards. All measurements were performed after conditioning all samples under atmospheric conditions for 24 h.

A JUKI 1-needle lockstitch machine (DDL-9000A) was used to sew the specimens at 3 stitches/cm, using two layers of fabric in the warp direction. The specimens were sewn with an SES needle. No. 90 needle was used for threads between 24 and 40 tex and No. 110 for threads between 50 and 105 tex. The sewing speed, thread tension, and other settings were kept constant during the sewing process.

After sewing, the samples were classified into two groups (before and after 10 washing cycles). Then, the fabric specimens were subjected to 10 washing cycles in a washing machine according to the EN ISO 6330:2012 standard. Washing was carried out using a standard detergent at 40°C. After washing, the fabrics were allowed to lie flat on a table for 24 h under atmospheric conditions.

After sample preparation, the needle threads were carefully removed from the seam to assess the change in tensile properties after sewing and washing. The breaking

force of the parent threads, the sewn threads, and the washed-sewn threads were measured at a gauge length of 250 mm on the Zwick ZO10 tensile testing machine. Each measurement was performed five times. The percentage of decrease in tensile strength was calculated according to Eq. (1) and Eq. (2). The change in thread strength after washing was calculated based on the washed-sewn and sewn thread strengths to study only the effect of washing. Thus, the strength loss during sewing had no effect on the result.

The seam strength test was carried out using a Zwick Roell ZO10 tensile tester, in accordance with the standard TS EN ISO 13935-1. Measurements were made with five repetitions. The average value of the seam strength was determined by averaging five measured values for each specimen.

The statistical software SPSS was used to analyze the test results. ANOVA and Student-Newman-Keuls tests were performed to determine whether the influence of the selected parameters on the measured properties was statistically significant at the 95% confidence level ($p<0.05$).

$$\text{Change after sewing (\%)} = \frac{\text{Tenacity after sewing} - \text{Tenacity of parent thread}}{\text{Tenacity of parent thread}} x\ 100 \quad (1)$$

$$\text{Change after washing (\%)} = \frac{\text{Tenacity after washing} - \text{Tenacity after sewing}}{\text{Tenacity after sewing}} x\ 100 \quad (2)$$

Table 1. Physical properties of sewing threads

Sewing thread code	Sewing thread type	Linear density (tex)	Number of plies	Twist (turns/meter)	Breaking strength (N)	Breaking elongation (%)
PES27	Polyester spun	27	2	728	10,25	14,50
PES30	Polyester spun	30	2	925	10,23	16,59
PES40	Polyester spun	40	2	696	15,31	14,49
PES60	Polyester spun	60	2	560	22,69	19,69
Co30	Cotton spun	30	2	795	7,66	4,72
Co35	Cotton spun	35	3	753	9,86	6,06
OCo35	Organic cotton spun	35	3	743	10,34	5,12
OCo60	Organic cotton spun	60	3	578	16,51	5,28
PESCo24	Polyester-cotton core-spun	24	2	1210	9,92	21,11
PESCo30	Polyester-cotton core-spun	30	2	1099	12,05	19,80
PESCo40	Polyester-cotton core-spun	40	2	875	18,72	20,66
PESCo60	Polyester-cotton core-spun	60	3	640	28,49	23,41
PESPES18	Polyester-polyester core-spun	18	2	1185	7,55	20,45
PESPES24	Polyester-polyester core-spun	24	2	1010	13,02	19,33
PESPES30	Polyester-polyester core-spun	30	2	945	15,55	20,16
PESPES40	Polyester-polyester core-spun	40	2	674	20,38	20,75
PESPES60	Polyester-polyester core-spun	60	2	580	31,66	22,13
PESPES80	Polyester-polyester core-spun	80	2	538	38,84	18,96
PESPES105	Polyester-polyester core-spun	105	2	508	44,38	19,28
RPESPES24	ster-polyester core-spun (recycled)	24	2	874	12,15	21,43
RPESPES40	ster-polyester core-spun (recycled)	40	2	718	20,35	20,84
RPESPES60	ster-polyester core-spun (recycled)	60	3	695	30,42	21,08
GPESCo40	Polyester-cotton core-spun (glace)	40	2	912	19,47	19,96
GPESCo60	Polyester-cotton core-spun (glace)	60	3	638	27,14	15,48

Table 2. Physical properties of fabric

Material	100% Co
Construction	Plain
Warp thread density (thread/cm)	28
Weft thread density (thread/cm)	20
Thickness (mm)	0.37
Mass per unit area (g/m^2)	140

3. RESULTS AND DISCUSSION

3.1 Changes in Thread Strength

The average breaking force values of the parent thread, the sewn thread, the washed-sewn thread, and the changes in thread strength after sewing and washing were compared, as shown in Table 3.

As shown in Table 3, the highest breaking force values for the different sewing thread types were measured for the parent threads, followed by the sewn threads, and the lowest strength values were obtained for the washed-sewn threads. The breaking force value of each parent thread was significantly higher than that of the corresponding sewn and washed-sewn threads. This result is related to the mechanical effects that occur during both sewing and repeated washing cycles. The reduction in the strength of the sewn thread is an undesirable effect of the sewing process. During sewing at high speeds, the needle thread is subjected to repeated tensile stresses, heat, bending, pressure, torsion and wearing. These stresses repeatedly affect the thread, and the thread has to pass through the fabric, needle eye and bobbin case mechanism 50-80 times before it is incorporated into the seam. Furthermore, local abrasion and cutting of the needle thread may occur due to impact and rubbing at the top of the needle eye [1, 22, 23]. In addition, repeated washing abrades the fabric, sewing thread and sewing area, resulting in a severe reduction in strength.

Table 3. Thread strength results according to sewing thread type and count

	Breaking force (N)			Strengthloss after sewing (%)	Strengthloss after washing (%)
Sewing thread code	**Parent thread**	**Sewn thread**	**Washed-sewn thread**		
PES27	10,25	9,80	8,34	4,39	14,87
PES30	10,23	8,66	8,02	15,35	7,39
PES40	15,31	14,07	12,86	8,10	8,62
PES60	22,69	18,10	16,40	20,23	9,39
Co30	7,66	6,36	3,11	16,97	51,15
Co35	9,86	7,04	3,33	28,61	52,68
OCo35	10,34	7,07	3,81	31,66	46,08
OCo60	16,51	10,10	5,24	38,84	48,15
PESCo24	9,92	9,03	8,49	8,94	5,98
PESCo30	12,05	11,19	9,90	7,16	11,53
PESCo40	18,72	17,57	16,87	6,16	3,98
PESCo60	28,49	25,62	24,46	10,07	4,53
PESPES18	7,55	6,09	6,22	19,34	+2,08
PESPES24	13,02	10,21	9,65	21,58	5,52
PESPES30	15,55	13,81	13,06	11,17	5,45
PESPES40	20,38	19,34	17,21	5,12	11,00
PESPES60	31,66	27,56	26,66	12,95	3,25
PESPES80	38,84	35,39	30,72	8,88	13,19
PESPES105	44,38	40,81	35,01	8,04	14,22
RPESPES24	12,15	11,15	9,53	8,26	14,53
RPESPES40	20,35	19,32	17,91	5,22	7,30
RPESPES60	30,42	29,37	28,77	3,46	2,04
GPESCo40	19,47	17,67	16,09	9,26	8,94
GPESCo60	27,14	25,65	24,77	5,49	3,44

Among the threads used in the study, in general, the highest breaking force values were calculated with PES-PES core-spun threads. The lowest values were obtained with PES-PES core spun thread of 18 tex and mercerized cotton threads for the parent thread, sewn thread, and washed-sewn thread. Statistical analysis showed that the difference between the breaking force values of the different sewing thread types was significant (p=0.001). This situation can be explained by the relatively higher strength values of core-spun threads. PES-PES core-spun has the highest breaking strength and elongation value due to the polyester filament in its structure, whereas mercerized cotton has the lowest value due to its fiber properties. The lowest value of PES-PES thread of 18 tex can be associated with the smallest yarn count used in the study. The polyester spun threads also have higher breaking force values compared to cotton threads. This can be attributed to the higher fiber strength and longer length of polyester fibers. PES-PES core-spun threads are stronger than PES-Co core-spun threads due to longer polyester sheath fibers providing more friction among the core filaments, which adds more strength to the thread than the cotton sheath does [5].

Moreover, it was observed that as the thread size increased, the tensile strength followed the same manner in each sewing thread type. This is because more fibers are incorporated in the coarser sewing thread, resulting in higher strength. However, no significant relationship was found between sewing thread size and strength loss.

When comparing PES-PES core-spun and recycled PES-PES core-spun sewing threads, the breaking force values of both threads are very close to each other and the difference between them is not statistically significant. The same situation is valid for PES-Co and glace PES-Co core-spun threads.

As mentioned by Midha et al. (2010), both spun and core-spun threads undergo structural damage and rupture of surface fibers due to abrasion during sewing. The spun threads, the weakest among all the thread groups, show the highest strength loss. This is because fiber pull-out in threads spun from staple fibers loosens the structure and results in a significant loss of thread strength. In the case of core- spun threads, on the other hand, the thread strength depends on the filament core, so the pull-out of surface fibers has no significant effect on the strength to a certain extent [11].

In addition, PES-PES core-spun threads are stronger than PES-Co core-spun threads, however, the strength reduction after sewing is higher for PES-PES core-spun threads. This is because thermoplastic materials such as polyester can be deformed by the needle heat, resulting in higher strength loss.

Comparing the strength loss after washing and after sewing, it can be said that the loss after sewing is generally higher, so the damage caused by sewing is greater than the damage caused by washing. However, it can be seen that the strength loss due to washing is much higher than the strength loss due to sewing for cotton fabrics. It can also be seen from Table 3 that the highest strength loss after washing was measured for cotton sewing threads at about 50%. This result is due to the low abrasion resistance of cotton threads during washing.

3.2 Seam Strength

Thread structure affects seam strength because the friction between the sewing threads and the fabric yarns affects the translation of thread strength to seam strength [5]. The results of the seam strength test of the unwashed and washed samples are shown in Table 4.

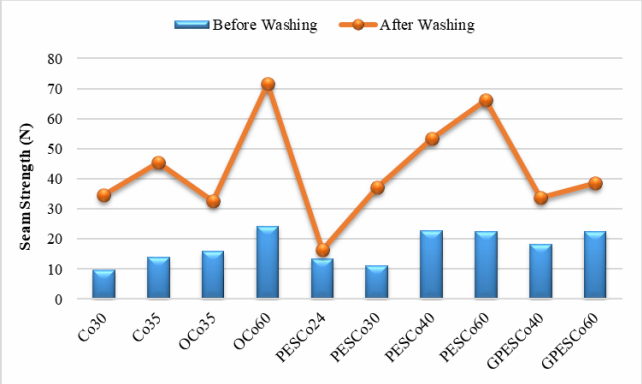

Figure 1. Seam strength of samples sewn with cotton spun and PES-Co core-spun sewing threads

As can be seen in Figure 1, it is clear that for the samples sewn with cotton spun and PES-Co core-spun threads, the seam strength generally increases with increasing thread count and the strength values after washing are higher than before washing. This is attributed to the increase in the diameter of the cotton thread with the effect of washing as stated by Dobilaite and Juciene (2006), Fan et al. (2009) [24, 25]. Although the breaking force values of cotton threads decrease after washing, there are several factors that affect seam strength. The natural fibers are hygroscopic and therefore they absorb the ambient moisture and increase the fiber diameter and thereby the yarn diameter. As the sewing thread and fabric shrinks due to washing, the sewing area is compressed and friction at the sewing line is increased. As a result, the resistance to shrinkage and the seam strength increase [26].

Table 4. Seam strength results according to sewing thread type and count

Sewing thread code	Seam strength – before washing (N)	Seam strength – after washing (N)	Strength change after washing (%)
PES27	8.75	5.11	-41.60
PES30	9.79	5.87	-40.04
PES40	17.77	17.17	-3.38
PES60	21.90	20.88	-4.66
Co30	9.55	34.57	261.99
Co35	13.83	45.49	228.92
OCo35	15.81	32.57	106.01
OCo60	24.30	71.63	194.77
PESCo24	13.48	16.38	21.51
PESCo30	11.21	37.09	230.87
PESCo40	22.70	53.41	135.29
PESCo60	22.60	66.18	192.83
PESPES18	8.25	7.27	-11.88
PESPES24	11.45	8.25	-27.95
PESPES30	11.52	10.94	-5.03
PESPES40	21.35	17.69	-17.14
PESPES60	28.13	27.52	-2.17
PESPES80	50.27	28.28	-43.74
PESPES105	71.91	31.32	-56.45
RPESPES24	7.63	6.21	-18.61
RPESPES40	15.72	17.56	11.70
RPESPES60	15.36	23.42	52.47
GPESCo40	18.27	33.73	84.62
GPESCo60	22.50	38.47	70.98

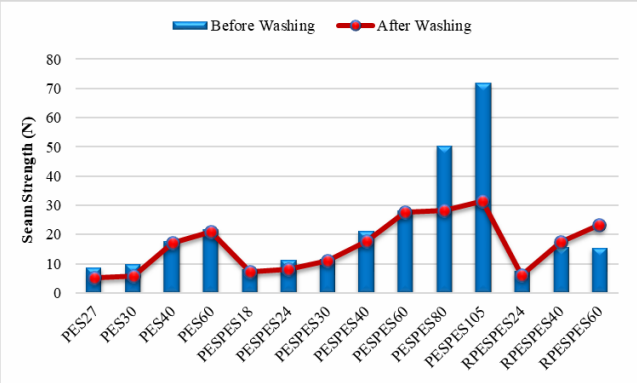

Figure 2. Seam strength of samples sewn with staple polyester spun and PES-PES core-spun sewing threads

As shown in Figure 2, the seam strength generally increases with increasing yarn count for the samples sewn with polyester spun and polyester-polyester core-spun threads. However, the seam strength values measured after washing are lower than those measured before washing. This is due to the abrasion effect of repeated washing cycles to the fabric, the sewing thread, and the sewing area, resulting in a severe decrease in strength, as stated by Zervent Unal and Duru Baykal (2018) [27].

The test results and statistical analysis of the samples sewn with different sewing threads after sewing and washing are given in Table 5 and Figure 3. It is found that the highest strength value was measured with core-spun threads before washing, however, the difference between the results sewn with different threads is not statistically significant. After washing, the samples sewn with PES-Co core-spun and cotton threads had the highest average seam strength values, whereas those sewn with polyester staple threads had the lowest.

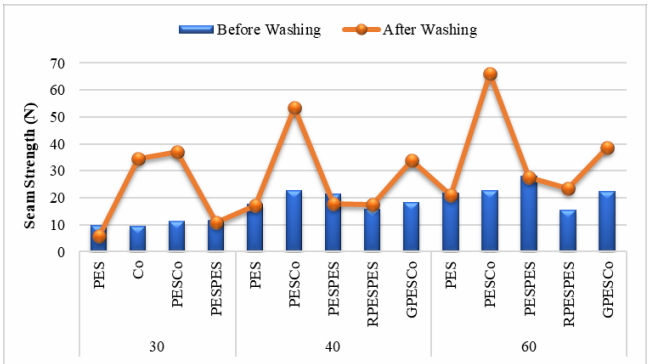

Figure 3. Seam strength of samples sewn with different sewing threads after sewing and washing

The breaking force values of PES-PES core-spun and recycled PES-PES core-spun sewing threads are very close, and the difference between them is not statistically significant. The same situation is valid for PES-Co and glace PES-Co core-spun threads. However, there is a significant difference between the seam strength values of the samples sewn with these threads. The seam strength values of the samples sewn with recycled threads were lower before and after washing, as shown in Figure 4. This can be explained by the fact that the recycled yarns are hairier. Hairy yarns cause higher friction between the fabric and the yarn. This results in an increase in abrasion and a reduction in the seam performance.

Table 5. Student-Newman-Keuls test results (effect of sewing thread type on the seam strength)

Sewing thread count	Sewing thread code	Subset for alpha = 0.05		
		1	2	3
30-Before Washing	Co	9.5533		
	PES	9.7900		
	PESCo	11.2100		
	PESPES	11.5200		
	p	0.164		
30-After Washing	PES	5.8667		
	PESPES		10.9367	
	Co			34.5667
	PESCo			37.0867
	p	1.000	1.000	0.056
40-Before Washing	RPESPES	15.7200		
	PES	17.7733		
	GPESCo	18.2667		
	PESPES	21.3500		
	PESCo	22.7000		
	p	0.078		
40-After Washing	PES	17.1667		
	RPESPES	17.5600		
	PESPES	17.6867		
	GPESCo		33.7267	
	PESCo			53.4133
	p	0.993	1.000	1.000
60-Before Washing	RPESPES	15.3600		
	PES	21.9000	21.9000	
	GPESCo	22.4967	22.4967	
	PESCo	22.6533	22.6533	
	OCo	24.3033	24.3033	
	PESPES		28.1267	
	p	0.111	0.375	
60-After Washing	PES	20.8833		
	RPESPES	23.4233		
	PESPES	27.5233		
	GPESCo	38.4667		
	PESCo		66.1800	
	OCo		71.6267	
	p	0.180	0.509	

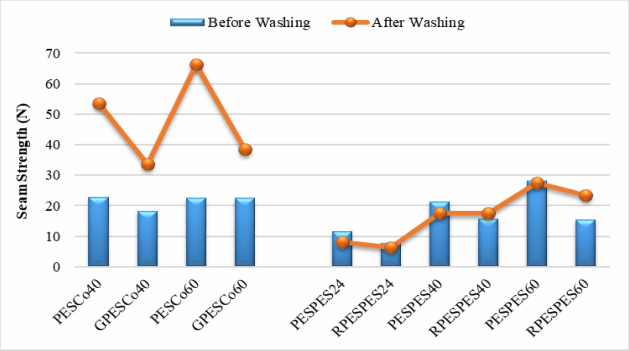

Figure 4. Seam strength of samples sewn with conventional and recycled sewing threads

The correlations between the objective evaluations were found and shown in Table 6. As shown in Table 6, there is a significant correlation between all measured properties except for seam strength after washing.

A high correlation (r=0.990) was found between the parent and sewn thread strength measurements. Similarly, higher correlations were observed between the parent thread and washed-sewn thread strength (r=0.964) and the seam strength before washing (r=0.856).

As the breaking force of the parent thread increases, the sewn thread strength, washed-sewn thread strength, and seam strength increase which means a higher breaking force of the sewing thread leads to a more durable structure in the next steps.

4. CONCLUSION

In this study, the influence of sewing thread properties, sewing process, and repeated washing cycles on the strength reduction of sewing threads and the seam strength of sewn samples was investigated. For this purpose, 24 different types of sewing threads with different linear densities were selected. The samples were sewn with specific sewing parameters. Half of the fabric samples were then subjected to 10 repeated washing cycles. To evaluate the strength reduction of the threads, the tensile strength of the parent threads, the sewn threads, and the washed-sewn threads were measured. The percentage decrease in tensile strength was then calculated. The seam strength of the sewn and washed-sewn samples was also measured.

The main results obtained by these analyzes are summarized below.

- It was observed that the breaking force of each parent thread was significantly higher than its corresponding sewn and washed-sewn thread strength. The breaking force value was higher for the parent threads because the thread is subjected to repeated forces during sewing, which reduce the breaking strength.
- The highest value for breaking force was calculated for PES-PES core-spun and the lowest for mercerized cotton, for both the parent and the sewn thread. As the thread size increased, the breaking strength increased for each sewing thread type.
- Considering the strength loss after sewing and washing, it was found that, among the different types of sewing threads, the samples sewn with core-spun threads showed lower strength loss, while the samples sewn with cotton threads showed the highest loss.
- The values of seam strength after washing are higher for PES-Co core-spun thread and mercerized cotton thread than before washing. However, an opposite trend was observed for the samples sewn with polyester spun and PES-PES core-spun thread.

- High correlations were observed between the parent thread and the strength of the sewn thread (r=0.990), the strength of the washed-sewn thread (r=0.964) and the seam strength before washing (r= 0.856). If the thread has a high breaking strength value, the seam strength will also be higher after it is incorporated into the seam. Thus, the higher breaking strength of the sewing thread leads to a more durable structure in the next steps.

Table 6. Correlation coefficients of the mechanical parameters

	Parent thread strength	Sewn thread strength	Washed-sewn thread strength	Seam strength - before washing	Seam strength - after washing
Parent thread strength	1	0.990*	0.964*	0.856*	0.254

* Correlation is significant at the 0.01 level (2-tailed).

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