The effect of loop length, yarn twist and dyeing process on seam strength of knitted fabrics

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ABSTRACT – REZUMAT

The effect of loop length, yarn twist and dyeing process on seam strength of knitted fabrics

Seam strength is a key factor both in terms of aesthetics and the life of the apparel. There are many factors affecting seam strength, some of which are relevant to fabric construction and treatment, and the others are about sewing thread and sewing parameters. This research paper focuses on the effects of fabric construction, sewing parameters and the dyeing process on the seam strength of knitted fabrics. For this purpose, seven single jersey knitted fabrics were produced, differing in loop length and yarn twist. The samples were dyed and then sewn with different sewing parameters. The seam strength values were calculated and statistically evaluated. The results showed that fabric construction, sewing thread type and count, stitch density and dyeing process profoundly influence the seam strength of single jersey fabrics. When comparing the effects of dyeing, it was found that dyeing leads to a decrease in seam strength values.

Keywords: *seam, seam strength, knitted fabric, loop length, yarn twist, dyeing*

Influența lungimii buclei, torsiunii firului și procesului de vopsire asupra rezistenței asamblării tricoturilor

Rezistența asamblărilor prin coasere este un factor cheie atât în ceea ce privește estetica, cât și durata de viață a îmbrăcămintei. Există mulți factori care afectează rezistența asamblării prin coasere, dintre care unii sunt relevanți pentru construcția și tratarea materialului textil, iar ceilalți se referă la ața de cusut și parametrii de coasere. Această lucrare de cercetare se concentrează asupra influenței structurii materialului textil, parametrilor de coasere și procesului de vopsire asupra rezistenței asamblărilor prin coasere ale tricoturilor. În acest scop, au fost produse șapte tipuri de tricot glat, care diferă prin lungimea buclei și torsiunea firului. Probele au fost vopsite și apoi asamblate cu diferiți parametri de coasere. Valorile rezistenței asamblărilor prin coasere au fost calculate și evaluate statistic. Rezultatele au arătat că structura tricotului, tipul și finețea aței de cusut, desimea cusăturii și procesul de vopsire au o influență importantă asupra rezistenței asamblărilor prin coasere ale tricoturilor glat. Când se analizează influența vopsirii, s-a constatat că vopsirea duce la o scădere a valorilor rezistenței asamblărilor prin coasere.

Cuvinte-cheie*: asamblare prin coasere, rezistența asamblării prin coasere, tricot, lungimea buclei, torsiunea firului, vopsire*

INTRODUCTION

The insertion of needle and thread into several layers of fabric must be regarded as the most complex phenomenon in the textile process from the conversion of the raw fibres to the finished garment. Textile consists of a long series of manufacturing processes and making-up are usually the last process. A garment that is spoiled at this late stage represents a waste of time, effort and material [1]. Therefore, sewing is both the most labour-intensive process and one of the critical processes in determining the productivity and quality of the finished garment [1, 2]. In cut and sewn apparel products, seams are formed when two or more pieces of fabric are held together by stitches [3]. The main function of a seam is to ensure an even transfer of load from one piece of fabric to another, thus maintaining the overall integrity of the fabric assembly. For proper appearance, the seam should not have any defects such as skipped stitches, unbalanced stitches, seam grin, puckering, unsteadiness, improper drapeability, uneven seam density and yarn severance or damage [4].

Since the seam is one of the basic requirements for garment construction, seam quality is an important parameter that determines garment performance [3, 5]. Apparel manufacturers focus on seam quality during the manufacturing and production of garments [4]. Objective and efficient evaluation of seam quality is of paramount importance for the apparel industry [6].

In the apparel industry, overall seam quality is defined by various functional and aesthetic performances desired for the apparel product during its end use [7]. The performance and quality of seams depend on various factors such as seam strength, slippage, puckering, appearance and yarn severance [8]. For better seam quality, it is important to consider the complete harmony of the main fabric properties, sewing thread properties and sewing conditions used. Adjustment of all sewing parameters is necessary to ensure quality [7, 9].

Despite the very high level of technology and automation in the processes of garment manufacturing, the desired sewing quality cannot always be achieved in the production of knitwear. One reason for this is that insufficient attention is paid to the quality of the material, in this case, knitwear. Such inferior quality seams in knitwear cause major defects that may be detected too late. This results in greater financial expenses and marketing risks [10].

Therefore, it is very important to be able to identify and be aware of yarn, fabric and sewing parameters that cause faults in the sewing of knitwear.

Various studies have been carried out to investigate the factors which affect the seam performance of woven fabrics. However, studies on knitted fabrics within this scope are limited. Bansal et al. studied the effects of sewing needle size, seam angle and sewing needle type on seam strength and seam efficiency of knitted fabrics. The test results revealed that with an increase in seam angle and needle size, seam strength decreases. However, with the sewing needle type, an increase in seam strength was observed for all tested fabrics. It is noted that seam efficiency increases with seam angle and sewing needle type [11]. Nassif investigated the effects of loop length, yarn twist factor and number of washing cycles on seam elongation, seam strength and efficiency. The results of this study revealed that both loop length and number of washing cycles had a positive effect on fabric dimensional stability at all twist factors. It is also found that loop length and yarn twist factor had a positive effect on seam elongation. On the contrary, both factors have a negative influence on seam strength and efficiency [12]. Wang et al. investigated the influences of stitch density on the strength, extensibility, and stress with stand retention of three types of stitches commonly used for knitted fabrics [13]. Rajput et al. investigated the influence of weft knitted fabric structures, sewing thread types and stitch types on seam strength and efficiency of superimposed seam type for cotton garments. The test results revealed that polyester-wrapped threads with a polyester filament core thread show better seam strength and seam efficiency [14]. Farhana et al. compared the seam strength and seam performance between dyed and un-dyed gabardine garments. For this purpose, different stitch classes, seam types, stitch densities, sewing thread linear densities and needle sizes were used. It can be concluded that the seam strength of dyed fabrics is lower than that of undyed fabrics due to the different stages of the dyeing process [15].

The related studies on knitted fabrics are limited and further investigation is required. Therefore, in this paper, more parameters, such as yarn twist and loop length of knitted fabric, dyeing process, sewing thread type and count, and stitch density were explored to provide a more detailed study. As fabric type, we focused on a single jersey, the most widely used knitted fabric, which is widely used in the apparel industry, such as T-shirts, underwear, cardigans and leggings.

MATERIALS AND METHODS

Sample preparation

Seven single jersey fabrics with different structural properties were produced on an E28 gauge, 32” diameter Pailung circular knitting machine, at constant machine settings. The fabric samples were produced from 30/1 Ne 100% cotton yarns with two twist factors and four different loop lengths, as listed in table 1. The samples were produced with four different loop length values of 2.6, 2.9, 3.2, and 3.6 mm to obtain tight, medium and loose fabrics, respectively.

After the knitting process, the fabrics were subjected to dry and wet relaxation treatments. Firstly, the fabrics were laid on a flat surface for 24 hours for dry relaxation. The wet relaxation of the samples was performed as reported in the literature [16]. After the relaxation process, half of the fabrics were bleached and then dyed with reactive dyes. All the samples were dyed in the same bath to eliminate variations due to the process.

The undyed and dyed fabric samples were sewn using SES 80/12 needle size on an overlock sewing machine. ISO 504 stitch type was used with three different stitch densities (3, 4 and 5 stitches/cm). All fabric samples were tested coursewise. During the sewing process, the sewing speed, thread tension

Table 1

PHYSICAL PROPERTIES OF FABRICS

Properties	Fabric code						
	F1	F2	F3	F4	F5	F6	F7
Yarn linear density (Ne)	30	30	30	30	30	30	30
Loop length (mm)	2.6	2.9	3.2	2.6	2.9	3.2	3.6
Yarn twist	Low	Low	Low	Medium	Medium	Medium	Medium
Wales/cm	13	13	13	13	13	13	13
Courses/cm	22	19	17	22	19	17	14
Thickness (mm)	0.56	0.57	0.63	0.59	0.60	0.64	0.74
Mass per unit area (g/m^2)	147	140	132	154	149	142	123
Tightness factor (Tex/mm)	1.71	1.53	1.39	1.71	1.53	1.39	1.23

Table 2

PROPERTIES OF SEWING THREADS						
Properties	**Sewing Thread Code**					
	ST1	**ST2**	**ST3**	**ST4**	**ST5**	**ST6**
Thread type	Mercerized cotton	Mercerized cotton	PES-PES core-spun	PES-PES core-spun	PES-Co core-spun	PES-Co core-spun
Yarn count (tex)	30	35	24	30	24	30
Twist (TPM)	795	753	1010	945	1210	1098
Breaking strength (CN/tex)	23.93	28.43	54.63	55.37	41.88	40.33
Elongation at break (%)	4.51	6.42	19.43	20.67	21.25	20.15

and other settings were kept constant. Three types of sewing threads with two different yarn counts were selected. Table 2 shows the characteristics of the sewing threads used.

Testing

Based on the parameters used in this study, an experimental plan was developed using a full factorial experimental design. The input variables of sewing thread type, sewing thread count, and stitch density, each at different levels, were used to create an experimental design. The variables and their values were selected based on the literature review and the general requirements of the apparel industry. By using these variables during the sewing process, undyed and dyed 252 fabric samples were prepared as a whole.

The loop lengths were measured by counting the loop numbers knitted by a predetermined yarn length and dividing this yarn length by the loop numbers. The tightness factor was calculated according to the given formula:

$$Tightness\ Factor = \frac{\sqrt{tex}}{L} \qquad (1)$$

where L is loop length in mm.

Seam strength is the crucial index to represent the mechanical properties of the seam [17]. The seam strength test was performed on a Zwick Roell ZO10 tensile tester, in accordance with the standard TS EN ISO 13935-1. The test speed specified in the standard is 50 ± 10 mm/min. However, this speed is not sufficient to cause the knitted fabric to break at the seam. Preliminary tests showed that breakage at the seam occurred at a test speed of 200 mm/min. For this reason, the device setting was kept constant for all tests: The set distance between jaws was 100 mm and the test speed was 200 mm/min [18].

Measurements were made with five repetitions. By averaging five readings for each sample, the average seam strength value was obtained.

Analysis of variance (ANOVA) was used to analyse the test results using SPSS software. To derive whether the group means were significantly different, the significance level (p-value) was determined. In this analysis, only those cases that showed statistical significance beyond the 5% level were considered significant.

RESULTS AND DISCUSSION

Statistical results related to p-values are given in table 3. For Tamhane's T2 and Duncan tests, the mean values are followed by letters. Any values followed by the same letter are not significantly different ("a" shows the lowest value and "c" shows the highest value).

Table 3

STATISTICAL ANALYSIS RESULTS FOR SEAM STRENGTH VALUES					
Parameters		**Un-dyed**		**Dyed**	
		p-value	**Seam strength**	**p-value**	**Seam strength**
Fabric type	F1	0.006*	75.01 ab	0.036*	57.39 a
	F2		80.40 ab		61.55 a
	F3		88.32 bc		65.91 ab
	F4		82.02 ab		59.62 a
	F5		92.07 c		71.5 ab
	F6		94.22 c		76.03 b
	F7		71.68 a		61.39 a
Sewing thread type	ST1	0.113	78.81	0.023*	59.11 ab
	ST2		87.59		69.96 bc
	ST3		86.14		64.19 abc
	ST4		77.82		56.01 a
	ST5		77.75		64.96 abc
	ST6		92.23		74.74 c
Stitch density	3	0.000*	50.96 a	0.000*	35.42 a
	4		72.29 b		53.37 b
	5		126.92 c		105.54 c

Note: * Statistically significant ($p < 0.05$).

Effect of the dyeing process

The test results and statistical analysis of the samples are given in table 3 and figure 1. The statistical analysis showed that the difference between the seam strength values of the undyed and dyed samples was significant. As shown in figure 1, the seam strength values measured before dyeing were higher than the values measured after dyeing for each fabric type. This is due to the mechanical effects that occur during dyeing. Dyeing abrades the fabric, the sewing thread and the sewing area, resulting in lower seam strength. As stated by Nurrunnabi et al., the seam strength decreases at different rates during dyeing with all dyestuffs (direct, reactive, vat and pigment dyes) [19].

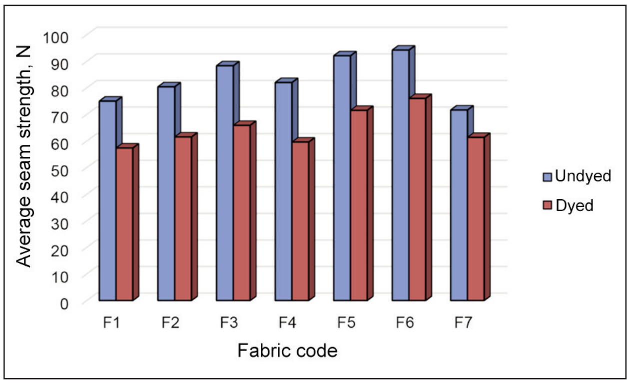

Fig. 1. Effect of dyeing process on seam strength

Effect of the fabric structure

As can be seen in figure 1, the highest seam strength value was measured at F6 before dyeing. The lowest seam strength values were measured at F7 and F1, respectively. However, the statistical test results show that the differences between the lowest values are insignificant. A similar situation was observed after the dyeing process.

Moreover, it was observed that the seam strength values of the fabrics with higher yarn twist and loop length were higher. When the effect of yarn twist in fabrics with the same loop length is examined, it can be seen that the value of seam strength tends to increase with higher yarn twist in all fabric types (figure 2). However, the statistical test results show that the differences between the results are insignificant. In general, it is found that yarn twist has a positive effect on seam strength. As the yarn twist increases, so does the fabric strength, which results in better seam strength values.

Comparing the loop lengths of fabrics with the same twist value, it is found that the seam strength increases with increasing loop length for F1, F2 and F3. However, the difference between them was found to be insignificant. Comparing the medium-twisted fabrics (F4, F5, F6 and F7), it can be seen that seam strength increases between F4 to F6 and decreases very sharply at F7. This means when the loop size increases more than a certain amount, at some point the fabric becomes too loose and it becomes much more sensitive to deformations (figure 3).

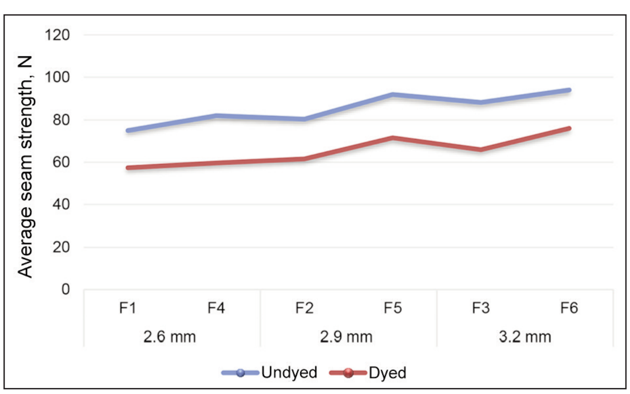

Fig. 2. Effect of twist factor on seam strength

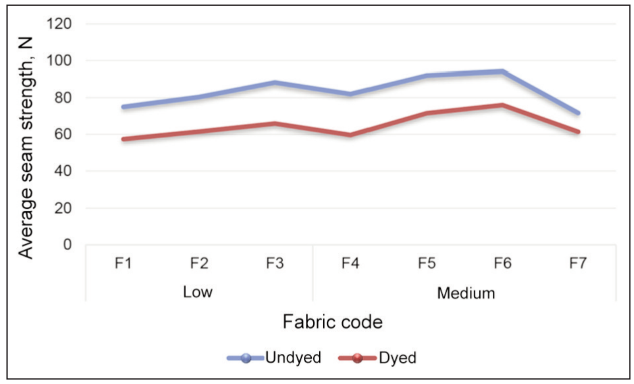

Fig. 3. Effect of loop length on seam strength

Effect of sewing thread

The seam strength values of the fabrics sewn with different sewing threads are presented in figure 4. As can be seen from figure 4, the highest value for seam strength was calculated with ST6 and the lowest with ST4 and ST5 before dyeing. However, the difference between the results is not statistically significant. After dyeing, the samples sewn with ST6 had the highest average seam strength values, whereas those sewn with ST4 had the lowest values.

When the sewing threads are evaluated by sewing thread type, it is found that the seam strength increases with increasing sewing thread count (tex) for PES-Co core-spun thread and mercerized cotton thread. However, an opposite trend was observed for the samples sewn with PES-PES core-spun thread.

There is an interesting phenomenon that occurs in samples sewn with different types of sewing threads. It is known that the PES-PES core-spun sewing thread is the strongest among the others used in the study. However, the lowest value for seam strength was measured with PES-PES core-spun thread both before and after the dyeing process. This can be

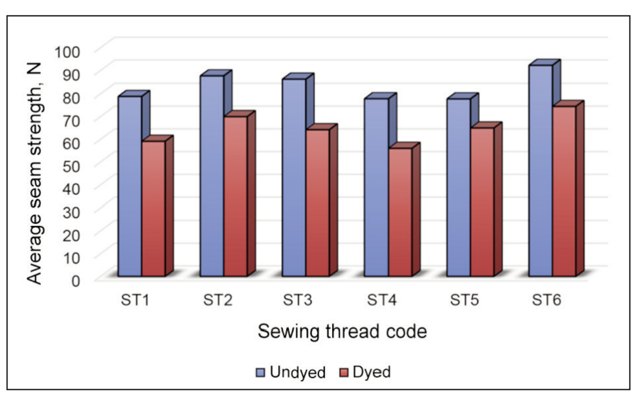

Fig. 4. Effect of sewing thread on seam strength

attributed to the interactions between fabric and sewing thread composition [18].

Effect of stitch density

Statistically, a significant difference was found between the seam strength values of the specimens sewn with different stitch densities. In figure 5, an increasing trend was observed that as the stitch density increased, the seam strength followed the same manner. As mentioned in the literature, as the stitch density increases, the number of contact points between the sewing thread and the fabric yarns increases, resulting in a denser surface [20, 21]. Consequently, the tensile force is distributed to a larger number of points and the resistance is higher. In addition, as the stitch density increases, the sewing thread consumption increases, so the seam resistance becomes higher.

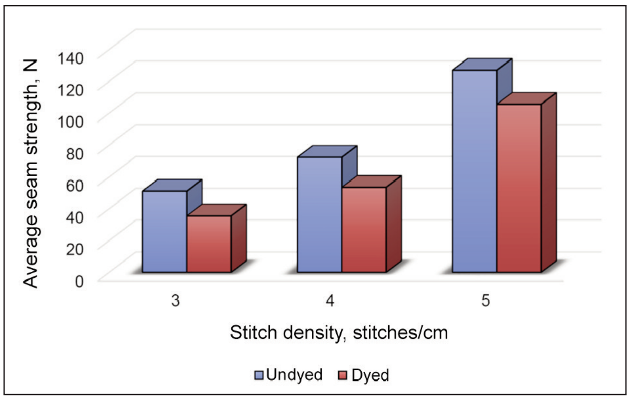

Fig. 5. Effect of stitch density on seam strength

CONCLUSION

In this study, single jersey knitted fabrics were produced with different yarn twist and loop length. Then half of the fabrics were dyed. Dyed and undyed fabric samples were sewn with selected sewing parameters. As mentioned earlier, there are few studies on the seam performance of knitted fabrics. The related studies on knitted fabrics are limited and require further investigation. Therefore, this study focused on the effects of fabric parameters (yarn twist and loop length), sewing parameters (sewing thread count, sewing thread type, stitch density) and dyeing process on seam strength of knitted fabrics. The data obtained from experimental studies were statistically evaluated and the factors affecting the seam strength were analysed.

The main results of these analyses are summarized below.

- The seam strength values of the samples after the dyeing process are lower than those measured before dyeing. This is due to the mechanical damage that occurs during dyeing.
- Fabric construction, sewing thread type, thread count, and stitch density have statistically significant effects on the seam strength values, whereas sewing thread type shows no such effect before dyeing.
- When analysing the results of the seam strength tests, the highest strength values were observed in fabrics sewn with PES-Co core-spun thread at 5 stitches/cm.
- In general, it is found that yarn twist has a positive effect on seam strength. As the yarn twist increases, the fabric strength also increases, resulting in better values for seam strength.
- As the loop length increases, the seam strength increases, however at some point the fabric becomes too loose and the fabric becomes much more sensitive to deformation.
- The general perception is that the core-spun sewing thread is the strongest among the other sewing threads used in the study. However, the interactions between fabric composition and sewing thread may alter the results. For cotton fabrics, PES-Co core-spun and mercerized cotton threads are recommended to achieve the highest seam strength values, both before and after dyeing. This result shows that fabric composition is important in the selection of sewing thread types.

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