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Investigation of the Effects of Elastic Sewing Thread on Seam Performance Properties of Stretch Denim Fabrics

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ABSTRACT

It is seen that stretch denim fabrics manufactured by adding elastane fiber are fashionable and highly preferred by consumers. In this study, comparison of seam performance propeties of elastic and regular polyester sewing threads on stretch denim fabrics was investigated that has not been studied before. As the test material, four denim fabrics were used in twill and satin weave structures and containing 2% elastane with different mixing ratios. Elastane core spun polyester and polyester core spun polyester sewing threads were used in sewing processes. The samples were sewn with lock and chain stitches at the stitch densities of 3 and 4 stitches/cm in both warp and weft directions. The results revealed that the elasticity of the sewing thread has an effect on increasing the seam strength but the strength of the sewing thread is more effective on seam strength and seam efficiency property. Higher seam performance values are obtained in weft directions with chain stitches and at 4 stitches/cm.

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KEYWORDS

Stretch denim fabric, elastic sewing thread, seam strength, seam efficiency

1. INTRODUCTION

Denim fabrics, which are used in the production of durable workwear for the first time, have come from the past to the present and have a wide usage area in textile with its unrivaled comfort [1]. Denim fabrics are produced from yarns such as cotton, polyester and elastane in different weights. Denim fabrics can be woven in various weave patterns and consist of undyed weft yarns together with the warp yarns which dyed with indigo dyestuff [2, 3]. The appearances of the front and back faces of denim fabrics are different. On the front side of the fabric, warp yarns dyed with blue indigo and on the back undyed weft yarns are seen. Denim fabrics are mostly woven with 2/1 and 3/1 twill weaves [3].

The clothes produced from denim fabrics were started to be used long years ago and have reached to the present day without losing their actuality. They are attracted great attention by people from all walks of life. The main reasons for this interest are the comfort and durability of denim fabrics. Today, it is seen that denim fabrics manufactured by adding elastane fiber are fashionable and are widely preferred by consumers.

Stretch denim fabrics containing elastane are woven in different weaving structures from 100% cotton or polyester blended warp yarns and elastic weft yarns produced by twisting together cotton or polyester yarn with elastane yarn [4]. It is used a lot in casual clothes and sportswear by people from all walks of life in terms of its comfort and durability along with its appearance and body fitting structure. It is important that the seams can adapt to the flexible structure of the stretch denim fabric. A product made of stretch denim is affected by the movements of the wearer due to its body fitting structure and is exposed to

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some forces while taking shape according to the body. The tension that occurs at this time also causes stretching of the seams. The seams should also be able to stretch with the fabric so that the seams do not burst.

Seam strength is an important parameter deciding the seam performance of a garment. Fabric structure, sewing thread type and size, stitch and seam types and stitch density affect the seam strength [5, 6]. Seam efficiency is a useful parameter which shows the performance of seam in terms of durability by means of the ratio of seam strength to unsewn fabric strength [7]. Seam efficiency is also defined as the capacity of the material itself to carry a seam [8]. It is stated that the results of seam efficiency is more appropriate to be used for comparison purposes since the value is in percentage and differences between fabrics are justified [9]. Seam efficiency value between 60-85% is expected, seam efficiency between 85-90% is difficult to achieve [9, 10]. The higher seam efficiency value means the selection of sewing parameters is good where damage to the fabric is minimized [9].

There are many studies on the sewing performance characteristics of denim fabrics. The studies related to seam performance of denim fabrics in literature were evaluated and selected studies were summarized below.

Behera et al. (1997) examined the sewability of denim fabrics in connection with the dimensional and mechanical properties of the fabric and sewing threads. Seam efficiency of light denim fabrics was increased with the decrease in the count of sewing thread but in heavy denim fabrics seam efficiency decreased with the increase of sewing thread count. For better seam efficiency; it was recommended that light denim fabric should be sewn by using thinner polyester or thicker cotton sewing threads and heavy denim by thicker core spun or thicker polyester sewing threads [11].

Yeşilpınar and Bahar (2007) investigated the effects of different seam and washing types on seam strength of 100% cotton denim fabric. It was determined that the effects of washing and seam types on seam strength were important. The highest seam strength values in warp and weft directions were seen in felled seam. In overlock sewing, a 30% – 40% reduction in seam strength was observed after some of the washing processes [12].

Korkmaz and Çetiner (2007) found that, in denim fabrics have different weights, core spun sewing threads showed higher seam strength performance compared to staple sewing threads and higher values were obtained before washing. It has been observed that the strength of the fabric affects the seam strength of the weft direction more than the warp direction [13].

Nayak, Padhye and Gon (2010) examined the sewing performance of spun polyester and core spun yarns in denim fabric containing different amounts of lycra. They found that the increase of the lycra ratio in the fabric increased the seam efficiency. Higher seam efficiency was obtained with core spun yarn, while the silicone finish applied to fabric was reduced the seam strength [14].

Erdem et al. (2012) investigated the seam strength of cotton and polyester sewing threads on denim fabric with elastane. They found no significant difference on the seam strength between the sewing thread types. After washing, there was no significant change in the seam strength of the samples sewn by polyester sewing thread, but it was observed that the seam strength of the samples sewn with cotton sewing thread decreased [15].

Zervent Ünal (2012) noted that, in cotton denim fabrics, the seam strength increases as the sewing thread thickness and the stitch density increase. However high seam strength in warp direction was obtained by using coarse sewing thread, higher seam strength values were seen with fine sewing thread in weft direction. It has been determined that polyester/polyester core spun sewing thread has higher seam strength than poly/cotton core spun and staple polyester yarns [16].

The findings of Ali et al.'s (2014) research on 100% cotton denim fabric revealed that highest seam strengths are obtained with class 600 stitch in lapped and bounded seams and also with class 400 stitch in superimposed seam. In the study, it was concluded that the seam strength increased as the stitch density increased [17].

Zervent Ünal and Duru Baykal (2018) investigated the sewing performance of different sewing threads on cotton denim fabric containing elastane. It was seen that the highest seam strength in the warp direction is in the sample sewn with polyester filament sewing thread and also in the sample sewn with polyester/cotton core spun sewing thread in the weft direction. The average performance in both directions is obtained from polyester/polyester corespun thread [18].

Maarouf (2015) performed seam performance tests on 100% cotton denim fabrics. In the study, it was observed sewability decreases with increasing seam puckering. A positive relationship was found between sewability and seam efficiency of denim fabric. It was noted that the seam strength increases with the increase of the stitch density [19].

In Doba Kadem and Bakıcı's study (2016) made on cotton/elastane blended denim fabrics, seam strength increased with increasing sewing thread strength and stitch density [20].

Malek et al. (2017) examined the effects of sewing thread count, stitch density and some fabric properties on seam efficiency on denim fabrics in different mix ratios and different weights. It has been seen that seam efficiency increases as sewing thread count and stitch density increase. The increase in fabric weight showed a random effect on seam efficiency. The presence of elastane in the fabric

structure increased seam efficiency, while the presence of polyester decreased seam efficiency. Seam efficiency in weft direction was found to be higher than warp direction [21].

Ateş, Gürarda and Çeven (2019) investigated the seam performance of the chain stitch and lock stitch on denim trousers considering fabrics structure and stitch density parameters. It was noted that increment of stitch density increases seam strength and chain stitch is stronger than lockstitch. Seam efficiency of denim fabric with elastane was found higher than that of without elastane [8].

As it is mentioned above, many researchers have studied the effects of different sewing and fabric parameters on denim fabrics. When the previous studies are examined; there is not any study about the seams obtained by using elastic sewing thread on stretch denim fabrics. A stretch denim product with its body fitting structure is affected by movements of the wearer and is exposed to some forces while taking shape according to the body. In the meantime, the tension in the fabric causes the seams to stretch. It is important that the seams should be able to stretch with the fabric so that the seams do not burst. It is thought that by using of elastic sewing thread in the seams of stretch denim fabrics will allow the seam to stretch more so that it does not burst when the fabric is stretched. In this study, the stitches formed by PBT (polybutylene terephthalat) yarn which is known as elastic polyester and the polyester core spun yarn were compared with each other on different denim fabrics containing elastane. Seam strength and seam efficiency values of seams formed in different directions by different sewing threads, stitch types, stitch densities were investigated and the results were evaluated statistically.

2. MATERIAL AND METHOD

2.1 Material

In the study, four elastane denim fabrics were used in different blend ratios, with twill and satin weave structures and in different weights. All fabrics have 2% elastane content in the weft direction. The warp yarns of all fabrics are cotton and two of fabrics have polyester fibre in the weft direction. Table 1 shows the properties of the denim fabrics used in the study.

Fabric samples were prepared and sewn in warp and weft directions. In the sewing process of samples, two different yarns, which are 40 tex elastane core spun polyester sewing thread and 40 tex polyester core spun polyester sewing thread were used. Yarns are supplied from Coats and their commercial names are Eloflex (elastane core spun polyester sewing thread) and Epic (polyester core spun polyester sewing thread). Table 2 shows the properties of the sewing threads used in the study. Samples were seamed with lock and chain stitches at 3 stitches/cm and 4 stitches/cm stitch densities. Lock stitches (ISO 4915:1991, type 301) were performed by using the Brother S-7200C-403 electronic lock stitch sewing machine and chain stitches (ISO 4915:1991, type 401) of samples were performed by using the Broaden & Toyou TY-3810 single needle chain stitch sewing machine [22]. The sewing thread used as the needle thread is also used in the bottom thread. Thread number and needle size were chosen in accordance with the unit mass values of the fabrics. The needle used in sewing processes was in size of Nm 90.

Table 1. Properties of denim fabrics

Fabric code	Raw material	Warp density (ends/cm)	Weft density (picks/cm)	Unit mass (g/m^2)	Weaving type
T2P	84% Cotton 14% Polyester 2% Elastane	31	20	269	2/1 Twill
SP	75% Cotton 23% Polyester 2% Elastane	54	30	241	5-Warp Satin
T3	98% Cotton 2% Elastane	35	19	283	3/1 Twill
S	98% Cotton 2% Elastane	52	22	255	5-Warp Satin

Table 2. Characteristics of the sewing thread used in the study (Coats Turkey)

Thread structure	Commercial name	Thread count (Tex)	Ticket No	Strength (cN)	% Elongation (min-max)
Polyester core spun polyester	Epic	40	80	1965	16-23
Elastane core spun polyester	Eloflex	40	80	880	40-70

2.2 Method

The tensile strength and tensile elongation values of the unsewn fabrics used in the study were measured. Seam strength tests were performed to seamed fabric samples. Prior to tensile strength and seam strength tests, samples were conditioned for 24 hours under standard atmospheric conditions (20 ± 2 ° C temperature and 65 ± 2% relative humidity).

2.2.1 Tensile strength

Samples prepared in warp and weft directions were subjected to tensile strength test according to TS EN ISO 13934-2:2002 [23]. The tensile strength test was performed using the Instron 4411 multi-purpose strength tester. The distance between the jaws is 100 mm and the test speed is 50 mm/min. The tests were repeated for five times.

2.2.2 Seam strength

The seam strength tests were performed to sewn fabrics in both warp and weft directions by using the Instron 4411 multi-purpose strength tester according to TS EN ISO 13935-2:2014 [24]. The distance between the jaws is 100 mm and the test speed is 50 mm/min. Samples 350×700 mm were taken from the fabrics. Folding the sample in the half with the fold parallel to longer dimension, the samples were sewn as the seam allowance to be 13 mm. Seams were sewn for testing parallel to the warp and weft direction. Five test specimens of widht 100 mm were cut from this sample. On each test specimen, a line was drawn at a distance of 38 mm from one edge running the full length of the test specimen. The preparation of the seam strength test specimen is shown in Figure 1. Five measurements were taken for each type of sewn sample.

2.2.3 Calculation of seam efficiency

Seam efficiency, which is a parameter indicating the performance of the seam in terms of durability; calculated after determination of fabric strength and seam strength values [25]. Seam efficiency is calculated as the ratio of seam strength to fabric strength as given in Equation (1) below.

$$\text{Seam Efficiency}\,(\%) = \frac{\text{Seam Strength}}{\text{Fabric Strength}} \times 100 \qquad (1)$$

2.2.4 Data analysis

The effects of fabric type, fabric direction, sewing thread type, stitch type and stitch density on fabric tensile strength, seam strength and seam efficiency were analyzed statistically with the one-way variance analysis (ANOVA) in SPSS 23 statistical data analysis programme ($\alpha = 0.05$).

3. RESULTS AND DISCUSSION

3.1 Strength and Tensile Elongation Results

The tensile strength and tensile elongation values of denim fabrics containing elastane are given in Table 3. The values in Table 3 are the averages of 5 measurements and the standard deviations are given in parentheses. All results are shown graphically in Figure 2.

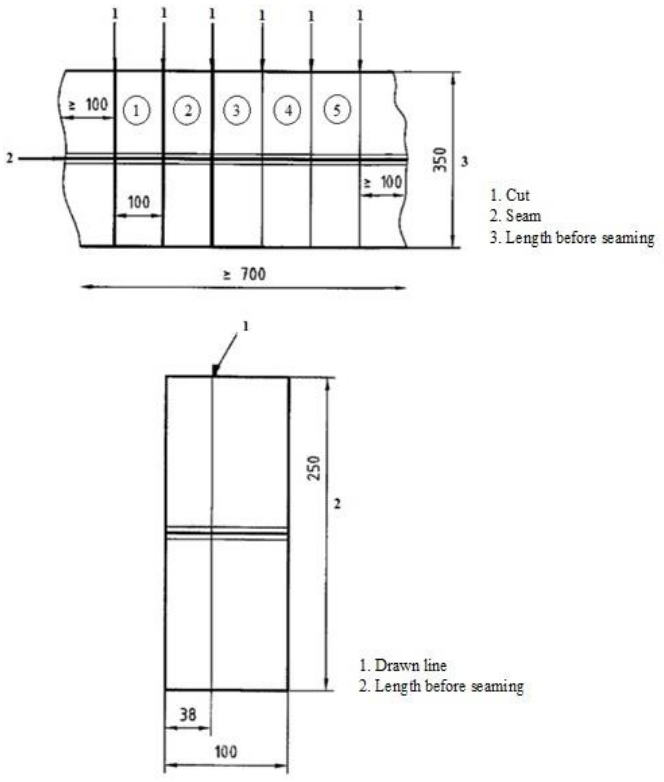

Figure 1. Seam strength test specimen preparation

Table 3. Tensile strength (N) and tensile elongation (%) values fabrics

	T2P		SP		T3		S	
	Warp (SD)	**Weft (SD)**	**Warp (SD)**	**Weft (SD)**	**Warp (SD)**	**Weft (SD)**	**Warp (SD)**	**Weft (SD)**
Tensile strength (N)	1093.0 (78.6)	550.6 (34.4)	932.4 (40.1)	656.0 (18.4)	1084.0 (44.1)	463.2 (15.6)	982.8 (29.9)	490.2 (18.6)
Tensile elongation (%)	24.93 (0.62)	60.53 (2.21)	21.72 (0.52)	76.99 (1.60)	27.21 (1.48)	25.89 (0.97)	25.86 (0.77)	40.64 (2.12)

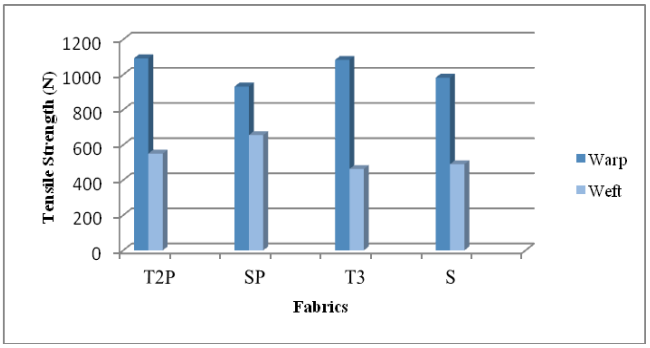

Figure 2. Tensile strength values of denim fabrics

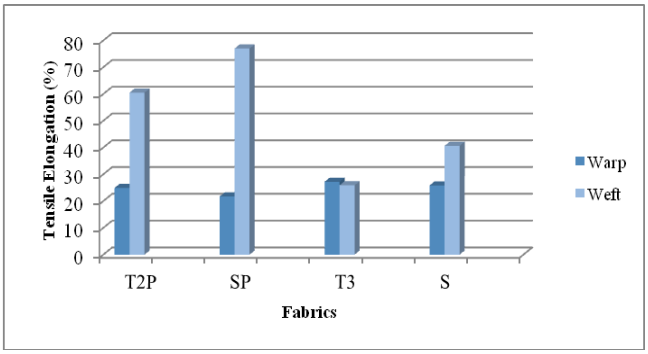

Figure 3. Tensile elongation values (%) of denim fabrics

When the obtained tensile strength values are examined in general (Figure 2); it has been found that the tensile strength of the warp direction is higher than that of in the weft direction. This is expected as the yarn density in the warp direction is higher than in the weft direction. Because as the number of yarns increases, more load is needed to break it. This is consistent with the literature [13, 26].

The tensile strength of the T2P and T3 twill fabrics in the warp direction is found to be higher than that of SP and S satin fabrics because the number of interlacements in the twill weave structure is more than that of in the satin weave structure. Since the twill weaves have higher strength in warp direction due to the increased number of crossover points compared to satin weave types.

It is seen that, T2P and SP fabrics, which have polyester yarns in the weft, have higher tensile strength values in the weft direction compared to the non-polyester fabrics. Due to the high strength of polyester, the strengths of the fabrics in this direction have increased. Among the denim fabrics, SP fabric, which has the highest weft density, has also the highest tensile strength in the weft direction. It is found that the lowest weft tensile strength is in T3 fabric with lowest weft density. As the number of yarns per unit length increases, the load required for breaking also increases, so the strength also increases. It can be said that increasing the weft density increases the tensile strength. It has also been seen in the literature that weft tensile strength increases as weft density increases [27, 28].

While the fabric direction is statistically significant on the tensile strength values ($p<0.05$), it is observed that the fabric type has no statistical difference on the tensile strength values ($p>0.05$).

When the obtained tensile elongation values are generally examined as seen in Figure 3; the tensile elongation in the weft direction is observed to be higher that in the warp direction. All fabrics have 2% elastane content in the weft direction The presence of the elastane fiber which has stretch property in the weft direction of the fabrics, is increased the elongation values in this direction. This result was also indicated in the study of Karazincir (2014) [29]. In T3 fabric, it is found that the tensile elongations in the weft and warp directions are very close to each other. It is thought that there is so little difference between them is due to the fact that the T3 fabric has high warp strength while it has the lowest strength in the weft direction.

When the weft tensile elongation values are compared, it is found that T2P and SP fabrics which contain polyester have higher values than T2 and S1 fabrics that contain no polyester. It is seen that, SP fabric which have 23% polyester content show more elongation compared to T2P that have 14% polyester. Here, it can be said that the ability of the polyester fiber to have a positive effect on the fabric elongation properties.

When warp tensile elongation values are taken into account, it has also been found that SP which has the lowest tensile strength in the warp direction, has the lowest warp tensile elongation. Furthermore, because of the yarns in the fabric have less crimps in 5-satin weave structure compared to twill structure, satin fabrics are less elongated than the twill fabrics. The higher elongation of twill fabrics can be ascribed to the higher intersections between warp yarns and weft yarns in the fabric structure. The lower breaking elongation of satin weave fabrics may be related to the higher float length of the warp yarns in this type of fabrics.

In addition, when weft densities of denim fabrics are considered, SP which has the highest weft density among the four denim fabrics, has the highest weft extension value, and T3 which has the lowest weft density, has the lowest weft extension. As the weft density increases, it can be said that the fabric elongation in the weft direction increases.

The effects of fabric type and fabric direction are found statistically significant on tensile elongation ($p<0.05$).

3.2 Seam Strength Results

Seam strength values of denim fabrics containing elastane are given in Table 4. The values in Table 4 are the averages of 5 measurements and the standard deviations are given in parentheses. The seam strength values are separately shown for 3 and 4 stitch densities in Figure 4 and Figure 5, respectively.

Seam strength is influenced by fabric quality, sewing thread strength, stitch density and stitch and seam types [8, 11, 14]. When looking at the obtained values in generally (Figures 4 and 5); the seam strength values in the weft direction are higher than that of in the warp direction. It is seen that the presence of elastane fiber in the weft direction increases the seam strength. Elastane fiber provide yarn more flexible structure and this increased the fabric elasticity and seam strength. This result is in accordance with the previous studies in literature [8, 30].

It is determined that the seam strength of the samples sewn with the chain stitch are higher than the seam strength of the samples which are seamed with the lock stitch. In lock stitches, needle thread and bobbin thread are bounded together by interlacing. In chain stitches, needle thread and looper thread are bonded together by interlooping and interlacing [9] Therefore, chain stitch is more extensible and has higher thread consumption than lock stitch [8]. It is thought, since the amount of yarn in a single stitch unit of the chain stitch is longer than the lock stitch, it is delaying the break of the seam. In some previous studies, it was also stated that the chain stitches show higher strength than the lock stitches [5, 8, 31].

Table 4. Seam strength values of denim fabrics (N)

	Polyester core spun polyester sewing thread (Epic)								**Elastane core spun polyester sewing thread (Eloflex)**							
	Chain stitch				**Lock stitch**				**Chain stitch**				**Lock stitch**			
	3 stitches/cm		**4 stitches/cm**		**3 stitches/cm**		**4 stitches/cm**		**3 stitches/cm**		**4 stitches/cm**		**3 stitches/cm**		**4 stitches/cm**	
	Warp (SD)	**Weft (SD)**	**Warp (SD)**	**Weft (SD)**	**Warp (SD)**	**Weft (SD)**	**Warp (SD)**	**Weft (SD)**	**Warp (SD)**	**Weft (SD)**	**Warp (SD)**	**Weft (SD)**	**Warp (SD)**	**Weft (SD)**	**Warp (SD)**	**Weft (SD)**
T2P	258.4 (24)	211.3 (7)	332.5 (9)	227.6 (15)	226.3 (9)	238.2 (19)	289.2 (18)	241.7 (16)	158.0 (5)	204.5 (7)	205.9 (7)	236.4 (15)	143.6 (7)	185.1 (12)	171.6 (10)	237.8 (4)
SP	249.8 (18)	328.9 (20)	333 (14)	426.6 (36)	213.6 (26)	274.3 (10)	291.2 (28)	338.2 (55)	157.5 (16)	179.3 (15)	199.3 (5)	240.7 (11)	146.4 (3)	170.9 (8)	179.1 (5)	215.6 (7)
T3	260.6 (15)	291.4 (12)	320.5 (21)	313.7 (20)	226.1 (19)	222.9 (28)	276.3 (26)	292.3 (18)	185.7 (8)	168.7 (8)	208.7 (7)	228.3 (8)	154.8 (10)	166.3 (3)	181.9 (9)	198.3 (7)
S	263.8 (13)	271.4 (13)	341.4 (16)	347,2 (21)	234.4 (22)	243.5 (27)	285.9 (18)	317.6 (7)	164.8 (9)	167.4 (5)	225.6 (8)	226.7 (12)	160.1 (3)	162.2 (3)	182.8 (9)	192.9 (4)

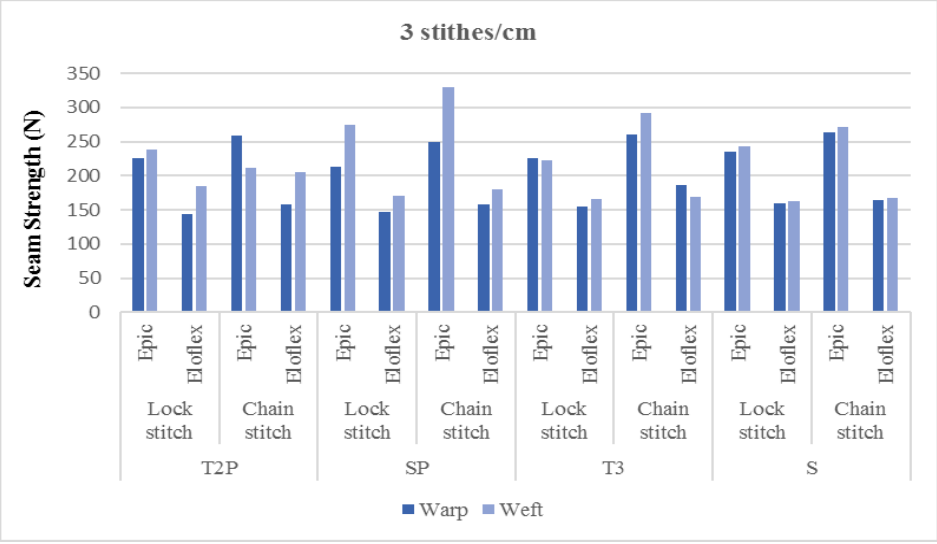

Figure 4. Seam strength values at 3 stitches/cm

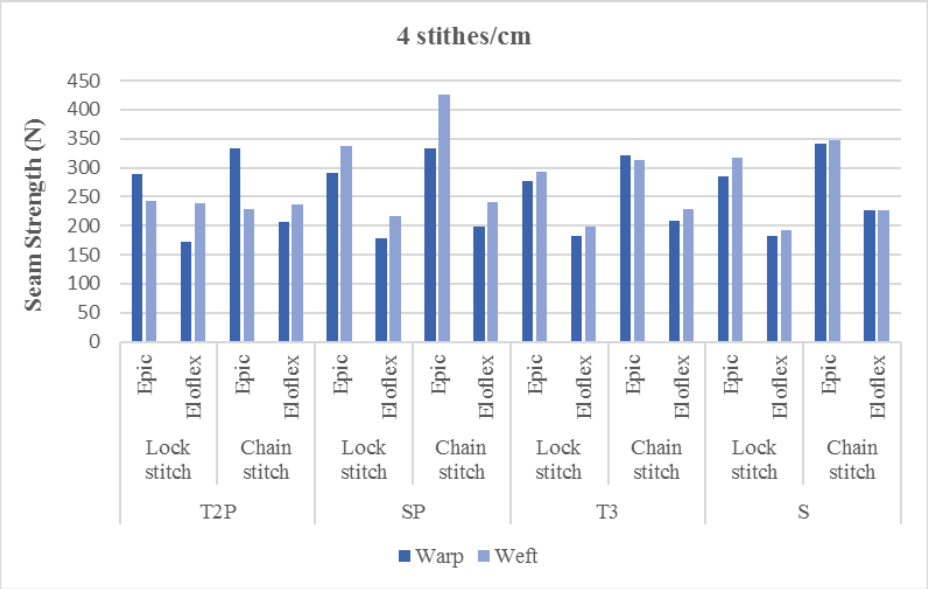

Figure 5. Seam strength values at 4 stitches/cm

When the results according to sewing thread type are compared, it has been found that seam strength of Epic (polyester core spun polyester) is higher than that of Eloflex (elastane core spun polyester). It is reported in the literature that the strength of the sewing thread also influences the seam strength [7, 16, 20, 32]. As seen in Table 2, the strength of Eloflex is 880 cN and Epic is 1965 cN that is 2.3 times of Eloflex. When the seam strength values are examined there is not such a high difference between Epic and Eloflex. It is seen that the elasticity of the thread has an effect on increasing the seam strength. Despite the elasticity of the sewing thread is affected the seam strength, such a large difference between the thread strengths showed that thread strength is more important than thread elasticity for seam strength. It is an advantage that the seams can adapt to the flexible structure of the stretch denim fabric, but low strength of the elastic sewing thread is a disadvantage in terms of seam strength.

The seam strength of the samples sewn with 4 stitches/cm stitch density are found to be higher than that of the samples sewn with 3 stitches/cm stitch density as expected. As the stitch density increases, the seam strength increases. Obtained results were in line with the studies in the literature [16, 17, 19, 20, 33].

In the samples sewn with Epic, SP fabric, which has the highest weft and warp densities and polyester ratio, has the highest seam strength values. Such a situation is not observed in the ones sewn with Eloflex. It can not be made a generalization about the fabric type. When statistical analysis for all seam strength values are examined, it is seen that the effects of sewing thread type, stitch type, stitch density and fabric direction on the seam strength property are found statistically significant ($p<0.05$) while the fabric type is not significant ($p>0.05$).

3.3 Seam Efficiency Results

Seam efficiency values of stretch denim fabrics are given in Table 5. The seam efficiency values are presented graphically for 3 and 4 stitch densities in Figure 6 and Figure 7, respectively.

Table 5. Seam efficiency values (%) of denim fabric

	Polyester core spun polyester sewing thread (Epic)								**Elastane core spun polyester sewing thread (Eloflex)**							
	Chain stitch				**Lock stitch**				**Chain stitch**				**Lock stitch**			
	3 stitches/cm		**4 stitches/cm**		**3 stitches/cm**		**4 stitches/cm**		**3 stitches/cm**		**4 stitches/cm**		**3 stitches/cm**		**4 stitches/cm**	
	Warp	**Weft**	**Warp**	**Weft**	**Warp**	**Weft**	**Warp**	**Weft**	**Warp**	**Weft**	**Warp**	**Weft**	**Warp**	**Weft**	**Warp**	**Weft**
T2P	23.64	38.38	30.42	41.34	20.70	43.26	26.46	43.90	14.46	37.14	18.84	42.93	13.14	33.62	15.70	43.19
SP	26.79	50.14	35.71	65.03	22.91	41.81	31.23	51.55	16.89	27.33	21.37	36.69	15.70	26.05	19.21	32.87
T3	24.04	62.91	29.57	67.72	20.86	48.12	25.49	63.10	17.13	36.42	19.25	49.29	14.28	35.90	16.78	42.81
S	26.84	55.37	34.74	70.83	23.85	49.67	29.09	64.79	16.77	34.15	22.95	46.25	16.29	33.09	18.60	39.35

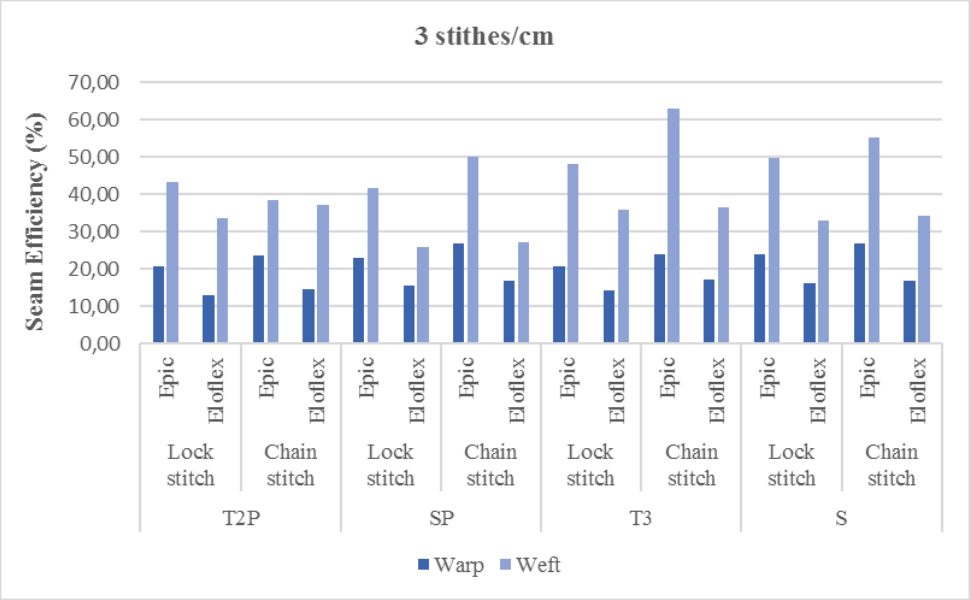

Figure 6. Seam efficiency values (%) at 3 stitches/cm

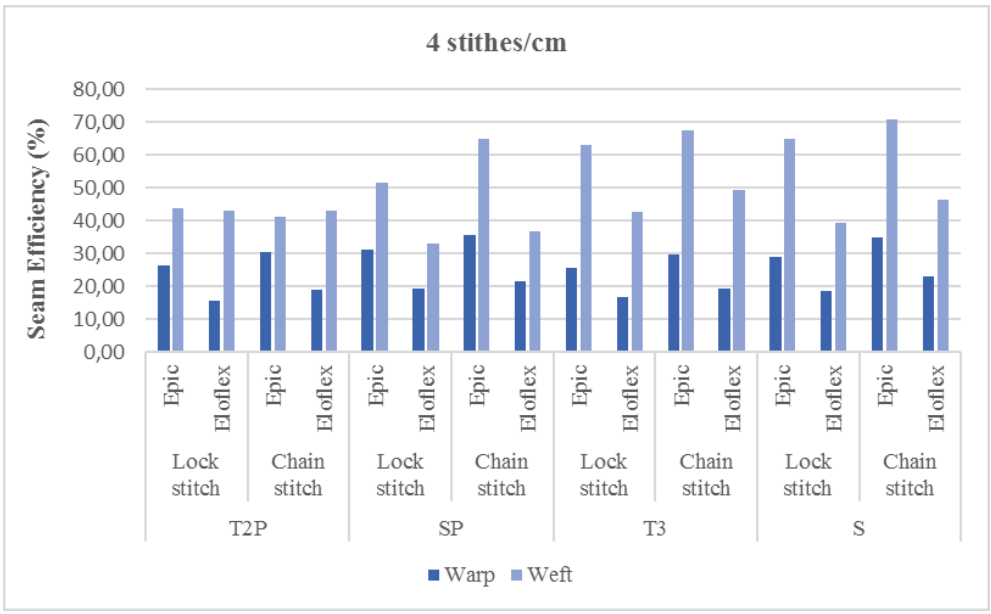

Figure 7. Seam efficiency values (%) at 4 stitches/cm

It has been predicted that seam efficiency largely depends on tensile behaviour of fabric and thread, the combination of fabric and thread, the dimensional and surface characteristics of sewing thread and other machine and process parameters [11]. As can be seen from Figures 6 and 7, the seam efficiency results are between 13–27% and 16-36% in the warp directions and 26–63% and 33-71% in the weft directions of the fabrics for 3 and 4 stitch densities, respectively. It is found that the seam efficiency in the weft direction is higher than the seam efficiency in the warp direction. Since the addition of elastane gives the yarn a more flexible structure, this increased the fabric elasticity and the seam strength and so the seam efficiency. The presence of elastane in the fabric in the weft direction increases the seam efficiency in this direction as observed in Malek et al.'s study [21]. Seam efficiency of samples seamed with the stitch density of 4 stitches/cm has been observed to be higher than that of sewn with 3 stitches/cm ones. Seam efficiency increases as stitch density increases as reported in literature [6, 17, 19-21, 34, 35].

The seam efficiency results of Epic thread are between 21–63% and 26-71% while Eloflex thread are between 13–37% and 16-49%, for 3 and 4 stitch densities, respectively. It is observed that the seam efficiency of the denim fabrics sewn with Epic thread are higher than those samples sewn with Eloflex. This may be because of higher breaking strength property of Epic increases the seam efficiency [7, 14, 30]. Similar to seam strength results, the strength of the sewing thread is found more important than thread elasticity for seam efficiency.

The seam efficiency results of the chain stitches sewn with Epic are between 24–63% and 30-71% while the lock stitches are between 21–50% and 26-65%, at 3 and 4 stitch densities, respectively. The seam efficiency results of the chain stitches sewn with Eloflex are between 15–37% and 19-50% while the lock stitches are between 13–36% and 16-43%, at 3 and 4 stitch densities, respectively. It is seen that the seam efficiency results of the chain stitches are between 15–63% and 19-71% while the lock stitches are between 13–50% and 16-65%, at 3 and 4 stitch densities, respectively. When the seam efficiency values compared according to stitch type, it is determined that samples sewn with the chain stitch have higher values than the samples sewn by lock stitch. This result is accordance with Ateş et al.'s study [8]. Generally, it can be said that the acceptable sewing efficiency values above 60%, were obtained in the samples sewn with Epic thread in the weft direction at 4 stitch density. The effects of sewing thread type, stitch density and fabric direction are found statistically significant ($p<0.05$) on the seam efficiency, but the fabric type and the seam type are insignificant ($p>0.05$).

4. CONCLUSION

Stretch denim fabrics are used a lot in casual wear with its comfortable body fitting structure. A stretch denim product is affected by the movements of the wearer and is subjected to some forces while taking form according to the body. The tension in the fabric that occurs at taking shape also causes stretching of the seams. It is important that the seams can adapt to the flexible structure of the stretch denim fabric. The seams should also be able to stretch with the fabric so that the seams do not damage. It is thought that sewing stretch denim fabrics with elastic thread will allow the seam to stretch more so that it does not burst. In this study, the effect of elastic sewing thread on the seam strength and the seam efficiency properties of denim fabrics containing elastane were investigated. For this purpose, Eloflex (elastane core spun polyester) and Epic (polyester core spun polyester) sewing threads were used. Four different stretch denim fabrics in twill and satin weave structures containing 2% elastane with different blending ratios were used. Denim fabrics were sewn with lock and chain stitches in both warp and weft directions at the stitch densities of 3 and 4 stitches/cm.

Seam strength values of Epic which has high breaking strength, are higher than the seam strength of Eloflex. The experimental results reveal that the elasticity of the sewing thread has an effect on increasing the seam strength but the strength of the sewing thread is more effective on seam strength property. Higher seam strength values are generally obtained in the weft direction. Seam strength is affected by the fabric elasticity in the weft direction due to elastane fiber, so that the seam strength values are increased in this direction. The highest seam strength value (426.6 N) has been obtained in SP satin fabric, which has the highest polyester ratio and the highest % elongation, sewn with chain stitch at 4 stitch density by using Epic sewing thread in the weft direction. It is concluded that the seam strength of the chain stitched samples are higher than that of the lock stitched ones. Increasing the stitch density increases the seam strength. It can be said that higher seam strength can be obtained by the chain stitches at 4 stitch density sewing with Epic sewing thread. Sewing thread type, seam type, stitch density and fabric direction are found statistically significant on the seam strength.

When the seam efficiency results are considered, it is observed that seam efficiency of Epic is higher than Eloflex due to stronger strength property. The seam efficiency results of Epic thread are between 21-71% while Eloflex thread are between 13-49%. Chain stitch show better seam efficiency performance than lock stitch. The seam efficiency results of the chain stitches are between 15–63% and 19-71% while the lock stitches are between 13–50% and 16-65%, at 3 and 4 stitch densities, respectively. Seam efficiency increase with the increase of the stitch density. Besides, it is determined that seam efficiencies in the weft directions are higher than in the warp directions. Elastane in the weft direction of the fabrics increases the seam efficiency. The effects of sewing thread type, stitch density and fabric direction are found statistically significant.

Compatibility of seams of elastic sewing thread to the flexible structure of the stretch denim fabric is an advantage but low strength elastic sewing thread Eloflex is not satisfied the expected seam performance. The strength of Epic sewing thread used in this study is 2.3 times of the strength of Eloflex elastic sewing thread at the same thread count. Such a large difference between the strengths of the threads showed that the sewing thread strength is more important than the thread elasticity for the seam strentgh and the seam efficiency.

In the future studies, different elastic sewing threads which are coarser and have higher strength can be compared in terms of seam performance. The seam performance characteristics of stretch denim fabrics with different elastane blending ratios can be examined. Different fabric directions and different seam types can be selected and studied to determine how these sewing parameters affect the seam performance. In addition to seam strength, seam pucker, seam slippage properties can also be examined.

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