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Short Communications

Assessment of the dynamic elastic recovery behaviour of seams in woven polyester fabric - The effect of stitch type and stitch length

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Due to the various movements of the body while wearing clothes; not only fabric but also clothing seams encounter different and alternative tensile strains. In this regard, the elastic recovery behavior of seams against these strains considerably influences the performance maintenance, quality, and appearance of seam. This study compared the dynamic elastic recovery of the seam in a plain woven polyester fabric prepared by lockstitch and double chain stitch with various stitch lengths and sewing threads with different counts. The dynamic elastic recovery of sewn samples was measured under various strain levels including 10%, 20%, 30%, 40%, and 50% of breakage strains in five loading cycles. The results of this study indicate that the double chain stitch samples owing to the formation of yarn to the loop in the stitch structure have more significant dynamic elastic recovery than lockstitch. Furthermore, in both stitch types, the reduction of stitch length causes the increment of dynamic elastic recovery due to the rise of reserve yarn in the stitch structure and the needle penetration points in the fabric. The application of thinner sewing thread for sewing samples improves the dynamic elastic recovery. In all test samples, by increasing the exerted strain, due to the large deformation of samples, dynamic elastic recovery diminished. The trend of residual strain variation of samples was the opposite of dynamic elastic recovery. By selecting the proper parameter of the seam including stitch type, stitch length, and sewing thread count; it is possible to optimize the dynamic elastic recovery of seams under tensile cyclic loading to keep their shape and performance during use.

Keywords: Dynamic elastic recovery, Seam, Sewing thread count, Stitch density, Strain level, Stitch type

The fabric and garment seams encounter with different and alternative tensile strains because of the various movements of the body during wearing the garment. The performance maintenance, quality and appearance of garment are considerably influenced by the elastic recovery behavior of seams against these strains. Therefore, evaluation of the influence of parameters that are related to the seam including sewing thread properties, stitch length, stitch and seam types on the elastic recovery of seams during various loading is important. Because even by choosing proper fabric, lack of attention to the effective factors on the seam behavior during strain exertion leads to the undesirable change of seam such as seam deformation, seam slippage, seam grinning or seam rupture.

The dynamic elastic recovery of textile (DER) helps to evaluate the response of sample to body movement, immediately and it is calculated by the ratio of unloading work to the loading work at any studied strain level. A textile material with further DER, due to the instant response to the exerted strain does not restrict body movement and keep shape, as well. Due to the importance of elastic recovery and dynamic elastic recovery property of fabric and its assemblies on the ease of body movement and shape retention, this subject was considered from various aspects by researches in last years.

Elastic recovery performance of garment can be considered in terms of both fabric and seam. From the point of view of fabric, using elastic yarns in both warp and weft directions improves elastic recovery of fabrics than fabrics made of both elastic and non-elastic yarns in warp direction (Senthilkumar *et al*. (2011)[1], (Mukhopadhyay *et al*. (2003)[2]), (Barsa *et al*. (2020)))[3] . In addition, weave patterns including the lower warp and weft interlacing points presented further extensibility and recovery in the warp direction (Jiang *et al*. (2023))[4]. Similarly, in weft knitted fabrics not only using elastic yarns in the fabric enhances elastic recovery of fabric, but also the knit pattern and loading direction can affect dynamic elastic recovery of fabric ((Panahi *et al*. (2023))[5], (Motamedi *et al*. (2025))[6]). In this regard, cotton/spandex single jersey fabric not only increases the dynamic elastic recovery property of fabric, reduces the induced stress in the fabric in comparison with cotton single jersey fabric (Senthilkumar and Anbumani (2014))[7]. Even the method of spandex yarn feeding in the single jersey fabrics can change the dynamic elastic recovery of fabric such that spandex plated cotton fabrics have further dynamic elastic recovery than core-spun spandex/cotton fabric; hence, is a proper selection for close-fit sport wear (Senthilkumar and Anbumani

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(2011))[8]. The elastic recovery of denim fabrics woven of cotton/lycra core spun yarn with various yarn counts can be affected by the yarn count. In this regard, when the linear density of lycra filament is similar for all yarns, using thicker core spun yarns decreases the elastic recovery of fabric. Moreover, feed tension and linear density of lycra filament changes the elastic recovery of fabric, negatively ((Bansal *et al*. (2018))[9], (Umar *et al*. (2015))[10]). In addition, the feed percentage of elastic core-spun yarn in the weft direction of fabrics improves the extensibility and shape retention of fabric due to the proper elastic recovery of fabric and also provides ease body movement ((Özdil (2008))[11], (Mourad *et al*. (2012))[12], (Jovanovic *et al*. (2022))[13], (Doan *et al*. (2003))[14]). However, it should be noticed that the increase of exerted strain percent on the fabric, decreases the dynamic elastic performance of fabrics (Yu *et al*. (2015))[15]. In other words, elastic recovery behaviour of elastic woven fabric depends on the extension rate, initial sample length and maximum applied load on the fabric (Ogulata *et al*. (2006))[16].

The structural parameters of fabrics can be considered to optimize the elastic recovery performance. The raise of the weft density of denim fabrics made of dual-core spun yarn consisted of two elastane and polyester filaments as core and cotton as sheath, enhances the extensibility and elastic recovery of fabrics and causes to the diminish of the residual strain (Ertaş *et al*. (2016))[17]. Although fabrics including lycra yarns have further elastic recovery performance, they have higher surface density and thickness that decreases the porosity of fabrics. However, the increment of loop length diminished the elastic recovery property of fabric (Eltahan (2016))[18]. Consequently, it can be concluded that by selecting proper parameters in producing knitted fabrics such as feed tension of elastic yarns, elastic yarn count and surface density of fabrics, it is possible to optimize the elastic recovery characteristics of fabric (Senthilkumar *et al*. (2012))[19]. Similarly, in woven fabrics, selecting suitable weave pattern and weft density help improve elastic recovery of fabric and the shape maintenance of fabric against sequential deformation (Doustar *et al*. (2010))[20]. In this regard, the elastic recovery of woven fabrics can be estimated by regression model in terms of fabric structural features such as elastic yarn count, the number of floating yarns in the weave structure, weave pattern and density and also the exerted force ((Maqsood *et al*. (2016))[21] , (Kaynak (2017))[22]).

Although the dynamic elastic recovery of cotton/spandex fabric is more than cotton fabric, the impact of the laundering on the dynamic elastic recovery of fabric is not significant (Senthil kumar and Anbumani (2012))[23]. While various finishing treatments improves the denim fabrics comfort and performance, cotton/elastane denim fabrics are preferred than cotton denim fabrics by customers due to the body comfort and easy of body movement (Eryuruk (2019))[24]. In weft knitted fabrics, besides the fabric structures and its constituent yarn properties, the home washing sequences and the time regarded for recovery can affect the permanent deformation of fabrics (Sular and Oner (2019))[25]. Moreover, the number of loading cycles due to the residual deformation can affect shape retention of fabrics even in fabric made of core-spun cotton/spandex yarn (Baghaei *et al.* (2010))[26].

While elastic recovery of fabric prevents garment deformation during use, the elastic recovery performance of seams and their behavior under cyclic loading determines the seam deformation and strength during use. Due to the various tensions and frictions that tolerated by sewing thread in every sewing cycle, viscoelastic and the tensile and recovery properties of sewing threads before and after sewing are different (Ajiki and Postle (2003))[27], (Kechi (2014))[28]. In sewn sample by ISO -301 stitches, the elastic recovery of seams is influenced by interaction of fabric, sewing thread and seam properties (Webster *et al*. (1998))[29]. Assessment of grinning behavior of knitted fabrics under tensile loading illustrated that the raise of fabric rigidity, sewing thread extensibility and also stitch length, increases the seam grinning ((Ucar (2002))[30], (Bansal *et al*. (2021))[31]). Moreover, seam deformation under repeated tensile loading is influenced by the sewing thread properties, stitch length, exerted load and the number of loading sequences (Shimazaki and Lloyd (1990))[32]. However, the seam behavior of elastic woven fabrics under tensile loading depends on the both fabric extensibility and stitch length (Namiranian *et al*. (2014))[33] and it is possible to estimate the seam opening of woven fabrics by considering weave density, stitch length and yarn count of fabric's constituent's yarn under static and dynamic loading (Yildirim (2010))[34]. Although seam strength is lower than unsewn fabrics, tensile loading of seams by lesser loads than breaking can change the tensile performance of seams (Rogina-Car *et al*. (2018))[35].

By reviewing former researches, it can be observed that dynamic elastic recovery of seams that can present the resistance of seams against exerted tensile loading and also its instant reaction to the applied strains and shape retention is not considered. In this regard, the purpose of this study is to investigate the dynamic elastic recovery of seams. To this end, dynamic elastic recovery of two main stitch types that are used to assemble fabrics including lockstitch and double chain stitch is considered and compared. In addition, the influence of stitch length and sewing thread count on the dynamic elastic recovery of seams was assessed. Due to the effect of strain level and also the number of loading cycles on the dynamic elastic recovery, the tests were performed under five strain levels and repeated five times.

Experimental

Material

On the purpose of assessing the dynamic elastic recovery behaviour of seams and also investigating the influence of stitch type and stitch length on the dynamic elastic recovery of seams, a polyester woven fabric with plain weave pattern, the areal weight of 114 g/m^2 and thickness of 0.28 mm under pressure of 20 g/cm^2 was used for sample preparation. The warp and weft density of the fabric were 28 and 16 per centimetre, respectively. In order to sew test samples, four 100 % polyester core spun yarns with various counts including 20, 25, 30 and 40 tex were utilized. The core of all sewing threads was a filament yarn with the count of 15 tex that includes 48 filaments.

Sample Preparation and Testing Procedure

Seam Strength

In order to measure the seam strength and also examine the influence of stitch type and stitch length on the seam strength, fabric strips with the dimension of 200 mm × 50 mm were cut along the warp direction. Each test sample was made by sewing two fabric strips along the smaller edge of fabrics. Test samples were prepared by using four sewing threads with various yarn counts. As it was mentioned previously, the samples were joined to each other by lockstitch (lockstitch Durkopp Adler sewing machine Model 272) and double chain stitch (double chain stitch JACK sewing machine Model JK8558 W-1) with various stitch lengths including 2, 3 and 4 mm (the double chain stitch samples were prepared with stitch lengths of 2 and 3 mm due to technical limitation) and by constant thread tension and similar seam allowance of 10 mm for all samples. In all studied conditions, five samples were sewn to repeat the test.

Seam strength measurement was performed based on the ASTM D434 standard test method which is a transverse direction test. It means that the load direction is perpendicular to the seam line. Seam strength was measured by the Instron 5566 tensile testing machine and the initial distance of device jaws was set to 75 mm. The upper jaw of the testing machine moves upward with the speed of 100 mm/min. A pre-tension of 8 g was exerted for all test samples to provide similar testing condition.

In addition, the tensile behaviour of tested fabric was evaluated by the Instron 5566 tensile testing machine according to the BS 2576 standard test method. In this regard, five fabric strips with the dimension of 350 mm × 50 mm were cut in both warp and weft directions. The initial length of samples was 200 mm and the extension rate was 100 mm/min. A pre-tension of 8 g was used for all samples to provide same testing condition.

Dynamic Elastic Recovery

With the aim of assessing dynamic elastic recovery of seams and probe the influence of sewing thread count, stitch type and stitch length on the DER, the applied tensile force should be lower than breaking force of seam. Beside, considering to this point that during wear, the garment encounters with various strains, the dynamic elastic recovery of sewn samples were evaluated in five levels of strains including 10, 20, 30, 40 and 50 percent of the breaking strain.

Similar to the seam strength test, dynamic elastic recovery of seams was measured by Instron 5566 tensile testing machine. The sample dimension, sample preparation method and setting of testing device are similar to the seam strength, as well. It means that the gauge length and elongation rate were 75 mm and 100 mm/min, respectively. Also a pre-tension of 8 g was applied for all samples. However, in dynamic elastic recovery test, the samples are extended in lower strain than breaking strain including 10, 20, 30, 40 and 50 percent of the breaking strain. In addition, since during use, the garment and seams faced with repetitive extension, in order to evaluate the influence of repetitive extensions on the dynamic elastic recovery of test samples, DER examinations were performed in five loading-unloading cycles, such that, after exerting the chosen strain, the upper jaw of the test device returns to its initial position and the desired strain is applied to the sewn sample again. Then, the DER of all samples for whole tests and each test cycle individually can be calculated by Eq.1

$$DER = \frac{area\ under\ the\ unloading\ curve}{area\ under\ the\ loading\ curve} \times 100 \quad \ldots(1)$$

Results and Discussion

Evaluation of the Tensile Properties of Fabric and Seams

The seam strength of sewn samples prepared with various stitch types, stitch length and sewing thread counts were examined and the obtained results are summarized in Table 1. In samples codes (Table 1), LS and CS code are used for lockstitch and double chain stitch samples, respectively. The number of 20, 25, 30 and 40 states the yarn count of sewing thread and the number of 2, 3 and 4 presented the stitch length of sample. The fabric stress in the warp and weft direction was 1726.94 and 586.18 cN/mm, respectively. The breaking strain of testes fabric in the warp and weft direction was 27.42% and 15.01%, respectively.

The influence of seam parameters including stitch type, stitch length and sewing thread count on the seam performance of samples in terms of seam strength and seam strain was illustrated in Fig. 1. It was perceived that at the similar condition, the increase of sewing thread count results in the improvement of seam strength and seam strain. For example, using sewing thread with the count of 40 tex instead of 20 tex leads to the 105.81% and 136.9% increment of seam strength in the lockstitch and double chain stitch samples, respectively. In other words, using thicker sewing thread is a way to improve seam performance. Because in sewing thread with same structure and fibre blend, the increase of thread counts means the raise of the number of fibre in cross-section. As it is known, the increase of the number of fibre in cross-section of yarn enhances the sewing thread strength and at the similar condition, increase of sewing thread strength leads to the raise of seam strength. On the other hand, the increment of stitch length in both stitch types diminished the seam strength and strain. As it is known, the raise of stitch length causes to the reduction of stitch density and in turn the fall of the number of needle penetration points and joining of fabric strips and sewing threads. Consequently, the exerted tensile load is tolerated by the less points; hence, further tensile load is applied on each point that accelerates the seam rupture. The comparison of seam strength of lockstitch and double chain stitch at the similar condition indicates that the samples prepared with double chain stitch have further seam strength than lockstitch. In Fig. 2, a

Table 1 — Seam strength and strain of samples

Stitch Type	Stitch Length, mm	Sample Code	Seam Strength, cN/mm		Seam Strain, %	
			Average	SD	Average	SD
Lock Stitch	2	40-LS2	460.61	0.69	23.33	0.03
	3	40-LS3	251.59	0.60	22.22	0.01
	4	40-LS4	120.59	0.08	19.26	0.13
	2	30-LS2	308.83	0.43	18.15	0.01
	3	30-LS3	152.02	0.08	17.04	0.01
	4	30-LS4	105.66	0.11	15.92	0.01
	2	25-LS2	284.98	0.37	16.29	0.02
	3	25-LS3	151.73	0.21	15.92	0.02
	4	25-LS4	89.23	0.02	14.07	0.02
	2	20-LS2	223.08	0.09	16.29	0.03
	3	20-LS3	114.67	0.24	14.44	0.02
	4	20-LS4	74.26	0.07	13.33	0.03
Double Chain Stitch	2	40-CS2	589.61	1.24	24.07	0.03
	3	40-CS3	473.52	1.09	23.7	0.03
	2	30-CS2	508.02	0.41	20.74	0.01
	3	30-CS3	388.08	0.43	19.26	0.01
	2	25-CS2	503.44	0.2	20	0.01
	3	25-CS3	361.11	0.65	16.67	0.01
	2	20-CS2	248.89	0.27	14.08	0.01
	3	20-CS3	101.51	0.10	13.7	0.01

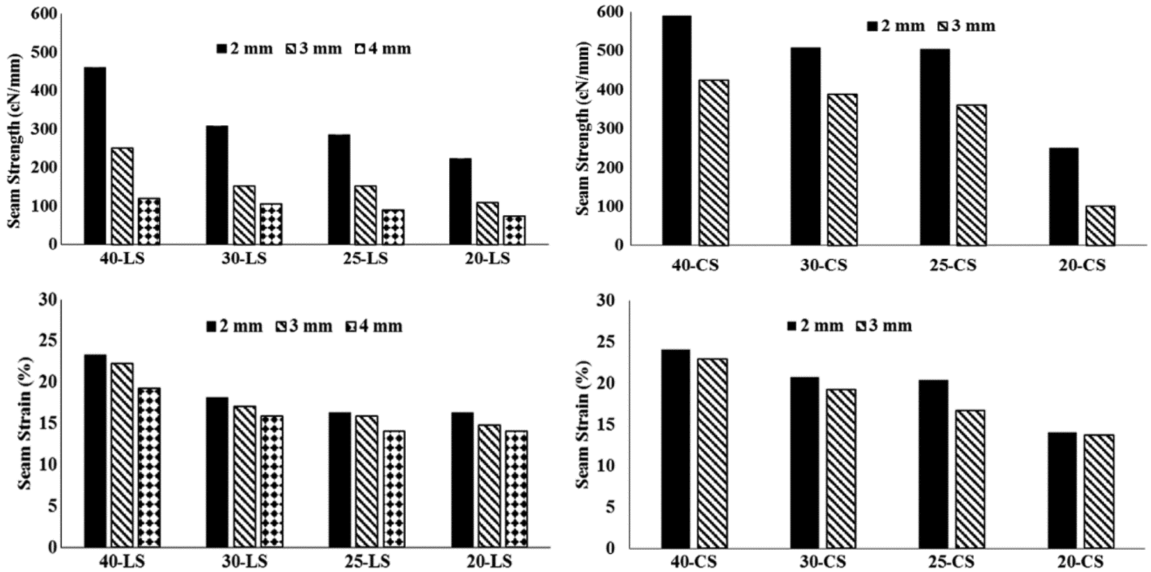

Fig. 1 — The seam strength and strain of various sewn samples

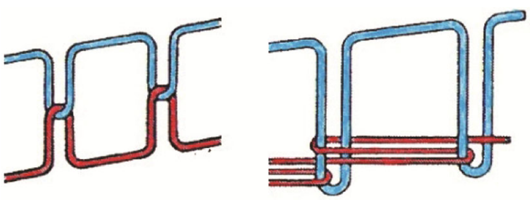
Fig. 2 — The schematic of lockstitch and double chain stitch

schematic of both lockstitch and double chain stitch is presented.

It was observed that both stitch types are formed by two sewing threads; however, the shape of stitch formation is different. The lockstitch is formed by interlacing of needle thread and bobbin thread; but, the double chain stitch is made by 7 interlooping of needle thread and looper thread. Consequently, the number of sewing thread contact points in a stitch is different in both studied stitches. As it is noticed in Fig. 2, the number of sewing thread contact points in double chain stitch is twice the lockstitch. Besides, in lockstitch, between two adjacent needle penetration points, the sewing thread is placed straight on the fabric; however, in double chain stitch, sewing thread formed loops. When tensile load is exerted on the double chain stitch, at first the load is used to deform the sewing thread loops and after that sewing thread extension. This phenomenon postpones the seam rupture. Conversely, when the tensile load applied on the lockstitch, due to the straight shape of yarn between two successive needle penetration points, the exertion of tensile load elongates the sewing thread and less seam strength is obtained. In other words, higher force is required for seam rupture of double chain stitch than lockstitch. Therefore, seam strength and seam strain of double chain stitch is greater than that of lock stitch.

The results of statistical analysis confirmed that the influence of sewing threads count, stitch length and stitch type on the seam strength at the confidence level of 95 % is significant.

Assessment of the Dynamic Elastic Recovery of Seams

In order to evaluate the dynamic elastic recovery of test samples, the sewn fabrics were loaded in five successive cycles under different strains including 10, 20, 30, 40 and 50 % of the breaking strain. In Fig. 3, the diagram of cyclic tensile loading of samples sewn with sewing thread with the count of 40 tex under 50 % of breaking strain are presented. It can be observed that in all diagrams, there is a difference between first and other loading cycles; however, by increasing the loading cycles from 2 to 5, the difference between diagrams is negligible. This phenomenon is due to the elastic recovery property of samples. The elongation made in sample in the first cycle needs time to recover and due to the loading samples in continuous cycles, there is no enough time for recovery of samples and some of strain remained in the sample. Since during cyclic loading, the applied strain remains unchanged for all cycles, the difference between force-extension diagrams of 2 to 5 loading cycles is insignificant. Moreover, according to the Fig. 3, the increase of stitch length leads to the lower tensile force at the applied strain which is due to the tensile

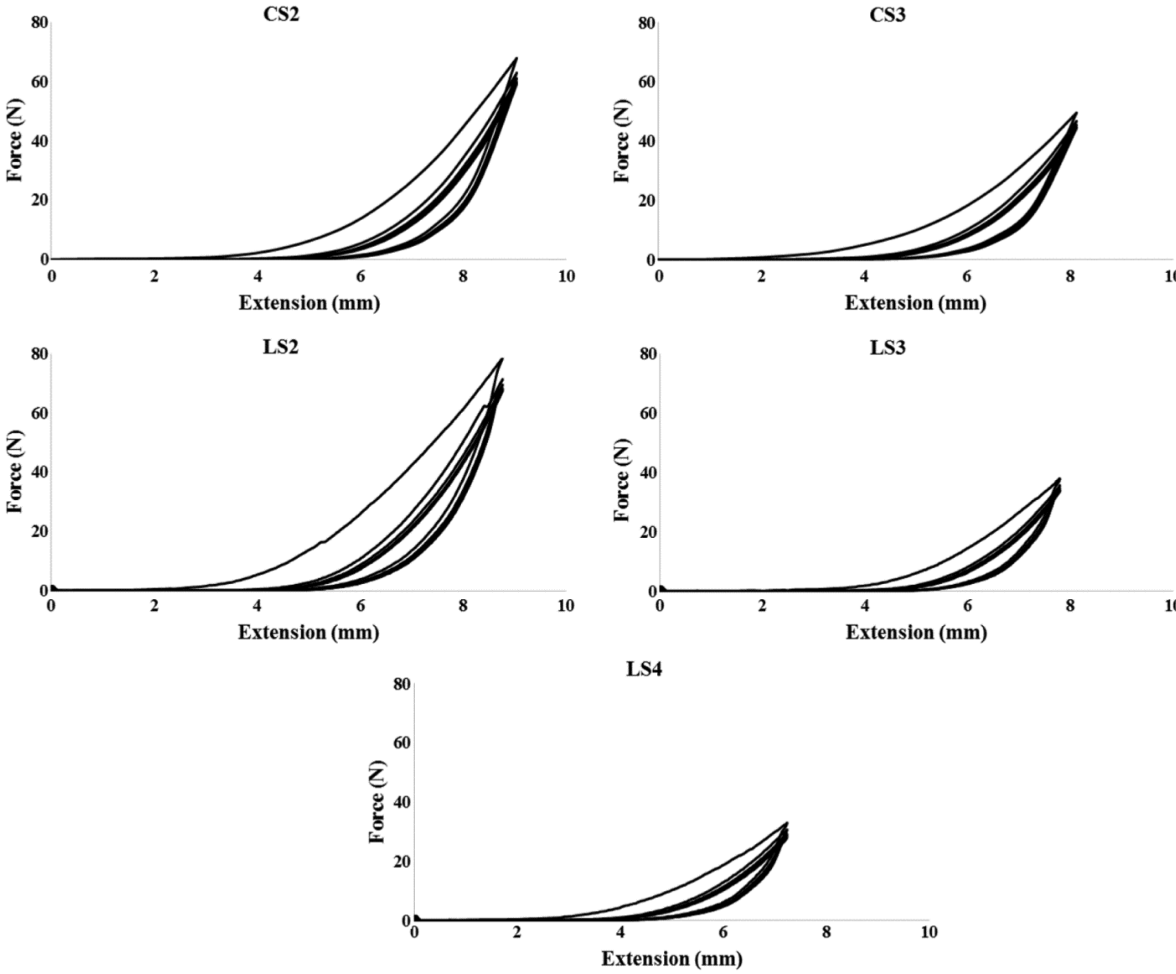

Fig. 3 — The cyclic tensile loading of samples under 50% of breaking strain

behaviour of seams that was explained previously. As it was demonstrated before, samples sewn with greater stitch length due to the lower joining points between fabrics and sewing thread have lower seam stress and strain. Since the applied strain for DER test is 10, 20, 30, 40 and 50% of the breaking strain of each samples; therefore, by increase of stitch length the applied strain level decreases and according to the Hook law, the initial force in samples diminish.

The value of total dynamic elastic recovery percent of sewn samples (calculated by considering the first loading cycle and the last unloading cycle), considering the stitch type, stitch length and sewing thread count under various strains 10, 20, 30, 40 and 50% of the breaking strain, were computed and summarized in Table 2.

In the next sections, the influence of stitch type and length, strain level, sewing thread count and the number of loading cycles on the dynamic elastic recovery performance of seams are assessed.

The Influence of Stitch Length and Strain Level on the Total DER

In Fig. 4 the influence of stitch length and the applied strain on the total dynamic elastic recovery are compared for sewn sample with sewing thread count of the 30 Tex for both lockstitch and double chain stitch with various stitch length, respectively. The same trend was obtained for sewing thread count of 20, 25 and 40 Tex.

Based on Fig. 4, it can be perceived that in both stitch types, the raise of stitch length causes to the diminish of dynamic elastic recovery. As it was stated before, in each stitch type, increase of stitch length leads to the reduction of needle penetration points in the fabric. In each needle penetration point, due to the interlooping of needle thread and looper thread in the double chain stitch and also interlacing of needle thread and bobbin thread in the lockstitch, a reserve of sewing thread is formed and when the tensile load is exerted on the seam, at first the load is used for

Table 2 — Total dynamic elastic recovery percent of sewn samples

Sample Code	Strain, %	Sewing Thread Count, Tex 20 Mean	20 SD	25 Mean	25 SD	30 Mean	30 SD	40 Mean	40 SD
LS2	10	76.95	0.78	75.34	1.66	71.58	2.75	66.51	1.52
	20	56.35	2.43	53.09	3.1	55.52	2.01	48.04	3.43
	30	52.53	1.52	49.33	1.75	48.78	0.69	43.05	2.88
	40	44.16	4.63	44.52	4.01	43.44	2.16	39.12	2.32
	50	43.8	1.33	38.32	2.44	37.18	5.9	35.74	2.69
LS3	10	73.22	5.15	69.50	4.63	68.83	2.30	63.14	0.15
	20	54.15	7.56	50.27	2.76	52.62	3.79	44.64	1.51
	30	48.99	2.05	45.99	9.58	45.74	0.99	41.64	1.17
	40	45.89	4.47	40.35	1.80	41.21	3.64	37.89	1.50
	50	36.51	0.6	35.69	3.63	34.54	0.08	33.53	1.80
LS4	10	68.97	2.88	62.75	0.28	63.10	0.49	59.80	1.18
	20	50.24	3.19	46.20	0.34	50.59	1.93	42.34	1.79
	30	43.96	6.35	41.16	3.91	41.46	2.37	37.49	1.41
	40	40.07	0.56	39.23	2.78	38.03	5.69	33.49	2.44
	50	33.62	2.75	31.09	4.94	30.59	3.22	30.31	3.22
CS2	10	78.17	1.67	76.22	8.96	72.55	2.96	68.19	1.45
	20	63.51	5.68	59.32	6.10	57.06	0.18	53.98	3.58
	30	54.72	6.31	51.22	2.55	49.21	2.96	46.35	2.68
	40	47.33	2.71	44.17	0.56	43.58	1.87	40.23	1.34
	50	45.77	2.87	41.64	0.11	39.72	2.00	36.30	2.11
CS3	10	75.84	3.23	73.36	4.15	70.70	3.85	65.18	2.95
	20	58.35	1.42	56.48	7.14	54.81	9.72	50.11	4.57
	30	52.85	0.66	50.86	5.85	49.05	1.04	45.17	1.58
	40	47.47	1.13	46.16	3.33	44.50	3.80	40.21	0.79
	50	38.89	1.33	39.25	0.62	37.47	1.07	34.08	0.83

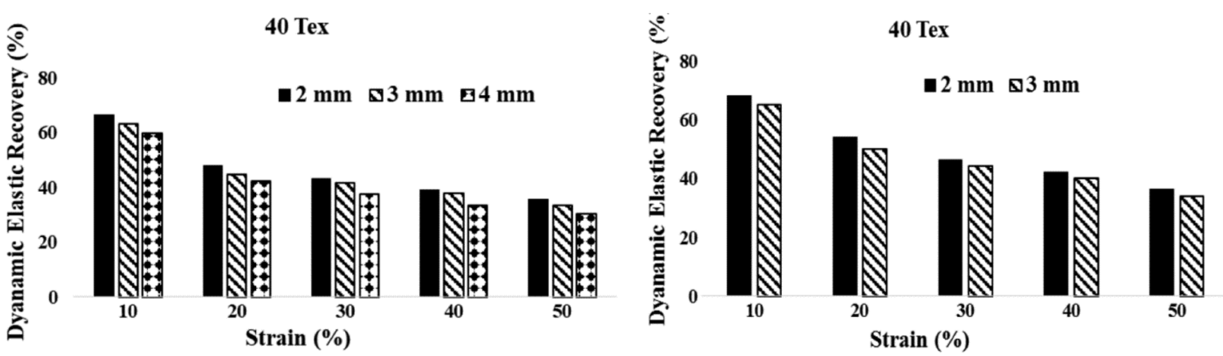

Fig. 4 — The influence of stitch length and strain level on total DER of lockstitch samples

straightening of the reserved yarn and then, the sewing thread extension occurred. Consequently, by reduction of stitch length, owing to the lower sewing thread deformation, better recovery of yarn obtained during unloading and in turn dynamic elastic recovery percent improves. In addition, in all tested samples, regardless of stitch type, stitch length and sewing thread count, rise of applied strain level from 10 to 50 %, leads to the reduction of dynamic elastic recovery by 18.75 % to 51.52 % in various conditions. Because, by increasing the applied strain level, due to the greater extension of seams and in turn sewing thread, the amount of large deformation of seam and sewing thread enhances. Since large deformation are usually time dependent or irreversible deformations, the dynamic elastic recovery of seams under higher levels of exerted strains decreased and some residual strain remained in the sample.

The Influence of Stitch Type and Sewing Thread Count on the Total DER

The total dynamic elastic recovery of samples considering stitch type and sewing thread count is compared in Fig. 5.

According to the Fig. 5, it can be observed that irrespective of stitch length, strain level and sewing thread count, the dynamic elastic recovery of double chain stitch seams is greater than lock stitch. This result is due to the shape of both studied stitches. As it was explained previously and presented in Fig. 2, in double chain stitch due to the higher number of contact points between needle and looper threads owing to the interlooping, and also formation of sewing thread in loop shape on the back of the seam, under tensile loading, the sewing thread extension occurs after sewing thread loop deformation; hence, the deformation of sewing thread is limited. However, in lockstitch, straight shape of yarn between two successive needle penetration points and interlacing of needle and bobbin thread limits the reserved sewing thread and in the similar condition of tensile loading, the sewing thread extended higher and hence, less elastic recovery and in turn dynamic elastic recovery is obtained.

In case of sewing thread count, based on Fig. 5, the thicker yarns have lower dynamic elastic recovery than thinner ones. As it was explained before, the utilized sewing threads are core spun yarns consisted of similar polyester filament yarn and polyester staple fibres. Since the count of filament yarns in all tested sewing thread are constant, in thicker yarns the percent of polyester staple fibres is higher to obtain the final yarn count. Since elastic recovery of filament yarns is higher than polyester staple fibres, by raise of sewing thread count the portion of polyester staple fibres increases and diminishes the dynamic elastic recovery of yarn and in turn sewn seams.

The Effect of Loading Cycles on DER

In Fig. 6, the influence of the number of loading cycles on the variation of dynamic elastic recovery of lockstitch and double chain stitch sewn with stitch length of 2 mm that were prepared by sewing thread with the count of 30 tex in various strain level are presented. As it is observed in Fig. 6, in both samples, during successive five loading cycles, the increase of strain level decreases the dynamic elastic recovery level. Moreover, in each strain level, first loading cycle has the lowest dynamic elastic recovery and a raise of dynamic elastic recovery is noticed in the second loading cycles. After that, during the rest of loading cycles, the dynamic elastic recovery remains unchanged, approximately. This outcome is related to the time dependent behaviour of sample after each loading. Since the cycles are performed continuously,

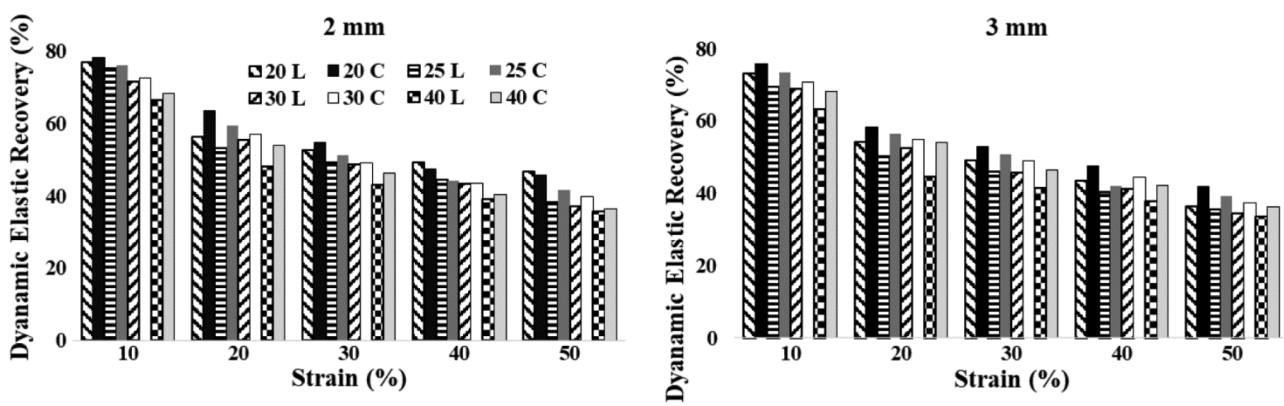

Fig. 5 — The influence of sewing thread count and stitch type on the total DER of samples

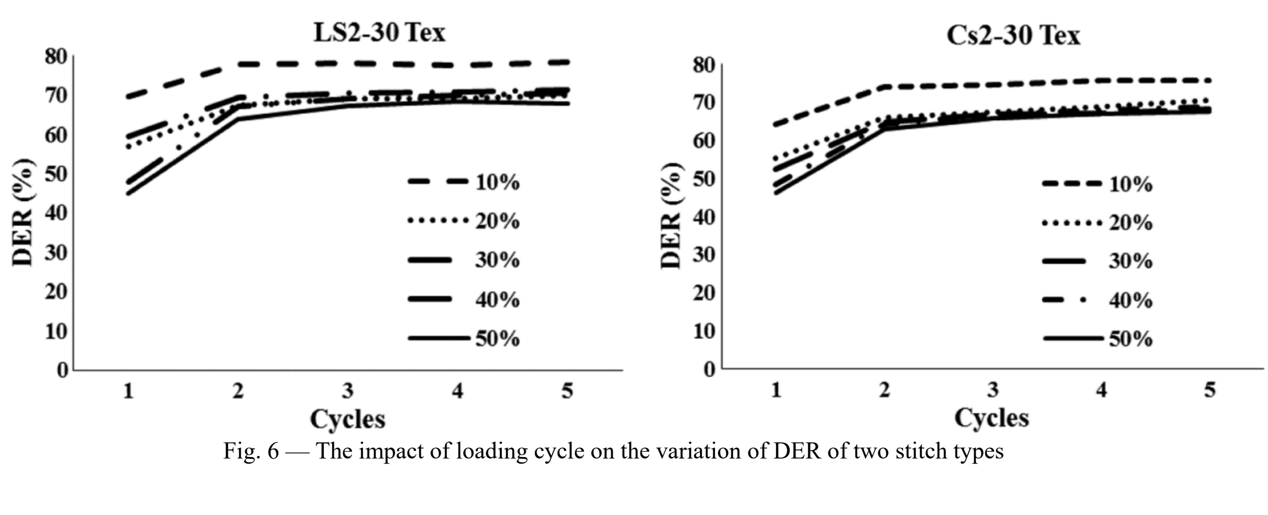

Fig. 6 — The impact of loading cycle on the variation of DER of two stitch types

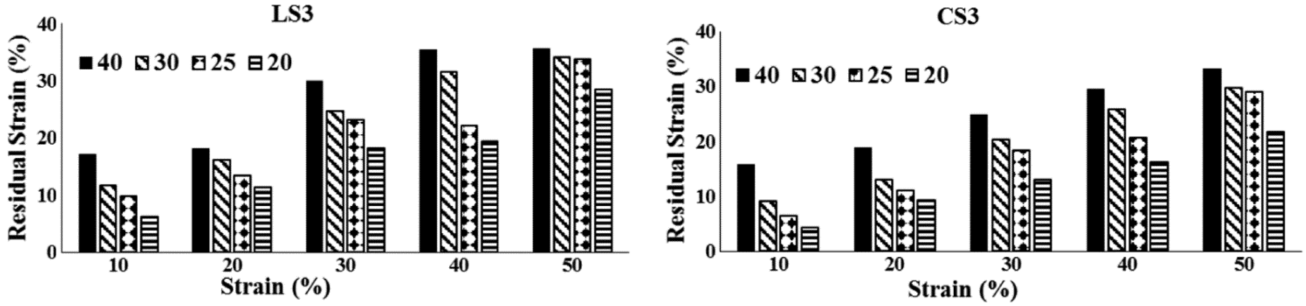

Fig. 7 — Comparison of residual strain of samples at various strain levels

there is no sufficient time for sample to recover to initial length. As during all loading cycles, the value of applied strain is constant, the sample does not extend anymore; consequently, an increase in the dynamic elastic recovery percent is obtained from first to second cycles and after that it remains almost constant. According to the Fig. 6, the increment of the exerted strain level, leads to the enhancement of the dynamic elastic recovery difference between first and second cycles; because by increasing the strain level, more deformation is made in the first cycle and in turn greater residual strain remained in the sample at the end of first cycle that raise the dynamic elastic recovery difference between first and second cycles. The same trend was observed for other tested samples.

According to the statistical analysis, the effect of sewing threads counts, stitch length and stitch type, applied strain level and number of loading cycles on the dynamic elastic recovery of seams at the confidence level of 95% is meaningful.

Investigation of the Residual Strain

Residual strain is another parameter to assess the elastic recovery behaviour of samples that is vice versa of dynamic elastic recovery and presents the remaining strain in the sample after unloading. This parameter can be computed by Eq. 2 as given below,

$$Residual\ Strain\ (\%) = \frac{Residual\ Extension}{Initial\ Extension} \times 100 \quad \ldots(2)$$

The residual strain of test samples after applying various strain level and loading cycles are illustrated in Fig. 7 for stitch length of 3 mm. It can be observed that the increment of exerted strain level due to the higher deformation of sample and remaining some extension in the sample after unloading, leads to the higher residual strain percent. In addition, in both stitch types, increase of stitch length causes higher residual strain. Moreover, seams prepared with thicker sewing threads presented greater residual strain and generally residual strain of lockstitch samples are higher than double chain stitch ones. The similar trend was observed for stitch length of 2 mm and 4 mm.

In other words, the trend of residual strain variation is opposite of dynamic elastic recovery. It is reasonable, samples with greater dynamic elastic recovery, presented less residual strain; however, samples with lower dynamic elastic recovery have more residual strain. This point should be considered during designing seams to select seam parameters including stitch type, stitch length and sewing thread, properly to minimize their residual strain. In this regard, the deformation of seam under tensile loading reduces and helps keep shape and optimize its performance.

Conclusion

Due to the importance of dynamic elastic recovery of seams in a garment to prevent seam deformation and keep its appearance and performance, in this study, the influence of stitch type, stitch length and sewing thread count on the dynamic elastic recovery of seams under various strain levels in five successive loading cycles were assessed by using a plain woven polyester fabric. In this regard, two common stitch types that are used for assembling fabrics in a garment, including lockstitch and double chain stitch were considered. The obtained results of this study reveal that the seams which were prepared with larger stitch length, present lower dynamic elastic recovery; however, sewing samples with thin sewing thread improve the dynamic elastic recovery of seam. Increase of applied strain level from 10 to 50 % in all samples due to the higher extension of samples and making large deformation diminished the dynamic elastic recovery by 18.75 % to 51.52 % in various samples. Among five loading cycles, the first cycle has the lowest dynamic elastic recovery percent due to the extension of seam in the first cycle and time dependent property of sample and also lack of the time to recover to its initial length. On the other hand, the dynamic elastic recovery remains almost unchanged in the following cycles due to the application of same strain level in each test. According to the outcomes, double chain stitch presented better dynamic elastic recovery than lockstitch and these results should be considered in designing seam for garment especially for garment made of elastic fabrics and active sport wear to adapt seams with the fabric properties and garment requirements. In this way, it is possible to keep performance and appearance of seam during use. As it was expected, the trend of residual strain of all samples were opposite of dynamic elastic recovery. Although the structural properties of fabrics such as weave pattern and warp and weft density can affect the results, the aim of this study was to compare the dynamic elastic recovery of two stitch type namely lockstitch and double chain stitch and also the influence of stitch length on the dynamic elastic recovery of seams. The influence of fabric structural parameters on the dynamic elastic recovery of seams may consider in future studies.

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