Journal of Textile and Apparel, Technology and Management
NC STATE UNIVERSITY

Volume 8, Issue 4, Spring2014

Effects of Dynamic Loading of Sewing Process and Viscoelastic Property of Threads on Seam Puckering

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ABSTRACT

Dynamic loading of sewing process causes the reduction in strength and weakening of viscoelastic property of threads during sewing. The reduction in thread strength during sewing is technically unwanted effect since this affects garment productivity and seam performance, particularly at high speed of sewing. In this study, it is strength reduction in sewing thread during sewing is considered to be an important factor for controlling seam puckering caused by sewing thread relaxation and recovery that follow the sewing. To ascertain this idea with experimental work, three types of sewing threads (100 % spun polyester, core spun of polyester- cotton and core spun of polyester-polyester) were selected for this study. For making stitches, a polyester–cotton (40/60) blend woven suiting fabric was used. The stitched threads were carefully taken out of the seam for testing strength, extension, relaxations, recovery and contraction of threads for the purpose of comparing the changes in them before and after sewing. The strengths of threads were reduced in the range of 26.6-31.1% for the three types of threads after sewing. For extension tests made at equal load, higher extensions were shown after sewing. Stress-relaxation index and recovery of threads were reduced after sewing. The reduction in recovery ranged from 25 % to 58% after sewing for the three types of threads against the recovery results of threads before sewing. The contractions were greater in the range of 55.2- 344.4 % after sewing for all threads considered under the study. The increase in extension and contraction, as well as the decrease in relaxation index and recovery after sewing, are important factors in controlling seam puckering, which caused by sewing threads. All these were caused by dynamic loading of sewing process and viscoelastic property of threads, through strength reduction and weakening of viscoelastic properties of threads after sewing.

Keywords: Dynamic load, sewing process, viscoelastic property, stress-relaxation, inverse stress-relaxation

1. INTRODUCTION

In apparel industry, sewing is one of critical processes in the determination of productivity and quality of finished garment and it is the most common way of fabric assembly in order to achieve the required seam strength and flexibility during manufacturing and use (Thanaa, 2011; Ukponmwan, et al., 2000). To perform sewing, thread is one of important element and there is still no substitute for it. Sewing threads are mostly made from spun, filament and core-spun yarns. Cotton and polyester fibers sewing threads are most commonly used for garment manufacturing. Polyester is considered the best for most sewing thread applications, due to its low cost, high strength, good chemical resistance, favorable elastic characteristics, and good dye fatness (Ukponmwan, et al., 20002). However, one of the problems associated with polyester sewing threads is seam pucker, which still arises from its elastic property.

The properties of a seam, such as its appearance and performance, are influenced by sewing thread's characteristics (Ukponmwan, et al., 2000). Seam quality mainly depends on the strength and the appearance of the seam itself (Bharani and Mahendra, 2012). Good seam appearance characterized by smooth joints with no missed or uneven stitches to create style feature. The main problem that arises as to appearance of seam is that of seam pucker. Seam puckering or distortion of the fabric along the seam may be appear immediately after sewing or may develop in use, possibly after several launderings (Rajkishore and Debi,2010).Seam pucker problems in lightweight fabrics are serious in garment manufacturing plant, reducing the aesthetic value and degrading quality of garment (Fathy,2012). There are many reasons for seam puckering, such as differential fabric stretch and the dimensional instability of the fabric, extension of the sewing thread, sewing thread shrinkage, structural jamming, improper selection of sewing thread and mismatched patterns (Krop, 1960).

During sewing, the thread is subjected to complex kinematic and dynamic conditions. In a lockstitch machine running at 6000 stitch/minute, the thread is accelerated to over 16.1 x 10^4 meters/hr in the forward direction through the needle edge brought to rest momentarily, and then accelerated again backwards as the stitch is pulled tight. The whole cycle is repeated 100 times per second, and at the moment at which the thread is caught by the sewing hook, the speed reaches 2000 m/s (Ukponmwan, et al., 2000). In such a condition, the thread is subjected to friction, tensile and other complex stresses (Bharani and Mahendra, 2012; Andreja and Gersak, 2012; Vinay, et al., 2010). Such a severe working condition can reduce the initial strength of a thread by as much as 60 % (Ukponmwan, et al., 2000; Vinay, et al., 2010). This causes increased breakage in the needle thread at high speed sewing. Modern garment –manufacturing process involve high speed sewing operations, for which the selection criteria of the sewing thread become more stringent (Gersak, 1997).The high tension imposed on thread during sewing process is the most important cause of seam puckering. Currently available sewing threads have a certain amount of controlled elasticity and elongation, and they become overstretched when sewing tension is high. After sewing, the thread gets to start relaxation to recover its initial length and thus gathers up seam (Rangasamy and Samuel, 2011). The needle thread is subjected to too much higher tension than the bobbin thread, which mainly contribute to seam pucker (Ukponmwan, et al., 2000).

On the other hand the viscoelastic property of sewing threads directly influences by dynamic load of threads during stitch formation (Gersak, 1997; Sabit, 1995). The relaxation between dynamic cyclic loading and inverse –stress relaxation depends on viscoelastic properties of threads and fibers, (Sabit, 1995). The behavior of textile materials as of any polymeric bodies is mostly viscoelastic. The response of a material to the specific mechanical action depend not only the action itself but also on the formed actions undergone i.e. it depends on mechanical pre- history of the material. This implies that time-dependence of the response of any textile materials opposing the applied forces, should be taken into account (Rita and Arvydas, 2005). During the dynamic loading (tensioning), there are viscoelastic effects which will influence relaxation and creep behavior of a thread (Sabit, 1995). During a selected period of progressive loading viscoelastic materials function as perfectly elastic or spring -like (following Hook's law) and during another period of loading will exhibit viscous flows or creep type deformation (follows Newton's law) (Sabit, 1995). Generally, these two mechanisms will act together with varying contributory amounts at the same time and thus give viscoelastic type of stress-strain characteristics. The behavior of viscoelastic materials depends on relative values of their viscous and elastic components (Sabit, 1995). Thread can be relaxed from stress if held stretched during its extension, whereas the stress in thread can be increased if the thread held retracted during stress recovery (Ajiki and Postle, 2003).

In present study the effects of dynamic loading of sewing process and the viscoelastic property of sewing threads were considered as important factors for controlling seam pucker caused by sewing threads. To justify this situation with experimental work, tensile strength, stress-relaxation, recovery, extension and contraction of selected sewing threads were studied before and after sewing.

2. MATERIALS AND METHODS

2.1. Materials

2.1.1. Sewing Threads

A commercial 100 % spun polyester and core spun of polyester-cotton and core spun of polyester-polyester sewing threads were selected for the study. In order to compare the variations, threads with equal fineness were considered. The resultant thread fineness was obtained by multiplying the individual yarn linear density by number of plies. Twist per meter (t.p.m.) for 'S' and 'Z' were preliminarily determined before carrying out the intended investigation on selected sewing threads. The technical specifications for selected sewing threads are shown in Table 1.

Table 1. Technical specifications of sewing threads

Code	**Description**	**Fineness** (Tex)	**Twist** (S) (t.p.m)	**Twist** (Z) (t.p.m)
SP-60-2	100 % spun polyester	60(2x30)	635	560
PC-CS-60-2	Polyester-Cotton core spun	60(2x30)	750	530
PP-CS-60-3	Polyester-Polyester core spun	60(2x30)	1008	582

The codes, which designated to describe individual threads in Table1, are used in the text to represent the threads. To ease the explanation, in the text threads before and after sewing, are named as parent and sewn threads respectively. For SP-60-2 and PP-CS-60-3 sewing threads, cotton and staple spun polyester are the sheath materials respectively, while polyester filament is the core material for both threads.

2.1.2. Fabric

A commercial polyester-cotton (60/40) woven suiting fabric was used for making stitch with selected sewing threads. The weight of the fabric was 226 g/m^2 with thread density of 82 picks and 126 ends per inch.

2.2 Methods

2.2.1. Comparison of Stress-Strain Characteristics of Parent and Sewn Threads

Lockstitch sewing machine was used for sewing two layers of the fabric together using needle number 16. Sewing speed was adjusted to 2000 stitches per minute in order to make 6 stitches per inch. Thread was pre-tensioned to 0.5 cN/tex force before sewing. The dynamic tension and the bobbin tensions were maintained constant during sewing. After sewing, the sewn threads were carefully taken out of the seam manually from parallel stitched fabric by slightly loosening the stitch with help of hand needle. Tensile strengths of parent and sewn threads were determined according to ISO 2062 test methods. Testing was performed under standard atmospheric conditions using TNSOMAXX-7000 laboratory single thread testing machine. Testing was carried out with the conditions of 0.5 cN/tex force of pre-tension, 350 mm/min speed and 500 mm gauge length.

2.2.2. Stress-Relaxation, Inverse Stress-Relaxation and Recovery Trends of Parent and Sewn Threads

Elastic recovery and inverse relaxation of polyester staple fiber rotor spun yarns was studied by Manich and Castellar, 1992 .Viscoelastic properties of threads before and after sewing were studied by Ajiki and Postle, 2003. The present study attempt to investigate the stress-relaxation ,inverse-stress relaxations and recovery effects of sewing threads in relation to seam puckering problem, which caused by sewing threads. The aforementioned parameters for parent and sewn threads were tested on Instron testing machine using the test procedures suggested by Ajiki and Postle, 2003 and Manich and Castellar, 1992. First threads were subjected to tension by constant load or force of 4N. Then the tensioned threads were allowed to be relaxed in six levels of retraction loads in the order of 4, 3, 2, 1, 0.5, and 0 N. After testing, the changes in stress-relaxation, inverse stress-relaxation and recovery were compared for parent and sewn threads.

2.2.3. Contraction Effects of Parent and Sewn Threads

Thread contractions were tested in order to determine secondary creep effect of parent and sewn threads that caused by the reduction in thread strength due to dynamic load of sewing process. The 'residual extension' remains on thread after full retraction load levels (i.e. 4, 3,2,1,0.5 and 0 N) called a secondary creep. This is achieved first by gradually increasing tension loads from 0 to 4N in the order of 0, 0.5 1, 2, 3 and 4 N. At 4 N loads, the crosshead of the Instron was stopped and the threads were subjected to be retracting in opposite order of the loads used for tensioning. At 100 % level of retraction load, 6 minutes of time was given for measurement of contraction constant of the threads. If the contraction is constant during this time under 'zero load' it is considered as secondary creep (Sabit, 199512).

3. Results and Discussions

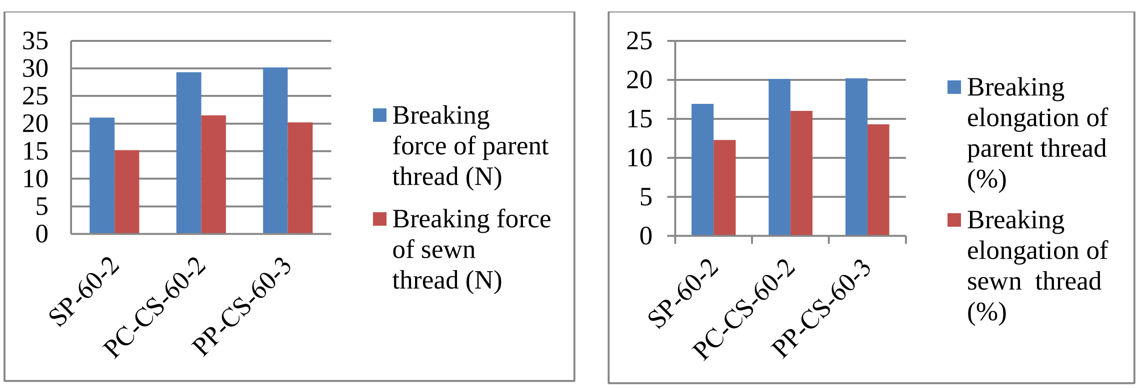
3.1. Effects of Dynamic Loading of Sewing Process on Sewing Thread Strength

Tensile test was carried out 100 times for each type of parent and sewn thread. The changes in thread strengths before and after sewing were compared. The average breaking force and breaking elongation for parent and sewn threads are shown in Table 2.The breaking force and breaking elongation for three types of threads were decreased after sewing. The structural openness of the thread, namely, the pull-out of fibers and the displacement of the piles at the thread interlocking point in the stitch, were to be the dominant factor influencing the strength reduction during sewing (Sundareasan, et al., 1997 & 1998). The reduction in strength for sewn thread is unwanted sewing process effect; since seam strength and sewing performance of threads is depend on residual strength of threads and seam strength (Vinay, et al., 2010). Among the three types of sewing threads, strength reduction after sewing was highest for PP-CS-60-3 thread and the least for PC-CS-60-2 thread. The extent of sewn thread strength reduction for SP-60-2 thread was within the extremes of the two types of threads; even its singling twist is the least as shown in Table 1. Further the strength reduction for each parent and sewn threads are compared using the graphs of Figure 1. The percentage strength reduction rates of sewn threads indicate that PP-CS-60-3 thread was more affected by dynamic loading of sewing process than the two types of sewing threads.

Table 2. The average strengths of threads before and after sewing

Threads	Breaking Force (N)		Reduction of Breaking Force by Sewing Process (%)	Breaking Elongation (%)		Reduction of Breaking Elongation by Sewing Process (%)
	Parent	Sewn		Parent	Sewn	
SP-60-2	21.1	15.2	28.0	16.9	12.3	27.2
PC-CS-60-2	29.3	21.5	26.6	20.1	16.0	20.4
PP-CS-60-3	30.2	20.8	31.1	20.2	14.4	29.2

Thread strength reduced during sewing, in turn causes reduction in its recovery after sewing, due to the change in viscoelastic properties of threads by the influence of dynamic load of sewing process. Consequently seam puckering incited by thread recovery after sewing, will be reduced owing to decreased recovery of sewn threads. Hence from the three types of sewing threads considered under the study, PP-CS-60-3 thread would cause less seam puckering than the two types of sewing threads because of its high strength reduction during sewing process as shown in Table 2 and Figure 1.



(a) **(b)**

Figure 1. Breaking force and breaking elongation of parent and sewn threads: (a) Breaking force of parent and sewn threads, (b) Breaking elongation of parent and sewn threads

3.2. Effects of Relaxation, Inverse Relaxation and Recovery of Threads on Seam Puckering

Both parent and sewn threads were first, tensioned with increasing load from 0 - 4 N at speed of 10 mm/min using Instron testing machine. Extension measurement was taken at load of 4 N. The test at constant load or force, related to a creep as well as viscoelastic recovery (R) or inverse stress relaxation (R_I) (Rita and Arvydas, 2007). The extension time (t_1) of threads was recorded. The crosshead of the Instron is stopped at 4 N and the tension of 4 N is designated as Q_1 (extension load). A thread held stretched during extending become stress-relaxed due to gradual diminishing of stress to a limiting value or completely decaying (Ajiki and Posttle, 2003). The crosshead of the Instron had reversed and the specimen was allowed to retract up to thread tension reaches at a low value. The thread tension, at this point is assigned as load Q_2 (recovery load), and at this instant of time (t_2), the Instron crosshead is stopped, and this is understood as typical relaxation phenomenon.

On the other hand, when the sewing thread is held retracted during stress recovery the stress in the sewing thread may increase with time to some extent, and the load at this point is called Q_3(residual load) against Q_2. This phenomenon is called inverse stress-relaxation (Ajiki and Posttle, 2003). The force line from load Q_1 to Q_2 corresponds to thread recovery, which its extent causes seam puckering after sewing. The recovery load Q_2 was set in to six levels of load variables in the order of 4, 3,2,1,0.5, and 0 N. For each level of load variables of Q_2, recovery time (t_2) and residual load Q_3 were determined correspondingly. For each case the residual load Q_3 was determined after 6 minutes of time against Q_2. The measurements for extension and retraction parameters were replicated 5 times and the average results are reported in Table 3.

Extension rates exhibited before sewing and after sewing were different for each type of thread, for applied equal load of extension. The extension of each sewn threads was significantly greater than its corresponding parent threads extensions. The sewn threads extensions were exceeded the parent threads in the range of 92-157 % for all three types of threads as shown in column 4 of Table 3. The increase in extension for PP-CS-60-3 sewn thread was the highest and the least for PC-CS-60-2 sewn thread, further as shown in Figure 2.

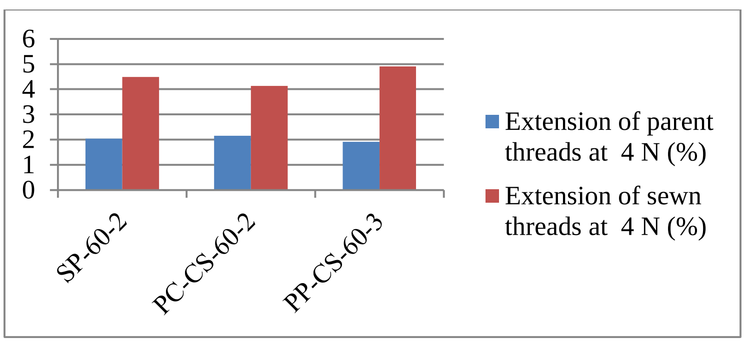


Figure 2. The extension of parent and sewn threads at 4N load of extension

The increase in extension for sewn threads of PP-CS-60-3 and PC-CS-60-2 were correlated to their strength reduction, since the strength reduction for these two threads were the highest (31.1%) and the least (26.6%) respectively as it was discussed based on results given in Table 2. Hence the high extension rate of sewn threads against parent threads can be explained due to reduced strength of sewn threads by dynamic loading of sewing process. High extension rate of sewn thread leads to high rate of secondary creep effect than the parent threads after the removal of extension load.

Table 3. Measured values for thread extension, residual load, and recovery

Thread	Extension Load (%)	Extension (%)		Increase of Extension in Sewn Thread (%)	Extension Time (t_1) (second)		Recovery Load (Q_2) (N)	Recovery Time (t_2) (second)		Residual Load (Q_3) (N)	
		Parent	Sewn	Sewn thread against parent thread	Parent	Sewn	Equal for parent & sewn threads	Par.	Sew	Par.	Sew.
SP-60-2	4.0	2.04	4.49	120.0	83.0	135.5	4.0 3.0 2.0 1.0 0.5 0.0	- 92.3 104 128 136 158	- 147 157 176 190 203	2.98 2.91 2.13 1.32 0.84 0.43	3.42 2.95 2.14 1.36 0.92 0.44
PC-CS-60-2	4.0	2.15	4.13	92.0	63.0	124.0	4.0 3.0 2.0 1.0 0.5 0.0	- 72 83 99 105 114	- 133 143 157 168 182	2.95 2.94 2.14 1.30 0.7	3.2 2.98 2.15 1.31 0.76 0.3
PP-CS-60-3	4.0	1.91	4.90	157.0	55.8	148.1	4.0 3.0 2.0 1.0 0.5 0.0	- 65 74 90 95 108	- 158 169 185 195 207		

The time (t_2) spent thread tension to reach into each six level of recovery load Q_2 became increased for increased level of recovery loads from 4-0 N as shown in column 7 of Table 3. The increase in recovery time (t_2) for increased levels of recovery (or retraction) loads was greater for each type of sewn threads against the corresponding parent threads, indicting more delayed recovery of sewn threads than parent threads. The increase in residual load Q_3 was observed for each level of recovery load Q_2 both for parent and sewn threads. However, the increase for Q_3 is relatively high for sewn threads than the parent threads, as shown in column 8 of Table 3.The increase in residual load Q_3 of sewn threads for increased level of retraction loads do not show a definite trend, due to mixed relaxations, which can be relate to viscoelastic property of threads. The increase in residual load Q_3 for sewn thread resulted due to cyclic loading of threads during sewing process (Rita and Arvydas, 2005). The increase in residual load Q_3 on the other hand, provokes the condition for more seam puckering.

The percentages of stress-relaxation index, inverse stress -relaxation index and level of retraction loads were calculated using the load values of Q_1, Q_2, and Q_3 from columns 2, 6 and 8 of Table 3. The recovery percentages were also calculated using the measured values of extension time (t_1) and recovery time (t_2) again from columns 5 and 7 of Table 3. Analogous approach was used by different researchers to determine stress-relaxation index, inverse stress -relaxation index and recovery percentage of threads (Ajiki and Postle, 2003; Manich and Castellar, 1992). Hence calculations for aforementioned variables were performed according the relations mentioned underneath:

$$Rl(\%) = \frac{Q1 - Q2}{Q1}\ x\ 100 \ldots \quad (1)$$

$$Rs(\%) = \frac{Q3 - Q1}{Q1}\ x\ 100 \ldots \ldots (2)$$

$$Ri(\%) = \frac{Q3 - Q2}{Q1}\ x\ 100 \ldots \ldots (3)$$

$$R(\%) = \frac{t2 - t1}{t1}\ x\ 100 \ldots \ldots \ldots (4)$$

Where; R_l = percentage retraction load; R_s = percentage stress relaxation index; R_i = percentage inverse stress-relaxation index; R= percentage viscoelastic recovery; Q_1= extension load (N); Q_2= recovery load (N); Q_3= residual load (N); t_1= extension time (sec.) and t_2=, recovery time (sec.).

The calculated results for the variables are given in Table 4. The absolute values of stress- relaxation index were increased for increased percentage level of retraction loads, both for parent and sewn threads as shown in column 3 of Table 4. However, the increase in stress-relaxation index for sewn thread is less compared to corresponding parent threads, indicating the reduction of stress –relaxation for sewn thread. Particularly the reduction in stress –relaxation index for sewn thread at zero level of retraction load is high compared to the corresponding parent threads, for all three types of threads. The decrease in stress-relaxation index for sewn thread enhances diminishing of seam puckering, which caused by sewing threads themselves.

On the other hand, the inverse –stress relaxation index ratio of sewn to parent threads indicate that the inverse –stress relaxation index for all the three types of sewn threads are greater than the corresponding parent threads at high level of retraction loads (i.e. ≥ 50 % of R_l). The existence of inverse stress- relaxation after high level of retraction loads and a large number of load cycles were reported in earlier research works (Ajiki and Postle, 2003; Vangheluwe, 1992a, b, & 1993).Similar results was obtained from the present study work for inverse relaxation index. Also for an increased percentage level of retraction loads, the recovery of parent and sewn threads were correspondingly increased as shown in column 7 of Table 4. However, the increases in recovery for sewn threads are less compared to the corresponding parent threads. The comparative decrease in percentage recovery for sewn threads are shown in the last column of Table 4.The percentage decrease in recovery for sewn threads are relatively increases as the level of retraction load increases up to 75%, beyond this limit the recovery of sewn threads were reversed due to increased inverse stress-relaxation of threads at high level of retraction loads. For all three types of sewn threads the highest recovery decrease was achieved at 75 % level of retraction loads.

With variation in thread type different recovery rates were resulted for sewn and the corresponding parent threads under the full level of retraction loads, as shown in Table 4. The decrease in recovery for SP-60-2 sewn thread was ranged from 25 % to 46 % compared to its parent thread, due to its 28 % strength reduction during sewing as shown in Table 2. Similarly 43-53 % and 55-58 % recovery reductions were attained for PC-CS-60-2 and PP-CS-60-3 sewn threads compared to their corresponding parent threads due to their strength reduction of 26.6 % and 31.1 % respectively by dynamic loading of sewing process .In general, the decrease in recovery was observed for sewn threads compared to parent threads for all three types of sewing threads through the full level of retraction loads as shown in Figure 2 from (a) to (c). The recovery for SP-60-2 parent thread is greater than 70 % and it is less than 50 % for sewn threads as shown in Figure 2(a). Similarly the recovery effects for parent and sewn threads of PC-CS-60-2 and PP-CS-60-3 threads are illustrated in Figures 2(b) and (c) respectively. Figure 2(d) illustrates the recovery trends of all the three types of sewn threads, which the highest and the least recoveries observed from the curves for PP-CS-60-3 and SP-60-2 sewn threads respectively. Clear recovery differences for three types of sewn threads were observed at high level of retraction loads.

The decrease in recovery for sewn threads resulted from the strength reduction of threads during sewing process, indicating that sewing process not only causes strength reduction of threads it also affects the viscoelastic property of threads, which causes the decrease in recovery for sewn threads. This is important effect in controlling seam puckering to minimum level, which is initiated by elastic recovery of threads. In general, as the level of retraction load increases from 0 -100%, the thread recovery both for parent and sewn threads increases as shown in Figure 3 from (a) to (c).

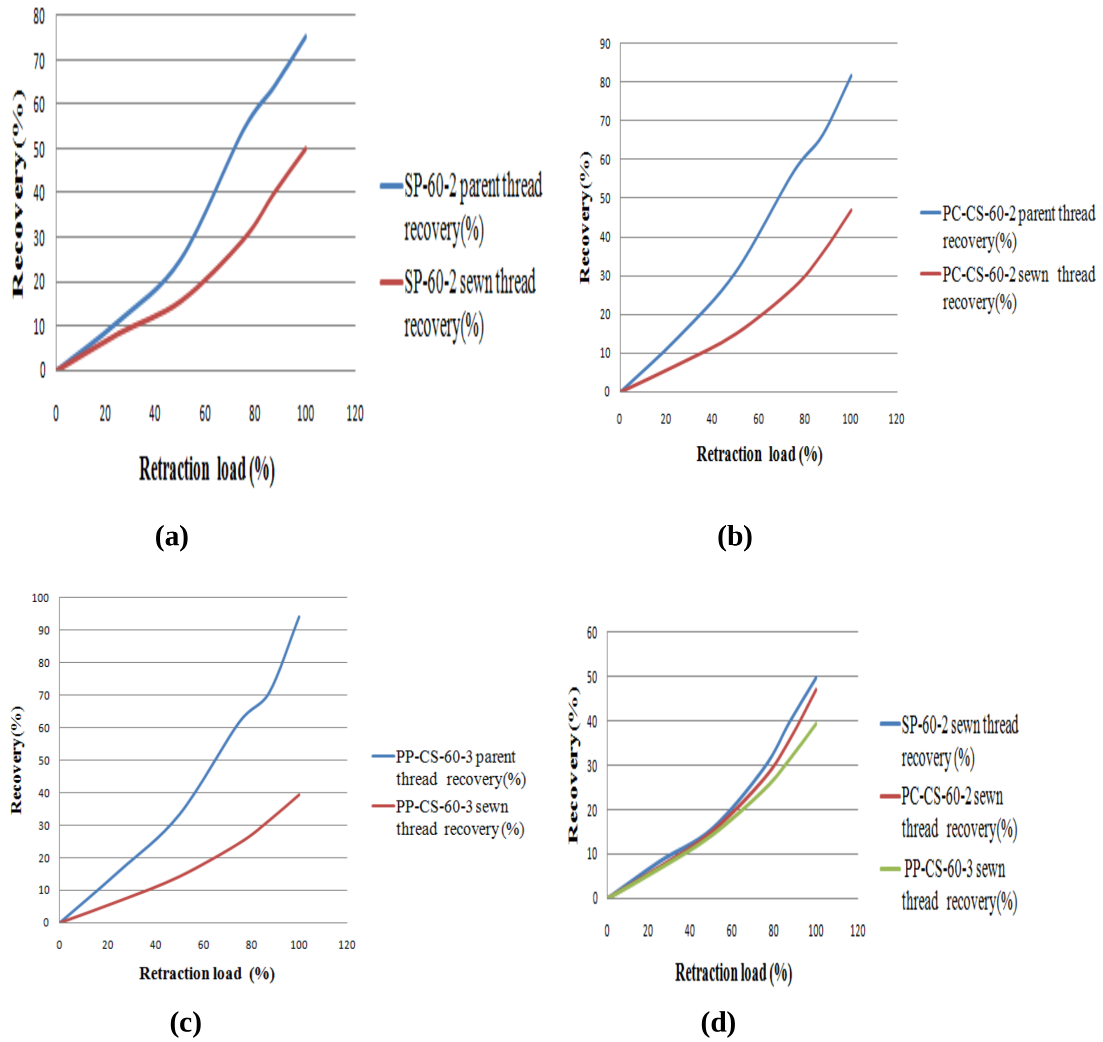


Figure 3. The recovery characteristics of parent and sewn threads: (a) SP-60-2 sewing thread, (b) PC-CS-60-2 sewing thread, (c) PP-CS-60-3 sewing thread, and (d) recovery rates of the three types of sewn threads

Table 4. Calculated results of indexes of stress-relaxation and inverse -relaxation and recovery of threads before and after sewing

Thread	**Load** (%)	**Stress-relaxation Index of Thread** (%)		**Decrease in Relaxation Index of Sewn Thread** (%)	**Inverse-relaxation index** (%)		**Inverse -relax. Index Ratio** (%)	**Recovery Rate (%)**		**Decrease in Recovery of Sewn Thread (%)**
		Parent	Sewn	Sewn against Parent thread	Par.	Sewn	Sewn to parent	Par.	Sewn	Sewn against parent
SP-60-2	0	-25.5	-15.0	41.2	25.5	15.0	0.59	0.0	0.0	-
	25	-27.5	-26.3	4.4	-2.3	-1.25	0.54	11.2	8.4	25.0
	50	-46.8	-46.5	0.6	3.3	3.5	1.06	25.2	15.7	38.0.
	75	-67.0	-66.0	1.5	8.0	9.0	1.13	54.2	29.5	46.0
	87.5	-79.0	-77.0	2.5	8.5	10.5	1.24	64.1	40.1	37.0
	100	-89.3	-89.0	0.3	10.8	11.0	1.02	75.2	49.9	34.0
PC-CS-60-2	0	-26.3	-20.0	24.0	-26.3	-20.0	0.76	0.0	0.0	-
	25	-26.5	-26.4	0.4	-1.5	-0.5	0.33	14.1	7.1	50.0
	50	-46.5	-46.5	0.0	3.5	3.5	1.00	31.0	15.0	52.0
	75	-67.5	-67.3	0.3	7.5	7.8	1.04	56.8	26.9	53.0
	87.5	-81.3	-81.0	0.4	6.3	6.5	1.03	66.2	35.8	46.0
	100	-94.8	-94.5	0.3	7.5	8.0	1.07	81.6	46.9	43.0
PP-CS-60-3	0	21.8	18.5	15.1	-21.8	-18.5	0.85	0.0	0.0	-
	25	-27.5	-27.3	0.7	-2.5	-2.3	0.90	16.0	6.8	53.0
	50	-47.5	-48.7	2.5	-1.5	3.8	-2.50	33.3	14.3	53.0
	75	-69.3	-67.8	2.2	5.8	7.3	1.26	61.7	24.6	60.0
	87.5	-84.0	-81.5	3.0	3.5	6.0	1.71	70.8	31.6	55.0
	100	-94.0	-90.1	4.2	6.0	9.5	1.58	85.9	39.5	54.0

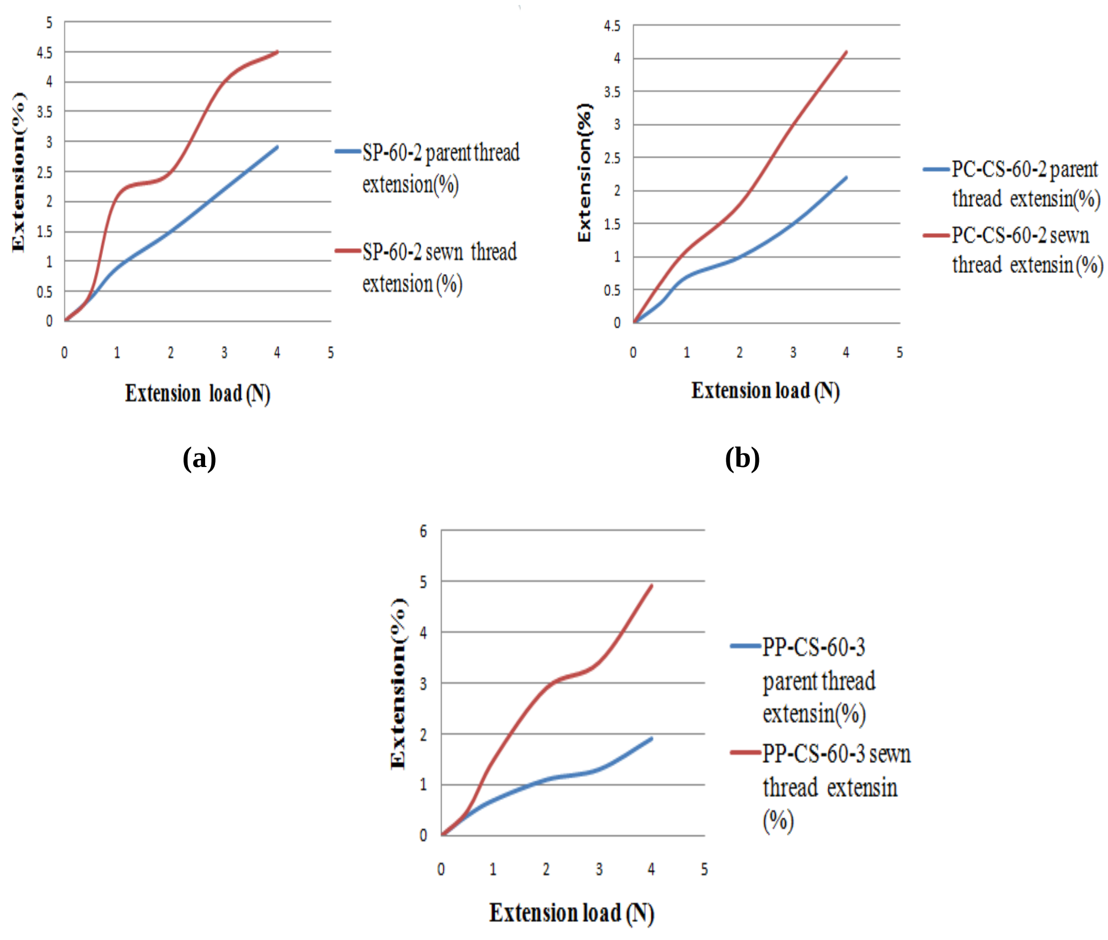
3.3. Effects of Extension versus Creep of Parent and Sewn Threads on Seam Puckering

As it was discussed in earlier section high extension was observed for sewn threads against the parent threads under constant load of extension. In this part of test, extension were recorded for load variations from 0-4 N in the order of 0, 0.5,1,2,3 and 4 N in order to compare the changes in thread extension before and after sewing for progressively increased loads. The results in column 3 of Table 5 showed that extensions were increased for increased level of loads. However, the increased extension rate for sewn threads at each level of extension load is significantly greater than the corresponding parent threads. The extensions rate of sewn threads against the parent threads are greater in the range of 25-81.8 %, for SP-60-2 sewn thread and 45.5-100 % and 25-136.6 % for PC-CS-60-2 and PP-CS-60-3 threads respectively for equally increased extension loads as shown in column 4 of Table 5. The extension rates for each type of parent and sewn threads for increased level of extension loads are also graphically shown in Figure 4.

Table 5. Extension and contraction results of parent and sewn threads for progressively increased extension loads

Threads	Extension Load (%)	Extension (%)		Increase of Extension in Sewn Thread (%)	Retraction Load (%)	Contraction (%)		
		Parent	Sewn	Sewn against Parent thread		Parent	Sewn	Increase in contraction of sewn thread against parent thread (%)
SP-60-2	0.0	0.0	0.0	-	0.0	2.9	4.5	52.2
	0.5	0.4	0.5	25.0	25.0	2.5	4.5	80.0
	1.0	1.2	1.8	50.0	50.0	2.2	4.1	86.4
	2.0	1.5	2.5	66.7	75.0	1.9	3.3	73.7
	3.0	2.2	4.0	81.8	87.5	1.3	3.3	153.8
	4.0	2.9	4.5	52.2	100.0	1.3	2.6	100.0
PC-CS-60-2	0.0	0.0	0.0	-	0.0	2.2	4.1	86.4
	0.5	0.3	0.6	100.0	25.0	1.8	3.7	105.6
	1.0	0.7	1.1	45.5	50.0	1.4	3.4	142.2
	2.0	1.0	1.8	80.0	75.0	1.1	3.1	181.8
	3.0	1.5	3.0	100.0	87.5	0.7	2.8	300.0
	4.0	2.2	4.1	86.4	100.0	0.6	2.5	316.7
PP-CS-60-3	0.0	0.0	0.0	-	0.0	1.9	4.9	157.9
	0.5	0.4	0.5	25.0	25.0	1.5	4.7	213.3
	1.0	0.7	1.5	114.3	50.0	1.4	4.5	221.4
	2.0	1.1	2.9	163.6	75.0	0.9	4.0	344.4
	3.0	1.3	3.4	161.6	87.5	0.8	2.4	200.0
	4.0	1.9	4.9	157.9	100.0	0.6	1.9	216.7

High extension of sewn threads at each level of extension load indicates the lessening of thread's resistance to applied load due the reduced strength of threads by effect of dynamic loading of sewing process. The increase in extension rate is different for the three types of sewn threads for increased extension loads. It is highest for PP-CS-60-3 and the least for PC-CS-60-2 sewn threads as shown in Figure 4 from (a) to (c). This is expected due to the thread's highest and least strength reduction after sewing respectively.



(a) **(b)**

(c)

Figure 4. The extension characteristics of parent and sewn threads for increased extension loads from 0-4 N (a) SP-60-2 sewing thread, (b) PC-CS-60-2 sewing thread, and (c) PP-CS-60-3 sewing thread

After extension, the threads were reversely subjected to contraction. For an increased level of contraction loads (i.e. 4, 3,2,1,0.5 and 0 N), threads contractions became gradually decreased both for parent and sewn threads as shown in column 5 of Table 5. The contraction rate of sewn threads at each level of retraction load is greater against the corresponding parent threads. The contraction of sewn threads under full level of retraction load (i.e. 0-100 %) is greater from 55.2% to 153.8% for SP-60-2 thread, and 86.4 to 153.8% and 157.9 to 344.4% for PC-CS-60-2 and PP-CS-60-3 threads respectively against the corresponding parent threads as shown in the last column of Table 5. The increased contraction of sewn threads resulted from the weakening of viscoelastic property of threads by dynamic loading of sewing process. Further the contraction conditions for all three types of parent and sewn threads are graphically shown in Figure 4 from (a) to (c).

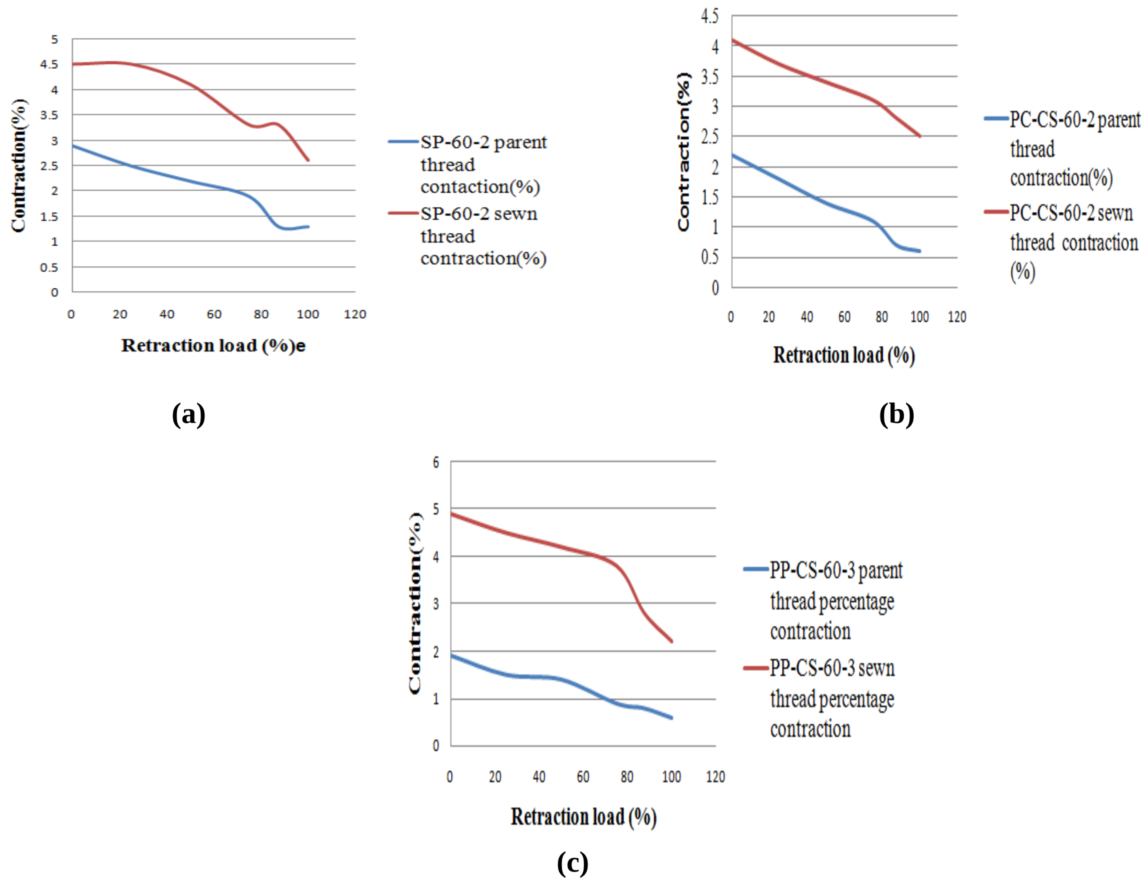


Figure 5. The contraction characteristics of parent and sewn threads under variation of retraction loads from 4-0: (a) SP-60-2 sewing thread, (b) PC-CS-60-2 sewing thread, and (c) PP-CS-60-3 sewing thread

The contraction rates for sewn threads are greater against the corresponding parent threads for all three types of threads as shown in Figure 4 from (a) to (c). As a level of retraction load increases, the contraction for both parent and sewn threads become decreases. The distance between the curves of parent and sewn threads at zero level of retraction load revealed the secondary creep effect of sewn threads. This effect is high for PP-CS-60-3 sewn thread, due to its highest strength reduction compared to the other two types of sewn threads as shown in Figure 4 and Table 5. The viscoelastic property of threads which is influenced by dynamic load of sewing process causes secondary creep effect of threads, which can be considered as sewing process advantage for controlling seam puckering caused by sewing threads recovery after sewing.

4. CONCLUSIONS

Sewing process dynamic loading causes strength reduction and influences the change in viscoelatic property of threads after sewing. The reduction in strength and weakening of viscoelastic property threads after sewing in turn causes the reduction in recovery and the increase in creep effect of threads. The reduction in thread strength after sewing is different for different types of threads having the same linear density. The recovery rate of threads after sewing is reduced against the corresponding parent threads. The strength reduction of threads after sewing is proportional to the reduction of recovery, i.e. high rate of strength reduction consequently causes the high rate of recovery reduction. On the other hand, the contractions of threads were markedly increased after sewing, again due to the influence of dynamic loading of sewing process and the viscoelastic properties of threads. The increase in contraction for threads after sewing causes secondary creep effects of sewn threads. In general, strength and recovery reductions and increase in contraction of threads after sewing favors the conditions for lessening of seam puckering caused by sewing threads. In order to consider sewing process and sewing thread property advantages in controlling seam pucker in garment manufacturing, further work is required in order to correlate the rate of load that going be subjected on sewing thread by sewing machines and the rate of sewing thread strength reduction as a consequence.

5. ACKNOWLEDGMENT

The author wish to thank, Prof. Dr. R.B. Chavan, Prof.Dr. Subramanian Kathirrvelu and Prof.Dr.Josphat Igadwa Mwasiagi for their support in giving valuable comments during preparation of the manuscript.

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