Tensile Fatigue, Stress Relaxation, and Creep Behaviors of Worsted Core Spun Yarns

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ABSTRACT: The objective of this research was to investigate the time-dependent behaviors of yarns, which have significant bearings upon the properties of stretch fabrics made from them. In this study, 100% wool, wool–lycra (W-L) (97 : 3), and polyester–wool–lycra (P-W-L) (52 : 45 : 3) blended yarns were considered. These yarns were subjected to the tensile fatigue failure, stress relaxation, and creep experiments. The findings showed that of these three yarns, P-W-L blend exhibited maximum fatigue lifetime, stress retention, and creep recovery, the pure wool yarn followed suit albeit to a lesser extent, whereas the W-L blend made it least. The investigation suggests that wool alone with lycra as a core component is not sufficient to impart the expected properties upon stretch fabrics, rather a blend of polyester and wool with lycra as in the former would definitely make a worthwhile product. © 2011 Wiley Periodicals, Inc. J Appl Polym Sci 121: 2123–2126, 2011

Key words: blend; core spun; creep; fatigue; stress relaxation; wool

INTRODUCTION

Attributes of a premium quality apparel in today's world to a consumer are its intrinsic aesthetic merit along with physical comfort. There is a rising demand for stretch property in garments that epitomizes freedom. One of the methods to produce yarns for stretch fabrics is to introduce elastomeric filament such as lycra at the core which contributes outstanding elastic recovery, whereas other staple fibres enwrap it to make ultimate core spun yarns.

Yarns and garments are subjected to varying stresses of small magnitude during service. Repeated loading and unloading under small stresses often cause failure of a yarn even when the stress intensity is well below the measured strength in static condition. The capacity of the yarn to sustain failure gradually diminishes as the applied stress increases. This phenomenon of decreased resistance of a material to cyclic loading is termed as fatigue.

A textile material undergoes a time-dependent deformation on the application of a load and removal of the load gives rise to a time-dependent recovery. These time-dependent deformation and recovery phenomena are known as creep and creep recovery, respectively. The complementary effect of creep is the stress relaxation phenomenon, whereas the stress reduces with time under a given extension.

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Understanding fatigue failure, behavior of yarns under repeated loading is an important aspect because of many end use applications such as apparel, furnishings, upholstery fabrics, and especially in the sports wears. The textile materials are frequently subjected to various levels of mechanical stresses, and therefore, the phenomena of creep and creep recovery are of great practical significance. Furthermore, stress relaxation behavior of the yarn have a direct bearing in the process of weaving and knitting where the yarns are put under varying level of stretches.[1]

Although considerable investigations have been devoted to the fatigue, creep, and stress relaxation behaviors of various continuous filaments,[2–16] limited information is reported for spun yarns.[17–20] No study is available on these behaviors for the core spun yarns intended for stretch fabrics. This study is aimed to fill this gap.

EXPERIMENTAL

Materials

A total of 100% wool (W), wool–lycra (W-L), and polyester–wool–lycra (P-W-L) blended yarns, each having a nominal count of 36 tex, were prepared using Siro spinning technology. Usual commercial method of worsted spinning was used to produce two rovings one of which is 100% Australian merino wool of 22 μm and another of its blend with 3 denier polyester staple fiber. A total of 100% wool yarn was spun by feeding two rovings in each drafting unit of

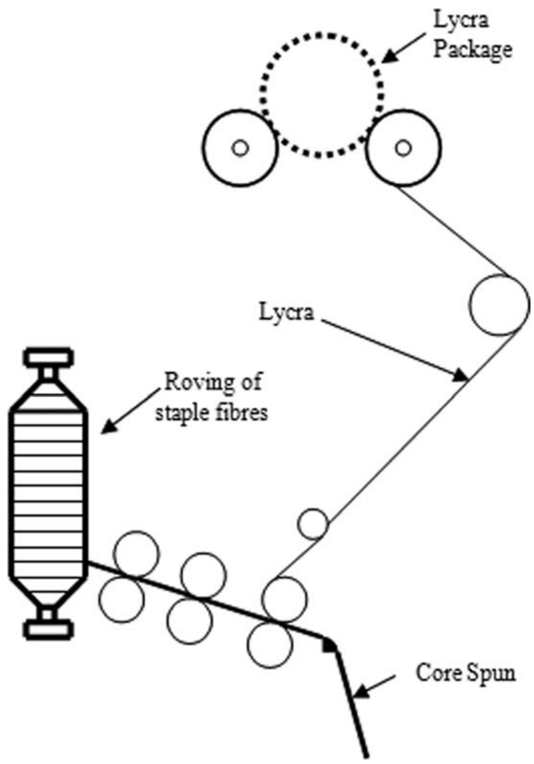

Figure 1 Core spinning attachment on a spinning frame.

ring frame. By adopting the same technique, other two blended yarns viz., W-L and P-W-L were also spun by feeding a lycra filament (40 denier) at the nip of the delivery roller such that lycra at the core gets enwrapped with a drafted sheath of staple fibers from twin rovings of pure wool and polyester-wool blend, respectively. A schematic representation of core spinning attachment on a spinning frame is depicted in Figure 1. The ultimate blend ratios in the core-spun yarns thus obtained were 97 : 3 and 52 : 45 : 3 for W-L and P-W-L products, respectively.

Methods

All the yarn samples were conditioned for 24 h at the standard atmospheric condition before the experiments.

Determination of tensile fatigue failure cycles

To begin with, the samples were subjected to the static tensile testing. The average breaking load and elongation of each sample were measured based on 50 tests in an Instron universal tensile tester (Model 4301) at a gauge length of 200 mm and extension rate of 200 mm/min. Then, the samples were subjected to repeated loading and unloading maintaining the same gauge length and extension rate as used earlier. Although the lower bound of load kept at zero, the upper bound of stresses were restricted to 75, 80, 85, 90, and 95% of the average breaking stresses corresponding to all three samples. The loading and unloading of samples were continued till their failure and number of cycles thus required was noted. Fifteen readings were taken for each set of experiment.

TABLE I
Average Tensile Fatigue Failure Cycles for Different Yarns at Various Upper Limits of Stresses

	Upper limit of stress as a percentage of ultimate tensile stress				
Yarn samples	75%	80%	85%	90%	95%
W	1241	325	248	72	25
W-L	517	215	79	24	16
P-W-L	1827	1208	503	218	83

Determination of stress relaxation

Stress relaxation phenomenon was observed by holding each sample between two jaws with an initial separation of 200 mm in the Instron tensile tester at a pretension of 0.5 cN/tex. The sample was then extended up to a strain level of 15% by moving the upper jaw. The specimen was constrained to remain at that strained condition by stopping the upper jaw, and the load values were recorded over 1 h at regular intervals.

Determination of creep

The measurement of creep and creep-recovery of all yarns was carried out on a specially designed simple set up by suspending a 200 mm length of sample from a hook fixed to a wooden stand. The sample was given pretension of 0.5 cN/tex by a paperclip. After taking the initial reading, a predetermined load equal to 60% of the average breaking load of

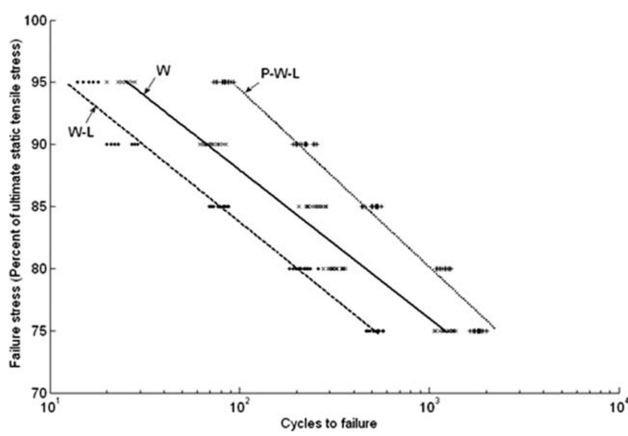

Figure 2 Fatigue failure stress (% of ultimate tensile stress) versus the number of cycles to failure (logarithamic scale).

TABLE II
Tensile- and Time-Dependent Characteristics for Different Yarns

	Tensile		Stress relaxation		Creep	
Yarn samples	Tenacity (cN/tex)	Breaking strain (%)	Relaxation (%)	Stress retention (%)	Permanent extension (%)	Recovered extension (%)
W	7.14	24.26	38.11	61.89	6.56	93.44
W-L	7.04	27.94	44.6	55.4	10.1	89.9
P-W-L	14.94	33.62	37.67	62.33	4.45	95.55

each yarn was suspended from the free end of the sample. The extension of the sample was measured by a traveling microscope at different intervals of time starting from 30 sec onward till 60 min. After 60 min, the load was withdrawn from the sample and the immediately contracted length was measured by adjusting the traveling microscope. The recovery that continued thereafter was measured at different intervals of time up to 70 min.

RESULTS AND DISCUSSION

The average values of tensile fatigue failure cycles at different levels of upper bound of stresses, which are expressed as percentage of the corresponding breaking stresses of various experimental yarns, are shown in Table I. The *S-N* diagrams for different yarns are illustrated in Figure 2, where the ordinate represents the fatigue failure stress, expressed as a percentage of the ultimate static tensile stress of the yarns, and the abscissa corresponds to the number of cycles at which the failure occurred. The number of cycles is plotted on a logarithmic scale. It is evident from the Table I that as the upper limit of stress increases the fatigue lifetime reduces invariably for all yarns. This is due to the fact that as the upper limit of stress increases during a cyclic stressing, the initial crack in the yarns propagates at faster rate and thereby reducing the fatigue failure cycle. It is also apparent from the Figure 2 that when lycra is introduced into the core of wool, it brings down the fatigue lifetime. This may be ascribed to the fact that when the W-L yarn is subjected to cyclic stressing, the very poor modulus as well as breaking stress of lycra lead to its failure before the sheath component fails. However, the P-W-L yarn shows a significant increase in the fatigue lifetime, which may be attributed to the boosting of yarn breaking stress in the presence of polyester as sheath component as evident from Table II.

The plots of the stress relaxation and creep for different yarns are demonstrated in Figures 3 and 4, respectively. Table II summarizes the results of stress relaxation and creep experiments. It is noted from Table II that the level of stress retention (%) is higher for P-W-L yarn, which is followed by W and W-L yarns. Therefore, it appears that the presence of lycra assists in relaxation of stress; however, it is more than off set by the presence of polyester, which reinforces the yarn structure. It is observed from Figure 4 that the total extension during creep experiment is maximum for P-W-L yarn, whereas W-L yarn shows a minimum value. This is attributable to the differences in the magnitude of load applied during the creep experiment for different yarns. The load equals to 60% of the average breaking load of each yarn was selected for creep experiment, and therefore, the suspended load was kept highest for P-W-L yarns and that was followed by W and W-L yarns. As far as the creep recovery on the removal of load is concerned, significant differences were

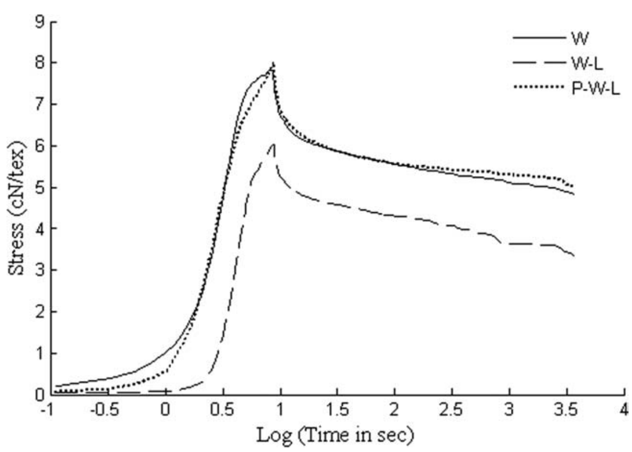

Figure 3 Stress relaxation plots.

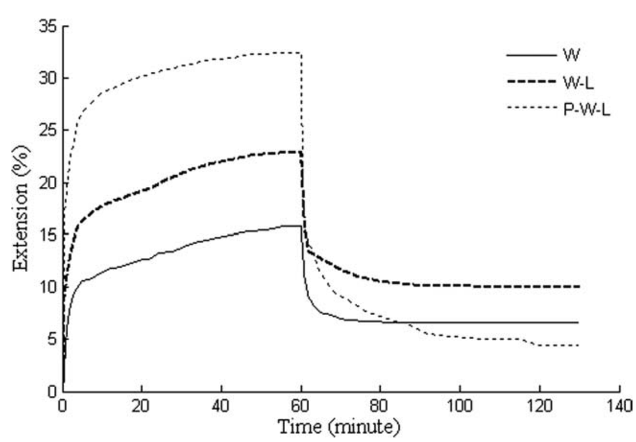

Figure 4 Creep and creep recovery plots.

observed in the permanent extension values, which were 4.45, 6.56, and 10.1% for P-W-L, W, and W-L yarns, respectively. This result may be ascribed to the differences in the viscoelastic natures of lycra and polyester fibers. The viscous part is awfully dominated in the lycra fiber, which will induce easy flow under the application of stress; however, polyester being high-modulus fiber adds structural stability to the yarn by consolidating the elastic part.

CONCLUSIONS

An introduction of lycra filament into the core of wool fibers reduces the tensile fatigue lifetime, stress retention, and creep recovery due to its poor strength and elasticity. However, the reduction of these values due to the presence of lycra is more than compensated when polyester component is incorporated into the blend. As an outcome, P-W-L yarn shows maximum tensile fatigue failure cycle, stress retention, and creep recovery due to the inclusion of polyester, which has high tenacity and elasticity. An inference may be drawn that the polyester as a blend component along with lycra is an imperative, which can confer not only the desired yarn property upon stretch fabrics but also making them a cost-effective products.

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