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Elastic recovery properties of polyester-cotton blended Eli-Twist yarns

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The influence of blend ratio, as well as amplitude and rate of extension on recovery properties of polyester-cotton blended Eli-Twist yarns have been studied. The composition of the yarn and the testing parameters are found to play important role in deciding the recovery characteristics of the yarn. A higher rate of extension is found to result in more immediate recovery, while a low rate of extension results in higher permanent deformation and low immediate recovery. On the contrary, the increase in amplitude of extension results in low immediate recovery and higher permanent deformation. Increase in the percentage of polyester assists higher recovery and low permanent deformation.

Keywords: Delayed elastic recovery, Eli-Twist yarn, Immediate elastic recovery, Polyester-cotton yarn, Yarn permanent deformation

1 Introduction

The elastic recovery of textile product is an important mechanical property. Textile products are not generally subjected to breaking stress and strain. In most of the applications and during manufacturing, it is subjected to low level of stress and strain of repetitive nature. It is important for it to regain its original physical state on withdrawal of applied load. Failure of any product to regain its original dimension may lead to loss in process performance and its value. The elastic recovery of textile material, a time-dependent phenomenon, plays a special role as one of the mechanical properties[1]. Recovery is not only dependent on its structure but also on the magnitude, rate and duration of applied stress or strain. The longer it is kept at a given extension, the lower is the level of recovery[2,3]. A repetitive nature and level of applied stress cause delayed elastic and plastic after effects in [illegible]

Tyagi *et al.*[illegible], while working on the recovery of polyester jet spun yarn, observed the rate of extension and its amplitude to influence elastic recovery and permanent deformation behaviour. Available spinning technologies produce yarns with different structural arrangement of the constituent fibres. The variation in the structural arrangement leads to a difference in their properties under load. Eli-Twist spinning is a derivative of Siro spinning and is capable to produce a compact ring double yarn. It combines compact spinning and doubling of yarn in one single operation. In this process, two rovings are passed through the twin condensers which are separated by a distance at the entrance of the drafting system and are drafted separately. The drafted roving leaves the front roller pair of the drafting system and passes through the compacting zone. During compaction, the distance between the drafted fibre strands is about 8 mm, which enables the twisting point to come very close to the delivery clamping line and thus influencing the structural arrangement of fibres. Most suitable process parameters for a better quality Eli-Twist yarn are 8 mm distance between the drafted fibre strand and 24 mbar negative pressure in suction tube[5].

Shape retention of a textile substrate being an important property, the recovery from stress, thus plays the key role. A new product must always be [illegible]uate its suitability for various end uses. The feasibility of using Eli-Twist yarn as sewing thread has also been reported[6]. The knowledge of its elastic behavior may help in widening its application area.

Different studies are available on elastic recovery of ring-spun, rotor-spun, air-jet spun and MJS yarns[7-11]. However, no report is available on the elastic recovery properties of the Eli-Twist yarns. The present work therefore aims at investigating the influence of associated parameters, viz blend ratio, amplitude of extension and rate of extension on the recovery properties of polyester-cotton blended Eli-Twist yarns.

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2 Materials and Methods

2.1 Preparation of Yarn Samples

For the present study, polyester (1.2 denier, 38mm) and cotton (4.2 mic, 30mm) fibres were used to produce homogeneous and blended yarns. The Eli Twist yarns (29.5 tex) were produced on Lakshmi short staple spinning line with Suessen Elite compact set. In order to produce blended yarn, the blending of combed cotton fleece with polyester was done at the blow room stage. The yarns were spun with twist factor 40 (tpc × tex^{½}) at 17000 rpm spindle speed. In the Eli-Twist system, the distance between the two roving strands in drafting system and the negative pressure were kept 8 mm and 28-35mbar respectively.

2.2 Measurement of Elastic Recovery Parameters

The elastic recovery parameters of yarns were determined using Zwick UTM according to ASTM D1774-79. For each yarn sample, 250 mm long specimen were elongated at an extension rate of 25 mm/min and 120 mm/min. The immediate elastic recovery (IER), the delayed elastic recovery (DER), and the permanent deformation (PD), each one is obtained for an initial extension level of 2% and 4%. For a selected level of extension, the yarns were allowed to fully retract and then relaxed for 3 min; the variations in extension were observed. Figure 1 shows the typical load versus extension in an elastic recovery measurement[7]. Thirty observations were taken for each yarn sample to get result at 95% confidence limit.

The yarn was extended up to a predetermined level ‘G’ and immediately retracted up to ‘O’, the origin via point ‘C’ on tex/2 g load line. After allowing the yarn to relax for 3 min, it was again extended till it crossed the tex/2 g load line at ‘B’. Recovery components were calculated from the following expressions:

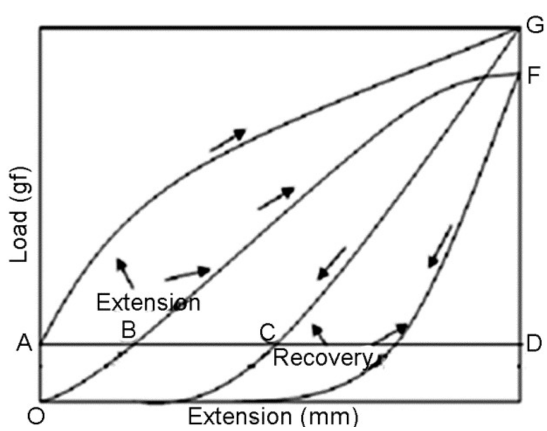

Fig. 1 — Extension cycling for evaluation of elastic recovery parameters

Immediate elastic recovery (%) = [CD / AD] × 100
Delayed elastic recovery (%) = [BC / AD] × 100
Permanent deformation (%) = [AB / AD] × 100

3 Result and Discussion

3.1 Theory of Extension and Recovery

A yarn is composed of visco-elastic fibre. When a load is applied, the extension in a yarn may occur due to one or more of the following reasons:

- Straightening of fibre
- Stretching of individual fibre and their eventual breakage
- Slippage of individual fibre

When applied load in a yarn is small and falls within its elastic limits, the yarn extension takes place due to straightening of the fibres. On removal of load yarn recovers completely with the help of stored elastic potential energy.

When applied load to a yarn is higher but below the breaking load, the extension of yarn takes place due to the slippage &/or breakage of constituent fibres. In the process, extension of individual fibres also adds to the extension of yarn. Fibre breakage/slippage leads to loss in strain energy. On removal of load, yarn fails to recover fully due to loss in energy. However, recovery of neighbouring fibres helps the yarn structure to recover partially due to induced strain energy in fibres.

The extension occurred due to the breakage and slippage of fibre is difficult to recover. Following factors may influence the extension and recovery behaviour of a yarn:

- Mechanical property of constituent fibres
- Composition and arrangement of fibres in yarn
- Frictional characteristics of constituent fibres
- Fibre packing and hence compactness and inter-fibre cohesion
- Ability of structure to maintain its integrity
- Imperfections including shortfall in required number of fibres

The results of the influence of three factors, viz. blend ratio, rate of extension and amplitude of extension on the yarn recovery characteristics are given in Table 1.

3.2 Immediate Elastic Recovery

The immediate elastic recovery refers to the ability of the textile material to recover from deformation

Table 1 — Influence of blend ratio, extension rate and amplitude of extension on recovery properties of polyester-cotton blended Eli-Twist yarns

Blend ratio (polyester/cotton)	Immediate elastic recovery %				Delayed elastic recovery, %				Permanent deformation %			
	2[a]		4[a]		2[a]		4[a]		2[a]		4[a]	
	25[b]	120[b]	25[b]	120[b]	25[b]	120[b]	25[b]	120[b]	25[b]	120[b]	25[b]	120[b]
100:0	30.5	35.36	25.94	31.62	36.53	33.87	39.45	35.71	32.97	30.77	34.61	32.67
80:20	29.23	33.46	22.03	29.36	36.66	35.39	41.38	37.1	34.11	31.15	36.59	33.54
65:35	25.42	30.2	19.06	26.91	40.12	37.74	43.02	38.07	34.46	32.06	37.92	35.02
50:50	23.3	29.46	18.64	24.46	41.99	36.56	41.41	37.68	34.71	33.98	39.95	37.86
0:100	18.37	24.32	16.59	21.39	38.18	36.19	27.67	31.64	43.45	39.49	55.74	46.97

[a]Amplitude of extension (%); [b]Extension rate (mm/min).

immediately after withdrawal of load and is measured by the recovered length with respect to the total extension imposed. The immediate elastic recovery is associated with the straightening/stretching of fibres from their position of equilibrium and with their spontaneous and immediate return on removal of the applied force. This recovery is predominant below the yield point at low stresses and strains. The effect of blend ratio, extension rate and amplitude of extension on immediate elastic recovery is presented in Table 1.

It is observed that the immediate elastic recovery is higher at higher extension rate, while it is lower for higher amplitude of extension. At low extension rate, the phenomenon of stress-relaxation predominates during the actual stretching time, which impairs the recovery characteristics. Low extension rate helps in dissipating the elastic energy, leading to loss in recovery. At small amplitude of extension, small deformation due to fibre extension in yarn takes place, which can be recovered after the load removal. But higher extension leads to higher deformation as a result of fibre slippage and/or fibre breakage &/or extension, which may not be recovered immediately. It is also observed from Table 1 that the reduction in percentage of polyester content in yarn leads to reduction in immediate elastic recovery. Stored elastic energy for polyester is higher than that in cotton. This elastic energy assists in regaining the original shape. With reduction in polyester component, a fall in the stored elastic energy causes reduction in immediate elastic recovery.

3.3 Delayed Elastic Recovery

The delayed elastic recovery refers to the ability of the textile material to recover from deformation with time. The delayed elastic recovery is hindered recovery, which requires time for the displaced fibres to absorb energy from their neighbouring fibres in order to return to their original positions. The effect of blend ratio, extension rate and amplitude of extension on delayed elastic recovery is presented in Table 1.

It is observed that an increase in extension rate leads to reduction in delayed elastic recovery, while it does not show any significant effect of amplitude of extension on delayed elastic recovery ($p=0.99$). At a higher amplitude of extension, the stored elastic energy in the yarn is more. A lower immediate elastic recovery in this state might not have consumed the energy. The residual energy must have helped the recovery more with time, which is reflected as higher delayed elastic recovery. At low extension rate, the stress gets redistributed within yarn during stretching. Such redistribution of stress fails in helping the recovery, thereby reducing the delayed elastic recovery. In Eli-Twist yarn, integration of the surface fibre into the yarn exerts additional inward radial pressure and thus makes the structure more compact. It is also observed that the delayed elastic recovery increases up to a certain level and then falls with decrease in the polyester content. High inter-fibre cohesion in polyester makes the structure more compact and restricts the fibre movement. With addition of cotton, the compactness of structure reduces due to difference in the surface properties of polyester and cotton. On removal of load, the polyester component in the yarn tries to recover and due to openness in the structure, it pulls cotton fibres with it. It happens up to a certain level and as the cotton with less extensibility and higher bending rigidity increases, the ability of the structure to recover from stress reduces. Hence, delayed elastic recovery initially increases and after certain level again decreases with reduction in polyester content.

3.4 Permanent Deformation

The permanent deformation refers to the change or deformation in structure of the textile material which cannot be recovered at all. The effect of blend ratio, extension rate and amplitude of extension on permanent deformation is presented in Table 1.

It is observed that at a higher extension rate, the amount of permanent deformation is lower. It is also

Table 2 — Recovery properties of Eli-Twist and ring-spun TFO yarn at 2% extension

Yarn	Immediate elastic recovery, %	Delayed elastic recovery, %	Permanent deformation, %
Eli-Twist	25.42	40.12	34.46
TFO	29.23	42.39	28.38

lower at low amplitude of extension. It is found that an increase in percentage of polyester content in blended yarn leads to decrease in permanent deformation. At higher extension rate, the structure gets less time for readjustment and hence the stored elastic energy dissipation is less. Thus, the structure can retract back near to its original state. When the amplitude of extension is less, the deformation of the structure is also less and thus the structure can retract back easily.

3.5 Comparative Assessment of Elastic Behaviour of Eli-Twist and Ring-spun TFO Yarn

Typical results for recovery properties of equivalent Eli-Twist and ring-spun TFO yarns made from 65/35 P/C fibre mix are given in Table 2.

It is observed that the immediate and delayed elastic recovery values of ring-spun TFO yarn are higher than that of Eli-Twist yarn. The permanent deformation, however, is higher for Eli-Twist yarn. A high degree of compactness in yarn structure restricts the rearrangement of fibre during relaxation. Hence, Eli-Twist yarn shows poor recovery behaviour compared to equivalent ring spun TFO yarn.

4 Conclusion

The findings are summarized below:

4.1 Immediate elastic recovery increases with increase in polyester content in fibre mix and increase in extension rate. However, it decreases with an increase in amplitude of extension.

4.2 Delayed elastic recovery initially increases and after certain level again decreases with reduction in polyester content.

4.3 Delayed elastic recovery decreases with an increase in extension rate. An increase in amplitude of extension increases the permanent deformation of the structure, but its effect on delayed elastic recovery is not clear.

4.4. The permanent deformation increases with decrease in polyester content in the fibre mix and amplitude of extension. However, it decreases with increase in extension rate.

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