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Stress relaxation and elastic recovery behaviour of dual core stretchable ring spun yarn

Abstract

The main goal of using dual core spun yarn is to take advantage of all properties of its different components. Dual-core yarns comprising three components are currently in vogue. They combine the pleasant wear properties of elastic core yarns with high dimensional stability. The production of these yarns is a challenging process even at the spinning stage, but they are making high demands in the market. Such stretchable core yarns are produced using a modified Ring frame. In this system, dual core spun yarn is produced with a view to combining the advantageous aspects of two components, namely (i) Lycra and polyester filament as dual core elements and (ii) cotton fibres as sheath component that form a structured yarn. The main aim is to combine the good characteristics of two different fibers in a single yarn. Tensile properties, elastic recovery behaviour and stress decay of these dual core spun yarns are studied and a comparative analysis with conventional ring spun yarns are presented in this article. It is found that the dual core yarn is better in tensile behaviour, elastic recovery behaviour and stress decay as compared to conventional ring spun yarn.

Keywords: dual core yarn; stretch yarn, lycra, elastic recovery, stress decay

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Introduction

The demand for highly stretchable fabrics is increasing day by day because of their better properties in terms of stretch, comfort, feel, and absorbency. They have attracted the attention of researchers to constantly involve in blending of natural and artificial fibres to improve such qualities into the yarns. There are several methods available for yarn blending, but commonly used method is core spinning and the typical yarn is called core spun yarn. Core spun yarn is denoted as a yarn in which a core is completely wrapped by dissimilar sheath fibres. Among the core spun yarns that are quite popular in textile industry are containing Lycra as a core and cotton fibres as sheath. The presence of Lycra in the core provides stretch and recovery properties. The cotton fibres at the sheath covering the core provide aesthetic and comfort properties. There are lots of core spun yarns available in the market like Lycra-cotton core spun yarn, cotton- spandex core spun yarn, T400-cotton core spun yarn, cotton-polyester core spun yarn, etc. Lycra presents very good stretch elasticity that reaches about 600%, with its remarkable elastic recovery upto 90%.[1] Only 1–5% Lycra blend with cotton will stretch the fabric over the body for a more comfortable fit. Such a small quantity of Lycra has been found to influence the mechanical properties of the yarn.[2]

Nowadays, dual-core yarns comprising three components are currently in vogue. Different components of dual-core yarn provide different types of advantages. Outer sheath layer provides the appearance of the yarn, and the inner core component provides required strength and extensibility. The preparation technique of dual core spun yarns is simple and a little bit different to ring spun yarns. Core spinning techniques are demonstrated by researchers where some extra attachment is required for manufacturing dual core yarns.[3]

Parameters like yarn count, core and sheath components, twist etc., play major roles for the performance of the core spun yarns. There is little information available in literature regarding the effects of various parameters on tensile characteristics of stretch yarns. The tensile properties of core-spun stretch yarns were investigated long back by Balasubramanian & Bhatnagar.[4] They found higher strength of the yarn at low twist level by the incorporation of the elastane filament in the core. Later on, wool/spandex core-spun yarns were prepared on a modified woolen spinning frame, and the tenacity and breaking extension of the yarns were found to be better than pure woolen yarns.[5] In another study, effects of Lycra content on physical and stretch properties of a denim fabric were investigated by Mourad, Elshakankery & Almetwally.[6] Tensile strength of the fabric was found to be decreased with an increase in Lycra content and stretch applied on it during manufacturing of the yarn. However, they also found that the breaking elongation of fabric increased with the increase of Lycra content as usual due to the higher elongation of Lycra fibers. Ozdil (2008) conducted a study on the stretch and bagging properties of denim fabrics containing different percentages of elastane which revealed that the breaking strength of the core spun yarns containing elastane was lower than the breaking strength of non-elastane yarns.[7] He also reported that the bagging property deteriorated, and the elastic recovery values increased due to the increase in elastane content in the fabric. Using a higher denier elastane in the core-spun cotton yarn, the fabric tear strength, stretchability and recovery increased but the fabric tensile strength decreased.[8]

To better understand the recovery behavior of the yarn it can be segregated as following. The total recovery of the yarn can be segregated into three parts as defined following:

(i) Immediate elastic recovery which is time-independent and fully recoverable,

(ii) Delayed elastic recovery which is fully recoverable with time, and

(iii) Permanent deformation which cannot be recovered at all.[5,9]

The recovery properties of stretch yarn depend on material and manufacturing parameters. Tyagi, Goyal & Patnaik (2002) found that the recovery properties of the coarser count air-jet spun polyester yarns had low immediate elastic recovery, high delayed elastic recovery and a large permanent set than that of finer count yarns prepared under the identical processing conditions.[10] Das & Chakraborty (2013) had investigated on Lycra-cotton core spun stretch yarn and fabric and reported that the yarn tenacity initially increased and then decreased

with the monotonous increase in stretch ratio.[11] The same trend was observed for all levels of twist multiplier and Lycra core content. However, there is little information available on the performance of the dual core spun stretch yarns which may perform better than conventional Ring spun yarn.

Therefore, in the present study, dual core spun yarns are prepared in a modified Ring frame machine using polyester and Lycra filaments in core and staple cotton fibres on sheath. Effects of parameters like yarn count, twist, and polyester/Lycra content in core on the tensile behaviour, stress decay and elastic recovery properties of the yarns are investigated and compared with conventional Ring yarns.

Materials and methods

Materials

Two varieties of cotton fibers viz. J34 & Shankar 6 are used in 50/50 blend proportion as sheath fibre. Two Lycra (T166L) monofilaments (4.44, 7.77 Tex) and two polyester (T400) multifilament (5.55 & 8.33 Tex) are used to insert in core for preparation of dual core yarn.

Method of preparation of dual core yarns

Total 16 yarn samples are prepared according to 2^4 full factorial design. The factors and their levels are: linear density of resultant yarn (36.9 and 24.6 Tex), liner density of Lycra filament (4.44 and 7.77 Tex), linear density of polyester filaments (5.55 and 8.33 Tex), and twist multipliers (3.5 and 4). According to this sampling plan, the dual core yarn samples are prepared on a Lakshmi Rieter G 5/1 Ring frame machine with the help of an extra Lycra feeder and polyester filament feeder attachment at a spindle speed of 17000rpm. Schematic diagram of the dual core spinning system is shown in Figure 1.

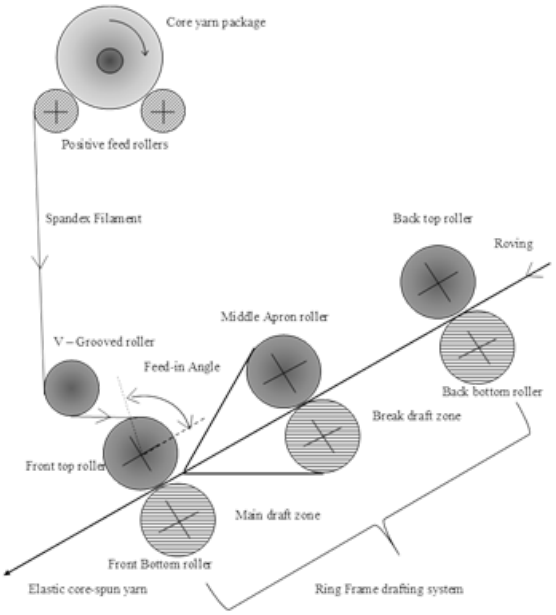

Figure 1 Dual core yarn formation on ring frame.

Ordinary Ring spun yarns are prepared with 100% cotton fibres (50/50 blend of J34 & Shankar 6) of linear density 36.9 Tex, using 3.5 twist multiplier (TM) on the same ring spinning system without the feeding attachment of Lycra and polyester core.

Measurement methods

Mass unevenness of the yarn samples is measured on Uster tester-5, and 30 observations are taken for each sample. For measuring the tensile properties of yarn, Universal tensile tester (ZWICK) is used following ASTM D 2256 standard. The gauge length is kept at 250 mm with 85 mm/min cross-head speed for measuring the yarn samples. 50 observations are taken for each sample and test results are evaluated at 95% confidence level. The yarns are tested under standard tropical atmospheric condition of 65±2% RH and 27±2˚C temperature.

Measurement of elastic recovery

The test method covers measurement of the elastic behaviour of the yarns by assessing their ability to recover strain induced energy and to recover their original dimensions following a known extension on a Zwick UTM tester. ASTM D1774-79 standard is used to determine yarn recovery parameters. The immediate elastic recovery (IER), delayed elastic recovery (DER) and the permanent deformation (PST) are obtained for an initial extension level of 20%, 35% & 50% for each yarn sample. Yarn specimens of 250 mm long are elongated at an extension rate of 25 mm/min as per the standard. The yarns are extended up to a predetermined level and are kept on holding for 1 minute, followed by retracting up to the origin via point 'B' on yarn Tex/2g load line as illustrated in Figure 2. After allowing the yarn to relax for 3 min, it is again extended till it crosses the Tex/2 g load line at 'C' and another same cycle is followed. Figure 2 shows the recovery components and equations (1) to (4) are used to calculate yarn recovery parameters.[12,13]

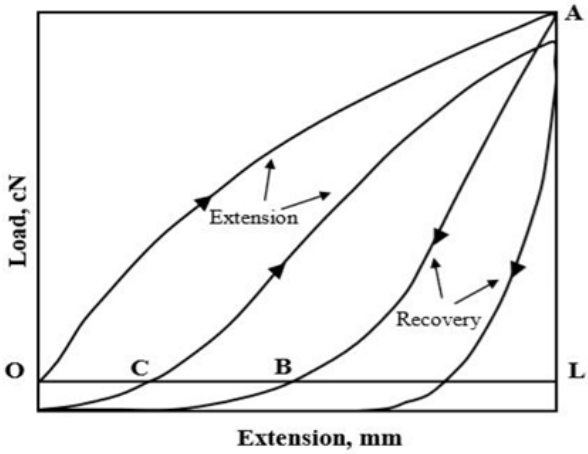

Figure 2 Extension cycling for evaluation of elastic recovery parameters.

$$\text{Immediate elastic recovery (IER)} = [BL/OL] \times 100 \quad (1)$$

$$\text{Delayed elastic recovery (DER)} = [CB/OL] \times 100 \quad (2)$$

$$\text{Permanent set (PST)} = [OC/OL] \times 100 \quad (3)$$

$$\text{Total Elastic recovery (TER)} = \text{IER} + \text{DER} \quad (4)$$

Measurement of stress relaxation

For stress relaxation, all the yarns are tested using 250mm test specimen length and 25mm/min cross-head speed. The testing is conducted on Zwick universal tensile tester. Stress relaxation is obtained for an extension level of 20%, 35% and 50% for each yarn sample. The stress decay% (manifests stress relaxation) is calculated according to equation (5).

$$\text{Stress decay\%} = \frac{[Ft(before) - Ft(after)] \times 100}{Ft(before)} \quad (5)$$

Where, $Ft(before)$ = upper limit of load after which relaxation get started, and $Ft(after)$ = value of load after completion of the test

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Results and discussions

Yarns unevenness (U%)

Unevenness of all dual core spun yarns are tested on Uster Tester-5, and average Uster U% results of 30 observations are shown in Table 1. It can be seen that as twist in the yarn increases U% increases for all yarns. Keeping Lycra Tex and twist multiplier (TM) constant, as polyester Tex increases, U% decreases. Similarly, keeping polyester Tex and TM constant, as Lycra Tex increases U% decreases. As yarn count decreases, U% increases. The average U% of 36.9 tex dual core spun yarn is 8.31, whereas U% of conventional Ring spun yarn is 9.13, which is higher than that of the dual core spun yarn. Therefore, dual core spun yarn has better evenness as compared to conventional ring yarn.

Table 1 Yarn unevenness results of dual core yarns

Yarn Count(tex)	PET (Tex)	Lycra (Tex)	Twist Multiplier (TM)	Unevenness (U%)
36.9	5.55	4.44	3.5	8.58
36.9	5.55	4.44	4	8.76
36.9	8.33	4.44	3.5	8.12
36.9	8.33	4.44	4	8.59
36.9	5.55	7.77	3.5	8.37
36.9	5.55	7.77	4	8.4
36.9	8.33	7.77	3.5	7.76
36.9	8.33	7.77	4	7.96
24.6	5.55	4.44	3.5	9.11
24.6	5.55	4.44	4	9.27
24.6	8.33	4.44	3.5	8.87
24.6	8.33	4.44	4	8.41
24.6	5.55	7.77	3.5	9.27
24.6	5.55	7.77	4	8.98
24.6	8.33	7.77	3.5	8.26
24.6	8.33	7.77	4	8.94

Effects of parameters on tensile behaviour of the yarns

Tenacity of all dual core spun yarns are measured and results are analysed to understand the effects of factors like core structure and twist multiplier on tenacity. Linear density is found to have no significant effect on the tenacity of yarn. The tenacity of yarn without a core i.e. for the conventional Ring spun yarn is 8.88cN/tex, which is significantly lower than all the core spun yarn. The effects of yarn count, core polyester content, core Lycra content, and TM are shown in Figure 3 and Figure 4.

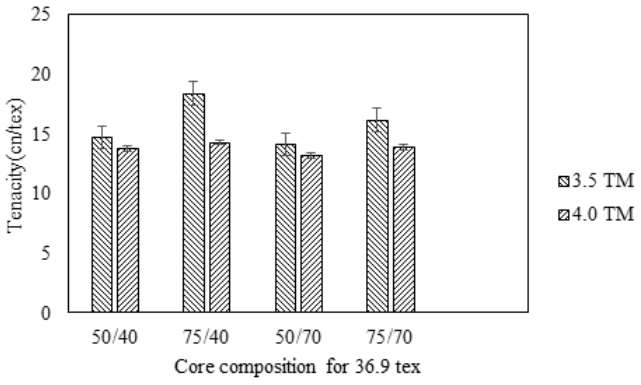

Figure 3 Effect of parameters on tenacity of 36.9 tex core spun yarns.

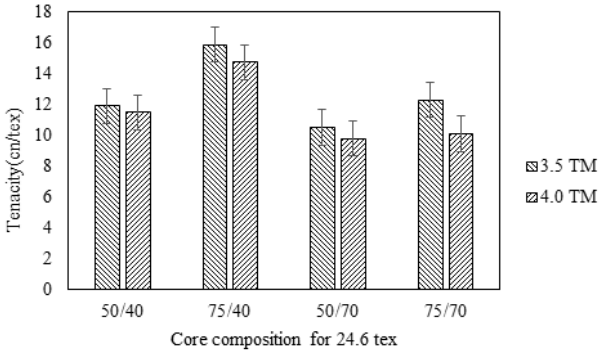

Figure 4 Effect of parameters on tenacity of 24.6 tex core spun yarns.

It is observed from Figure 3 and Figure 4 that as polyester content in core increases, the tenacity increases. A change in the number of filaments directly influences the number of load-bearing components. For a coarser yarn, more fibers are available for sharing the applied load. If appropriate compactness is maintained, the higher number of load-bearing components in polyester core should yield stronger yarn. The tenacity of the yarn is found to decrease with increase in twist multiplier. In a core spun yarn, initial load sharing is done by the core component. The relationship between the yarn modulus and fibre modulus is $E_y = E_f \cos^2\alpha$, which reveals that any twist inserted

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into a bunch of filaments reduces its strength. The core component here is composed of a bunch of filaments and on the application of twist the strength of core filaments reduces. Thus, increase in the twist multiplier causes the tenacity of core yarn to reduce. When Lycra content increases, the tenacity decreases. As the Lycra content increases, while keeping the polyester content same, the extensibility of Lycra will predominate the extensibility of other components like polyester and the sheath component. So, its extensibility will cause disintegration of staple fibres surrounding it, thus lowering the strength of yarn.

Effects of parameters on breaking extension of the yarn

The breaking extension results of the yarns suggest that the core composition and twist multiplier (TM) significantly affect the breaking extension of yarn. In contrast, the yarn count has no significant effect on it. The breaking extension of conventional ring spun yarn is 5.9%, and that of dual core yarn is 12.27% which is significantly higher than conventional ring spun yarn. The graphical representation of results is shown in Figure 5 and Figure 6 for the 36.9 tex and 24.6 tex yarns, respectively. The breaking extension has been found to increase with the increase in linear density polyester filament while keeping Lycra content unchanged. This is due to polyester T_{400} contains good elasticity because of its structure. It is composed of two types of polyester, (40% 3-GT type and 60 % 2-GT) which shows smooth and regular crimp that is the cause of the elastic properties shown by the yarn. This characteristic of the core causes less disintegration of the sheath structure, thus resisting failure of the yarn. This is manifested as breaking extension. While keeping the linear density of polyester unchanged, as the linear density of Lycra increases, breaking extension of yarn decreases. Lycra being highly extendable, a differential nature of extension of core and sheath is expected. The core component can easily extend on loading, which causes early disintegration of the sheath leading to the failure of the yarn. Thus, the breaking extension of yarn reduces with increasing the Lycra content. Breaking extension starts to decrease with increase in twist multiplier. This happens because the yarn becomes compact, and cohesion between the fibres of sheath and between core and sheath increases. The failure of the yarn is also expected to be dominated by fibre breakage.

Effects of parameters on stress relaxation

Stress relaxation of a yarn signifies the time-dependent mechanical behaviour under load. When yarn is kept stretched, load develops on it, which reduces due to the redistribution of load among the constituent fibres to minimize the localized stress. The load developed in the individual fibres due to load application also gets distributed. Loading of yarn imposes strain in the fibres and this strain energy is dissipated through rearrangement within the structure and the developed stress relaxation with time. Such decay in stress can be caused due to time-dependent visco-elastic nature of fibres, fibre rearrangement in yarn and sharing of stress between component fibres.

In ring spun yarn, stress relaxation for 20%, 35% and 50% extension are 52.5%, 40.4% and 36.9% respectively, whereas the same for these dual core spun yarns are 32. %, 28.1% and 26.1%, respectively. The value of stress relaxation decreases for both yarns when polyester content and twist multiplier increase. For Lycra yarns, the stress relaxation increases as increasing the Lycra content. Stress relaxation reduces when extension % increases. In ring spun yarn the value of stress relaxation decreases as extension % gradually increases.

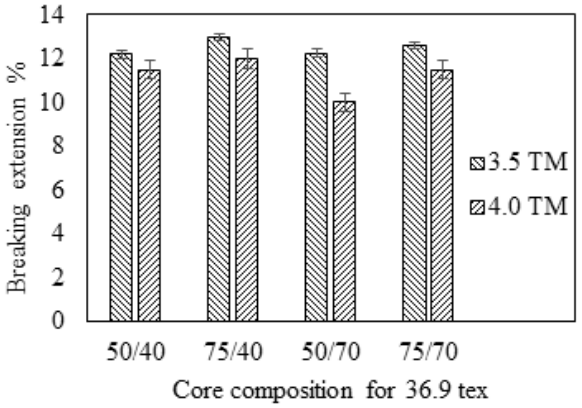

Figure 5 Effect of parameters on breaking extension of 36.9 tex core spun yarns.

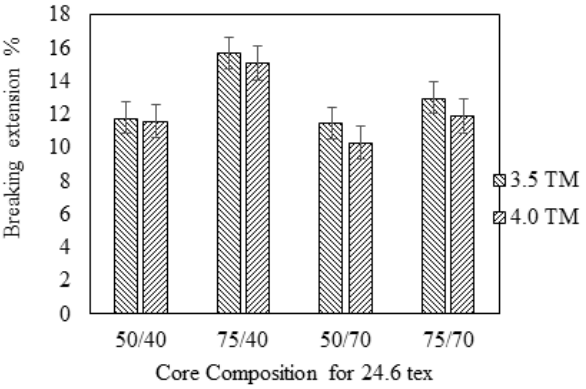

Figure 6 Effect of parameters on breaking extension of 24.6 tex core spun yarns.

Effects of parameters on elastic recovery properties

The recovery properties refer to the ability of the textile material to recover from deformation on withdrawal of load. When a core spun yarn is subjected to loading and unloading, it would allow structural modification. The degree of structural modification would decide the behaviour of the yarn due to the application of load. The recovery behaviour includes immediate elastic recovery, delayed recovery (recovery with time) and permanent deformation.

Immediate elastic recovery

The immediate elastic recovery refers to the ability of the textile material to recover from deformation immediately on withdrawal of load. For the conventional ring spun yarn, immediate elastic recovery for 20%, 35% and 50% extension are found to be 13.8%, 17.6% and 18.4%, respectively. Whereas, the immediate elastic recovery for dual core spun yarns is found to be 23.4%, 29.1% and 34.1%, respectively. Immediate elastic recovery decreases with increase in the linear density for both the yarns at all the levels of extension. Immediate elastic recovery increases as polyester content increases and similar trend is observed for different levels of the twist multiplier of dual core yarn. In case of conventional ring spun yarn, immediate elastic recovery increases with increase in the extension level.

Delayed elastic recovery

The delayed elastic recovery refers to the ability of the textile material to recover from deformation with time on withdrawal of load. For conventional ring spun yarn, delayed elastic recovery for 20%,

35% and 50% extension are found to be 37.6%, 38.9% and 39.4%. respectively. Whereas delayed elastic recovery for the dual core spun yarns are 57.3%, 49.6% and 40.5%, respectively. It is observed that delayed elastic recovery decreases with decrease in linear density. Delayed elastic recovery decreases with decrease in extension %. Increasing the Lycra content, the delayed elastic recovery decreases.

Permanent deformation

The permanent deformation refers to the change or deformation in structure of the textile material, which cannot be recovered at all. This may cause a remarkable change in the shape of the textile product after use and hence undesirable. For conventional ring spun yarn permanent deformation for 20%, 35% and 50% extension are found to be 50.3%, 43.1% and 42.6%. Whereas the same for dual core spun yarns are found to be 19.2%, 22.2%, 25.5% respectively. It is observed that the permanent set decreases with decrease in the linear density while it reduces with increase in polyester content. Permanent set increases with increase in extension % and Lycra content of the yarn. Permanent set decreases with increase in twist multiplier.

Comparison of dual core spun yarn with conventional ring spun yarn

A conventional ring yarn of 36.9 tex with 3.5 TM was produced on the same machine for a comparative assessment with an equivalent dual core spun yarn.

Comparison between tenacity

The tenacity of the conventional ring spun yarn and dual core yarn of 36.9 tex was 8.88 cN/tex and 14.76 cN/tex, respectively. A significant difference between the tenacity of two yarns reflects the contribution of the core as shown in Figure 7. When an axial load is applied, the load is primarily shared by the core filament in a core spun yarn. The contribution of core component is reflected by the difference in the strength.

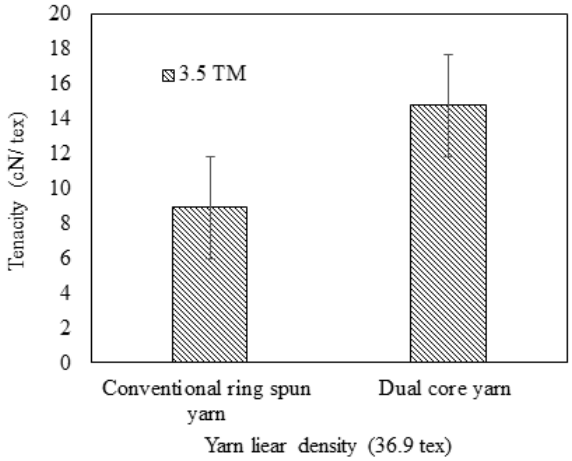

Figure 7 Tenacity of conventional and dual core yarn.

Comparison between breaking extensions

The breaking extension of conventional ring spun yarn and dual core yarn are 5.9% and 12.55%, respectively. The Lycra/polyester filament in the core adds additional extensibility to the core spun yarn as compared to the conventional ring spun yarn which is shown in Figure 8.

Comparison between stress relaxations

Both conventional and core spun yarns are subjected to stress relaxation using 20%, 35% and 50% extension. The decay in stress is represented in Figure 9. The conventional ring spun yarn is found to exhibit higher stress relaxation than the core spun yarns. In case of core spun yarn, a differential nature of extension between core and sheath can be observed. Extensibility of core being high and accordingly, at a higher extension, the possibility of disintegration of staple fibre sheath is more which cannot retain the developed stress. Thus, the decay of core spun yarn is more than that of conventional yarn.

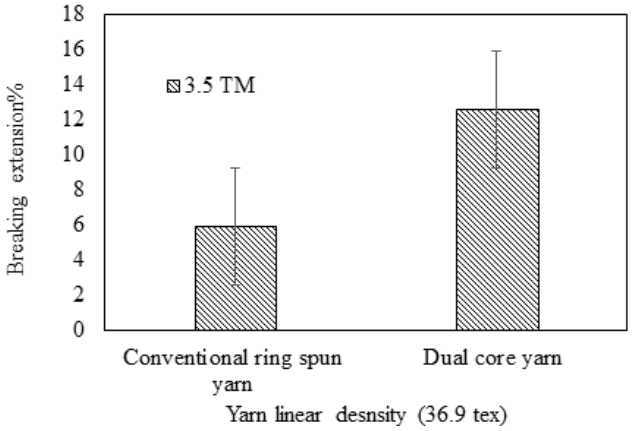

Figure 8 Breaking Extension of conventional and dual core yarn.

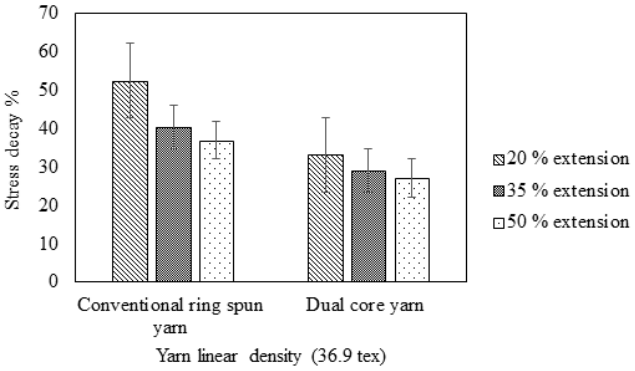

Figure 9 Stress Decay of conventional and dual core yarn.

Comparison between elastic recovery

The elastic recovery of conventional ring spun yarn and dual core spun yarn for 20%, 35% and 50% extension are 51.4%, 56.7%, 57.6% and 77.87%, 74.11%, 70.89%, respectively which is higher than the core spun yarn as shown in Figure 10. In the core spun yarn, presence of stretchable component in core helped in recovery, although staple fibre sheath disintegrated. Thus, dual core yarn shows higher elastic recovery.

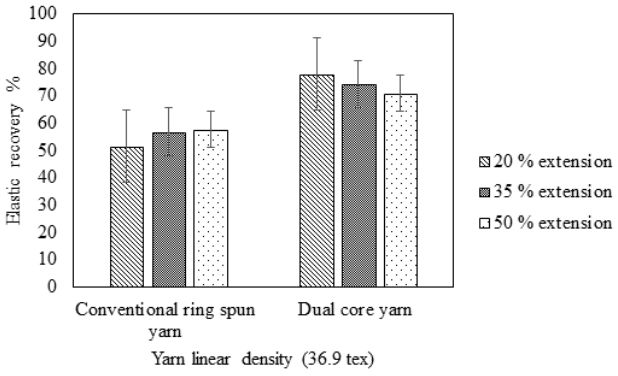

Figure 10 Elastic Recovery of conventional and dual core yarn.

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Conclusion

In this study, an attempt is made to understand the effect of yarn count, polyester content, Lycra content, twist multiplier and extent of load/extension on tenacity, breaking extension, recovery and stress relaxation behaviour of dual core spun stretchable yarn. It has been observed that the yarn tenacity gradually increases with increase in polyester content, and decreases with increase in twist multiplier. The breaking elongation of the yarn increases with both increase in polyester content and Lycra content. The breaking elongation decreases with increase in twist multiplier. Stress relaxation increases with increase in polyester and Lycra content. The stress relaxation decreases with increase in twist multiplier as well as increase in extension%. The tenacity and breaking extension of dual core yarn are found to be higher than the conventional ring spun yarn. The stress decay of dual core yarn is found to be lower than the conventional ring spun yarn. The elastic recovery of dual core yarn is found to be better than the conventional ring spun yarn. Therefore, overall performance of the dual core spun yarn is found to be better than conventional Ring spun yarn which makes it suitable for various end use applications, including stretchable denim. Advantages of dual core spun yarn are good elastic recovery, better shape fitting, facilitating ease of movement and also high dimensional stability of the end product.

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Conflicts of interest

Authors declare that there is no conflict of interest.

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