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Cotton-elastane ring core spun yarn: A review

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ABSTRACT

The quest for highly stretchable fabrics with good and lasting handle properties such as absorbance, feel, and comfort has inspired researchers to constantly involve in blending of natural and artificial fibres. One of the commonly used methods of blending is core yarn spinning. Core spun yarn structure consists of two components; the sheath and the core. Normally, a continuous multifilament yarn is used as a core while cotton staple fibres are used to cover the filament. Cotton staple fibres have been a favourite choice for the sheath of core spun yarns because of their aesthetic properties. Cotton is known for its commendable absorbance properties, comfort feel among other unique properties that can hardly be found in most man-made fibres. On the other hand, most filaments used like Lycra, polyester, and spandex, among others possess stretching/extensible properties and they are also responsible for the tensile properties of the resulting yarn. This review focused on structural properties, end use, and the important spinning parameters of Cotton/Lycra, Cotton/spandex, Cotton/Polyester elastic core spun yarns.

KEYWORDS

Core spun yarn;
Ring spinning parameters;
T-400/Cotton;
Cotton/ Polyester;
Cotton /Spandex.

INTRODUCTION

Core spun yarns have a structure in which one of the constituents, in most cases a synthetic filament either mono or multi, is concealed by a different component, a staple fibre sheath[1,3,37]. Therefore a core yarn consists of a core part and a sheath (Figure 1). Core spun yarns can be produced mostly on ring and friction spinning machines. Ring spinning has been favoured compared to other spinning systems, however friction spinning has also been described as quiet good apart from the major disadvantage of false-twisted core material and low core-sheath slippage resistance[1-4]. The main aim of using core spun yarn is to take advantage of the different properties of its both components. The filament increases yarn strength and also permits the use of lower twist level, while the sheath provides the staple fibre yarn appearance and surface physical properties[1,5-7].

The method for the preparation of core-spun yarn is very simple and the selection of core and cover materials can be made from assortment of fibers with preset end use. Nylon and Polyester continuous filaments are the common core materials[7-9]. Core spun yarn is said to possess far better properties as compared to 100% cotton yarn or 100% filament yarn[10-12]. This is due to the combination of different properties which consequently gives good aesthetic and durability prop-

Mills.

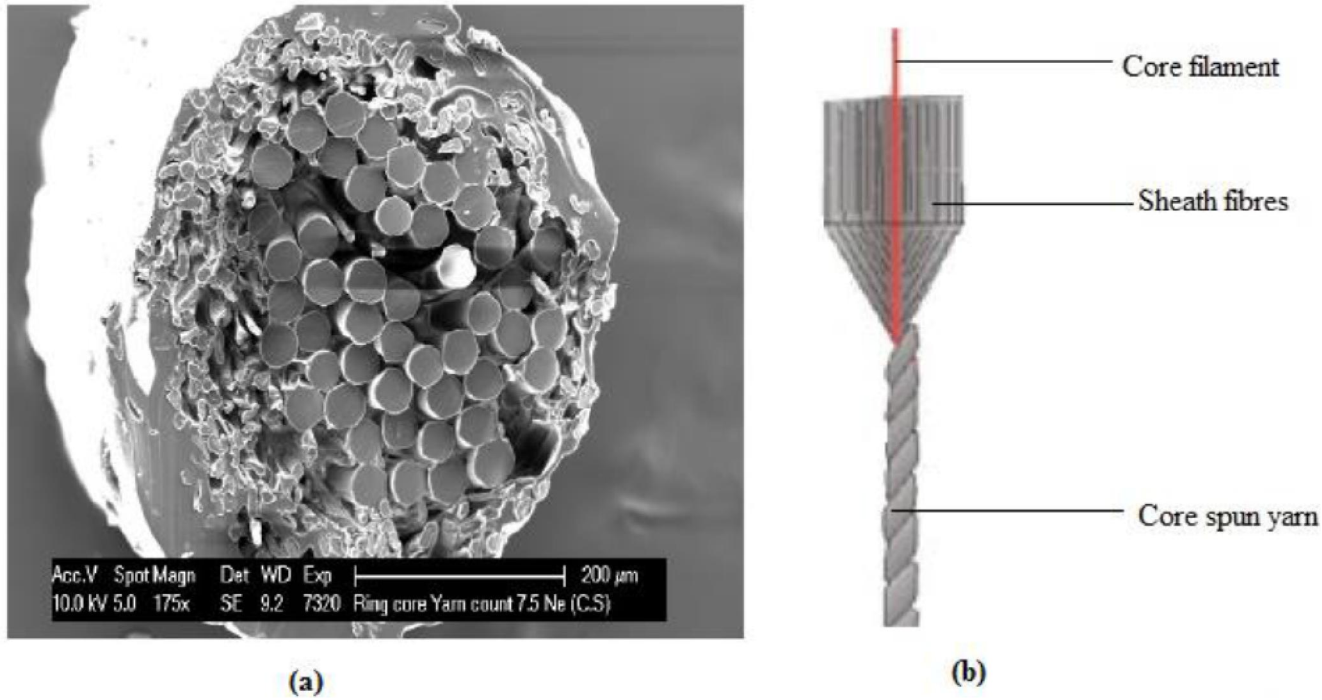

Figure 1 : (a) Cross-sectional image of cotton-nylon core yarn [1], reproduced with copyright permission from World Cotton Research Conference on Technologies for Prosperity, (b) Structure of core-spun yarn[73] reproduced with copyright permission courtesy of Spininnovation, The Magazine for Spinning mills.

erties. Considering a combination of cotton and polyester filament, cotton definitely is responsible for moisture absorption, heat resistance, air permeability among other properties. The synthetic filament on the other hand gives good tensile properties[1, 3].

Core spun yarn spinning is preferred to other yarn blending types because the technique has proved effective in integrating core filament properties with sheath filament properties[27]. Elastic core spun yarns find application in manufacture of elastic fabrics for sports, creating novelty effects in fabrics through enhancement of functional properties such as strength, durability, stretch and comfort[5-7,27].

Applications have further been realised in manufacturing of industrial and household threads, lightweight apparel fabrics, industrial clothing, tents, underwear and outwear[3,6,12,61]. Core spinning also has an advantage preferred due to its compatibility with a number of spinning methods such as conventional core spinning attachment with ring spinning systems, siro spinning, core wrapping spinning method, Patterned spinning system, composite electrostatic spinning system, rotor spinning system, friction spinning system and air jet spinning system[12,54,60,62]. This gives opportunity to utilise different spinning systems' benefits to achieve anticipated end use.

The common materials used for an elastic core spun yarn are nylon, polyester, spandex, cotton among others. The traditional elastic fibres were commercialised many years back, however new research and developments have focused on the functional fibres[54,55]. Despite the early discovery of elastic fibres of polyester PBT and PTT in 1940s, it took a couple of years for companies to revolutionise the industry[55, 57]. Several companies such as DuPont have discovered key elastic filaments that have found credible applications in textiles. However, blending them with other fibres through core spinning is a great deal to enhance the physical characteristics of the yarn and hence of the resulting fabric[13,46,59].

Lycra/Cotton core spun yarn

Commercialised in 1952 by Dupont[13], Lycra can simply be defined as a synthetic fiber in which the fiber constituent is a long chain polymer consisting of at least 85% of segmented polyurethane[14]. The polyurethane is made from a polymer glycol and chain extender and processed through melt-spinning process. It can be dry-spun or wet spun to form the spandex fibers[15-16]. Sadek[15] found that the extension of single jersey fabrics greatly influences the fabric properties. Therefore optimising the extension of Lycra is a great deal to achieve better fabric performance.

Properties, influencing Lycra/cotton yarn/fabric performance

Lycra presents very good stretch elasticity that reaches about 600% with its remarkable elastic recovery reaching 90%, although with a poor tenacity that cannot exceed 0.9cN/tex[16,17]. Studying the effect of elastane draft on the rheological modelling of Lycra/ Cotton core spun yarn, Baby et al[17] noted an increase in both the modulus of elasticity and decrease in the viscosity coefficient with rise in the elastane draft. Relaxation curves of elastic core spun yarn 59 yarns tex with 156 dtex of elastane was produced with dissimilar elastane drafts and showed a falling exponential trend which demonstrates the viscoelastic comportment of the elastic core spun yarns. This implies that the elastane draft during core spun manufacture is a very important factor to consider since it enhances the mechanical properties of the resulting yarn as well as the fabric properties[17,59,60].

The final performance of a cotton-lycra fabric will however also depend on weaving or knitting techniques[16,58]. For example, in knitted fabrics, as the Lycra extension rises, the air permeability drops for both half plated and full plated knitted fabrics. Half plated fabrics have Lycra positioned in alternating courses in a knitted fabric; while full plated is when the cotton and the Lycra yarn are knitted parallel or side by side in every course with the Lycra yarn always kept one side of the cotton yarn[15].

As demonstrated in Figure 2 above, the lycra extension has an inverse relationship with the air permeability for dyed fabrics hence that elastane fibres have a significant effect on the properties of the fabric[15, 18-19]. In a related study, Helali et al[17] in theier study, used elastane count 156 and 78 dtex for yarn counts of 59 tex and 50 tex respectively. By varying the elastane draft in the production of two yarns, an exponential trend in the relationship between the draft and stress was realised (Figure 3, 4).

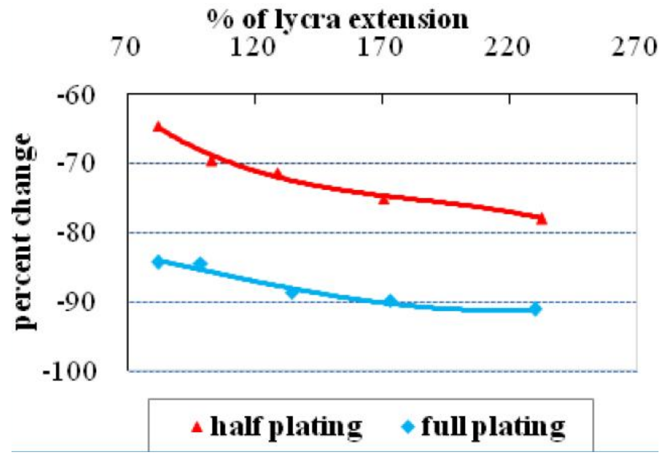

Figure 2 Effect of Lycra extension on the air permeability for dyed fabrics in half and full plating [15]. (Reproduced with copyright permission courtesy of Journal of Engineered Fibers and Fabrics (JEFF))

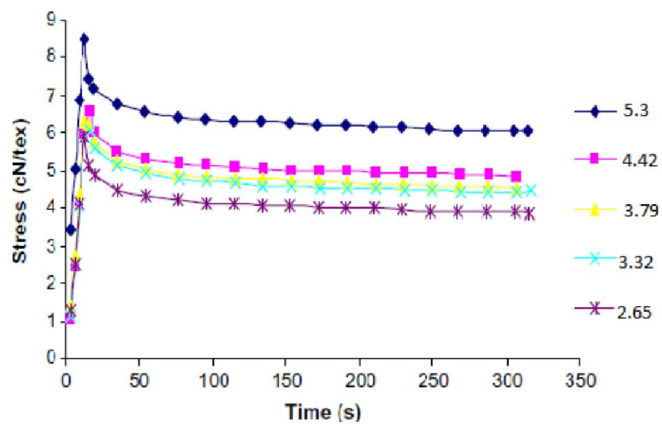

Figure 3 : The relaxation curves of the elastane core spun yarn 50tex yarn/156tex elastane for different elastane drafts [17] (Copyright 2012 Taylor and Francis Group reproduced with permission).

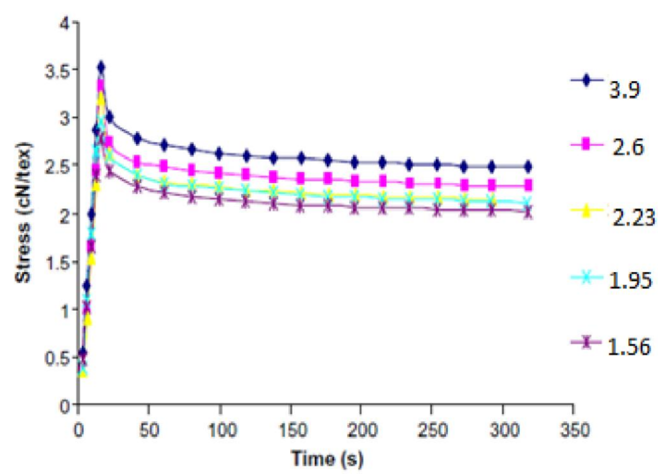

Figure 4 : The relaxation curves of the elastic core spun yarn 50tex yarn/78tex elastane for different elastane drafts [17]. (Copyright 2012 Taylor and Francis Group reproduced with permission).

Relaxation curves in Figures 3, 4, and 5 clearly show that, the higher the draft, the more the stress applied with time. Stress-extension curves exhibit more extension at higher drafts[20-22,59]. These indicate a significant relationship between the draft and mechanical properties of the core spun[17] yarn. Filament draft, pre-tensioning, twist multiplier as well as the spindle speed are considered important parameters during lycra-cotton core spinning[17, 23]. Researchers have further revealed that, filament draft is an important factor especially the tension draft/pre-tensioning as it ensures proper core alignment as well as uniformity in yarn strength[15,17,23]. The twist multiplier[20-22] is also imperative as it contributes to the core spun yarn strength and proper arrangement of the sheath around the core. The amount of twist inserted is responsible for holding the fibres at intact to the yarn axis. In addition to influencing the production rate, the spindle speed also affects the stability of core yarn alignment; slower speeds show poor alignment[21].

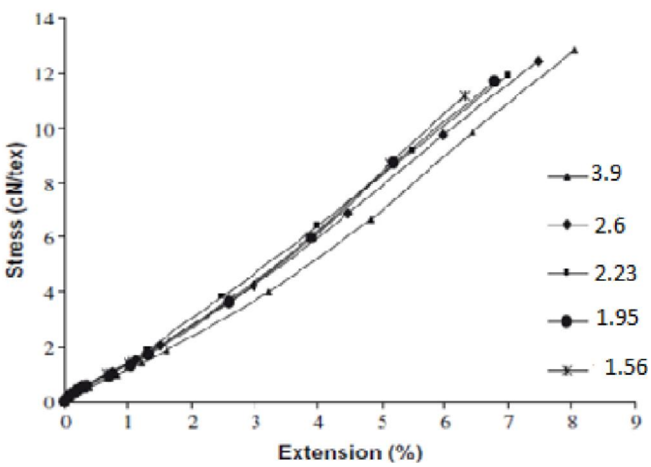

Figure 5 : Tensile curves of elastic core spun yarn 50tex yarn /78tex elastane for different elastane drafts [17]. (Copyright 2012 Taylor and Francis Group, reproduced with permission).

Cotton/Spandex Core spun yarns

Spandex is a general term used to represent elastomeric fibres which have an extension-at-break greater than 200%[58]. Chemically, spandex is composed of a long-chain polyglycol combined with a short diisocyanate, and contains at least 85% polyurethane. It is an elastomer, which means it can be stretched to a certain degree and it recovers when released. These fibers are superior to rubber because they are stronger, lighter, and more versatile[71]. These fibres also show quick recovery when tension is withdrawn. They show a rubber-like comportment with high flexible extension as high as 400-800%. They are also lightweight, soft and strong. This provides fabric manufacturers with a wide range of possibilities since they can be core spun with a wide range of fibres[24-28, 61,63]. Studies on the spinning process of spandex core spun yarns, for optimum properties of the yarn, focus is mainly put on the draw ratio, spandex filament fineness, twist factor and control of sheath- core ratio[21,24,27]. Due to end-use requirements, spandex core spun yarn has in most cases been of nylon or rayon wrapped rather than cotton. This is due to the anticipated stretch and excellent physical properties of the resulting yarn and fabric. Much as the yarn determines the final properties of the fabric, Singh[29] notes that the weave structure too has a big influence on the stretching properties of the final product[15,29].

Spinning parameters of cotton/spandex elastic yarn and their influence on yarn/fabric performance

In their studies on dimensional stability of core spun cotton/spandex single jersey fabric under relaxation, Najar et al[28,31] and Herath and Kang[30,33] established that yarns with elastomeric constituents upsurge tightness factors, which have a major effect on the dimensional behaviours, giving better dimensional stability to single jersey fabrics[30,31]. They further noted that under full relaxation conditions, effects of yarn and fabric parameters on a knitted fabric become a minimum energy condition and the stitches give a foreseeable geometrical configuration[31]. The dimensional stability was examined by calculating the dimensional constants. Comparing cotton/spandex core spun yarn knitted fabric with 100% cotton knitted fabric, it was established that a core spun yarn can lead to better relaxation of a cotton/spandex knitted structure. This is because the relaxation forces acting on straight core spandex filaments may force to return back to original states with their outer shield cotton yarn[27,32, 33].

Studies about the dimensional characteristics of core spun cotton-spandex 1 X 1 rib fabrics in laundering, revealed that cotton-spandex rib structures came to a more stable state (minimum energy state) after a 10th

laundering cycle[27, 32, 33]. Cotton did not come to such a state, even after the 10th cycle proceeded. ANOVA analysis done under 95 percent confidential level indicated that fabric tightness and relaxation processes give major effect on dimensional characteristics of cotton-spandex fabric. However, area shrinkage variations of cotton rib fabrics showed exception to this. It was also noticed that cotton-spandex fabric have high length shrinkages and the reason to this was accredited to very good power of resilience of spandex core[33].

The mechanical properties of core spun yarn containing spandex fibres can be enhanced by optimising the draw ratio[34,35,60]. Research on the effect of draw ratio on elastic core spun yarn properties in friction spinning has revealed that, the elastic filament is responsible for the strength of the resulting yarn whereas the sheath fibres are responsible for the traditional look, feel and comfort[25,54,58]. And that further, the general properties of the core spun yarn will be determined by the properties of the core and sheath, and their ratio and method of spinning[53,64,65]. The spandex draw ratio is the most significant parameter that defines the way the spandex filament is oriented in the core spun yarn. This is therefore taken as a very important factor to consider when manufacturing an elastic core yarn. The staple fibres will simply be around the filament, hence a good core spun yarn should have a good orientation of the filament and well covered sheath fibres[28,36].

Konda et al[37] argued that the tensile properties of core yarn depend on the elongation behaviour of their constituent components citing that filament pre-tensioning, draft ratio and the twist multiplier play a great role in the mechanical properties of core spun yarn. Konda et al[37] asserted that, the core yarn strength is better than that of equivalent cotton yarns, and that also the core strength determined by the pre-tension exerted on the filament forming zone[21,37,66].

Recent studies on the draw ratio of filament during the cotton-spandex core yarn manufacture suggest that as the draw ratio rises, the yarn twist declines primarily due to the increasing proportion of cotton sheath fibers to sustain a constant count[31].

A decline in yarn hairiness was recorded with increasing draw ratios up to 3.5 (Figure 5). From 3.5 to 4.2, draw ratio, no change in yarn hairiness was recorded. The hairiness of elastic core spun yarn is lower than that of the 100% cotton yarns[37]. The elongation of core spun yarn was found to be the same as that of 100% cotton yarn at spandex draw ratio of less than 3.75, while the elongation of the elastic core spun yarns increased sharply as the spandex draw ratio exceeded 3.75. An optimum draw ratio of 4 was recorded[37].

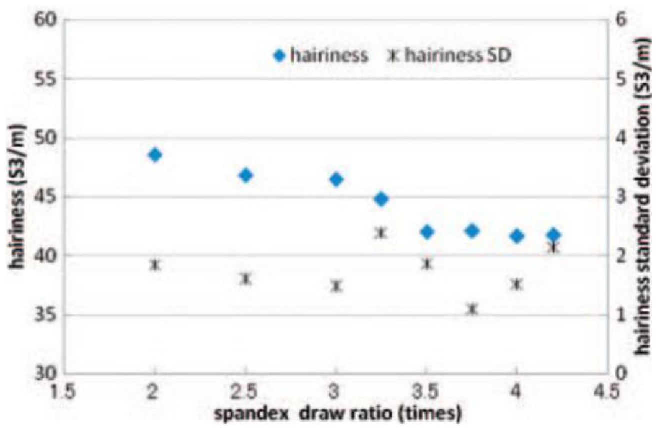

Figure 6 : Change of elastic core spun yarn S3 hairiness with spandex draw ratio [28]. (Copyright 2012 SAGE publications, reproduced with permission).

Cotton/Polyester core-spun Yarn

In quest to improve the mechanical properties and performance of fabrics, blending of natural and synthetic fibres has been widely used research to investigate the key parameters and their optimum control during spinning has always been explored over the time[38]. Such parameters include; tensile strength, elongation, count, twist, evenness and hairiness among others

Spinning parameters of cotton/polyester elastic core spun yarn and their influence on yarn/fabric performance.

Canoglu and Tanir[39] studied the yarn hairiness of polyester/cotton blended ring spun yarns made from different blend ratios. In their study, 36 tex polyester/cotton yarns were spun with five blend ratios using two traveller weights, and the variations in yarn hairiness among other yarn properties was examined. They observed that with cotton/polyester blends the irregularities of the yarn fall with increase of polyester percentage in the blend[39]. This was attributed to the non-existence of the thickness variations in polyester, which is a synthetic fiber. The breaking tenacity and elongation values declined with the rise of the cotton percentage of blend yarn. The hairiness of polyester/cotton blend yarns largely dropped as the traveller weight increased. In general, this implies that the properties of a cotton/ polyester depend on the spinning parameters, the blend ratios as well as the individual properties of the constituents[39-40,69].

In core yarn manufacture, the use of core yarns for example polyester is to improve the strength, comfort, durability, aesthetics, and other functional properties of the yarn[41,42,60-62]. The core yarn has improved properties compared to 100% cotton ring spun yarn in many aspects such as yarn strength, elongation, energy to break, and yarn imperfections. In their study Pramanik et al[42], found that air-jet core yarn showed lower yarn strength than 100% cotton yarn in addition to superiority in other properties compared to 100% cotton yarn. When cotton is used as a sheath fibre, the yarn properties such as moisture absorption, heat resistance, air permeability[31], and depth of shade in dyeing are improved compared to other synthetic yarns. The tensile strength of yarn also increases especially when an elastane filament is used[17,42]

Pramanik et al[42] studied the physical properties of cotton/polyester core spun yarn made using ring frame and air-jet systems, the core yarn used was the polyester filament of different denier and the covering was cotton of fibre length at 33.5mm, strength 28gram/tex, uniformity ratio (UR%) 48 and micronaire value 4.2. In their study, material and machine parameters such as drafts and denier of polyester were varied. The twist multiplier and other spinning parameters were kept constant. It was reported that 100% cotton yarn showed the worst physical properties compared to core spun yarn in aspects of yarn strength, elongation, energy at break, and yarn imperfection. Although air-jet spun yarns exhibited lower strength when compared to 100% cotton, better performance in other properties was observed[42].

Harper et al[3] compared cotton/polyester core spun yarns, staple blend yarns and their respective fabrics. Filament core and staple blend yams were spun with combed cotton in proportions of 70% cotton and 30% polyester. For purposes of comparison, 100% cotton yams were spun from both carded and combed stock. The cotton used was a mixture of equal portions of middling-grade irrigated and rain-grown upland varieties, with an average classer's staple length of 28.6 mm and a fineness of approximately 0.172 mg/m. The staple polyesters were 38 mm long, with a fineness of 1.5 denier. Their findings signified that stronger, more durable fabrics were produced from cotton/polyester filament core yams than from cotton/polyester staple fibres. Core yarns spun with high tenacity polyester filament cores made the strongest yarns and fabrics. The core-yam fabrics retained their strength superiority after scouring, bleaching, and resin finishing. Related studies by Danuta et al[68] revealed comparable findings with further emphasis that the greatest influence of yarn properties is attributed to the percentage share of the blend components[68,69].

The tensile strength of the ring core spun yarns has different variation with the core to sheath weight ratios depending on the core filament material used. The core yarn from aramid or the basalt filaments has a monotone falling strength as the twist is increased. Especially, the influence of the core filaments on the yarn strength gets radically reduced from the view point of the specific strength. The more extensional filaments like PET, on the other hand, affect the yarn strength positively by increasing twist[1,43].

T-400/Cotton Core spun yarn.

In 2001, DuPont declared that the U.S. Federal Trade Commission (FTC) had permitted approval of a new generic fibre subclass in a bid to recognise the exclusive and extra-ordinary qualities of T-400, the latest innovation to be marketed under the "Lycra" brand by DuPont Textiles & Interiors (DTI)[44]. T-400 is a bicomponent filament yarn based on "Sorona" 3GT polymer from the bio-based business of DuPont and polyester. T-400, is nicely positioned between spandex and textured yarns and carries a new value hence new opportunities[45,46]. The T-400 fibre offers stretch and recovery properties superior to textured yams with the added performance benefits of dimensional stability, easy care and chlorine resistance[4,47].

One of the end uses of T-400 has been optimized in knitting[16]. This brings a new level of performance of fabrics in terms of aesthetic properties, smooth surface and uniformity. Benefits of T-400 in knit wear include among others aesthetics, where T-400 confers a regular exceptionally clean and smooth surface, with a hand much softer than attained by other common textured threads. Due to dimensional[16] stability properties it is evident that the shape of the knitwear will not be altered once T-400 filament is used. This makes it perfect for bags among other knit wear garments. T-400 develops elasticity through a heat treatment, which in addition offers a better process ability to spinners. It can be used solely, twisted or core spun with other fibres such as cotton, for producing compound yarns[16,45,48]. The denim benefit of the characteristics of T-400 is the feasibility of a new range of effects since before it was difficult to obtain stretch jeans. The chlorine resistance of T-400 allows the use of a series of treatments and washing conditions, not applicable to the common stretch fabric. T-400 allows you to produce jeans that retain wrinkles, and good elasticity[16]. Comfort is precisely one of the characteristics of fabrics made with T-400 core spun yarns. Elasticity determines the feeling of comfort without any pressure and with maximum freedom of movement. The Jeans not only look smart but also have the ability to keep their shape original, despite prolonged use[44,48].

Belleti[16] reports that the focus for research and development was put in use of T-400 hosiery to create more market opportunities. The stretchability and overall physical properties of a cotton-elastane core spun yarn entire depend on the spinning process. The control of spinning parameters has a great impact on the final yarn. For an elastic core spun yarn, optimisation of spinning parameters mainly involves controlling filament draft, twist multiplier, spinning speed, core-sheath ratio, the twist angle as well as the pre-tensioning[16,26,47] among other factors. Research conducted by Babar et al[20] emphasized on these parameters especially the twist multiplier, core-sheath ratio, and elastane draft among others. The study assessed the effect of different elastane contents at different twist multipliers by feeding a single and double roving upon 14^s elastic core cotton covered yarn. A higher interaction of different parameters was observed, with significant effect of the parameters on the elastic core spun yarn. Single roving was however found to possess good mechanical properties compared to double roving 14^s elastic core cotton covered yarn. On a related development, Su et al[53] studied the structure and performance of elastic core-spun yarn, and recommended a spandex draw ratio of 3.5, and that a feed angle of more than 120^0 gave better yarn strength properties[53].

Key core yarn spinning parameters

Core yarn spinning parameters refer to the most suitable important parameters to be considered during the spinning process in order to come up with a desired yarn structure with prospected properties. It has been massively reported that for desirable properties of a cotton/elastane core spun yarn, parameters such as the draft, the core-sheath ratio, twist multiplier, twist angle, pre-tensioning, spindle speed, yarn linear density, uniformity ratio, fineness of fibres, maturity, span length among others are paramount[1,17,26,28]. ÿþ Bouhjar et al[50], using a Lloyd dynamometer LR5K and comparing with models by Vangheluwe, they concluded that though estimation of optimum parameters has been based on previous models, there are some parameters which influence considerably more than others[49,50].

Effect of spinning parameters on the elastane core yarn quality properties

A number of spinning parameters have been reported by previous researcher[1,17,26,28], however filament draft, twist, core-sheath ratio and filament pre-tensioning have been widely reported and emphasised[13,25,26,28].

Filament draft

Due to high elasticity of the core component in the core spun yarn, controlling the elastane draft is very key in optimising the resulting properties, such as tensile properties, hairiness, evenness among other properties[26-25]. Due to differences in core part component properties, the effect of elastane draft varies from material to material. While the elongation of the elastic core spun yarns is the same as 100% cotton yarn at low spandex draw ratios of less than 3.75, when the spandex draw ratios exceed 3.75, the elongation of the elastic core spun yarn increases sharply[28]. On the other hand, T-400/cotton core spun yarns have been recommended to have a filament draft ranging from 0.9 to 1.05 [13]. Previous studies on spandex/cotton yarn, Najar et al[28], reports that much as increasing the filament draft beyond 3.5 did not have a significant effect on yarn hairiness, the hairiness of spandex/cotton core spun yarn was found lower than that of 100% cotton yarn[28, 43, 72].

Twist

For elastane core spun yarn, twist multiplier is an important parameter to consider in optimizing the yarn properties. Previous studies show that[5,6,53], variation in twist have significant influence on the yarn properties. Kim et al[5] report that increasing the number of twists leads to a regular decline in the strength of aramid core-spun yarn, whereas the high tenacity PET core-spun yarn displays almost unaffected tenacity for various twist levels. The basalt core-spun yarn, shown a twist factor level that indicated a potential maximum yarn tenacity. The breaking elongation of the aramid core-spun yarn increased with the number of twists. PET/cotton core-spun yarn doesn't show significant increase in elongation as twist is varied. The basalt/cotton core spun yarn had noticeably greater elongation as the number of twists increased[5]. This response of different core spun yarns, show that depending on the constituents in a yarn, variation in twist gives different yarn properties. As much as elastane core spun yarns have close properties, their physical properties vary from material to material and hence the variation in effects resulting from spinning parameters.

Core-sheath ratio

Kim et al[1] studied the influence of core-sheath weight ratio on the tensile properties of the ring core-spun yarns in different ways according to the core filaments used for the yarn. Increasing the twists generated a monotone decreasing strength for the aramid and the basalt core yarns, whereas the PET core yarns showed almost unchanged strength. This can be attributed to extensional property of the filaments. The role of a core sheath weight ratio on a core yarn is different depending on the core material. It has also been urged that, the sheath is responsible for dislocation of filament from the yarn axis, therefore as the filament changes location, its core yarn strength will be influenced by the deformation[7]. Core sheath ratio has also been associated with the percentage elongation of a core spun yarn, with increase in filament percentage in a core yarn leading to increased elongation[42]. This can be attributed to the fact that since normally the core element is elastic, increasing the core percentage in a yarn would enhance stretching properties of entire core spun yarn.

Pre-tensioning

Pre-tension of filament could affect the core spun yarn's properties especially when the core spun yarn is produced by friction spinning[42]. The position of the core in the yarn depends on the pre-tension where by at low filament pre-tensioning, the filament becomes multiple and has a buckle structure. This definitely influences the final core spun yarn properties since the better the position of the filament in the yarn axis, the better the properties of the resulting yarn[41, 52, 53]. Precise pre-tensioning, results into better strength, elongation, hairiness and abrasion resistance in core spun yarns[54].

CONCLUSION

It still remains a challenge to satisfy the dynamic and highly demanding market. Stretch yarns with high level of comfort is constantly being demanded. With competition among different companies, more and more modification and optimisation research is being done to ensure maximum exploitation of the potential of different fibres/filaments. Elastane core yarn spinning has increasingly gained attention of researchers since their applications in the textile and industrial field has been diversified. The challenge is to control the spinning parameters in order to be able to come with desired stretch and flexibility suitable for the targeted end-use without compromising the mechanical properties of a yarn. For example, some filaments like lycra and DuPont T-400 which are known for their commendable extra-ordinary stretching properties have to be blended with cotton staple fibres and manufactured under controlled conditions to achieve targeted end use properties. There has been less significant research on optimising cotton/T-400 spinning parameters to achieve the best quality yarn yet it has one of the well know remarkable stretch and aesthetic properties. More emphasis should be directed towards effective optimization of spinning parameters for an elastic core spun yarn, customized for individual elastic filaments, rather than universal settings since different elastic filaments have varying degree of stretch among other physical properties.

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