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Influencing sheath type and core draft ratios on the physical properties of stretchable yarns

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Abstract : Composite yarns based spandex have gained much concern and popularity during the last two decades all over the world due to their elastic and comfort properties. Draft ratio of the core, namely spandex, and the sheath type are the main parameters controlling the physical properties of this type of yarns. In this study, the influences of spandex draft ratio and the sheath type on the yarn properties were investigated. Two types of staple fibers were used as a sheath, i.e. polyester and cotton staple fibers. The core (spandex monofilament) was subjected to four different levels of draft ratios, namely 2%, 3%, 4% and 5% respectively. An analysis of variance in the form of Two-way was conducted to study the influence of sheath type and the draft ratio of the core on the physical properties characteristics of the produced yarns. It was revealed that increasing the spandex draft ratio leads to an increase of the yarn tensile properties also enhanced yarn uniformity and imperfection index. While the draft ratio of spandex monofilament increased yarn hairiness significantly. It was also noticed that polyester staple fiber that incorporated as a sheath improved significantly the most core-spun yarn properties unexpectedly, as compared to cotton staple fibers.

Key words: Sheath type, core draft ratios, stretchable yarns, physical properties.

Introduction

Spandex is a manufactured fiber in which the long chain synthetic elastomer is considered the fiber - forming substance that consists of at least eighty five percent by weight of segmented polyurethane. Various chemistries have been evaluated for spandex in the last few years; only polyester and polyether are still in use today. The various production process such as, dry spinning, wet spinning and melt spinning were used to produces elastane with different tensile properties and cross-sectional geometry [1-3].

Nowadays there are many spandex producers worldwide, different brands, kinds and costs of spandex fibers in the markets [4-6]. Also, core-spinning, cover spinning, air entangling and siro-spinning are some spinning techniques which are used to combine spandex with the other textile fibers [7-11]. Core spinning is one of the most famous techniques to produce core-spun yarns based spandex, and can be applied by friction spinning, air jet and ring spinning techniques [12]. Composite yarns containing spandex as a core which is covered with other staple fibers have different important characteristics. These yarns possess good moisture absorption have the same feel as the types of outer fibers [12, 13].

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Generally, the high stability, elasticity, high degree of recovery, simple care and better dimension stability associated with spun yarns containing spandex led to the fabrics woven from these yarns have a wide applications value [14-16]. These types of fabrics, especially in apparel industry, are used for leisure and sport cloths, underwear, hosiery and swimwear garments [17].

In general, outer layer in core-spun yarns containing spandex often will be natural or synthetic fibers, especially cotton or polyester fibers. Thus this study sheds light upon the comparison between cotton/spandex and polyester/spandex core-spun yarns in relation to their physical and mechanical properties.

Materials and methods

To evaluate the effects of sheath type and the core draft ratios, eight core-spun yarns containing spandex were produced on Zinser type spinning machine which has a modified spandex feed device. The sheath in the first half of the yarn samples was made up of cotton fibers; and the sheath of the second half composed of polyester fibers. The core type, i.e. spandex in both types of yarns was drafted to four drafting ratios, namely, 2%, 3%, 4% and 5 % drafting ratios.

For all yarn samples, spandex of 78 dtex was used as a core in order to produce 20 tex (20.9 Ne) polyester/spandex and cotton/spandex core-spun yarns. The properties of spandex monofilament used as a core in this study were listed in table 1. Also the characteristics of polyester and Egyptian cotton fibers of type Giza 86 used as a sheath were also listed in tables 2 and 3 respectively.

Table 1: Main features of spandex monofilament.

Parameter	**value**
Luster	Clear
Denier, d	78
Strength, g	97.5
Tenacity, g/d	1.25
Elongation, %	550
U, %	1.29

Table 2. Characteristics of polyester fibers used as a sheath

Effective length, mm	38
Breaking strength, g/tex	53.1
Breaking elongation, %	22
Fineness, dtex	1.4

Table 3. Characteristics of cotton fibers used as a sheath

Effective length, mm	32.5
Uniformity, %	86.6
Breaking strength, g/tex	45.1
Breaking elongation, %	6.4
Micronaire, μg/inch	4.52
Fineness, dtex	1.7
Maturity, %	89

Laboratory testing

Before testing, all yarn samples were kept in a standard atmosphere for full day, namely 20 ± 2 ^{o}C temperatures and relative humidity 65% ± 2. Polyester/spandex and cotton/spandex core-spun yarns were tested for their physical properties such as breaking strength, breaking elongation, work of rupture, unevenness, imperfections, and hairiness index according to ASTM standards. Tensile properties of the produced yarns were investigated on Uster Tensorapid tensile tester with constant rate of elongation (according to ASTM-2256-97) at a cross-head speed 300 mm/min and a pre-tensional force 9.85 gf. Fifty readings were taken and average was calculated for each yarn sample.

Yarn unevenness (CV_m %), thin (-50%) places, thick (+50%) places, and neps (+200%) were evaluated on an Uster Tester 3. Total hairiness length (hairiness Index) was also obtained on an Uster Tester 3. For each yarn sample, 3 cones were randomly selected and 1000 meter length of each sample was tested at testing speed 400 m/ min.

Statistical analysis

Analysis of variance of the form 4×2 was used to assess all test results; in order to detect the significant effects of the sheath type and the core draft ratios on the produced core-spun yarn properties.

To derive regression lines which correlate core draft ratio with the yarn properties, a regression analysis was conducted. These regression models have the following forms:

$y= a + b x + c x^2$
Where,
y= yarn properties, for example, breaking force, elongation, ---etc.
a = constant.
x= core draft ratios (%), and
b, and c = regression coefficients.

The coefficient of determination, i.e. R^2 value, was used to validate the derived regression models. This coefficient ranges between zero and one, and the regression line will fit the data very well when it approaches one.

Results and discussion

Breaking force

The variation of breaking force of blended core-spun yarns versus the variation of spndex draft ratio was depicted in figure 1. It was noticed that core draft ratio and type of the sheath have a powerful effect on the yarn breaking force at significant level 0.01. It was shown breaking force increases with increasing spandex draft ratio. It was also found that the draft ratio accounted for 80% of the effects on the yarn breaking force, while sheath type accounted for 16% of the influences on the breaking force. It was estimated that breaking strength of composite yarns have increase b by 20% with the increase in spandex draft ratio. Whereas, irrespective of the levels of the draft ratio, the sheath of polyester type enhanced the breaking force of the core-spun yarn by about 34%. The positive effect of draft ratio on the breaking force is ascribed to increase of the fiber amount wrapped around the core of the yarn, whether these fibers were polyester or cotton fibers. It is well known that the breaking force of cotton and polyester fibers is greater than strength of spandex monofilament. Thus, increasing the amount of fibers wrapped around the yarn core of spandex type will in turn enhance the breaking force of the core-spun yarn. Since the polyester fibers have a higher breaking strength compared to cotton fibers, this will be reflected in the higher breaking strength of spun yarns composed of polyester fibers as a sheath.

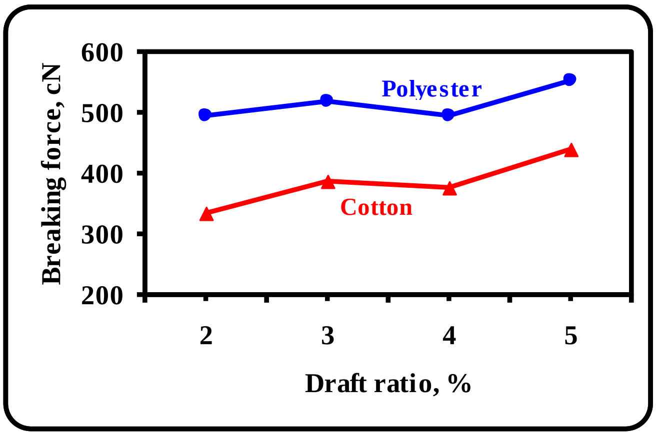

Figure 1: Breaking force variation of polyester/spandex and cotton/spandex

core-spun yarns against spandex draft ratio.

The non-linear regression models which correlate draft ratio of spandex to breaking force of cotton/spandex and polyester/spandex core-spun yarns are as follows:

Breaking force, cN (cotton sheath) = 321.82 +16.726 x + 2.7959x^2
Breaking force, cN (polyester sheath) = 521.55 - 28.89x +8.7799x^2

The value of R^2 for these regression models equal 0.75 and 0.82 for polyester and cotton sheath types. This signifies that these models represent the experimental data very well.

Breaking elongation

Main factors required for the design of stretch fabrics are the elastic recovery properties and the higher elongation at breaks of the yarns these fabrics made from. The influence of spandex draft ratio on elongation at break of cotton/spandex and polyester/spandex core spun yarns was depicted in figure 2. It was noticed that draft ratio of the core and the type of the sheath have a profound influence on the breaking strength of the core spun yarn. It was found that spandex draft ratio accounted for 98% of the impact on yarn braking strength while sheath type accounted for the remaining ratio. From this figure it can be seen that the higher the spandex draft ratio, the higher the breaking strength of composite yarn is. It was estimated that increasing spandex draft ratio from 2% to 5% causes increasing breaking strength of cotton/spandex and polyester/spandex core-spun yarns by about 9% and 12% respectively. Increasing breaking elongation with draft ratio may be due to increasing the amount of polyester or cotton fibers wrapped around the spandex core. It was also found that irrespective of the levels of spandex draft ratio, incorporating polyester fibers as a sheath have improved the breaking elongation of the produced yarns by approximately 90%. This is because the polyester fibers have higher breaking strength than their counterparts made of cotton.

The regression models which correlate spandex draft ratio to breaking elongation of cotton/spandex and polyester/spandex spun yarns have the following non-linear regression forms:

Breaking elongation, % (cotton sheath) = 5.24 + 0.94 x – 0.14 x^2
Breaking elongation, % (polyester sheath) = 11.5 + 0.671 x - 0.07 x^2

The R^2 values of these models were found to equal 0.95 and 0.99 in the case polyester and cotton sheath respectively.

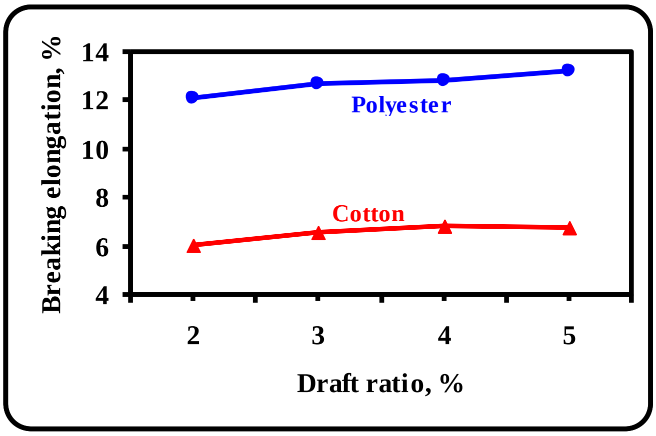

Figure 2: Breaking elongation variation of polyester/spandex and cotton/spandex

core-spun yarns against spandex draft ratio.

Work of rupture

The variation in work of rupture of the produced yarns according to the variation in draft ratio of spandex was illustrated in figure 3. Evidently the draft ratio has a profound influence on the yarn work of rupture. As the draft ratio increases, the work of rupture reacts in the same manner. This is a normal result because of increasing breaking force and elongation at break of the composite yarns with the increase in the draft ratio. As expected, and irrespective of the values of spandex draft ratios, polyester/spandex core-spun yarns exhibited considerably higher work of rupture than cotton/spandex core-spun yarn and the difference is statistically significant. The higher breaking force and elongation associated polyester/spandex yarns compared to the corresponding cotton/spandex yarns have been reflected in the higher breaking work of polyester/ spandex core-spun yarns.

The regression relationship which correlate spandex draft ratio to the work of rupture for both cotton/spandex and polyester/spandex core-spun yarns have the following forms:

Work of rupture, (cotton sheath) = 4.1 + 0.6337 x + 0.003 x2
Work of rupture, (polyester sheath) = 14.6 - 0.37 x + 0.25 x2

The R^2 values of these models were found to have 0.98 for both polyester and cotton sheath. That is these models fit the data perfectly.

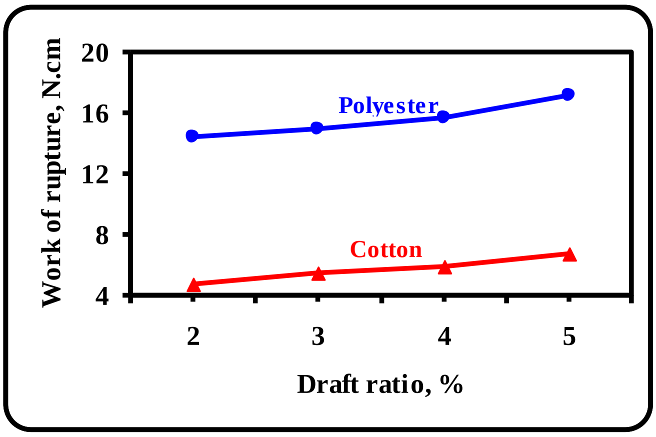

Figure 3: Work of rupture variation of polyester/spandex and cotton/spandex

core-spun yarns against spandex draft ratio.

Hairiness index

Yarn hairiness is one of the fundamental parameters which affect the yarn performance in the following processes. Yarn hairiness has a great influence on fabric appearance and handle, as well as on the formation of pills on fabric surface [18].

In present work, hairiness index can be defined as the total length of protruding fibers that project from the yarn body of length 1 cm. Provided that hairiness index is the ratio between two lengths (of hairs and yarn), it is a non-dimensional quantity. The relationship between spandex draft ratio and hairiness index of cotton/spandex and polyester/spandex core-spun yarns was depicted in figure 4. It was revealed that spandex draft ratio and the sheath type have a huge influence on the hairiness index. It was found that draft ratio and sheath type accounted for the effects on core-spun hairiness level by about 45% and 43% respectively. From this figure, it is shown that hairiness of core-spun yarns swiftly increase with the increase of spandex draft ratio. Increasing draft ratio leads to augment the cores-spun yarn hairiness by 33%. The impact of spandex draft ratio on the yarn hairiness may be due to the higher amount of wrapped fibres around yarn core with increasing the draft ratio

It is also proved that the sheath of polyester type enhanced the yarn hairiness. That is polyester/spandex core-spun yarn reduced yarn hairiness by 18.5% compared to cotton/spandex core-spun yarn. The reduction of hairiness index associated with the sheath of polyester type is due to the higher fineness and length associated with polyester fibers in comparison with cotton fibers.

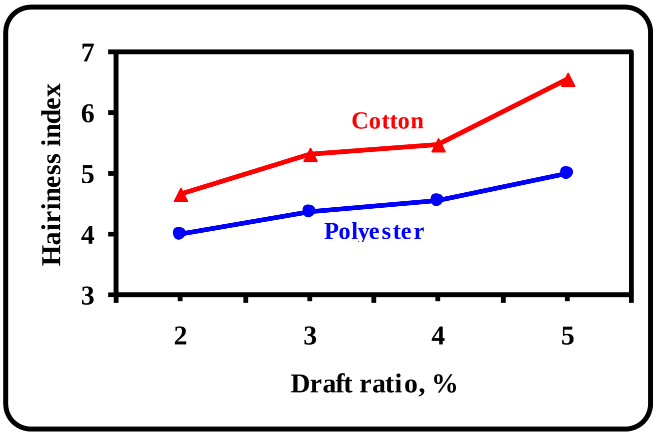

Figure 4: Hairiness index variation of polyester/spandex and cotton/spandex

core-spun yarns against spandex draft ratio.

The regression lines which correlate yarn hairiness to the spandex draft ratio have the following non-linear forms:

Work of rupture, (cotton sheath) = 4.6 + 0.06 x + 0.01 x2
Work of rupture, (polyester sheath) = 3.6 + 0.48 x – 0.05 x2

The coefficients of determination for these models were found to be 0.94 and 0.99 for cotton and polyester sheaths.

Yarn unevenness

The variation of polyester/spandex and cotton/spandex core-spun yarns unevenness against the spandex draft ratio was plotted in figure 5. It was detected that drafting ratio of spandex and the type of the sheath have a profound influence on yarn unevenness at 0.05 significance level. It was found that both the draft ratio and sheath type accounted for 31% and 54% of the effects on the yarn unevenness respectively. A decreasing trend was disclosed confirming that yarn unevenness decreases with increasing the draft ratio. Generally, increasing draft ratio enhanced the uniformity of core spun yarn by about 8%. This is due to increasing the amount of fibers wrapped around the core with increasing the draft ratio. It was also noticed that incorporation polyester fibers as a sheath enhanced significantly the yarn uniformity. That is cotton/spandex spun yarn has higher unevenness values than their counterpart made up of spandex and polyester fibers. The difference between uniformity of cotton/spandex and polyester/spandex core spun yarns is more pronounced at lower draft ratios. The uniformity of polyester/spandex core-spun yarns was better than cotton/spandex core spun yarn by 6%. The higher uniformity associated with polyester/spandex core-spun yarns may be attributed to the relative increase and lower variation in polyester fiber length compared to cotton fiber length.

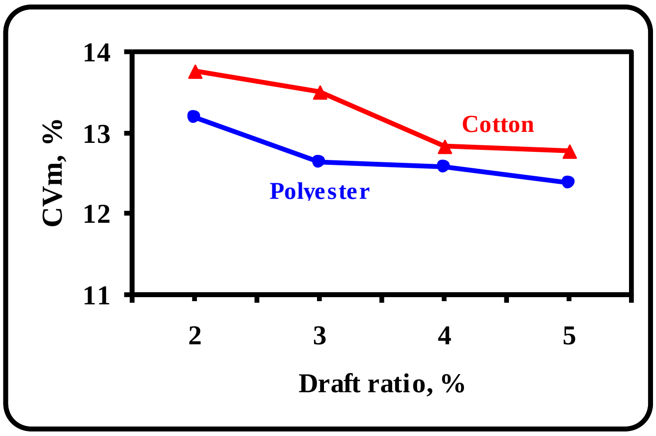

Figure 5: Unevenness variation of polyester/spandex and cotton/spandex

core-spun yarns against spandex draft ratio.

The regression relationship which correlates spandex draft ratio to yarn unevenness has the following forms:

Yarn unevenness, CV_m% (cotton sheath) = 14.5 -0.64 x + 0.06 x2
Yarn unevenness, CV_m% (polyester sheath) = 13.7 - 0.7 x + 0.09 x2

The coefficient of determination for these models was found to equal 0.93 and 0.94 for cotton and polyester sheath respectively.

Imperfection index

In this study, the imperfection index was denoted as IPI vanlue and calculated as the sum of the number of thick places, thin places and neps per one kilo meter of yarn length. The IPI value versus spandex draft ratio was plotted in figure 6. It was proved that draft ratio and the sheath type have a profound influence on then core-spun yarn imperfection index. It was found that spandex draft ratio and sheath type accounted 13% and 84% respectively of the effects on the imperfection index. A decreasing trend was disclosed from this figure assuring that imperfection index of the cotton/spandex and polyester/spandex decreases with increasing draft ratio. This is because increasing the spandex draft ratio would increase the amount of polyester or cotton fibers wrapped around the core. It was estimated that increasing spandex draft ratio from 25% to 5% lowered the imperfection index of the core-spun yarn by about 45%. It was also noticed that incorporation of polyester staple fibers as a sheath in the core-spun yarn leads to reduction of yarn imperfection index compared to incorporating the cotton fibers. The imperfection index of polyester/spandex core-spun yarns was 17% lower than their counterparts made of spandex and cotton fibers. The lower imperfection index associated with polyester/spandex core-spun yarns may be due to the higher length and fineness of the fibers that form the sheath for this type of yarns.

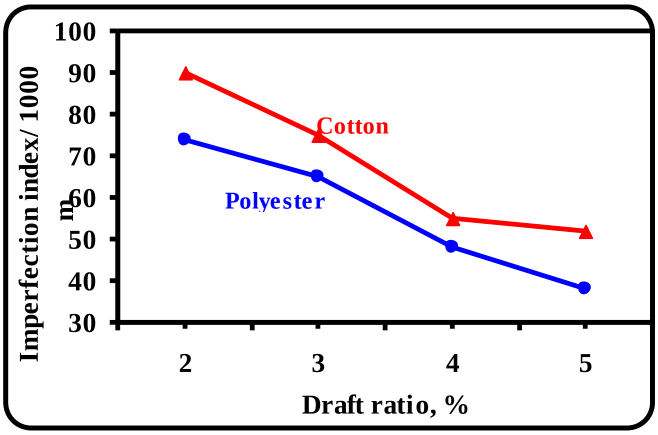

Figure 5: Imperfection index variation of polyester/spandex and cotton/spandex

core-spun yarns against spandex draft ratio.

The relationship between spandex draft ratio and the core-spun yarn imperfection index has the following forms:

Imperfection index, (cotton sheath) = $116.5 - 28.4\ x + 3\ x^2$
Imperfection index, (polyester sheath) = $86.3 - 11.3\ x - 0.25\ x^2$

The coefficient of determination for these models was found to equal 0.97 and 0.98 for cotton and polyester sheath respectively.

Conclusion

During the last two decades, composite yarns containing spandex gained much interest and popularity all over the world due to their elastic and comfort properties. The main factors which affect the properties of these yarns are the core draft ratio and the sheath type. In this study a comparison between cotton/spandex and polyester/spandex core-spun yarns with respect to their physical properties was conducted. In both type of yarns, the spandex core was subjected to four different draft ratios, i.e. 2%, 3%, 4% and 5%. The findings of this study can be concluded as follows:

- An increase of spandex draft ratio has enhanced the core-spun yarn tensile properties because of increasing the amount of fibers wrapped around the sheath.
- As expected and due to superior tensile properties of polyester fibers used as a sheath compared to cotton staple fibers this will be reflected in the higher tensile properties polyester/spandex core-spun yarns.
- Hairiness index of the produced yarns increased significantly with spandex draft ratio because of increasing the amount of fibers wrapped around the core of the yarn. Hairiness index of polyester/spandex yarns was found to have lower values compared to cotton/spandex ones.
- Unevenness and imperfection index of the yarns under study were considerably decreased with the increase in the spandex draft ratio. Also it was found that polyester/spandex core-spun yarns have lower values compared to cotton/spandex yarns in relation to these two properties.

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