Physical and Stretch Properties of Woven Cotton Fabrics Containing Different Rates of Spandex

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Abstract: Spandex fibers have superior stretch and elastic recovery. Cotton yarns containing spandex are frequently used to manufacture elastic textile products. In this study cotton fabrics containing different rates of spandex were woven. Statistical methods were used to detect the effects of spandex rates on physical and stretch properties of the produced fabrics. The findings of this study revealed that rate of spandex in cotton fabric has a significant influence on the physical and stretch properties of these types of fabrics.

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Key words: Spandex fibers, Stretchable fabrics, draft ratio, Elastic recovery, Fabric Growth, Maximum Stretching.

1. Introduction

Elastomeric fibers can be made from natural or synthetic polymeric materials that provide a product with high elongation, low modulus, and good recovery from stretching. Currently, these fibers are made primarily from polyisoprenes (natural rubber) or segmented polyurethanes, and to a lesser extent from segmented polyesters. In the United States the generic designation "spandex" has been given to a manufactured fiber in which the fiber-forming substance is a long-chain synthetic polymer consisting of at least 85% of segmented polyurethane [1-3]; in Europe the equivalent term "elastane" is commonly used.

There are many methods for merging spandex with other textile fibers, such as core spinning, cover spinning, siro spinning, and air entangling. Core spinning is one of these methods, and can be applied by the ring, Murata vortex, friction spinning, and rotor twister techniques [4-6]. In core yarns, there is an elastomeric filament in the core and around it, where staple fibers are located. Consequently, the resultant fabric has all the characteristics of the predominant staple fiber together with the advantages of stretch and recovery [7].

Several studies have been carried out to investigate the properties of core spun yarns. Satlow *et al.*,[8] studied core spun yarn properties and determined that the strength of PES/viscose core yarn is lower than PES/viscose yarn. Babaarslan [9] compared different core materials, such as lycra, textured PES and textured nylon filaments in the production of PES/viscose core yarn, and concluded that core yarn with lycra has the lowest strength and highest elastic recovery compared to core yarns containing textured filaments. Lewin [10] showed that Core spun cotton/spandex shows high resiliency property than 100% cotton yarns, due to its soft and rubbery isocyanate segments, which has a random coil structure, in the spandex yarn

Although there are many experimental studies [11-17] on the physical properties of cotton / spandex fabrics, there has no research into the properties of the fabrics containing different rates of spandex yarns. In this study, physical and stretch properties such as tensile strength, tearing strength, air permeability, fabric growth, permanent stretch, % fabric stretch of woven fabrics containing different amounts of spandex yarns were compared to each other.

2. Materials

In this study, five different fabrics samples with 1/1 plain structure having different amounts of spandex ratio were woven to investigate its stretch and physical properties. The fabric samples were woven on rapier weaving machine which has four harness frames and with insertion rate 350 ppm. The warp yarns and weft yarns without spandex made from 100% combed Egyptian cotton, Giza 86. The yarn count of the spandex used in the weft yarns was 44 dtex and drafting ratio of spandex in the production of core-yarn was 4 %. The characteristics of weft and warp yarns used in the woven fabric samples were tabulated in table 1. Weft - core yarns with different spandex rates were used and the layout of the weft yarns in the fabric structure was given in table 2.

Spandex ratio in the woven fabrics was calculated from equation (1) for fabric code S, and from equation (2) for fabric code 6S:1C through 1S: 1C.

$$\text{Spandex ratio \%} = \frac{P\% * Ty * \text{weft density}}{\text{warp count} * \text{warp density} + \text{weft count} * \text{weft density}} \text{--------(1)}$$

$$\text{Spandex ratio\%} = \frac{P\% * Ty * \text{weft density} * R}{\text{warp count} * \text{warp density} + \text{weft count} * \text{weft density}} \text{----------(2)}$$

Where P% is the percentage of spandex filament in the core spun yarn, which can be calculated from equation (3)

$$P\% = \frac{\text{spandex count (tex)}}{D * Ty} * 100 \text{--------(3)}$$

Where, D= Drafting ratio of spandex %
Ty= weft yarn count with spandex, and

R= the ratio of the No. of core yarns to the sum of the No. of core yarns and No. of plain yarns in the layout of the weft yarns in the fabric. The values of R for the fabric code 6S:1C through 1S: 1C are 6/7, 4/5, 2/3 and 1/3, respectively.

From the equations 1, 2 and 3, the values of spandex ratio in the woven fabrics are 3.68%, 3.16%, 2.94%, 2.46% and 1.23% for the fabric codes S through 1S: 1C.

Table 1. Characteristics of warp and weft yarns

Parameter	Weft yarns without spandex	Weft yarns with spandex (core-spun)	Warp yarns
Yarn count, Tex	19.7	19.7	9.85
Weft density, picks/cm	34		---
Warp density, ends/cm			35

Table 2. Woven fabric properties

Fabric code	The layout of weft yarns in the fabric
S	All weft yarns are spandex/cotton core-spun yarns
6S :1C	6 spandex/cotton core-spun yarn +1 plain (100% cotton) yarn
4S : 1C	4 spandex/cotton core –spun yarn+ 1 plain (100% cotton) yarn
2S : 1C	2 spandex/cotton core –spun yarn+ 1 plain (100% cotton) yarn
1S : 1C	1 spandex/cotton core-spun yarn+1 plain (100% cotton) yarn

Laboratory testing

All tests were carried out in the weft direction after conditioning specimens in a standard atmosphere (temperature 20 ± 2 °C, 65 ± 2% relative humidity). Tensile strength measurements of the fabric samples were carried out on a Cloth strength instrument (Asano Kikai Seisaku Co. Ltd) in accordance with ASTM D1682; and the air permeability tests were performed on a permeameter instrument No. 869 in accordance with ASTM D737. While in the case of tearing test, an Intensity tearing tester (Elmendorf type) was used according to ASTM D1424.

On the weaving machines and in the warp direction, tension is applied by the warp beam on one side and the cloth roll and loom temples on the other. In the filling direction, tension is applied by the loom temples and it is this tension which prevents the filling yarn from crimping. After the fabric leaves the loom temple, it is free to contract and form filling crimp [18]. In this study fabric contraction was measured as the following formula:

$$\text{Fabric contraction \%} = \frac{\text{fabric width on the loom} - \text{fabric width after removing from the loom}}{\text{fabric width on the loom}} \text{---------- (4)}$$

Stretching properties were determined according to ASTM D2594-04. A tensile testing instrument, consisting of a frame with separate clamps fixed at the top and at the bottom, was implemented to determine the stretch properties of the fabrics. Sample strips from weft direction were hung on the apparatus after marking a 250 mm index in the central part of each specimen. A 1.8 k g load, which was hung according to the fabric weight in the bottom hanger, was applied to the sample three times and after the fourth application; the marked distance was measured. The samples were hung for 30 minutes, and the distance was measured once again. After that fabric samples were removed from the tensile testing apparatus and let to be relaxed for one hour. Fabric growth, maximum stretching and elastic recovery values were calculated from these measured outcomes, as follows:

$$\text{Maximum stretching \%} = \frac{B - A}{A} * 100 \text{ ----(5)}$$

$$\text{Fabric growth\%} = \frac{C - A}{A} * 100 \text{ ----(6)}$$

$$\text{Elastic recovery \%} = \frac{B - C}{B - A} * 100 \text{ -----(7)}$$

Where,

A: The distance marked between the upper and bottom parts of the fabric (250 mm)

B: The distance between the marked points after hanging the sample for 30 minutes with the load (mm).

C: The distance between the marked points after 1 hour relaxation.

Statistical analysis

In this study all test results related to physical and stretch properties of the woven fabrics were assessed for significant differences in means using one–way ANOVA analysis of variance via SPSS statistical package. In order to deduce whether the rate of spandex in the woven fabric samples has a significant effect on fabric properties, the values of the significance level, i.e. p-value, should be examined. P-value must be less than or equal 0.05.

4. Results and Discussion

Since the spandex yarn was used in the weft direction, assessments of the produced fabrics for physical and stretch properties were carried out in the weft direction.

Fabric contraction

Owing to the crimp in the filling yarns, a component of the tension exists in the filling direction. This force tends to bring the ends closer together, causing a contraction in the fabric width. This contraction will be higher after removing the fabrics from the loom, and will be more noticeable in the case of stretchable fabrics. This contraction makes the fabrics have more thickness and becomes stiffer, which in turn affects the most of the physical and mechanical properties.

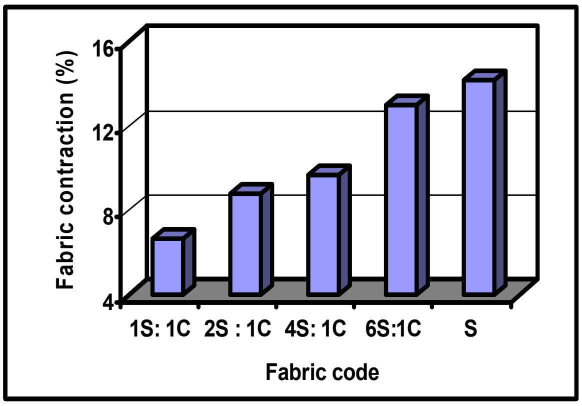

Figure 1: Contraction of woven fabrics at different spandex rates

Fabric contraction levels in the weft direction for different stretchable woven fabrics were plotted in figure 1. The statistical analysis revealed that the spandex content has a significant effect on the fabric contraction at significance level 0.01. As the spandex content increases the contraction of the woven fabrics reacts in the same manner. From this figure we noticed that the maximum contraction was associated with fabric sample S and the minimum was observed for the fabric sample 1S:1C.

Fabric tensile strength

Figure 2 shows the values of woven fabric tensile strength versus spandex content. The statistical analysis proved that the fabric tensile strength was affected significantly at significance level 0.01 by the amount of spandex. A Decreasing trend is detected confirming that as the amount of spandex increases, the tensile strength of the woven fabrics decreases. This is due to the lower tenacity of spandex fibers compared to cotton fibers.

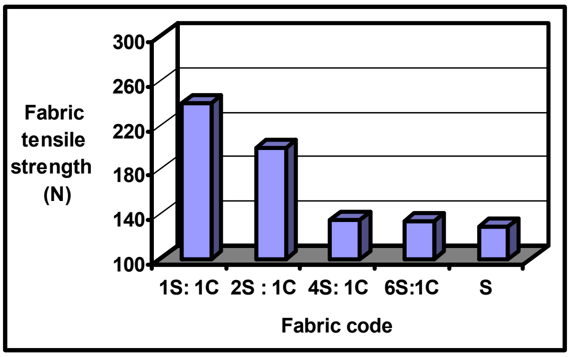

Figure 2: Tensile strength of woven fabrics at different spandex rates

The statistical analysis showed that the maximum tensile strength was associated with the fabric sample 1S:1C and the minimum value of tensile strength was observed for the sample S

Breaking elongation

Breaking elongation of different fabric samples which have different rates of spandex was depicted in figure 3. The statistical analysis proved that the breaking elongation of fabric samples was significantly affected by the rate of spandex at significance level 0.01. As seen from this figure, the fabric breaking elongation increases with the increase in spandex content. This is because the breaking elongation of spandex fibers (500%) was higher than that of cotton fibers (7%). That maximum breaking elongation of 36% was observed for fabric sample S and the minimum value of breaking elongation 16% was also observed for the fabric sample 1S: 1C.

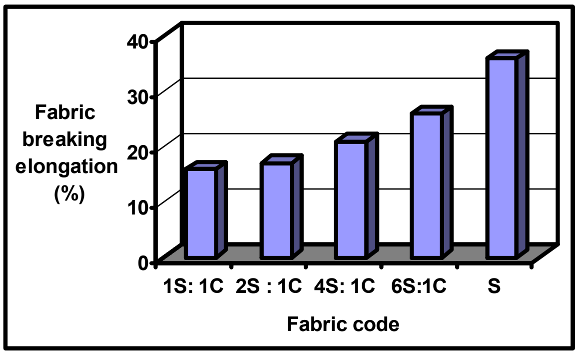

Figure 3: breaking elongation of woven fabrics at different spandex rates

Air permeability

Air permeability is a very importance factor in the performance of some textile materials. Especially it is taken into consideration for clothing, parachutes, sails, vacuum cleaner, and fabric for air bags and industrial filter fabrics. Air permeability depends on many factors such as, weave structure, fabric thickness, weight and porosity.

Air permeability of different stretchable fabrics was illustrated in figure 4. From this figure it is shown that air permeability was affected significantly with the rate of spandex in weft yarns of the woven fabrics. As the rate of spandex in weft yarns increases, the air permeability decreases. The statistical analysis proved that the maximum air permeability was associated with the fabric sample 1S:1C, while the lowest air permeability was noticed for the sample S.

The significant influence of spandex content on air permeability may be due to the woven fabrics will shrink more in the weft direction after removing it from the weaving machines. This shrinkage will be higher with the increase in the spandex content in the weft yarn, which in turn leads to the woven fabrics becomes more thicker and compact, and then less permeable to air flow.

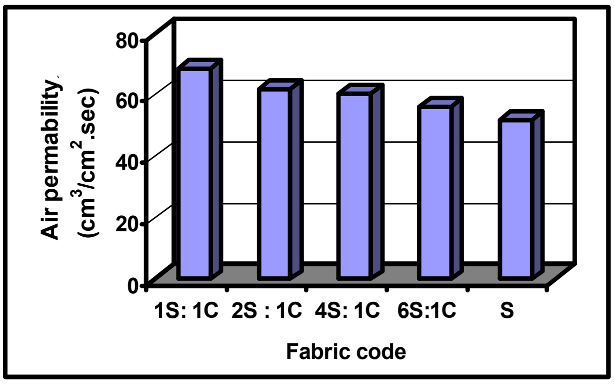

Figure 4: air permeability of woven fabrics at different spandex rates

Tearing strength

Tear strength of woven fabrics is mainly related to its serviceability and depends on fabric structure and its weight. Tearing strength of tested fabric samples in this study versus spandex rate was plotted in figure 5

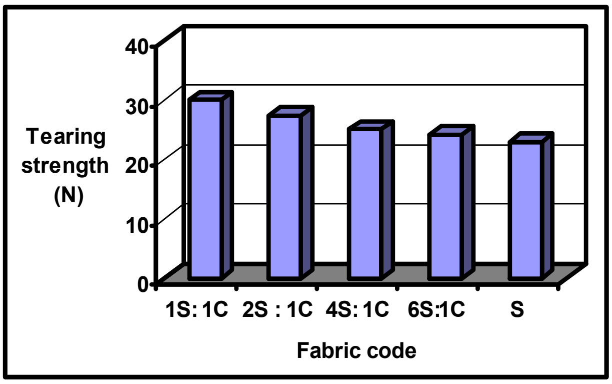

Figure 5: Tearing strength of woven fabrics at different spandex rates

The statistical analysis showed that fabric tear strength significantly affected by the rate of spandex in weft yarns. The negative relationship between tearing strength and spandex rate was detected. As the spandex rate decreases the fabric tearing strength increases. The values of tearing strength of the woven fabric has the following order 1S: 1C > 2S: 1C > 4S:1C > 6S:1C >S. This is because the lower fabric weight and relatively loose fabrics are always accompanied by lower spandex rate. In relatively dense fabrics, individual weft yarns oppose to the tearing load one by one. But if the number of yarns per unit length is low, then the yarns are allowed to displace themselves and form groups to resist the tear in groups rater than individually, which increases tear resistance of woven fabrics.

Fabric Growth

The influence of spandex rate on fabric growth was illustrated in figure 6. The statistical analysis confirmed the significant effect of spandex rate on fabric growth. A negative relation between spandex rate and fabric growth was detected, assuring that as the spandex rate increases the fabric growth decreases. The order of growth values of the woven fabrics is as follows: 1S: 1C > 2S: 1C > 4S:1C > 6S:1C >S.

The inversely effect of spandex rate on fabric growth can be attributed to the higher extensibility ranges of the elastic complex yarn, which associated with higher spandex amount. The reduction of fabric growth can be showed in a good fit of fabrics containing spandex.

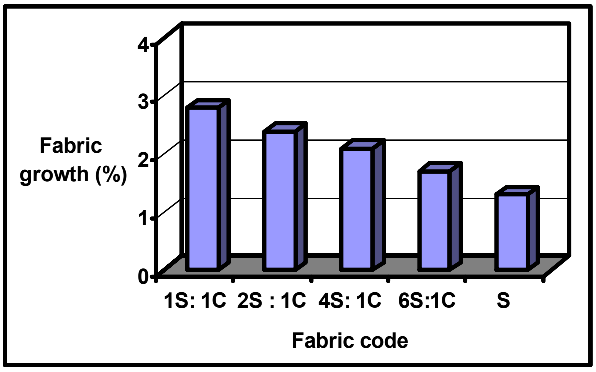

Figure 6: Fabric growth at different spandex rates

Maximum stretch

Figure 7 displays the values of maximum stretch of woven fabrics which contains different rates of spandex. The statistical analysis revealed that these values differ significantly at 0.01 significant level. A positive trend is detected confirming that as the spandex rate increases the maximum stretch of the woven fabric samples reacts in this manner. The values of maximum stretch has the following order 1S:1C < 2S:1C < 4S:1C < 6S:1C < S. The significant influence of spandex rate on maximum stretch may be due to the increase of extension of spandex fibers (500%) compared with cotton ones (7%).

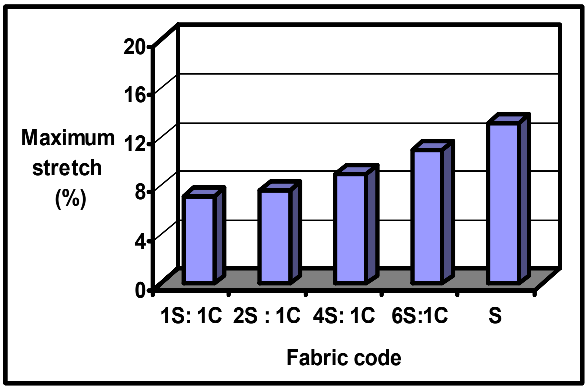

Figure 7: Maximum stretch of woven fabrics at different spandex rates

Elastic recovery

Elastic recovery values of woven fabric samples at different spandex rates were plotted in figure 8. The statistical analysis revealed the significant difference between fabric samples respecting elastic recovery. It is shown a positive relation between spandex rate and elastic recovery assuring that as the spandex rate increases the elastic recovery increases.

These results were to be expected because the spandex in the yarn behaves like a spring, which tends to return to its original length after stretching. As with a spring, the recovery of core-spun spandex yarn is not 100 percent because the cotton fibers in the sheath of the weft yarn exert transversal pressure on the spandex core and prevent the recovery of the yarn [18].

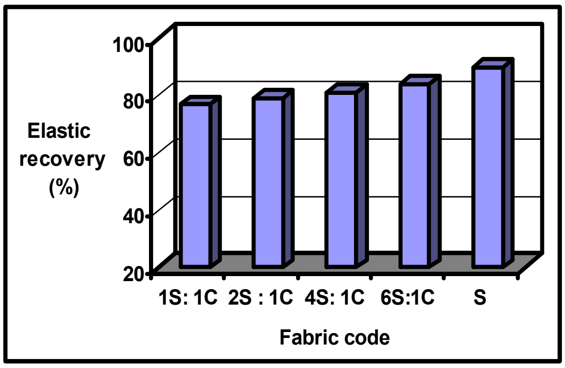

Figure 8: Elastic recovery of woven fabrics at different spandex rates

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Conclusion

The results obtained in the present work indicated that the amount of spandex has a significant influence on physical and elastic properties of woven fabrics. Fabric contraction increases with the increase in spandex rate. Fabric tensile strength decreases with spandex rate, while fabric breaking elongation increases because of the higher elongation of spandex fibers.

Air permeability and tearing strength decreased significantly with the increase in spandex rate. This is because the fabrics will be thicker and more compact with the increase in spandex rate in the woven fabrics. Statistical analysis proved that maximum stretch and fabric elastic recovery increases with spandex rate inside fabric. On the other hand, there is a negative relationship between spandex rate and fabric growth.

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