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ÖRME SPOR GİYİMİNDE KİŞİSEL KORUMA SAĞLAMAYA YÖNELİK YENİ BİR İPLİK TASARIMI

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A NOVEL YARN FOR PERSONEL PROTECTION IN KNITTED SPORTSWEAR

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ABSTRACT: In the textile and clothing sector, a wide range of auxetic textiles have been made and shown great application potential in many areas. Creating auxetic effect at the yarn stage is relatively a simple approach since helical auxetic yarns (HAY) can be made only by winding or twisting different conventional filaments together with existing spinning machinery. Employing sports safety equipment is a cost-effective solution for avoiding injury and increasing the safety and protection. In the area of materials development for sports safety equipment, an important candidate is auxetic materials. In this study, polyester filament/elastane based helical auxetic yarns (HAY) and knitted fabrics from the yarns were developed that will offer dampening effect against injuries during sports activities. Effects of count of the elastane component and the presence of a third component in the HAY structure on the auxetic behaviour of the knitted fabrics were also studied.

Keywords: Helical auxetic yarn, HAY, Knitted fabric, Safety, Sports

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ÖZ: Tekstil ve giyim sektöründe negatif Poisson oranına sahip (auxetic) çok çeşitli tekstiller üretilmiş ve birçok alanda büyük uygulama potansiyeli göstermiştir. Helisel auxetic iplikler, farklı konvansiyonel filamentlerin mevcut eğirme makineleri yardımıyla beraberce sarılması veya bükülmesiyle yapılabildikleri için iplik aşamasında auxetic etki yaratmak nispeten basit bir yaklaşımdır. Spor güvenlik ekipmanı kullanmak, yaralanmayı önlemek ve güvenliği artırmak için uygun maliyetli bir çözümdür. Spor güvenlik ekipmanına yönelik malzeme geliştirme alanında, auxetic malzemeler önemli bir adaydır. Bu çalışmada spor aktiviteleri sırasında yaralanmalara karşı sönümleme etkisi sağlayacak polyester filament/elastan esaslı helisel auxetic iplikler ve bu ipliklerden örme kumaşlar geliştirilmiştir. Elastan bileşeni numarasının ve helisel auxetic iplik yapısında üçüncü bir bileşenin varlığının örme kumaşların auxetic davranışı üzerindeki etkileri de incelenmiştir.

Anahtar Kelimeler: Helisel auxetic iplik, Örme kumaş, Güvenlik, Spor

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1. INTRODUCTION

Auxetic materials are a relatively new class of functional materials which exhibit negative Poisson's ratio [1]. Auxetic behaviour opens up a number of possible technological benefits and applications for auxetic textiles like shockwave protection fabrics, medical bandages, compression hosiery and support garments, etc. [2]. Injuries in sports are common and preventive measures, such as using sports safety equipment, are more cost effective than reactive procedures, such as medical interventions. In order to reduce sports injuries and meet the expectations of the relative standards, novel materials are needed and developed. Auxetic materials have a negative Poisson's ratio (NPR) since they expand laterally when extended axially. Sportswear and personal protective equipment (PPE) made from auxetic materials have been shown to be low in mass and bulk to ease the movement of the user, reduce fatigue and heat build-up, enhance comfort and performance [3,4].

One of the methods to fabricate auxetic textiles is to use conventional fibers and yarns to create auxetic effect by knitting or weaving them in a special configuration. Another approach is to use auxetic fibers or yarns to fabricate auxetic textiles by using simple weaving or knitting constructions. Creating auxetic effect at the yarn stage is a novel and interesting approach and a helical auxetic yarn (HAY) can be made simply by winding or twisting different conventional filaments together using existing spinning machinery [5]. In the structure of the helical auxetic yarn (HAY), which consists of a thick low-stiffness elastic core and a thin stiffer yarn, the thin stifer component is wrapped around the thick soft one. When the HAY is stretched in the longitudinal direction, the stiffer wrapping yarn becomes straight, forces the low-stiffness core yarn to wrap around the stiffer yarn. Although the original elastic core becomes thinner with the stretching effect, it still extends in the sideways, leading to the overall expanding of the auxetic yarn diameter (effective diameter) [6,7]. The effective diameter of the yarn (D_y) is expressed in terms of the initial diameters of core (D_c) and wrap fibre (D_w) diameters as $D_y = D_c + 2D_w$. An example of effective diameter measurement is given in Figure 1.

Several studies (and numerous others cited within) have concentrated on the structure, production, properties and modelling of HAYs [8-11]. In these studies, a third component has not been included into the helical auxetic yarn structure in order to augment the auxetic behaviour of the yarns. Also, there is limited research reported regarding the performance of HAYs in conventional knitted structures [12]. Therefore, the current work aims at comparatively studying the performance of HAYs with a roving component in a knitted structure. Effects of the core count were also included.

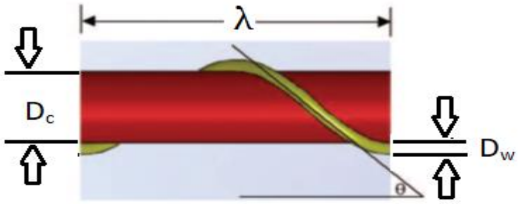


Figure 1. Image of effective diameter measurement of an HAY [2].

2. EXPERIMENTAL STUDY

A hollow spindle machine was used to produce the auxetic yarns with/without roving component having different core yarn count and twist amount. Count of the core elastane was 1280 den for producing single elastic core and (1280+1280) den for producing double elastic core wrap yarns. 150 denier PET filament was used as the wrap yarn whereas Nm 11, 8 and 5 acrylic rovings were employed as the third component. The yarns were tested for determining their tenacity/elongation properties according to TS EN ISO 2062. A laboratory type circular knitting machine was used for the production of single jersey knitted samples. Two 1x1 rib fabric samples were also produced for comparative purposes. Each type of fabric was produced at the same knitting parameters, i.e. the loop length and yarn input tension remained the same. Thickness of the fabrics was measured using R&B Cloth Thickness Tester according to ASTM D1777-96 under pressures of 5, 30, 40, 50 cN/cm^2 for determining the auxetic tendency of the knitted samples, BS EN ISO 20932-1 standard method was adopted. Accordingly, the fabrics were subjected to tensile loading and the resulting changes in the dimensions of their unit area (2 cm x 2 cm) was measured while applying the load. Elongation of the samples in lengthwise direction was also recorded after application of 10N load was released.

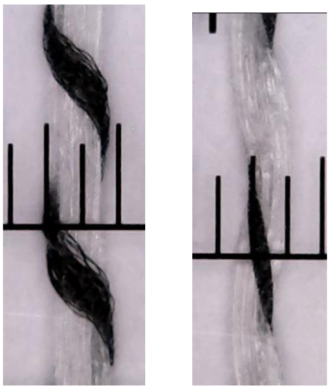
2.1. Properties of the yarn and fabric samples

Yarn count, tenacity and extension properties of the yarns are presented in Table 1.

Table 1. Tested properties of the yarn samples

	COUNT (NM)	TENACITY (CN/TEX)	EXTENSION (%)
1280 R_0-300	7,1	3,39	51,19
1280 R_{11}-300	4,2	6,88	43,73
1280 R_8-300	3,7	6,37	41,89
1280 R5-300	2,9	7,67	34,84
1280+1280 R_0-300	3,7	2,12	64,70
1280+1280 R_{11}-300	2,8	4,73	51,57
1280+1280 R_8-300	2,6	4,99	55,29
1280+1280 R_5-300	2,0	5,28	43,71

In the Table, 1280 stands for the core elastane count, R_0 means there is no roving and the others indicate the presence of roving, the count of which is given as the indices. Examples for the bare and roving including HAY samples are demonstrated in Figure 1.



(a) (b)

Figure 2. Bare HAY without roving (a) without tension (b) under 45% extension.

In Table 2, the final dimensions of the 2 cm x 2 cm square after cyclic application of 10 N as well as the elongation of 100 mm length of the specimens after releasing the load (10 N) are presented. Change in the thickness values refer to the change when the applied pressure is increased 10 times as much, namely increased from 5 to 50 N. In the table, SJ and R stand for the single jersey and R rib fabric, respectively.

In the table, and also in Figure 2, A_W and A_L represent the width and length of the initial "2 cm x 2 cm square" drawn onto the sample under 10 N load. l_{10N} is the elongation of initial 100 mm distance on the samples determined by placing reference marks and immediately measured after removing the specimen and laying it on a flat surface.

3. RESULTS

The tested yarn results presented in Table 1 shows that the presence of roving in the wrap yarn structure as the third component restricted the elongation potential of the highly elastic core component and resulted in a decrease in the elongation of the yarns while increasing their tenacity. Accommodation of the coarser roving in the structure seemed to contribute more to the observed tendency. Doubling the core component thickness appeared to increase the elongation potential of the yarn at the expense of yarn tenacity. This may be due to the fact that the proportion of yarn components, namely the wrap filament and the roving, that mainly contribute to yarn strength decreased. As was expected, the weight and thickness of the samples tended to increase whereas the fabric density tended to decrease as the wrap yarn count increased (Table 2).

Determination of the change in the dimensions of a 2 cm x 2 cm square under a tensile load was used as an approach to observe the auxetic behaviour of the knitted samples from HAYs. For conventional structures, when under a tensile load, the square width is expected to narrow while its length is expected to increase. We supposed that no or a small change in the width of the samples could be an indication of an auxetic tendency that can be further improved. According to the results presented in Table 2, for the fabrics from single elastic core helical auxetic yarns, it was observed that the higher the roving count, the lower the change in width of the square on the fabric. The change in the lengthwise direction, which did not perform a certain tendency, was within the range of 20 to 35%.

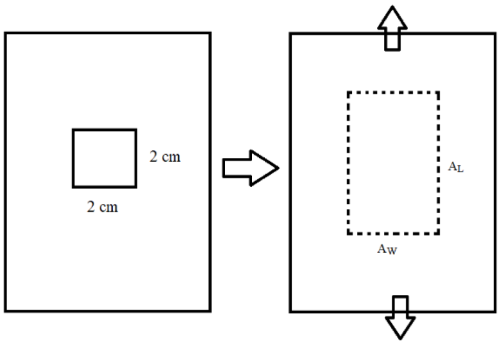


Figure 3. Schematic representation of the change in 2 cm x 2 cm square

Table 2. Properties of the fabric samples

	A_W	A_L	L_{10N} (MM)	WEIGHT (G/M^2)	THICKNESS (MM-50N)	FABRIC DENSITY (KG/M^2)	CHANGE IN THE THICKNESS (%)
1280 R_0-300-SJ	1,1	2,5	66,2	488	1,08	451,9	33
1280 R_{11}-300-SJ	1,6	2,7	36,9	800	1,88	425,5	14
1280 R_8-300-SJ	1,8	2,5	32,1	802	2,08	385,6	14
1280 R_5-300-SJ	2,0	2,4	13,5	881	1,97	447,2	22
1280+1280 R_0-300-SJ	2,0	3,1	10,3	987	1,30	759,2	28
1280+1280 R_{11}-300-SJ	2,0	2,9	10,5	1115	1,88	593,1	19
1280+1280 R_8-300-SJ	1,9	2,5	9,8	1145	2,15	532,6	12
1280+1280 R_5-300-SJ	1,9	2,1	5,1	1173	2,28	514,5	15
1280 R_0-300-R	2	2	9,7	1027	1,44	713,2	13
1280 R_{11}-300-R	2	2	10,2	1076	1,5	717,3	19

For the knitted samples from double elastic core HAYs, on the other hand, no change in the width was observed while increase in the length of the square consistently decreased from 55% to 5% as the roving became coarser. This might be due to the fact that use of coarser roving resulted in stiffer structure which resist transverse dimensional change under tensile loading. Independent of the elastic core thickness, incorporating roving into the helical yarn structure seemed to contribute to the auxetic tendency of the samples. The results also show that using roving in either single or double elastic core HAY structure resulted in a lower change in the thickness of the samples. Comparatively higher thickness change of fabrics in the presence of coarser roving (s) could be due to the bulky structure of such yarns.

After releasing the load applied, the knitted samples from the single elastic cores with the coarser rovings tended to keep lower elongation values on themselves. This is parallel to the behaviour of corresponding yarn elongations observed. The residual elongation on the fabric samples from the double elastic core wrap yarns were lower than those of the ones from single core wrap yarns. For both single and double elastic core yarns, it was the sample knitted from the coarsest yarn that had the lowest residual elongation. Finally, for comparative purposes two rib fabrics were produced from 1280 R_0 and 1280 R_{11} yarns. These structures seemed to be more stable than the single jersey ones Accordingly, the approach proposed to observe the auxetic behaviour of the yarns developed appears to be not applicable to such fabrics.

4. CONCLUSION

This work aimed to serve the studies that will be conducted to improve the auxetic properties of knitted fabrics from helically auxetic yarns (HAYs). With this intention, the helical auxetic yarns were developed and their auxetic behaviour was observed with the help of single jersey and rib fabric structures. So far as the single jersey fabrics from the novel yarn designs suggested promising results in terms of auxeticity, though the rib fabrics from the very same yarns were too stable to reflect the auxetic behaviour of the developed yarns. utilizing such yarn structures in simple knit structures help the development of auxetic fabrics. In the later stages of the study, the effect of wrapping twist amount change and performance of HAYs in both rib and single jersey fabric structures' auxetic behaviour will be studied in addition to varying knitting parameters in detail in an attempt to explore the use of the developed yarns in knitted sportswear for personal protection purposes.

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