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AN EXPERIMENTAL STUDY OF MECHANICAL PROPERTIES AND COMFORTABILITY OF KNITTED IMITATION WOVEN SHIRT FABRICS

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Abstract:

The weft knitted shirt fabric has good elasticity and comfortability, but it is difficult to achieve the formability of woven shirts. In this study, 30D XLANCE® elastic fibers and 30D Lycra® elastic fibers were used, which paired with 40S cotton and 75D/36F moisture-absorbing and quick-drying polyester DTY to develop the woven shirt fabrics on a 32 needle/25.4 mm single-sided circular machine. The results indicate that the 30D XLANCE® knitted shirt fabric has undergone sufficient heat setting treatment, and its mechanical properties are close to those of the standard woven fabric, superior to 30D Lycra® and 30D XLANCE® without sufficient heat setting treatment fabrics. The ultraviolet resistance behavior of XLANCE® fabrics is significantly better than that of Lycra® fabrics. Meanwhile, the XLANCE® fabrics after heat setting still maintain the excellent elasticity and resilience, breathability, moisture absorption, and quick drying performance, and the dimensional stability after washing is also very good. In addition, compared with spandex, XLANCE® fabrics have the lower heat setting temperature, which is beneficial for reducing energy consumption and carbon emissions. It can be considered that XLANCE® elastic fibers are the ideal raw materials for the knitted woven products.

Keywords:

Knitted imitation woven fabric, mechanical properties, comfortability

1. Introduction

Shirts are mostly made of woven fabrics, which have neat appearance and good dimensional stability. However, the structures are relatively tight. In summer, it is easy to get stuffy for the consumers. Knitted fabrics can effectively avoid these drawbacks [1]. Therefore, by studying the breathability, wicking, and water transport properties of knitted fabrics, the mechanism of comfortability can be further revealed. Oner and Okur, respectively, studied the thermal and wet comfortability of fabrics with loop and float structures and found that the polyester and cotton/Coolmax®-blended yarns show the better water transfer performance when using the float structures, while fabrics with loop structures using viscose and Tencel® yarns have the poorer breathability [2]. Qian et al. studied the breathability, heat transfer performance, water management performance, and dynamic cooling performance of fabrics by changing their parameters, further characterizing the comfort performance of these fabrics related to heat, humidity, and cooling [3]. In addition, Qing et al. made subjective and objective evaluations of the polo shirt fabrics with the plant bionic structure using dummy tests and human wearing experiments; it was found that the plant bionic fabrics exhibit the better heat dissipation performance and faster moisture removal performance [4].

Ah et al. studied the physical properties of polyethylene terephthalate (PTT)/Tencel®/cotton air vortex yarn and the wearing comfort of its knitted fabric. They found that due to the sensible heat shrinkage of PTT fibers, the heat shrinkage rate of air vortex yarn is higher than that of ring spun yarn, which leads to a higher relaxation shrinkage rate of air vortex-knitted fabric than that of compact knitted fabric [5]. According to the DU Bois empirical formula [6], the trunk part occupied a large area, the heat dissipation of the trunk part was accelerated, and the problem of thermal and wet comfortability can be solved [7]. Wang conducted the studies on the high-needle and high-density cotton-like polyester knitted shirt fabrics [8]; it showed that the fabrics have good mechanical properties and anti-pilling performance, and they were relatively stiff with good dimensional stability and good moisture permeability. They can be used as ideal materials for making spring/summer knitted shirts.

The traditional knitting elastic fibers are spandex, with tradenames such as Lycra®, Roica®, and Creora®. The basic chemical structure is polyurethane. XLANCE® fibers are another kind of commercially elastic fiber originating from DOW XLA® fibers [9,10], which are fundamentally different from spandex. Zhang used the polyolefin elastic fibers (DOW XLA®) to make knitted fabrics, but the dyeing and finishing process was directly carried out on gray fabrics without high-temperature predetermined shapes. Therefore, the performance of DOW XLA® fabrics was not fully used [11]. Wang used the DOW XLA® fibers to make knitted fabrics without predetermined shape process. Although the washing stability was better than that of spandex fabrics, DOW XLA® was still used as the alternative elastic fiber to replace spandex, without truly unleashing the unique power of DOW XLA® fibers, especially the size stability [12,13].

Therefore, it is necessary to continue exploring the new technologies for knitted woven fabrics.

In this article, the production process of XLANCE® fiber knitted fabrics is improved by analyzing the basic thermal properties. Moreover, the comparative analysis is conducted as compared with the 30D Lycra® knitted fabrics to develop a type of knitted woven shirt fabric. The mechanical properties and comfortability are analyzed, which expands the new ideas for the development of such kind of product.

2. Experimental

2.1. XLANCE® and Lycra® fibers

30D XLANCE® fibers and 30D Lycra® fibers have the completely different chemical structures. Lycra® macromolecule is divided into two parts: hard chain segment and soft link segment. The hard chain segment is a urea-based structure, which provides the stable connection function. The soft link segment is composed of carbamate, which provides the elasticity. The elasticity of XLANCE® is generated by the deformation of hydrogen molecules. Lycra® has the better elasticity, elastic recovery, and elongation at break than XLANCE®. But XLANCE® performs better than Lycra® in terms of thermal stability, ultraviolet (UV) resistance, and acid and alkali resistance [14,15]. Their physical properties are listed in Table 1.

The elongation at break of Lycra® is higher than that of XLANCE®, as well as the fracture stress. However, as for knitting production, the elongation used for elastic fibers is usually less than 300%, considering the elongation at break of the fibers exceeding above 500%; thus, both can meet the weaving requirements. It can also be seen that the tensile stress of Lycra® is higher than that of XLANCE®. Therefore, if XLANCE® elastic fibers are only used, the elasticity and elastic recovery of the produced fabric will be inferior to those with Lycra® fibers. But XLANCE® has the excellent heat setting characteristics and the ability to resist UV/acid/alkali. If reasonable processes are used, the unique products can be produced.

2.2. Heat setting efficiency

The structure of a typical Lycra® fiber is relatively dense, with the density of 1.28 g/cm^3, while XLANCE® fibers are mainly formed by the polymerization of ethylene and octene, with a relatively loose cross-linked network structure, with the density of 0.9 g/m^3 [15]. The setting temperature of Lycra® is higher than that of XLANCE®. The setting temperature of elastic fibers has a significant impact on the setting effect, and it even determines the mechanical properties, washing dimensional stability, and comfortability [16,17].

To determine the heat setting efficiency of the elastic fibers, 17 groups of 30D XLANCE® and 30D Lycra® fibers were prepared, respectively. A tensile force of 0.3 cN was applied during the preparation of fiber samples to ensure the uniform sampling. As shown in Figure 1(a), the fibers were stretched three times of the original length and then placed in different oven temperature conditions for 60 s to simulate the high-temperature setting process.

Assuming that the original length is L_0, and after drying in the oven, it naturally shrinks to L_1, then the thermal qualitative effect η:

$$\eta = (L_1 - L_0/L_0).$$

The heat setting efficiency is shown in Figure 1(b).

It can be seen that XLANCE® fibers need to be shaped for 60 s at 140°C, with a heat setting efficiency of 90%, which can be considered fully shaped. However, Lycra® needs to be shaped for 60 s at 190°C to achieve the same efficiency. Full shaping is a prerequisite for ensuring the good quality of the fabrics, but it is not necessarily better with higher values. Excessive heat setting efficiency means that the elastic fibers undergo thermal aging, which can lead to a decrease in the elastic recovery force [18].

2.3. Fabric preparation

Target a woven shirt with the fabric specification of 40S cotton/poly 65/35% plain weave and a warp and weft density of 42 × 38/cm, with the weight of 150 g/m^2. Using the knitted fabric to imitate this woven fabric, as each loop of the weft knitted fabric has two loops, the density of the weft knitted fabric is set to half of the woven density, i.e., 21 cm^{-1}. The yarn of the weft knitted fabric is arranged in intervals of 40S/1 cotton yarn and 75D/36F DTY moisture wicking yarn. The length of cotton and polyester yarn is 12.0 and 11.6 cm per 50 coils, respectively. The loom is KARL MAYER with 32 needles/25.4 cm. The reason for using two types of yarn combinations to replace 40S/1 cotton/poly 65/35% yarn is that the combination of the two types of yarns adopts a loop structure, which can ensure the breathability and flat appearance. If 40D/1 cotton/poly 65/35 is used, the fabric will have a grainy texture. The fabric organization, yarn arrangement, and coil diagram are shown in Figure 2.

Two weaving schemes were designed: (1) 30D XLANCE® paired with 40S/1 cotton yarn and 75D/36F DTY moisture wicking yarn and (2) 30D Lycra® paired with 40S/1 cotton

Table 1. Physical properties of 30D XLANCE® and 30D Lycra® fibers

Material	Break elongation (%)	Tensile stress (cN)	Tensile at 300% elongation (cN)	Recovery after 300% elongation (%)
XLANCE®	542	4.02	2.64	95.4
Lycra®	586	4.60	2.98	99.2

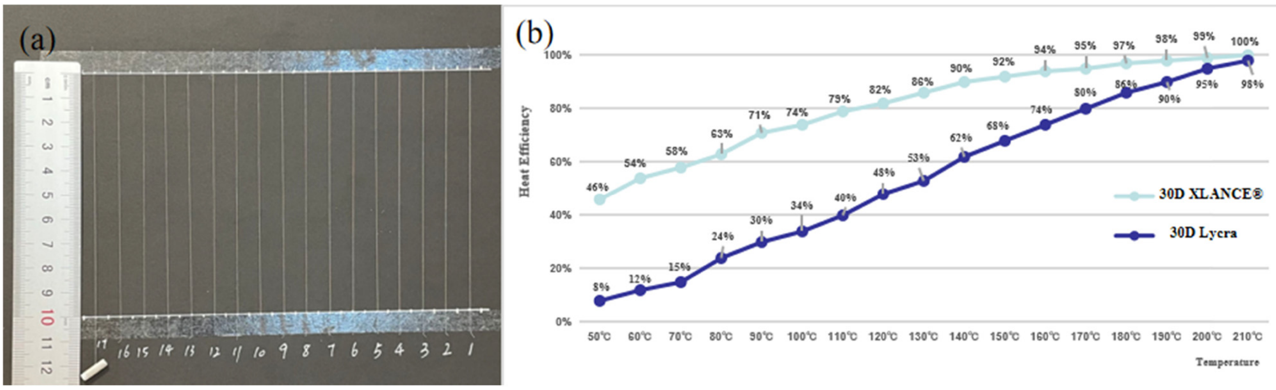

Figure 1. (a) Pretensioned fiber samples and (b) setting efficiency of 30D XLANCE® and 30D Lycra® fibers at different temperatures with 3.0X extension.

(a) 75D/36F + 30D	O	^	O	^
40S + 30D	^	O	^	O
75D/36F + 30D	O	^	O	^
40S + 30D	^	O	^	O
O --- stitch	^ --- tuck			

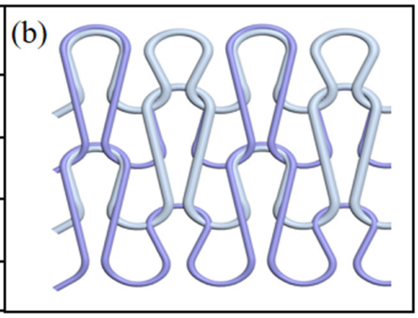

Figure 2. (a) Yarn arrangement and (b) fabric structure and loop diagram.

yarn and 75D/36F DTY moisture wicking yarn. The dyeing and finishing production process includes gray fabric, high-temperature setting, mercerization, dyeing, and finished product setting.

In the heat setting efficiency tests, XLANCE® fibers can achieve the 90% heat setting efficiency. In this work, 150°C was used for XLANCE® fibers, which can achieve a more rational shaping effect. Besides, the setting temperature of spandex was 195°C, which was also a relatively mature temperature for commercial production.

To illustrate the impact of shaping effect on fabrics, the fabrics without fully shaped were also tested together. Along with the standard samples, four types of fabrics are listed in Table 2.

3. Test method

3.1. Shear and bending performance

The samples were balanced for 24 h in standard atmosphere with a temperature of 21 ± 1°C and a relative humidity of 65 ± 2%, using KES-F tester. Shear force (gf/cm) and the shear hysteresis 2HG5 (gf/cm) at a shear deformation angle of 5° were recorded. Bending stiffness B (gf cm^2/cm) and the bending hysteresis 2HB (gf cm^2/cm) were recorded.

$$B = \frac{dM}{d_k},$$

where M is the torque per unit width of the sample, gf cm/cm. k is the curvature of the sample, cm^{-1}.

Table 2. Fabric information and temperature

Fabric	Yarn	Composition	Weight (g/m^2)	Temperature (°C)
Fabric 1	40S	Cotton/poly 65/35%	150	/
Fabric 2	40S + 75D/36F DTY + 30D XLANCE®	Cotton/poly/XLANCE® 63/31/6%	152	150
Fabric 3	40S + 75D/36F DTY + 30D Lycra	Cotton/poly/Lycra® 63/31/6%	154	195
Fabric 4	40S + 75D/36F DTY + 30D XLANCE®	Cotton/Poly/XLANCE® 63/31/6%	151	140

3.2. Elongation and recovery

In accordance with the Ameican standard test method (ASTM) D6614-07 test standard, the samples were balanced for 24 h in standard atmosphere with a temperature of 21 ± 1°C and a relative humidity of 65 ± 2%; a sample size of 50 mm × 350 mm was tested under a load of 20 N. The elongation was tested after 2 h, and the recovery was tested after 1 and 30 min after removing the load. Each fabric was tested three times to obtain the average.

3.3. Curling and UV resistance

The samples were balanced for 24 h in standard atmosphere with a temperature of 21 ± 1°C and a relative humidity of 65 ± 2%; fabric picker was then used to get round samples to observe the curling behavior.

In accordance with the American association of textile chemists and colorists test method 186 test standard, the samples were balanced for 24 h in standard atmosphere with a temperature of 21 ± 1°C and a relative humidity of 65 ± 2%; with a UV irradiance of 340 nm at 1 W/m^2, the fabric sample was exposed to a blackboard temperature of 60°C for 192H, 288H, and 384H on the front side. The change in XLANCE® fiber and Lycra® fiber was observed.

3.4. Shrinkage and longitudinal wicking

In accordance with the AATCC 135 test standard, the samples were balanced for 24 h in standard atmosphere with a temperature of 21 ± 1°C and a relative humidity of 65 ± 2%; a sample of 50 cm × 50 cm was washed with 92 g of without optical brightener laundry detergent at a water temperature of 49°C for 45 min, was washed repeatedly, and was dried for three times; then, the dried sample was placed for at least 4 h before measuring the size change.

In accordance with the AATCC 179 test standard, the samples were balanced for 24 h in standard atmosphere with a temperature of 21 ± 1°C and a relative humidity of 65 ± 2%, a sample of 25 mm × 178 mm was prepared, and the lower end was immersed in distilled water. After 30 min, the water absorption height of the fabric was measured.

4. Results and discussions

4.1. Shear properties

The KES-F tester was used to conduct shear testing, the shear force (gf/cm) was recorded, and the shear hysteresis was 2HG5 (gf/cm) with a shear deformation angle of 5°. The results of the transverse and longitudinal shear tests are shown in Figure 3.

The shear performance of fabrics is related to the straightness and drape, which affects the formability of clothing [19,20]. From Figure 3(a) and (b), it can be seen that the shear angle varies from 0 to 7.85°. Fabric A shows the relatively higher shear values in both the horizontal and vertical directions, with a maximum shear value of 9.87 gf/cm in the horizontal direction and 10.89 gf/cm in the vertical direction. Fabric B is made of the fully shaped XLANCE® fibers. The bending performance is closest to that of woven fabric, with the maximum shear values of 8.90 and 9.57 gf/cm in the horizontal and vertical directions, respectively. Fabric C is a normal-shaped Lycra® knitted fabric, whose shear performance gradually deviates from the shear performance of woven fabrics. The maximum shear values in the horizontal and vertical directions are 6.93 and 8.32 gf/cm, respectively. However, knitted fabric made of XLANCE® fibers with insufficient shaping has the lowest shear performance, with the transverse and longitudinal shear values of 6.00 and 6.75 gf/cm, respectively. The shear angle returned from 7.85° to 0°, and then, the reverse shear test was carried out at −7.87°. No matter horizontally or vertically, it still showed the same variation pattern, i.e., the fully shaped XLANCE® fabrics have the closest shear performance to woven fabrics, followed by Lycra® fabrics and XLANCE® fabrics, which without sufficient shaping are the lowest.

For the shear hysteresis, as shown in Figure 3(c) and (d), the shear hysteresis at the shear angle of 5° is the difference in force between going and returning during shear testing. No matter horizontally or vertically, the fully shaped XLANCE® fabrics have the relatively large values, and the values of woven fabrics are larger. Because the internal yarn arrangement of both fabrics is relatively tight. For Lycra® fabrics and XLANCE® fabrics that are not fully shaped and have relatively loose structures, the friction is relatively low; thus, Lycra® and XLANCE® fibers contribute more to the result, which results in smaller shear hysteresis.

Woven fabrics have the high shear stress because of their compact structure and are less prone to deformation. And the fully formed XLANCE® fabrics have the high shear stress, which is related to the morphology, as shown in Figure 4.

As shown in Figure 4(a), the fully shaped XLANCE® fibers are bonded into an elastic mesh in the fabric, and when subjected to shear force, adjacent fibers are also pulled, requiring higher shear force to undergo deformation. Lycra® fibers and XLANCE® fibers that have not been fully shaped are still in the dispersed state. When the fabric is subjected to shear force, the knitted fabric is relatively loose, and the yarn will slip and cannot bear the force, resulting in a relatively lower shear force. And Lycra® fabrics have the higher shear strength due to the higher recovery force.

4.2. Bending performance

Bending performance is an important indicator of fabrics, which has a significant impact on the appearance, smoothness, and wearing comfortability. The bending stiffness is high, and the fabric appearance will be relatively neat, but the movement is not free enough. The fabric with low bending stiffness is relatively comfortable to wear, but the appearance is not neat enough [21]. Therefore, reasonable bending stiffness is very important.

In Figure 5(a) and (b), it can be seen that the bending stiffness curves of woven Fabrics 1 and 2 are centrally symmetrical, which is in line with the characteristics of woven fabric. However, Fabrics 3 and 4 do not possess this feature, as single-

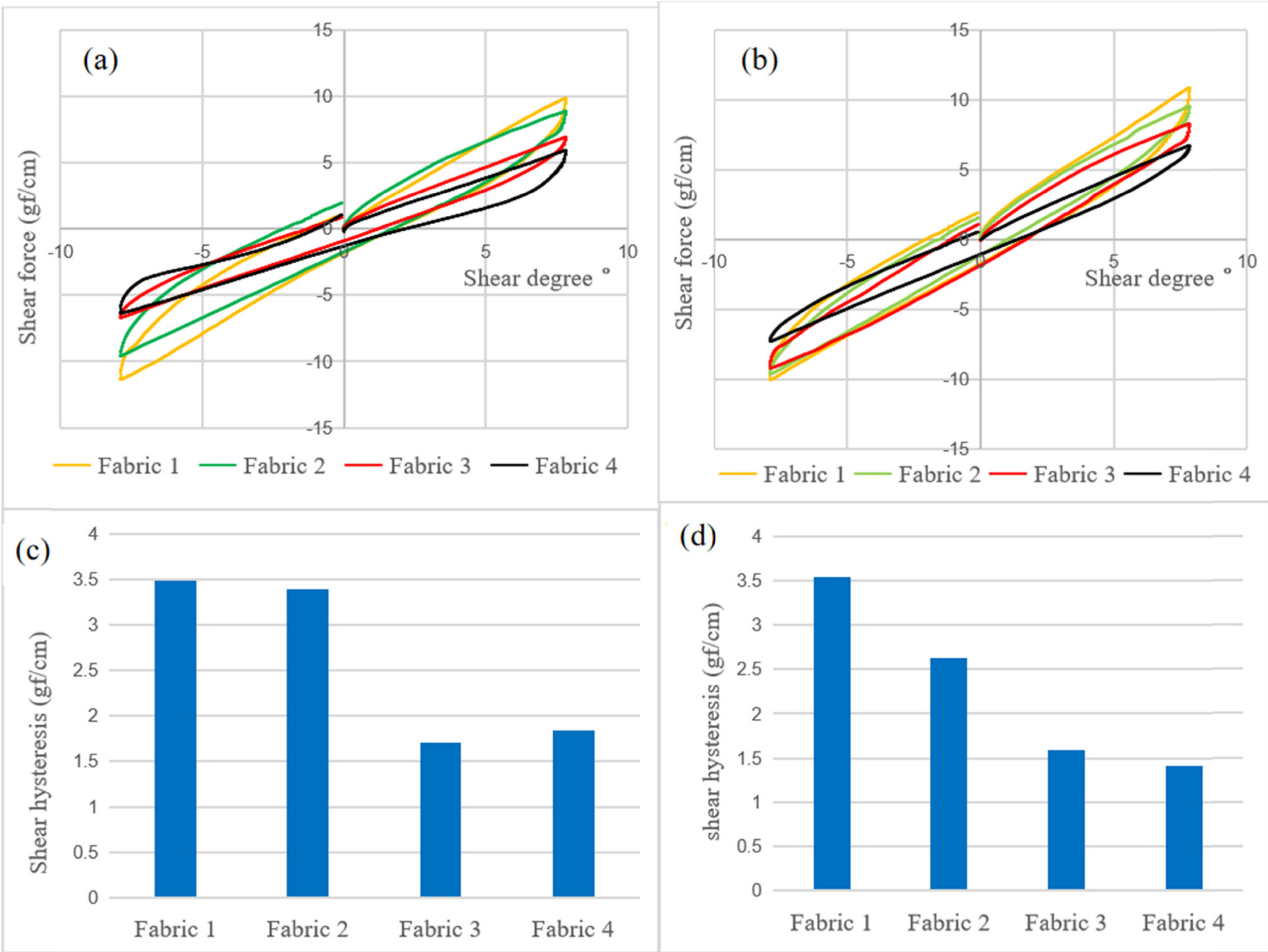

Figure 3. (a) Lateral shear force, (b) longitudinal shear force, (c) lateral shear hysteresis, and (d) longitudinal shear hysteresis.

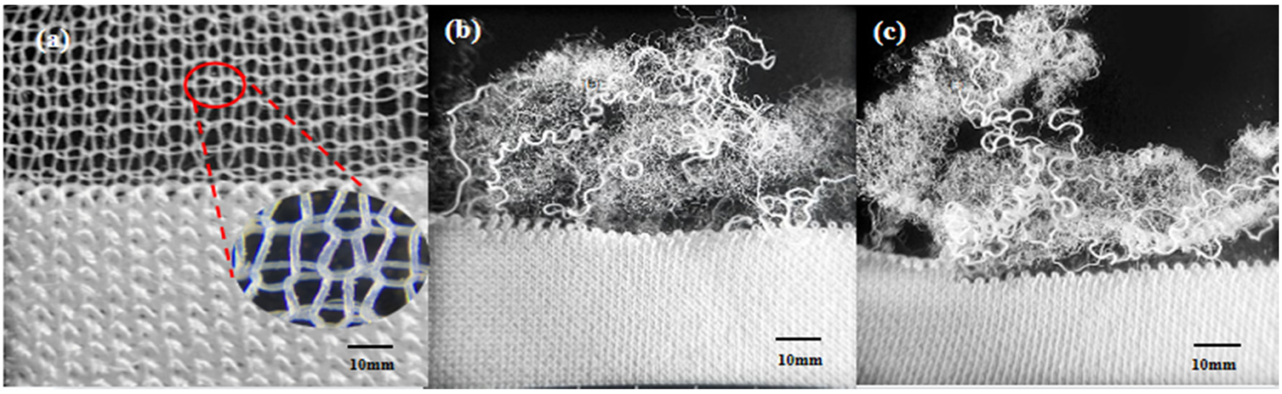

Figure 4. Morphology of elastic fibers in finished fabrics: (a) Morphology of XLANCE® fibers in Fabric 2 at 150°C, (b) morphology of Lycra® fibers in Fabric 3, and (c) morphology of XLANCE® fibers in Fabric 4 at 140°C.

sided knitted fabrics typically exhibit curling. During bending and recovery, the curling force of the fabric itself can lead to asymmetric test results. From the figure, it can also be seen that the woven fabric has a high bending height, followed by the fully formed XLANCE® fabric and Lycra® fabric, insufficiently shaped XLANCE®. The fabric has the smallest bending stiffness. This phenomenon is also related to the structure of the fabrics. Woven fabrics are relatively tight, and they are more likely to reflect rigidity when bent. However, the fully shaped XLANCE® fabrics with elastic mesh gives the good bending force, while Lycra® fabrics and XLANCE® fabrics without fully shaped are prone to slippage due to their loose structures, resulting in the relatively low bending force.

The bending hysteresis of the four fabrics is shown in Figure 5(c) and (d), where the same pattern is followed in both the horizontal and vertical directions. Woven fabrics have the highest bending hysteresis, followed by fully shaped XLANCE® fabrics, Lycra®

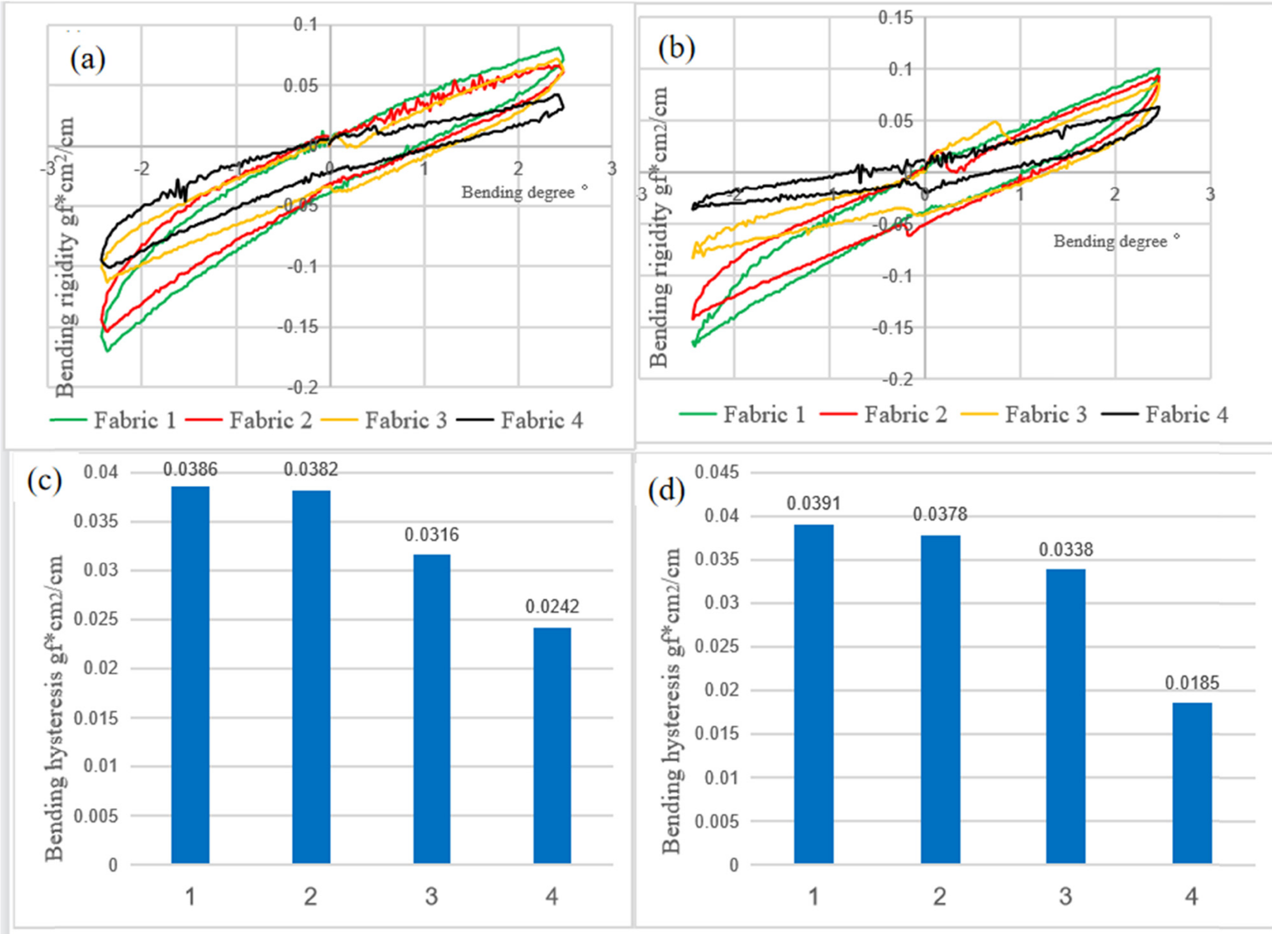

Figure 5. (a) Lateral bending stiffness, (b) longitudinal bending stiffness, (c) lateral bending hysteresis, and (d) longitudinal bending hysteresis.

fabrics, and the XLANCE® fabrics not fully shaped having the lowest bending hysteresis. Bending hysteresis reflects the level of viscosity in the bending deformation of the fabric. Woven fabric and fully set XLANCE® fabric have relatively tight structures, making them less likely to recover after bending deformation. On the other hand, Lycra® fabric and not fully set XLANCE® fabric have relatively loose structures, giving them a more elastic style, resulting in lower bending hysteresis.

4.3. Stretch recovery

According to ASTM D6614-07, the sample size is 50 mm × 350 mm, the load is 20 N, the testing period is 2 h; then, the load was removed and the recovery rate was determined after 1 and 30 min, respectively. The results are shown in Table 3.

It can be seen that the longitudinal elongation and transverse elongation of woven fabrics are relatively low, while three knitted fabrics have much higher elongation in both directions, mainly due to the fabric structure. Knitted fabrics are formed by stringing loops. When subjected to external force, the yarns reflect a high elongation rate. At the same time, it can also be seen that the longitudinal and transverse elongation values of the knitted fabrics are similar, because the loops undergo sufficient deformation when subjected to a tensile force of 20 N. The yarns used are the same, and the weaving process is also the same, so the elongation is obtained.

The elastic recovery rates of woven fabrics are the highest. This is because their tensile deformation is small, and after removing external forces, mechanical elasticity enables the fabric to quickly recover. Second, Fabric 2 has a higher response rate,

Table 3. Elongation and recovery results

Fabric	Weft elongation (%)	Warp elongation (%)	Weft recovery/ 1 min (%)	Warp recovery/ 1 min (%)	Weft recovery/ 1 min (%)	Warp recovery/ 1 min (%)
Fabric 1	11.3	8.9	98.5	97.2	99.1	99.6
Fabric 2	64.4	47.6	94.3	96.6	98.8	99.2
Fabric 3	66.2	48.5	90.0	92.1	93.4	94.5
Fabric 4	65.3	48.7	89.7	90.2	92.6	93.1

because the network structure of XLANCE® fabric allows for the good rebound behavior. Fabrics 3 and 4 have low resilience, which is caused by deformation under tensile force, resulting in the relative slippage of the yarns. If there is no external force, it will cause permanent deformation. Fabric 3 has slightly higher resilience than Fabric 4 because Lycra® monofilament has the stronger resilience, and the surface of XLANCE® fiber is relatively sticky, which will affect the recovery of the fabric.

4.4. Curliness

Curling is a common phenomenon in knitted fabrics, while it is rare for woven fabrics. In knitted fabrics, the yarns are in the curved state, and the imbalance in bending tension between the front and back faces causes curling [22,23]. Curling brings inconveniences to the production. Therefore, when developing the knitted woven fabrics, the phenomenon of curling is a very important assessment indicator. Figure 6 shows the curling of the fabrics.

It can be seen that the curling of Fabrics 1 and 2 is significantly better than that of Fabrics 3 and 4. The formed XLANCE® fiber network effectively prevents the curling.

4.5. UV resistance

The UV resistance performance affects the life cycle of shirt fabrics, especially in high-humidity summer when elastic fibers are prone to losing elasticity under humid and hot lighting conditions. As shown in Figure 7, it can be seen that the UV resistance of XLANCE® fibers is significantly higher than that of Lycra® fibers. After being exposed to UV for 192 h, the Lycra® fibers began to break. After 288 h of exposure, the Lycra® fibers became sticky. After 384 h of exposure, the Lycra® fibers were almost broken, while the outer layers of XLANCE® fibers were damaged only.

The UV resistance characteristics of two types of fibers are determined by their respective characteristics. XLANCE® fibers are formed by cross-linking of polyolefin hydrogen molecules, and the main intermolecular linking modes are three types of junctions: crystal sites, entanglements, and equivalent cross-links, which are less affected by UV irradiation. Moreover, polyene hydrogen does not contain hydrophilic groups, and humid environments do not cause the aging of polyene hydrogen. Lycra® is polymerized from the soft link segment and the hard link segment, as shown in Figure 7. Under the irradiation of UV light, the hard link segment undergoes rearrangement reaction, and the molecular chain breaks. Lycra® contains a large amount of

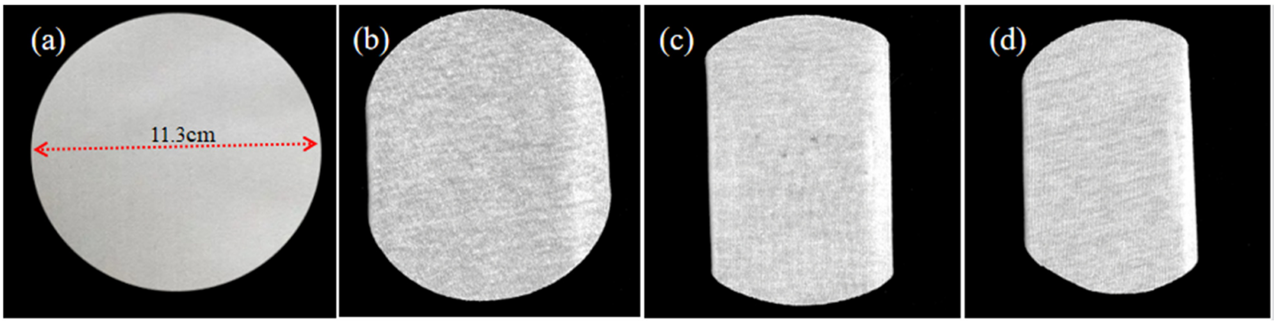

Figure 6. Curling of (a) Fabric 1, (b) Fabric 2, (c) Fabric 3, and (d) Fabric 4.

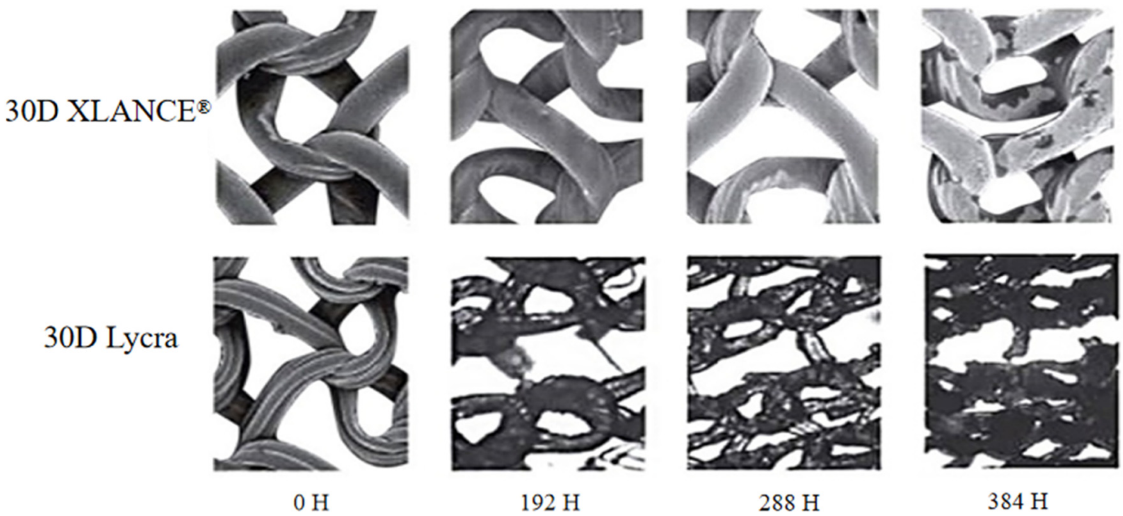

Figure 7. UV resistance tests of XLANCE® and Lycra® fibers.

hydrophilic groups, which absorb moisture in the air, promote the hydrolysis of the internal carbamate, and finally cause the overall fracture of the spandex [24–26].

4.6. Shrinkage rate and breathability

The shrinkage results are listed in Table 4. It can be seen that the shrinkage rate of Fabric 2 is relatively low in both vertical and horizontal directions, which is attributed to the relatively stable network structure of XLANCE® fibers after rebonding, and the washed size is relatively stable. Next is Fabric 1, which is attributed to the relatively stable structure of woven fabric. The shrinkage rate of Fabrics 3 and 4 can be considered as the normal shrinkage rate of knitted fabrics. According to the testing standards, the shrinkage rate is within the range of 5%, which is an acceptable result.

Breathability is an important indicator, especially in hot summer. Good breathability can help consumers maintain a refreshing body feel. In Table 4, it can be seen that Fabric 1 has the lowest air permeability, while Fabrics 2–4 have significantly increased air permeability, which is closely related to their tight structures. Among the three knitted fabrics, Fabric 4 has the highest air permeability, followed by Fabrics 3 and 2, which have the lowest air permeability. Because the fabric undergoes deformation, the network structure makes it less prone to deformation, while Fabrics 3 and 4 are more easily pulled apart, resulting in larger pores and higher air permeability.

Table 4. Shrinkage and air permeability results

Fabric	Weft shrinkage (%)	Warp shrinkage (%)	Air permeability (mm/s)
Fabric 1	1.2	1.8	85.5
Fabric 2	1.4	0.7	256.3
Fabric 3	2.9	3.4	293.2
Fabric 4	1.5	3.2	320.7

4.7. Wicking performance

The wicking tests reflect the ability of the fabric to absorb and transport moisture. After the fabric absorbs moisture, it quickly transports the moisture out, increasing the evaporation area, which is beneficial for maintaining the dry state. The ability of a fabric to absorb and transport moisture is influenced by its composition, structure, and finishing aids. The wicking results of the fabrics are shown in Figure 8.

It can be seen that on both lateral and longitudinal directions, the wicking speed of Fabric 1 is relatively slow, while the diffusion speed on the three knitted fabrics is much faster. The tight structure of woven fabric can hinder the transport of moisture. Although there is a difference in the diffusion speed of the three knitted fabrics, the difference is not significant and can be considered consistent, which provides the good water absorption and hydrophobicity.

5. Conclusions

Both the mechanical properties and comfortability of the knitted imitation woven fabrics are needed to be comprehensively considered. In this article, the aforementioned properties of 30D XLANCE® and 30D Lycra® fabrics are experimentally studied, and the following conclusions are obtained.

(1) After the sufficient heat setting, the 30D XLANCE® fibers will adhere into an elastic network structure and are fully shaped, giving the fabric excellent shear and bending properties. And 30D spandex and 30D XLANCE® fibers without sufficient heat setting show a dispersed state with low shear and bending forces and severe curling.

(2) 30D XLANCE® fibers glued into a network structure still maintaining excellent elasticity, and the elongation of the fabric is close to that of the 30D Lycra® fabric, but there is no slippage in the fibers of the finished fabric, and its 1- and 30-min elastic recovery rates are significantly higher than those of the 30D Lycra® fabrics and the 30D XLANCE® fabrics.

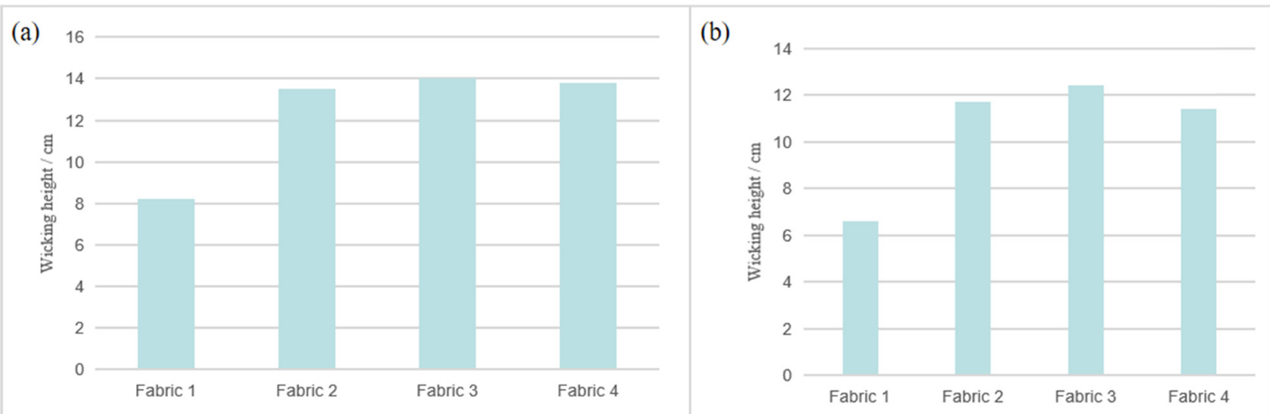

Figure 8. Wicking results for: (a) wicking height on longitudinal direction and (b) wicking height on lateral direction.

(3) XLANCE® fabrics have the better washing stability, with breathability and water absorption. Besides, they have the lower heat setting energy consumption and longer durability, which are beneficial for reducing carbon emissions.

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