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MOISTURE RESPONDED TRANSFORMABLE PROPERTY OF INTELLIGENT COOLNESS KNITTED FABRICS FOR SPORTSWEAR CLOTHINGS

Hyun Ah Kim[1], Seung Jin Kim[2]

[1] Korea Research Institute for Fashion Industry, Daegu, Korea
[2] Dept. of Textile Eng. And Technology, Yeungnam Univ, Gyeongsan, Korea

Abstract:

The present study examined the physical properties related to the intelligent coolness characteristics including the wearing comfort of Huvis elastic fiber (HEF) knitted fabrics. For this purpose, three kinds of covered filament yarn specimens, such as PET-HEF, Aerocool-HEF, and PET-spandex, were prepared, and their knitted fabric specimens were made using these covered yarn specimens. These knitted fabric specimens were dyed at different dyeing temperatures and times to analyze the dyeing characteristics. The moisture absorption rate, drying, and hygral expansion of the three kinds of knitted fabric specimens were measured and compared with the yarn characteristics to determine the wearing comfort of HEF knitted fabrics.

Keywords:

MRT, HEF, FAST, absorption and drying rate, dye affinity

1. Introduction

Coolness textile technology includes perspiration absorption and quick-dry materials with the noncircular cross-section shape of fiber and contact coolness material by improving the heat phase characteristics with polymer and cross-section modification technology. Recently, phase change material (PCM) and moisture responded transformable (MRT) fiber have become applicable to coolness textile materials, which are called intelligent textiles. Mather [6], in his review paper on intelligent textile, proposed that a breathable fabric, PCM, shape memory materials, including thermochromism or photochromism, can be applicable to intelligent textiles. Many studies [2][3][7]~[9] related to the PCM have been carried out. Choi et al. [2] investigated the thermal storage/release properties of PET fabric using PCM, and Choi et al. [3] studied the clothing temperature changes of a PCM-treated warm-up garment. Mondal [7] surveyed PCM for smart textiles as an overview paper. On the other hand, Shin et al. [9] developed natural dyed textiles with thermoregulating properties, but there was less on the MRT fiber. MRT fiber was developed by Teijin in Japan, which has been commercialized to knitted wear for sports garments. [4] Recently, Huvis in Korea developed MRT filament called Huvis elastic fiber (HEF). MRT fibers are expanded after moisture absorption like hygral expansion (HE) of wool fibers. Processing technology in the yarn finishing and dyeing processes of the MRT fiber is very important, and more detailed technology related to MRT property is needed. Therefore, this study examined the physical properties of intelligent coolness yarns (HEF) [5] and their knitted fabrics with MRT property. For this purpose, three kinds of covered yarn specimens were prepared with HEF in the core part covered with PET and aerocool as a sheath part, respectively, and the covered yarn with spandex in the core part covered with PET as a sheath was also prepared as a control yarn to compare with HEF yarns covered with PET and aerocool, respectively. Knitted fabric specimens were prepared on a double knitting machine. PET 75d/144f semidull DTY was used as the surface yarn on the knitted fabric, and three kinds of covering yarns prepared previously were used on the back side of the knitted fabrics. The physical properties, such as absorption rate, drying rate, and HE, were measured and discussed with the yarn and knitted fabric characteristics. The mechanical properties of the knitted fabrics, such as extension, bending, shear, and compression, were also measured and discussed with the characteristics of the yarns and knitted fabrics for predicting the wear performance of the garment.

2. Experimental

2.1 Preparation of Covering Yarn Specimens

Three types of covered yarn specimens were prepared using HEF $70^d/3^f$ (Huvis, Korea) and spandex 40d (Hyosung, Korea) as core and PET $75^d/72^f$ DTY and Aerocool ($75^d/72^f$, DTY) as a covering filaments. Table 1 lists the physical properties of three types of covered yarn specimens. A HEF-PET covered yarn specimen (no.1, 120d) was made on a covering machine (STC-110 Soosan Co., Korea) using HEF $70^d/3^f$ as a core filament and PET $75^d/72^f$ DTY as the covering filament. The draw ratio of HEF $70^d/3^f$ was 3.1 and the covering twist was 525 tpm. The HEF-Aerocool covered yarn specimen (no.2) and spandex-PET covered yarn specimen (no.3) were also made using the same procedure as a control specimens for comparing with the HEF-PET specimen. Figure 1 shows the structure of the covered yarn specimens.

Table 1. Physical characteristics of the moisture responded transformable covering yarn specimens.

Specimen no.	Yarn	Composition	Denier	Draft	Tpm
1	HEF-PET	PET 75/72 DTY + HEF 70/3 (HEF)	120d	draw ratio 3.1	525
2	HEF-Aerocool	PET 75/72 DTY(Aerocool) + HEF 70/3 (HEF)			
3	SPAN-PET	PET 75/72 DTY + SPAN 40d			

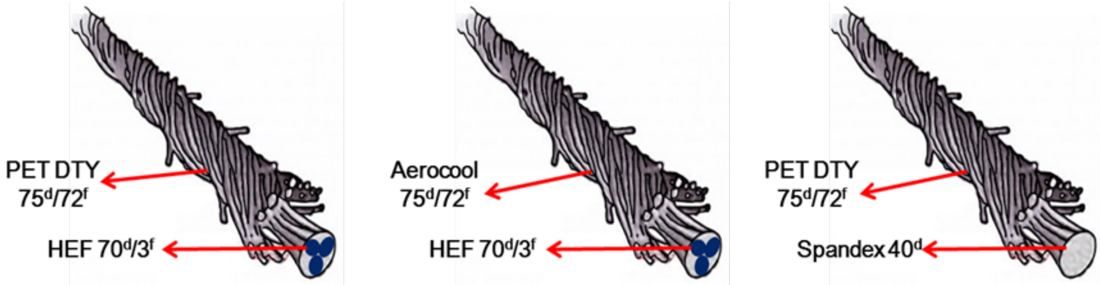


Figure 1. Structure of yarn specimens.

2.2 Preparation of Knitted Fabric Specimens

Knitted fabric specimens were prepared with double knitted fabric on a circular knitting machine and PET $75^d/144^f$ DTY was used as the surface yarn of the knitted fabric. The three kinds of covered yarns prepared previously were used on the back side of the knitted fabrics. Table 2 lists the knitting condition of the three types of knitted fabric specimens.

2.3 Dyeing Condition

The dyeing temperature was changed from 80 to 110°C in 10°C increments and two types of dyeing times (30 and 60 min) were used when treating with dispersed dyestuff of FORON Yellow Brown S-2RFL 150 (o.w.f 3%). Before dyeing, scouring was processed with a scouring agent of Hostapal MRZ liquid (3 g/l, 80°C, 30 min) and the dyed specimens were reduced with a dispersing agent, Lyocol® RDN liquid (0.5 g/L, 60°C, 15 min) on the dyebath. Table 3 lists the dyeing conditions for examining the dyeing characteristics of the three kinds of knitted fabrics.

2.4 Assessment of Physical Property of Yarns and Knitted Fabrics

2.4.1 Measurement of physical properties of yarn

The mechanical properties of the yarn specimens were measured using Instron (England, model Micro 350) by KSK0416. Tenacity and initial modulus were measured with a gauge length of 100 mm, and the testing speed was 100 mm/min. For each yarn specimen, 20 tests were conducted. The wet and dry thermal shrinkage of yarn specimens were also measured by KSK0215. The yarn specimen as a hank form was treated in boiling water for 30 min. Length of the hank before(L_1) and after (L_2) boiling water treatment were measured under 0.1 g/d initial load, and the wet thermal shrinkage was calculated using equation $(L_1 - L_2)/L_1 \times 100$. The length of the hank before (L_1) and after (L_2) 180°C dry heat treatment in the heat chamber for 2 min were measured under 0.1 g/d initial load and the dry thermal shrinkage was calculated using equation $(L_1 - L_2)/L_1 \times 100$. For each yarn specimen, five tests were conducted. The yarn cross-section was measured by using scanning electron microscopy (SEM, S-4300, Hitachi Co. Japan).

2.4.2 Measurement of the physical properties of the knitted fabrics

The water absorption of the knitted fabrics was measured using the Bireck method, KS K0815(B). From one end, 100 mm of the strip specimen (20 cm × 2.5 cm) was dipped into distilled water in a 27 ± 2°C water bath; the wicking length (mm) was measured after 10 min. An average of five readings for each specimen was reported. The drying rate of the knitted fabric was also measured by KS K0815(A). A square fabric specimen (40 cm × 40 cm) was fully submerged in distilled water at 27 ± 2°C in a water bath, and the fully absorbed fabric specimen was then picked out and hung on the measurement equipment. The weight of the dried fabric specimen was measured using a sensor attached to the equipment. The time (in minutes) till which the fabric weight did not change was recorded as the drying rate. For each specimen, five tests were conducted.

2.4.3 Moisture responded transformable property of the knitted fabric

The MRT property of knitted fabric specimens was measured using the FAST-4 system [1], which can measure the HE of a fabric. MRT and HEF were expanded after moisture absorption; that is, they have self-expansion properties, so the self-expansion of HEF knitted fabric specimen after moisture absorption was measured and substituted by the HE measurement using a FAST-4 system. Figure 2 presents a schematic diagram of the HE measurement using the FAST

Table 2. Knitting condition of the knitted fabric specimens.

<table>
<tr><th>Knitting M/C</th><th colspan="2">Circular Hosiery Knitting Machine</th></tr>
<tr><td>Knitting structure</td><td colspan="2">Interlock single pique</td></tr>
<tr><td>Knitting diameter(inch)</td><td colspan="2">30</td></tr>
<tr><td>Knitting speed(rpm)</td><td colspan="2">15</td></tr>
<tr><td>Knitting gauge(G)</td><td colspan="2">28</td></tr>
<tr><td rowspan="2">Weave pattern</td><td>
• Cam sequence :
<table>
<tr><th>Yarn</th><th></th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th></tr>
<tr><td rowspan="2">Dial</td><td>B</td><td>∪</td><td>∨</td><td>∪</td><td>∨</td><td>–</td><td>∨</td><td>–</td><td>∨</td></tr>
<tr><td>A</td><td>–</td><td>∨</td><td>–</td><td>∨</td><td>∪</td><td>∨</td><td>∪</td><td>∨</td></tr>
<tr><td rowspan="2">Cylinder</td><td>A</td><td>∧</td><td>–</td><td>∧</td><td>–</td><td>∧</td><td>–</td><td>∧</td><td>–</td></tr>
<tr><td>B</td><td>∧</td><td>–</td><td>∧</td><td>–</td><td>∧</td><td>–</td><td>∧</td><td>–</td></tr>
</table>
</td><td>· note :
∪ : tuck
∨ : knit
— : miss

· note:
1,3,5,7: $75^d/72^f$ covered yarns
2,4,6,8: $75^d/144^f$</td></tr>
<tr><td>
• Stitch sequence
<table>
<tr><th>Yarn</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th><th>7</th><th>8</th></tr>
<tr><td>Dial</td><td>A</td><td>B</td><td>A</td><td>B</td><td>A</td><td>B</td><td>A</td><td>B</td></tr>
<tr><td>Cylinder</td><td>A</td><td>B</td><td>A</td><td>B</td><td>A</td><td>B</td><td>A</td><td>B</td></tr>
</table>
</td><td>· note: 1,3,5,7: $75^d/72^f$ covered yarns
2,4,6,8: $75^d/144^f$</td></tr>
</table>

Table 3. Dyeing condition of the knitted fabric specimens.

<table>
<tr><th>Dyeing temperature (°C)</th><th colspan="2">Dyeing time (min)</th><th>Fixed condition</th></tr>
<tr><td>80</td><td>30</td><td>60</td><td rowspan="4">· Scouring
Scouring agent (Hostapal MRZ liquid), 3 g/l, 80°C, 30 min
· Dyeing
Disperse dye (FORON Yellow Brown S – 2RFL 150), o.w.f. : 3%
Dispersing agent (Lyocol®RDN liquid), 0.5 g/l
Leveling agent (Eganal®PS liquid), o.w.f. : 3%
Buffer acid (Opticid), 1 ml/l
· Reduction clearing
Dispersing agent (Lyocol®RDN liquid), 0.5 g/l, 60°C,15 min</td></tr>
<tr><td>90</td><td>30</td><td>60</td></tr>
<tr><td>100</td><td>30</td><td>60</td></tr>
<tr><td>110</td><td>30</td><td>60</td></tr>
</table>

system. A 20 cm × 20 cm specimen was dried for 10 min in a dryer and the L_1 was then measured. Subsequently, the specimen was soaked for 30 min in a water bath and the L_2 was measured. The specimen was dried for 15 min in the dryer and the L_3 was measured. Finally, the HE of specimen was calculated using Eq. (1). An average of five readings for each specimen was reported.

$$HE = \frac{L_2 - L_3}{L_3} \times 100 \quad (1)$$

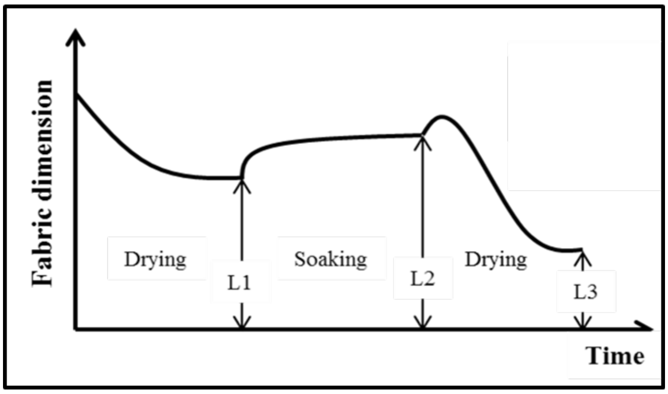


Figure 2. Schematic diagram of the hygral expansion measuring method.

2.4.4 Mechanical properties of knitted fabric

The mechanical properties of the knitted fabric specimen were measured using the FAST system. The mechanical properties such as bending, shear, compression, and tensile deformation for the three types of the knitted fabric specimens were measured using three samples for each knitted specimen. The fabric thickness and surface thickness were measured using FAST-1 compression meter. Thickness was measured over a circular area of 10 cm^2 at 2 and 100 gf/cm^2. Surface thickness was defined as the difference between these two values, which was used as compressibility in this study. Bending length (C) was measured using a fabric strip of 5 cm wide on the FAST-2 bending meter. Bending rigidity (B) was calculated using the cloth mass per unit area (M, g/m^2) and bending length (C) as follows: B = 9.8 × 10^{-6} MC^3(μN·m). Extensibility and shear rigidity were measured on the FAST-3 extension meter. Extensibility was adopted as strain (%) at 50 gf/cm tensile load applied in the direction of the longer length 100 mm × 50 mm specimen. Shear modulus (G) was calculated using the equation $G = \frac{123}{EB5} \times 1N/m$ and EB5 as a bias extension (%) under 5 gf/cm was measured using 100mm×50mm bias specimen.

2.4.5 Dyeing characteristics of the knitted fabric

Dye affinity (K/S) of the knitted fabric specimens was calculated using the reflectance (R) measured using a computer color matching device, as shown in Eq. (2). The color fastness of the knitted fabric specimen to washing was assessed according to the KSK ISO104-C06.

$$K/S = \frac{(1-R)^2}{2R} \tag{2}$$

3. Results and discussion

3.1 Mechanical Properties of HES Yarn Specimens

According to Huvis (Home page), HEF is an elastic fiber that is made by condensation polymerization with polybutylene terephthalate (PBT), polyol, and hydrophilic ionomer, such as MRT made by Teijin in Japan. In addition, HEF expands via moisture absorption and shrinks when it is dried, that is, HEF undergoes an elastic and reversible change according to the moisture absorption. Therefore, the tensile property of HEF covered yarn was investigated and compared with spandex covered yarn. Table 4 list the physical properties of base filaments used for the covered yarns specimens. As shown in Table 3, the elastic properties data of the HEF filament such as breaking strain and elastic recovery indicate high extensibility and resilience like spandex, and high absorption rate estimates hydrophilic property and moisture transformable characteristic of the HEF filament. Aerocool filament showed higher breaking strain and thermal shrinkage than those of regular PET; however, initial modulus was much lower than that of regular PET even though the tenacity was same.

Figures 3 and 4 show the mean value of the tenacity and initial modulus with maximum and minimum values of the yarn specimens. As shown in Fig. 3, the tenacity of the HEF-PET covered yarn was lower than that of the HEF-aerocool and span-PET covered yarns. On the other hand, as shown in Fig. 4, the initial modulus of HEF-PET and HEF-aerocool covered yarns were higher than that of the span-PET covered yarn. This means that the elastic property of the HEF-PET covered yarn was lower than that of the spandex-PET covered yarn. On the other hand, considering the mechanical data of these three kinds of covered yarns, this does not appear to be a problem, such as yarn break during weaving and knitting.

3.2 Thermal Shrinkage of the HES Yarn Specimens

The wet and thermal shrinkage percentages of yarns needs to be considered for examining the process performance of dyeing and finishing. Figure 5 shows the mean values of the dry and wet thermal shrinkages with maximum and minimum values. As shown in Fig. 5, the dry thermal shrinkages of the HEF covered yarns covered with PET and aerocool were 35–40%, which is much higher than that of the span-PET covered yarn. The wet thermal shrinkages of the HEF covered yarns covered with PET and aerocool were also higher than that of the span-PET covered yarn. These phenomena were attributed to the high thermal stress of the MRT HES filament, and the high thermal shrinkages from 35% to 40% of the HES filaments need to be considered at the process design in the dyeing and finishing processes for obtaining high emotional knitted and woven fabrics.

3.3 Absorption and Drying Characteristics of HES Knitted Fabrics

Figures 6 and 7 show the absorption and drying of the knitted fabrics. As shown in Fig. 6, the moisture absorption of the HEF-PET and HEF-aerocool knitted fabrics were higher than that of the span-PET specimen. This was attributed to the better

Table 4. Physical property of base filaments used for covered yarn specimens.

Filament	Linear density	Tensile property			*Elastic recovery (%)	Thermal shrinkage		**Absorption rate (%)
		Tenacity (gf/d)	Breaking strain (%)	Initial modulus (gf/d)		Dry (%)	Wet (%)	
HEF	$70^d/3^f$	1.05	670	-	85.6	-	-	35
Spandex	40^d	1.07	470	-	96.2	-	-	1.3
Aerocool DTY	$75^d/72^f$	4.54	5.35	85.93	-	16.42	17.90	-
PET DTY	$75^d/72^f$	4.89	1.86	298.94	-	9.56	4.35	-

Note: * :value at the 50% extension, **: the data offered from company

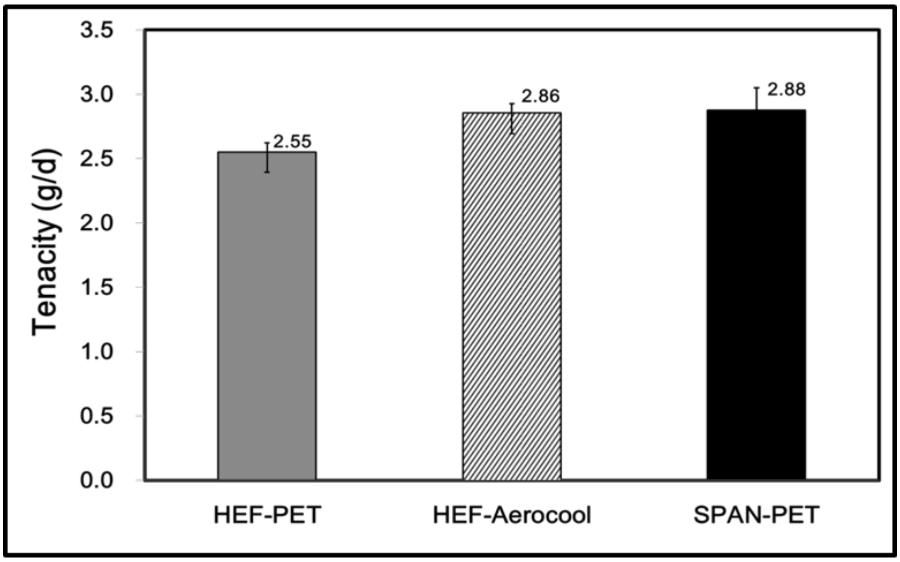


Figure 3. Tenacity of the yarn specimens.

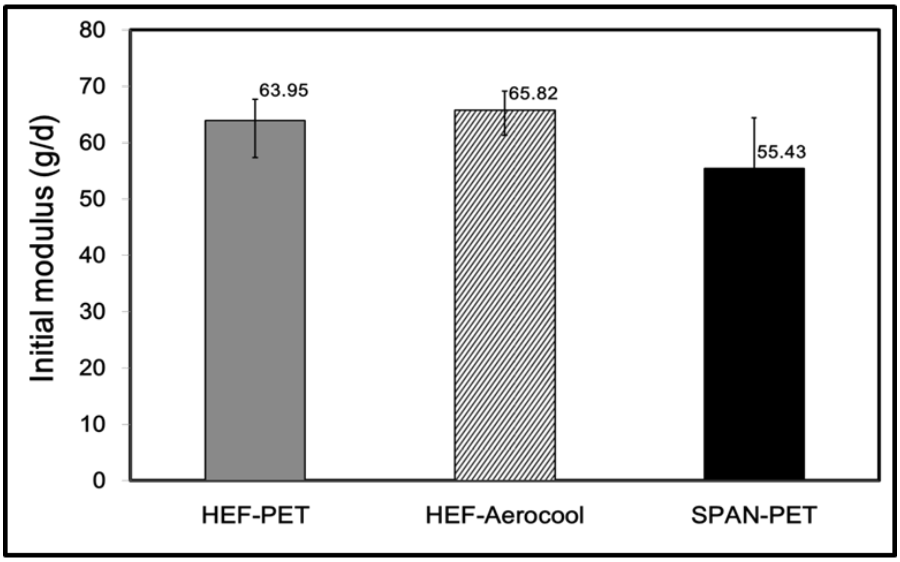


Figure 4. Initial modulus of the yarn specimens.

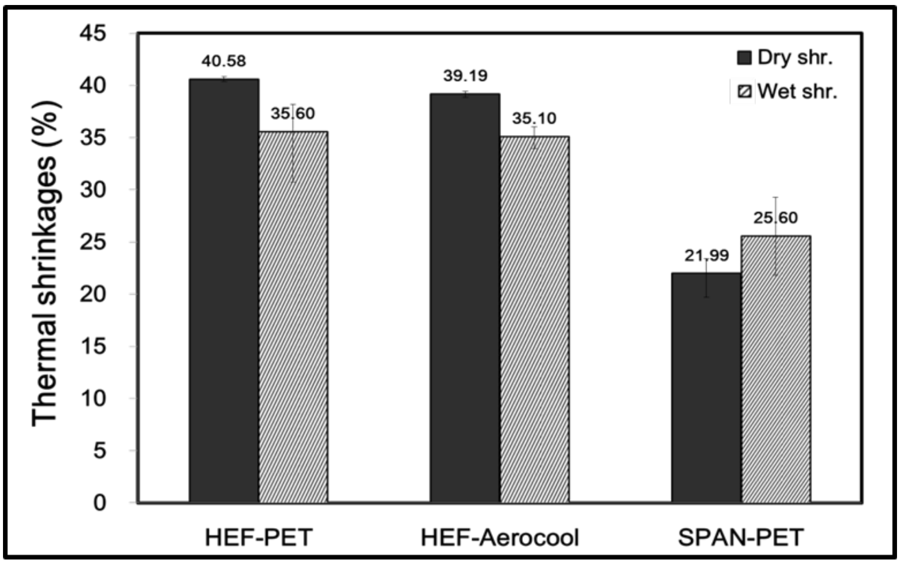


Figure 5. Thermal shrinkage of the yarn specimens.

moisture affinity of HEF than that of the spandex fiber. The moisture absorption of the HEF-aerocool knitted fabric was higher than that of the HEF-PET one, which was attributed to the high hygroscopicity of aerocool due to the capillary effect of the noncircular cross section of aerocool fiber. As shown in Fig. 7, the drying rate of the HEF-PET knitted fabric was lower than that of HEF-Aerocool and span-PET knitted fabrics, which appears to be due to the high open space because of self-extension of HEF fiber and the high wicking property of the HEF-aerocool knitted fabric followed by moisture absorption. Figure 8(a) shows a noncircular cross section of Aerocool fiber by SEM. Figure 9 explains the high open space of HEF knitted fabric. As shown in Fig. 9, the hygral expansion of HEF-PET and HEF-aerocool knitted fabrics were higher than that of the span-PET knitted fabric. These elongated lengths of the wale and course on the knitted structure make it a high open space, which results in a shorter drying time. The HE of the HEF knitted fabrics ranged from 5% to 6%; however, the spandex knitted fabric ranged from 1% to 3%, which makes a larger open space on the course and wale of knitted fabric, and the absorbed water and moisture can easily go out through the large open space. Figure 8(b) shows cross sections of the HEF by SEM.

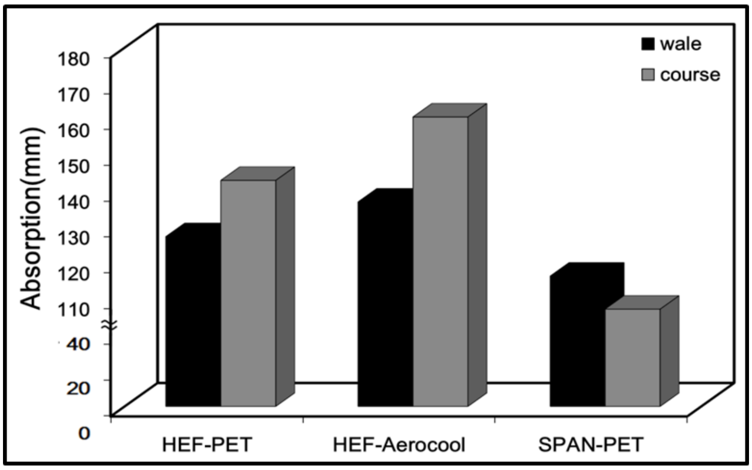


Figure 6. Absorption of the knitted fabric specimens.

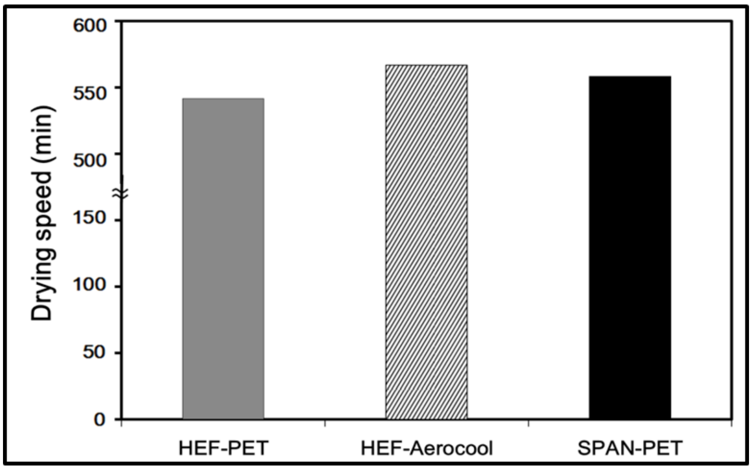
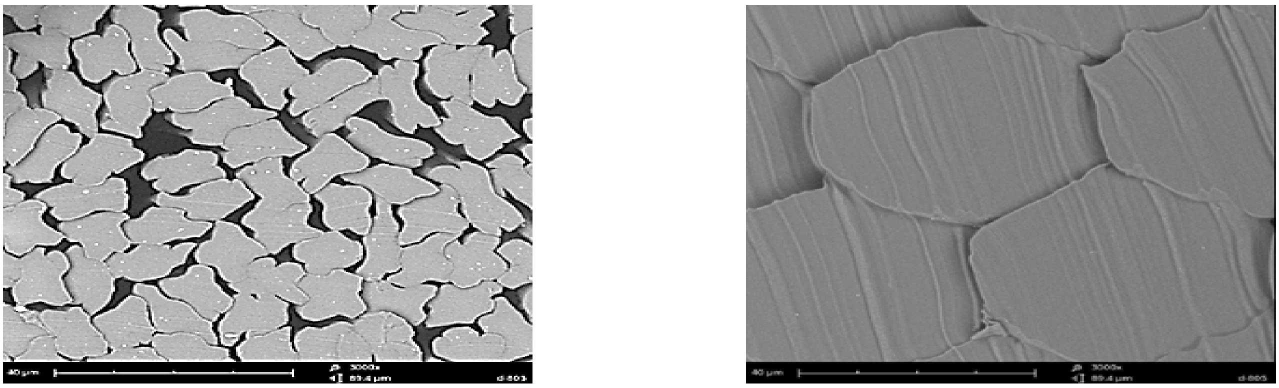


Figure 7. Drying characteristics of the knitted fabric specimens.



(a) (b)

Figure 8. SEM image of the yarn cross section. (a) Aerocool and (b) HEF

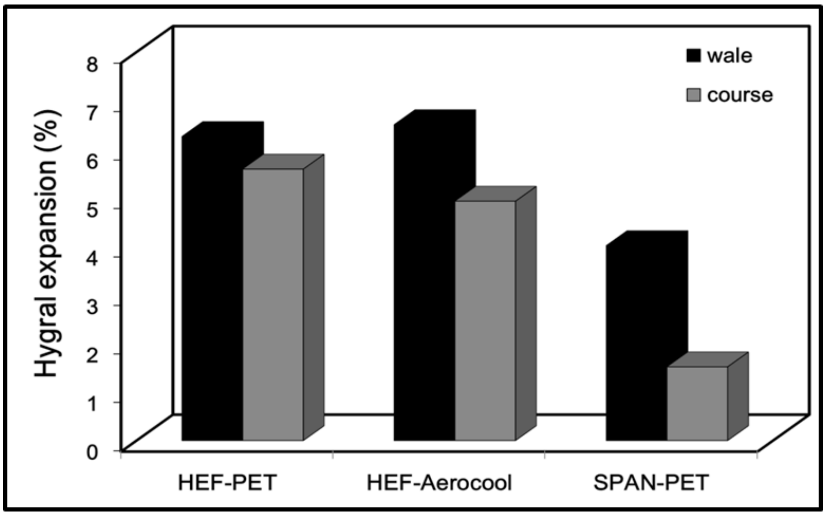


Figure 9. Hygral expansion of the knitted fabric specimens.

3.4 Wearing Comfort of Knitted Fabric Specimens

Tactile hand and wearing comfort properties of the HEF knitted fabrics are very important for evaluating the wearing performance of garments, which can be estimated by the mechanical properties of fabrics. Figure10 shows the mechanical properties of the three kinds of knitted fabric specimens measured using the FAST system. The ratio of each of the mechanical properties of the HEF-Aerocool and spandex-PET knitted fabrics to the mechanical properties of the HEF-PET knitted fabric is plotted on the Finger chart diagram in Fig.10. The low compressibility of the HEF-PET knitted specimen gives it a stiff hand. The bending rigidity and shear rigidity of the HEF-PET and HEF-aerocool knitted fabrics were much lower than that of span-PET, which deteriorates the wearing stability and shape retention of the HEF knitted garment. There was no difference in extensibility among the three kinds of knitted fabrics, and this phenomenon was estimated as no difference in the extensibility between HEF and spandex in the high extensible knitted fabric structure.

3.5 Dyeing Characteristics of Knitted Fabric Specimens

The dyeing performance of the HEF moisture responded elastic fiber was examined in comparison with the dyeing property of the spandex elastic fiber knitted fabric. Figure 11 shows the K/S of three kinds of knitted fabric specimens according to the dyeing temperature and time. As shown in Fig. 11, the K/S of HEF-PET knitted fabric was higher than that of the HEF-aerocool and span-PET knitted fabrics. This appears to be due to the high diffusion rate and dissolution speed of dye-stuff inside HEF-PET covered yarn by the water-soluble property and hygroscopicity of ionomer in HEF polymer. In addition, the K/S of the HEF-aerocool knitted fabric was lower than that of the HEF-PET knitted one, which appears to be caused by the lower dye-affinity because of the hydrophobic property and noncircular cross section of the aerocool fiber. This shows that the good dye affinity of HEF can be obtained at the yarns

covered with the circular cross section and nonhydrophobic PET filament. In addition, the K/S of the three kinds of knitted fabrics increased with increasing dyeing temperature; however, there was little difference in K/S between 30 and 60 min of dyeing time. A rapid increase in K/S was observed at temperatures between 90 and 100°C. Table 5 lists the color fastness to washing of the knitted fabric specimens. As shown in Table 5, the color fastness by rubbing fabrics, such as acetate and nylon was third grade, respectively. On the other hand, the color fastness by cotton, PET, wool, and acrylic rubbing fabrics showed a good value as the fourth and fifth grades, respectively

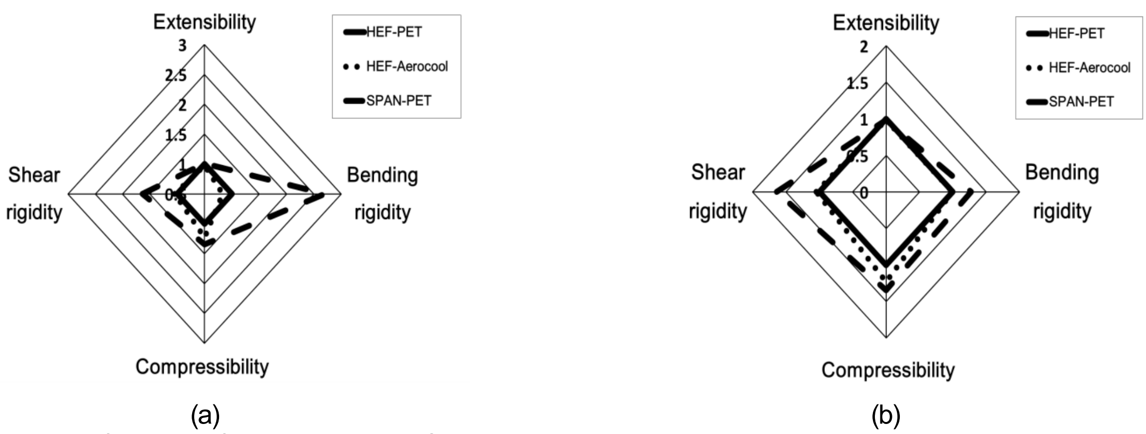


Figure 10. Finger chart of the knitted fabric specimens. (a) Course and (b) wale.

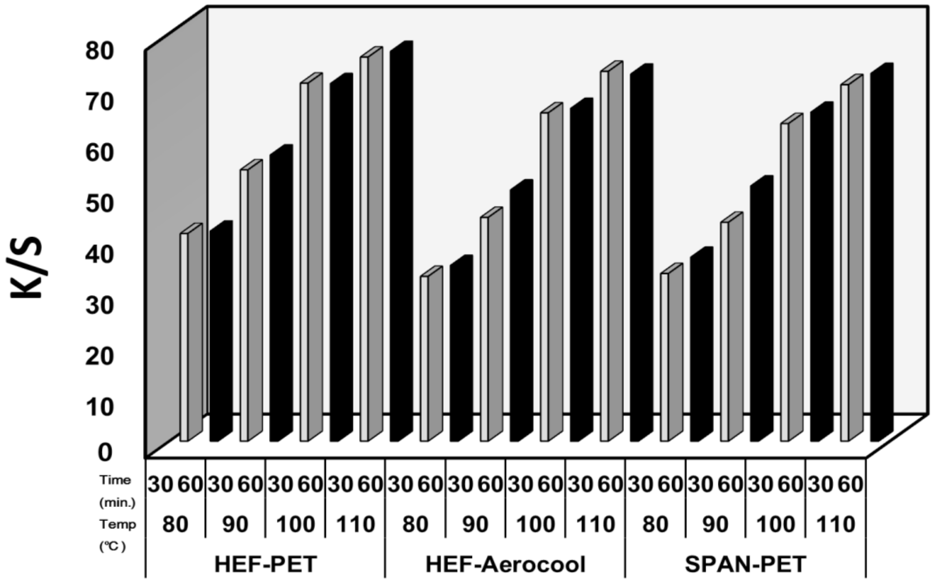


Figure 11. K/S of the knitted fabric specimens.

Table 5. Color fastness to washing of the knitted fabric specimens.

			Acetate			Cotton			Nylon			Polyester			Acrylic			Wool		
Temperature (°C)	**Time (min)**	**Mass (g/yd)**	**HEF- PET**	**HEF- Aerocool**	**SPAN- PET**	**HEF- PET**	**HEF- Aerocool**	**SPAN- PET**	**HEF- PET**	**HEF- Aerocool**	**SPAN- PET**	**HEF- PET**	**HEF- Aerocool**	**SPAN- PET**	**HEF- PET**	**HEF- Aerocool**	**SPAN- PET**	**HEF- PET**	**HEF- Aerocool**	**SPAN- PET**
80	**30**	**170**	3	3	3	4	4	4	3	3	3	4	4	4	4-5	4-5	4-5	4	4	4
	60	**170**	3	3	3	4	4	4	3	3	3	4	4	4	4-5	4-5	4-5	4	4	4
90	**30**	**170**	3	3	3	4	4	4	3	3	3	4	4	4	4-5	4-5	4-5	4	4	4
	60	**170**	3	3	3	4	4	4	3	3	3	4	4	4	4-5	4-5	4-5	4	4	4
100	**30**	**170**	3	3	3	4	4	4	3	3	3	4	4	4	4-5	4-5	4-5	4	4	4
	60	**170**	3	3	3	4	4	4	3	3	3	4	4	4	4-5	4-5	4-5	4	4	4
110	**30**	**170**	3	3	3	4	4	4	3	3	3	4	4	4	4-5	4-5	4-5	4	4	4
	60	**170**	3	3	3	4	4	4	3	3	3-4	4	4	4	4-5	4-5	4-5	4	4	4

4. Conclusions

The physical properties of intelligent coolness yarn (HEF) and its knitted fabrics with MRT property were investigated.

The tenacity of the HEF-PET covered moisture respondable yarns was slightly lower than that of HEF-aerocool and span-PET covered yarns, but although the initial modulus of HEF-PET was higher than that of the span-PET covered yarn, it was not serious for the weavability and knittability in weaving and knitting processes.

The wet and dry thermal shrinkages of the HEF covered moisture respondable yarns ranged from 35% to 40%, which were much higher than those of the span-PET covered yarns. The high thermal shrinkage characteristics of the HEF covered yarns need to be considered as a process design point in dyeing and finishing processes.

The moisture absorption and drying properties of the HEF covered knitted fabric were superior to those of the span-PET covered knitted fabrics. These phenomena were attributed to the good moisture affinity of HEF and high open space because of the self-extension of HEF fiber. The self-expansion characteristic of the HEF knitted fabric was observed by high HE (5–6%) through moisture absorption.

The tactile hand property of HEF covered knitted fabric was not soft compared to span-PET knitted fabric by the low compressibility, and the shape retention during the wearing of the HEF covered knitted fabric was no better than that of the span-PET knitted fabric because of the low bending and shear rigidity.

The dye affinity(K/S) of the HEF-PET knitted fabric was better (higher) than that of span-PET knitted fabric and the fastness to washing of the HEF knitted fabric to rubbing fabrics, such as cotton, polyester, acrylic, and wool, showed a relatively good result between the fourth and fifth grades.

This study showed that the moisture absorption and drying properties of HEF-PET covered yarns and their knitted fabrics showed good results compared to spandex-PET knitted fabrics because of good moisture affinity of HEF and high open space by self-extension of HEF fiber. Although the tactile hand and shape retention properties of the HEF covered yarn knitted fabrics were no better than those of spandex-PET knitted fabric, the dye affinity and fastness to the washing of HEF knitted fabric were better than those of the spandex-PET knitted fabric.

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References

[1] Bona, M. (1994). Textile quality. Torino: TEXILIA, 312.

[2] Choi, K., Cho, G., Kim, P. and Cho, C. (2004) Thermal Storage/Release and Mechanical Properties of Phase Change Materials on Polyester Fabrics. Textile Research Journal, 74(4), 292-296.

[3] Choi, K., Chung, H., Lee, B., Chung, K., Cho, G., Park, M., Kim, Y. and Watanuki. S. (2005). Clothing Temperature Changes of Phase Change Material-Treated Warm-up in Cold and Warm Environments. Fibers and Polymers, 6(4), 343-347.

[4] Han, J. S. (2014). MRT fiber. Textopia. Retrieved 03 27, 2014. Web site: http://www.textopia.or.kr.

[5] Huvis. Intelligent Functional Fiber, Huvis Home Page. Retrieved 03 27, 2014. Web site: http://www.huvis.com.

[6] Mather, R. R. (2001). Intelligent Textiles. Rev. Prog. Color., 31, 36-41.

[7] Mondal, S. (2008) Phase Change Materials for Smart Textiles – An Overview. Applied Thermal Engineering, 28, 1536-1550.

[8] Shim, H., McCullough E. A. and Jones, B. W. (2001). Using Phase Change Materials in Clothing. Textile Research Journal, 71(6), 495-502.

[9] Shin, Y., Son, K. & Yoo, D.I. (2010). Development of Natural Dyed Textiles with Thermo-Regulating Properties. Thermochimica Acta, 511, 1-7.