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Development Processes and Property Measurements of Moisture Absorption and Quick Dry Fabrics

Abstract
In this study, a new type of honeycomb-patterned micro-porous polyester fibre was used to develop good moisture absorption and quick drying properties of woven fabrics. Details of the development and after-finish processes of the fabrics were illustrated. The water transport, vapour transmission and quick dry properties of the seven different end products were also investigated. It was evident that weaving parameters and after-finish processes are crucial factors in the fabric production process. The final products can also have good water transport and quick dry properties without additive treatment.

Key words: *micro-porous fibre, honeycomb structure, after-finish, water transport, vapour transmission, quick drying.*

Introduction

Polyester fibres are one of the main members of the synthetic family, which are widely used in garment materials due to their excellent physical and chemical characters. However, their hydrophobic property limits their broad application. Therefore, it is necessary to design a kind of polyester fibre with both a good hygroscopic character and quick dry property [1, 2].

When a person perspires, the sweat can be transported through the micro-porous structure of functional fabrics to the surface and then evapourates, which makes human skin feel dry and comfortable. Profiled fibres are widely used to produce moisture absorption and quick dry fabrics in the market worldwide, such as the tetra-channel fibre “Coolmax” by DuPont of the U.S. and the hollow fibre “Welky” by Teijin of Japan etc. [3]. The air trapped inside of a hollow channel fibre can serve as a kind of thermal insulation material which reduces the weight of textiles and keeps the body warm[4 - 6]. However, profiled polyester fibres cannot improve all the disadvantages of traditional polyester, for example a blend of vegetable or animal fibres may reduce water transport and quick dry properties, and the lack of anti pilling property and high temperature dyeing needs more energy etc.

In this paper, moisture absorption and quick dry fabrics were developed using a new kind of polyester fibre with a micro-porous honeycomb structure fibre. Details of the design processes and after-finish technology are illustrated. Measurements of the water transport, water vapour transmission and quick dry properties of the final products were also conducted and investigated.

In the paper, we use a new kind of polyester fibre with a micro-porous honeycomb structure to develop moisture absorption and quick dry fabric. In the market profiled fibres are widely used for making such fabrics. No study has yet reported on honeycomb micro-porous fibre.

Development processes

SEM images and pore size

A kind of polyester fibre with a micro-porous honeycomb structure fibre was developed by Zhejiang Honjoy Color Polyester Co. Ltd. of China [7], two SEM images of their lengthwise section were shown in ***Figure 1***. It was observed that there are mainly two kinds of pores on the fiber surface. One type of pore has a long channel structure, which is named as linear channel pore (LCP); another type of pore has an ellipse structure, which is named as ellipse pore (EP). These two types of pores can greatly increase the fiber specific area, which enormously enhanced the water transport property of fiber assembles.

The major diameter, minor diameter and pore surface area of these micro-pores were measured using JEOL Smile View software for image processing [8], as seen in ***Figure 2***. It was found that the average major diameter, minor diameter and pore surface area of 1,000 LCPs are 5.99 um, 1.03 um and 6.18 um^2 respectively. Similarly, the average major diameter, minor diameter and surface area of 1,000 EPs are 0.49 um, 0.26 um, and 0.099 um^2 respectively.

Weave specifications

The warp yarn used was a kind of normal draw textured yarn (DTY) with a linear density of 16.7 tex, and weft yarns were micro-porous polyester yarns but of different linear density. All the fabrics were of plain or twill weave and produced on

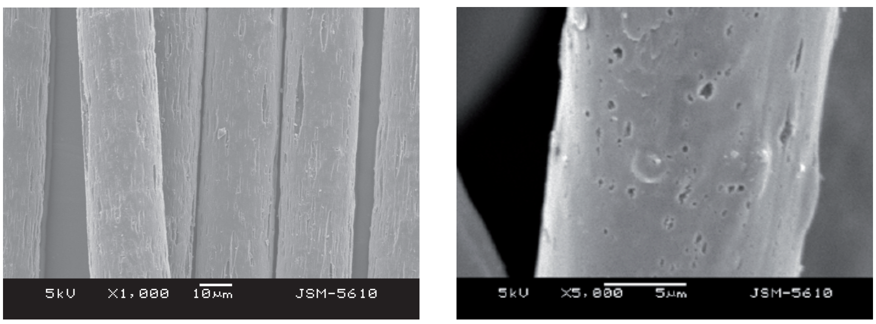

Figure 1. *SEM images of honeycomb-patterned micro-porous fiber; a) linear channel pores (LCP) on fiber surface; b) ellipse pores (EP) on fiber surface.*

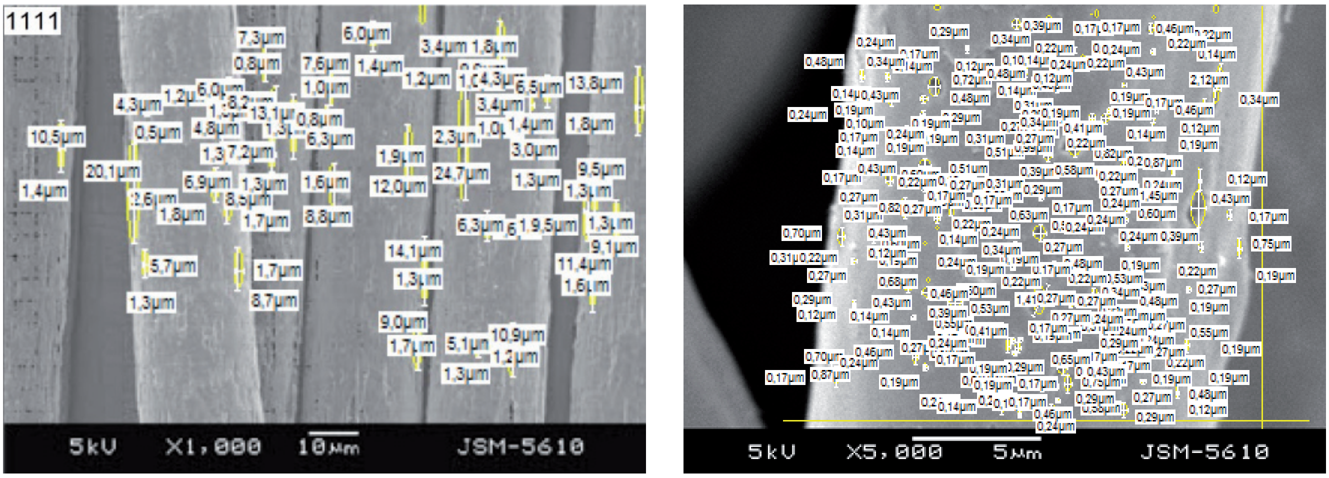

***Figure 2.** Measured pore sizes by JEOL SMile View software.*

a Toyota JAT710 air-jet loom. The weaving specifications are shown in ***Table 1***.

After-finish process

The after-finish processes of the fabrics were as follows: shrink finish, scouring, rinsing, dyeing, soaping, rinsing, dewatering, fabric setting.

In the scouring process, additives were added at room temperature (20 ˚C), then the temperature was raised to 90 ˚C and maintained for 30 minutes. The temperature was then lowered to 65 ˚C, and the fabrics were washed in clean water for about 20 minutes.

In the fabric dyeing process, low temperature dyeing was used, which can save a large of amount energy. The dyeing temperature must be maintained at 90 ˚C for 40 minutes, and the maximum temperature should not be more than 100 ˚C.

All the fabrics were sufficiently washed in clean water after the dyeing process to ensure the micro holes did not get clogged with the pigments. The process was as follows: the fabrics were washed for 20 minutes at a temperature of 80 ˚C, then lowered to 65 ˚C and repeatedly washed in changed clean water for approximately 15 minutes. The most important final finishing process is the fabric setting, in which the fabric setting temperature should not exceed 140 ˚C. The over-feed ratio of fabrics 1 to 5 was set at 8 ~ 10%.

In order to study the influences of additive treatments on fabric water transport, vapour transmission and quick drying properties, fabrics 2 and 4 were treated with a kind of hydrophilic additive, while fabric 5 was treated with a silicon softening agent.

Product specifications

The warp and weft density, area density, and thickness of the final products were measured according to ISO7211/2-1984, ISO3801-1977 and ISO5084-1977, respectively [9 - 11]. The cover factors of the fabrics were also calculated. The specifications of each fabric are listed in ***Table 2***.

Methodology

Water transport property

The water transport rate was measured according to the vertical fabric strip wicking test. One end of a strip (30 cm × 2.5 cm) was clamped vertically with the dangling end immersed to about 3 mm in distilled water at an ambient temperature of 20 ± 2 ˚C and relative humidity of 65 ± 2 % [12]. The height to which the water was transported along the strip was continuously measured at 5 minute intervals for 30 minutes and reported in centimetres (cm). All the tests were conducted in strict conformance with the National Chinese Standard FZ/T01071-2008 [13].

Vapour transmission property

The traditional wet cup test was used according to ASTM E96-95 [14]. A cup was filled with distilled water leaving a small gap (0.75 inch to 0.25 inch) of air space

***Table 1.** Weaving specifications*

Fabric No.	1, 2	3, 4, 5	6	7
Weave	plain	twill	plain	twill
Warp yarn	16.7 tex DTY (PET)			
Weft yarn	15 tex/2 PET		30 tex PET	
Total ends number	6144		5616	7722
Reeds, space/cm	180		175	175
Reeds, number/cm	17		16	11
Weaving density, ends/cm	21		26	28

***Table 2.** Fabric specifications.*

Fabric No.	Fabric count, /per 10 cm)	Cover factor, %			Area density, g/m²	Thickness, mm
		warp direction	weft direction	total		
1	470 × 260	73.65	52.23	87.41	197.3	0.437
2	450 × 260	70.52	52.23	85.92	190.4	0.413
3	350 × 270	54.85	54.24	79.34	210.6	0.557
4	340 × 270	53.28	54.24	78.62	217.7	0.560
5	330 × 270	51.71	54.24	77.90	210.3	0.543
6	460 × 260	69.48	68.02	90.24	235.2	0.357
7	430 × 280	64.95	73.26	90.63	284.1	0.517

Table 3. Drying rate of textiles

Remaining water ratio after 40 minutes, %		Grade	Classification
knitted fabric	woven fabric		
X < 5	X < 3	5	excellent
5 ≤ X < 15	3 ≤ X < 10	4	very good
15 ≤ X < 40	10 ≤ X < 30	3	good
40 ≤ X < 60	30 ≤ X < 50	2	moderate
X ≥ 60	X ≥ 50	1	fair

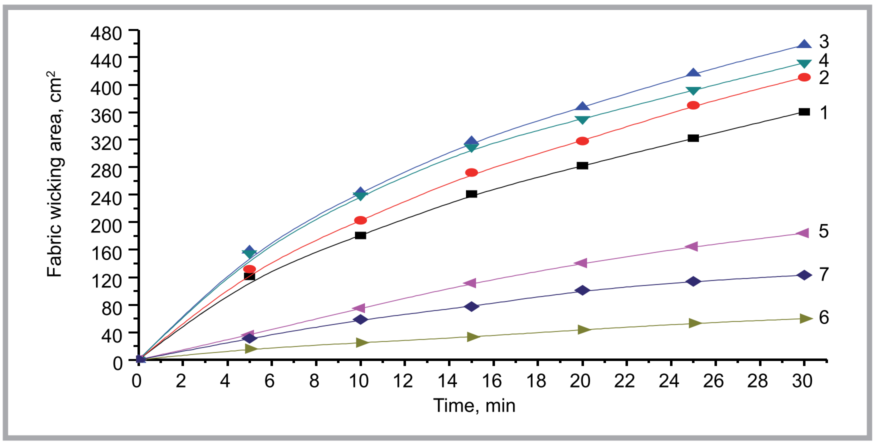

***Figure 3.** Wicking area of the fabric with time.*

between the specimen and water. The cup was then sealed to prevent vapour loss, except through the test sample. The initial weight of the specimen was taken and then periodically weighed over time until the results became linear. Caution must be used to assure that all weight loss is due to water vapour transmission through the specimen. A 4 × 4 inch specimen is often used, as it needs to fit exactly over the liquid container. The experiments were carried out in an ambient temperature of 38 ˚C, a relative humidity of 90% and air velocity of 0.3 ~ 0.5 m/s. The result is usually expressed as grams per 24 hours per square meter (g/24 h·m^2). The water vapour transmission rate can be expressed as:

$$WVT = 24 \cdot \Delta m/(S \cdot t)$$

where, WVT is the water vapour transmission rate in g/(24 h·m^2); Δm is the assemble weight decreased after one hour in g; S is the measurement area of the fabric sample in m^2; t is the test time in h.

Quick dry property

The quick dry property is the drying rate of textiles wetted by water (perspiration). The quick dry rate of the fabric was measured according to Taiwan Standard FT-FS-FA-004. All the fabric samples were put in a climatic chamber, where there were standard conditions: 20 ± 2 ˚C, 65 ± 3% relative humidity. The procedures were as follows[15]: the specimen was cut to 5 cm × 5 cm square, put with the face side up on the weighing plate of the balance with three-decimal precision, and the dry weight w_f (in grams) was recorded by a computerised system. A micropipette was used to drip water of 0.2 ml in volume from a one centimetre height above the centre of the testing square, and the wet weight w_0 (in grams) was recorded. The change in water w_i (in grams) was continuously recorded at 10-minute intervals for the 80-minute observation. The "Remained Water Ratio" (*RWR*) was calculated by the equation below to express the change in water remaining in the specimen by time, and to draw an evaporating curve from 100 % to 0 %. The 40th minute *RWR* was chosen to be the index for the assessment. The equation is expressed as

$$\text{Remained water ratio at the } 40^{th} \text{ minute in } \% = (w_i - w_f)/(w_0 - w_f) \times 100\%$$

If necessary, the result can be indicated as "non-washed" or "after X-time washed". The recommended washing condition is a 5-time wash according to AATCC 135-1995 [16]. Details of the drying rate are listed in ***Table 3***.

The quick dry rate was divided according to Taiwan Standard FTTS-FA-004, Test Method of Specified Requirements of Moisture Transferring and Quick Drying Textiles.

The standard gives limits for woven fabric and knitted fabric, probably because of their different structure: in a knitted fabric the yarn is arranged in a series of interlocking loops, while in woven fabric the warp and weft yarn cross each other.

Results and discussions

Water transport property

The wicking height along the fabric warp or weft directions cannot characterise the total water transport property. As a result, it was suggested that the wicking area of the fabric symbolised the fabric water transport property, which can be expressed as:

Wicking area of the fabric in cm^2 is the product of wicking height along fabric's warp direction in cm and the wicking height along fabric's weft direction in cm.

Curves of the wicking area of the fabric with time are shown in ***Figure 3***.

It can clearly be seen that the wicking area of the fabric increased significantly more slowly with the test time, probably because the fabric wicking speed became slower as the test progressed . The cover factor of fabrics 6 and 7 are the highest of all, while their wicking areas were the worst, which was probably because a high cover factor can prevent water from penetrating the fabric. Simple waterproof fabrics were developed according to this principle; they have a cover factor of 2000 or more [17]. It is evident that the fabric cover factor can greatly influence the wicking area. Obviously, a lower cover factor can, to some extent, enhance both the wicking area and wicking speed. It seems that additive treatments have no influence on the fabric water transport property.

Vapour transmission property

The water vapour transmission rate of the fabric is shown in ***Figure 4***. Fabric 2 had a *WVT* value of 608 g/(24 h·m^2), which was 20 % more than fabric 7. The reason was mainly attributed to the hydrophilic additives, which can enhance the water vapour transmission property. The fabric cover factor and thickness also determine the vapour transmission property [18]. Fabric 7 has the highest cover factor, and its construction is the tightest, which prevents water vapour from transmitting through the fabric. Although the thick-

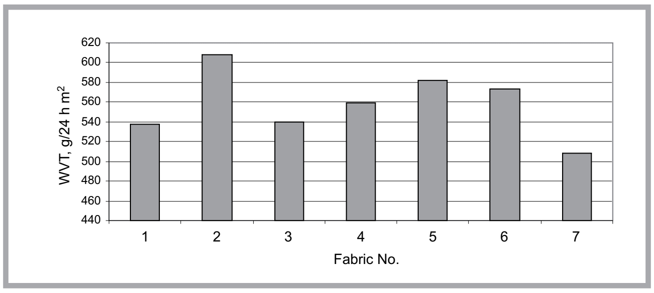

Figure 4. Vapour transmission rate of the fabric.

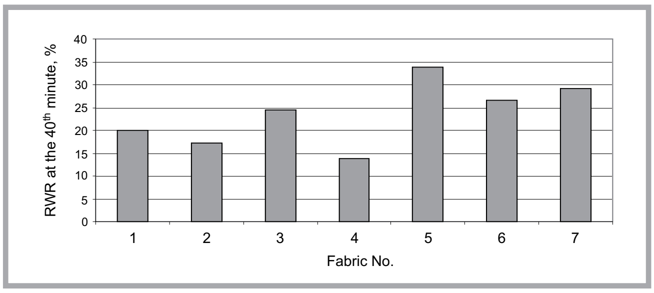

Figure 5. RWR at the 40th minute.

ness of fabric 6 is lower than that of fabric 2, the water vapour transmission rate of fabric 2 is much higher than that of fabric 6, which is due to the hydrophilic additive treatment of fabric 2. It indicates that hydrophilic additive treatment can improve the water vapour transmission property of the fabric.

Quick dry property

The remaining water ratio (*RWR*) at the 40^{th} minute was calculated, see ***Figure 5***.

After 40 minutes, the remaining water ratio of all the fabrics was less than 35 %. Though the construction of fabric 5 is nearly the same as fabric 3 and 4, its drying speed was the lowest. This was attributed to treatment using a silicon softening agent , which can significantly reduce the quick dry property of the fabric.

Table 4 shows the fabric dry grade and classification. The dry grade of fabric 5 is grade 2, the moderate ones and others are grade 3, which indicates the fabrics have a good classification.

Conclusions

Moisture absorption and quick dry fabrics were developed using polyester fibre with a micro-porous honeycomb structure. Low temperature dyeing was adapted in the after-finish process, which can save large amounts of energy. Based on the measurements of the properties, the products showed effective water transport and good quick dry properties. It was found that the fabric cover factor determines the water transport property, and that additive treatment has no significant influence on the wicking area of the fabric. The water vapour transmission rates of those fabrics range from 508 g/(24 h·m^2) to 608 g/(24 h·m^2). It was also found that treatment using a silicon softening agent was not appropriate for moisture absorption and quick dry fabrics.

Table 4. *Fabric dry grade and classification.*

Fabric No.	Grade	Classification
1	3	good
2	3	good
3	3	good
4	3	good
5	2	moderate
6	3	good
7	3	good

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