

Properties of honeycomb polyester knitted fabrics

A F Feng

Hebei University of Science and Technology, Shijiazhuang, Hebei, China

E-mail: fengaf774@sohu.com

Abstract. The properties of honeycomb polyester weft-knitted fabrics were studied to understand their advantages. Seven honeycomb polyester weft-knitted fabrics and one common polyester weft-knitted fabric were selected for testing. Their bursting strengths, fuzzing and pilling, air permeability, abrasion resistance and moisture absorption and perspiration were studied. The results show that the honeycomb polyester weft-knitted fabrics have excellent moisture absorption and liberation. The smaller their thicknesses and area densities are, the better their moisture absorption and liberation will be. Their anti-fuzzing and anti-pilling is good, whereas their bursting strengths and abrasion resistance are poorer compared with common polyester fabric's. In order to improve the hygroscopic properties of the fabrics, the proportion of the honeycomb microporous structure modified polyester in the fabrics should not be less than 40%.

1. Introduction

Polyester fabrics have so many advantages like excellent elasticity, wrinkle resistance, durability etc, that they are widely used in the production of various types of clothing. However, in terms of moisture absorption, the clothing made from them is poor in comfort, and also easy to produce static electricity which brings about dust absorbing and clinging to body. Therefore, the main focus of this study on polyester fibers is to give hygroscopic polyester fiber with certain moisture absorption. It is well known that many polyester fibers with moisture wicking performance come into the world [1].

Honeycomb polyester fiber is developed through physical and chemical modification by "Shangyu Hongqiang color polyester Co. Ltd.". On its surface and in the interior, there are a lot of micropores which absorb and release moisture quickly and dissipate heat fast. What is more, cationic dyes can be used to dye the fiber at 100°C and atmospheric pressure with a short time and a high dye-uptake, so that the energy can be saved and the production cost can be decreased. Because the honeycomb polyester fiber is softer and fluffier than common polyester fibers, its fabric has better drape and air permeability than common polyester fibers' fabric does [2-6]. It can be widely used in various kinds of clothing and accessories [7], and will also be used in other areas such as bedclothes, washcloth, military uniforms and so on. Since army training, exercises, and fights are usually performed in harsh natural conditions, especially in hot weather, one's mood and health will be affected by excessive sweating and overheating. Therefore, if he wears clothing that is cool and comfortable, the troubles would be solved easily and quickly [7-9]. Water vapor mainly diffuses through the micropores in a fabric and capillary action, and it is absorbed by the fiber and evaporates in a lower vapor pressure inside of the fabric [10]. Domestic scholars have already extensively studied the moisture absorption and perspiration of fabrics [11-19]. Wicking behavior of fabrics was widely investigated [20-28].



The bursting strength, wear resistance, fuzzing and pilling, air permeability and moisture absorption and perspiration of honeycomb polyester knitted fabrics were investigated and compared with those of an ordinary polyester knitted fabric to provide theoretical basis for the product development, production and application of the honeycomb polyester.

2. Experimental

2.1. Materials

Seven weft-knitted fabrics with honeycomb polyester fiber and one common polyester knitted fabric were prepared and their parameters are shown in table 1.

Table 1. Parameters of weft-knitted fabrics

Sample No.	Fiber and yarn count	Structure	Thickness (mm)	Area density ($\text{g} \cdot \text{m}^{-2}$)	Density (loops \cdot 25cm^{-2})
1	16.4 tex 80%H/20%B blended yarn	Jersey	0.804	Article I. 178.00	9 582.4
2	14.8 tex 80%H/20%B blended yarn, 2.2 tex lycra	Jersey	0.838	188.98	13 106.8
3	14.8 tex 65%H/35%B blended yarn	Jersey	0.609	130.66	6 663.0
4	9.8 tex 60%H/40%B blended yarn, 2.2 tex lycra	Jersey	1.045	185.30	14 481.0
5	11.8 tex 40%H/60%B blended yarn	Jersey	0.671	117.79	9 901.3
6	14.8 tex 100%H	Mesh	0.916	212.55	7 584.1
7	14.8 tex 70%H/30%B blended yarn	Mesh	1.185	330.04	11 029.9
8	14.8 tex 100% common polyester	Interlock	0.801	269.89	10 732.8

*Note: where H= honeycomb polyester and B=bamboo pulp fiber.

2.2. Methods and instruments

2.2.1. Bursting strength. The bursting strengths of the fabrics were measured using YG065 Electronic Cylinder Bursting Strength Tester according to “GB/T 19976—2005 Textiles—Determination of bursting strength—Steel ball method”.

2.2.2. Abrasion resistance. The damaged cycles of a fabric were measured using Y522 Fabric Abrader according to “ASTM D3884-2009 Standard Guide for Abrasion Resistance of Textile Fabrics (Rotary Platform, Double-Head Method)”.

2.2.3. Fuzzing and pilling. The fuzzing and pilling grades of the fabrics were evaluated using YG502 Fuzzing and Pilling Tester according to “GB/T 4802.1—2008 Textiles—Determination of fabric propensity to surface fuzzing and to pilling—Part 1: Circular locus method”.

2.2.4. Air permeability. The tests were carried out using an Digital Fabric Air Permeability Tester Y461E-II according to “GB/T 5453—1997 Textiles-Determination of the Permeability of Fabrics to Air”.

2.2.5. Moisture absorption and perspiration.

(1) *Water absorption.* Water absorption was evaluated by the following equation according to “GB/T 21655.1—2008 Textiles—Evaluation of Absorption and Quick-Drying—Part 1: Method for Combination Tests”:

$$A=(m-m_0)/m\times 100 \quad (1)$$

Where A is the water absorption rate of the sample (%), m is the original mass (g) of the sample and m_0 is the mass (g) of the sample after water soaked dropping.

(2) *Moisture permeability.* The moisture permeability was evaluated by the following equation according to “GB/T 12704—1991 Fabrics—Determination of water vapour transmission rate (WVT , $g/(m^2\cdot h)$)—Dish method”:

$$WVT = \frac{\Delta m}{S \cdot t} \quad (2)$$

where Δm is the difference (g) of the two masses of the same test assembly, S is the test area (m^2) of the sample and t is the test time (h).

(3) *Capillary effect.* The capillary effect of the sample was measured using YG (B) 871 Capillary Effect Tester according to “FZ/T 01071-2008 Textiles—Test method for capillary effect”.

3. Results and discussion

The test results of the bursting strength, abrasion resistance, fuzzing and pilling resistance and air permeability of the samples are shown in table 2.

Table 2. Properties of the weft-knitted fabrics.

Sample No.	Bursting strength (cN)	Abrasion resistance (cycle)	Fuzzing and pilling (grade)	Air permeability rate ($mm\cdot s^{-1}$)
1	173.5	52	4	1114.36
2	160.7	126	3.5	580.32
3	165.9	54	4	2152.66
4	106.6	220	4	626.93
5	149.2	57	4.5	1997.88
6	238	127	4.5	989.13
7	352.9	241	4	490.55
8	612.1	788	4	575.71

3.1. Bursting strength and discussion

The bursting strengths of the knitted fabrics with the honeycomb microporous polyester are smaller than that of the pure polyester knitted fabric. This is because the strengths of the honeycomb microporous polyester and bamboo pulp fiber are both smaller than that of the ordinary polyester. What is more, the pure polyester fabric has interlock structure.

It has been found that there is a positive correlation between the bursting strengths and area densities of 7 fabrics with the honeycomb microporous polyester, while there are no correlation between the bursting strengths and the honeycomb polyester contents, or fabric thicknesses, or total densities after the influences of their honeycomb contents, thicknesses, area densities and total densities on the bursting strength were analyzed. The bursting strength of fabric 7 is the largest, the bursting strength of fabric 6 (pure honeycomb polyester) is second larger, and others bursting strengths are smaller. Though both Fabrics 6 and 7 are mesh structures, the thickness, area density and total density of fabric 7 are larger than those of fabric 6. Fabrics 1 to 5 are all jersey and their area densities and thicknesses are basically smaller than those of fabrics 6 and 7, so their bursting strengths are also

smaller. There is positive correlation between the bursting strength and yarn finenesses of fabrics 1 to 5 by regression analysis, as shown in figure 2. The finer the yarns are, the smaller their fabrics. Because the yarn of fabric 4 is the finest, its bursting strength is the smallest.

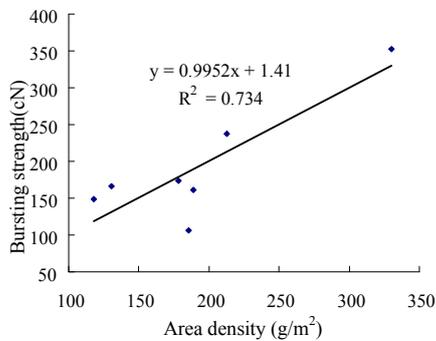


Figure 1. Relationship between bursting strengths and area densities of 7 honeycomb fabrics

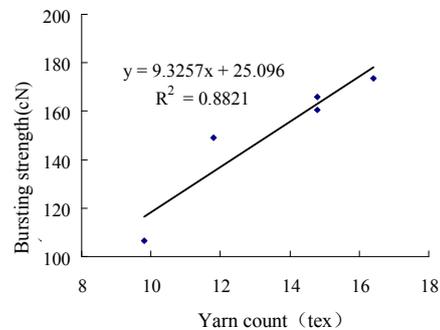


Figure 2. Relationship between bursting strengths and yarn counts of 5 honeycomb jersey fabrics

3.2. Abrasion resistance and discussion

The abrasion resistance of the pure common interlock polyester fabric is much better than that of the fabrics with honeycomb polyester, and the reasons are shown as in the fabric bursting strength. It has been found that there are some correlations between the abrasion cycles and the thicknesses and area densities of 7 fabrics with the honeycomb polyester, but there are no correlation between the abrasion cycles and the total densities, after the influences of their area densities, thicknesses and total densities on the abrasion resistance were analyzed. The regression equation between the abrasion cycles and area densities is $y=0.8911x-45.71$, $R^2=0.6143$ with certain relevance and the relationship between the abrasion cycles and the thicknesses is shown in figure 3. In general, by increasing the thicknesses of the fabrics, their abrasion resistance is also increased. The abrasion resistance of fabric 6 is the best whereas the abrasion resistance of fabric 1, 3 and 5 is poor. In addition, adding Lycra to the fabrics helps to improve the abrasion resistance. Fabrics 2 and 4 contain lycra, so they have relatively good abrasion resistance, although the yarn of fabric 4 is the finest. This may be the fabrics with Lycra having good extensibility and elasticity to improve their abrasion resistance.

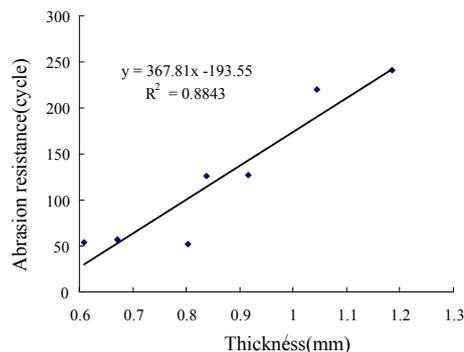


Figure 3. Relationship between abrasion cycles and thicknesses of 7 honeycomb fabrics

3.3. Fuzzing and pilling and discussion

During wearing and maintaining garments, they are often subjected to a variety of abrasions, which not only can make garments wear, but will make them fuzz and pill. The fabric fuzzing and pilling will not only affect the appearance surface gloss and wear resistance of clothing, but also influence its

comfort. All fabrics in test have good fuzzing and pilling resistance (table 2). The fuzzing and pilling resistance of the fabrics with the exception of fabric 2 (grade 3.5) have reached 4 grade and above. The fuzzing and pilling of knitted fabrics is influenced by raw materials, and other factors like yarn count and twist, fabric density, area density, thickness, and spandex [29]. Theoretically, the larger the density of the weft-knitted jersey fabric is, the better its fuzzing and pilling resistance is. The density of fabric 4 is the largest, followed by fabric 2, however, because of them containing Lycra, the fuzzing and pilling of fabric 2 is the worst and fabric 4 is the second lowest.

3.4. Air permeability and discussion

The air permeability of the fabrics with the honeycomb polyester except-fabric 7 is better than the air permeability of the common polyester fabric. Among 7 fabrics with the honeycomb polyester, the air permeability of fabric 3 is the best while fabric 7 is the worst.

After the influences of the area densities, thicknesses and total densities of 7 honeycomb polyester fabrics on the abrasion resistance were analyzed, and it was found that there is negative correlation between the air permeability and the thicknesses, which is shown in figure 4, and that there are no relationships between the total densities and area densities. In addition, there is a negative correlation between the air permeability and the thickness of the fabrics. The thinner the fabric is and the smaller the resistance when the air passes through the fabric, the better its air permeability is. The air permeability for fabric 7 is the worst because its thickness and area density are the largest. The air permeability of fabric 6 with larger area density and thickness is good because of its mesh structure. Although the yarn of fabric 4 is the finest, Lycra in it leads to it having both larger density which makes gaps in the fabric smaller [12] and larger thickness which makes air pass through a longer distance, so its air permeability is poorer. Fabric 2 also contains spandex and its thickness is large, so its ventilation is poor.

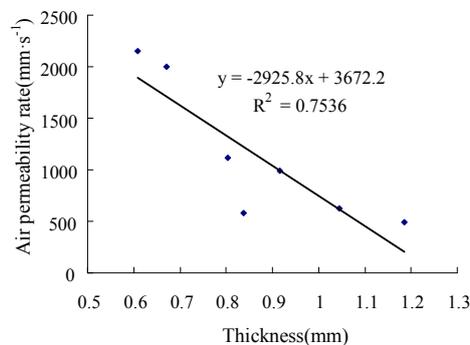


Figure 4. Relationship between air permeability rate and thicknesses of 7 honeycomb fabrics

Table 3. Results of moisture absorption and perspiration of the weft-knitted fabrics.

Sample No.	Water absorption rate (%)	Water vapour transmission rate($\text{g}\cdot\text{m}^{-2}\cdot\text{d}^{-1}$)	Capillary effect		
			Walewise wicking height(cm)	Coursewise Wicking height(cm)	Comprehensive value(cm^{-2})
1	185	279	11.8	12.4	146.32
2	197	223	12.5	13.5	168.75
3	252	290	13.2	11.0	145.20
4	257	275	13.2	12.8	168.96
5	258	309	13.6	13.8	187.68
6	190	306	12.2	10.6	129.32
7	209	289	17.1	16.6	283.86
8	134	211	4.9	6.4	31.36

3.5. Moisture absorption and perspiration and discussion

The results of the moisture absorption and perspiration of the fabrics are shown in table 3.

3.5.1. Water absorption and discussion. It can be seen from figure 3 that the water absorption rates (WAR) of fabrics 3, 4, 5 and 7 are more than 200% and meet the requirements of the moisture absorption rate for absorbent fabrics according to the standard “GB/T 21655.1-2008”. The water absorption rate of the common polyester fabric is the worst. The other fabrics except for fabric 6 among 7 honeycomb polyester fabrics are honeycomb polyester and bamboo pulp fiber blended ones. Bamboo pulp fiber is regenerated cellulose fiber with excellent moisture absorption, and the moisture regain of the honeycomb polyester is higher than ordinary polyester’s because of its microporous structure with large specific surface area. So the water absorption rates of 7 honeycomb polyester fabrics are higher.

The water absorption rate increases with the increase of honeycomb polyester fiber content. When the honeycomb polyester content reaches up to 40-65%, the water absorption rate is the maximum, and then it decreases with increasing honeycomb polyester content. The rate of the fabric is not only related to the water absorption rate of the fiber used, but also related to its structure, thickness, area density and so on.

When the fitting processes of the water absorption rate with the area density and thickness were done, it was found that fabric 4 had big deviation, therefore it was eliminated. The regression equations of the water absorption rates of 6 honeycomb polyester fabrics with their thicknesses and area densities are shown in figures 5 and 6.

The water absorption rates of the fabrics decreases with the increase of their area densities. That is why when the area densities of the fabrics are smaller, their structures are loose and their air rates are larger. Although the area density of fabric 8 is the largest, its structure is mesh and its thickness is the largest, which leads to looser and bigger air rate. Therefore fabric 8 has a bigger air rate.

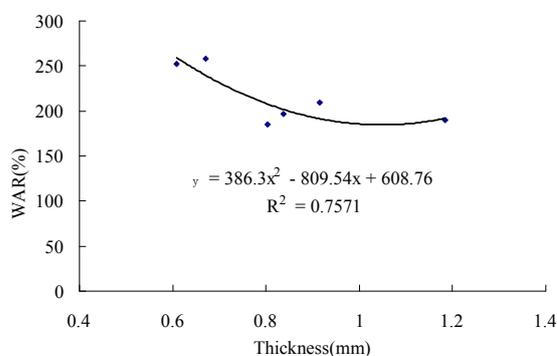


Figure 5. Relationship between water absorption rates and thicknesses of 6 honeycomb fabrics

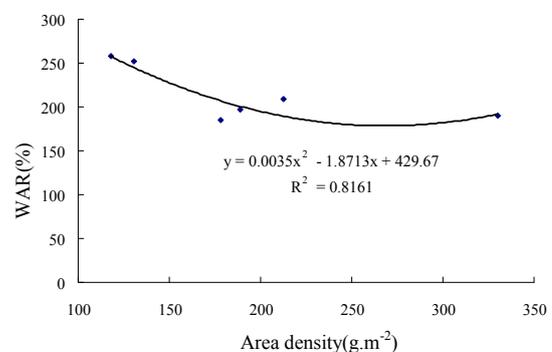


Figure 6. Relationship between water absorption rates and area densities of 6 honeycomb fabrics

3.5.2. Moisture permeability and discussion. It is known from figure 3 that the order of the water vapour transmission rates of the fabrics is 5 # > 6 # > 3 # > 7 # > 1 # > 4 # > 2 # > 8 # . The common polyester fabric has the worst water vapour transmission rate. There are no significant correlations between the water vapour transmission rate and the honeycomb polyester content, density, area density and thickness. Therefore, the moisture permeability of the honeycomb polyester fabrics is affected by various factors.

Because fabric 5 with the finest yarn has the least density and area density, which makes it loose and big gaps, there is no wonder that its moisture permeability is the best. The moisture permeability of fabric 6 is very good because it is made from pure honeycomb polyester. Owing to its density being

small, when the fiber absorbs moisture, its cross section does not expand, unlike other cellulosic fibers.

3.5.3. Capillary effect and discussion. On the basis of the standard “GB/T 21655.1-2008”, when the wicking height is either 10cm or higher than 10cm, the fabric is hygroscopic. Table 3 shows that all honeycomb polyester fabrics have excellent capillary effects. Their walewise and coursewise wicking heights are larger than 10cm. The walewise and coursewise wicking heights of fabric 7 are the largest with 17.1cm and 16.6cm respectively. The fabric has excellent wicking property because of its mesh structure with good wicking effect and high proportion of the honeycomb polyester (70%). The capillary effect of fabric 5 among the jersey knitted fabrics is the best. The walewise and coursewise wicking heights of the common polyester fabric are the lowest.

Combined with the water absorption test results, bamboo fiber has good moisture absorption and water absorption, whereas its moisture permeability is worse than that of the honeycomb polyester fiber. Therefore, when two fibers are blended with their ratio about 50% to 50%, their jersey weft-knitted fabrics have good wicking effects.

4. Conclusions

The honeycomb polyester weft-knitted fabrics have excellent moisture absorption and liberation. The smaller their thicknesses and area densities are, the better their moisture absorption and liberation. Their anti-fuzzing and anti-pilling is as good as the common polyester fabric's, while their bursting strengths and abrasion resistance are poorer compared with than the common polyester fabric's. If the fabrics with good hygroscopic property are developed, the proportion of the honeycomb microporous structure modified polyester in the fabrics should not be less than 40%.

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