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Development of tricot warp knitted fabrics with moisture management for casual shirt

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Abstract

Warp knitted mesh fabric was usually applied to sportswear due to good air transmission, but without multilayer structure and one-way transport property. In order to solve this problem, the miss-lapping structure was applied to examine the possibility to fabricate multilayer and improve water transport in warp knitting structure. Besides, the effect of thread type and warp density on comfort properties were also exploited to enhance the moisture management. The moisture management test, water vapor permeability and air permeability were examined. Long float at the back side in structure I formed by miss-lapping could improve liquid transport and air permeability, but slightly reduce water vapor permeability. With proper density, there existed the optimal one-way transport capacity and overall moisture management. Warp density in 20 cpc was an optimal parameter of knitting process. Taking advantage of miss-lapping, sample 5 where polypropylene was partly threaded on GB1 provided best moisture management, water vapor permeability and air permeability.

Keywords: Liquid transport, Water vapor permeability, Air permeability, Warp knit

Introduction

Personal and wearable thermal and moisture regulating products were developed to improve the comfort. A local heating device was designed to supply warm air to subjects' feet and calves directly. The environmental temperature decreased to 14 °C and 12 °C, subjects' thermal sensation for both feet and overall were increased significantly when local heating was supplied (Du et al., 2020). The moisture management property of fabrics significantly affected the moisture diffusion and temperature distributions in the cold protective clothing systems, and influenced the thermal and moisture sensations (Wang, 2007). The cotton-wool blended fabric with overall moisture management capability at 0.86 significantly improved the clothing system which contained 4 garment layers and total 9 fabrics. Besides, many advanced membranes were developed using different technique recently. For instance, a double-sided synergetic Janus textile was developed, featuring reversible diode-like water transportation and adjustable thermal convection upon temperature change (Wang et al., 2020). Tree-like structure driven water transfer in 1D fiber assemblies was invented (Mao et al., 2020). Multi-scaled, inter-connected hierarchical fibrous membranes for directional moisture transport was fabricated (Ahmed et al., 2020). Highly flexible monolayered porous membrane with superhydrophilicity-hydrophilicity was developed for unidirectional liquid penetration (Zhang et al., 2020). A double-layered fibrous mat of modified polypropylene/cotton fabric for the function of directional moisture transport was reported (Xu et al., 2020). However, those membranes are not suitable for reusable clothing material.

Many studies developed moisture management fabrics. A special knitting method of hydrophilic/hydrophobic materials was used to combine the "power pump" organizational structure with weft knitted seamless clothing, and strong unidirectional moisture transfer characteristics were obtained (Lin et al., 2015). Dynamic water pumping fabrics whose overall moisture management capacity id about 0.58 were made of polyester, cotton and Lycra in single jersey tuck stitch. The local breast skin temperatures of sports bra made of novel fabrics (33.43 ± 0.09 °C) were significantly lower than bras without dynamic moisture transfer properties (33.96 ± 0.06 °C). A cool elastic fabric was woven with intelligent cool fiber, which improved the wearing comfort (Kim et al., 2017). Aerocool-HEF (Huvis elastic fiber) covered filament yarn had better drying and absorption property compared to the PET-HEF and PET-spandex yarn. An all hydrophilic fluid diode for unidirectional flow in porous systems was realized, which was produced with asymmetric porous materials (Shou & Fan, 2018). Based on the differential Laplace pressure, fluid can wick through AHFD in one direction with ease, but was blocked in the opposite direction. A "skin-like" directional liquid transport fabric enabled continuous one-way liquid flow through spatially distributed channels acting like "sweating glands" yet repels external liquid contaminants by creating gradient wettability channels across a predominantly superhydrophobic substrate (Lao et al., 2020).

Knitted fabrics were widely applied in daily garment, especially in casual wear, sportswear, underwear due to its elasticity. The moisture management and drying properties of weft knitted plating fabrics was investigated using different yarn combination in double layers (Chen et al., 2020). The large difference of hydrophilicity determined the one-way transport capacity, such as cotton (outer side)—polypropylene (inner side) fabric. But the fabric with polypropylene (inner side)—polyester (outer side) exhibited highest vertical wicking and drying rate. Different double-face fabrics were produced with inner layers as polypropylene, polyester, acrylic and nylon yarn and outer layer as cotton yarn (Babu et al., 2020). Cotton and polypropylene double-face knitted fabrics showed better results for the moisture transfer characteristics as polypropylene has the ability to wick and transfer the moisture to the next layer of cotton in a faster way than the other blended fabrics.

Warp knitted fabrics were widely applied. For example, 3D spacer fabric can be used for composites, cushion, or footwear; and elastic warp knitted fabric can be used for swimming suit or pressure garment. Most of research on performance of warp knitted fabrics were compression and comfort for spacer (Arumugam et al., 2019; Raja & Das, 2020; Rajan & Sundaresan, 2020; Rajan et al., 2019) and elasticity (Uyanik & Kaynak, 2019). Hexagonal net fabrics can improve the air permeability of car seat (Arumugam et al., 2019). The water vapor permeability and thermal resistance increased, although the air permeability and thermal conductivity decreased with the atmospheric plasma processing (Rajan & Sundaresan, 2020). Porosity and air permeability of spacer fabric were estimated by surface structure, yarn count, and density (Raja & Das, 2020). The vertical wicking properties were not affected by fabric thickness, but in open structure on two surfaces. In in-plane wicking, the polyester monofilament in the middle layer of spacer fabric plays a major role rather than the outer surface layers of fabric (Rajan et al., 2019). Hence, the moisture management of tricot warp knitted fabric was seldom studied.

Warp knitted mesh fabric was applied to sportswear due to good air transmission, but without multilayer structure and one-way transport property. A elastic warp knitted fabric was prepared on a crochet machine, and the metal composite yarn/viscose yarn and bamboo polyester/polyester blended yarn were used as the front and back surfaces of the knitted fabric structure respectively to achieve a double-layer structure (Yu et al., 2015). It was found that blending ratio significantly influenced water vapor transmission and water evaporation rate. Warp knitted plant structure were developed to mimick the branch structure in order to facilitate the liquid water transport, but those fabrics contained one type of yarn (Chen et al., 2012, 2015). In weft knitting structure, it is easy to achieve two layered structure by single jersey or double jersey knitting structure, but for warp knitting it is usually to construct two layered structure by double needle bed warp knitting machine. For single needle bed warp knitting structure, the ordinary two guide bar warp knitted fabric shows one yarn (threaded on front guide bar) on face and back side, and the other yarn (threaded on back guide bar) in the middle. Therefore, it is difficult to form two surfaces with different material for single need bar warp knitted fabric. This paper reported a newly developed warp knitted fabrics. All fabrics were tested by moisture management tester, water vapor permeability and air permeability. Compared with traditional warp knitting structure, it had better moisture management and air permeability due to its unique structure.

Methods

Samples

Figure 1(a) shows the knitting structure utilized in this study. The basic mesh structure was formed by guide bar GB2 and GB3, the knitting notations were 2-3/1-0// for GB2 and 1-0/2-3// for GB3. The 50D/24f polyester yarn was part-thread (|○|○) for both GB2 and GB3, where “|”represents a threaded guide needle and “○” represents an empty guide needle. Miss-lapping was used in GB1 (1-0/1-1/1-2/1-1//) for structure I, while ordinary tricot structure for control was used in GB1(1-0/1-2//) for structure II. Miss-lapping occurs when a guide bar (which has usually been knitting) makes neither overlaps nor underlaps for one or more courses, so that it is a front bar, its threads will float at the technical back.

Figure 1b shows the typical example of misslapping structure. The fabric was made by two guided bars on single needle bar warp knitting machine. The front guide bar (GB1) was threaded with blue yarns, and the back guide bar (GB2) was threaded with white yarns. The back guide bar always made stitches on every course, but the front guide bar made stitches on several courses and made misslap on four courses. As a result, on the face side there were four white stitch courses which were formed only by white yarns on back guide bar. On the back side, there were four long float courses which were formed by blue yarns on front guide bar. Hence, two layered structures were fabricated on these four courses. The blue yarns on front guide bar appeared on back side, while the

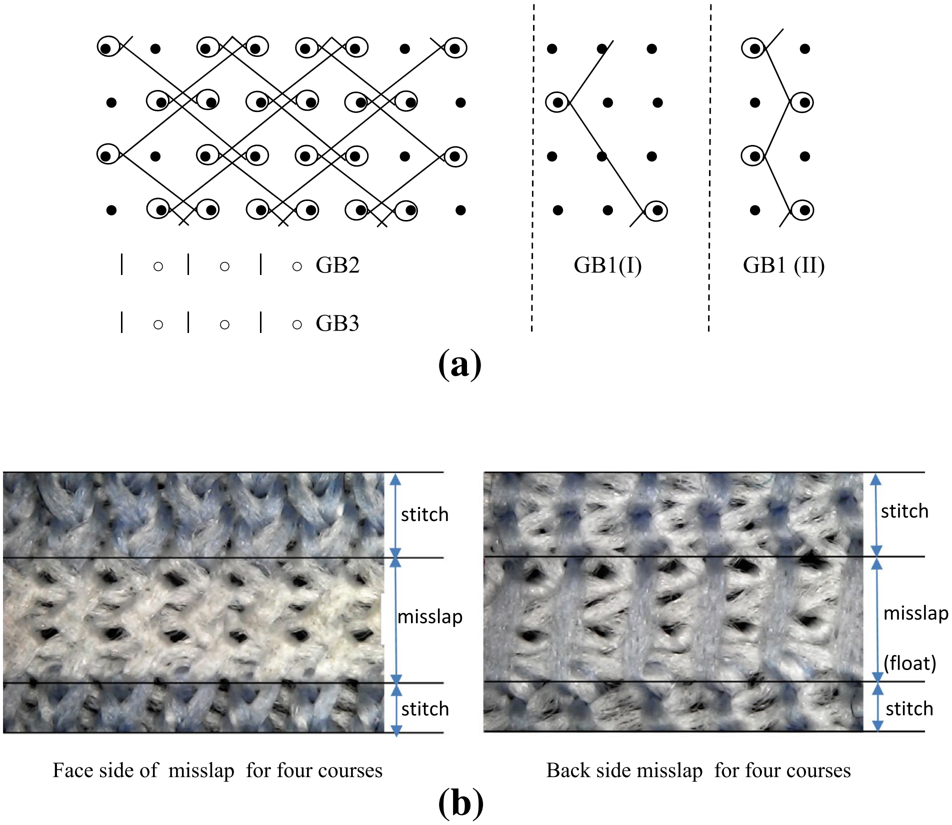


Fig. 1 The lapping diagram of structure I and structure II ("|" represents a threaded guide; "○" represents an empty guide.)

white yarns on back guide bar showed on face side. But, if the front and back bar made stitches at the same time, the blue yarns showed both on face side and back side. For single needle bed warp knitting structure, the ordinary two guide bar warp knitted fabric shows one yarn (threaded on front guide bar) on face and back side, and the other yarn (threaded on back guide bar)in the middle. Hence, it is difficult to form two surfaces with different material. If the misslapping movement occurred, the floats were formed by the blue yarns on front guide bar on the back side and stitches were formed by the white yarns on back guide bar on the front side.

Table 1 demonstrates the knitting notation, thread type, yarn type and warp density. Samples 1-1, 1-2, 1-3, 1-4 and 1-5 were developed by the structure I with 100D/72f DTY polypropylene fully threaded in GB1 in five warp densities(16, 18, 20, 22, and 24). Samples 2-1, 2-2, 2-3, 2-4 and 2-5 were developed by the structure II with 100D/72f DTY polypropylene fully threaded in GB1 in five warp densities (16, 18, 20, 22, and 24). Sample 3 was developed by structure I with 75D/36f DTY polyester fully threaded in GB1 at 20 cpc warp density. Sample 4 was developed by structure II with 75D/36f DTY polyester fully threaded in GB1 at 20 cpc warp density. Sample 5 was made by structure I with 100D/72f DTY polypropylene partly threaded in GB1 at 20 cpc warp density. Sample 6 was made by structure II with 100D/72f DTY polypropylene partly threaded in GB1 at 20 cpc warp density.

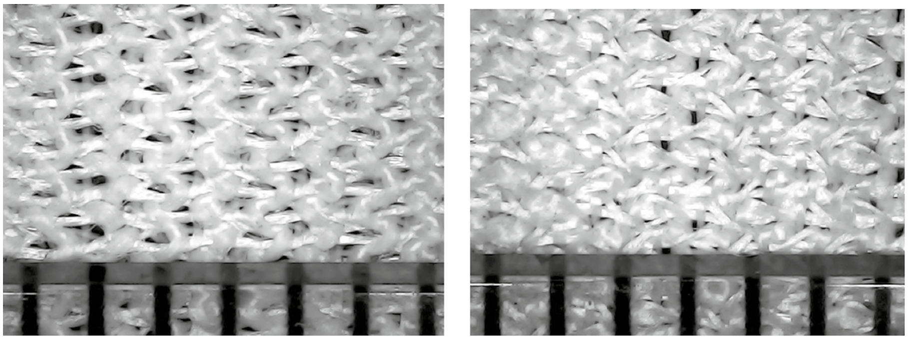
Table 1 The sample preparation

Sample no.	Knitting notation	Thread type	Yarn	Warp density (course per centimeter)
1-1	Structure I: GB1:1-0/1-1/1-2/1-1// GB2: 2-3/1-0// GB3: 1-0/2-3//	GB1: Full-thread GB2: Part-thread (|○|○) GB3: Part-thread (|○|○)	GB1: 100D/72f DTY polypropylene GB2 and GB3: 50D/24f polyester	16
1-2				18
1-3				20
1-4				22
1-5				24
2-1	Structure II: GB1: 1-0/1-2// GB2: 2-3/1-0// GB3: 1-0/2-3//	GB1: Full-thread GB2: Part-thread (|○|○) GB3: Part-thread (|○|○)	GB1: 100D/72f DTY polypropylene GB2 and GB3: 50D/24f polyester	16
2-2				18
2-3				20
2-4				22
2-5				24
3	Structure I	GB1: Full-thread GB2: Part-thread (|○|○) GB3: Part-thread (|○|○)	GB1: 75D/36f DTY polyester GB2 and GB3: 50D/24f polyester	20
4	Structure II	GB1: Full-thread GB2: Part-thread(|○|○) GB3: Part-thread(|○|○)	GB1: 75D/36f DTY polyester GB2 and GB3: 50D/24f polyester	20
5	Structure I	GB1: Part-thread (|○|○) GB2: Part-thread (|○|○) GB3: Part-thread (|○|○)	GB1: 100D/72f DTY polypropylene GB2 and GB3: 50D/24f polyester	20
6	Structure II	GB1: Part-thread (|○|○) GB2: Part-thread (|○|○) GB3: Part-thread (|○|○)	GB1: 100D/72f DTY polypropylene GB2 and GB3: 50D/24f polyester	20

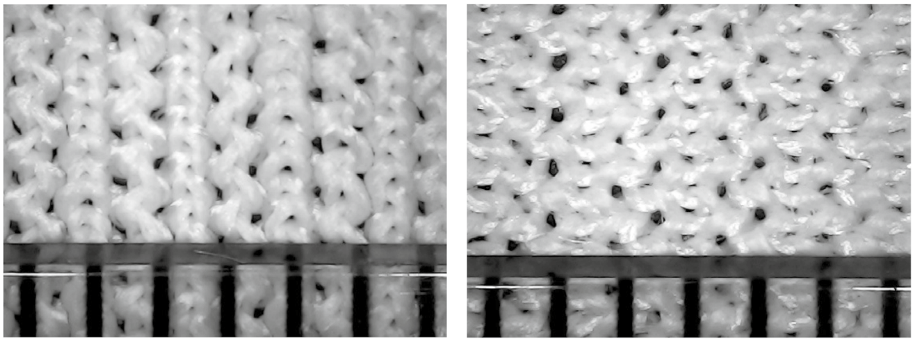
Table 2 The specification of samples

Sample no.	Wpc (wale per centimeter)	Cpc (course per centimeter)	Thickness (mm)	Mass (g/m^2)
1-1	13	17	0.53	152.7
1-2	13	19	0.53	154.6
1-3	13	21	0.54	155.2
1-4	13	23	0.54	157.3
1-5	13	25	0.55	160.8
2-1	12.5	24	0.51	148.1
2-2	12.5	25	0.52	150.3
2-3	12	25.5	0.53	151.7
2-4	12.5	26	0.53	153.4
2-5	12	26.5	0.54	154.9
3	13	25.5	0.43	101.1
4	12.5	25	0.41	127.6
5	12.5	21.5	0.37	87.0
6	12.5	25.5	0.45	97.3

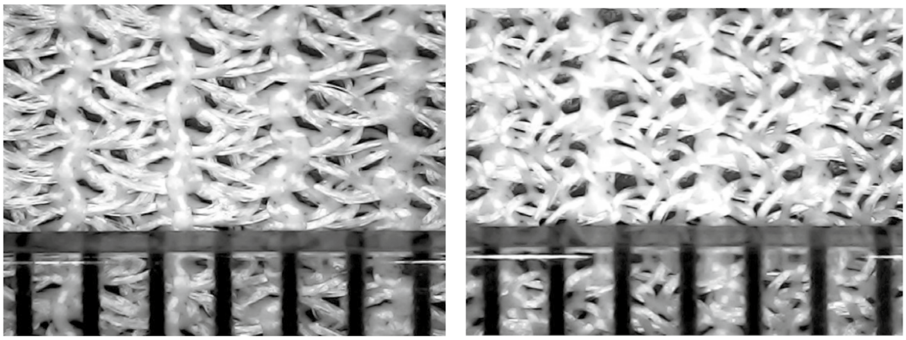
Table 2 shows specification of all samples. Mass ranged from 87 to 160.8 g/m^2, while thickness ranged from 0.37 to 0.55 mm. Samples 1-1 to 1-5 in structure I had slightly higher mass (about 4–5 g/m^2) and thickness (about 0.1–0.2 mm) than that of samples 2-1 to 2-5. Figure 2 shows the photos of samples 1, 2, 5 and 6. Due to the partial



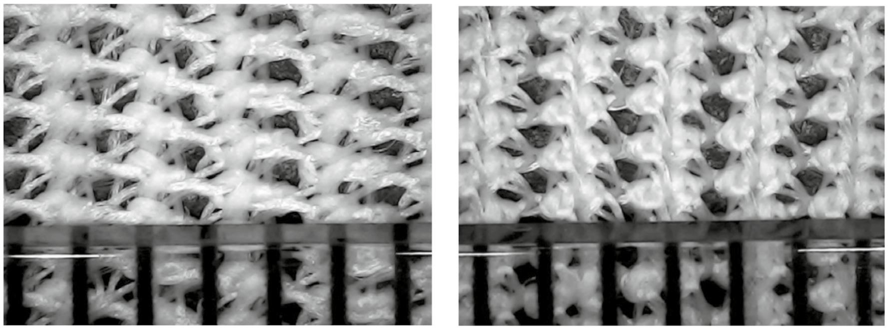
The face side of sample 1 The back side of sample 1



The face side of sample 2 The back side of sample 2



The face side of sample 5 The back side of sample 5



The face side of sample 6 The back side of sample 6

Fig. 2 The photos of samples 1, 2, 5 and 6 thread on GB1 of samples 5 and 6, they had more pores compared with samples 1 and 2 which were made by full thread on GB1.

Moisture management tester

According to AATCC 195, MMT can measure the electrical resistance of the inner side (upper surface during testing) and outer side (lower surface during testing) of the fabric. During the test, 0.2 ml physiological saline was dropped onto the back side of the fabric. The sample size is 5 cm × 5 cm. The test was conducted 3 times for each fabric.

Water vapor permeability

Water vapor permeability was d according to the china standard GB/T 127042-2009 (the water vapor permeability of textile measurement method). Fabric samples and water were conditioned at least one day in the environment of temperatures of 20 ± 2 °C, relative humidity of $65 \pm 2\%$. The amount of 10 ml water was filled into the cup, then put each sample on the cup, and seal each permeability cup with tape. The radius of cup is 3 cm. The cup and fabric was weighted as an original weight of assembly (M1), after 24 h the total weight of cup and fabric were measured (M2). Three pieces of each sample were tested. The average values were calculated as equation below. A is the tested area, and t is 24 h.

$$WVP = \frac{M2 - M1}{A \cdot t}$$

Air permeability

Air permeability test was confirmed with the principle that the permeability was determined by the difference of pressure on both sides of the fabric and the air flow rate though the fabric. According to the china standard of GB/T 5453-1997 (the determination of textile fabric permeability), YG(B)461E was used to measure the air permeability of fabrics. The results were shown on apparatus directly. The area of the fabric sample is 20 cm^2, and the pressure drop of 100 Pa on both sides of the fabric sample is selected. All of fabrics were tested with the face side up and the back side up respectively.

Statistical analysis

In order to test the difference of performances (maximum wetted radius, one-way transport capacity, overall moisture management capacity, water vapor permeability and air permeability) based on testing results, one-way ANOVA test was conducted by SPSS statistical software. The significance level was set at 0.05.

Results and discussion

Moisture management test

Maximum wetted radius

Maximum wetted radius indicates maximum radius of wetting area. According to SPSS One-way ANOVA results, the difference of top radius among all samples was significant ($F_{(13,69)} = 28.185$, $P = 0.000 < 0.05$). The difference of bottom radius among all samples

Table 3 The one-way ANOVA test of maximum wetted radius (top and bottom)

ANOVA—top maximum wetted radius					
	Sum of squares	**df**	**Mean square**	**F**	**Sig**
Between groups	327.143	13	25.165	28.185	< 0.001
Within groups	50.000	56	0.893		
Total	377.143	69			
ANOVA—bottom maximum wetted radius					
Between groups	327.143	13	25.165	28.185	< 0.001
Within groups	50.000	56	0.893		
Total	377.143	69			

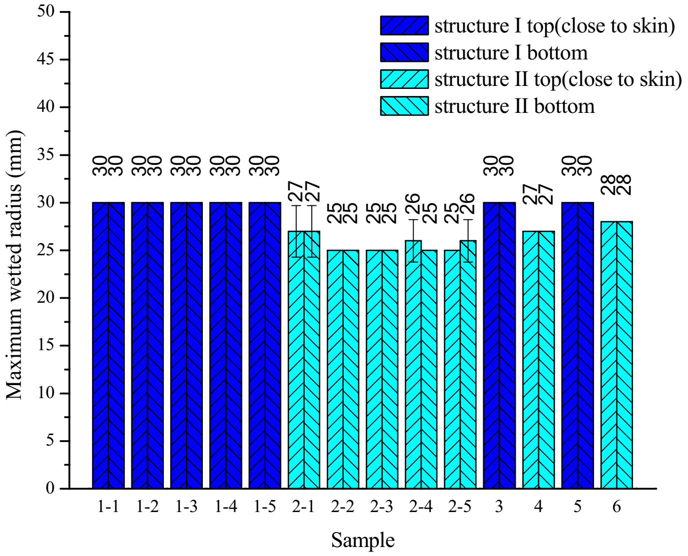


Fig. 3 The results of maximum wetted radius by MMT test

was also significant ($F_{(13,69)} = 28.185$, $P = 0.000 < 0.05$) showed in Table 3. The maximum wetted radius is 50 mm in tester.

As Fig. 3 shows, to compare the sample group 1 (1-1, 1-2, 1-3, 1-4, 1-5) and sample group 2 (2-1, 2-2, 2-3, 2-4, 2-5) where GB1 used 100D polypropylene, full-thread and density(16–24 cpc), Structure I had larger maximum wetted radius (30 mm) than that of structure II (25–27 mm). It was also the same observation, when comparing samples 3 (radius in 30 mm) and 4 (radius in 27 mm) which were manipulated by 75D polyester, full-thread and 20cpc density, samples 5 (radius in 30 mm) and 6 (radius in 28 mm) where GB1 used 100D polypropylene, part-thread and 20 cpc density, Therefore, it proved that the structure I can spread water further. This might be the miss lapping in knitting create long float on the inner surface which can spread water in yarn but not between yarns. More interloop by yarns will impede conductive pathway and weaken the diffusion ability.

Under the same warp density (20cpc) and thread type, the result of wetted maximum radius was 30 mm for the sample 1-3 (100D polypropylene on GB1) and sample 3 (75D polyester on GB1) in structure I. But there was a difference between sample 2-3 (25 mm) and 4 (27 mm) in structure II. This might be there is a denser construction for structure II. Sample 4 had finer yarn which could spread liquid further.

Under the same warp density (20 cpc), GB1 treaded with 100D polypropylene, the result of wetted maximum radius was 30 mm for the sample 1-3 and sample 5 in structure I. But, sample 6 in structure II exhibited larger wetted radius than sample 2-3.

Under same thread type and structure, warp density did not affect the maximum wetted radius for structure I. But for structure II, the lower warp density could result in higher maximum wetted values.

In this study, when varied the density, material and thread type, no differences were found. Besides, there was no difference on the maximum wetted radius between top layer and bottom layer.

One-way transport capacity

One-way transport capacity is the ability of liquid water to transfer from the top surface to the bottom surface is the ratio of the difference of water absorption on both sides of the fabric. According to SPSS One-way ANOVA results, there was a significant difference of one-way transport capacity among all samples ($F_{(13,69)} = 76.560$. $P = 0.000 < 0.05$) showed in Table 4. One-way transport capacity presents the water content difference between face and back side. If the value is high, it means the top surface (close to skin) retain less water than bottom surface.

From Fig. 4, when comparing sample group 1 and 2 which were made of same yarns, density and threading, structure I exhibited higher one-way transport capacity. The increase reached 103.57%, 86.91%, 102.75%, 86.77% and 158.67% correspondingly. Besides, when comparing the samples 3 and 4, samples 5 and 6 which were made of same yarn, density and thread type, structure I also exhibited higher values than structure II. This is due to miss lapping of structure I on GB1. The underlap at the back side of structure I is longer than that of structure II. The long float was not interstitched into the loop and appeared at the back. This could increase the continuous transport channels by which water can be directly transported along yarns but not by contact areas between yarns. It was prove that the large difference of hydrophilicity determined the one-way transport capacity, such as cotton (outer side)-polypropylene (inner side) fabric (Babu et al., 2020; Chen et al., 2020).

To compare samples 1-3 and 3 with different yarn on GB1 (in structure I, 20 cpc, and full thread), samples 2-3 and 4 with different yarn on GB1 (in structure II, 20 cpc, and full thread), the values of one-way transport capacity decreased from 133.05 (sample 1-3) to 61.9 (sample 3), and from 65.62 (sample 2-3) to 42.61 (sample 4). The decrease attained 144.83% and 54% respectively. It can be concluded that polypropylene used on

Table 4 The one-way ANOVA test of one-way transport capacity

ANOVA—one way transport capacity

	Sum of squares	df	Mean square	F	Sig
Between groups	79,558.518	13	6119.886	76.560	< 0.001
Within groups	4476.430	56	79.936		
Total	84,034.948	69			

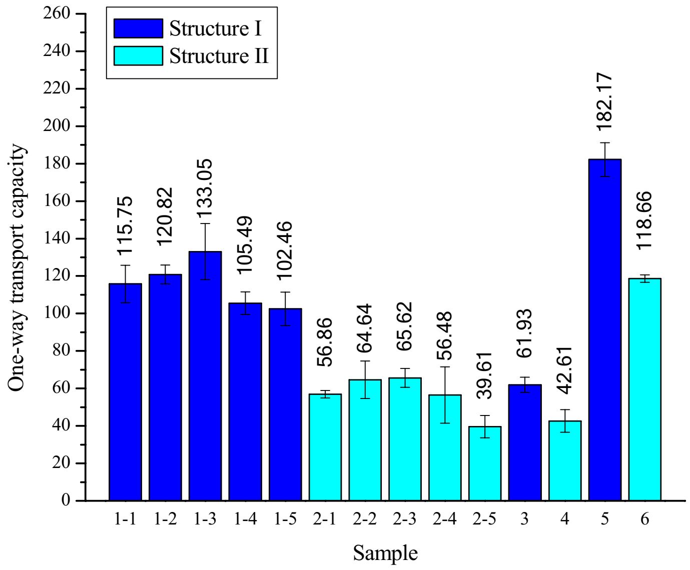


Fig. 4 The results of one-way transport capacity by MMT test

GB1 could increase one-way transport capacity with comparison of polyester on GB1. Even more importantly, miss lapping used on GB1 could highly improve water transport. Firstly, this is because GB1 was threaded with polypropylene which is hydrophobic in both structures I and II. Furthermore, the longer float at the back side in structure I could make water flow easier than short underlap in structure II.

When thread type varied from full thread to part thread in structure I, sample 5 exhibited 182.17 which increased by 36.79% compared with sample 1-3 (133.05). For structure II, there was also increase by 80.8% from 65.62 (sample 2-3) to 118.66 (sample 6). This is probably that the density of underlap at the back side reduce to a half. The less water could be retained at the back side, and this increased the difference of water content retained between back and face side.

Regarding the effect of density on one-way transport capacity, it is interesting that for both structures I and II, the values increased to a peak from 16 to 20 cpc, and then decreased from 20 to 24 cpc. This demonstrated that the density at 20 cpc could help to reach the optimizing one-way transport for one-way transport capacity within groups 1 and 2.

Overall moisture management capacity

Overall moisture management capacity is weighted values of water absorption rate, one-way transfer index and liquid water diffusion rate on bottom surface of fabrics. According to SPSS One-way ANOVA results, there was significant difference of overall moisture management capacity among all samples ($F_{(13,69)} = 38.540$. $P = 0.000 < 0.05$) showed in Table 5. The value of overall moisture management capacity given by tester ranged from 0 to 1 (Fig. 5).

When comparing the groups 1 and 2, samples in structure I always exhibited higher overall moisture management capacity than samples in structure II. Besides, When

Table 5 The one-way ANOVA test of overall moisture management capacity

ANOVA—Overall moisture management capacity

	Sum of squares	df	Mean square	F	Sig
Between groups	0.086	13	0.007	38.540	< 0.001
Within groups	0.010	56	0.000		
Total	0.096	69			

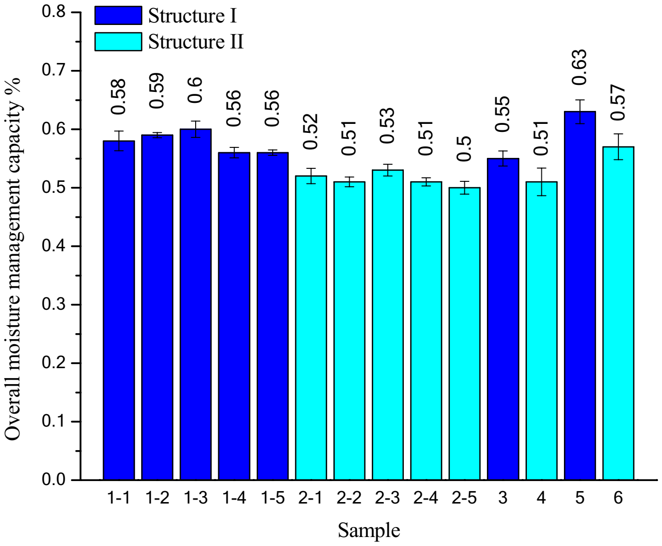


Fig. 5 The results of overall moisture management capacity by MMT test

GB1 was full-threaded with 75 D polyester, samples 3 made in structure I and full thread also had higher values than samples 4. When GB1 was part-threaded with 100D polypropylene, sample 5 in structure I had higher values than sample 6 in structure II. This might be that the back side surface of sample 1-3 exhibited more hydrophobic properties than that of sample 3.

Base on same conditions such as structure I, 20 cpc, and full thread, samples 1-3 (0.6) with 100 D on GB1had higher overall moisture management than sample 3 (0.55) with 75D on GB1. Samples 2-3 and 4 were both in structure II. The former (0.53) had higher overall moisture management than the latter (0.51). The same conclusion was conducted that polypropylene used on GB1 could enhance the overall moisture management. As a results, the water absorption and transport difference of face side and back side could be enlarged.

When the number of thread reduced to 50% in structure I, sample 5 (0.63) had higher overall moisture management than sample 1-3 (0.6). For structure II, sample 6 (0.57) had higher overall moisture management than sample 2-3 (0.53). This might be that the relatively loose knitting structure could help to transport liquid water.

Regarding the effect of density on overall moisture management capacity, the same observation with one-way transport capacity was found. The samples with 20 cpc in structure I or II still reached the best performance.

Table 6 The one-way ANOVA test of water vapor permeability

ANOVA—water vapor permeability

	Sum of squares	df	Mean square	F	Sig
Between groups	3461.501	13	266.269	10.218	< 0.001
Within groups	729.613	28	26.058		
Total	4191.114	41			

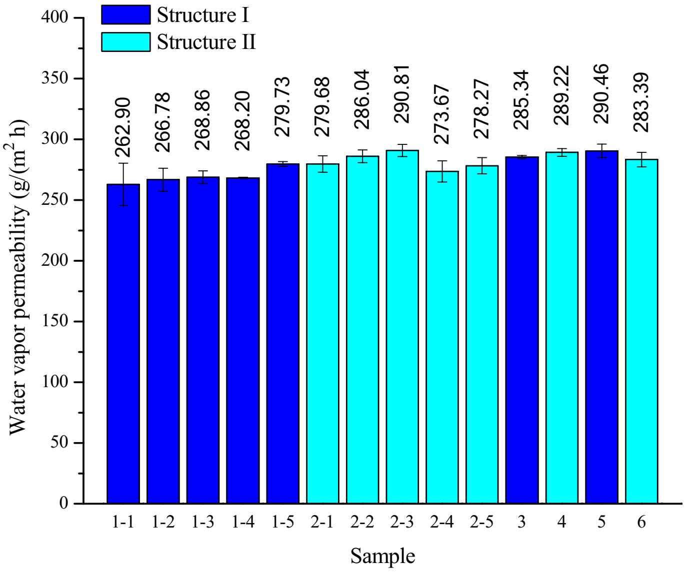


Fig. 6 The results of water vapor permeability

Water vapor permeability

According to SPSS One-way ANOVA results, there was significant difference of overall moisture management capacity among all samples ($F_{(13,41)} = 10.218$. $P = 0.000 < 0.05$) showed in Table 6. As noted in Fig. 6, sample group 1 exhibited lower water vapor permeability than sample group 2 under same density by comparing samples in two structures correspondingly. This is because the long floats formed by miss-lapping in structure I could result fabric bulkier, the pores size within fabrics increase. In addition, the fabrics in group 1 had higher mass and thickness than that in group 2, the average increase by 4–6 g/m^2 and 0.1 mm.

Samples 3 and 4 where GB1 threaded with 75D polyester had higher water vapor permeability than that of samples 1-3 and 2-3 where GB1 threaded with 100D polyproperlene. This is due to thinner yarn was used in samples 3 and 4 where mass and thickness reduced by 25–50 g/m^2 and 0.1 mm.

As a result of the varition of thread type, sample 5 and 6 had higher water vapor permeability than samples 1-3 and 2-3 correspondingly. This is due to the fabric mass dropped from 155.2 to 87 g/m^2 and 151.7 to 97.3 g/m^2, and thickness dropped from 0.54 to 0.37 mm and 0.53 to 0.5 mm.

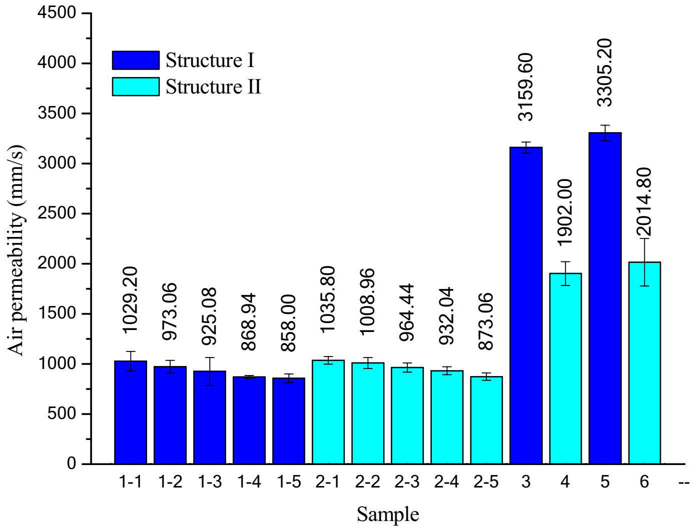


Fig. 7 The results of air permeability

Table 7 The one-way ANOVA test of air permeability

ANOVA—air permeability

	Sum of squares	df	Mean square	F	Sig
Between groups	4.714E7	13	3,626,386.068	410.387	< 0.001
Within groups	494,844.740	56	8836.513		
Total	4.764E7	69			

When density increased from the 16cpc to 24 cpc, there was no consistent conclusion drawn from structure I and II. For structure I, there was a increasing trend when warp density increased. This might be that the structure with long float become denser, less still air could trapped in fabric.

Air permeability

Figure 7 illustrates the air permeability test results. There was significant difference of overall moisture management capacity among all samples ($F_{(13,69)} = 410.387$. $P = 0.000 < 0.05$) showed in Table 7. Compared with the results of water vapor permeability, the variation of knitting structure, yarn type, threading type as well as density could lead to much difference.

When yarn type, threading type, density were same, structure I had lower air permeability. This is because structure I had loose and bulky structure which resulted in higher fabric thickness (0.53–0.55 mm) and mass (152.7–160.8 g/m^2). Structure II had relatively lower values (0.52–0.54 mm, 148.1–154.9 g/m^2). Air permeability of fabric were determined by structure, yarn count, and density (Raja & Das, 2020).

According to the test results, sample 3 (3159.6 mm/s)and 4 (1902 mm/s)possessed much higher air permeability than sanples 1-3 (925.08 mm/s) and 2–3 (964.4 mm/s) at same density and structure. The GB1 of sample 1-3 and sample 2-3 were threaded

100D polypropylene, and that of sample 3 and sample 4 were 75D polyester. This is mainly due to the change of the yarn fineness, the decrease of the volume density and the increase of the porosity of the fabric.

When thread type varied from full to part, air permeablity of samples 5 (3305.2 mm/s)and 6 (2014.8 mm/s) increased highly compared with 1-3 (925.08 mm/s) and 2-3 (964.4 mm/s) respectively. It can be seen that the threading type imparted air flow, and the fabric with part-thread was better than that with full-thread. This is due to the thin thickness, light weight, small volume density, and more air exchange spaces. Therefore, the air permeability of sample 5 had highest values.

With the same raw material, threading type and structure, the influence of the density on the air permeability of the fabric was analyzed. The comparison group was sample 1-1 to 1-5, sample 2-1 to 2-5, and the warp density of samples was 16, 18, 20, 22, 24. It can be seen from the test results that the air permeability of the fabric decreased with the increase of the density of the fabric. When density increased from 16 to 24cpc, the air permeability decreased by16.6% for structure I, and by 15.6% for structure II. When the warp density was 16, the air permeability was the best, where sample 1-1 was 1029.20 mm/s and sample 2-1 was 1035.8 mm/s. The main reason that the structure II in the plain knit was tight. When the density of the fabric increases, the structure of the fabric becomes more compact, the volume density increases, and the channels for air pass through become less.

Conclusions

In this work, structure I (partial miss lapping on GB1) and structure II (ordinary lapping) were compared, the miss lapping structure could result larger maximum wetted radius, one-way transport capacity as well as overall moisture management capacity. On one hand, this is due to the long float at the backside. On the other hand, guide bar 1 was threaded with polypropylene. As a result, the fabrics had better water transport property compared with 100% polyester fabrics. Besides, density, thread type, and yarn type also affected moisture management property. By varying the parameters in this study, there was not very much difference with regard to water vapor permeability. Finer yarn and part thread could highly enhance air permeability. Sample 5 made of part threaded polypropylene in structure I at 20cpc had best comfort related properties.

Authors' contributions

Conceptualization, JF; methodology, QC; formal analysis, BF; data curation, BM; writing—QC; project administration, RZ; funding acquisition, RZ. All authors read and approved the final manuscript.

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Availability of data and material

All data generated or analysed during this study are included in this published article.

Declarations

Competing interests

The authors declare that they have no competing interests.

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