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Comfort properties of moisture management finished bi-layer knitted fabrics: Part II - Moisture Management

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Moisture management properties of six samples of bi-layer fabrics have been determined after optimised finish and their statistical analysis is done. It is found that the finished fabrics show better properties than those of unfinished fabrics. The bi-layer fabric structure along with the application of optimized moisture management finish makes the fabric more suitable for sportswear, exhibiting excellent moisture management properties in terms of wetting radius, absorption rate, wetting time and spreading speed of sweat. The results indicate that, the inner and outer microdenier polyester fabrics show better moisture management property, offering high levels of comfort, and hence are preferred during summer for active and sportswear due to the appreciable wetting radius, as well as good absorption rate, wetting time and well spreading speed of sweat.

Keywords: Bi-layer knitted fabrics, Fabric comfort, Moisture management finish, Polyester, Sportswear

1 Introduction

One of the important aspects of any fabric meant for sportswear, which decides the comfort level of that fabric, is the moisture management property. Human being sweats during different kinds of activities. The way it transports this water out of the body surface to make the wearer feel comfortable is an important feature of any fabric. So, moisture management can be defined as the controlled movement of water vapour and liquid water (perspiration) from the surface of the skin to the atmosphere through the fabric. Important aspects in the performance of products are wetting, wicking and moisture vapour transmission properties.

Wang *et al.*[1] stated that the moisture and temperature distribution play a major role in the moisture management property of fabrics. Oner *et al.*[2] observed that the cellulosic-based fabrics have higher Overall Moisture Management Content (OMMC) as compared to the polyester fabrics. Bedek *et al.*[3] suggested that the fibre type along with the moisture regain and knitted structure characteristics affect the fabric comfort properties. Alam *et al.*[4] applied moisture management finish on the micro-denier polyester fabric to study the hydrophilic property, where overall results showed improved hydrophilicity for the treated fabrics.

The modification in moisture management properties of cotton fabrics can be achieved without altering the comfort-related properties, using surface treatment with water repellent agents, fluropolymers, etc. to increase the water transport, air permeability and moisture regain. Fluropolymers not only reduce the capacity of absorption, but also reduce the fabric drying time. For wrinkle free treatments, common chemical and or resins are used to reduce the absorbent capacity of cotton in the order of 15-20% or more, thus reducing the amount of water to hold within the fabric structure[5].

Margret and Kavitha[6] developed a bi-layer fabric of modal and polyester yarns, and it was observed that plated jacquard fabric is better as compared to Interlock jacquard structure, making it more suitable for sportswear with good moisture absorbency, thermal resistance and wicking property. Plated jacquard fabric has a good absorbency and quick drying nature. The dimensional stability and wrinkle-free nature also found good in this fabric. Kandhavadivu *et al.*[7] studied tri-layer fabrics made of bamboo charcoal, lyocell, bamboo and micro polyester yarns, to observe the moisture and thermal

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management properties. They found that the tri-layer weft knitted fabric show good functional characteristics due to their structural factor. Margret and Kavitha[8] developed a bi-layer fabric of wool and polyester yarn. They found that bi-layer fabric structure has a greater impact on the water vapor permeability. As the stitch density and the tightness factor increase, the moisture absorbency of the bi-layer knitted structure also increases. It transfers perspiration from the inner layer of the fabric to the outer layer, and then it easily gets evaporated and dried. This can be achieved by the bi-layer knitted fabric structure made of polyester as the inner layer and wool as the outer layer, recommended for sportswear.

Senthil kumar *et al.*[9] and Suganthi *et al.*[10] developed six uniform bi-layer fabrics of Tencel yarn as outer and micro fibre polyester yarn as inner layers. It is observed that the bi-layer fabric made from micro polyester fibre as the inner layer with less tuck points shows a good air permeability, water vapor permeability, drying rate and wick ability and a low thermal resistance. Furthermore, it is also found that the thickness and porosity of the fabric determine the water vapor permeability. So, the thinner fabric with more pores has good water vapor permeability. Mohammad *et al.*[11] concluded that the application of moisture management finishing agents, such as hydroperm SRHA liquid improves the moisture management properties of the fabric by increasing the water absorption, wicking rate, air permeability, water vapour transmission and drying rate. In addition, as the concentration increases the absorption properties of the fabric improve, offering a good scope to the sports textiles. In this work, six bi-layer fabric samples are given the moisture management finish using ethoxylated alcohol as wetting agent, and combination of amino silicone polyether copolymer and hydrophilic polymer as finishing agent at the optimum values of *p*H, temperature and finishing agents combination. The fabrics are then tested for moisture management properties.

2 Materials and Methods

Sample details and experimental studies has already been reported Part I of this series[12].

2.1 Moisture Management Study

The moisture management behaviour of bi-layer fabric specimens was estimated by the SDL-ATLAS moisture management tester as per the AATCC 195-2009 standard. This equipment is based on the principle of electrical resistance change with respect to the content of water in the fabric sample when it is exposed to the moisture medium. The electrical resistance depends on the content of water on the fabric surface, and the electrical conductivity behaviour of the water used. All the bi-layer fabrics samples were conditioned. Moisture management tester has upper and lower moisture sensors. The bi-layer fabric sample was placed between the two sensors. A simulated 0.15 g sweat solution was dropped on to the surface, where it started moving in all the three directions, by radially spreading on the top surface, and then transferred to the bottom surface. The change in resistance was estimated by the two sensors as per the content of water.

3 Results and Discussion

The moisture management finished bi layer fabrics have been tested for their wetting time, absorption rate, spreading speed, maximum wetting radius, OWTC and OMMC characteristics, and their results are discussed hereunder.

3.1 Wetting Time

Figure 1 shows the wetting time for the top (inner) and bottom (outer) layers of the treated and untreated fabrics. From the results, it can be seen that the treated fabrics show lower wetting times, both in the outer and inner layers for all the fabrics studied. MDPF/MDPF fabric shows the lowest wetting time (2.26s for top layer and 3.97s for bottom layer) of all

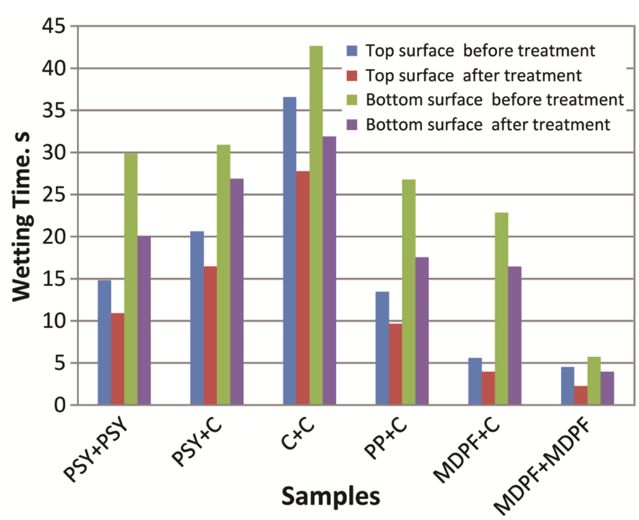

Fig. 1 — Wetting time of bi-layer knitted fabrics after treatment [PSY – polyester staple yarn, C – cotton, PP – polypropylene and MDPF – micro polyester filament (inner layer + outer layer)]

the fabrics tested. MDPF/C after the treatment shows wetting time of 3.97 s on the top side and 16.45 s on the bottom side. PP/C after the treatment shows 9.67 s and 17.54 s wetting time for both top and bottom side respectively. Wetting time of both top and bottom side of PSY/PSY after the treatment is 10.91 and 20.08 s respectively. For PSY/C, after the treatment wetting time is 16.46 s and 26.87 s for both top and bottom side respectively. Wetting time for C/C after the treatment is 27.78 s on the top side and 31.88 s on the bottom side. Cotton-cotton sample has the highest wetting time values, indicating that the sweat solution is slowly absorbed than in other fabrics.

The top and bottom surfaces in treated MDPF (inner) – MDPF (outer) fabric has the lowest wetting time values, due to the hydrophobicity of the MDPF, where the nonpolar molecules of the fibre repel the water molecules. Through capillary forces, liquid is transferred through the fabric from the bottom layer to the top layer. Cotton fibre is hydrophilic, where the molecules join from ionic or hydrogen bonds with the water molecules. This results in the retention of water by the fibres, which have poor moisture transportation and release. Longer wetting times by C/C shows that there is poor liquid transfer from the bottom layer to the top layer of the fabric. Higher thickness and mass per unit area cause changes in the yarn type[13]. On the other hand, wetting time ($p<0.05$) and lower thickness on both the layers promote higher liquid transfer in MDPF-MDPF fabric, making it more suitable for active sportswear.

3.2 Absorption Rate

The rate of absorption of the textile material is highly influenced by the type of fibre, yarn and the structure of the fabric. Absorption rate measures the degree of liquid transfer on the top and bottom layers (%/s), which is the average ability to absorb the moisture in a predetermined time. From Fig. 2, it is clearly evident that the absorption rate of the MDPF/MDPF after the treatment is 48.78 %/s on the top side and 42.66%/s on the bottom side. Similarly, for MDPF/C the value is 41.98 %/s and 33.89 %/s on top and bottom side respectively. For PP/C the value is 33.54 %/s and 27.98 %/s , for PSY/PSY fabric the value is 30.11 %/s and 26.11 %/s, for PSY/C fabric the value is 27.65%/s and 21.92 %/s, and for C/C, fabric the value is 23.45 %/s and 19.32 %/s for both top and bottom side respectively.

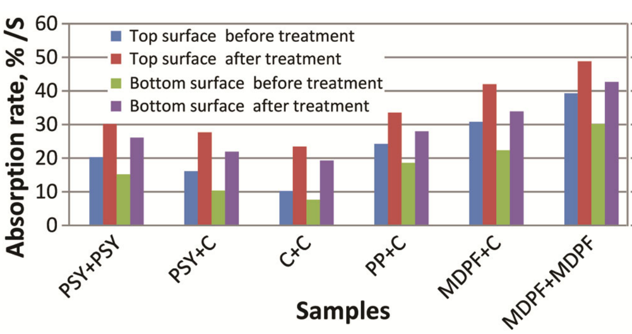

Fig. 2 — Absorption rate of bi-layer knitted fabrics after treatment

MDPF/MDPF fabric shows a higher absorption rate than the other fabrics after the moisture management treatment. More inter fibre space in yarns creates a large surface area, and the addition of finish improves its rate of absorption. The untreated fabrics show a lower absorption rates and classified as ‘slow’. MDPF/MDPF finished fabrics show a significant increment in the absorption rate ($p<0.05$) on both the top and bottom layers, and the standard absorption rating is increased to “fast” at the bottom and “very fast” at the top layers with the p value 1.16×10^{-05}, and 1.66×10^{-06} for the top and bottom layers respectively.

3.3 Maximum Wetted Radius

The maximum wetting radius on the top and bottom layers of the fabric denotes how wide the liquid moisture spreads on the fabric surface. The higher the wetting radius, the higher will be the drying capacity. It is clearly evident from Fig. 3 that the maximum wetting radius of the MDPF/MDPF bi-layer knitted fabric after the treatment is 34mm on the top side and 39mm on the bottom side.

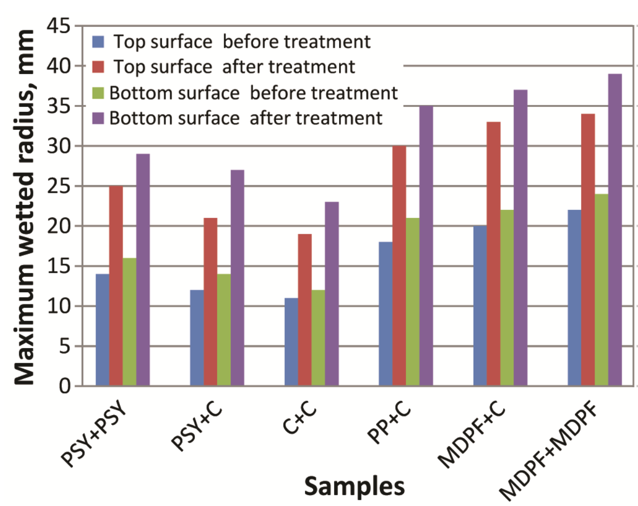

Fig. 3 — Maximum wetted radius of bi-layer knitted fabrics after treatment

Similarly for MDPF/C fabric, it is 33mm and 37mm on top and bottom side respectively. For PP/C it is 30mm and 35mm on top and bottom side respectively. For PSY/PSY it is 25mm and 29mm on top and bottom side respectively. For PSY/C fabric, it is 21mm and 27mm on top and bottom side respectively. For C/C fabric, it is 14mm and 23mm on top and bottom side respectively. There is a good improvement in the maximum wetting radius in all the fabrics after the moisture management treatment, and on comparison among the six bi-layered knitted fabrics the MDPF/MDPF fabric shows the highest maximum wetting radius. The MDPF has a large surface area due to the higher inter fibre space in the yarn and hence the after the addition of the finish, this fabric improves its maximum rate of wetting radius. This increases the capillary action in the fabric, helped by the fineness of the yarn causing wider spreading of the absorbed moisture and quicker drying[14]. There is a inherent channelled structures in the micro denier polyester yarn, supporting in effective transportation of water and evaporation. After treatment, the MDPF/MDPF shows a significant increment in the maximum wetting radius ($p<0.05$) on both the top and bottom sides. (p value: 3.75×10^{-05} for top and 1.66×10^{-06} for bottom.

3.4 Spreading Speed

The speed at which a liquid spreads on a surface and evaporates over is defined as the spreading speed. From Fig. 4, it is clearly evident that the spreading speed of the MDPF/MDPF bi-layer knitted fabric after the treatment is 3.99 mm/s on the top side and 4.98 mm/s on the bottom side. Similarly, for MDPF/C fabric, the value is 3.76 mm/s and 4.56 mm/s, for PP/C fabric the value is 2.98 mm/s and 4.01 mm/s , for PSY/PSY fabric the value is 1.67 mm/s and 1.98 mm/s, for PSY/C fabric the value is 2.02 mm/s and 3.12 mm/s, and for C/C fabric the value is 2.65 mm/s and 3.98 mm/s on top and bottom side respectively. The filament fineness and the continuous channel structured, offer a larger exposed surface area, promoting evaporation at a faster rate. After the finishing treatment, fabric shows a significant increment in the spreading speed ($p<0.05$); p value: 0.000324 and 0.000323 respectively for top and bottom layer.

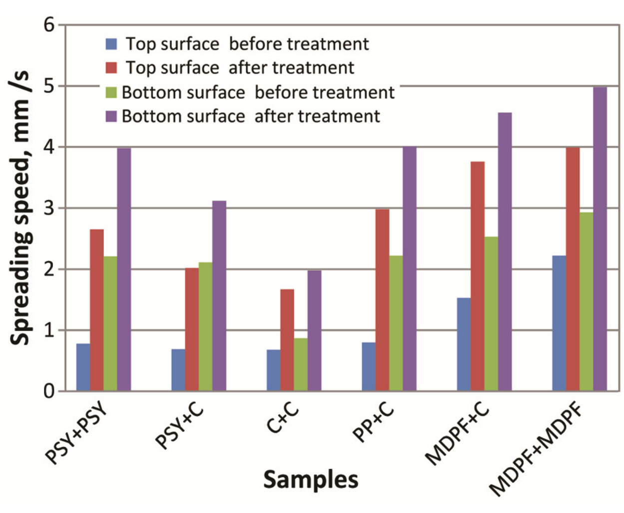

Fig. 4 — Spreading speed of bi-layer knitted fabrics after treatment

3.5 Overall Moisture Management Capacity

One way transport capacity is the difference in the cumulative moisture content between the two layers of the fabric at a unit testing time. From Fig. 5, it is observed that the one-way transport capacities for the fabrics MDPF/MDPF, MDPF/C PP/C, PSY/PSY, PSY/C and C/C are 134.67, 94.67, 64.56, 46.78, 32.66 and 24.09 % respectively. However, the treated MDPF/MDPF is classified as ‘very good’, due to lesser difference in the cumulative moisture content between the layers.

The all-inclusive moisture management (OMMC) is an index on the overall ability of the fabric to manage the liquid moisture transport. It is governed by the moisture absorption rate of the bottom layer, one–way liquid transport-ability and the spreading speed. The all-inclusive moisture transport-ability of the fabric results in higher overall moisture management capacity. From the results, it can be noted that OMMC value of MDPF/MDPF is higher, shows a significant improvement in the overall moisture management capacity and is rated as “good”

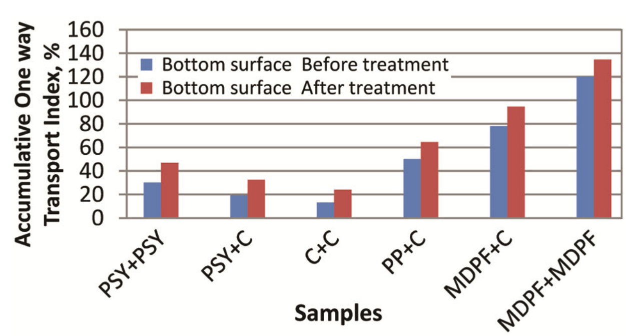

Fig. 5 — Accumulative one way transport index of bi-layer knitted fabrics after treatment

as per the standards. From Fig. 6, it is clearly evident that OMMC values are positively correlated with spreading speeds (3.99 mm/s for SSt and 4.98 mm/s for SSb), maximum wetted radius (34mm for MWRt and 39mm for MWRb) and a week wetting time (WTt – 2.26 s and WTb – 3.97 s). The treated MDPF/MDPF fabric shows better moisture management property, such as lower WT, higher SS and higher MWR, than those of other selected fabrics, which is more suitable for active sportswear.

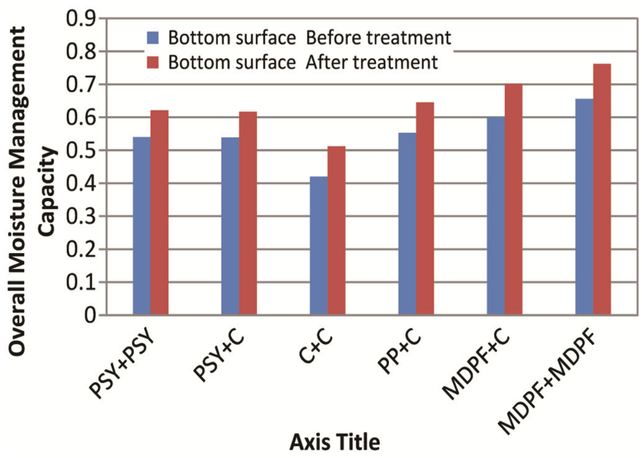

Fig. 6 — Overall moisture management capacity of bi-layer knitted fabrics after treatment

3.6 Statistical Analysis

ANOVA, using the SAS System testing (version 8 for Windows) has been carried to analyse the statistical importance of the knitted fabrics on the moisture management properties. The variables are considered as significant if the probability (p) value is less than 0.05.The results of One-way ANOVA are given in Table 1. The p-value for moisture management properties of the bi-layer knitted fabrics after the application of the finish is < 0.05.

The findings clearly indicate that there is a significant difference on the moisture management properties of the bi-layer knitted fabrics at a 95% confidence level. So, it can be concluded that the application of the finish affects the wetting time, absorption rate, spreading area, spreading speed, accumulative one way transport index and overall moisture management capacity of the fabrics respectively.

Table 1 — Two-way ANOVA on wetting time of the top surface of the bi-layer fabric after treatment

Property	Factor	SS	Degrees of freedom	MS	F	p-value	F-critical
Wetting time, s							
Top	Bi-layer fabric	50.51203	1	50.51203	16.17092	0.010108	6.607891
	Type of treatment	1113.146	5	222.6293	71.27253	0.000121	5.050329
Bottom	Bi-layer fabric	146.93	1	146.93	23.10007	0.004857	6.607891
	Type of treatment	1166.919	5	233.3837	36.69216	0.000605	5.050329
Absorption rate, % /s							
Top	Bi-layer fabric	346.9778	1	346.9778	301.8617	1.16×10^{-05}	6.607891
	Type of treatment	986.8138	5	197.3628	171.7005	1.38×10^{-05}	5.050329
Bottom	Bi-layer fabric	380.5092	1	380.5092	660.8287	1.66×10^{-06}	6.607891
	Type of treatment	697.8148	5	139.563	242.3784	5.85×10^{-06}	5.050329
Maximum wetted radius, mm							
Top	Bi-layer fabric	352.0833	1	352.0833	186.9469	3.75×10^{-05}	6.607891
	Type of treatment	289.4167	5	57.88333	30.73451	0.000925	5.050329
Bottom	Bi-layer fabric	380.5092	1	380.5092	660.8287	1.66×10^{-06}	6.607891
	Type of treatment	697.8148	5	139.563	242.3784	5.85×10^{-06}	5.050329
Spreading speed, mm/s							
Top	Bi-layer fabric	8.94586	1	8.94586	76.42502	0.000324	6.607891
	Type of treatment	5.63765	5	1.12753	9.632557	0.013279	5.050329
Bottom	Bi-layer fabric	7.938133	1	7.938133	76.59826	0.000323	6.607891
	Type of treatment	7.699467	5	1.539893	14.85905	0.005062	5.050329
AOTI %	Bi-layer fabric	626.068	1	626.068	275.9145	1.44×10^{-05}	6.607891
	Type of treatment	17166.09	5	3433.218	1513.054	6.09×10^{-08}	5.050329
OMMC	Bi-layer fabric	0.025181	1	0.025181	424.5286	4.98×10^{-06}	6.607891
	Type of treatment	0.066428	5	0.013286	223.983	7.12×10^{-06}	5.050329

4 Conclusion

Moisture management properties of bi-layer knitted fabrics with different yarn combinations have been studied using the moisture management tester. From the OMMC values, micro-denier polyester/micro denier polyester fabric shows better moisture management property, i.e. lower wetting time, higher absorption rate, higher wetting radius, higher spreading speed than those of other selected bi-layer fabrics. The moisture management properties of the bi-layer fabric treated with the moisture management finish is better than the untreated fabrics. The bi-layer fabric structure along with the finish make the fabric more suitable for active sportswear.

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