Investigating the Liquid Moisture Transport Behavior of Cotton and Polyester Cotton Blended Woven Fabric

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ABSTRACT

This study focused on the effects of varying the warp and weft densities and blend ratio on the overall liquid transport behavior of plain woven 100% cotton and polyester/cotton blended fabric. Overall Moisture Management Capability (OMMC) and Accumulative One-way Transport Index (AOTI) along with wetting and spreading time of the top and bottom surfaces was measured on moisture management tester. The results were used as a basis to grade the fabric for its moisture transport behavior. It was observed that polyester/cotton blends have an overall higher accumulative one-way transport index and overall moisture management capability than 100% cotton fabric. Furthermore, an increase in the polyester content in the fabric resulted in a significant increase in the transport of moisture. However less number of warp and weft yarns in the blended fabric improved the overall moisture management capability of the fabric.

Keywords: Liquid Moisture Transport Behavior, Accumulative One-way Transport Index, Blend Ratio, Overall Moisture Management Capability, Warp Density and Weft Density.

1. INTRODUCTION

The thermo-physiological comfort level of apparel can be determined by its ability to transport perspiration from the layer next to the skin to the outer layer and subsequently to the environment. In hot and humid climate, perspiration affects wearer comfort. Wearer will feel more comfortable when this is quickly transported away from the skin in the form of a liquid or vapour. This is because the fabric touching the skin will feel dry. An effective moisture management system includes complete transfer of moisture vapour and liquid from the skin to the environment [1]. The moisture management properties of a fabric are influenced by numerous factors such as the nature of fibre (hydrophilic or hydrophobic), blend ratio and yarn and fabric constructional parameters *etc*.

Yarn constructional parameters have a substantial effect on the moisture management properties of woven as well as knitted fabrics [2]. Finer counts yield higher absorption rate and high wetted radius with reduced wetting time. However, higher twist coefficient results in reduced absorption rate and wetted radius. Das *et al*. [3] claimed that blend ratio, yarn count and twist are the significant factors for vapour and liquid moisture transmission in a polyester/viscose blended fabric. Finer count, low yarn twist level and an increase in polyester proportion of a polyester/viscose blended woven fabric resulted in decreased air and water permeability [3].

Namligöz *et al*. [4] compared the moisture transmission indices of pure cotton, polyester and polyester/cotton blends and concluded that a fabric made of 100% cotton and 100% polyester is not suitable for efficient transport and wetting of a liquid.

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However polyester/cotton blended fabrics were found to possess acceptable liquid absorption and conveyance. Effect of polyester filament linear density on liquid moisture management property, air permeability and thermal conductivity was described as major factor for the comfort level of the fabric as claimed by Kaynak and Babaarslan [5]. The researchers pointed out that coarser polyester filament knitted fabric had rapid liquid transfer. Microfilament polyester knitted fabric has less air permeability than regular filament polyester. In one related study, it was found that vapour permeability is not dependent upon the linear density of polyester filaments. However, the thermal properties can be affected with the change in linear density. It was also reported that air permeability and wettability both decreases with an increase in fibre diameter but wickability of a fabric improved with finer count of the yarn [6]. In one study related to the effect of yarn linear density on the water absorbency of a double layer knitted fabric, it was concluded that a coarser polypropylene yarn with finer cotton yarn double layer fabric has better permeability [7].

Kara and Akgun [8] assessed the effects of the weft yarns having different fiber contents (different blended ratios of fibers such as cotton, coolmax, cordura, thermocool and elastane) and the effects of certain fabric constructional parameters on moisture management properties of commercially used denim fabrics. It was observed that the AOTI and OMMC values of denim fabrics also increased when the cotton ratio in weft yarn was increased. It was also reported that the fabric parameters which have a marked influence on the moisture management properties of fabrics are the fabric thickness, fabric weight, fabric bulk density and also crimp and floating length of yarns in the weave structure [8]. The effect of increasing bamboo content on the moisture management capability of a bamboo/cotton knitted fabric was investigated by Chidambaram Prakasha et al. and concluded that increase in bamboo content decreases the overall OMMC values of the fabric [9]. It has also been observed that when different weft yarns (mainly regenerated) but same warp yarn was used in a woven fabric bamboo and promodal have almost similar behavior as far as air permeability, wetting, and wicking and water vapour permeability of

woven fabric is concerned. A slightly better effect was observed with tencel and modal but these fibres are relatively expensive [9].

Baltušnikaitė *et al.* [10] reported that the transmission of moisture is greatly affected by the fabric structure and fibre surface energy. It was claimed that plain knitted fabric has lower moisture transport capability than fleecy fabrics, and the fabrics with higher surface energy can effectively manage the moisture in comparison to the fabrics with lower surface energy. Also, tightness factor has to be taken into consideration as increase in covering factor improves the moisture management properties. In one study, the effect of texturizing on the wicking and drying rate of 100% polyester woven fabric was investigated and it was found that the non-texturized yarn dried faster but the texturized polyester possessed better wicking capability [11].

In the light of the review of related work presented above, this work aimed to investigate the effects of warp density and weft density on moisture transmission of 100% cotton and in a polyester/cotton blended fabric. The effect of the variation in warp per inch and weft per inch was evaluated in terms of wettability, transfer rate and Moisture management index. This research will help to develop an appropriate woven fabric especially for shirting during hot and humid climate.

2. EXPERIMENTAL SETUP

2.1 Materials and Methods

Nine samples of woven fabric having 40s English cotton count and three different warp and weft densities (90×50, 100×65 and 110×70) were developed and used in this study. Out of these nine samples, three samples were of 100% cotton and six were of the polyester/cotton blended woven fabrics with different blend ratios (65:35 and 80:20). Detailed specifications of the samples are provided in Table 1. All the fabric samples were prepared on SL 8900 Evergreen loom, which is a single rod, single rapier weft insertion loom with dobby controlled shedding system.

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Table 1: Technical Specifications of the Developed Samples			
Sample No.	Fiber Type	Polyester (%)	Cotton (%)
1	Cotton	0	100
2	Polyester/Cotton	65	35
3	Polyester/Cotton	80	20
4	Cotton	0	100
5	Polyester/Cotton	65	35
6	Polyester/Cotton	80	20
7	Cotton	0	100
8	Polyester/Cotton	65	35
9	Polyester/Cotton	80	20

Table 2: Recipes used for Desizing, Scouring and Bleaching of Developed Samples			
No.	Reagent Name	Generic Name	Quantity (g/l)
Desizing			
1	Levotan RGA	Wetting agent	3
2	Bexion NE	Sequestering agent	4
3	Optisize cool	Enzyme	0.1
Scouring			
1	Levotan RGA	Wetting agent	2
2	Inverter ED	Sequestering agent	1
3	Sodium hydroxide	Caustic	15
Bleaching			
1	Levotan RGA	Wetting agent	2
2	DSP	Stabilizer	8
3	Inverter ED	Sequestering agent	1
4	Sodium hydroxide	Caustic	15
5	Hydrogen peroxide		35

The samples were desized, scoured and bleached in the laboratory using exhaust techniques as per recipes given in Table 2. Fabrics that are coated with a layer (size or finish) and have impurities are not recommended for fabric thickness and moisture management testing as presence of these impurities have adverse effect upon the fabric absorbency and appearance.

Desizing was done at 90°C for 45 minutes which was followed by hot and cold wash. Scouring was done at 95°C for 40–45 minutes which was followed by hot and cold wash respectively. The desized and scoured fabrics were then bleached using H_2O_2 as a bleaching agent. Bleaching was performed for 35 minutes at 95°C using Ahiba HT dyeing machine. After the completion of the bleaching process fabric was hot washed followed by cold wash and finally dried.

2.2 Fabric Physical Properties

Physical properties of these developed fabrics such as yarn count (English system, Ne), thickness and mass per unit area (area density) were determined according to ASTM D1907/D1907M–12 [12], ASTM D1777–96 [13], and ASTM D3776 / D3776M–09a [14], respectively. Fabric density and porosity of a fabric were calculated using equation (1) and (2), respectively, and the results are provided in Table 3. The samples were conditioned at 20°C and 65% relative humidity for 24 hours prior carrying out any measurement.

$$\text{Fabric Density} = \frac{\text{Area Density } (g/m^2)}{\text{Thickness (m)}} \tag{1}$$

$$\text{Porosity} = 1 - \left(\frac{\text{Fabric Density}}{\text{Fiber Density}} \right) \tag{2}$$

2.3 Moisture Management Testing

SDL ATLAS MMT tester was used to measure the moisture management properties of the nine samples according to AATCC 195–2011 test method [15]. This tester measures electrical resistance by direct contact which is then used to calculate the wetting time, spreading rate, transport of moisture from bottom to top layer and moisture management capability [15].

3. RESULTS AND DISCUSSION

The results for the moisture transport properties including Wetting Time (WT_t and WT_b), Spreading Speed (SS_t and SS_b), Absorption Rate (AR_t and AR_b), Accumulative One-way Transport Index (AOTI) and Overall Moisture Management Capacity (OMMC) of each of the samples are presented in Table 4. In order to evaluate the effects of blend ratio and density (w_p, w_f) on the AOTI and OMMC value of the fabrics Analysis of Variance (ANOVA) test (two-way) was also performed. The results are shown in Table 5.

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Table 3: Physical Properties of the Developed Samples									
Sample No.	Density (W_p, W_f)	Blend Ratio (PC)	Thickness (mm)	Count (W_p, W_f)	Ends per inch	Picks per inch	Area Density (g/m²)	Fibre Density (g/m²)	Fabric Density (g/m²)	Porosity (%)
1	90×50	0:100	0.32	40	90	50	89	1540000	276719	82
2	90×50	65:35	0.25	40	90	50	89	1390500	354200	75
3	90×50	80:20	0.25	40	90	50	89	1356000	354200	74
4	100×65	0:100	0.28	40	100	65	102	1540000	367703	76
5	100×65	65:35	0.28	40	100	65	104	1390500	372723	73
6	100×65	80:20	0.26	40	100	65	104	1356000	401394	70
7	110×70	0:100	0.28	40	110	70	114	1540000	406607	74
8	110×70	65:35	0.28	40	110	70	114	1390500	406607	71
9	110×70	80:20	0.27	40	110	70	114	1356000	421667	69

Table 4: Moisture Transport Properties of Developed Samples									
S. #	Density (W_p, W_f)	Blend Ratio (PC)	WT_t (sec)	WT_b (sec)	AR_t (%/sec)	AR_b (%/sec)	SS_t (mm/sec)	SS_b (mm/sec)	AOTI (%)	OMMC
1	90×50	0:100	2.30	2.33	50.95	63.75	7.18	7.14	115.97	0.584
2	90×50	65:35	2.79	2.81	24.39	52.61	7.66	8.10	195.35	0.674
3	90×50	80:20	1.98	2.02	66.21	76.55	9.16	9.08	227.43	0.736
4	100×65	0:100	3.64	4.12	43.5	39.69	5.49	4.99	151.77	0.557
5	100×65	65:35	2.63	2.64	37.51	59.84	6.89	8.16	202.98	0.689
6	100×65	80:20	2.11	2.12	52.14	68.85	8.95	8.90	232.33	0.727
7	110×70	0:100	2.43	2.59	50.47	62.84	6.74	6.64	148.25	0.617
8	110×70	65:35	2.17	2.17	53.19	68.69	8.38	8.43	214.68	0.707
9	110×70	80:20	2.25	2.42	35.04	55.93	8.66	8.55	239.10	0.698

Table 5: Two-Way Anova Analysis of AOTI And OMMC				
Source of Variation	AOTI		OMMC	
	F-value	p-value	F-value	p-value
Blend Ratio	91.17	0.000*	21.67	0.007*
Density (W_p, W_f)	4.74	0.088	0.30	0.758
*statistically significant at 95%				

3.1 Effect on Accumulative One-Way Transport Index (AOTI)

It can be seen from Fig. 1 that blends have an overall higher accumulative one-way transport index (AOTI). Furthermore, a higher proportion of polyester in the blended fabrics resulted in a higher accumulative one-way transport index (%). Higher AOTI values imply that perspiration will be transferred quickly from the layer next to skin to the outer surface thus improving the comfort to the wearer. Cotton is hydrophilic in nature and has large number of hydrogen bonding sites in its structure which are responsible for holding the moisture. Thus, in case of cotton fiber, the transfer of moisture to the environment is relatively slower. While polyester being hydrophobic is unable to hold moisture and therefore transfer it rapidly to the bottom
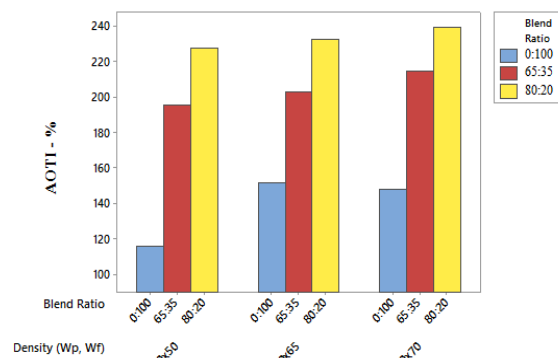

Fig. 1: AOTI Values of Developed Samples

surface [4, 16] which is quite apparent from the wetting time of the bottom surface (WT_b) in Table 4. Changing the warp and weft densities has a substantial effect on AOTI value, greater the number of warp and

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weft per inch of a fabric higher will be the transport index. This may be due to the lower porosity and higher capillary rise in tightly woven fabric. Moreover, it is observed from Table 5 that the effect of blend ratio on AOTI is statistically significant at 95% level.

3.2 Effect on Overall Moisture Management Capability

Fig. 2 shows the overall moisture management capability of prepared fabric samples which was calculated by using equation (3) keeping in consideration the transport behavior, absorbency and spreading speed of the fabric.

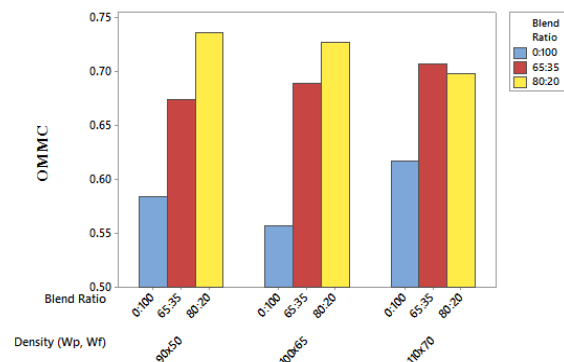$$OMMC = C_1 AR_b + C_2 AOTI + C_3 SS_b \qquad (3)$$

Fig. 2: Overall Moisture Management Capability (Ommc) Values of Developed Samples

In equation (3), $C_1 = 0.25$, $C_2 = 0.5$ and $C_3 = 0.25$. The higher output of equation (3) will show that a fabric has excellent moisture management properties [17]. It is evident from Fig. 2 that blends have an overall higher moisture management capability. Blending ratio plays also an important role on an overall OMMC values. Higher the polyester portion higher will be the OMMC value. It is because of the fact that synthetic fibres have higher transport index and drying rate in comparison to natural fibres which have good absorption but low spreading rate. It was also observed that the variation in warp and weft densities have an impact on overall moisture management capacity of the fabric. Higher the density lower would be this capacity. This change in OMMC is basically related to quick change in AOTI and AR_b with change in warp and weft density. Furthermore, it is observed that the

effect of blend ratio on OMMC is statistically significant at 95% level. Among all the samples, the highest OMMC values were observed for the fabrics with 80:20 blend ratio. It is interesting to note than increase in warp and weft densities for blends with higher polyester content affect negatively to the OMMC behavior while for blends with higher cotton content a positive impact on OMMC have been observed.

4. CONCLUSION

It can be concluded that a woven fabric constructed using polyester/cotton yarns has an overall improved moisture management capability compared with an identically constructed fabric using 100% cotton yarn. For all those blends which have higher polyester content, lower warp and weft densities will favor higher OMMC values but with an increase in cotton content this will be accomplished by increasing these densities in the fabric. Though warp and weft densities do not contribute significantly to the overall moisture management behavior of the woven fabric but higher warp and weft densities favors quick transport of moisture from inner to outer surface, whether it is 100% cotton or a polyester/cotton blended fabric.

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