Effect of Plasma Treatment on Moisture Management Properties and Drying Behavior of Polyester and Blend Fabrics for Sportswear Application

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Abstract

The hygienic and comfort properties of fabrics for clothing are basically determined by their electrifiability and ability to absorb moisture, i.e. the hygroscopicity and capillarity, which are quantitative characteristics of the hydrophilicity of materials. Unfortunately, the most common synthetic fibre, Polyester exhibits high electrifiability and low hydrophilicity, which makes it unsuitable for fabrication of fabrics with properties close to cellulosic fibre and significantly restricts the area of their application. However, now a days, it is more preferable in the active sportswear due to its excellent physical properties like abrasion resistance, strength etc. and low cost. The present study aims at increasing the hydrophilicity of polyester and polyester blends by combination of plasma modification and chemical treatment. Surface modification of the developed fabrics is carried out by di-electric barrier discharge plasma in presence of air and subsequently the fabrics are subjected to chemical treatment to impart hydrophilic property to make it suitable for active sportswear. The moisture management properties, drying rate and air permeability, abrasion resistance etc. of these fabrics are evaluated.

Keywords: Sportswear; Hydrophilicity; Polyester; Plasma modification; Moisture management

Abbreviations: DBD: Di-Electric Barrier Discharge; OWTC: Accumulative One-Way Transport Capacity; OMMC: Overall Moisture Management Capability

Introduction

Polyester fiber is one of the most widely consumed fibers (about 70%) in sportswear application but its hydrophobic properties causes discomfort to the wearer [1]. Hydrophobic nature of polyester can be a disadvantage for certain applications like moisture management properties, dyeing, finishing, detergency, etc. [2]. During sports activity, wearer perspires a lot and it is essential that the perspiration should transfer to the outer surface of the fabric from where it gets evaporated and wearer feels dry and comfortable. Physical or chemical modification of polyester to make it more hydrophilic is therefore desirable for certain performance characteristics. Surface modification of polyester for hydrophilicity can be achieved by application of adsorbing polymers on the polyester surface [3].

Moisture management is one of the important property in Active sportswear fabrics with respect to thermo-physiological comfort. Therefore, it is essential to increase the hydrophilicity of polyester. In moisture management fabrics, the body perspiration is transported away from the skin to the outer surface of fabric where it can evaporate quickly in order to accomplish the consumer satisfaction of comfort [4]. To achieve such moisture management, the structural design and quality of fibers are modified so that the textile products can have good performance in absorbing, transporting, and dissipating moisture [5,6]. According to The Tai Lee Textiles Company, moisture management is related to wickability of the fabric which mainly depends upon the type of fiber and its chemical characteristics, diameter of the fiber, diameter of the yarn, yarn regularity, surface structure of the fabric, fabric construction,

weave pattern, the cover factor, fabric weight etc. [7]. Das et al. [8] also described that moisture management can be enhanced through a suitable chemical treatment or coating [8].

It is evident that fiber type, yarn properties, fabric structure, finishing treatments affects the clothing comfort. The use of blended fibre combinations in sportswear has grown in the past decade as brands attempt to improve function and comfort using different fiber blends. The use of blending technologies and the chemical finishing available for sportswear will continue to provide a source of innovation for sportswear products. Therefore, the present study aims to investigate the moisture management properties and drying rate of commercial garments, and 16 knitted fabrics developed for sportswear application, composed of plasma and chemically modified polyester and polyester blend fabrics.

Table 1: Construction parameters of polyester and polyester blend fabrics.

S. No.	Fabric Parameters	K1	K2	K3	K4
		Polyester	Polyester/Lycra	Polyester	Polyester/Cotton
2.	Blend Composition %	100	95/5	100	68/42
3.	Polyester filament denier	2 D	2 D	2 D	2 D
4.	Cotton/Lycra count	--	20 D Lycra (Spandex)	--	60 Ne
5	Yarn Count	85 D/48 filament filament	85 D/48 filament	85 D/48 filament	85 D/48
6.	Wales per cm	14	14	14	14
7.	Course per cm	14	12	18	18
8.	Grams per square meter (GSM)	114.0	123.0	298.0	298.0
9.	Stitch Length (in mm)	2.5	2.7	4.5	4.5
10.	Knit Structure	Single layer Knitted fabric	Single layer Knitted fabric	Double Layer interlock Knitted fabric	Bi layer interlock Knitted fabric

Table 2: Construction parameters of commercial garments.

S. No.	Test Parameters	Results		
		Commercial Garment (CG-1)	Commercial Garment (CG-2)	Commercial Garment (CG-3)
1	Application	Bottoms	Top	Top
2	Blend composition	100% polyester	Cotton - 26.0% Polyester - 74.0 %	Cotton - 57.0 Polyester - 43.0 %(dotted portion) Cotton - 59.5 Polyester - 40.5 %(plain portion)
3	Count of yarn (in Nm) (IS 3442)	1/150.2	1/42.7	1/47.5
4	Yarn twist (IS 832)	Texturized yarn	17.7	15.0
5	Fiber Denier (ASTM D 1577)	0.8	1.5	1.5
6	Weave (visual)	Double jersey	Single jersey	Single jersey
7	GSM	161.59	103.27	145.17 (dotted portion) 157.14 (plain portion)
8	Thickness (in mm)	0.414	0.525	0.49 (dotted portion) 0.519 (plain portion)
9	Wales per inch	112.75	34.25	35.25
	Course per inch	126.25	54.75	58.5

Materials and Methods

Materials

Polyester filament yarn (85 denier), Cotton yarn (Count 60 Ne), Lycra (20 denier), three sport fabrics were procured from specialty sportswear store. Single Layer interlock knitted fabric with lycra (Spandex) and polyester was developed. Lycra filament yarn was added to the single layer knitted polyester fabric to provide stretchability to the fabric. Similarly, Double Jersey interlocks and bi-layer interlocks knitted fabrics were also developed. Construction parameters of Single layer and double layer developed knitted fabrics are mentioned in Table 1. And construction parameters of commercial garments are mentioned in Table 2.

Plasma treatment of developed fabrics

To study the effect of plasma treatment on moisture management properties and drying behavior of knitted fabrics, a Di-electric Barrier Discharge (DBD) plasma chamber was employed for plasma treatment of polyester fabric at different duration keeping voltage and electrode spacing constant. Air

was used as non-polymerizing gas for plasma treatment. Undyed microfilament polyester fabric of sample size 40cm width and 50cm length was spread between the two electrodes and then plasma treatment was carried out. The treatments were given only on one side of the fabric i.e., inner side of the garment to be worn. Table 3 indicates the details of plasma trials conducted on single layer and double layer knitted fabrics.

Table 3: Plasma trials conducted on polyester and polyester blend fabrics.

S. No.	Sample Code	Duration of plasma treatment in mins (at 4.0KV Voltage and 3mm Electrode Spacing)
1	K1 - UT	-
2	K1 - A	5min
3	K1 - B	10min
4	K1 - C	15min
5	K2 - UT	-
6	K2 - A	5min
7	K2 - B	10min
8	K2 - C	15min
9	K3 - UT	-
10	K3 - A	5min
11	K3 - B	10min
12	K3 - C	15min
13	K4 - UT	-
14	K4 - A	5min
15	K4 - B	10min
16	K4 - C	15min

Application of moisture management finish

To remove the impurities like lubricants and antistatic agents, 100% polyester and Modal/Cotton, Modal/Polyester woven and knitted fabrics were scoured using 1gpl nonionic surfactant (Archroma) at 65 °C for 30min followed by rinsing, hydro extraction and drying at room temperature. These scoured fabrics were then used for moisture management finish. 30gpl Hydrophillic Softener (Archroma) which is a modified polyester copolymer based nonionic chemical; was used for finishing of polyester fabrics with 60% weight pickup. The trials were conducted using pad - dry - cure method on laboratory pad dry cure machine (R. B. Electronics and Electrical Pvt. Ltd., Mumbai); curing was carried out at 120 °C for 4min.

Results & Discussion

Moisture management properties

Fabric liquid moisture transport properties in multi dimensions, called moisture management properties

significantly influence human perceptions of moisture sensation. Moisture management tester has been developed by SDL Atlas to evaluate textile moisture management properties. This method can be used to quantitatively measure liquid moisture transfer in one step in a fabric in multiple directions. Moisture spreads on both surface of the fabric and transfer from one surface to the opposite. Here ten indices are introduced to characterize the liquid moisture management properties of fabric. It measures electrical conductivity changes as a test solution migrates across the top of, through, and across the bottom of the test specimen. Factors affecting this movement include fabric water repellency, water resistance, and water absorption, and fiber and yarn wicking properties. Perspiration is mimicked with TM 195. The results obtained with this test method are based on water resistance, water repellency and water absorption characteristics of the fabric structure, including the fabric's geometric and internal structure along with the wicking characteristics of its fibers and yarns.

Moisture management tester indices

The indices of the MMT that are used to characterize the moisture management properties of a fabric are as mentioned below:

- Wetting time top (WT_t)
- Wetting time bottom (WT_b)
- Top absorption rate (MAR_t)
- Bottom absorption rate (MAR_b)
- Top maximum wetted radius (MWR_t)
- Bottom maximum wetted radius (MWR_b)

- Top spreading speed (SS_t)
- Bottom spreading speed (SS_b)
- Accumulative One-Way Transport Capacity (OWTC)
- Overall Moisture Management Capability (OMMC) [9,10].

The OWTC is the difference of accumulative moisture content between the two surfaces of fabric. The OWTC reflects the one-way liquid transport capacity from the top (inner) surface to the bottom (outer) surface of the fabric Table 4. The OMMC is an index indicating the overall capacity of the fabric to manage the transport of liquid moisture, which includes three aspects:

Table 4: Grading of MMT Indices.

Index		Grade				
		1	2	3	4	5
Wetting Time	Top	≥120	20-119	5-19	3-5	<3
		No wetting	Slow	Medium	Fast	Very fast
	Bottom	≥120	20-119	5-19	3-5	<3
		No wetting	Slow	Medium	Fast	Very fast
Absorption rate	Top	0-10	10-30	30-50	50-100	>100
		Very Slow	Slow	Medium	Fast	Very Fast
	Bottom	0-10	10-30	30-50	50-100	>100
		Very Slow	Slow	Medium	Fast	Very Fast
Max wetted radius	Top	0-7	7-12	12-17	17-22	>22
		No wetting	Small	Medium	Large	Very Large
	Bottom	0-7	7-12	12-17	17-22	>22
		No wetting	Small	Medium	Large	Very Large
Spreading Speed	Top	0-1	1-2	2-3	3-4	>4
		Very Slow	Slow	Medium	Fast	Very Fast
	Bottom	0-1	1-2	2-3	3-4	>4
		Very Slow	Slow	Medium	Fast	Very Fast
OWTC		<-50	-50-100	100-200	200-400	>400
		Poor	Fair	Good	Very Good	Excellent
OMMC		0-0.2	0.2-0.4	0.4-0.6	0.6-0.8	>0.8
		Poor	Fair	Good	Very Good	Excellent

- Average moisture absorption rate at the bottom surface;
- One-way liquid transport capacity;
- Maximum moisture spreading speed on the bottom surface [11,12].

According to AATCC Test Method 195-2009, the indices are

graded and converted from value to grade based on a five point grade scale (1-5), The five grades of indices represent: 1-Poor, 2-Fair, 3- Good, 4- Very Good, 5- Excellent. Table 1 shows the range of values converted into grades.

The moisture management properties of the commercial garments and developed fabrics in grades are mentioned in Table 5.

Table 5: MMT results in grades of commercial garments and developed fabrics.

Fabric	WT _t	WT _b	MAR _t	MAR _b	MWR _t	MWR _b	SS _t	SS _b	OWTC	OMMC
Commercial garment (CG-1)	5	5	3.5	3.5	5	5	5	5	1.5	2.5
Commercial garment (CG-2)	5	4.5	4	4	5	5	5	5	1.5	2.5
Commercial garment (CG-3)	4.5	4.5	3.5	3.5	5	5	5	5	1.5	2.5
K1- Untreated	5	5	3	3	5	5	5	5	2	3
K1 - A	3	5	3	2	4	4	3	5	5	4
K1 - B	3	5	3	2	5	4	3	4	4	4
K1 - C	3	5	4	2	5	4	4	4	4	4
K2 - Untreated	5	5	3	3	5	5	5	5	1	2
K2 - A	3	5	3	2	4	4	3	5	5	4
K2 - B	3	5	3	2	4	4	3	4	4	4
K2 - C	3	5	4	2	4	4	4	4	4	4
K3 - Untreated	4	4	2	2	4	5	4	5	2	3
K3 - A	3	3	3	3	4	5	5	5	5	4
K3 - B	4	3	3	3	4	5	5	5	5	4
K3 - C	4	4	3	2	4	5	4	5	5	4
K4- Untreated	4	4	3	2	5	3	5	3	1	1
K4 - A	3	3	4	2	5	3	2	4	4	3
K4 - B	3	3	4	2	4	3	3	3	4	3
K4 - C	3	3	4	4	2	2	2	3	4	3

Figure 1: Accumulative One Way Transport Index grades of commercial garments and developed fabrics.

Figure 1 indicates mean grade of accumulative one way transport index for all 3 commercial fabrics and 16 developed fabrics. In non blended fabric 100% Polyester (K1-UT and K3-

UT) has fair one way transport capacity whereas Polyester/Lycra (K2-UT) blend fabric and Polyester/Cotton blend fabric (K4-UT) shows poor one-way transport capacity. Commercial garment

has fair OWTC. Plasma and chemically treated Polyester (K1A- K1C, K3A- K3C), Polyester/Lycra (K2A- K2C) and Polyester/Cotton (K4A- K4C) fabric shows very good to excellent one way

transport index grade indicating that these fabrics can also be effectively used for sportswear application.

Figure 2: Overall moisture management capability grade of commercial garments and developed fabrics.

Figure 2 indicates overall moisture management capability for all 3 commercial fabrics and 16 developed fabrics. 100% Polyester (K1-UT and K3-UT) has good OMMC grades. Whereas Polyester/Cotton blend fabric (K4-UT) shows poor OMMC grades and Polyester/Lycra (K2-UT) blend fabric shows fair OMMC

grades. Commercial garment has fair to good OMMC properties. Plasma and chemically treated Polyester (K1A- K1C, K3A- K3C), Polyester/Lycra (K2A- K2C) fabric shows very good overall moisture management capability grade indicating that these fabrics can also be effectively used for sportswear application.

From the Table 5, it is observed that 5minute plasma treatment is optimum as giving higher one way transport index and overall moisture management capability grade in almost all the fabrics. It can be seen that OWTC grade and OMMC grades are higher for plasma pre-modified followed by chemical treated samples compared to untreated and commercial fabric samples indicating suitability of developed fabrics for effective moisture management properties required in sportswear application.

Drying rate

This drying rate test determines the drying rate of textile fabrics based on the evaporation rate at standard atmospheric conditions. This testing is based on measuring the weight of water content which is applied on the fabric for a particular time period by using a weighing balance and with drying rate software connected to it. Table 6 elaborates drying rate of 3 commercial fabrics and 16 developed fabrics. Drying rate of commercial garment is in the range of 0.29-0.38%/min.

Table 6: Drying Rate of commercial garments and developed fabrics.

Sample Code	Dry Rate (%/min)
Commercial garment (CG-1)	0.38
Commercial garment (CG-2)	0.34
Commercial garment (CG-3)	0.29

K1- Untreated	0.60
K1 - A	0.32
K1 - B	0.25
K1 - C	0.21
K2 - Untreated	0.47
K2 - A	0.28
K2 - B	0.24
K2 - C	0.22
K3 - Untreated	0.43
K3 - A	0.34
K3 - B	0.29
K3 - C	0.29
K4- Untreated	0.57
K4 - A	0.29
K4 - B	0.26
K4 - C	0.21

Figure 3: Drying rate of commercial garments and developed fabrics.

Figure 3 shows that untreated Polyester fabric shows drying rate of 0.60 and 0.43%/min whereas Polyester/Lycra and Polyester/Cotton blend fabric shows drying rate of 0.47 and 0.43%/min respectively. From the results it is observed that after plasma and chemical treatment drying rate of Polyester, Polyester/Lycra and Polyester/Cotton blend decreases. It is found that with the increase in plasma treatment time, the drying rate (%) per minute decrease. It may be due to the more surface roughening of Polyester fabric resulting in more absorption of the hydrophilic chemicals. But even after considerable drop in drying rate of developed fabric their drying behavior are comparable with commercial garment. This indicates that plasma and chemically modified Polyester and Polyester blends show low drying rate compared to untreated fabrics but still they are suitable for sportswear application when compared with commercial garment.

Conclusion

Sportswear is a very vast and challenging field in which required functionality can be designed by suitable choice of raw materials, structure and geometry of fibers, yarns and fabrics, surface modification and garment assembly techniques. Moisture management properties like sweat absorption, sweat dissipation and faster drying are the primary desirable functions of high active sportswear which affects the comfort sensation of a player during a game. To achieve these properties, Polyester and Polyester/Lycra and Polyester/Cotton blend fabrics are treated with air plasma followed by a chemical treatment to enhance hydrophilicity. Plasma treatments help in surface roughening of Polyester. Plasma pre-modified knitted Polyester fabrics are given hydrophilic chemical treatment. The plasma treatment time of 5min followed by chemical treatment is found to give the optimum results with respect to moisture management properties and drying rate. The study indicates that after plasma and finishing with hydrophilic finishing chemical; the Polyester fabrics shows enhance moisture management properties with

moderate drying rate which makes it suitable for sportswear application. These modified and light weight moisture management fabrics will be helpful to keep the sportsman free from uncomfortable clinginess and it can also improve the performance of sportsperson.

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