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Comparison of Moisture Management Properties of Plasma Treated Single Jersey Fabric with Different Types of Polyester Yarns

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Abstract
In this study, the moisture management properties of plasma treated single jersey knitted fabric with different types of polyester yarns: spun polyester, continuous filament yarn and micro denier yarn with different linear densities were analysed and investigated. The moisture management properties of the same were measured using a moisture management tester. The results of the treated and untreated single jersey fabric were tested for their wetting time, absorption rate, maximum wetted radii, spreading speed, and overall moisture management capacity . It was observed that for the plasma treated fabrics, the time taken for wetting and the absorption rate of spun polyester are faster. Continuous filament polyester shows the maximum wetted radii, and the spreading speed and overall moisture management capacity (OMMC) of spun polyester significantly increases when compared with untreated fabrics. The plasma treatment significantly improved the overall performance of polyester fabric.

Key words: *polyester, plasma, moisture management, single jersey, knitted fabric.*

Introduction

The important aspect of any apparel fabric that determines the comfort level is moisture management properties [1-3]. The liquid moisture transmittance in clothing apparently affects the perception of the wearer's moisture comfort sensation. When water droplets fall on a fabric surface, the water spreads radially in all directions. The movement of that water merely depends on the property of the fabric. Hu et al. [3] concluded that the ability of a textile fabric to control the movement of liquid humidity from the skin and transport it from the inner textile to the outer surface is called the moisture management of textile material. Hu et al. [5] defined moisture management as the transport of liquid moisture of textile fabric in a multi-dimensional direction.

Kan and Yuen [6] observed that plasma treatment is a physio-chemical method that is used for surface modification, as the surface of fabric is affected both physically and chemically without altering its bulk properties. Leroux et al. [7] found that atmospheric air plasma treatment of polyester fabrics caused a significant increase in their water wettability, surface energy and water capillarity due to the production of hydroxyl and carboxylic groups. Seki et al. [8] showed that O_2 plasma improved the tensile and flexural strength of jute fiber/polyester composites when treated with both the low and radio frequency plasma systems. Au [9] found that knitted fabrics have their own excellent properties, such as comfort, easy care, resistance to wrinkle, and cost effectiveness. They have various end uses due to these various properties. Choi and Ashdown's [10] results show that among the various knitted fabrics, single jersey are commonly used, which has a good amount of widthwise extensibility, a moderate amount of lengthwise extensibility, and a thin structure when compared to other types of knitted fabrics.

Achour et al. [11] observed that a blend of polyester fibres along with cotton fibre relatively improved many of the moisture management properties. It was also found that the spreading speed also increases with the blend of polyester fibre. This paper aims to highlight the effect of oxygen plasma treatment on different polyester fabrics and its impact on moisture management properties.

Materials and methods

Materials

Three different types of polyester, namely spun (166 dtex) yarn, continuous filament yarn (111 and 166 dtex) and micro denier polyester (111 and 166 dtex) yarns, were taken. Single jersey knitted fabrics were produced using a 21-feed circular knitting seamless machine – KNITMAC 24E gauge, of 16 inch cylinder diameter and 27 rpm velocity, with a special attachment – a positive storage feeder. The loop length setting was kept constant at 0.25 cm for all the samples, respectively. All the cut knitted samples were relaxed on a flat surface for 48 hours in a tension free state in a conditioning cabinet. A standard atmosphere of 21 °C ± 1 and 65% ± 2 relative humidity were maintained in the cabinet.

Plasma treatment

In this study, polyester fabric samples were treated with a vacuum plasma device from Diener electronic GmbH. Fabric samples of 30 cm x 30 cm size were treated with uniform glow discharge plasma. The fabric samples were placed in between the cathode and anode plate with an electrode gap of 2 cm. Plasma treatment of the fabric sample was carried out with oxygen in a 12" DC plasma chamber under a power of 40KHz. The samples were treated for about 5 minutes. After the treatment, the plasma treated fabrics were subjected to conditioning for 24 h at 25 °C and relative humidity of 65%.

Moisture management testing

Moisture management properties of the fabric samples were tested by an SDL Atlas MMT (AATCC TM 195), produced by SDL Atlas company, which is standard testing equipment from the USA. The samples were evaluated by placing them between the upper and lower horizontal sensors, each having seven concentric pins. Predetermined amounts of the test solution were dropped on the center of the upper surface of the fabric sample. The test solution moves in three different directions: spreading radially on the top surface, movement through the fabric sample from the top to the bottom surface, and spreading radially on the bottom surface. During the test, changes in the electrical resistance of the samples were measured and recorded.

To identify the significance of differences between the various fabric samples and the overall moisture management capacity, Two-way ANOVA was used. The differences were considered to be significant if the *P*-value was equal to or less than 0.05 Ergun, 1995 [12].

Results and discussion

Fabric physical properties

Physical properties of continuous filament, spun and micro denier polyester knitted fabric are shown in ***Table 1***.

Statistical data analysis

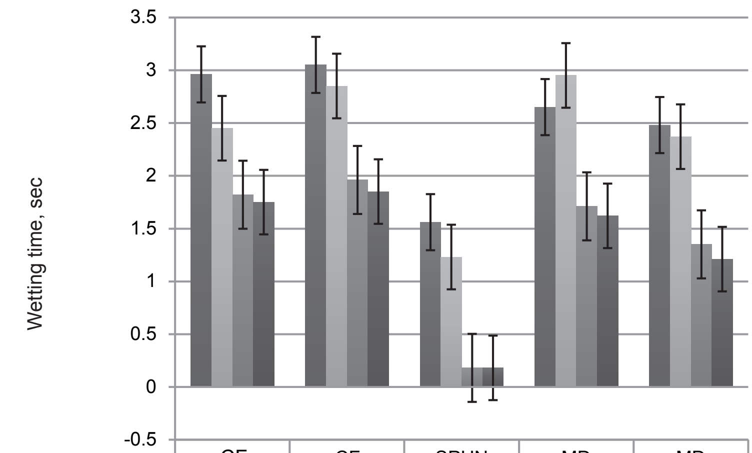
To evaluate the statistical data of the results, two-way analysis of variance (ANOVA) was used to find the significance of the plasma treatment for the overall moisture management capacity of the different types of polyester fabrics. To find out whether the results are significant or not, *p* values are taken into account. Results of the two-way ANOVA are given in ***Table 2***. From the values given in the Table, it is revealed that continuous filament polyester, spun polyester and microdenier polyester are significant factors for the OMMC at $p < 0.05$, respectively.

Moisture management properties

Effect of plasma treatment on wetting time

Wetting time values in seconds of the top WT_t (seconds) and bottom surfaces WT_b (seconds) of the fabric samples are given in ***Figure 1***, showing the time taken for the top and bottom surfaces of the fabric to begin to wet after commencement of the test.

It can be seen that the wetting time for both the face and reverse sides of the fabrics changes with the different yarn



	CF (111 dtex)	CF (166 dtex)	SPUN (166 dtex)	MD (166 dtex)	MD (111 dtex)
Untreated WT top, sec	2.96	3.05	1.56	2.65	2.48
Untreated WT bottom, sec	2.45	2.85	1.23	2.95	2.37
Treated WT top, sec	1.82	1.96	0.18	1.71	1.35
Treated WT bottom, sec	1.75	1.85	0.18	1.62	1.21

Figure 1. *Wetting time values (sec) of polyester knitted fabrics.*

Table 1. *Physical properties of continuous filament, spun and microdenier polyester knitted fabric.*

Samples	Linear density, dtex	GSM	WPI	CPI	Loop length, cm
Continuous filament yarn	111	0.95	47	36	0.25
	166	0.74	48	35	
Micro denier yarn	111	1.36	53	39	
	166	1.57	54	41	
Spun yarn	166	1.62	59	45	

Table 2. *Statistical comparison.* ***Note:*** ** Significant for α = 0.05.*

Source of variation	Sum of square value (SS)	Degree of freedom (df)	Mean square value (MS)	F-Value	*P*-Value	F crit
Fabric samples	0.0607	4	0.0151*	55.479	0.001	6.388
OMMC	0.0127	1	0.0127*	46.574	0.002	7.709
Error	0.0011	4	0.0003			

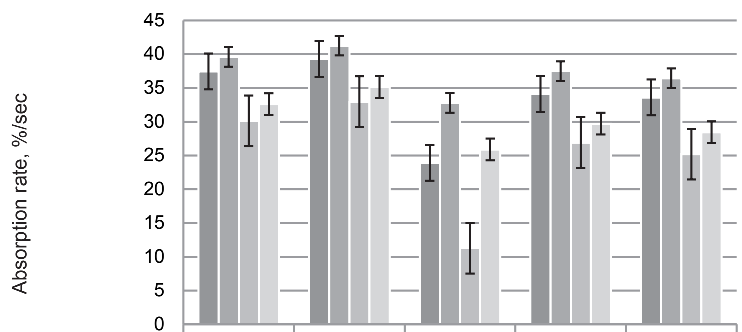
and its count as well as with the plasma treatment.

The results indicate that the wetting time of the top surface is higher than that of the bottom surface for all the fabric samples. The wetting time for the spun polyester fabric is satisfactory, and the fabric has good absorbency.

From ***Figure 1***, it is observed that the plasma treated fabric samples show improved absorbency when compared with the untreated fabric samples, which is because of the surface etching created by the plasma treatment. It is also observed that as the count increases, the wetting time also increases, with that of the spun polyester fabric showing the fastest for both the top and bottom fabric surfaces. Also the effect of O_2 plasma is very well shown in that the wetting time considerably decreases compared with that of the untreated fabric. Furthermore Wrobel et al. [13] stated that the wetting time of plasma treated fabric considerably drops in comparison to untreated fabric, and the best results are obtained by treatment in nitrogen, oxygen and air plasma.

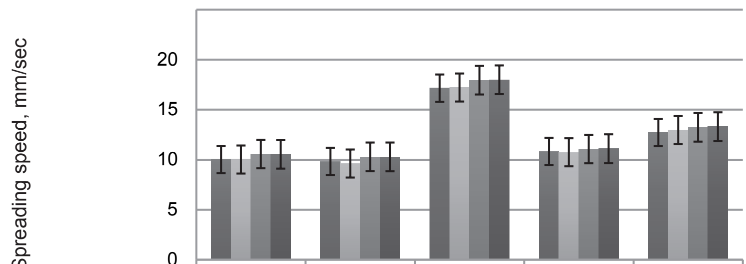
Effect of plasma treatment on absorption rate

The absorption rates of the top and bottom surface of before and after plasma treated fabric are given in ***Figure 2***, from which it is clearly seen that the absorption rates are dependent on the count and plasma treatment; as the count



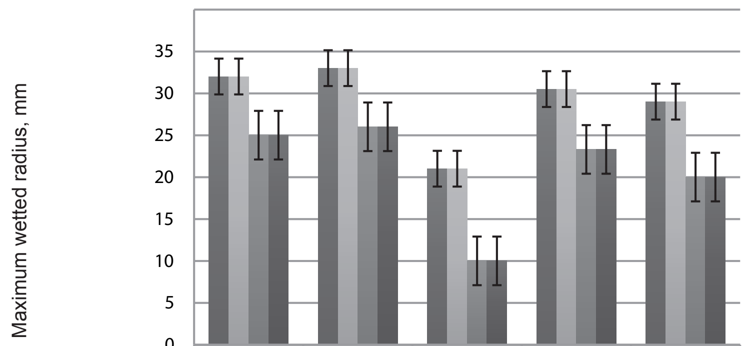
	CF (111 dtex)	CF (166 dtex)	SPUN (166 dtex)	MD (166 dtex)	MD (111 dtex)
Untreated AR top, %/sec	37.43	39.27	23.91	34.11	33.59
Untreated AR bottom, %/sec	39.58	41.25	32.77	37.47	36.43
Treated Ar top, %/sec	30.11	32.96	11.26	26.91	25.19
Treated Ar bottom, %/sec	32.58	35.14	25.88	29.71	28.43

Figure 2. *– Absorption rates (%/sec) of polyester knitted fabrics.*



	CF (111 dtex)	CF (166 dtex)	SPUN (166 dtex)	MD (166 dtex)	MD (111 dtex)
Untreated SS top, mm/sec	10.01	9.83	17.15	10.83	12.71
Untreated SS bottom, mm/sec	10.01	9.61	17.21	10.73	12.95
Treated SS top, mm/sec	10.56	10.28	17.94	11.06	13.23
Treated SS bottom, mm/sec	10.54	10.27	17.98	11.09	13.29

Figure 3. *Spreading speed (mm/sec) of polyester knitted fabrics.*



	CF (111 dtex)	CF (166 dtex)	SPUN (166 dtex)	MD (166 dtex)	MD (111 dtex)
Untreated MWR top, mm	32	33	21	30.5	29
Untreated MWR bottom, mm	32	33	21	30.5	29
Treated MWR top, mm	25	26	10	23.3	20
Treated MWR bottom, mm	25	26	10	23.3	20

Figure 4*. Maximum wetted radius (mm) of polyester knitted fabrics.*

increases, the absorption rate also increases, and the plasma treated fabrics show a reduced absorption time for all the samples. Ömeroğulları and Kut [14] stated that there was an increase in the hydroxyl group and surface roughness, which thereby showed an improvement in hydrophilic properties of the oxygen plasma treated polyester fabric. Due to the increase in the hydrophilic property, there was an increase in the absorption rate of the plasma treated fabric. Karaca et al. [15] explained in their paper that there was a significant increase in the absorption rate of plasma treated fabric, whereby the absorption performance was attributed to the etching effect. Sójka-Ledakowicz, J and Kudzin, M [18] observed that atmospheric water vapour gets absorbed by plasma treated fabric due to the more hydrophilic nature of the surfaces of the fibres, which is due to the broad peaks that are formed owing to hydroxyl groups: –OH and > C-O or > C-O• on the plasma treated surface of the fabric

Effect of plasma treatment on water spreading speed

Water spreading speed test results for the untreated and treated fabrics are given in ***Figure 3***. A comparison of the spreading speed values clearly reveals that the spreading speed decreases as the count increases. It was noted earlier that with the plasma treated fabrics, the wetting time decreases, and consequently the spreading speed for the wetting of the treated fabric is higher compared to that of the untreated fabric.

Kaynak et al. [19] states that coarser filament yarn has a higher value in the plane liquid moisture transfer capability due to its large macro-pores. Therefore fabrics with coarser filaments transfer liquid moisture more rapidly through the surface of the fabric.

Wang and Wang [16] clearly stated that the treatment of polyester fabric with oxygen plasma creates micro-pits on the surface, thereby improving the water absorption time due to the improved hydrophilic properties.

Effect of plasma treatment on maximum wetted radius

In the study, the MWR of the fabrics wetted with the same amount of liquid for both the treated and untreated fabrics was also investigated. The results for all the fabrics are given in ***Figure 4***. It can be seen that the MWR is lower for the plasma treated fabrics. Leroux et al. [7] stated that plasma treated polyester fabric produces a carboxylic group at the fabric surface and generates oxidation, which thereby increases the wettability and surface energy of the fabric. Because of the wettability and hydrophilic character created by the plasma treated polyester fabric, some of the liquid gets absorbed and penetrates into the fibre structure, which would result in lower moisture spreading along the fabric. Karaca et al. [15] states that plasma treated fabric shows low maximum wetted radii due to the increased surface area caused by the etching effect. Hence a lower value of MWR for plasma treated fabric means a less clammy touch, a less chilly sensation and, thus, overall better comfort close to the skin. Since the treated fabrics have the lowest MWR values for their top and bottom surface, it reflects a good moisture transport property and dry feeling as a result.

Effect of plasma treatment on fabric's accumulative one-way transport index and overall moisture management capacity

The OMMC is dependent upon the absorption rate, one-way liquid transport index and liquid spreading speed. ***Figures 5*** and ***6*** show values of the accumulative one-way transport index (AOTI) and OMMC, comparing them with the grading scale (0-0.2: very poor, 0.2-0.4: poor, 0.4-0.6, good, 0.6-0.8: very good, >0.8: excellent) (Yao et al.) [17]. From the results, it can be stated that continuous filament polyester fabrics of 166 dtex both untreated and treated show a low OMMC value. The plasma treated continuous filament (111 and 166 dtex) fabrics are in the 'good' category in terms of the moisture management capacity; however, all the other fabrics fall under the 'very good' category. Regarding the AOTI, all the fabrics are rated as 'very good', except the untreated and treated spun polyester fabric, which is rated as 'excellent' (Hu et al.) [5]

Conclusions

Plasma treatment plays an important role in the moisture-related comfort properties of clothing. This study focuses mainly on the effect of different counts of different polyester fabric on the moisture management properties of both plasma treated and untreated fabric. The results show that as the count

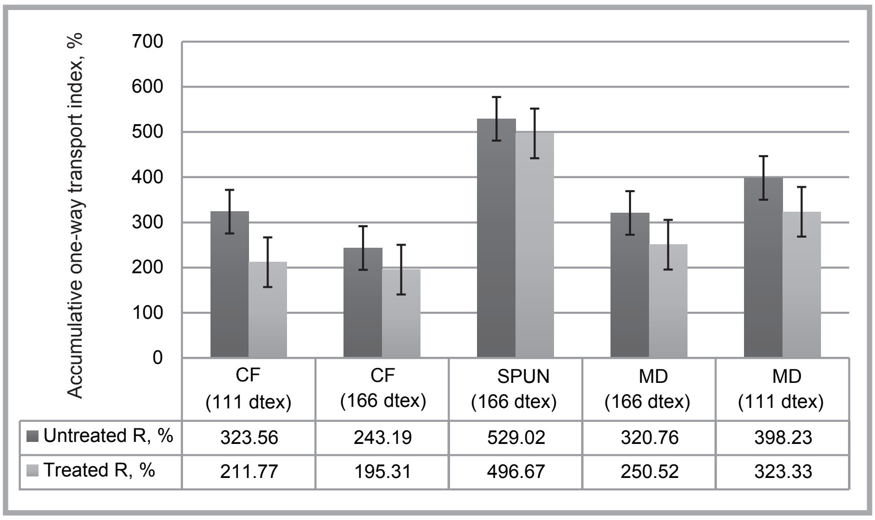


***Figure 5**. Accumulative one-way transport index (R%) of polyester knitted fabrics.*

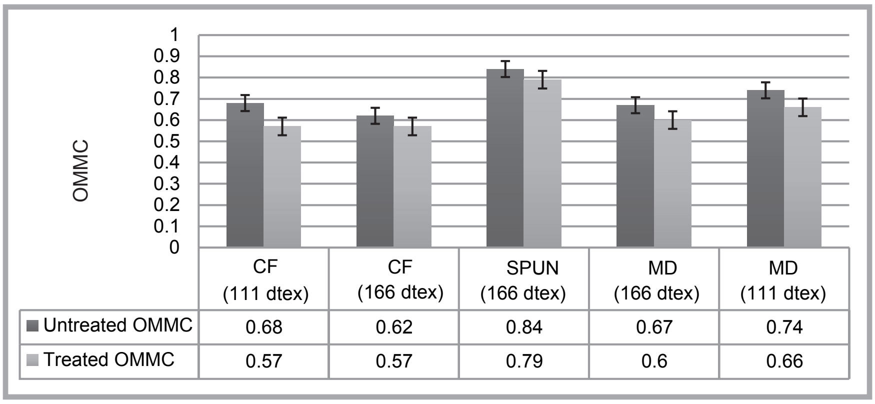


***Figure 6**. Overall moisture management capacity of polyester knitted fabrics.*

increases, the maximum absorption rate increases, whereas the wetting time of the plasma treated spun polyester is very low. The MWR and overall moisture management of the plasma treated fabrics decrease. The different counts and plasma treatment influence the moisture management properties of the fabric significantly. It is concluded that as the count increases, the wetting time, maximum absorption rate and MWR also increase. This means that with an increase in the count, more time is required to wet a knitted fabric. The OMMC can serve as an indicator of the moisture behaviour of fabrics. In general, most of the fabrics are in the 'very good' category, and only a few are in the 'good' category in terms of moisture management capacity.

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