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Investigation of Moisture Management Properties of Cotton and Blended Knitted Fabrics

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Abstract**—**The main idea of this work is to investigate the effect of knitted fabrics characteristics on moisture management properties. Wetting and transport properties of single jersey, Rib 1&1 and English Rib fabrics made out of cotton and blended Cotton/Polyester yarns were studied. The dynamic water sorption of fabrics was investigated under same isothermal and terrestrial conditions at 20±2°C-65±4% by using the Moisture Management Tester (MMT) which can be used to quantitatively measure liquid moisture transfer in one step in a fabric in multidirections: Absorption rate, moisture absorbing time of the fabric's inner and outer surfaces, one-way transportation capability, the spreading/drying rate, the speed of liquid moisture spreading on fabric's inner and outer surfaces are measured, recorded and discussed. The results show that fabric's composition and knit's structure have a significant influence on those phenomena.

Keywords**—**Knitted fabrics characteristics, moisture management properties, multidirections, the Moisture Management Tester.

I. Introduction

KNITTING structures are important due to several advantages such as comfort, high elasticity, conformity with the shape of the body and ease of care…[1]. Functional knits must have excellent moisture management properties and be claimed to have quick drying rates, most efficient movement of moisture away from the skin with excellent breathability. In fact, moisture transfer through textile fabrics is a critical factor affecting physiological comfort especially in sportswear, underwear, working garment or protective clothing [2], [3]. When the metabolism is very high, people sweat and perspiration spreads all over the skin, that's why, clothes should transfer quickly the sweat outside to provide tactile and sensorial comfort for the wearer and even to prolong sport exercise performance [4], [5].

Extensive publications on liquid flow through porous medium are available [6]-[17] and many investigations [18], [19] were used the well-known equation of Lucas and Washburn to describe the phenomenon of dynamics of capillary penetration and determine the diffusion coefficient. Other researches [1], [20]-[24] studied the influence of fibre and fabric type on thermophysiological comfort. However, the existing methods are unable to measure the behavior of dynamic liquid transfer in clothing materials in multidirections.

In the present study, different kinds of fabric knitted with cotton and cotton matched with polyester are designed and made out in different knit structures. Their liquid moisture transfer properties are characterized by using the Moisture Management Tester (MMT), by which the liquid moisture transport behaviors in three dimensions are sensed, measured, and recorded.

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II. Materials and Methods

A. Knitting

A 14-gauge Single Jersey Circular Knitting Machine of 30 cm diameter was used for manufacturing pure cotton and blended jersey fabrics: By adjusting the stitch cams the rate of yarn feeding to knitting needles was adjusted. The amount of yarn feeding in one revolution was not varied in order to produce fabrics with same loop length values "ℓ".

Rib 1&1 and English Rib are produced on a STOLL CMS 320 TC automatic straight knitting machine which has a double fall electronic jacquard selection on both needle beds and E gauge equal to 7 at same tightening values in order to investigate the knit structure effect. Table I presents the characteristics of knitted fabrics tested.

Following the AATCC method, the dimension of the dry sample used in experiments was 8 cm x 8cm +/- 0.1 cm square. Five specimens for each batch of fabric are recommended.

B. Fabrics Preparation

To remove all the waxes and the oils attached to greige fabrics and consequently to increase its hydrophilic properties, we make a scouring treatment for all the samples: the fabric was treated 1 hour at 100°C with a solution contained 2 mL of caustic soda, 3 g/L of wetting product and 3g/L of reducing agent.

C. Fabric Relaxation

Specimens are placed onto a flat surface and conditioned in the standard atmosphere for testing textiles (refer to ASTM D1776 method), which is 21 ± 1°C (70 ± 20°F) and RH 65% ± 2% relative humidity, for at least 24 hours prior to testing.

TABLE I
CHARACTERISTICS OF KNITTED FABRICS TESTED

Sample	Composition	Knit structure	Yarn spinning	Tightness factor ($tex^{1/2}/cm$)	Thickness (mm)	Weight per unit area (g/m^2)	Porosity (%)
1	*100% Cotton*	Jersey	Combed	13,58	0,968	153,9	89,68
2	*80% cotton -20% Polyester*	Jersey	Combed	13,58	0,980	128,5	89,07
3	100% Cotton	Rib 1&1	Carded	12,65	2,960	551,5	87,90
4	100% Cotton	English Rib	Carded	18,33	3,745	468,9	91,87

D.Fabric Testing

1. *Fabric weight per unit area*: Standard procedure for measuring the weight per unit area using small samples as per EN 12127:1997 was followed using an electronic balance with the accuracy of 0,001 g.
2. *Fabric thickness:* ISO: 5084 was used; the thickness of fabric samples was measured as the distance between the reference plate and parallel presser foot of the thickness tester under a load of 1 ± 0,1kPa.
3. *Porosity:* The porosity "P" is defined by the volume fraction of empty. This parameter can be expressed as a function of the weight "m" (g/m2), the thickness of the fabric "e" (m), and the density of the fiber "ρ" (g/m3). [25], [26].

$$P = 1 - \frac{m}{\rho * e} \quad (1)$$

4. *Stitch length*: EN 14970: 2006 is used for the determination of stitch length and yarn linear density in weft knitted fabrics.
5. *Fabric tightness factor:* The tightness factor of the knitted fabrics was determined by the following equation [26].

$$K = \frac{\sqrt{T}}{\ell} \quad (2)$$

w "T" is the yarn count in tex and "ℓ" is the loop length in cm.

To determine the statistical importance of the variations, correlation tests were applied.

E. Principal of Test Method and Apparatus Design

The Moisture Management Tester "MMT" is used as an experimental devise (Fig. 1); it was developed to test the liquid water transfer and distribution properties of top and bottom surfaces of fabrics [27]:

1. Absorption Rate - Moisture absorbing time of the fabric's inner and outer surfaces.
2. One-way Transportation Capability - One-way transfer from fabric's inner surface to outer surface.
3. Spreading/Drying Rate - Speed of liquid moisture spreading on fabric's inner and outer surfaces.

MMT consists of upper and lower concentric moisture sensors. The specimen is held flat under fixed pressure between the sensors while standard drop of test solution is pumped onto the top surface of the fabric to simulate a sweat drop (Fig. 2). Electrical resistance changes between the upper and lower sensors are then recorded dynamically on computer and processed by the MMT software [27]. The top surface of the fabric is the surface close to the skin of the human body when worn, and the bottom surface of the fabric is that closest to the surrounding environment.

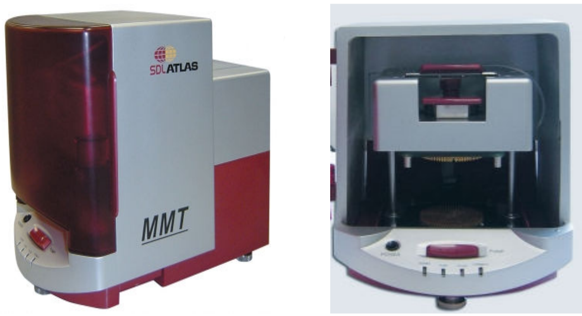


Fig. 1 Moisture Management Tester (MMT)

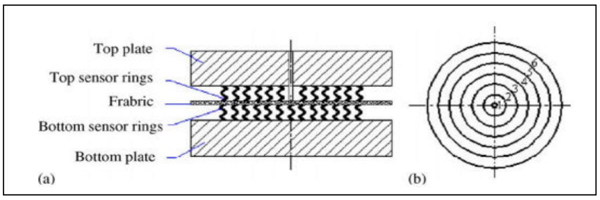


Fig. 2 Sketch of MMT sensors: (a) sensor structure; (b) measuring rings [27]

III. RESULTS AND DISCUSSIONS

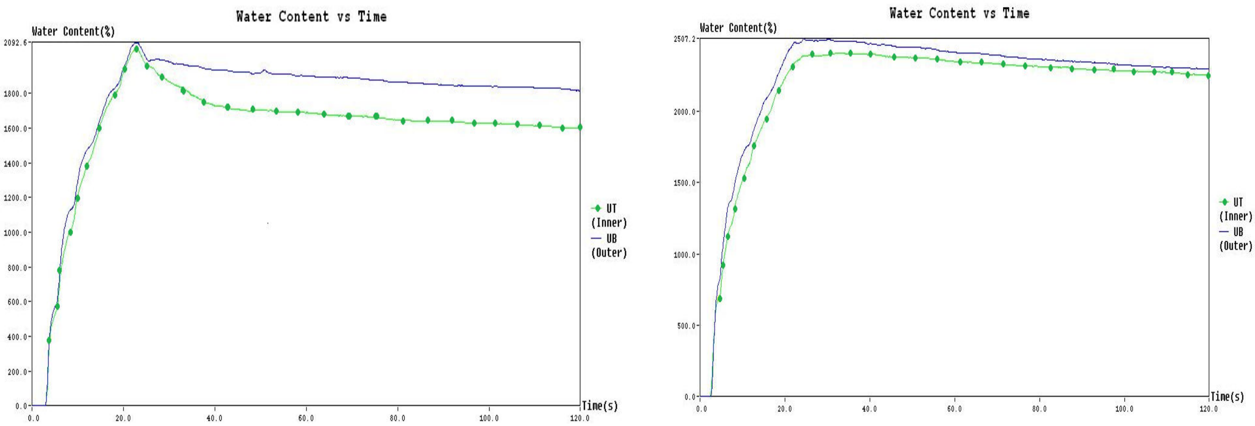
In this section, effect of knitted fabrics characteristics on moisture management properties is investigated, we note, fabric composition, knit structure. Indeed, wetting and transport properties of single jersey, Rib 1&1 and English Rib fabrics made out of cotton and blended Cotton/Polyester yarns were studied.

We measure the liquid moisture transport behaviors in three dimensions for every sample and we deduce the fabrics geometrical parameters effect, such as porosity and thickness on absorption rate and wetting properties.

A. Effect of Fabric Composition

The typical "MMT" relative water content curves versus time on the top and bottom surfaces (UT and UB) of knitted fabrics made out of pure cotton and blended Cotton/Polyester yarns are shown in Fig. 3 (a) and (b).

For the two samples, the relative water content of the top and the bottom surface increased suddenly at around 4seconds. And, it can be seen that water content on the top surface is lower than that on bottom one indicating quick transfer of liquid from top to bottom for both fabrics.



(a) (b)

Fig. 3 (a) Water content curves of 100% cotton fabric and (b) water content curve of Cotton/Polyester (80:20) blended fabric

The results of moisture management properties are summarized in Table II, it can be seen that the blending of PES fibers with cotton improves many of the moisture management properties. The spreading speed of PES-blended cotton fabrics was found to be higher than that of 100% cotton fabric. Only a marginal improvement in "OMMC" was observed which is explained by the little percentage of PES blended. It is essential to work with more amounts of PES fibers in the blend, to contribute to faster spreading of liquid moisture.

TABLE II
MOISTURE MANAGEMENT OF 100% COTTON AND COTTON/POLYESTER BLENDED KNITTED FABRICS

Parameters	Symbols	Cotton (100%) Mean	Cotton /PES (80:20) Mean
Wetting Time Top (s)	WTT	2,20	1,79
Wetting Time Bottom (s)	WTB	2,15	1,87
Top Absorption Rate (%/s)	TAR	102,55	98,82
Bottom Absorption Rate (%/s)	BAR	99,78	109,17
Top Maximum Wetted Radius (mm)	MWRT	30	30
Bottom Maximum Wetted Radius (mm)	MWRB	30	30
Top spreading spread (mm/s)	TSS	8,90	9,40
Bottom spreading spread (mm/s)	BSS	8,84	9,34
Accumulative One-Way Transport Index (%)	AOTI	98,92	122,23
Overall moisture management capability	OMMC	0,76	0,90

In fact, the OMMC is an index to indicate the overall capability of the fabric to manage the transport of liquid moisture, and is defined as [27]:

$$OMMC = C_1 \times BAR + C_2 \times AOTI + C_3 \times BSS \quad (3)$$

where $C_1 = 0.25$, $C_2 = 0.5$ and $C_3 = 0.25$ are the weights of "BAR", "AOTI", and "BSS" respectively, determined on the basis of analyzing the relative importance of the absorbance, one-way transport, drying speed and the correlations of the indexes with subjective moisture sensations [28]. The larger the "OMMC" is, the higher the overall moisture management capability of the fabric [5].

The higher one Way-Transport Index "AOTI" of Cotton/PES 80:20 blend means that the fabric can transmit sweat to the other side much faster. This is explained by the fact that the good ability of water molecule to penetrate and to be fixed in the interior of cotton fiber slows down the transfer from top to bottom.

In contrary, water molecules were absorbed only in surface of polyester fiber which is highly crystallin (65-85%) and hydrophobic. Moreover, this fiber creates more liquid water transfer channels with a wicking force. Thus, liquid transport is more difficult in case of pure cellulosic hydrophilic fibers where the water is well attached.

B. Effect of Knit Structure

The fingerprints of moisture management properties of 1&1 rib and English rib pure cotton knitted fabrics are shown in Fig. 4. In fact, from the "MMT" measurements curves, a set of indexes for determining the two kinds of knitted fabric moisture management properties were derived and expressed as a classification from 1 to 5, representing poor, fair, good, very good and excellent [27].

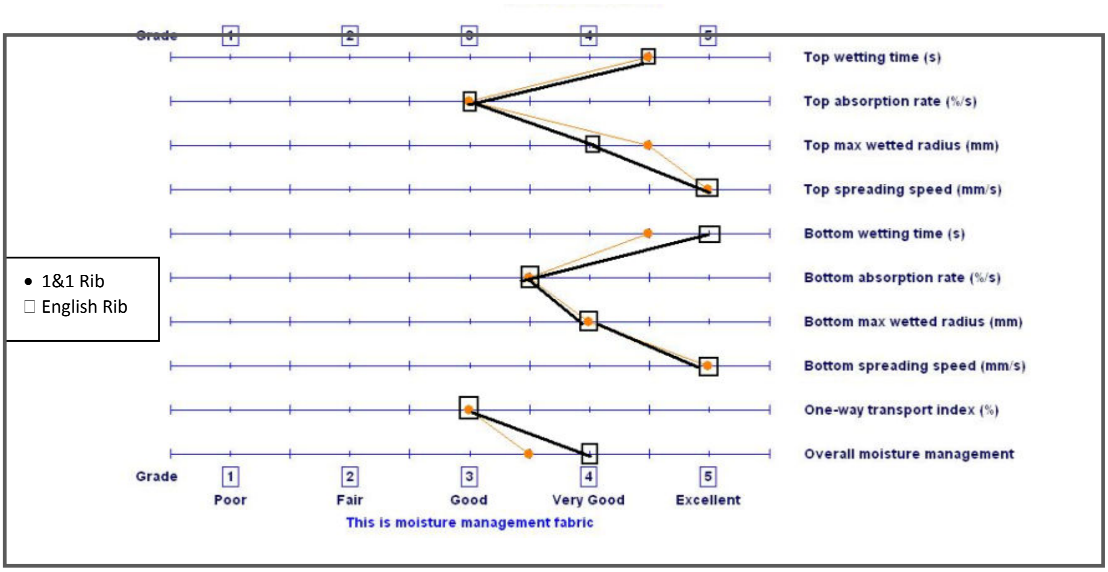
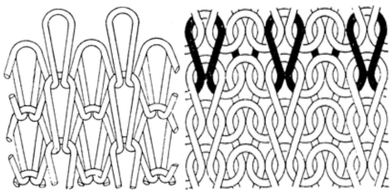


Fig. 4 Fingerprints of moisture management properties of 1&1 rib and English rib pure cotton knitted fabrics

Fig. 4 shows that for both samples, "WTT", "TAR", "BAR", "TSS", "BSS", "MWRB" and "AOTI" are nearly the same but English rib fabric had the higher mean scale of the bottom surface wetting time "WTB" and the overall moisture management capability "OMMC".

"WTB" are the time period in which the bottom surface of the fabric just start to become wet respectively after the test commences [27]; the lower scale represents a longer wetting time. It can be seen that for English rib fabric, the wetting of the bottom surface was detected earlier than that of the Rib 1&1. That's explained by the fact that fabric properties such as thickness, tightness factor, porosity…change according to knit structure (see Table I) and consequently, it influence the liquid moisture transport performance of cotton knitted fabrics [1]. In fact, we note that porosity of English rib (0,9187) is greater than porosity of Rib 1&1 (0,8790) (Fig. 5). Moreover, the very good overall moisture management capability "OMMC" of the English rib confirmed its better moisture transport performance.



(a) (b)

Fig. 5 (a) English Rib Knit Structure, (b) Rib 1&1 knit structure

IV. Conclusion

It can be seen that the "MMT" can characterize the liquid moisture transport performance of cotton knitted fabrics in multidirections: transfer through the fabric from the top surface to the bottom surface and spreading on the top and bottom surface of the fabric. Moreover, the series of indexes are very helpful to express the specific features of the liquid water transfer and distribution properties of the knitted fabrics.

Moisture management capacity of the fabric can be summarized and classified by trying to simulate the liquid sweat on the skin absorbed and transferred to the outside of clothing through the fabric by pumping a preset volume of liquid solution onto the upper surface of the fabric.

The higher one-way transport capability coupled with higher spreading speed and bottom absorption rate resulted in higher "OMMC" value for cotton /PES 80:20 fabric. In fact, with blending polyester proportions, an improvement in moisture transport performance is noted. However, it's necessary to vary the PES percentage in the blend in order to determine the ideal blend proportion for producing fabrics that require higher moisture transport like sportswear knitted fabrics. On the other hand, effect of fabric design on overall moisture management capability is investigated; the English rib knitted fabric has the better moisture transport performance.

References

[1] M. Yanılmaz and F. Kalaoglu, "Investigation of wicking, wetting and drying properties of acrylic knitted fabrics". *Textile Research Journal*, vol. 82, no. 8, 2012, pp. 820–831.

[2] R. Stämpfli, P. A. Brühwiler, I. Rechsteiner, V. R. Meyer and R. M. Rossi, "X-ray tomographic investigation of water distribution in textiles under compression – Possibilities for data presentation," Measurement, vol. 46, no. 3, April 2013, pp. 1212-1219. Switzerland.

[3] J. Youngmin, H. P. Chung and J K. Tae, "Effect of heat and moisture transfer properties on microclimate and subjective thermal comfort of caps." Textile research journal, vol. 80, no. 20, 2010, pp. 2195-2203.

[4] A. D. Gat, A. Vahdani, H. Navaz, A. Nowakowski and M. Gharib. "Asymmetric Wicking and Reduced Evaporation Time of Droplets. Penetrating a Thin Double-Layered Porous Material". Applied Physics Letters, vol. 103, no. 13, 2013.

[5] K. Atkins, M. Thompson, "Effect of textile hygroscopicity on stratum corneum hydration, skin erythema and skin temperature during exercise

in the presence of wind and no wind". J. Exerc. Sci. Fit., Vol. 9, no. 2, December 2011, pp. 100-108, Australia.
[6] D. Lukas, J. Chaloupek, E. Kost'akova, N. Pan, and I. Martinkova, Physica A, 371, 226 (2006). "Morphological transitions of capillary rise in a bundle of two and three solid parallel cylinders". Physica A: Statistical Mechanics and its Applications, vol. 371, 2006, pp. 226-248.
[7] D. Lukas and J. Chaloupek, "Wetting between parallel fibres; column-unduloid and column disintegration transitions". Proc. Inst. Mech. Eng. H., vol. 217, no. 4, 2003, pp. 273-280.
[8] A. Perwuelz, P. Mondon, C. Cazé, "Liquid organization during capillary rise in yarns – influence of yarn torsion" Polymer Testing, vol. 20, 2001, pp. 553-561.
[9] H. M. Princen, J. Colloid Interf. Sci., vol. 30, 1968.
[10] A. B. Nyoni and D. Brook, J. Text. Inst., vol. 97, 2006.
[11] M. Hamdaoui, F. Fayala and S. Ben Nasrallah, "Experimental Apparatus and mathematical model for determination of parameters of capillary rise in fabrics," Journal of Porous media, vol. 9, no. 4, 2006, pp. 381-392.
[12] E. Bayramli and R. L. Powell, Colloid Surface, vol. 56, 1991.
[13] J. L. Deng, Y. D. Zhu, J. H. Wang, and Z. H. Meng, J. Compos. Mater., vol. 249, 2003.
[14] Methods 21A and 21B, Methods for Determination of Resistance to Wicking and Lateral Leakage, BSI, 1996. BS 3424-Part 18: 1986 (1996).
[15] W. Zhong and M. Q. Xing, J. Colloid Interf. Sci., 275, 264, 2004.
[16] AATCC Test Method 79, Absorbency of Bleached Textiles, AATCC, 2000.
[17] M. Hamdaoui, N.S. Achour, S. Ben Nasrallah, "The Influence of woven fabric structures on Kinetics of Water Sorption". Journal of Engineered Fibers and Fabrics, vol. 9, no. 1, March 2014.
[18] M. Hamdaoui, F. Fayala, and S. Ben Nasrallah, J. Porous Media, vol. 9, 2007.
[19] A. Perwuelz, P. Mondon, C. Cazé, "Experimental Study of Capillary Flow in Yarns," Textile Res. J., vol. 70, no. 4, 2000, pp. 333-339.
[20] ISO 9073–8, Textiles—Test Methods for Nonwovens—Part 8: Determination of Liquid Strike-through Time, 1995.
[21] R. Guruprasad, M. V. Vivekanandan, A. Arputharaj, S. Saxena and S. K. Chattopadhyay. "Development of cottonrich/polylactic acid fiber blend knitted fabrics for sports textiles". Journal of industrial textiles. vol. 0, no. 0, October 2014.
[22] E. Nergiz and K. Yasemin."Effects of Knit Structure on the Dimensional and Physical Properties of Winter Outerwear Knitted Fabrics". Fibers and Textiles in Eastern Europe. Vol. 67, no. 2, 2008, pp: 69–74.
[23] R. M. Crow and R. J. Osczevski, "The interaction of water with fabrics", Textile Research Journal, vol. 68, no. 4, 1998, pp: 280–288.
[24] Q. Zhuang, S. C Harlock and D. B. Brook."Transfer wicking mechanisms of knitted fabrics used as undergarments for outdoor activities". Textile Res J, vol. 72, no. 8, 2002.
[25] N. Ozdil, A. Marmarah and S. D. Kretzschmar, "Effect of yarn properties on thermal comfort of knitted fabrics", International journal of thermal sciences, vol. 46, no. 12, December 2007, pp. 1318-1322, Turkie.
[26] S. S. Bhattacharya and J. R. Ajmeri, "Investigation of Air Permeability of Cotton & Modal Knitted Fabrics". International Journal of Engineering Research and Development, vol. 6, no. 12, May 2013, pp: 01-06.
[27] J. Hu, Y. Li, K.W. Yeung, A. S. W. Wrong and W. Xu. "Moisture Management Tester: A Method to Characterize Fabric Liquid Moisture Management Properties", Textile Res. J., vol. 75, no. 1, 2005, pp: 57–62.
[28] L. Zhou, X. Feng, Y. Du and Yi Li. "Characterization of Liquid Moisture Transport Performance of Wool Knitted Fabrics". Textile Research Journal, vol. 77, no. 12, 2007, pp. 951–956.