(REFEREED RESEARCH)

COMPARISON OF MOISTURE TRANSPORT PROPERTIES OF THE VARIOUS WOVEN FABRICS

FARKLI DOKUMA KUMAŞLARIN NEM İLETİM ÖZELLİKLERİNİN KARŞILAŞTIRILMASI

E. Sema NAMLIGÖZ
Ege University Textile Engineering Department
e-mail: sema.namligoz@ege.edu.tr

Süleyman ÇOBAN
Ege University Textile Engineering Department

M. İbrahim BAHTİYARİ
Ege University Textile Engineering Department

ABSTRACT

Clothing comfort is an attractive topic of clothing science and today it is known that clothing comfort have a good relation with the several factors such as thermal, tactile properties, etc of fibers and also fabrics. Moisture management property of fabrics is also another important parameter related with clothing comfort. In this study, it was focused on the evaluation of indices of liquid moisture management properties, grading and classification methods of woven fabrics with various fibers by using MMT tester. It was found that unlike 100% Cellulosic and PES fabrics, Cellulosic/PES blended fabrics allowed the liquid absorption and transportation efficiently.

Key Words: Liquid moisture management, Woven fabric, Cellulosic, Polyester, Moisture management tester.

ÖZET

Giysi konforu, giysi biliminin çekici bir konusudur ve günümüzde giysi konforunun liflerin ve hatta kumaşların ısıl özellikleri, dokunma hissi vb. gibi birçok faktörlerle iyi bir bağlantısı olduğu bilinmektedir. Kumaşların nem iletim özelliği de giysi konforuyla ilgili başka bir önemli parametredir. Bu çalışmada, MMT test cihazı kullanılarak farklı liflerlerden dokunan kumaşların sıvı nem iletim özelliklerinin göstergeleri, derecelendirilmesi ve sınıflandırma metotlarının değerlendirilmesi üzerine odaklanılmıştır. % 100 selülozik ve poliester kumaşların aksine, selülozik/poliester karışımı kumaşların etkili bir şekilde sıvı absorbsiyonu ve iletimini sağladığı bulunmuştur.

Anahtar Kelimeler: Kelimeler: Sıvı nem iletimi, Dokuma kumaş, Selülozik, Poliester, Nem iletim cihazı.

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1. INTRODUCTION

Recently, with rising living standards, people's needs and expectations of clothing and textile products have also become different (1-3).

Clothing comfort can be induced by thermal, pressure related, and tactile properties, etc. Among these factors affecting clothing comfort, the thermal factor is the most decisive one affecting the comfort level. Many researchers have examined the effects of the fiber type and the fabric composition on thermal comfort. The fiber composition and the fabric structure or the presence of layers was revealed to affect the heat and moisture transfer properties of textiles (4).

Good moisture absorption and release can be found in fibers with greater specific surface area. Such rapid transportation of moisture or diffusion of sweat in the form of steam from the body towards the outside enables good moisture absorption and release, thus maintaining dryness and comfort of the fiber properties. Natural fibers such as cotton and viscose are hydrophilic, meaning that their surface has bonding sites for water molecules. Therefore, water tends to be retained in the hydrophilic fibers, which have poor moisture transportation and release. On the other hand, synthetic fibers such as polyester are hydrophobic, meaning that their surface has few bonding sites for water molecules. Hence, they tend not to get wet and have good moisture transportation and release. Neither natural nor synthetic fibers can perform well in both moisture absorption and release at the same time. To achieve such would require moisture absorption and release finishing through which the structural design and quality of fibers are modified so that the textile products thus manufactured can have good performance in absorbing, transporting, and dissipating moisture. Fabrics with good moisture absorption and release that have been developed include profiled polyester fibers and hollowed and micro porous fibers. They are usually of multilayer structure with two or three alternating layers of hydrophilic fiber and hydrophobic fiber (5).

Moisture is transported in textiles through capillary action or wicking. In textiles, the spaces between the fibers effectively form tubes, which act as capillaries, and transport the liquid away from the surface (6).

The liquid moisture management performance of fabrics results from complex properties including their absorbent capacity, absorption rate, and evaporation (7). Fabric liquid moisture transport properties in multi-dimensions, referred to as moisture management properties, influence the human perception of moisture sensations and comfort significantly (8).

The moisture management properties of porous polymeric materials depend on their water resistance, water repellency, water absorption, the wicking of the fibers and yarns, as well as the geometric and internal structures of the constituent materials such as fibers and yarns. However, the existing standards are unable to measure the dynamic behavior of liquid transfer in clothing materials. To objectively characterize the spread of moisture and the transfer properties on and between fabric surfaces, a new instrument, named the moisture management tester (MMT), have been jointly developed by Polytechnic University and SDL Atlas Firm, to evaluate the moisture management capacity of fabrics (8-11).

In this study, it was focused on the evaluation of indices of liquid moisture management properties, grading and classification methods of woven fabrics with various fibers using MMT tester.

2. MATERIAL AND METHOD

For experiments, 21 different types of pre-treated fabrics were used (Table 1). Fabrics are all 3/1 twill construction and for blended fabrics rate is 65/35. The yarn count used for fabrics is constant, for cellulosic yarn's count is 36 Ne and for synthetic yarn's count is 167 dtex. Twist coefficient: α_e= 3.7. Fabric count is also constant which is 48 yarn/cm for warp, 31 yarn/cm for weft.

Table 1. Fabrics used for the experiments

Warp material	Weft material	Code
Cotton	Cotton	CO/CO
Lyocell	Cotton	LY/CO
Viscose	Cotton	CV/CO
Cotton	Lyocell	CO/LY
Lyocell	Lyocell	LY/LY
Viscose	Lyocell	CV/LY
Cotton	Viscose	CO/CV
Lyocell	Viscose	LY/CV
Viscose	Viscose	CV/CV
Cotton	Circular cross-section polyester	CO/CPES
Lyocell	Circular cross-section polyester	LY/CPES
Viscose	Circular cross-section polyester	CV/CPES
Cotton	Hexachannel polyester	CO/HPES
Lyocell	Hexachannel polyester	LY/HPES
Viscose	Hexachannel polyester	CV/HPES
Cotton	Microfibre polyester	CO/MPES
Lyocell	Microfibre polyester	LY/MPES
Viscose	Microfibre polyester	CV/MPES
Circular cross-section polyester	Circular cross-section polyester	CPES/CPES
Hexachannel polyester	Circular cross-section polyester	HPES/CPES
Microfibre polyester	Circular cross-section polyester	MPES/CPES

Table 2 shows the synthetic yarns' properties.

Table 2. Used synthetic yarns' properties

Yarn type	Number of filaments	Entanglement (number/m)
Circular cross-section polyester	48	110
Hexachannel polyester	48	105
Microfibre polyester	288	96

All fabrics were desized additionally 100% synthetic and synthetic/cellulosic blended fabrics were thermofixed in a stenter. All the measurements managed after conditioning of the fabrics for 24 hours under the standard atmosphere conditions (20ºC±2 temperature, 65±2 % relative humidity).

In order to evaluate the moisture management properties of all fabrics MMT equipment was used to investigate the indexes such as wetting time top/bottom (WTt/WTb), maximum absorption rate top/bottom (Mat/MAb): moisture absorbing time of the fabric's inner and outer surfaces, maximum wetted radius top/bottom (MWRt/MWRb), spreading speed top/bottom (SSt/SSb): Spreading/drying rate-speed of liquid moisture spreading on fabric's inner and outer surfaces, accumulative one-way transport capability (OWTC) : One way transportation capability-one way transfer from fabric's inner surface to outer surface and overall moisture management capacity (OMMC).

The principle employed by the MMT is based on the fact that when moisture transports through a fabric, the contact electrical resistance of the fabric will change, and the value of the resistance change depends on two factors: the components of the test solution and the water content in the fabric. When it is fixed components of the test solution, the electrical resistance measured is related to the water content in the fabric (8).

MMT is designed to sense, measure and record the liquid moisture transport behaviors in these multiple directions. A series of indexes are defined and calculated to characterize liquid moisture management performance of the test sample. MMT is connected to a computer with the special MMT software. After test, the results can be shown in MMT software. Before test, the testing samples must be placed in the laboratory in the standard atmosphere for condition (12).

The Moisture Management Tester consists of upper and lowers concentric moisture sensors, where the fabric being tested is placed in between the two sensors. A pre-defined amount of test solution (synthetic sweating) is introduced onto the upper side of the fabric, and then the test solution will transfer onto the material in three directions:

- Spreading outward on the upper (top) surface of the fabric
- Transferring through the fabric from the upper surface to the bottom surface
- Spreading outward on the lower (bottom) surface of the fabric (Figure 1) (9, 11, 12).

Figure 1. Moisture Management Tester

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. An improved structure design of the sensors is shown in Figure 2. The spring rings are applied in the improved design to ensure good contact of the fabric to the sensors. Using the measuring head with six rings, we can determine the water content and the liquid moisture transfer behavior in a fabric at both surfaces (top surface and bottom surface), as well as the transport between these two surfaces (13-15).

In this study, the moisture management properties of various woven fabrics were measured in SDL-ATLAS MMT and the obtained results were statically evaluated.

3. RESULTS AND DISCUSSIONS

The results (expressed as means/standard deviation) of all assays were compared using ANOVA, followed by a post hoc test (Duncan's test). For all statistical analyses, the software package SPSS (Statistical Analysis Program) was used.

In order to investigate the effect of fabric type, on WTt/WTb, MAt/MAb, MWRt/MWRb, SSt/SSb, OWTC, OMMC. ANOVA for these depended variables indicated that there was significant impact of fabric type (Table 3).

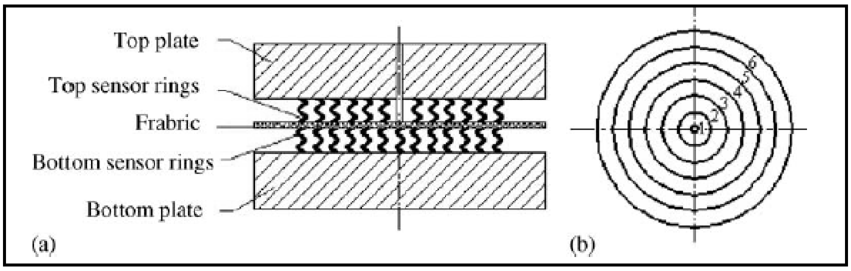

Figure 2. Sketch of MMT sensors: (a) sensor structure; (b) measuring rings (15).

Table 3. ANOVA Test for Fabric type

Source	Dependent Variable	Type III Sum of Squares	Df	Mean Square	F	Sig.
Fabric type	WTt	152.077	20	7.604	16.006	.000
	WTb	234.607	20	11.730	13.331	.000
	MAt	8027.342	20	401.367	7.780	.000
	MAb	8202.629	20	410.131	15.608	.000
	MWRt	799.714	20	39.986	11.827	.000
	MWRb	816.667	20	40.833	21.618	.000
	SSt	83.178	20	4.159	11.918	.000
	SSb	93.774	20	4.689	17.793	.000
	OWTC	409349.685	20	20467.484	15.292	.000
	OMMC	.493	20	.025	19.436	.000
Error	WTt	19.953	42	.475		
	WTb	36.956	42	.880		
	MAt	2166.868	42	51.592		
	MAb	1103.660	42	26.278		
	MWRt	142.000	42	3.381		
	MWRb	79.333	42	1.889		
	SSt	14.656	42	.349		
	SSb	11.068	42	.264		
	OWTC	56214.234	42	1338.434		
	OMMC	.053	42	.001		
Total	WTt	963.603	63			
	WTb	1156.924	63			
	MAt	126340.727	63			
	MAb	198446.410	63			
	MWRt	42908.000	63			
	MWRb	43484.000	63			
	SSt	1714.334	63			
	SSb	1666.191	63			
	OWTC	3770083.882	63			
	OMMC	28.639	63			

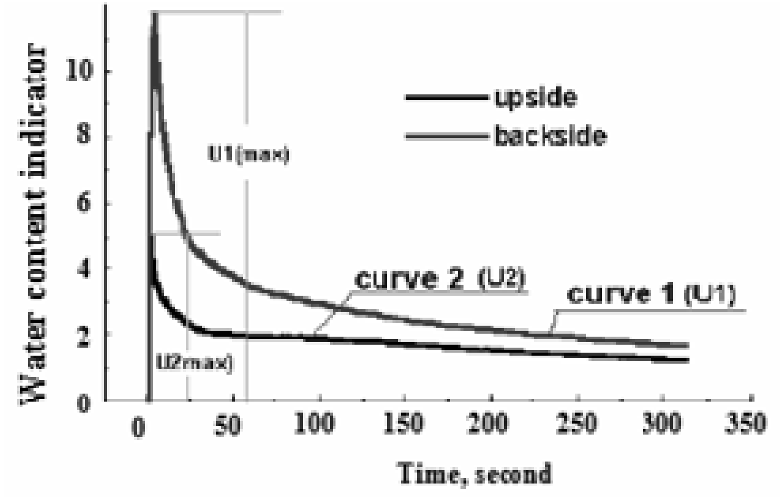

Figure 3. One way transport index

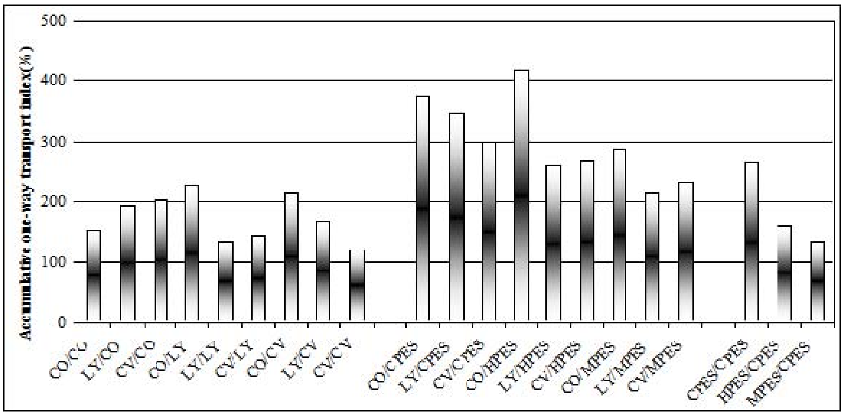

Figure 4. OWTC of all fabrics

Moreover, Duncan Post hoc test was carried out for the fabric type in order to evaluate the effect on accumulative one-way transport index (OWTC) and overall moisture management capacity (OMMC).

Accumulative one-way transport index is the difference of the accumulative moisture content between the two surfaces of the fabric.

OWTC = (Area (U_{bottom})-Area (U_{top}))/Total testing time (Figure 3) (Eq. 1)

One way transportation capability is liquid moisture one-way transfer from fabric's inner surface to outer surface.

Overall moisture management capacity (OMMC) is an index to indicate the overall capability of the fabric to manage the transport of liquid moisture, which includes three aspects of performance: Moisture absorbtion rate at bottom side (BAR); One way liquid transport capability (R); Moisture drying speed at bottom side, which is represented by accumulative spreading speed (BSS).

The overall moisture management capacity (OMMC) is defined as:

OMMC = C_1 x BAR_{ndv} + C_2 x R_{ndv} + C_3 x BSS_{ndv} (Eq. 2)

C_1 =0.25, C_2 =0.5 and C_3 =0.25 values are the weights of the non-dimension values (ndv) (12).

C_1, C_2 and C_3 values are constant and calculated according to the experiences and suggestions of the manual of the MMT instrument. C_1, C_2 and C_3 can be adjusted according to the relative importance of the three indexes in the situation where the final products are used. For example, if the test fabrics are going to be for cycling wear in a humid environment, one way transport of liquid sweat is very important for keeping the skin dry. In a humid environment, the evaporation of liquid water is relatively slow, so that the absorption rate and spreading speed are less important (8).

As seen from Equation 1 and 2, it can be easily told that OWTC and OMMC indexes are enough to summarize and explain the moisture management properties of all fabrics. This is why only OWTC and OMMC was evaluated by Duncan Post Hoc Test.

- **Evaluation of Accumulative one-way transport index (OWTC):**

OWTC exhibits the liquid transport form top surface to bottom surface of fabric. If the OWTC value of one fabric is between 200 and 400 it means that the one-way transport is very good. Also, for the fabric has the value higher than 400, one-way transport is defined as excellent (12).

In the light of this knowledge when Figure 4 examined, OWTC values of cellulosic/synthetic blends showed very good OWTC because values are approximately 200-400. However if the fabrics are only cellulosic based, in this case one-way liquid transport is limited. Especially, if the fabric is regenerated cellulosic blended; the OWTC is lower that the others since cellulosic fibers and particularly regenerated cellulosic fibers have a tendency to absorb moisture instead of transportation.

In order to compare the OWTC (one-way transport capability) values of all woven fabrics with each other, Duncan Post Hoc test was carried out and by this statistical analysis the fabrics were divided into 12 subsets according to significant intervals (Table 4).

Table 4. Duncan Post Hoc test of the Fabric Type for OWTC

Fabric type	N	Subset											
		1	2	3	4	5	6	7	8	9	10	11	12
CV-CV	3	119.53											
MPES-CPES	3	133.37	133.37										
LY-LY	3	134.06	134.06										
CV-LY	3	142.83	142.83										
CO-CO	3	153.84	153.84	153.84									
HPES-CPES	3	159.21	159.21	159.21	159.21								
LY-CV	3	167.80	167.80	167.80	167.80	167.80							
LY-CO	3		194.00	194.00	194.00	194.00	194.00						
CV-CO	3		203.00	203.00	203.00	203.00	203.00	203.00					
LY-MPES	3			213.76	213.76	213.76	213.76	213.76					
CO-CV	3			215.03	215.03	215.03	215.03	215.03					
CO-LY	3				226.64	226.64	226.64	226.64	226.64				
CV-MPES	3					231.47	231.47	231.47	231.47				
LY-HPES	3						260.45	260.45	260.45	260.45			
CPES-CPES	3						263.00	263.00	263.00	263.00			
CV-HPES	3							266.87	266.87	266.87			
CO-MPES	3								287.42	287.42	287.42		
CV-CPES	3									299.67	299.67		
LY-CPES	3										345.86	345.86	
CO-CPES	3											374.19	374.19
CO-HPES	3												417.56
Sig.		0.17	0.05	0.08	0.06	0.07	0.05	0.07	0.08	0.25	0.07	0.35	0.15

a) Uses Harmonic Mean Sample Size = 3.000. b) The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed. c) α= 0.05

As shown in Table 4, the fabric type is significant on OWTC values. Duncan Post Hoc test of the Fabric Type indicated that the fabric type was divided into 12 different sub-groups in terms of OWTC values. Especially, CO/CPES and CO/HPES blended fabrics have highest OWTC values. The lowest result was obtained by 100 % viscose fabric due to having hydrophilic character which does not allow the liquid transportation. In general, Table 4 showed that 100 % cellulosic fabrics and synthetic fabrics gave lower result than the others.

- **Evaluation of Overall moisture management capacity (OMMC):**

OMMC is an index to indicate the overall capability of the fabric to manage the transport of liquid moisture. The larger the OMMC is, the higher the overall moisture management capability of the fabric. Liquid moisture management capacity shows that liquid sweat can be easily and quickly transferred from next to the skin to the outer surface to keep the skin dry.

If the OMMC of one fabric is in 0.6 - 0.8 range it means that the liquid moisture management capacity is very good. Also, for the fabric has the value higher than 0.8, the overall capability of the fabric is defined as excellent (12).

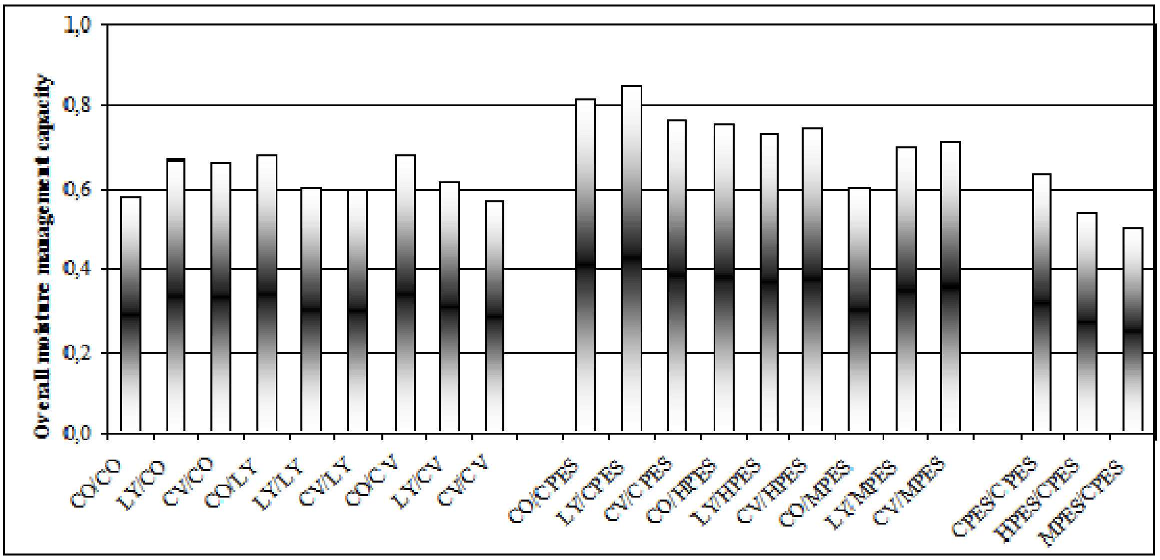

Figure 5. OMMC of all fabrics

Table 5. Duncan Post Hoc test of the Fabric Type for OMMC

Fabric type	N	Subset										
		1	2	3	4	5	6	7	8	9	10	11
MPES-CPES	3	0.50										
HPES-CPES	3	0.54	0.54									
CV-CV	3		0.57	0.57								
CO-CO	3		0.58	0.58								
CV-LY	3		0.60	0.60								
CO-MPES	3		0.60	0.60	0.60							
LY-LY	3		0.61	0.61	0.61							
LY-CV	3			0.62	0.62	0.62						
CPES-CPES	3			0.64	0.64	0.64	0.64					
CV-CO	3				0.67	0.67	0.67	0.67				
LY-CO	3					0.67	0.67	0.67				
CO-LY	3					0.68	0.68	0.68				
CO-CV	3					0.68	0.68	0.68				
LY-MPES	3						0.70	0.70	0.70			
CV-MPES	3							0.71	0.71	0.71		
LY-HPES	3							0.73	0.73	0.73		
CV-HPES	3								0.75	0.75		
CO-HPES	3								0.75	0.75		
CV-CPES	3									0.77	0.77	
CO-CPES	3										0.82	0.82
LY-CPES	3											0.85
Sig.		0.11	0.07	0.06	0.06	0.06	0.06	0.07	0.10	0.12	0.07	0.27
a) Uses Harmonic Mean Sample Size = 3.000. b) The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed. c) α= 0.05												

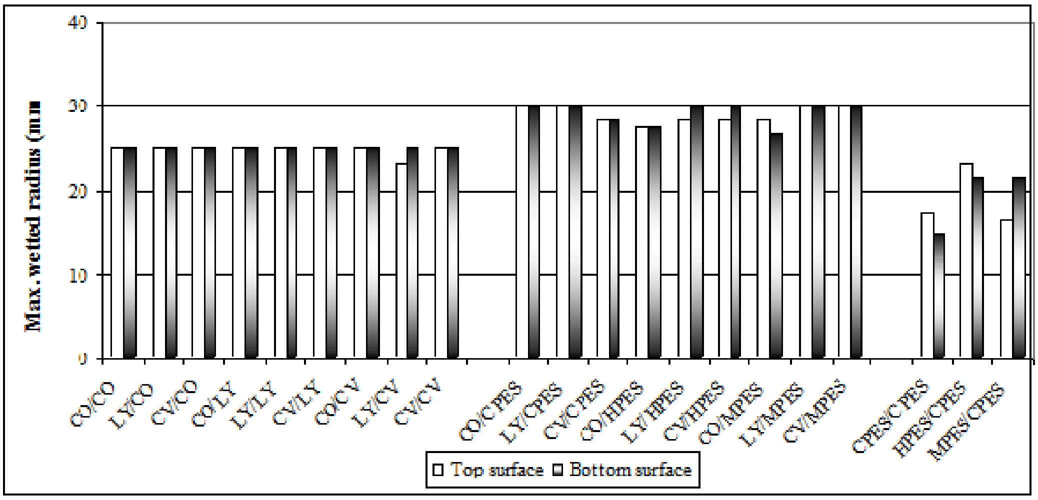

Figure 6. Maximum wetted radius of fabrics

In Figure 5, like OWTC results, OMMC values of cellulosic/synthetic blends showed the best OMMC values while synthetic fabrics had the lowest values in general. Especially, CO/CPES and LY/CPES fabrics were excellent in terms of OMMC because of the higher OMMC values than 0.8. In addition, the other cellulosic/synthetic blended fabrics had very good results range in 0.6-0.8.

In order to compare the OMMC (overall moisture management capacity) values of all woven fabrics with each other, Duncan Post Hoc test was carried out and by this statistical analysis the fabrics were divided into 11 subsets according to significant intervals (Table 5).

As shown in Table 5, the fabric type is significant on OMMC values. According to OMMC values, Duncan Post Hoc test of the Fabric Type indicated that the fabric type was divided into 11 different sub-groups. The lowest OMMC indexes were obtained from MPES/CPES and HPES/CPES blended fabrics. The reason of this is that synthetic fibers such as polyester are hydrophobic, meaning that their surface has few bonding sites for water molecules. They tend not to get wet and have only good moisture transportation and release which is not enough for good liquid moisture management capacity. However, if synthetic yarn is blended with cellulosic yarn to obtain blended fabric, the good liquid moisture management capacity can be succeeded. This term was also confirmed by Duncan test and it was found that CO/CPES and LY/CPES blended fabrics have highest OMMC values.

- **Evaluation of Maximum wetted radius**

Figure 6 indicates the maximum wetted radius (mm) of all fabrics.

Similar to results achieved from OWTC and OMMC, maximum wetted radius of synthetic fabrics had the lowest for top and bottom surfaces. On the other hand, the cellulosic/synthetic blends showed the highest wetted radius which could not obtained with 100% cellulosic fabrics.

4. CONCLUSION

Synthetic fibers such as polyester are hydrophobic, meaning that their surface has few bonding sites for water molecules. They tend not to get wet and have good moisture transportation and release. On the other hand, the cellulosic fabrics due to having hydrophilic character do not allow the liquid transportation generally but these properties good moisture transportation and absorption alone do not provide good comfort for the moisture management. This work, was performed with a new moisture management tester, was showed that both for the fabrics of 100 % PES and 100 % cellulosic fabrics had limited moisture management. However Cellulosic/PES blended fabrics allowed the liquid absorption and transportation sensitively.

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