Test Device for Liquid Moisture Transport Difference Evaluation of Fabrics

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Abstract

A test device was developed and a test method was proposed to characterize the dynamic liquid moisture transport properties of textile fabrics, based on the mechanical equipment, microelectronics, sensors and control system. Derived from the test data, five indices were defined to characterize the dynamic liquid moisture transport difference between two surfaces of textile fabrics. The test principle, the structure of the mechanical equipment and the evaluation method for the dynamic moisture transport difference were introduced. Six types of fabrics made from different textile materials were measured. The one-way ANOVA analysis was carried out to identify the significance of the differences of the indices among the test fabrics. The results show that each evaluation index is significantly different (P<0.05) among different test fabrics, and fabric 3 (pure cotton, knitted) has a better liquid moisture transport from inner surface to outer surface with the highest value of moisture transport difference.

Keywords: liquid moisture, transport properties, test device, difference, fabrics

1. Introduction

Dynamic moisture transport properties, which have close relationships with human perception of moisture sensations and wearing comfort, are considered as important and significant attributes in the purchase of textile and apparel products by modern consumers, especially under dynamic wear conditions [1]. The dynamic moisture transport properties is related to the thermal-wet comfort sensations of clothing, which together with tactile comfort and pressure comfort are identified as the three major sensory factors of clothing comfort [2]. The dynamic moisture transport properties have great influence on the warmth and moisture permeability, which are considered as the important attributes of the comfort sensations of textile fabrics [3]. The objective measurement of the dynamic moisture transport properties of textile fabrics and its applications to the objective evaluation of textile fabrics and apparel engineering surely help to produce higher quality textile fabrics and certain other porous materials. Therefore, it is highly required and desirable to investigate the dynamic moisture transport properties of textile fabrics.

Many measurement systems and evaluation methods have been proposed and carried out to characterizing the moisture transport properties of textile fabrics [4-11]. The MMT (Moisture Management Tester), developed by Hu et al, reported the measuring principle together with the apparatus design and the definition of performance indices of liquid moisture transport properties evaluation of textile materials. Hu et al also studied the relationships between subjective perceptions and the objective liquid moisture management properties measured by MMT [4]. The updated version of MMT, developed by Yao et al and widely used all over the world, is an improved and typical measurement system and evaluation method for the liquid moisture transport properties evaluation of porous polymeric materials such as textile fabrics. Yao's research for the improved MMT focused on the improvement of the test method and the evaluation of indices of liquid moisture management properties, grading and classification methods, data processing method and the expression of test results for industrial applications [5]. The MMT test method, developed by Yao et al, is widely used in extensive studies to evaluate the moisture management properties of various fabrics. Namligoz E.S. et al studied the liquid moisture transport properties, the grading and classification methods of various woven fabrics by using the MMT [6]. Gauthier Bedek et al analyzed and determined the relationship between the textile properties and the thermal comfort of six knitted types of

underwear using the MMT and other laboratory techniques [7]. Wu Hai-Yan et al studied the moisture transfer principle of waterproof breathable fabric by using the MMT and the moisture transfer properties provided by MMT [8]. E. Önera et al determined the effect of raw material, weave type and tightness on liquid absorption and transmission properties of knitted fabrics by the multi-dimensional liquid transport test of MMT [9]. McQueen R.H. et al recommended a protocol for handling test in order to manage the high variability of MMT and also identify some fabrics which are not suitable for evaluation using the MMT [10].

Although there are standard methods such as AATCC195-2009 [12] and maturely applied instrument MMT [13], which can be employed to measure the fabric moisture management properties including water absorbency, water repellency and overall moisture management properties, the test device and method reported in this paper focuses on the characterizing method of liquid moisture transport difference between two surfaces of textile fabrics, which is the most important parameter to reflect the dynamic liquid moisture transport properties and comfort sensations of textile fabrics. Moreover, the new apparatus together with the measurement system was developed from the semi-automatic test device of the MMT to the full-automatic test device with the mechanical equipment, microelectronics, sensors and control system.

2. Test Principle and Evaluation Method
2.1. Test Principle
As shown in Figure1, the mechanical equipment of the test device and system contains the following six main components:
(1) Lower measuring head 1;
(2) Upper measuring head 2;
(3) Water storage box 3;
(4) Driving component 4;
(5) Lifting system 5;
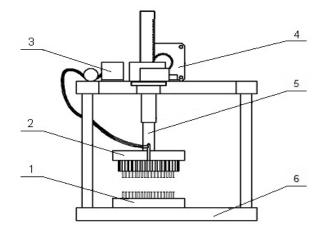(6) Measuring device frame 6.

Figure 1. Mechanical Equipment of the Test Device and System

There are upper and lower concentric liquid moisture sensors installed in the upper measuring head and lower measuring head, between which the fabric being tested is placed. The inner surface (upper surface) of the fabric contacts to the upper liquid moisture sensors, while outer surface (lower surface) contacts to the sensors in the lower measuring head. The structure of the liquid moisture sensor and the sensors arrangement in the measuring heads are shown in Figure 2. The sensor consists of fixing cap, cylindrical shell, spring, connecting rod and sensor head. The spring is applied in the sensor design to ensure good contact of the fabric to the sensors even if the fabric is rough or irregular. There is a fine water pipe fixed through the central sensor of the upper measuring head, which can supply a predefined amount of test solution (synthetic sweat) with the water storage box and control system during testing. In order

to measure the liquid moisture content at different areas of the fabric and the moisture transport behavior in different directions at both surfaces (upper surface and lower surface) of the fabric, eight measuring rings of sensors are applied in both measuring heads. By testing the resistance changes between the measuring rings of sensors, which will reduce when the fabric is wet or contains a quantity of moisture, the changes of water and liquid moisture content on the fabric upper and lower surfaces (U_U and U_L) can be measured.

(a) Sensors arrangement in measuring heads   (b) Sensor structure
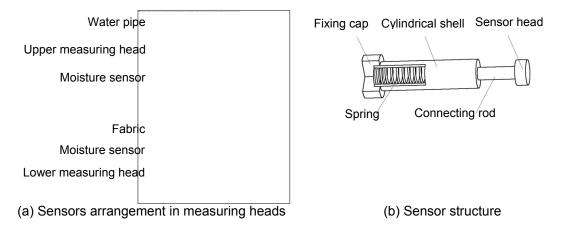
Figure 2. Sketch of Sensors in Measuring Heads

During testing, a predefined amount of test solution is introduced onto the center of the upper side of the fabric through a fine water pipe from the water storage box. Meanwhile, the liquid moisture sensors start to work and the test data is recorded and saved.

The real-time data of the liquid moisture content changes against time on the fabric upper and lower surfaces were acquired during the testing with the computer DAQ system of the control system.

2.2. Evaluation Method

Derived from the measuring curves and the test data, five indices have been defined and calculated for evaluation of dynamic liquid moisture transport difference between two surfaces of textile fabrics.

1) Wetted time: WT_U and WT_L (mm),

WT_U is defined as the time from test solution is introduced onto the testing fabric to the time when the fabric is just wetted on the upper surface of the fabric and WT_L is defined as the wetted time on the lower surface of the fabric.

2) Wetting speed: WS_U and WS_L (mm/s),

WS_U and WS_L are defined as the liquid moisture wetting speed from the center to the maximum wetted radius on the upper and lower surfaces of the fabric.

$$WS_U = \frac{WR_U}{T_U} \tag{1}$$

$$WS_L = \frac{WR_L}{T_L} \tag{2}$$

Where, WR_U and WR_L is the maximum radius of liquid moisture wetted area on the upper and lower surfaces of the fabric respectively. T_U and T_L are the times of liquid moisture reaching the maximum wetted rings on the upper and lower surfaces of the fabric.

3) Moisture transport difference: D_{MT} (%),

D_{MT} is defined as the difference of the liquid moisture transport capacity between the two surfaces of the fabric.

$$D_{MT} = (\int_0^T U_L dt - \int_0^T U_U dt)/T \tag{3}$$

Where, T is the total measurement time. U_U is the liquid moisture content vs. time on the fabric upper surface, and U_L is the liquid moisture content vs. time on the fabric lower surface. Here the liquid moisture content (%) means the liquid moisture content in percentage relative to the dry weight of the fabric.

3. Experiments setup

Six types of fabrics with different structural features and made from different materials were tested for the experiments of moisture transport difference between two surfaces of textile fabrics. The fabric structural parameters are listed in Table 1. The samples were cut into the size of 100mm×100mm. All the specimens were kept in a conditioning room, controlled at 21±1°C and 65±2% RH according to ASTM D1776, for at least 24 hours before testing.

In order to exclude the impact of the external environment, all the tests were carried out in a conditioning room. For each set of fabric, 5 pieces of specimens were cut and taken into experiments to exclude the individual uncertainty. During testing, the same quantity of the test solution was introduced onto the upper surface of each fabric specimen automatically.

Table 1. Fabric Structural Parameters

Fabric	Fabric weight (g/m2)	Fabric thickness (mm)	Fiber content	Fabric construction
1	120.0	0.75	100% polyester	knitted
2	136.0	0.56	100% polyester	knitted
3	183.0	0.77	100% cotton	knitted
4	214.0	0.83	100% cotton	knitted
5	180.0	0.86	70% cotton + 30% polyester	Single knitted
6	204.0	0.94	100% polyester	knitted

4. Results and Analysis

All the specimens were tested on the test device and system of liquid moisture transport properties by the same testing protocol according to the experiments setup. The mean values of the liquid moisture transport properties measurements are summarized in Table 2.

Table 2. The Mean Values of the Liquid Moisture Transport Properties Measurements

Fabric	WT_U (s)	WT_L (s)	WS_U (mm/s)	WS_L (mm/s)	D_{MT} (%)
1	3.011	3.2346	0.836	0.8016	-48.0332
2	4.8174	12.1784	0.407	0.264	173.5013
3	17.2336	2.3856	0.4271	0.9143	359.5741
4	3.266	4.4828	0.6197	0.6653	-273.1278
5	3.8906	3.7486	0.6695	0.6527	-78.754
6	3.426	119.9538	0.8599	0	-436.4399

The professional statistical software SPSS was used to identify the significance of the differences of the evaluation indices of all the tested fabrics by a one-way ANOVA analysis. The results are summarized in Table 3.

Table 3. One-way ANOVA Analysis Results of Evaluation Indices

Dependent Variable	Sum of Squares	df	Mean Square	F	Sig.
WT_U	775.276	5	155.055	2.663	0.047
WT_L	55178.252	5	11035.650	3754.948	0.000
WS_U	0.938	5	0.188	4.275	0.006
WS_L	3.021	5	0.604	209.808	0.000
D_{MT}	2088272.590	5	417654.518	23.673	0.000

It can be concluded from the one-way ANOVA analysis results that each index is significantly different (P<0.05) among the six tested fabrics in this study. Therefore, the fabrics' behaviors significantly affect the liquid moisture transport properties of all indices, and the measurement method and the indices defined are effective for characterizing the liquid moisture transport difference between two surfaces of textile fabrics.
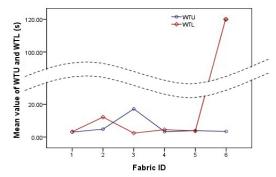

Figure 3. Mean Value of the Test Results of WT_U and WT_L

The mean value charts of the measurement results for indices WT_U, WT_L, WS_U, WS_L and D_{MT} are shown in Figure 3, Figure 4 and Figure 5.

Figure 3 is the mean value chat of the measurement results for the indices wetted time WT_U and WT_L. Fabric 1 was wetted more quickly, where the WT_U is 3.0 (s) and WT_L is 3.2 (s). However, fabric 6 was not wetted on the lower surface during the testing since the wetted time is the total measurement time.
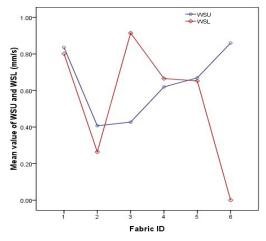

Figure 4. Mean Value of the Test Results of WS_U and WS_L

Figure 4 is the mean value chat of the measurement results for the indices wetting speed WS_U and WS_L. Fabric 6 has the highest value of wetting speed difference between two surfaces of fabric, where the WS_U is 0.8599 (mm/s) and WS_L is 0 (mm/s).

The test results of the evaluation index D_{MT}, which reflects the difference of the liquid moisture transport capacity between two surfaces of fabric, are shown in Figure 5. Fabric 3 has the highest value of moisture transport difference where D_{MT} is 359.5741%, and fabric 6 has the lowest value of moisture transport difference where D_{MT} is -436.4399%. The results show that fabric 3 has very good performance in transporting and absorbing liquid moisture and has best liquid moisture transport ability from inner surface to outer surface, while fabric 6 cannot absorb

and spread liquid moisture very well and has worst moisture transport ability from inner surface to outer surface.
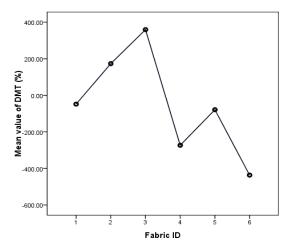

Figure 5. Mean Value of the Test Results of Moisture Transport Difference (D_{MT})

5. Conclusion

A new test device and system and the test method were developed and proposed to objectively and automatically measure and characterize the liquid moisture transport difference between two surfaces of textile fabrics by simulating the contact process of skin with fabrics under human perspiration conditions. Five indices were defined to characterize dynamic moisture transport properties and liquid moisture transport difference derived from the test data. Six types of fabrics with different structural features and made from different materials were tested. The test results show that the test device and system is effective for characterizing the liquid moisture transport difference between two surfaces of textile fabrics and is able to determine the significant differences in fabric liquid moisture transport properties to all defined indices. Fabric 1 was wetted more quickly than any other fabrics. Fabric 3 (pure cotton, knitted) has the best liquid moisture transport ability from inner surface to outer surface with the highest value of moisture transport difference, while fabric 6 (100% polyester, knitted) has the worst moisture transport ability from inner surface to outer surface with the lowest value of moisture transport difference.

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