NEAR-INFRAED SCATTERING METHOD FOR FABRIC THERMAL COMFORT

by

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Wetting behavior of a clothing assembly plays an important role in thermophysiological body comfort. The instruments and methods utilised for testing purposes should adequately quantify wetting parameters of fabric thermal comfort. The surface conductivity method has been used to for moisture management testing in fabrics, but that method cannot give the detailed information for fiber-liquid interaction. With the new near-infrared scattering method, the wetting mechanism is introduced and interpreted through liquid transfer process from an infinite liquid reservoir. Wetting results from two kinds of fabrics show the difference in fabric thermal comfort.

Key words: *wetting mechanism, near-infrared scattering method, fabric thermal comfort*

Introduction

Moisture transfer property of textiles is part of the most critical indicators of thermal comfort for clothing wearing. The visible light reflection principle was used to research the performance of liquid water wetting [1]. The method has not been widely applied due to the color of the textile and the incident angle of visible light. However, optical method as a test is worth developing. The progress of research in this field comes from moisture management tester (MMT) [2]. They characterized the fabric surface using the principle of surface resistance method which has been adopted by the AATCC testing method [3]. The parameters of this method include fabric soaked time, water absorption rate and maximum wet radius. The moisture transfer performance of sportswear can be solved by this way. To characterize the thermal comfort of fabric, the more advanced non-contact optical method should be researched [4]. This paper presents the principle of the new test method, followed by the calculation of characteristic parameters. Finally, the effectiveness of the evaluation system will be demonstrated in two different fabrics for thermal comfort evaluation.

Test principle

The core concept of the principles came from the different absorption rate by the infrared light in the solid and the liquid. Infrared light absorption rate in the liquid is low than in solid (textile product). During the process of liquid wetting in textiles, the intensity of infrared light will change. In order to illustrate the dynamic nature of the liquid wetting in textiles, we developed the new testing system – fibrous liquid transfer systems (FLTS)

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according to the principle of the method. The FLTS utilized the precision infrared optical system to measure and analyze the behavior of liquid wetting in textiles. In order to calibrate the wetting degree, we took pure dried textiles as the zero point and pure liquid as the thorough wetting point (100%) for reference. Firstly, we measured the infrared optical properties of the l00% wetting point (mark A, fig. 1). Then, fabric was hung and placed on top of liquid, the optical intensity of this moment was set as the point 0% (no wetting, mark B, fig. 1); then dip the textile gently under the liquid surface, wetting process began immediately, fig. 1(C). With the passage of time, the liquid transferred gradually into the gaps between the fibers and inner of fibers. Wetting degree gradually improves, figs. 1(D) and (E). Finally, the majority of empty bubbles disappear, and the wetting goes into the next stage, fig. 1(F). At this time, only a small amount of air bubbles between the fibers exhaust, and the optical intensity close to 100% wetting points. Figures 1 and 2 reflect the basic laws of fluid wetting process for fabric. By wetting curve converted from the infrared light value, we can accurately analyze the wetting property between the textile and the liquid.

Characteristic parameters

According to Erik's definition and description for wicking and wetting process of textile fibers, there are generally two stages [5]. The first process is capillary penetration (CP). Capillary effect is the major driving force for wicking process. Another is hygroscopic wetting, imbibition and adsorption (IA) [6]. When liquid goes into the interior of the fibers, the surface active agent is absorbed by fibers, which are the principal characteristic of the process.

By using a novel algorithm, the FLTS can analyze wetting characteristic D, E, F processes in fig. 1. Using the time axis logarithmic approach, we change the feature segments of wetting curve in fig. 1 to the logarithmic co-ordinate curve in fig. 2, and then obtain two apparent straight line segments. Respectively linear fit to the two linear segments, we get two high linear correlation equations. The slope of the equation is equivalent wetting rate (*WR*).

In FLTS, the wetting time (*WT*) is described as the period from the liquid contact with the fabric surface to the end of spreading. The value within the wetting curve is the turning point on the wetting time logarithmic line segment (fig. 2).

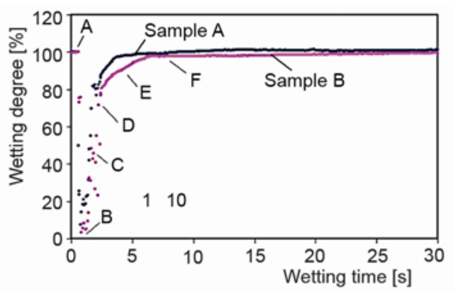

Figure 1. The moisture content curve

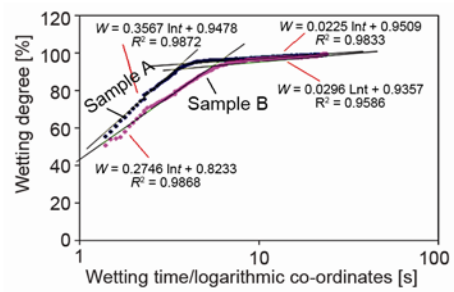

Figure 2. The wetting time logarithmic curve

MMT uses absorption rate as an indicator, which means the increase rate of fabric's moisture content per second [7]. It is comprised of two kinds of parameters: the largest water absorption rate and the average absorption rate. They used the maximum the slope of the moisture content curve as maximum water absorption rate. While in the GB standards, the average absorption rate usually is defined as the average value of moisture content curve within the test time [8]. This approach did not get a definite physical meaning. Because, with the water slightly spreading, the water leaves the surface to the depth of the fabric, but MMT utilized the surface resistance measurement method, it can only infer the internal situation through the fabric surface moisture content indirectly. While the surface moisture content curve increased and then declined, it can not directly reflect the wetting situation inside the fabric.

In FLTS, the equivalent *WR* is defined as the wetting change rate against wetting time logarithmic coordinates (fig. 2). Within the wetting degree and time logarithmic curve, it is the slope of the line segment:

$$W = a \ln t + b \tag{1}$$

Find the derivative of eq. (1), that's the wetting rate d*W*/d*t* as eq. (2) shows. The wetting rate is the inverse function of time, and *k* is a coefficient.

$$\frac{\mathrm{d}W}{\mathrm{d}t} = \frac{k}{t} \tag{2}$$

Discussion

To quantitatively compare the wetting efficiency of textiles, we define a coefficient in eq. (1) as the equivalent wetting rate. This parameter reflects a characterization of wicking and wetting process. With the invasion of wicking, the liquid gradually fills the fiber gaps, entering the hygroscopic wetting process. The indicator parameter of the process which is the slope of the latter part of the line is defined as the equivalent post wetting rate (*PWR*), fig. 2.

To verify the repeatability and reliability of the method, we sliced 80 mm diameter circular piece for 20 pieces in the same fabric as comparing samples. Sample A is a series of plain weave fabric of tencel fiber in the water and sample B is another series of plain weave fabric of cotton. The overall wetting performance of sample A is better than sample B. This phenomenon can be illustrated by fig. 2. By giving a statistical analysis of the 20 samples, we showed the results in tab. l. The wetting performance in the water of treated plain Tencel fabric is better than that of cotton, while the wetting rate after equivalent reflects a characteristic that cotton fiber is more easily swellable. Equivalent wetting rate parameter uses the classic time log method of physical meaning to propose an improved scheme for the current standard.

Table 1. Characteristic parameters for wetting

Sample	No.	Statistic value	*WR* %ln [s]	*WT* [s]	*PWR* %ln [s]
A/tencel	20	Average value	36.1	4.2	2.4
		Standard deviation	1.3	0.6	0.17
B/cotton	20	Average value	28.4	6.7	2.8
		Standard deviation	1.2	0.9	0.18

Due to use surface resistance test principle, the MMT system can be suitable for the hydraulic conductivity characterization of small-capacity conductive sweat in the fabric surface, and used for unidirectional perspire measurement in sportswear [9]. However, the interaction between textile and liquid requires representation not only of limited liquid system, but more research and characterization of relatively unlimited liquid systems, especially for the thermal comfort of textile [10].

Conclusions

In this paper, we present the test method for liquid dynamic immersion performance of textiles, and explain that using the principle of infrared optical system to measure liquid wetting performance has broader applicability. The wicking and wetting performance of fabric directly influence the thermal comfort, and FLTS system extends the measurement and research of sportswear's moisture comfort to characterization of the thermal comfort of all textile materials.

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