Evaluating the wettability and dynamic water absorption of textiles

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The liquid wetting process is often used to evaluate the hydrophilic tendency of different textile fabrics, which plays an important role in the development of medical and sporting materials. Based on the current methodology, the liquid transfer property of textiles was monitored by the designed photo-electric sensor equipment. The dynamic water absorption and wicking behaviour of five kinds of fabrics was assessed in three different directions: downward, lateral and upward. Results showed that the rate of moisture absorption varies among the fabrics and directions. The time for lateral infiltration was longer when they reached the same level of infiltration, compared to that in the downward and upward infiltration process. This is because different fabrics have different abilities to absorb near-infrared light (NIR) after we analysed the liquid transfer properties of each specimen with dot matrix CCD. Reasons for these phenomena lay in the fact that they had different internal structure and were also affected by gravity.

I. Introduction

The dynamic water absorption and wicking behaviour is an essential index to evaluate the comfort of garments, especially for sporting garments. Wong[1, 2] and his predecessors have examined the main three factors which influence people's subjective sense of comfort. They concluded that

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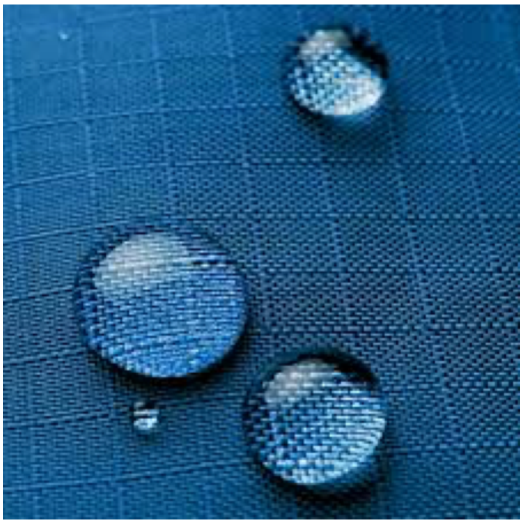
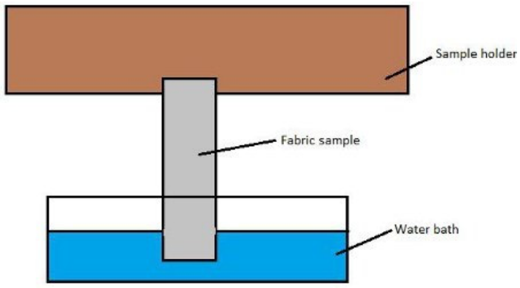
the property of heat-moisture constitutes around 50% of the amenity for garments, and thus researchers have devoted their energy and enthusiasm to investigate the liquid transport ability of hydrophilic sporting fabrics, such as an analysis of heat and moisture of comfort of fabrics[3], followed by another research on moisture permeability of woven fabrics[4] and the research into the process of permeability[5]. The liquid diffusibility in textile fabrics is often used to assess their internal structures and porosities in relevant experiments. It is therefore essentially to carry out a detailed study of the infiltration process of textile fabrics.

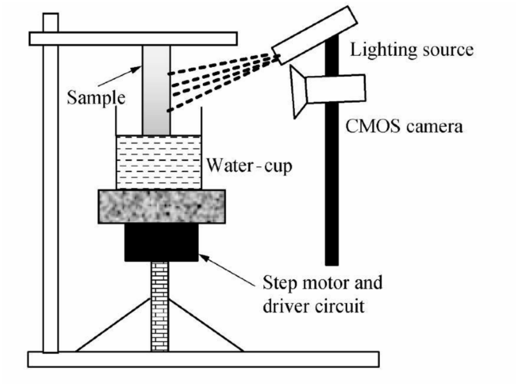
The main ways(figure 1) currently used to test the infiltration process include methods about dropping liquid[6], wicking height method[7], image acquisition method[8] .However, the most widely used system is MMT (acronym for Moisture Management Tester)[9]. This system requires conducting liquid in the test, while it may be inaccurate if the resin or liquid in low conductivity infiltrating into textiles. In order to do further research on the liquid transfer property of fabrics, underlying the principle of near-frared light technology, the equipment called Fibrous Liquid Transfer System (FLTS for short) was designed.



(a) Liquid-dropping method



(b) wicking height method



(c) image acquisition method

(d) Moisture Management Tester

Fig. 1: Existing method to test wicking property of textiles:a, Contact angle works as indexes which show the wicking property; b,The wicking height in a given time could show the information about the corresponding property; c, In stead of evaluate the height by rules, the height is obtained by the sensors which could be much more accurate; d, the widely used equipment in the industrial but their contact resistance would affect the local property about the material, thereby losing accuracy

II. Methodology

A. Fabrics and apparatus design

FLTS is equipped with the following parts: computer analytic system, test bed, constant-current power supply, near infrared light source (980nm wavelength), signal acquisition system, dot matrix CCD, water dropper, box and finally a piece of brown nonwoven fabrics(figure 2a). All the units can be seen from the diagrammatic sketch, which shows the principle of our measurement and the process of infiltration(figure 2b,2c).Here we choose five kind of textiles which are widely used in garments especially underwear, and their properties are shown in table 1.

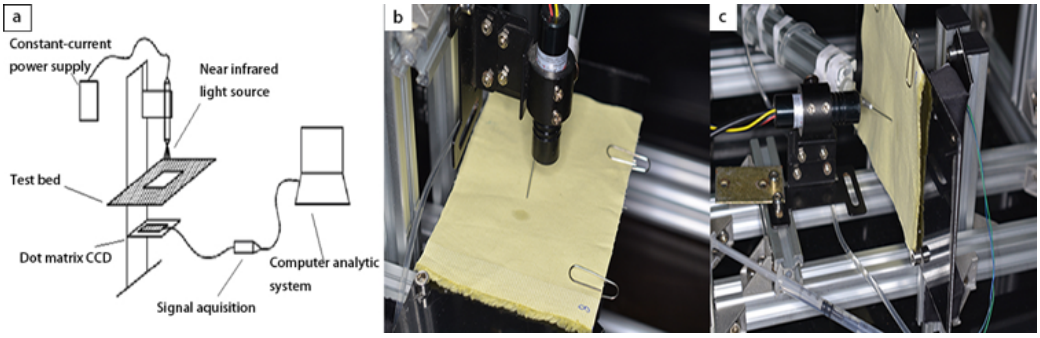


Fig. 2: Schematic diagram of the equipment: a, Working principle diagram; b, The water drop downwardly infiltrates the fabric; c, The water drop laterally infiltrates the fabric.

B. Experiments

1. Tests of downward infiltration

With FLTS, sample 1, sample 2, sample 3, sample 4 and sample 5 was tested. Three layers of brown nonwoven fabrics were used to cover the box so as to eliminate interference from natural

Table 1: The property of sample textiles

Specimen	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Material	PET	Cotton&Hemp	Hemp	PET&Cotton	Cotton
Average thickness(mm)	0.16	0.32	0.38	0.68	0.85
Average weight(g/m^2)	28.0	86.0	102.0	180.0	112.0

light.

At the first stage, air bubbles in the pipe were supplanted by deionized water and the textiles were put on the test bed. After ensuring that the box had been covered entirely, regulate the computer system waiting for the test and then start it to test the dry fabric 0.5-1s before the water being dropped. About one millilitre water was subsequently squeezed on the spot of the fabric under the light source and the curve can be observed on the monitor. The whole process lasted 18s. Repeat these steps three times in one sample specimen.

2. Tests of lateral and upward inflitration

In real cases, the contact between bodies and fabrics is not only downward but upward and lateral. Individuals may sweat profusely after they do some strenuous exercise, so it is essential to simulate this real process in which perspiration infiltrates into garments. Sample 4 was selected to see whether the infiltration property would be distinctly different if infiltration directions were changed. Sample 4 was tested three times in each direction, and the step was similar to the previous experiment. In this way, only to side lay or invert the apparatus, we can easily complete these tests.

III. Results and analyses

A. Results of downward infiltration

Infiltration level-time curves were obtained after data analyses, and the average level of infiltration in each test of the five samples was shown in figure 3a. Sample 1 was a piece of tropical black polyester fabric and it has a better property of infiltration because of the considerable pore radius. The level of infiltration of sample 1 also rose smoothly, thus showing that the liquid transfer is a steady process in this fabric. According to Wetting and Wicking stated by Erik Kissa in 1996, wetting and wicking were a different process. It was therefore supposed that wicking accounted for the main process of water infiltration in sample 1. Analysing the results of sample 1, sample 3 and sample 4, the level of infiltration of each increased to roughly 50% in 6s. The material of sample 3 whose infiltration level experienced a moderately upward trend in the test was hemp; however the infiltration property of sample 2 was between the level of sample 3 and sample 4. The liquid transfer properties of sample 4 was better than other samples, of which the level of infiltration reached around 90%; it also meant that this sample may perform better in liquid transfer. When curves reached their limit level at 90%, the infiltration rate of sample 2 and sample 4 decreased significantly whereas the figure for sample 5 climbed slightly. On the other hand, it may due to the different ways of liquid transfer that the inflection point of sample 3 emerged at 60%.

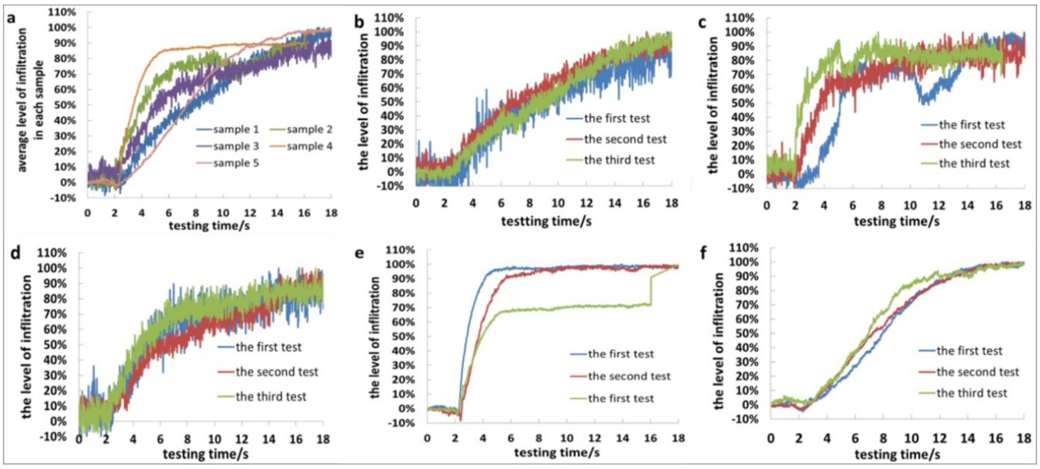


Fig. 3: Testing results of the downward infiltration process. a, Curve of average infiltration level of each sample; b, Three tests for infiltration curve of sample 1; c,Three tests for infiltration curve of sample 2; d, Three tests for infiltration curve of sample 3; e, Three tests for infiltration curve of sample 4; f, Three tests for infiltration curve of sample 5.

It was also noticeable that the level of infiltration of all samples showed a slight downward trend in the opening two seconds during the test. This may lie in the fact that the drop liquid had not infiltrated into the fabric at this stage and thus reduced the transmission of the near infrared light (figure 4a). The water was absorbed subsequently and it replaced the air in the fabric, which hence improved the index of refraction of transmitting medium in the fabric[10]. Light scattering was then weakened and the increasing light intensity stimulated the photoelectric sensor gradually as time went on (figure 4b,4c).

B. Results of lateral and upward infiltration

It was worth noting that the opening time of infiltration was delayed for about 1s, which means that hysteresis phenomenon appeared in lateral and upward infiltration. The rate of these two types of infiltration (the slope of the curve) was lower than the figure for the downward infiltration

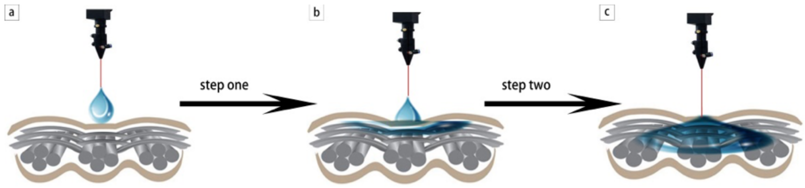


Fig. 4: Mechanism of liquid absorption: Step one, the drop water is absorbed into the fabric; step two, the drop water infiltrates into the fabric through wicking.

in the beginning 5.8s during the test. It explained that gravity had a comparatively effect on the liquid transfer property of fabrics at the beginning of infiltration. Furthermore, the rate of downward infiltration declined considerably because the fabric was relatively full more quickly due to the driving force of gravity, while the rate of lateral and upward infiltration grew gradually in the process. It was also shown that the rate of lateral infiltration was the lowest, since the liquid may be more likely to slide out of the interior or surface of the fabric (figure 5).

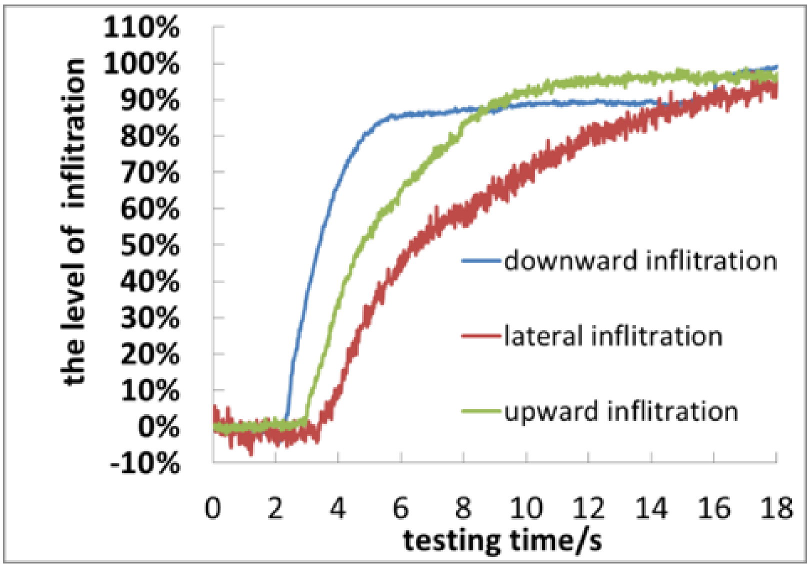


Fig. 5: The comparison of three kinds of infiltrations

IV. Conclusion

A new method and apparatus was designed to characterize the wettability and dynamic water absorption of textiles and measured their properties in three directions. These properties of them are different, which means that they have different moisture management ability. This is because different fabrics have different abilities to absorb near-infrared light after we analysed the liquid transfer properties of each specimen with dot matrix CCD. The time for lateral infiltration is longer when they upped to the same level of infiltration, compared to that in the downward and upward infiltration process. One reason for the variant rates of liquid transfer in fabrics is their different transfer mechanism. Another factor is that gravity, which may affect the rate of liquid transfer if directions of the infiltration and gravity are different.

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