Characterizing the dynamic water absorption and wicking behaviour of sportswear by the noncontact near-infrared method

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Abstract

The liquid diffusibility of textile fabrics is often used to assess their internal structures and porosities in relevant experiments. A new method and instrument called Fibrous Liquid Transfer System (FLTS) was devised to evaluate the liquid transfer properties of sporting fabrics, and this noncontact measurement can also be used to monitor the dynamic water absorption and wicking behaviour by the noncontact near-infrared. Five types of sporting fabrics were tested in three different directions including downward, upward as well as lateral infiltration, and the results show that their liquid transfer properties are significantly distinct from each other. This is because different fabrics have different abilities to absorb near-infrared light after we analysed the testing results of each specimen with the FLTS. The variant rates of water absorption and wicking in fabrics are due to their different liquid transfer mechanism. Gravity can also affect the liquid transfer property of fabrics and this is another factor.

1. 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 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 sporting fabrics.

The main ways currently used to test the infiltration process include methods about dropping liquid [6], wicking [7], image acquisition of the infiltration process [8] .However, the most mature system which is widely used for testing the liquid transfer property of fabrics is MMT (acronym for Moisture Management Tester) [9]. This system requires conducting liquid in the test, while it may be inaccurate or useless if the resin or liquid in low conductivity infiltrate into the fabric. In order to do further research on the liquid transfer property of fabrics, underlying the principle of near-frared light technology, we set up a new equipment called Fibrous Liquid Transfer System (FLTS for short), which is able to test the liquid transfer properties of fabrics from the perspective of comfort[10-14].

1. Methodology

1.1. Fabrics and apparatus design

Table 1, Performance features of the fabrics

Specimen	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Fabric content	PET	Cotton&hemp	Hemp	PET &cotton	Cotton
Average thickness(mm)	0.16	0.32	0.39	0.68	0.85
Average weight(g/m^2)	28.0	86.0	102.0	189.0	112.0

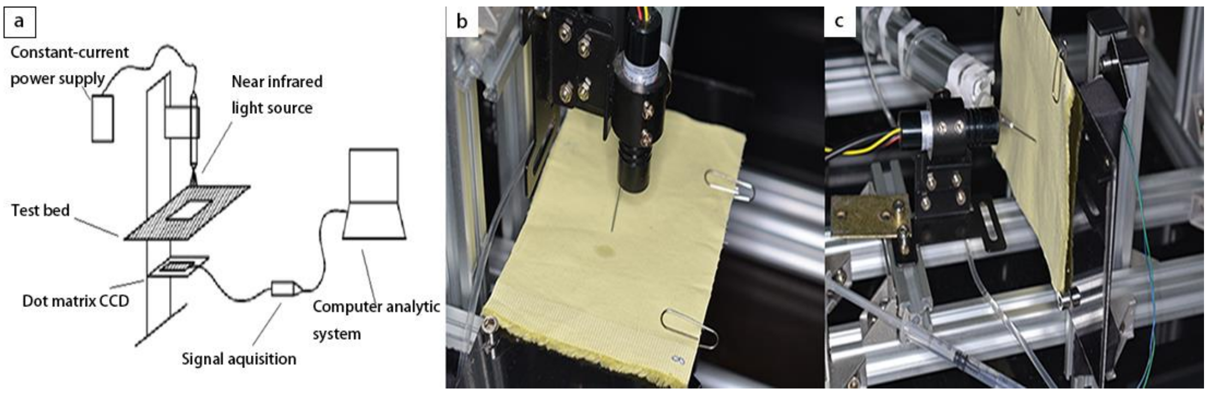

Figure 1, Equipment schematic diagram of the FLTS. **a,** Working principle diagram. **b,** The water drop downwardly infiltrates the fabric. **c,** The water drop laterally infiltrates the fabric.

Our FLTS is equipped with the following units: a computer analytic system, a test bed, a constant-current power supply, a near infrared light source (980nm wavelength), a signal acquisition, a dot matrix CCD, a water dropper, a box jib and finally a piece of brown nonwoven fabrics(Fig. 1a). All the units can be seen from the diagrammatic sketch, which shows the principle of our measurement and the process of infiltration (Fig. 1b, c).

1.2. Experiments

1.2.1 Tests of downward infiltration

We tested five kinds of fabrics with dot matrix CCD, sample 1, sample 2, sample 3, sample 4 and sample 5. Three layers of brown nonwoven fabrics were used to cover the box jib so as to eliminate interference from natural light.

At the first stage, air bubbles in the pipe were supplanted by deionized water and a textile fabric piece is put on the test bed. Regulating the computer analytic system was ready for the test after ensuring that the box had been covered entirely, and then starting this system to test the dry fabric as initial data 0.5s-1s before water being dropped on it. 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 and the data was saved promptly. Repeating these step three times in one sample specimen.

1.2.2 Tests of lateral and upward infiltration

In real cases, the contact between bodies and fabrics is not only downward but also upward and lateral. People may sweat profusely after they do some strenuous exercise, and it is therefore 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 foregoing experiment. In this way, only to side lay or invert our apparatus, we can easily and conveniently complete these tests.

2. Results and analyses

2.1. Results of downward tests

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 fig.2 a. 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 inflection point at the level of 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%.

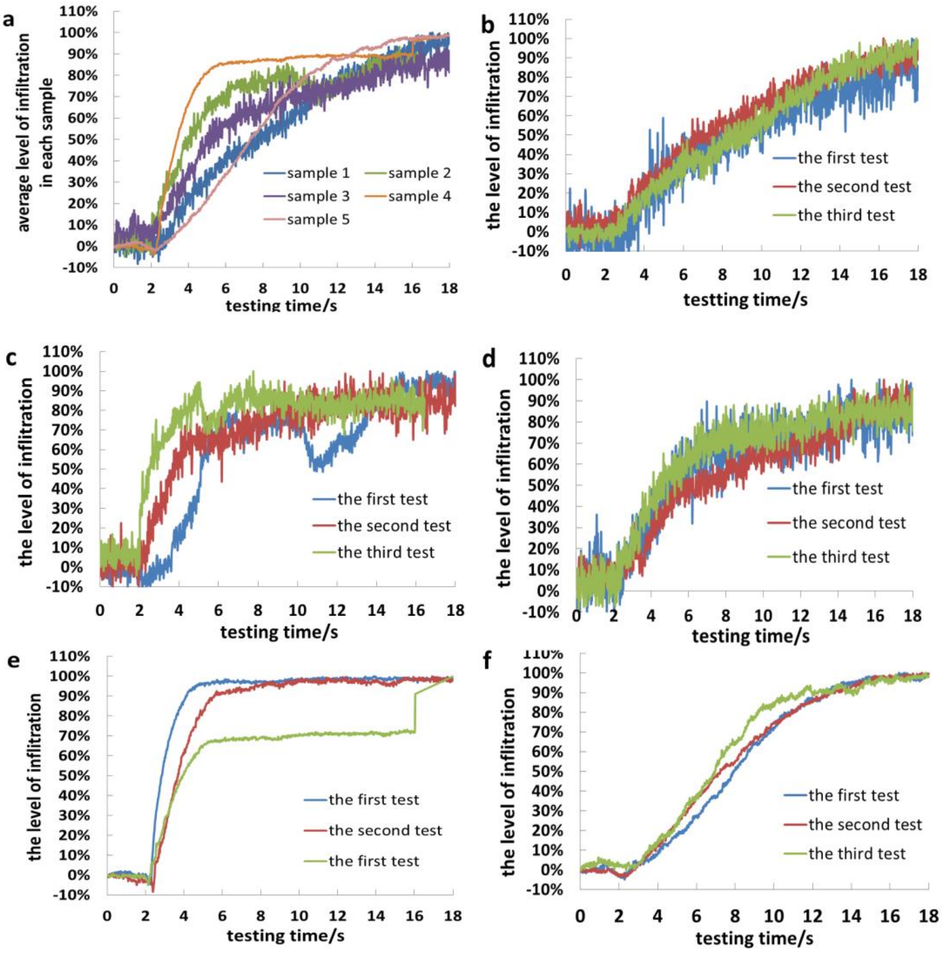

Figure2, Testing results of the downward infiltration process. a, Curve of average infiltration level of each sample. **b,** Three tests for infiltration curve of sample 1. **c,**Three tests for infiltration curve of sample 2. **d,** Three tests for infiltration curve of sample 3. **e,** Three tests 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 3a). 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 3b, c).

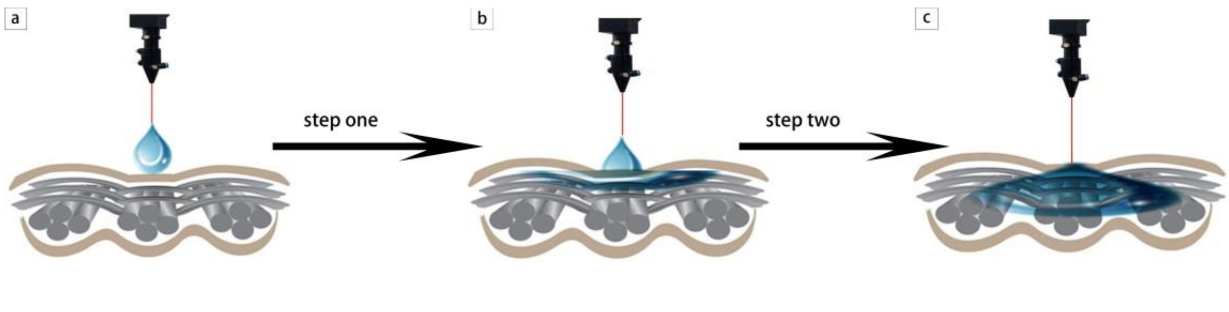

Figure3, Mechanism of liquid absorption. **a,** The drop water contacts the fabric inceptively **b,** The drop water infiltrates the water **c,** The drop water infiltrates the fabric completely.

2.2 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 in the beginning 5.8s during the test. It explained that gravity had a comparatively large 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 (Fig. 4).

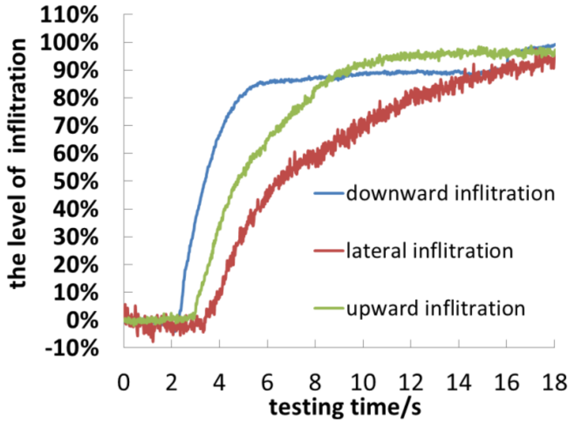

Figure 4, The comparison of three kinds of infiltrations.

3. Conclusions

We devised a new method and apparatus to characterize the dynamic water absorption and wicking behaviour of sporting fabrics and we can easily measure their properties in three directions. This property of the fabrics is much different, which means that they have different moisture absorptivity. It 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 handicap the rate of liquid transfer if directions of the infiltration and gravity are not the same, can also affect the liquid transfer property of fabrics.

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