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〈研究論文(學術)〉

Water Vapour Transfer through Fabrics for Outdoor Activities

[1]Ae-gyeong Oh and Jung-whan Park*

Department of Textiles Engineering, Pusan National University, Pusan, KOREA
*Department of Clothing and Textiles, Dong-Eui University, Pusan, KOREA
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야외 운동복용 직물에서의 수분전달

[1]오애경 · 박정완*

부산대학교 공과대학 섬유공학과
*동의대학교 생활과학대학 의상학과
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Abstract—야외 운동(outdoor activities)복에 사용되는 소재들은 외부로부터 신체를 안전하게 보호해 주어야 될 뿐 아니라 쾌적하게 유지시켜 주어야 한다. 의복착용시 쾌적감에 결정적인 영향을 미치는 인자는 몸의 열적 평형상태를 유지하기 위한 수단인 수분전달 특성이다. 본 연구는 여러 종류의 야외 운동복용 직물에서의 수분전달 현상을 조사하여 규명하므로써 이 직물들이 실제 의복생활에 응용될 의복계(clothing system)를 형성하였을 때의 수분전달 현상을 설명하고자 하는 기초연구이다. 연구의 결과는 base layer용, mid layer용 직물들이 shell layer로 쓰이는 waterproof breathable 직물보다 수분 전달률이 높았으며, waterproof breathable 직물의 수분 전달률은 microfibre 직물, PTFE-laminated 직물 그리고 polyurethane coated 직물 순 이었다. 또한 polyurethane 직물에서는 back coated 직물이 face-coated 직물보다 수분 전달률이 높았다.

Keywords : *water vapour transfer, clothing comfort, outdoor activities, waterproof breathable fabrics*

1. Introduction

The water vapour transfer of clothing materials is a critical property for clothing comfort that must maintain thermal equilibrium for the wearer. The evaporation of perspiration provides the means of cooling the human body. In outdoor activities, functional wear is regarded not as simple clothing but as equipment for protecting body from outdoor condition with safety and comfort. It is generally knwn that waterproof breathable fabrics easily transport water vapour through the fabric structure while they have resistance to the passage of water. To assess the clothing comfort performance of various textiles, many textile researchers have attempted to get the factors related with water vapour transfer.

Adler et al[1] have studied interfabric moisture transport through 100% cotton, 100% polyester, and cotton/polyester blend for sports fabrics. The moisture transport in cotton fabric rapidly decreases during the initial experiments, and then slowly approaches equilibrium. In the case of 100% polyester fabric, the moisture transport was shown slowly decreases and an intermediate value for the cotton/polyester blend fabrics.

Hong et al[2] have studied experimentally the

[1]Corresponding author. Tel. : +82-51-510-2449 ; Fax. : +82-51-512-8175 ; e-mail : agoh@pusan.ac.kr

influence of certain fibre types on the dynamic water vapour transfer through textiles with a simulated sweating skin. They used 100% cotton, 100% polyester, and cotton/polyester blend and found considerable differences between the dynamics water vapour transfer of these fibre types. The results show that the all polyester vapour pressure-time curve was consistently steeper in slope, and higher in overall moisture vapour pressure, than either the blend or all cotton fabric.

Ruckman[3] studied water vapour transfer in twenty-nine waterproof breathable fabrics under various conditions. The rate of water vapour transfer of the above fabrics initially falls in a roughly exponential manner for the first six hours, the falls becoming linear after that time.

The moisture vapour transfer rates of performance fabrics(specially waterproof beathable fabrics) have been measured using the evaporation dish method by Gretton et al[4], have shown similar results with Ruckman[3].

The present work was undertaken with the object of examining the water vapour transfer rate of various types of fabrics for outdoor activities using the Turl Dish under isothermal conditions, and of investigating the effect of the type of fabric on water vapour transfer.

2. Experimental

2.1 Materials

Eight fabrics were used; four waterproof breathable of various materials fabrics, such as polyurethane coated, PTFE laminated and microfibre fabrics as a shell layer, two of 100% polyester, such as single and double sided fleece fabric as a midlayer, and a 100% machine washable wool, and a cotton/polyester blend as a base layer. Descriptive characteristics of the fabrics are given in Table 1.

Table 1. *Specifications of samples*

Sample Fabrics		Material	Weight (g/m^2)	Thickness (mm)
1	shell layer	Laminated, face-coated with PU	128	0.43
2	shell layer	Microfiber fabric	68	0.10
3	shell layer	Back coted with PU	180	0.30
4	shell layer	PTFE laminated	195	0.45
5	mid layer	100% polyester single sided fleece	151	0.86
6	mid layer	100% polyester single double fleece	366	4.80
7	base layer	100% wool	211	0.56
8	base layer	polyester/cotton Blend	229	0.71

2.2 Fabric preparation and preparation for testing

Before testing the fabrics were given a conditioning period of at least 24 hours. The dishes were installed in a controlled room operating at 19.5℃ and 60% relative humidity. The method adopted for measurement of the transfer water vapour through a fabric was the straightforward one of determining the loss in weight, with evaporation time of water contained in a dish, the top of which was covered by the cover ring. Microscope and SEM measured the basic physical properties of fabrics for fibre contents and type of yarn, by scale for fabric weight, by dial test indicator for fabric thickness, and by counting glass for thread count.

2.3 Test methods

Water vapour transfer was measured according to BS 7209 : 1990. A sample was placed on the supported specimen, glue was firmly secured, and adhesive tape was then applied around the full circumference of the dish. Each assembly was placed onto its corresponding position on the eight-station turntable. The dishes had to be rotated gently to ensure that a saturated air layer above the fabric did not impede evaporation.

At the end of the equilibration period, the assemblies were weighed. Then, the test was carried out for a further period of several hours, at the end of which the dish was weighed again to determine the amount of water vapour, which had evaporated through the sample. The loss in weight over a period of 8 hours was then recorded for each dish.

3. Results and Discussions

The most convenient method of expressing the results is the water vapour transfer in $g/m^2/day$[5].

Water vapour transfer by the equation.

$$WVT = Q / TA \quad (1)$$

Where, Q : the loss in mass of water vapour over the time period (g)

T : between successive weightings of the water vapour (hr)

A : the area of the exposed test fabric (m^2)

The loss in weight of water is used to calculate the water vapour transfer of the fabric by Fick's equation[6] derived as above.

The results obtained from experiments conducted using a Turl Dish are shown in Figure 1 and 2. Figures illustrate the general curves of the rate of water vapour transfer until 30hr and 8hr later, respectively for polyurethane coated fabrics(PU), a microfibre fabric (MF), a PTFE-laminated fabric(PTFE), a 100% polyester fabrics(PET), a 100% wool fabric and a cotton/polyester blend fabric. From these figures it is clear that the rate of water vapour transfer rapidly falls during the initial experiments, decreases very slowly until 24hr, and then approaches equilibrium after that time. Microfibre fabric(MF) demonstrates the highest water vapour transfer rates, followed by wool(Wool), cotton/polyester blend(P/C), and polyester fabric (PET, S and PET, D), by PTFE-laminated fabric (PTFE) and by polyurethane coated fabrics(PU, F and PU, B). In the case of waterproof breathable fabrics as a shell layer, it is clear that can allow the highest water vapour transfer, followed by laminated and coated fabrics. Ruckman[3] has previously reported such behaviour. Microfibre fabric and PTFE-laminate fabric initially lose water vapour quickly and give superior results for water vapour transfer rate than

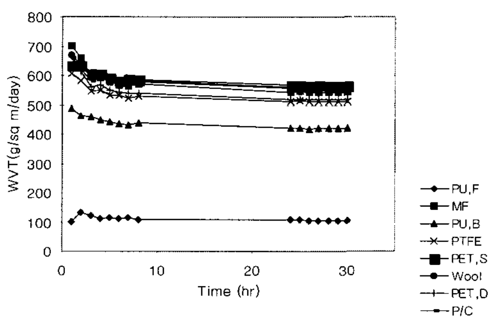

Fig. 1. The rate of water vapour transfer of fabrics until 30 hours.

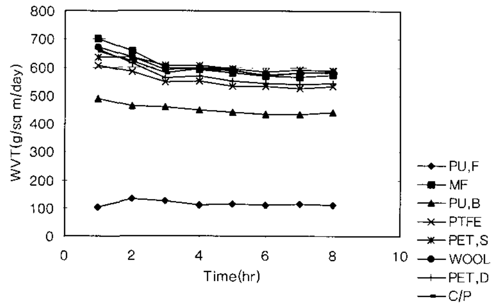

Fig. 2. The rate of water vapour transfer of fabrics until 8 hours.

fabrics coated with polyurethane.

The rate of water vapour transfer of back coated polyurethane fabric(PU, B) is higher than that of a face coated polyurethane fabric(PU, F). The structures of these two types of fabrics are shown in Figure 3 and 4. As shown in Figure 3(a) and 4(a), water vapour is transferred by the inner layer nearest to the water, then it can be assumed that it cannot be transferred to the outer layer very well due to the film and to the coating of polyurethane. After the water vapour fills the free spaces between the fibres, the yarns, and the interiors of the fibres in the inner layer, the still air cannot be kept in the free spaces. The rate of evaporation is directly proportion to the area under isothermal conditions. In other words, a face coated fabric with polyurethane kept more water vapour from escaping and therefore promoted an accumulation of water vapour beneath the fabric. The face coated

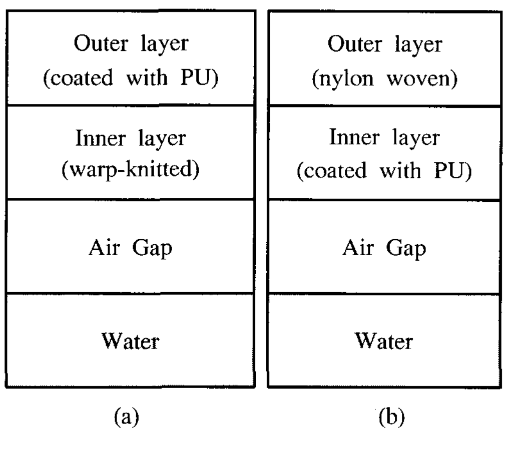

Fig. 3. The equipment diagram of PU,F(a) and PU,B(b).

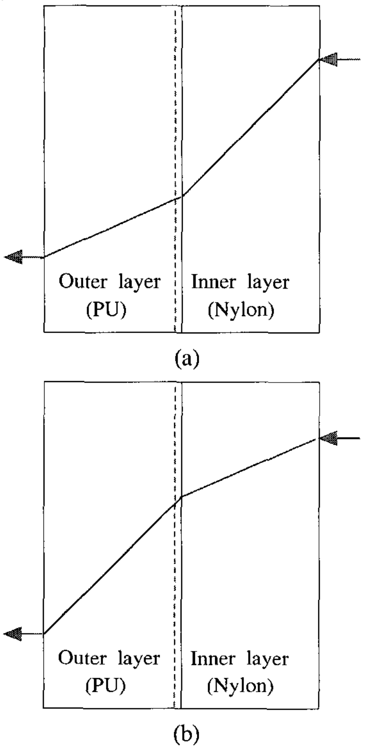

Fig. 4. The structure of PU,F(a) and PU,B (b).

polyurethane fabric, therefore, shows a lower water vapour transfer rate than back coated polyurethane fabric. While vapour concentration difference in the inner layer of the sample is low, it increases while passing through the film and the outer layer to the outside atmosphere. The vapour pressure through the inner layer is increased, and it increased gradually through the film and outer layer. According to Ficks law, the rate of water vapour transfer for a fabric is directly proportional to the vapour concentration (C) difference between the inner layer and outer layer of the fabric, it is a linear relationship to the vapour pressure (P) difference, and inversely proportional to the thickness (T) of the fabric under isothermal conditions. It is given by

$$WVTR = f\ \{(C_i - C_o),\ (P_i - Po),\ T\} \qquad (2)$$

Face coated polyurethane fabric(0.43mm) is thicker than back coated polyurethane fabric(0.30mm), so that makes it a lower water vapour transfer than back coated polyurethane fabric.

As shown in Figure 3(b) and 4(b), water vapour is with difficulty transferred directly to the inner layer coated with polyurethane, but it can be transferred to the outer layer with the aid of the capillary action of the inner layer. The outer layer(nylon woven fabric) can absorb water well; it can promote quick water vapour evaporation. In face coated polyurethane fabric, in contrast, the vapour concentration difference in the inner layer of the sample is high, it decreases through the outer layer, and the lower vapour pressure build-up in the inner layer increases quickly passing through the outer layer. It is well known that the water vapour transfer rate of woven fabrics is higher than that of warp-knitted fabrics.

The PTFE-laminated is intrinsically hydrophobic, while the laminating surface is a solid membrane with hydrophilic characteristics. For this laminating membrane, water vapour is known to diffuse through the holes that formed between the polymer chains.

As expected, the rate of water vapour transfer for most of the part of base layer fabrics and mid-layer fabrics is more higher than that of shell layer fabrics. Wool is more hygroscopic than any other fibre.

4. Conclusions

The purpose of this experiment was to clarify and to investigate preliminary principles and mechanisms of water vapour transfer through several fabrics for outdoor activities, which will be composed clothing systems. The clothing system usually composed of base layer, mid layer, and shell layer. The water vapour transfer rate of various types of fabric has been obtained with the Turl Dish under isothermal conditions.

In this study, the conclusions are as following: First, the rates of water vapour transfer for the most part of the base layer fabrics and mid-layer fabrics are higher than those of waterproof breathable fabrics as a shell layer.

Second, the rates of water vapour transfer in waterproof breathable fabrics forms a ranking: microfibre fabric followed by PTFE-laminated fabric and by polyurethane coated fabrics.

Third, the rate of water vapour transfer of a back coated polyurethane fabric is higher than that of a face coated polyurethane fabric. This suggests that the effective laminated part needs to be nearer the skin.

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