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Behavior of Water Vapor Permeability on Layered System

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Abstract : This study investigates the behavior of water vapor permeability of a layered system to find out a comfortable combination of a layered system for outdoor activities and examines the water vapor permeability of various types of outdoor clothing fabrics. The layered system includes the base layer such as sportswool and polyester/cotton fabrics, the middle layer such as single and double sided fleece fabrics, and the shell layer such as polyurethane-coated, PTFE-laminated and microfiber fabrics in this experiment. Results show that the layered system was applied, it was working together as a whole having some influence on each other layer, though every layer offered varying degree of water vapor permeability. Water vapor permeability of layered system exactly followed the same trend as the shell layer, which is all vapor permeable water repellent fabrics as a single layer. The rate of water vapor transfer through a layered system is mainly related to the type of vapor permeable water repellent fabrics used for the shell layer.

Key words : water vapor permeability, layered system, outdoor activity, clothing comfort, vapor permeable water repellent fabrics

1. Introduction

As emphasis on a healthy life style increases there is no doubt that most of the people are more likely to take part in outdoor activities. Owing to the increasing number of people participating in outdoor activities, outdoor activity wear takes a growing interest. Active wear meets the comfort needs of outdoor activities and the protection needs of outdoor conditions as well. It is well known that the water vapor transport properties of clothing contribute to determining the comfort(Keighley, 1985). The human body regulates its temperature to a large degree by the evaporation of perspiration. If moisture vapor in the clothing space is damp, the wearer may feel uncomfortable. Thus to develop comfortable active wear requires considering clothing water vapor transfer properties.

Layering fabrics is an effective way of controlling water transport properties in fabric systems and an analysis of these systems may be useful for designing comfortable clothing. Layering systems are recognized as the most efficient and practical method of dressing for outdoor activities. The common outdoor clothing layers usually comprise an under layer (base layer), a fleece fabric (middle layer) and vapor permeable water repellent fabric (shell layer). The base layer is normally worn for reasons of hygiene and comfort, it is also worn as thermal underwear used in outdoor activities. It allows the skin to breathe gently wicks moisture away from the body and enhances the performance of the next layer, of fleece. The middle layer is used to keep warm. The shell layer is used to provide the wearer with protection against the weather and loss of body heat. It is generally known that vapor permeable water repellent fabrics prevent penetration of liquid water from the outside, while at the same time permit the emission of water vapor from inside to outside(Horrocks & Anand, 1996). When all three layers are working effectively together, the result is a personal climate that will keep one comfortable and protected from the environment

The present work was therefore carried out with the objective of examining the water vapor permeability of layered system to permit testing under condition closer to actual wear and eventually to find out a more comfortable combination for outdoor activities. It is necessary to eliminate the effect of other factors in order to investigate the basic principle of layering related to the water vapor transfer in this study.

2. Experimental

2.1. Material

In order to develop a common use of a layered system for outdoor activities, various types of outdoor activities fabrics were used. Seven fabrics and twelve different layered system combinations typically were chosen for this experiment.

The shell layer usually has been vapor permeable water repellent fabrics, which are used in clothing for outdoor activities. There are three basic kinds of vapor permeable water

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Table 1. Specifications of samples

Sample Fabrics		Description	Materials	Weight (g/m^2)	Thickness (mm)
Shell layer	MF	Polyester woven Nylon warp-knitted Nylon warp-knitted	Microfiber fabric	68	0.10
	PU		Coated with PU	128	0.43
	PTFE		PTFE membrane laminated	195	0.45
Middle layer	PET,S	100% polyester knitted (single side fleece)		151	0.86
	PET,D	100% polyester knitted (double side fleece)		366	4.80
Base layer	WOOL	100% wool knitted		211	0.56
	C/P	35/65 polyester/cotton knitted		229	0.71

Table 1. Specifications of samples(continued)

Sample Fabrics		Linear density (denier)	Air Permeability ($cm^3/cm^2/s$)	Water absorbed height (mm)
Shell layer	MF	Warp : 74 Filling : 75	3.74	1
	PU	83	0.16	19
	PTFE	Warp : 83 Filling : 83	0.18	13
Middle layer	PET,S	192	86.57	8
	PET,D	183	63.6	2
Base layer	WOOL	115	54.4	0.5
	C/P	300	25.08	2

repellent fabrics; high-density fabrics consisting of microfiber yarns with compacted weave structures, laminated fabrics made from microporous and/or hydrophilic films, and coated fabrics made from microporous and/or hydrophilic coatings(Lomax, 1990), (Roye, 1991). Historically, the preferred fibers for underwear as a base layer have been cotton and wool.

Three vapor permeable water repellent fabrics, such as microfiber (MF), polyurethane coated (PU), and PTFE laminated (PTFE) fabrics as a shell layer, two of 100% polyester, such as single and double sided fleece (PET,S and PET,D) fabrics as a middle layer, and a 100% machine washable wool (WOOL), and a polyester/cotton blend (P/C) as a base layer. The specifications of these fabrics are described in Table 1. The layered systems which are all possible using the selected fabrics and the combinations of layers of fabrics, are shown in Table 2.

2.2. Test methods

Water vapor transfer was measured according to the Turl Dish, BS 7209 : 1990 (BSI, 1990). This method was a 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. The dimensions of the dish were calculated to give a 10mm deep layer of air between the surface of the water and underside of the base layer. At the end of the equilibration period, the assemblies were weighed. Then the test was carried out for a further period of six hours, at the end of which the dish was weighed again to determine the amount of water vapor which had evaporated through the layered system. When the each layer was added, glue was firmly applied around samples each in direct contact with the next without air gap. To evaluate the effectiveness of the experiments was set at 6 hours, five measurements were taken from each experiment. The measurements were made under standard conditions (20±1°C and 65±3% R.H.), and maintained throughout the experiment.

Table 2. Combinations of layered system

Layered System	Shell layer	Middle layer	Base layer
MSW	MF	PET,**S**	**WOOL**
MSP		PET,**S**	**P/C**
MDW		PET,**D**	**WOOL**
MDF		PET,**D**	**P/C**
USW	PU	PET,**S**	**WOOL**
USP		PET,**S**	**P/C**
UDW		PET,**D**	**WOOL**
UDP		PET,**D**	**P/C**
PSW	PTFE	PET,**S**	**WOOL**
PSP		PET,**S**	**P/C**
PDW		PET,**D**	**WOOL**
PDP		PET,**D**	**P/C**

3. Results and discussion

The results obtained experiments conducted using a Turl Dish are shown in Figure 1 and Figure 2. The water vapor transfer rates of single layers are plotted in Figure 1. Microfi-

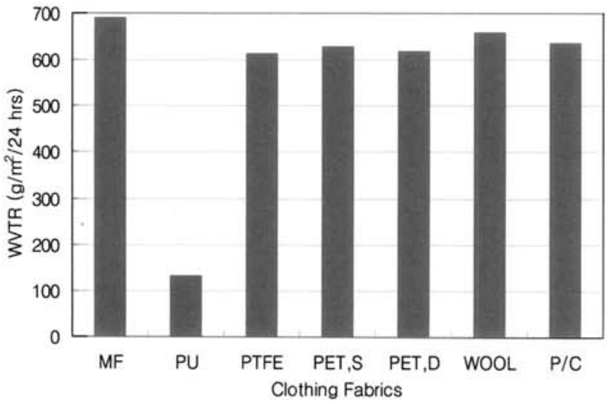

Fig. 1. The water vapor transfer rates of outdoor clothing fabrics.

ber fabric (MF) demonstrates the highest water vapor transfer rates, followed by wool, cotton/polyester blend and polyester fabric (PET, S and PET, D), by PTFE-laminated fabric (PTFE) and by polyurethane-coated fabrics (PU, F). In the case of vapor permeable water repellent fabrics as a shell layer, the water vapor transfer rates are ordered as MF, PTFE-laminated and PU-coated. Ruckman(Ruckman, 1997) has previously reported such behavior. This demonstrates that the water-repellent finishing on tightly woven fabrics allows the greatest water transfer followed by laminating and coating. Microfiber fabric and PTFE-laminated fabric initially lose water vapor quickly and give superior results for water vapor transfer rate than fabrics coated with polyurethane. Vapor permeable water repellent fabrics are ordered by the type of product rather than being ordered according to other factors such as thickness of the fabric or air permeability. Therefore, the type of product has an effect on the water vapor transfer rate of the vapor permeable water repellent fabrics.

Figure 2 shows water vapor transfer rates of layered system. From this figure, an interesting result was obtained which was analyzed to ascertain the effect of layering in a

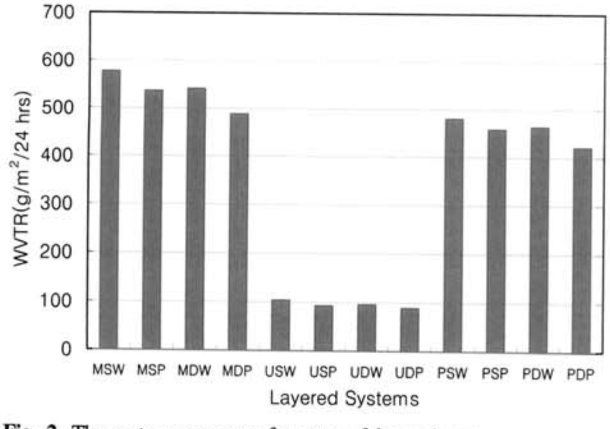

Fig. 2. The water vapor transfer rates of layered systems.

layered system. The layered system incorporating a MF shell layer and PTFE-laminated shell layer generally performs better than the layer system incorporating a PU-coated shell layer. The microfiber fabric group (MSW, MSP, MDW and MDP) illustrates the highest water vapor transfer rate, followed by the PTFE-laminated fabric group (PSW, PSP, PDW and PDP) and by the polyurethane-coated fabric group (USW, USP, UDW and UDP). It was revealed that the water vapor transfer rates of layered system are ordered into groups determined by the type of vapor permeable water repellent fabrics used for the shell layer. Having compared the water vapor transfer rates of shell layer, which is one of single layer in Figure 1, with Figure 2 exactly the same trend is followed.

The other interesting point is that the water vapor transfer rate differs according to the combination in which layered system was evaluated. When compared MSW, USW, PSW (base layer and middle layer: fixed, shell layer: variable) with MSW, MDW (base layer, shell layer: fixed, middle layer: variable) and MSW, MSP (middle layer and shell layer: fixed, base layer: variable), it is very clear that the water vapor transfer rate largely varies when the shell layer is changed rather than the base layer or middle layer in a layered system. In the case of MSP, USP, PSP with MSP, MDP and MDW, MDP and so on are the same. This shows that the shell layer is the main influence on the water vapor permeability of the layered system.

According to this figure, the water vapor transfer rates have the highest value when microfiber fabric is added to wool fabric. This is contrary to the common belief that polyester/cotton blend fabrics are used as a base layer rather than the wool fabrics. The absorbency of wools 13-18% that is higher than that of cotton(7-11%) and polyester(0.4%) under standard conditions. Wool absorbs more moisture vapor from the clothing microclimate than polyester, a fiber that can be regarded as almost nonhygroscopic.

The perceived superior comfort performance of cotton seems largely due to the packing behavior of the yarn. The substitutions of polyester for cotton in fabrics reduce their moisture-related properties, particularly when polyester becomes the dominant fiber in the blend. We do not know to what extent these moisture-related properties are translated into comfort characteristics of fabrics. However, everyone should be aware that increasing the polyester content reduces moisture-related properties, and that the reduction becomes significant with very high levels of polyester in the fabric.

Wool is a hygroscopic fabric. As the humidity of the sur-

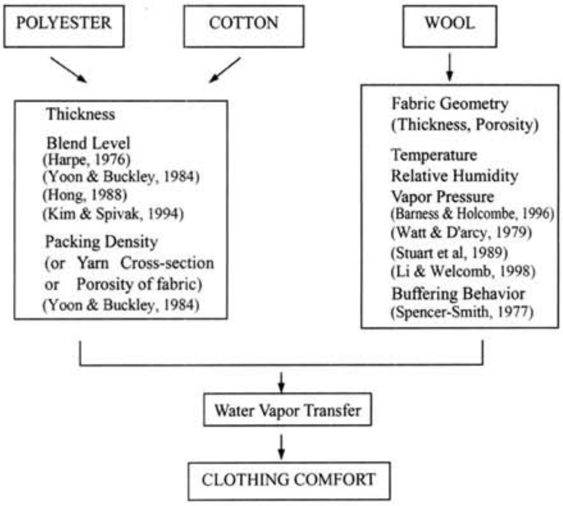

Fig. 3. Various factors influencing WVTR between polyester/cotton blend fabrics and wool fabrics.

rounding air rises and falls, the fiber absorbs and desorbs water vapor. Relative humidity and temperature could influence the water content of wool. Hygroscopic fabrics absorb water vapor when surrounded by humid air and release it in dry air. The relative humidity is higher near the water, consequently a hygroscopic fabric close to water should absorb water vapor and then desorbs the water vapor when it moves away. Hydrophilic fabrics can take up liquid from the skin, allowing it to evaporate away from the body, while hygroscopic fabrics can move moisture without the build-up of sweat on the skin, provided this effect is of sufficient magnitude (Barness & Holcombe, 1996). Figure 3 shows various factors influencing water vapor transfer rate between polyester/cotton blend fabrics and wool fabrics.

4. Conclusions

The purpose of this work was to examine the behavior of the water vapor transfer rate through a layered system and to find a more comfortable combination of layered systems for outdoor activities. The water vapor permeability of a layered system has been tested using the evaporation dish method, BS7209 under isothermal conditions.

The water vapor transfer rates through the layered system are ordered into groups determined by the shell layer and follow the exact trend as the shell layer, which is an all vapor permeable water repellent fabrics as a single layer. From this study, it is clear that the rate of water vapor transfer through a layered system is mainly related to the type of vapor permeable water repellent fabrics used for the shell layer. The shell layer is the main influence on the water vapor permeability of the layered system. It can be said that the optimal combination of a layered system is incorporating either a microfiber shell layer or a PTFE-laminated shell layer with middle layer and base layer made of wool, rather than incorporating a PU-coated shell layer with middle layer and base layer made of P/C blend fabric.

The findings from this study could provide useful information for choosing more comfortable combinations of layered systems for outdoor activities.

References

Keighley, J. H. (1985). Breathable fabrics and comfort in clothing, *J. coated Fabrics*, *15*, 89-104

Horrocks, A. R. and S. C. Anand. (1996). Handbook of Technical Textiles. New York : Marcel Decker.

Lomax, G. R. (1990). Hydrophilic polyurethane coating, *J. coated Fabrics*, *20*, 88-107.

Roye, M. V. (1991) Water-resistant breathable fabrics, *J. coated Fabrics*, *21*, 20-31.

British Standards Institution, BS7209(1990); Water Vapour Permeable Apparel Fabrics, BSI, London.

Ruckman, J. E. (1997). Water vapour transfer in vapor permeable water repellent fabrics; Part 1., *International Journal of Clothing Science and Technology*, *9*, 10-22.

Barness J. C. and Holcombe B. V. (1996)., Moisture sorption and transport in clothing during wear, *Textile Research Journal*, *66*, 777-786.

Harpe, R. J. et al, (1976). Moisture-related properties of cotton-polyester blend fabrics, *Textile Research Journal*, *46*, 82-89.

Yoon, H. N., and A. Buckley. (1984). Improved comfort polyester; Part 1., *Textile Research Journal*, *54*, 289-298.

Hong, K et al. (1988). Dynamics moisture vapor transfer through textiles; Part 1., *Textile Research Journal*, *58*, 697-706.

Kim, J. O., and Spivak, S. M. (1994). Dynamic moisture vapour transfer through textiles, *Textile Research Journal*, *64*, 112-121.

Watt, I. C. and D'Arcy (1979). Water vapour adsorption isotherms of wool, *Journal of Textile Institute*, *70*, 298-307.

Stuart, I. M. et al , Perception of heat of sorption of wool, *Textile Research Journal*, *59*, 324-329, (1989).

Li,Y., and Holcombe, B. V.. (1998). Mathematical simulation of heat and moisture transfer in a human-clothing-environment system., *Textile Research Journal*, *68*, 389-397.

Spencer-Smith, J. L. (1977). The physical basis of clothing comfort; Part 3., *Clothing Research Journal*, *5*, 82-100.

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