THE ANALYSIS OF COMFORT PORPERTIES OF PTFE-LAMINATED AND HYDROPHILIC PU-LAMINATED CLOTHING

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INTRODUCTION

A considerable amount of work has been done on thermal and moisture transfer through multilayer clothing combination using a temperature and water-vapor gradient, and the effect of condensation has also been analysed in different studies. These studies claimed that water vapor transmission is assisted by temperature due to the interaction occurring between heat and water vapor transport through clothing systems. Moreover, the assessment of water vapor transport through hydrophilic polymers is highly influenced by the test conditions [1] .It was found that, in non-isothermal test, the clothing systems incorporating hydrophilic polymers, especially those being determined as low transmission rates in the isothermal tests, are improved to greater amounts than those incorporating micro porous polymers [2] . Some experimental results further point out that the water vapor transfer rate of porous polyurethane laminated fabric was greater under isothermal conditions whilst the water vapor transfer rate of hydrophilic laminated fabrics was greater under non-isothermal conditions, especially when a fabric contains more condensation [3]. However, with the use of hot plate and sweating arm system, an EMPA study showed the hydrophilicity and condensation have little effect on effective water vapor resistance of multilayer textile combination in 20℃ but become larger with decreasing outside temperature [4].

To investigate if the difference between the microstructure of PTFE and the hydrophilicity of PU affects the comfort properties of leisure wearing especially in mild and cool temperature, a series of tests to analyse the parameters of comfort properties were conducted.

METHODS

In this study, water vapor resistance testing (R_{et}), EMPA sweating torso wearing trial simulation, and subjective wearing trials were carried out. Ret test based on ISO 11092 [5] was measured by hotplate system P156SGHP8-2 manufactured by MTNW Inc.. Normally, the R_{et} of breathable waterproof fabric is determined by the layer itself without including other layers. In wear trial, breathable waterproof outwear will be evaluated together with underwears for thermal comfort reason. Table 1 lists the summary specification of clothing material for the study.

Table 1. Clothing materials.

Code	Sample description
A	100% 75D Polyester interlock wicking enhanced underwear
B	100% 75D/144F*75D/36F Polyester wicking enhanced and one side brush fleece thermal wear
C	3-layered breathable waterproof outwear with PTFE membrane

D	3-layered breathable waterproof outwear with hydrophilic PU membrane

During EMPA Sweating Torso simulation, 2 pieces and 3 pieces garments were selected for the experiments under the climate condition of 25℃/ 80% R.H. and 10℃/ 50% R.H. respectively. They are described in Table 2. The difference between the two clothing systems is that there was a fleece thermal wear added in the middle of the clothing system at the temperature of 10℃.

Table 2. Clothing systems at the temperature of 25°C and 10℃.

No.	25°C condition	10°C condition
1	A+C	A+B+C
2	A+D	A+B+D

In Sweating Torso wearing test, temperature variation of the Torso surface and weight variation of fabric which was put on the Torso surface can be determined through three phases of protocols. Phase one is the acclimation phase which proceeded at a constant surface temperature of 35°C without sweating for 60 minutes to facilitate Torso to an equilibrium state. Phase two is activity phase simulating a human in metabolism 500W and sweat rate 400 ml/hr. Phase three is regarded as the recovering phase simulating a human in metabolism of 100W without sweating. The temperature variation in the sweating phase was used to demonstrate the efficiency of the heat loss caused by water vapor penetrating clothing system. The fabric weight course in this phase also illustrate the residual sweat water in the sample combination which could not evaporate. In general, the amount of residual moisture in the sample should be as low as possible, in order to avoid after-cooling effect in recovery phase.

For the purpose of confirming the experiment of Torso laboratory test, a subjective wearing trial at 10°C condition also was conducted. Six healthy male volunteers wore the same clothing system as that put on Torso at 10°C condition, and participated in the experiment. Each volunteer in either PTFE outwear with thermal fleece middle layer and polyester underwear, expressed as (A+B+C), or hydrophilic PU outwear with same middle and under wears, expressed as (A+B+D) clothing system, performed the same test protocol where there were involved in 15 minutes of acclimation (phase one), 60 minutes of 5 km/h walking (phase two) and 20 minutes return to original state (phase three). Volunteers dressed in the same shoes and trousers for both tests. Skin temperatures on 7 body parts and micro climate between underwear and thermal liner on 3 locations were continuously recorded by MSR 145 data logger (www.msr.ch) during the test protocol. The weights of clothing at the beginning and in the end of the protocol were also scaled to analyse condensation. The test subjects were also inquired at every 10 minutes during the protocol to rate the subjective wearing comfort.

RESULTS

Table 3. The result of R_{et} and Torso wear trial.

Samples	R_{et}(m^2Pa/W)	ISO 11092 R_{et} test (35°C, 40%)			
C	5.4				
D	9.5				
Samples	T10(°C)	T60(°C)	Residual Wt. (g)	Drying time (min.)	25°C, 80% Torso test
A+C	-0.31	-0.58	17.4	14	

A+D	-0.20	-0.76	14.3	13	
A+B+C	-0.83	-2.58	29.6	32	10°C, 50% Torso test
A+B+D	-0.82	-3.10	27.7	32	

Note1: T10, T60: the Torso surface temperature drop at the 10th and 60th minute respectively during the activity phase (Phase two)

Note2: Residual weight: the weight increase of clothing layers on the Torso at the end of activity phase (Phase two) .

Note3: Drying time in recovery phase (Phase three): the time when the total weight of Torso and clothing put on, returns to the value of the acclimation phase.

Table 3 displays the test result of R_{et} and Torso wear trial in which the R_{et} value of the PTFE-laminated fabric (C) is lower than that of the hydrophilic PU-laminated fabric (D). The result shows the PTFE-laminated fabric seems to have better water vapor permeability than the hydrophilic PU-laminated fabric.

With regard to the Torso experiment, the temperature decreased about 0.31℃ for (A+C) clothing system, which is higher than that of (A+D) clothing system at the 10th minute in the activity phase, but at the end of the experiment, (A+C) combination dropped to 0.58℃, which is slightly lower than 0.76℃ of (A+D) clothing combination. Moreover, (A+D) clothing system evaporated about 85% of the released sweat water amount, which is somewhat similar to that of (A+C) clothing system (83%). In the recovery phase, the drying time of (A+C) clothing system was 14 minutes, which makes no much difference to (A+D) clothing system (13 minutes). In terms of the result at the climate of 10°C /50%R.H., it seems to have the same tendency as that of 25°C/80%R.H., the temperature drop of (A+B+C) clothing system was 2.58℃ , which is lower than 3.10℃ of (A+B+D) combination at the end of the activity phase. The weight of (A+B+C) clothing system increased by 29.6 g, which is more than that of (A+B+D) clothing system (27.7g). However, both (A+B+C) and (A+B+D) clothing systems had the same drying time (32 minutes). Therefore, the finding suggests that the outer wear D, which is hydrophilic-laminated fabric, appeared to have a more efficient evaporative cooling and lower residual water content at the end of the activity phase. It is thought that the better water vapor transport mechanism occurred under non-isothermal condition for hydrophilic laminated fabrics [2].

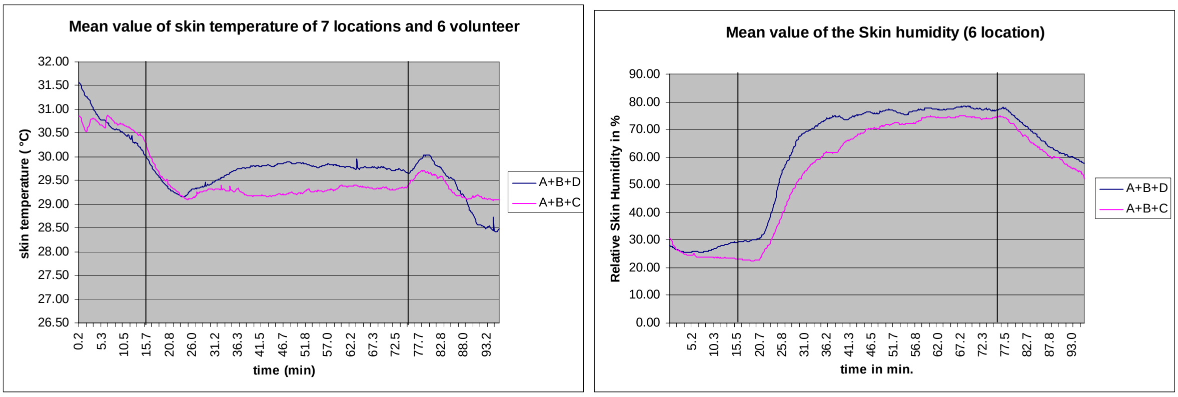

Figure 1. The mean value of skin temperature and humidity.

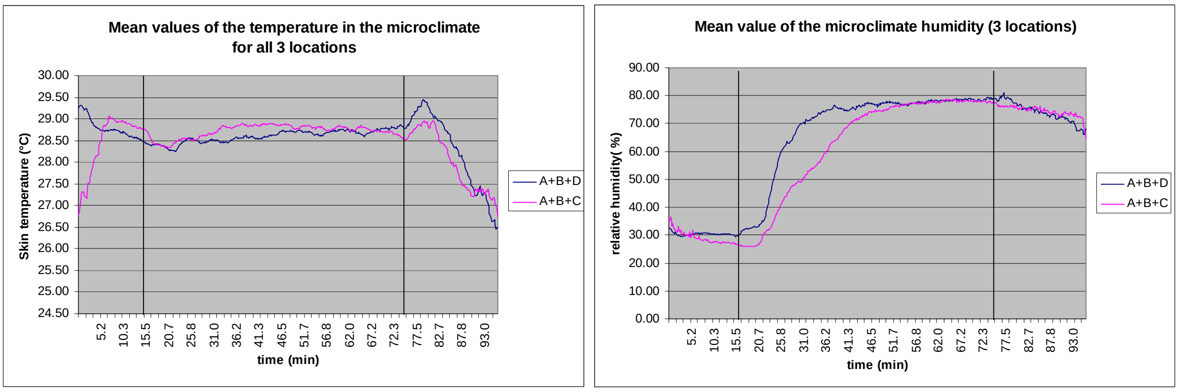

Figure 2. The mean value of microclimate temperature and humidity.

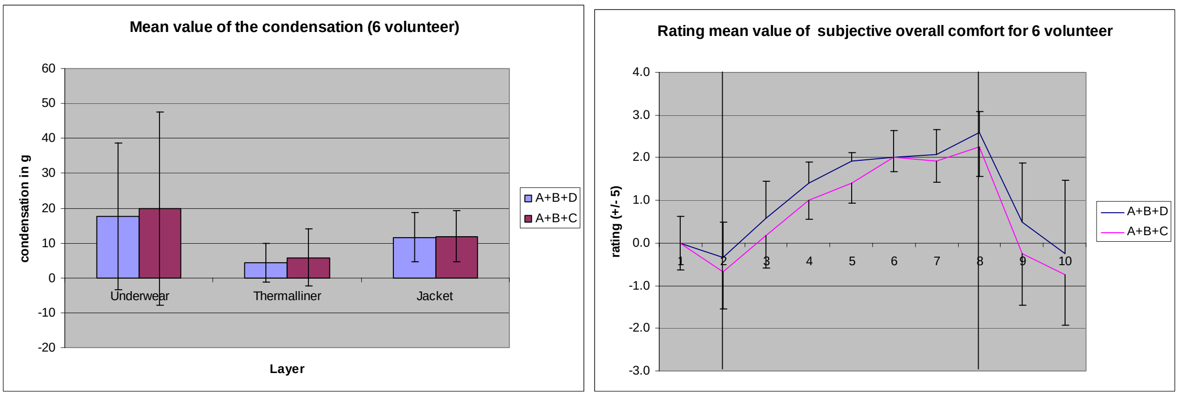

Figure 3. The result of clothing condensation and subjective comfort feeling.

Figures 1, 2, and 3 display the results of subjective wearing trail respectively. Figure 1 and Figure 2 show that (A+B+C) clothing system had a slightly lower relative humidity on the skin and in the micro climate. In terms of skin temperature, (A+B+C) clothing system in walking phase also was a bit lower than (A+B+D) one. However, there is only a marginal difference on 4 locations (shoulder humidity, lower arm humidity, clavicle microclimate temperature and spine microclimate humidity) for (A+B+C) clothing system. Figure 3 shows the condensation weights of different layers at the end of the scenario and subjective comfort feeling during the scenario. The (A+B+C) system seemed to bring slightly more condensation effect and a little bit better comfort feeling than the (A+B+D) clothing system. Nevertheless, the difference of the both observations was not very significant due to the enormous variations of the sweating rate among test subjects. This might suggest that the wear comfort with PTFE outwear made no much difference from that with hydrophilic PU outwear when they had the same middle and under wears. In terms of the subjective comfort feeling test, the thermal perception seems to be a dominant factor. The (A+B+D) clothing system had a better comfort feeling while the ensemble garments showed a higher skin temperature. Sample (A+B+C) has a better water vapour permeation and the evaporation cooling is stronger in phase 3. As more residual water is evaporating in the rest phase as colder is the temperature perception. Sample (A+B+D) has lower water vapour permeation will cool not so strong and the volunteers feels slightly warmer. Therefore, even though hydrophilic PU outwear (D) had a poorer breathable property, it demonstrated a better comfort feeling.

CONCLUSIONS

In this study, three kinds of experiments, R_{et}, EMPA Sweating Torso, and subjective wear trials, were conducted to characterize the comfort properties of PTFE laminated and hydrophilic PU laminated fabrics and garments. The results of water vapor resistance, so called R_{et}, revealed that the PTFE laminated outwear had better water vapor permeability than that of hydrophilic PU laminated outwear. In the non-isothermal state, the hydrophilic PU laminated outwear was found to have a slightly better sweat management than that of PTFE laminated outwear. The phenomenon could be attributed to the fact that the hydrophilic PU membrane tended to have a better liquid water transport to outwear from the underwear than the PTFE membrane. However, in subjective wear trial, both PTFE and Hydrophilic PU samples exhibited similar thermal comfort and no significant difference was observed. The PTFE laminated outwear seemed to have a better water vapor permeability, leading to a lower skin temperature and relative humidity in the microclimate. This might be due to the fact that some air trapped in the wearing condition which hindered the water to move and spread among the layers of the garments except the shoulder. As the temperature perception tended to dominate the subjective comfort feeling in the test, the test subjects in the hydrophilic PU laminated outwear felt more comfortable due to a higher skin temperature.

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REFERENCES

[1]. A. Mukhopadhyay, V.K. Midha, A Review on Designing the Waterproof Breathable fabrics Part I: Fundamental Principles and Designing Aspects of Breathable, J. of Industrial Textile 37(3)225-262(2008)

[2]. J.C. Gretton, D.B. Brook, H.M. Dyson, S.C. Harlock, Moisture Vapor Transport Through Water proof Breathable Fabrics and Clothing Systems Under a Temperature Gradient, Textile Res. J. 68(12), 936-941(1998)

[3]. Y.J. Ren, J.E. Ruckman Water Vapor Transfer in Wet Waterproof Breathable Fabrics, Journal of Industrial Textile 32(3), 165-175(2004)

[4]. R.M. Rossi, R. Gross, H. May, Water Vapor Transfer and Condensation Effects in Multilayer Textile Combinations, Textile Res. J. 74(1), 1-6(2004)

[5]. ISO 11092, Textiles-Physiological Effects-Measurement of Thermal and Water-Vapour Resistance under Steady-State Conditions (Sweating Guarded-Hotplate Test), International Organization for Standardization (1993).