Effect of material property and design of outdoor parker on its heat transfer and ventilation rate

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Abstract: This study aims to clarify the effect of material property and the design of clothing on its heat transfer coefficient and ventilation rate by using the walking manikin and the tracer gas method. It also aims to verify the validity of the indirect method to measure heat transfer coefficient from the ventilation rate. Under the wind condition, there were little effect of ventilating opening on heat transfer in both rest conditions and the walking conditions. When walking the ventilating opening was effective for the improvement of heat transfer, but it was not effective at the rest under the calm environment. As for local heat transfer, ventilating effect was significantly seen at the abdomen and the back. It was clarified that the ventilation rate and the heat transfer coefficient had the correlation (r=0.54).

Introduction

Thermal comfort of clothing is influenced by heat and water vapor transfer through clothing. For outdoor parker, it is necessary the heat and water vapor transfer through clothing with preventing rain from penetrating at the same time in preparation for rain. As a breathable microporous film has been introduced to improve the thermal comfort of the microclimate of the outdoor parker while keeping it waterproof. By using microporous film as outer material, the heat and moisture transfer through the outdoor parker was improved. But it was not enough to provide comfort in a long term exercise with water vapor permeable parker without any openings becase the vapor permeable material can not transfer the sufficient water vapor that the subject perspirates only by moisture diffusion throuth material in such a situation.

The heat and water vapor transfer in the parker would be affected by material physical properties such as thickness , thermal conductivity and air permeability of material. Construction factor such as air space, opening condition of clothing has also some effects. In such a case above, air exchange through vent openings during walking (bellows action) can reduce humidity and hydration in the parker, air exchange by this bellows effect is important for the heat and mass transfer from the human body when the wearer feels humid in a hot environment or during exercise. However it is yet unclear how much ventilation actually occurs and how it can reduce the humidity in a parker.

Crockford et al. (1972) have developed a way to measure the air exchange in protective clothing directly using a tracer gas method. Satsumoto et al. (2010) developed a device to evaluate the ventilation of diapers by using a tracer gas method. By the results of using the tracer gas method by the subjective experiments (Satsumoto et al, 2012), it was found that there were many individual variations and the time fluctuation because of the irregular movement of the human body. Therefore it is better to use the simulating device such as walking thermal manikin that simulates periodic movement of body in walking and the skin temperature distribution of human body.

In the present study, to clarify the effect of material property and the design of the outdoor parker on its heat transfer and ventilation by using the walking thermal manikin and the steady state tracer gas method. It also aims to verify the validity of the indirect method to measure heat transfer coefficient from the ventilation rate. The effect of the design- and material-factors of parkers on microclimate air exchange due to ventilation between the interior of the parker and the ambient atmosphere was studied quantitatively during rest or walking.

Experimental

Material and constructive condition of parker

Three parkers, whose vapor permeablity was impermeable (IM), middle permeable (MP) and high permeable (HP), was chosen for experimehts. The characteristics of parker materials are shown in Table 1. When the vent opening was closed, sealed with tapes as shown in Fig.1.

Table 1 Characteristics of parker material

Material	Thickness (mm)	Thermal conductivity (W/m/K)	Thermal resistance (K・mm²/W)	Vapor resistance (s/m)
HP	0.170	0.205	3.14	85.72
MP	0.270	0.175	5.02	113.7
IM	0.164	0.349	2.37	∞

Fig.1 Variation of outdoor parker when vent is closed

Walking thermal manikin

To estimate the effect of walking on the ventilation of the parker, a walking thermal manikin Newton (Measurement Technology Northwest CO., LTD) was used. The manikin's skin area is 1.8m² and devided 26 sections. In this study the walking speed was 1m/s (4km/hr).

Steady state tracer gas system

Figure 2 shows the schematic diagram of the ventilation system.

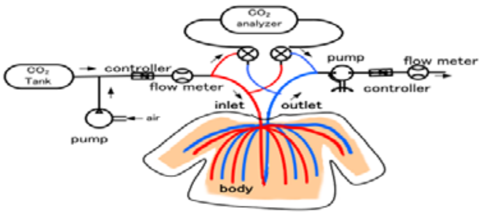

Fig.2 Schematic diagram of tracer gas system.

The tracer gas (100% CO_2) circulation pumps were switched on, the inlet CO_2 concentration was adjusted to about 5000ppm. Then the flow rate of inlet and outlet were equalized and monitored. Then by switching 3 way valves, the CO_2 concentration of inlet and outlet were monitored and recorded until all concentrations reached a steady state.

The inlet flow rate (V_{in}) and outlet flow rate (V_{out}) must be controlled to precisely the same value (0.5 l/min) in case of the steady state tracer gas method to avoid introducing forced ventilation. The pump and the flow controller were used to manage the steady state flow.

$$VENT = V\frac{CO_{2in}-CO_{2out}}{CO_{2out}-CO_{2e}} \quad (1)$$

Measurement procedure

To compare the vapor permeability of 3 materials, vent opening condition (open/closed), walking speed (walking 1m/s/ rest), environmental wind speed (still (0m/s)/wind 1m/s), there were 24 conditions. For each condition, experiments were repeated three times for evaluation. We have done 72 experiments. The experiment was carried out in an air conditioned chamber at 26±2.0 ℃, 65±10% relative humidity. The skin temperature and heat flux of mankin's each sections were also monitored and recorded every minute with ventilation evaluation until skin temperature reached steady state. Heat transfer coefficient h_t was calculated by using average data of last 10 minutes after the steady state.

$$h_t = \frac{q}{T_s - T_e} \quad (2)$$

Results and Discussion

Effect of vent opening on ventilation rate

In case of in rest at 1m/s wind environment, effect of vent opening on ventilation rate was only seen for MP significantly as shown in Fig.3.

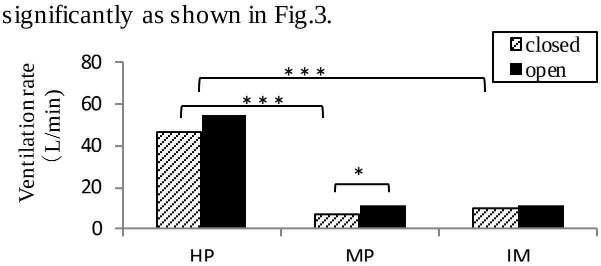

Fig.3 Effect of vent opening on ventilation rate in rest at 1m/s wind environment (* : p<0.05、***:p<0.001)

Effect of walking on ventilation rate

In case of the vent opening was closed in calm environment, effect of walking on ventilation rate was seen for IM significantly as shown in Fig.4.

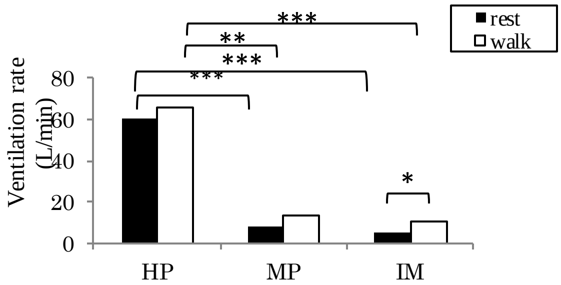

Fig.4 Effect of walking on ventilation rate at calm environment when the vent opening was closed (* : p<0.05,**:p<0.01,***:p<0.001)

Relation between heat transfer and ventilation rate

The correlation between heat transfer and ventilation was seen(r=0.54). So there is a possibility that we can estimate the heat transfer coefficient by ventilation rate.

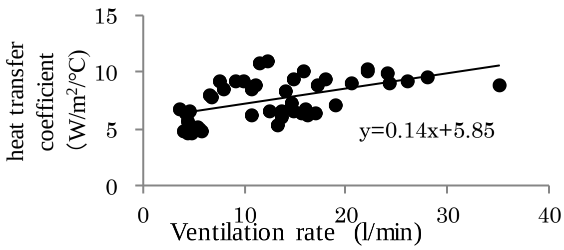

Fig.5 Relation between ventilation rate and heat transfer coefficient

Conclusions

The effect of permeability of material and the vent opening of the parker on its heat transfer and ventilation was evaluated by using the walking thermal manikin and the steady state tracer gas method. It was found that the ventilation was affected by not only by the material permeability but also by the vent openings, walking and environmental wind. It also aims to verify the validity of the indirect method to measure heat transfer coefficient from the ventilation rate. Because the correlation between ventilation and heat transfer were seen, there seems the indirect measurement can be done.

Acknowledgements

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