Thermal protective performance of membrane material used in protective clothing against hot water and steam

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1. Introduction

The waterproof and breathable fabric, composed by a membrane layer and a textile substrate, has been widely used for sportswear and protective clothing [1-3]. The previous studies reported that membrane material posed an important effect on human comfort. However, there exists few studies in understanding the effect of membrane material on thermal protective performance of clothing, especially against hot liquid and steam. Therefore, the aim of the research was to examine the effect of configuration and basic properties of membrane material on thermal protective performance against hot liquid and steam. The findings in this study would be useful in developing membrane material used for protection of hot liquid and steam.

2. Materials and methods

Four types of fabrics currently used in thermal protective clothing were selected as samples. Two kinds of composite fabrics with different air permeability were used for outer shell (B1 and B2). Two kinds of membrane materials were selected as moisture barrier in this study (A1 and A2). To evaluate the thermal protective performance of the protective fabric system under hot liquid and steam, two bench-scale test apparatus were developed by the Laboratories for Functional Textiles and Protective Clothing (Iowa state university, USA), as shown in Figure 1. In this study, the test fabrics were exposed to hot liquid and steam for 20 s, respectively. After the exposure, the skin-simulant sensor continued to record the skin temperature for another 40 s, as a cooling phase. Based on Duhamel's theorem [4], the thermal energy absorbed by skin was calculated to determine the performance of test fabric. To evaluate the effect of configuration of breathable fabric on thermal protection, both sides of moisture barrier, as well as assembled with outer shell as double layer fabric system, were exposed to hot liquid and steam.

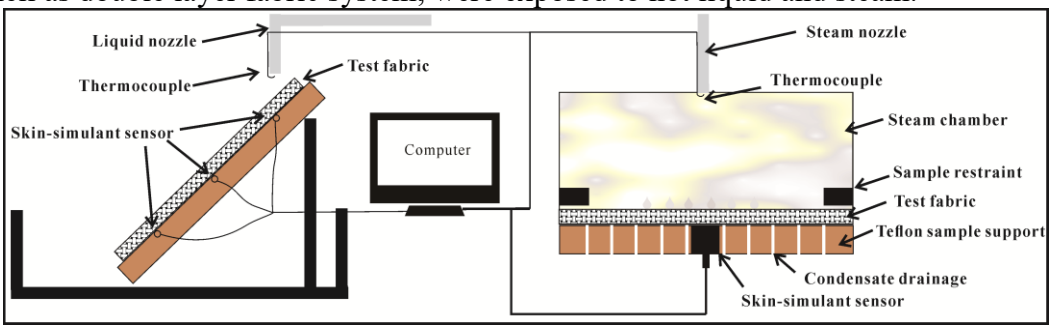
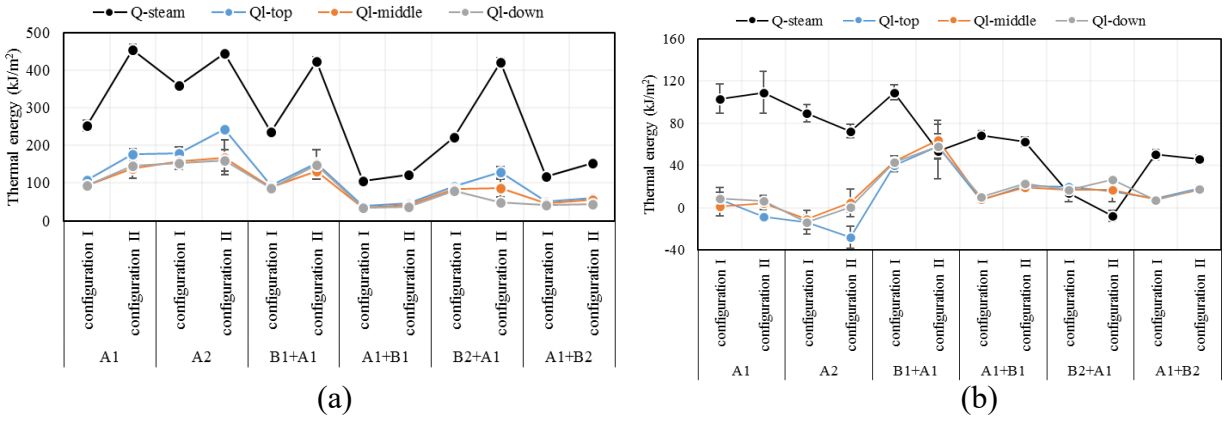


Figure 1. Schematic diagram of hot liquid (left) and hot steam (right) testers

3. Results and discussion

Figure 2(a) presents thermal energy absorbed by skin for different fabric systems during hot water and steam exposures. A significant difference between hot water and steam exposures was observed ($P<0.05$). The minimum and maximum differences between two heat exposures are 1.82 times and 8.67 times, respectively. Thus, the membrane material provides better thermal protection against hot water exposure. When membrane material was placed in different configurations and exposed to hot water and steam, the thermal energy absorbed for configuration I (membrane face up) is significantly less than that for configuration II (membrane face down) ($P<0.05$). Additionally, thermal protection against hot water and steam is influenced by the properties and position of fabric system. Figure 2(b) shows the change of thermal energy for different fabric systems during the cooling phase. Single-layer fabric discharges more thermal energy to skin surface for steam hazard while more thermal energy within double-layer fabric is absorbed by skin for hot water hazard.



(a) (b)

Figure 2. Thermal energy absorbed by skin during heat exposure (a) and cooling phase (b)

4. Conclusion

The configuration and position of membrane material presented a significant effect on protective performance of fabric systems exposed to hot water and steam. Membrane material should be treated as outer layer to resist the penetration of hot water and steam into fabric system. Secondly, a small amount of penetrating water and steam should be absorbed by the inner-layer fabric with the thicker and larger moisture regain to enhance the protective performance.

References

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