IOP Conf. Series: Materials Science and Engineering **254** (2017) 182012 doi:10.1088/1757-899X/254/18/182012

Effect of air gap on apparent temperature of body wearing various sizes of T-shirt

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Abstract. We investigated the effect of air gap on the apparent temperature. Using the developed thermocouple fabric and a thermal manikin, we measured temperature distribution of the measuring garments due to the change of T-shirt sizes. We were able to measure the apparent temperature distribution at points near a body while wearing different sizes of T-shirts. It was observed that the temperature distribution depending on different air gap between clothing and body. The apparent temperature depends on garment size and place. The effect of air gap on apparent temperature of body was experimentally confirmed.

1. Introduction

From the body surface to environment, heat transfer is mainly caused by conduction, convection, emission, and evaporation. Using a thermography, those influences on clothing are indirectly measured with the surface temperature of garment worn on a human [1]. There are also airgaps between garment and human body because of ease allowance. Li et al. [3] investigated the relationship between air gap sizes and clothing heat transfer performance by measuring 35 shirts. They showed that the thermal insulation of experimental shirts increased with air gap sizes. Zhang et al. [4] investigated the combined effects of the properties of clothing materials and wind on the physiological parameters of human wearers. Nielsen et al. [5] measured mean skin temperature of clothed persons in cool environments using thermal manikin. However, it is difficult to measure the temperature of body surface in wearing state of clothes due to the large influence of the insertion of sensors and cables [2].

The thermal insulation of clothing is affected by the air gap between skin and material and the air gap differs depending on places especially in wearing state of clothes. To measure the temperature distribution of body surface in wearing state of clothes, we used a smart textile which incorporated thermocouple temperature sensors [6], and then made a measuring garment with the textile. In this study, we investigated the effect of air gap on the apparent temperature. To change air gap, we used different sizes of T-shirts.

2. Experimental

A polyester double weave fabric was made by interweaving copper and constantan wires of 0.1mm in diameters constituting thermocouple temperature sensors. We made a measuring garment using the fabric with 12 measuring points for the back body to measure temperature distribution as shown in Figure 1. We put the measuring garment on a thermal manikin (THM, Kyoto Electronics Manufacturing Co., Ltd. Japan) and measured temperature distribution of the measuring garments due to the change of T-shirt sizes. We put four sizes of T-shirt (cotton 100%, S, M, L, LL sizes) over the measuring garment and measured the temperatures as shown in Figure 2. We recorded the temperatures every 20 seconds and measured for 20 minutes. Three-dimensional shape of a body (Nanasai Co. Ltd., MD-20A), which is similar size of the thermal manikin, and one of wearing a t-shirt were scanned. Air gap of each cross section was calculated. The environmental temperature was 10°C and the relative humidity was 65%. The electric power of the thermal mannequin was set to 58 W/m^2.

Figure 1. Measuring garment and measurement points

Figure 2. T-shirt on the measuring garment

3. Results and discussion

The measured temperatures distribution in wearing state of different sizes of T-shirt are shown in **Figure 3**. The increased temperatures by wearing T-shirt were calculated by subtracting the temperatures of wearing the measuring garment from the temperatures of wearing T-shirt on measuring garment. The increased temperatures are shown in Figure 4. As the sizes of the T-shirt

increases, the temperatures also increases. This is due to the heat retention effect which was enhanced by increasing the air gap between the T-shirt and the manikin. The measured temperatures of M and L sizes were similar. This is due to the small dimensional difference between the two T-shirts. The air gap on the back side was different depending on places. The temperature increases of measurement points from 5 to 12, where the air gap were larger, were higher than ones of measurement points from 1 to 4, where there are almost no air gap. However, the temperature increases of measurement points 7 and 8 were larger than ones of measurement points 11 and 12, where the air gap are the largest. This is due to the decreases of heat retention efficiency when the air gap exceeds a certain size [7].

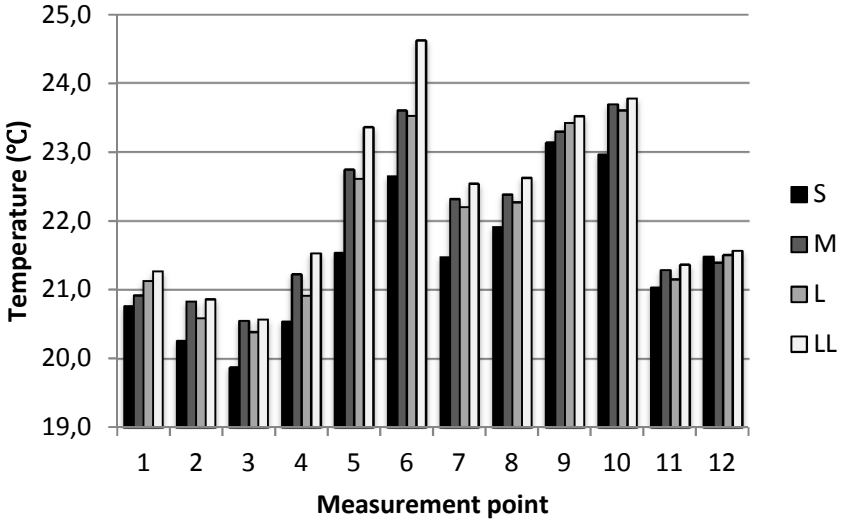

Figure 3. Measured temperatures distribution in wearing state of different sizes of T-shirt.

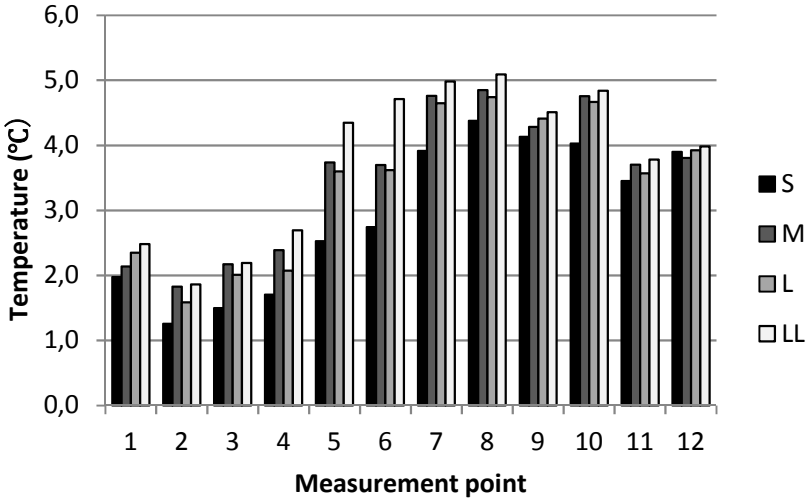

Figure 4. Increased temperatures distribution in wearing state of different sizes of T-shirt.

4. Conclusion

Using the developed thermocouple fabric, we were able to measure the apparent temperature distribution at points near a body while wearing different sizes of T-shirts. It was observed that the temperature distribution depending on different air gap between clothing and body. The apparent temperature depends on garment size and place. Therefore, the effect of air gap on apparent temperature of body [7] was experimentally confirmed.

Acknowledgments

This work was supported by the Japan Society for the Promotion of Science (JSPS) KAKENHI Grant number JP24220012 and JP16H01805.

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