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Volume of Air Gaps under Clothing and Its Related Thermal Effects

Zhaohua Zhang [a,b], Jun Li [a,c,*]

[a] *Protective clothing research center, Fashion Institute of Donghua University, Shanghai 200051, China*
[b] *Changzhou Textile & Garment Institute, Changzhou 213164, China*
[c] *Key Laboratory of Clothing Design & Technology, Donghua University, Ministry of Education, China*

Abstract

Influenced by clothing style and fit, as well as human body contour, the distribution of air gaps entrapped between human body skin and inner surface of clothing is complex and difficult to measure. The three-dimensional body scanning technology provides a realistic method to quantify the air gap volume by scanning the surface image of human body and clothing. This research measures the air gap volume of thirty experimental clothing using a 3D body scanner and analyzes the effect of clothing size and mechanical property of fabric on air gap volume under clothing. The experimental clothing is made of different fabrics with increasing chest circumference from 92 cm to 108 cm. To investigate the relationship between air gap volume and thermal property of clothing, a thermal manikin is used to measure the thermal insulations of experimental clothing. As the air gap volume increases with the garment size, the thermal insulations of clothing do not linearly increase. The thermal insulation begins to decrease when the chest circumference of experimental garments becomes more than 100 cm due to the onset of natural convection. This research is helpful to study the affecting factors of air gap volume under clothing and estimate the effect of air gap volume on the thermal property of clothing.

Keywords: Air Gap; Clothing; Thermal Insulation; KES; 3D Scanning

1 Introduction

The air gap under clothing is a critical factor to the thermal property of clothing due to the good thermal resistance ability of static air. Influenced by body contour, fabric physical property, clothing style and size, the volume of air gap is varying and difficult to measure. Hein Daanen et al. [1] summarized three common methods to quantify the volume of air layer under clothing, that is, vacuum suit method, cylinder model and 3D scanning method. He concluded that the vacuum suit method [2] is accurate but time consuming and complex, the cylinder model [3] is easy to operate but rough in results, and the 3D scanning is the most accurate and reproducible method. In recent years, 3D scanning technique has been widely used in apparel design

*Corresponding author.
Email address: lijun@dhu.edu.cn (Jun Li).

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and human engineering research [4], especially in heat transfer analysis of clothed human body. Some researchers investigated the relationship between air gap distribution and fire protective performance of clothing. Using a 3D body scanner and flash fire manikin, Song [5] analyzed the influence of fabric material and garment size on air gap layers under single layer thermally protective coveralls, the relationship between the burn patterns and air gap layers was also examined. Lee and Hong [6] measured the air volume by using 3D phase-shifting moiré topography and investigated the relationship between the air volume and clothing insulation value, but the effect of fabric mechanical property on air gap volume was not discussed. In this article, the influence of fabric mechanical property (KES) and garment size on air gap volume is analyzed. The regression model between air gap volume and thermal insulation of clothing is also established.

2 Problem Formulation

2.1 Experimental Materials

To investigate the effect of fabric property and garment size on the volume of air gap under clothing, six kinds of fabrics are selected to make thirty clothing with five sizes from tight to loose. The specifications of six fabrics are shown in Table 1. Every kind of fabric is made into five different sized clothing as shown in Table 2, thus in total thirty garments are prepared for experimental investigation. For example, W-B96 means the garment is made of wool and its breast girth is 96 cm.

Table 1: Fabric specification

Fabric code	Type	Weight (g/m^2)	Thickness (mm)	Density(/2.54 cm)	Moisture regain(%)
C	Cotton 100%	282.62	0.83	130×46	65.23
D	Cotton 100%	142.66	0.59	148×94	67.84
W	Wool 100%	182.88	0.66	133×72	12.35
F	Flax 100%	188.42	0.73	121×60	70.03
T	Polyester 100%	207.25	0.43	190×62	0.45
P	Polyester 100%	85.04	0.21	160×80	0.43

Table 2: The size of experimental garments

Garment code	Breast girth (cm)	Waist girth (cm)	Hip girth (cm)	Shoulder(cm)	Neck (cm)
B92	92	86	94	41	40
B96	96	90	98	41.6	40.5
B100	100	94	102	42.2	41
B104	104	98	106	42.8	41.5
B108	108	102	110	43.4	42