Progress in Engineering Application and Technology Vol. 2 No. 2 (2021) 887-892
© Universiti Tun Hussein Onn Malaysia Publisher's Office

PEAT

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/peat
e-ISSN : 2773-5303

Thermal Comfort Properties on Army Uniform with Objective and Subjective Evaluation

Ilya Fildzah Zamelia Jamil[1], Bachik Abu Bakar[1]*

[1]Department of Mechanical Engineering Technology, Faculty of Engineering Technology,
Universiti Tun Hussein Onn Malaysia, Pagoh, 84600, MALAYSIA

*Corresponding Author Designation

DOI: https://doi.org/10.30880/peat.2021.02.02.080
Received 13 January 2021; Accepted 01 March 2021; Available online 01 December 2021

Abstract: The function of clothing includes many aspects such as protection, adornment, status and modesty. Despite all the functions listed, clothing could also give the feeling of discomfort to the wearer. Therefore, there is a need to study the comfort properties of a clothing. This research will analyze the thermal comfort properties of army uniform in context of clothing. The sample used in this research is a standard army uniform from poly cotton fiber. All the experiments conducted in this research are in compliance with American Society for Testing and Materials (ASTM) standards. In the end, objective evaluations did not have the same results as subjective evaluation as human bodies work differently each person. As a possible suggestion, the use of new material to manufacture the army uniform shall be considered.

Keywords: Thermal Comfort, Objective Evaluation, Subjective Evaluation

1. Introduction

Clothing was a textile material that made up from any type of fiber that had been through different type of process making. Clothing was meant to protect the human body from any kind of danger. It has been worn long ago as human characteristics. Later, it was found that textiles and clothing can also be used for technical purpose in order to improve the quality of lives. The function of clothing includes many aspects such as protection, adornment, status and modesty [1]. Despite all the functions listed, clothing could also give the feeling of discomfort to the wearer. The environmental factors such as humidity and the heat will effect on wearer's thermal comfort. Comfort is a pleasant state of physiological, psychological and physical harmony between a human being and the environment [2].

Comfort is an experience that is caused by integration of impulses in the brain. It is a qualitative term and one of the most important aspects of clothing. Thermal comfort is related to the ability of fabric to maintain the temperature of skin through the transfer of heat and perspiration generated within human body. Comfort, as felt by the user, is a complex factor to be studied. Subsequently, there is no study conducted to give concrete evidence proving the army uniform is comfortable to be wear.

*Corresponding author: bachik@uthm.edu.my

Hence, this research was aimed to analyze the thermal comfort properties of army uniform. Besides, it was also to identify the relationship between the objective and subjective evaluation of the army uniform. It is hope that this study would give a better exposure of the army uniform thermal comfort properties.

2. Research methodology

There is only one material of fabric used in this research that is poly cotton fabric. The fabric is purchased from a licensed uniform clothing store. The material was a woven fabric of a plain weave.

2.1 Objective evaluation

Fabric density (ASTM D3775)The density of the fabric is calculated according to warps and wefts per inches of woven fabric. Five random places on each of the fabric sample were marked by 1 inch x 1 inch, and then they were cut. The number of warp yarns (ends) per unit distance and filling yarns (picks) per unit distance.

Fabric thickness (ASTM D3776 – 2009a)

The fabric was placed on the anvil base of the thickness gauge. Then, the pressure foot was lowered towards the fabric and the thickness reading can be taken from the scale. The reading was taken for 5 times at random spots of the fabric.

Moisture vapor transmission (ASTM E96 / E96M – 16)

5 fabric samples were cut to 16 cm x 16 cm and being tied on top of a beaker each with a rubber band. The beaker was filled with 350 ml of water which leave the air gap to the top of beaker mouth for 6 cm. The beaker was left in a controlled temperature room of 20 ℃ and 65.00 % relative humidity. The weight of the beaker was taken after 24 hours for 2 days straight. Moisture vapor transmission can be calculated using equation 1 below.

$$MVT = \frac{24M}{At} \qquad Eq. 1$$

MVT = rate of moisture vapor transmission (g/m^2/day)
M = the difference of mass before and after
A = test area (cup mouth area) (m^2)
t = time (h)

Thermal insulation (ASTM D1518)

The sample taken should be in full width and at least 75 cm x 75 cm long. They were placed on the copper plate inside the apparatus and the heat will be spread through. HE116 thermal conductivity apparatus was used in this experiment. The initial temperature was set to 40 ℃ and the temperature difference in every 10 minutes were recorded until it reached 30 minutes. However, the temperature must be maintained in the range of not more than 60 ℃. The heat insulation for textile is measured in Clo and can be calculated by equation 2 below.

$$1\, Clo = 0.155 \frac{m^2 K}{W} \qquad Eq. 2$$

K = temperature in Kelvin
W = weight of the sample
m^2 = refer to the area of the sample

2.2 Subjective evaluation

The subjective evaluation was adapted from (3). Five healthy army officers were selected as the participants. They were regular army officers having trainings every day. Their age was 20-23 years (SD, 1.22); height 1.79-1.91 m (SD, 4.71) and weight 72-77 kg (SD, 1.95). Each subjects were informed the general purpose, procedure and possible risks of the wear trials by written forms and training sessions. Wear trial program was arranged for performing the test at the same period of the day with each subject. Subjects were asked to eat their meal at least two hours before the trial session. Participants wore 100.00 % poly cotton gear produced from the test fabrics. The uniforms were conditioned in the test room before the sessions.

Subjective wear trials were carried out in a training room where the temperature and relative humidity can be controlled. Temperature and relative humidity of the environment was set to 24 ± 0.5 ℃ and 60 ± 5.00 % respectively for this study. These values were selected to enable comfort and sensible sweating during heavy activity. Details of the activity protocol are given in Table 1.

Table 1: Activity protocol of the wear trial test

Rating	Time, min	Activity
0	30	Sitting in test room for acclimatization after dressing
1	15	Sedentary work (reading a book, listening to music, etc.)
2	15	Moderate activity by walking on the treadmill at a speed of 6 km/h
3	5	Stand-up rest
4	15	High activity by walking on the treadmill at a speed of 9 km/h
5	10	Seated rest (cooling)

Five point rating scales were used to assess thermal comfort evaluation results at each rest span of the activity session. Mentioned evaluation results were determined by a preceding questionnaire survey study. Details of the questionnaire survey are given in Table 2.

Table 2: Questionnaire survey evaluation

Question 1	It feels hot and uncomfortable to wear the uniform
Question 2	When you are sweating, does your uniform has a good rate of absorption?
Question 3	The sweats absorbed on your uniform are drying fast
Question 4	How comfortable are you to move in the uniform?
Question 5	Can you bear to wear the uniform whole day?

3. Results and Discussion

The results are divided into four main testing that directly involved in thermal comfort of the fabric. This section will have the discussion on the fabric structure and all the experiments that have been evaluated on the fabrics.

3.1 Properties of fabric

The structure of the fabric is a 1 x 1 plain weave in which the simplest weave structure yet the strongest among all of the designs. The structure of the plain weave has more micro pores in between the interlacing of the warp and weft yarns. Thus, the fabric formed by using the two structure is a very tight fabric. The result of the test is recorded as in Table 3 below.

Table 3: Result for fabric thickness and fabric density

	Fabric thickness (mm)	Fabric density (/in^2)
Average	0.60	11 x 17

3.2 Moisture vapor transmission

The human body tends to secrete sweat when they are feeling hot. The sweat will then convert into moisture vapor and diffuse out through the fabric layers. This test is to measure the passage of moisture vapor through the material. Poly cotton fabric has been used to undergo the test as shown in Figure 1.

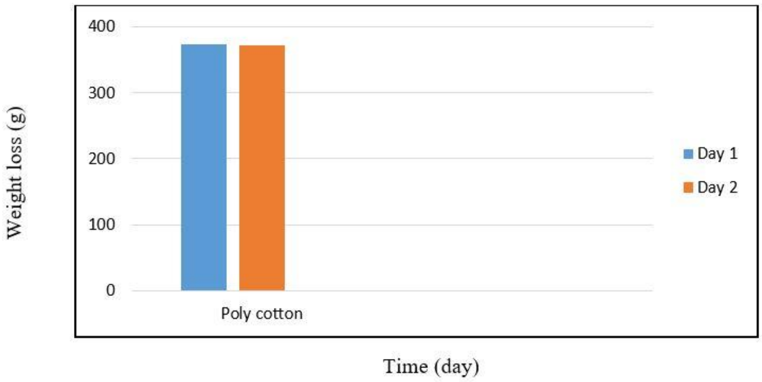

Figure 1: Graph of weight loss (g) against time (day) for moisture vapor transmission

The graph in Figure 1 demonstrated poly cotton fabric has a high moisture vapor transmission. The weight loss after 1 day for poly cotton fabric was 2.12 g. Meanwhile on the second day, the weight loss of poly cotton fabric was 2.13 g.

3.3 Thermal insulation

Thermal insulation test could be practiced to determine the rate of heat transport between object in thermal contact. As for clothing, the heat is produced by the human body while the fabric or garment worn will be the object. In a hot and humid environment such as Malaysia, the fabric should have low thermal insulation for the fabric to reflect the heat out of the wearer's body. The result for army uniform thermal insulation test are as in Table 4 below.

Table 4: Result of thermal insulation

Temperature difference, ℃			Thermal insulation, Clo
After 10 min	After 20 min	After 30 min	
4.1	3.2	2.9	0.0260
4.2	4.4	3.1	0.0259
Average Clo			0.0263

Table 4 showed the temperature reading detected by the thermal sensor. The average Clo of the fabric was 0.0263 Clo which is low referred to the International Standard of Clo (4). It signifies that the clothing has low thermal insulation where the heat can be easily reflect out from human body.

3.4 Subject wear trials

All the subjects were required to wear the full army uniform and done simple exercises for a certain period. The experiments were done in a closed training room. After they exercised and rest, they have answered a questionnaire regarding thermal comfort properties of the uniform. There is no absolute evidence to prove if the uniform is comfortable to be wear. Figure 2 illustrated the subjects' answer of the questionnaire.

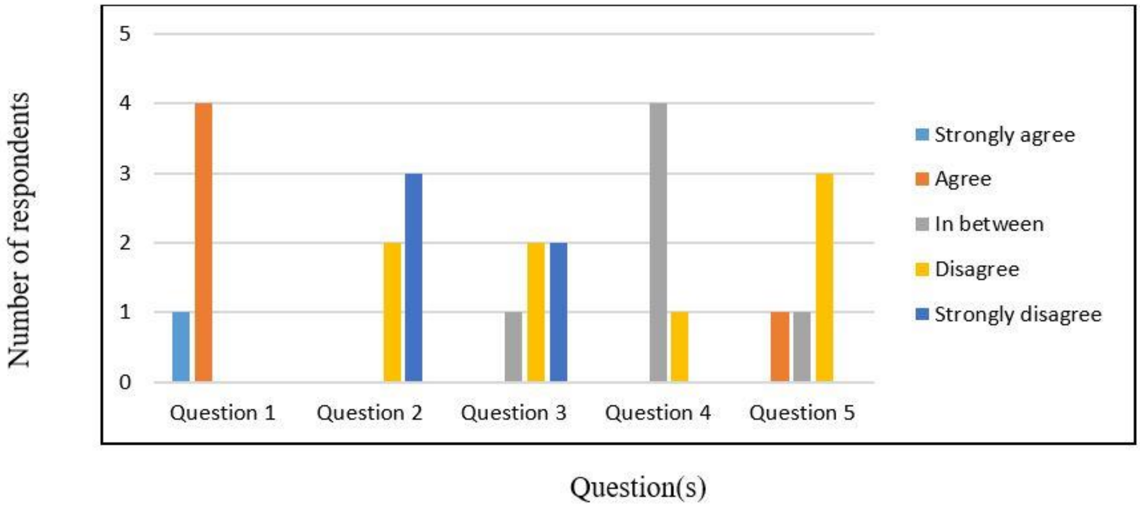

Figure 2: Graph of comfort evaluation by the subjects

For Question 1, 4 out of 5 were agree they felt hot and uncomfortable to wear the uniform with 1 participant strongly agree. For Question 2, 3 participants were strongly disagree that the fabric has a good rate of absorption. In Question 3, 1 participant was in between, 2 participants were disagree and the last 2 participants were strongly disagree of the sweat absorbed on the fabric was drying fast. For Question 4, most of them were standing in between and for the last question, Question 5, 1 participant was agree and feeling in between, with the other 3 participants stating disagree.

4. Conclusion

At the end of this study, it can be seen that the objective evaluation does not have the same results as the subjective evaluation. For instance, the fabrics were tested to have low thermal insulation according to the International Standards of Clo. However, in the subject wear trials, the value of the fabric thermal insulation was found not low enough for Malaysia's climate. Bear in mind, the International Standards of Clo was made in four season country thus, the difference. As conclusion, the subject wear trial was unsuccessful. It has proved that the mechanical testing cannot be related to the physiological of a person's state of mind.

Acknowledgement

The authors would like to thank the Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia for its support.

References

[1] Tugrul, R. (2006). Air permeability of woven fabrics, *Journal of Textile Apparel, Technology and Management*, Vol. 5, Issue 2

[2] A. Das & B. Biswas. (2011). Study on heat and moisture vapor transmission characteristics through multilayered fabric ensembles, *Indian Journal of Fiber & Textile Research*, Vol. 36, pp. 410 - 414

[3] Kaplan, S., & Okur, A. (2012). Thermal comfort performance of sports garments with objective and subjective measurements. *Indian Journal of Fiber & Textile Research, 37*(3), 46 – 54

[4] Thermal Comfort chapter, Fundamentals volume of the ASHRAE Handbook, ASHRAE, Inc., Atlanta, GA, 2005.

[5] Collier, B. J., & Epps, H. H. (1999). *Textile Testing and Analysis*. Upper Saddle River, NJ: Prentice-Hall, Inc.

[6] American Society for Testing and Materials (2000). *Annual Book of ASTM Standards*, 2000. ASTM D3776 – 96 Standard Test Method for Mass per Unit Area (Weight) of Fabric. Vol.7.02.Philadelphia, PA: ASTM.

[7] Jongmyoung C., & Shin-ichi T. (2002). Thermal comfort aspects of pesticide-protective clothing made with nonwoven fabric. *Journal of Korean Home Economics Association English Edition*: Volume 3, No 1

[8] Matusiak, M. (2010). Thermal Comfort Index as a Method of Assessing the Thermal Comfort of Textile Materials, *Fibers & Textiles in Eastern Europe,* Vol. 79, Issue 2

[9] Branson, D.H., & Sweeney, M. (1990). Sensorial comfort. Part I: Psychophysical method for assessing moisture sensation in clothing. *Textile Research Journal*, 60(7), pg. 371 - 377

[10] Roger, L. B. & Ryan, C. H. (2011). Factors affecting the thermal insulation and abrasion resistance of heat resistant hydro-entangled nonwoven, *Journal of Engineered Fibers and Fabrics,* Volume 6, Issue 1

[11] Weiner, L. I. (1970). The relationship of moisture vapor transmission to the structure of textile fabrics. *Textile Chemist and Colorist*, 2(22), pg. 378-385

[12] American Society for Testing and Materials (2001). *Annual Book of ASTM Standards*, 2001. ASTM E96 – 00 Standard Test Method for Water Vapor Transmission of Materials.

[13] Shadi, H., Rajiv, P., Olga, T., Rajkishore, N., Sandip, R. (2013). Evaluation and improvement of thermo-physiological comfort properties of firefighter's protective clothing containing super absorbent materials, *The Journal of Textile Institute.*

[14] Tamura, T., Iwasaki, F., & Shimane, U. (1993). Evaluation of heat and moisture transport properties of protective working wear from agriculture chemicals, *Home Economics of Japan*, 44(6), pg. 477-483

[15] Whelan, M. E., MacHattie, L. E., Goodings, A. C., & Turl, L. H. (1995). The diffusion of water vapor through laminae with particular reference to textile fabrics. *Textile Research Journal*, 25(3), pg. 197-223