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Influence of Fabric Structure and Properties on Thermal Comfort of Medical Protective Clothing

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Abstract

Medical protective clothing is an important personal protective equipment for medical staffs, especially in the pandemic. This research paper studied the effect of structure properties (material, yarn linear density and fabric thread density) of cotton and polyester fabrics on human thermal comfort. The main methodology entails using a CAD software to simulate the thermal comfort value of the individual when they wear a medical protective clothing made of 10 plain-woven fabric types. The normal effective temperature formula is used to simulate the clothing microclimate for evaluating the thermal comfort value. Three environment settings, indoor hospital conditions, outdoor environment of Manchester, UK in July and the outdoor environment of Hong Kong in July, are used in the simulation. Then analysis was conducted on the simulation results. The results indicate that yarn linear density has the biggest effect on the thermal comfort value. The cotton fabric with a yarn linear density of 131 Denier and thread density of 209/inch has the best thermal comfort performance. It also meets the physical strength requirements of surgical gown son EN 13795-1:2019. The result demonstrates that the moisture management capability of the fabric that affects dampness sensation of human body, is the most important ability to improve the thermal comfort value, and the influence of the yarn structure needs to be taken into consideration in the future studies.

Keywords: Personal protective equipment; Textile CAD technology; Mathematical modelling; Mathematical analysis

1 Introduction

Medical protective clothing (MPC) is a personal protective equipment (PPE) for medical staffs. MPC also refers to medical gown, protective coverall, procedure gown, medical scrub etc. MPC can reduce the transmission risk between patients and medical staffs[1].

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Covid-19 pandemic is the cause of worldwide shortage of medical PPE in 2022. Until June of 2022, only 20% of primary care facilities and 27% of healthcare facilities can provide the full PPE outfit[2]. Moreover, in less developed countries, only one third of healthcare facilities are able to correctly dispose used PPE[2]. Compared with disposal medical protective clothing (DMPC), reusable medical protective clothing (RMPC) can relieve the shortage of PPE, it can also save 28% energy and 41% water, while reducing 30% greenhouse gas and 93% solid waste[3].

On top of the safety and public trust requirements, the comfort performance of RMPC for wearers is a critical consideration[4]. Thermal comfort is an important part of clothing comfort and is essential for medical staffs due to their long working hours. Poor thermal comfort performance RMPC will result in physiological stress build-up as well as working efficiency of medical staff.

Compared to the variety DMPC material and fabric structure, RMPC is typically made of cotton, polyester or a mixture of cotton-polyester[5] with a plain weaving structure. The main factors of fabric structure that affect medical protective level are material, yarn linear density and fabric thread density. These three factors also affect the thermal comfort value.

Several studies have been conducted on the relationship between fabric structure and thermal comfort value. Shaker K et al studied thermal comfort of puckered fabrics and core spun yarn, found the relationship between thermal resistance and fabric thickness/core spun yarn[6]. Stankovic S et al studied the thermal comfort value of different yarn twist level and knitted fabrics for making thermal insulation textile product[7]. Aslan S et al studied the comfort value and the protective ability of four kinds of fabrics used in MPC[8]: the fibre types and fabric structures of four fabrics are all different, and two of them are used in DMPC. They found that disposal non-woven fabric has better microbial protection, but woven fabric has better thermal comfort performance; Maqsood M, et al studied the influence of fabric thread density and the weave structure on barrier performance and air permeability[9]. As all woven RMPCs use plain weave structure, the contribution to the study of RPMC fabric is limited to the area of thread density. Guo YP et al compared the tactile and thermal comfort value between 5 different kinds of MPC[10], which are made of different materials and/or fabric structures. They pay more attention to the influence of the clothing structure on the thermal comfort value but not the fabric material and structure. In conclusion, these studies did not consider the relationship between the fabric structure properties and the thermal comfort value in the plain weave structure systematically for the functional design of RMPC's.

Effective temperature (ET) is a subjective index of human body to the comfort value under a set of temperature and humidity. Missenard created a formula that uses air temperature and relative humidity to calculate ET through analysing people's subjective feeling on temperature when they wear clothes, with soft activity under a low wind speed environment[11]. This index was initially used in the indoor environment, Gregorczuk used this formula to evaluate the whole earth's climate[11]. ET can be further divided into two types: normal effective temperature (NET) and basic effective temperature (BET)[12]. NET is for the clothed person who does the light work, BET is applicable to unclothed persons. For calculating negative NET, Gregorczuk modified Missenard's formula, added wind speed into it to calculate NET[13]:

$$NET = 37 - \frac{37 - T}{0.68 - 0.001\,4\gamma + \frac{1}{1.76+1.4v^{0.75}}} - 0.29T\left(1 - \frac{\gamma}{100}\right) \tag{1}$$

T: air temperature, °C; wind speed, m/sec; γ: relative humidity.

Li PW and Chan ST used NET formula to define the extreme weather condition in Hong