A Computational Bioengineering System for Thermal Functional Design of Textile Products

Ai-Hua Mao[1], Yi Li[1*], Ruo-Mei Wang[1,2], Xiao-Nan Luo[2] , Yue-Ping Guo[1]

[1] *Institute of Textiles and Clothing, Hong Kong Polytechnic University, Hung Hom, Hong Kong*
[2]*School of Information Science and Technology, Sun Yat-Sen University, Guangzhou 510275, China*

Abstract: Textile thermal bioengineering design involves the integration of multidisciplinary knowledge. Utilizing computer power and popularity to realize it creates a huge potential in designing clothing with advanced functions in an effective, economical and scientific way. This paper presents a virtual thermal bioengineering system for life-oriented design of textile products, which, by the combination of multidisciplinary knowledge, creates a virtual space for the designer to achieve textile bioengineering design in a life-oriented way. The thermal bioengineering framework and design principles of thermal functional clothing are shown, the development of the computer-aid system including the life-oriented design, simulation, visualization and project management, as well as the engineering database, is reported with case illustration.

Keywords: textile thermal bioengineering, life-oriented design, thermal performance, computation, CAD

1. Introduction

Textile design focusing on excellent thermal performance to achieve high quality products, such as sportswear, personal protection clothing, is an interesting subject for both the researchers and manufacturers. However, designing a textile product with superior thermal functions in the traditional way of iterative making samples-testing-improving design is time consuming and complicated. Repeated actions of trail and error in the design need to be taken and the design cycle thus is limited as a long period. In order to achieve rapid and effective development of high thermal performance textile products, Li introduced an innovative concept of textile thermal bioengineering, and defined as the application of a systematic and quantative way of designing and engineering apparel products to meet the thermal biological needs of the human body to maintain an appropriate microclimate for the protection, survival and comfort of the wearer [1]. This system can be achieved by including the research from a number of areas: 1) development of theories, data and models for describing the thermal behaviors in textile material and the thermoregulatory behaviors of human body, as well as the thermal interactions between the human body, clothing and environment; 2) development of computational method, visualization technique and engineering database; 3) design and engineering of the material and clothing for desirable thermal functions; 4) achievement of final products by characterizing thermal biological functions from basic materials.

With the growing ability of the CAD technologies, this thermal bioengineering system is able to be realized and delivered to the user in the presence of a virtual CAD system. Given the definition of textile thermal bioengineering above, the development of this virtual system also indeed involves the integration of multidisciplinary knowledge, including textile design principles, involved physical and physiological mechanisms, mathematical simulation models, computational algorithms, CAD interfaces and functionalities, material engineering database and project data management.

This paper reports the development of a virtual thermal bioengineering system for life-oriented design of textile products. The combination of multidisciplinary knowledge is developed and

* Corresponding author's email: tcliyi@polyu.edu.hk

the theoretical framework for textile thermal bioengineering design is built up. Based on this framework, the virtual system is realized by the development of the CAD interfaces and functionalities of life-oriented design, simulation, visualization and project management, as well as the support of engineering database. The user is enabled with a virtual space to achieve the textile bioengineering design in a life-oriented way, which also is shown in the case demonstration.

2. Theoretical Developments

In the textile thermal bioengineering process, it is of critical importance to deeply understand the mechanisms and description models of the involved thermal and moisture behaviors in the textile material, which are the predominant facts to determine the thermal performance of textile products throughout the wearing scenarios. Commonly, the thermal and moisture behaviors in the textile material involve: 1) heat transfer in terms of conduction, convection and radiation, as well as the latent heat during various phase change processes, such as condensation/evaporation and freezing/melting happening in the fabric/yarn/fiber materials; 2) moisture transfer including the water vapor diffusion and convection in the fiber interstices, liquid water diffusion through capillary pores in the fabric, moisture absorption/desorption of fibers, and the mass of moisture in condensation/evaporation and freezing/melting. These description models consisting of mathematical equations are the significant foundation for simulating the thermal and moisture distributions of textiles with computational methods on the computer. The well-known theoretical models relevant to the heat and moisture transfer processes in textile materials have been developed and reported in various publications [2-4].

As the ultimate thermal function of clothing is to provide substantial thermal protection for the human body against various heat/cold environments and help wearers to achieve superior thermal comfort, it is necessary to take the human body and wearing scenarios into consideration to simulate the thermal performance of textile products. Besides the thermal protection from the clothing, the human body has an effective thermoregulatory system for biological balance with external environment. When the body feels hot or cold, corresponding regulatory behaviors except for basic metabolism, such as sweating and shivering, will be activated and sustained until the core temperature of the body returns to the neutral

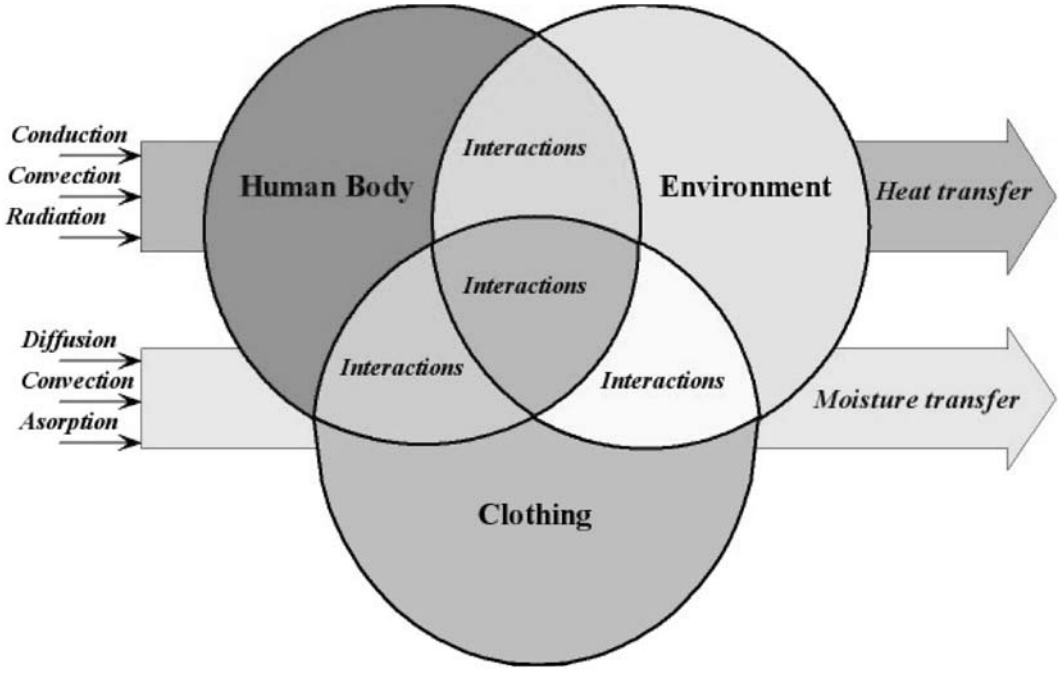

Figure 1 Thermal and moisture behaviors in the HCE system