Thermal Clothing Engineering Using a COMSOL® Simulation App

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Abstract

Design and production in apparel industry need cost-effective and user-friendly thermal comfort design software. First, the design tools should model all thermal functions that are depending on the complex interactive physical behaviors involved in the clothing wearing system, which consists of (1) the human body, (2) the clothing and (3) the external environment. On the other hand, the clothing is practically designed and made with textile materials and various technologies/functional treatments. With the development of Computational Fluid Dynamics (CFD), it should be possible to simulate and predict the thermal and moisture properties in the complete clothing wearing system including the microclimate flows [1,2]. However few researchers have examined the thermal mechanisms in complete clothed wearing systems including air gaps, using simulation methods [1].

In this paper the development of a simulation application or app for the engineering design of thermal quality clothing has been started. Specific design requirements lead to different simulation models for the clothing wearing system ranging from simple 1D, 2D to complex time-consuming 3D models using finite element method (FEM). The thermal behaviors that have been modelled are: (1) heat and moisture transfer behaviors in fibers, fabrics and garments, as well as their interactions and the influence from phase change process (condensation/evaporation, moisture absorption/desorption and micro-encapsulated phase change materials) and various functional treatments; (2) thermoregulatory behaviors of the human body responding to the clothing and external environments; and (3) interactions between the boundaries of clothing, human body and environment. These thermal behaviors of clothing wearing system actually are in different scales.
In the 1D model, the human body is represented as a cylinder with integrated thermoregulation model and surrounded by different textile and air layers. With this model a quick cost-effective multilayer design can be performed for global thermo-physiological comfort. Variation in wearing protocol, clothing design (layers, fabrics and fibers) combined with coatings, phase changing materials and self-heating materials can be investigated for different climatic conditions.
Within the 2D approach the human body is divided in different parts (cylinders) with each there own clothing design, leading to a tool where the local comfort for each part can be investigated including changes in the clothing style.

Ultimately in the 3D strategy a 3D FEM model of the human body will be used, where each surface element of the body is coupled with the integrated thermoregulation model and clothing design. The local comfort can be analyzed in detail for different clothing design for each surface element. The application is available using a web server and can be used on different operating systems, where the simulation can be sent to different PC's, clusters and clouds.

The development of a simulation app for thermal clothing design has been started considering a 1D design strategy. Successful validation with experimental results [4] will be reported. The app will be demonstrated and first promising results for a specific design case will be presented.

Reference

[1] A. Mao et al., A multi-disciplinary strategy for computer-aided clothing thermal engineering design, Computer-Aided Design, Vol. 43, pp. 1854–1869 (2011)
[2] P. Van Ransbeeck et al., Towards Virtual Engineering of Protective Clothing Comfort, 6th European Conference on Protective Clothing, 14-16 May 2014, Bruges, Belgium (2014)
[3] E. Mert et al., Determination of the Air Gap Thickness underneath the Garment for Lower Body Using 3D Body Scanning, 6th International Conference on 3D Body Scanning Technologies, Lugano, Switzerland, 27-28 October 2015
[4] P. Gibson, The Use of Volume-Averaging Techniques to Predict Temperature Transients Due to Water Vapor Sorption in Hygroscopic Porous Polymer Materials, Journal of Applied Polymer Science, Vol. 64, pp. 493-505 (1997)