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Simultaneous Determination of Thickness and Heat Conductivity in Fabric Design: Steady-state Modeling and PSO Algorithms

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Abstract

Fabric thickness and texture directly affect heat and moisture transfer characteristics in the human body–fabric–environment system, which determine the heat-moisture comfort level of the human body. Based on the model of steady-state heat and moisture transfer from skin to environment, we put forward an Inverse Problem of Thickness-texture Determination (IPTTD). Adopting the idea of the least-squares method, we formulate IPTTD into a function minimization problem. We employ Particle Swarm Optimization (PSO) method to directly search optimal solution of the objective function. The results of numerical simulation show the effectiveness of the presented algorithms and validity of the proposed IPTTD.

Keywords: Inverse Problems; Thickness and Texture Determination; Fabric; Heat and Moisture Transfer; Weighted Least-squares Solution; Particle Swarm Optimization

1 Introduction

In recent years, functional textile material design has been paid more and more attention due to the human increasing requirements on daily life and some special applications. Some mathematical models of heat and moisture transfer in the body-fabric-environment system have been formulated [1-8]. From these models, we can find some main factors which affect human body comfort and find out these factors' intrinsic rules. Thereby we usually call these models Direct Problems (DP). Now, some numerical methods have been put forward to solve the DP such as finite-difference method, finite-volume method, finite-element method and controllability volume-time- domain recursive method [9-11].

Although the DP helps us to know about human body heat-moisture comfort level for given textile materials and environmental conditions, we don't know how to determine the textile texture and thickness mathematically in order to make one feel more comfortable when the

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textile materials are not given. So the study of inverse problems of textile material design is fundamentally important for us to study human body comfort. Xu proposed inverse problems of textile thickness or type design for a single layer or bilayer textile material based on the model of steady-state or dynamic-state heat and moisture transfer through textile and presented effective numerical algorithms to solve the inverse problems [12-15].

In this paper, we formulate an Inverse Problem of fabric Thickness-texture Determination (IPTTD) which is based on the steady model of heat and moisture transfer from skin to environment through fabric [16] and make numerical calculation to IPTTD under the given environmental conditions.

2 Mathematical Formulation of Heat and Mass Transfer in the Body-Fabric-Environment System

2.1 The Schematic Diagram and Assumptions

The body-fabric-environment system discussed in this paper consists of human skin, an air layer between the skin and fabric (microclimate area), fabric and environment as shown in Fig. 1. The outer surface of fabric is exposed to the natural environment. The fabric and the skin are placed perpendicular to the direction of gravity, and this lay-out is called a horizontal system. Radiation and surface diffusion are considered in addition to conduction and convection [16]. The assumptions are described same as that in reference [17].

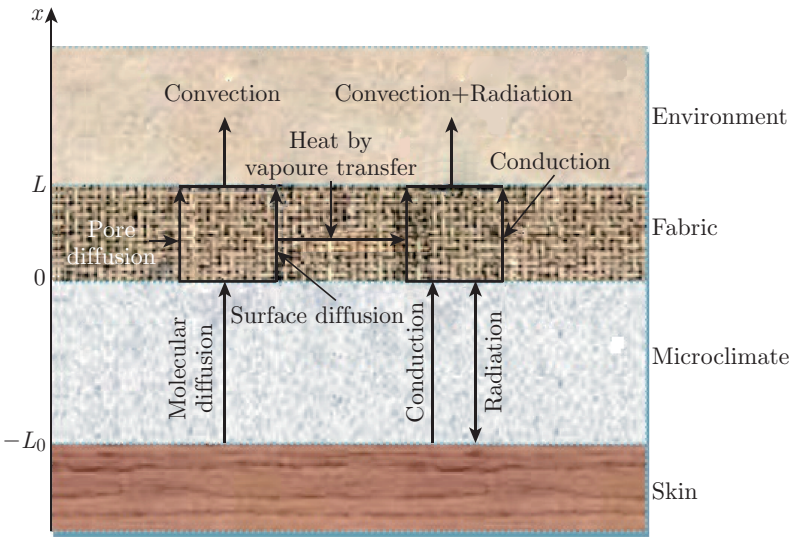

Fig. 1: Pathways of the heat and moisture transfer from skin to environment through fabric: horizontal system

2.2 The Direct Problems (DP)

Based on the above system and the model of heat and moisture transfer from skin to environment through fabrics, we attribute the model to the boundary problem of complicated nonlinear