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Modeling and Simulation of Moisture Transmission through Fibrous Structures Part I: Water Vapour Transmission

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Abstract

The moisture transmission behaviour of clothing plays an important role in determining its thermo-physiological comfort. The determination of the factors involved in moisture transmission of clothing and its prediction have become a main concern for researchers for many years. An attempt has been made to review the research studies on modeling and simulation of moisture transmission through fibrous assemblies. The review work has been divided in two parts. The first part deals with moisture vapour transmission and the second with liquid water transmission through fibrous materials. The various processes involved in water vapour transmission through fibrous materials are diffusion, absorption – desorption, convection, evaporation and condensation. The models on water vapour transmission through fibrous materials are based on the mass balance equation. Some of the studies involving theoretical work on vapour transmission have been conducted on individual processes. Others consider the inter-related effects involved. Moisture vapour transmission through textile materials is coupled with heat transfer phenomena, due to its hygroscopic nature. The atmospheric conditions, the structure of the fibrous materials and the hygroscopic nature of the fibres significantly influence the processes. Amongst the available models on vapour transmission, the model developed by Li and Zhu predicts simultaneous heat and moisture transfer considering moisture sorption, condensation and capillary liquid diffusion in porous textiles and this model is best suited for determining textile clothing comfort.

Keywords: Moisture Transmission; Textile Materials; Modeling; Simulation

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1 Introduction

Clothing is generally used to cover the human body. It may work as a fashion item or as a barrier against aggressive environmental conditions, including chemical and biological hazards. The functional properties of clothing have been a concern since ancient times. The factors which influence the choice of clothing depend upon its end use. One of the most important functions of clothing is to provide thermal comfort to the wearer [1]. In regular atmospheric conditions and during normal activity levels, the heat produced by the metabolism is liberated from the body to the atmosphere by conduction, convection and radiation.

The perspiration produced by the body is used to regulate the body temperature. During high levels of activity and in higher atmospheric temperatures, the production of heat is very high and the transmission of heat from the body to the atmosphere is not sufficient to keep the body temperature in the comfort zone. In these cases, the sweat glands are activated to produce perspiration [2]. The vapour form of perspiration is known as insensible perspiration and the liquid form as sensible perspiration. When the perspiration is transferred to the atmosphere, it carries heat (both latent and sensible) thus reducing the body temperature.

The fabric being worn should allow the perspiration to pass through; otherwise it will result in discomfort. The perception discomfort in the active case depends on the degree of skin wetness. It is also important to reduce the degradation of thermal insulation caused by moisture build-up. If the ratio of evaporated sweat to produced sweat is very low, moisture will accumulate in the inner layer of the fabric system, thus reducing the thermal insulation of clothing and causing unwanted loss of body heat [3]. Therefore, both in hot and cold weather conditions and during normal and high activity levels, moisture transmission through fabrics plays a major role in maintaining the wearer's body in comfort. Textile clothing is a capillary and porous material system with different pore sizes, and it may be saturated with both liquid and gaseous water during wear. The transport of perspiration through this material system at different temperatures is a very complex process, which involves convection, capillary flow, penetration, molecular diffusion, evaporation and solidification. Hence, a clear understanding of the processes involved in moisture transmission and the role of different processes in maintaining the body comfortable is of great importance [4, 5].

The phenomenon of water vapour transmission through textile materials has been widely investigated by a number of researchers and they have provided a clearer understanding by modeling the moisture transmission phenomenon through textile materials. However, due to the complexity of fibrous structures and the complicated relationship of the various factors involved, most of the predictions remain empirical in nature. Currently, many new tools such as artificial neural networks, computational fluid dynamics, fuzzy logic and genetic algorithms are being used to simulate the actual conditions. However, before using such tools it is necessary to understand the science behind the transmission phenomena. These tools have to be used with care and experience as they are also prone to give misleading results if used with improper initial and boundary conditions and inappropriate functions.

2 Moisture Transmission through Fibrous Structures

Mass transmission through fibrous materials takes place both in liquid and vapour form. The