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NUMERICAL ANALYSIS OF HEAT AND MOISTURE TRANSFER THROUGH BULKY PAN NANOFIBER MATS

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INTRODUCTION

Researchers found that the electrospun mats provided good aerosol particle protection, without a significant change in moisture vapor transport. It was shown that materials used in protective clothing must provide a combination of high barrier performance and thermal comfort . It has been recognized that the heat and moisture transport behavior of textile materials is one of the most important factors influencing the dynamic comfort performance of clothing in normal use.

The main aim of this study was to investigate the coupled heat and moisture transfer through nanofiber mats. We applied the model of coupled heat and moisture transfer to predict of transient moisture and temperature changes of PAN nanofiber mats. Also we developed a model that takes into account the role of convective heat transfer. The theoretical results are compared with those measured experimentally.

Mathematical model

We consider an element of nanofiber mats with unit area and thickness dx exposed to moisture and temperature gradients. Results obtained by scale analysis showed that the heat transfer by conduction and convection are important but heat transfer by radiation is negligible. The mass and energy balance lead to:

$$\varepsilon \frac{\partial C_a}{\partial t} + (1-\varepsilon)\frac{\partial C_f}{\partial t} = \frac{D_a \varepsilon}{\tau}\frac{\partial^2 C_a}{\partial x^2} \qquad (1)$$

$$C_v \frac{\partial T}{\partial t} - \lambda \frac{\partial C_f}{\partial t} = K\frac{\partial^2 T}{\partial x^2} + h_t \frac{\partial T}{\partial x} \qquad (2)$$

These equations are not linear and contain three unknowns, C_f, T, C_a. A third equation is needed to solve the equations.

Sorption kinetics for cylindrical fibers is described by diffusion process, which is governed by Eq. (3):

$$\frac{\partial C_f(x,r,t)}{\partial t} = \frac{1}{r}\frac{\partial}{\partial r}\left\{ r D_f(x,t)\frac{\partial C_f(x,r,t)}{\partial} \right\} \qquad (3)$$

The moisture content at the fiber surface is assumed to reach instantaneous equilibrium with the moister content of the adjacent air, as:

$$C_{sf}\left(x, R_f, t\right) = f'\left\{W_C\left(H_f\right)\right\} = f\left\{C_a(x,t)\right\} \qquad (4)$$

The relationship between W_c and H_f is commonly described as the sorption isotherm for a given fiber. For instance, the sorption isotherm for PAN can be expressed as:

$$R = 0.0236 H_f \qquad (5)$$

Initial conditions	Boundary condition
T_o=25°C 65% RH	at x=0, T= 35°C, RH= 90% at x=L, T= 25°C, RH=65%

Results and Discussion

The predicted curve of water vapor concentration in the air filling the interfiber void spaces in the nanofiber mat indicates that diffusion of water vapor into nanofiber mat through the void spaces is very fast and with a transient period of increasing pulse of water vapor concentration. Also the process of water vapor diffusion into PAN nanofibers is fast.

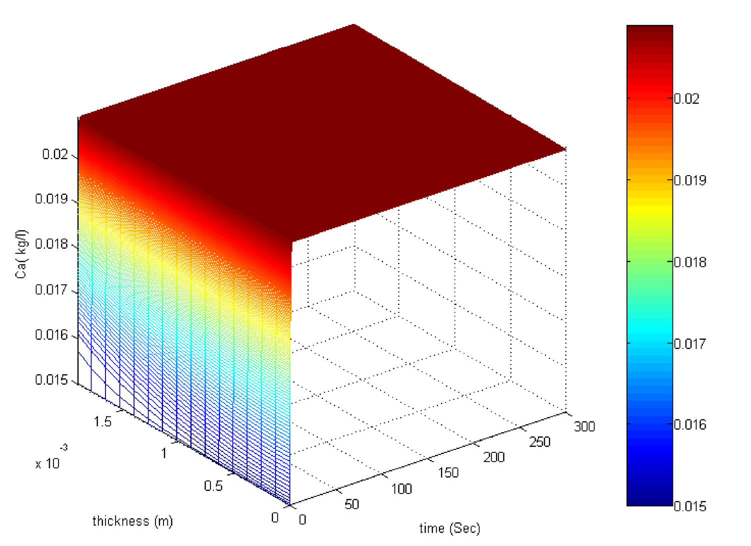

Figure 1- Distribution of water vapor into nanofiber mats

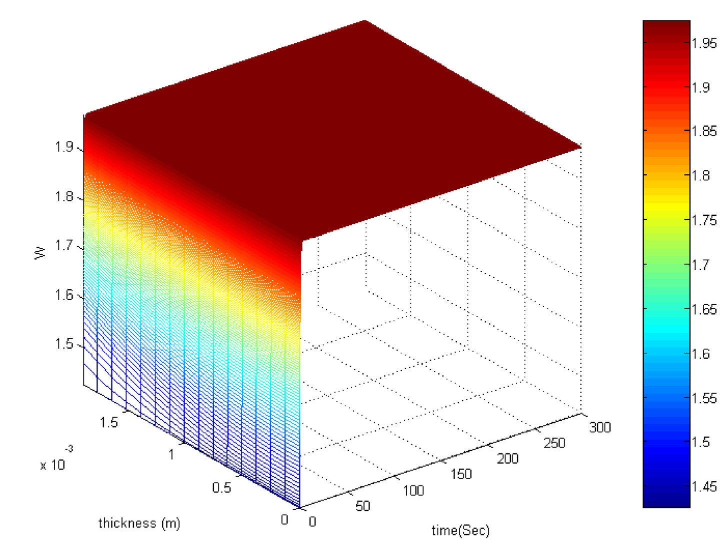

Figure- 2 Distribution of water content into the nanofiber mats

Temperature changes during the water vapor diffusion process, illustrates that the temperature rises initially and then decreases gradually and reaches steady state with environment.

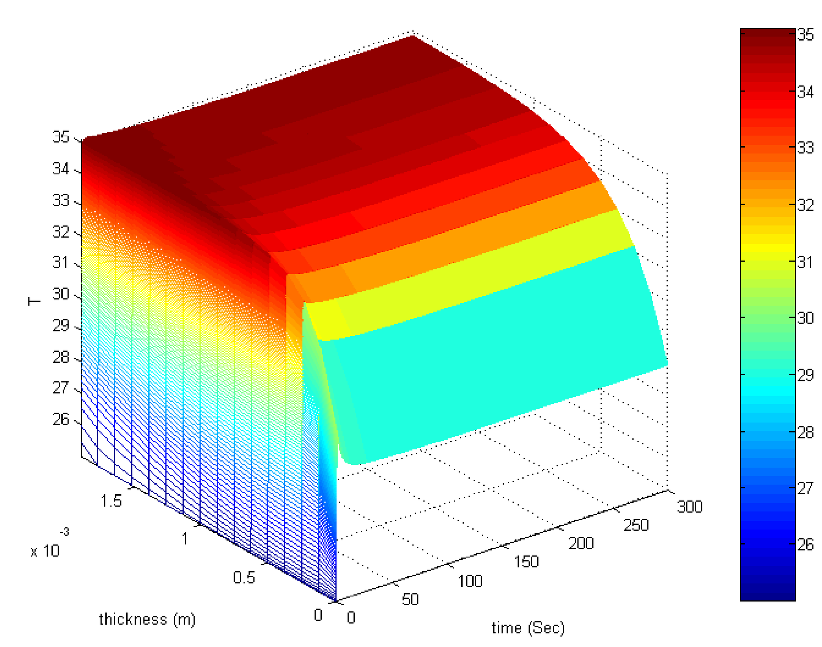

Figure 3
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Comparison of experimental and computational results

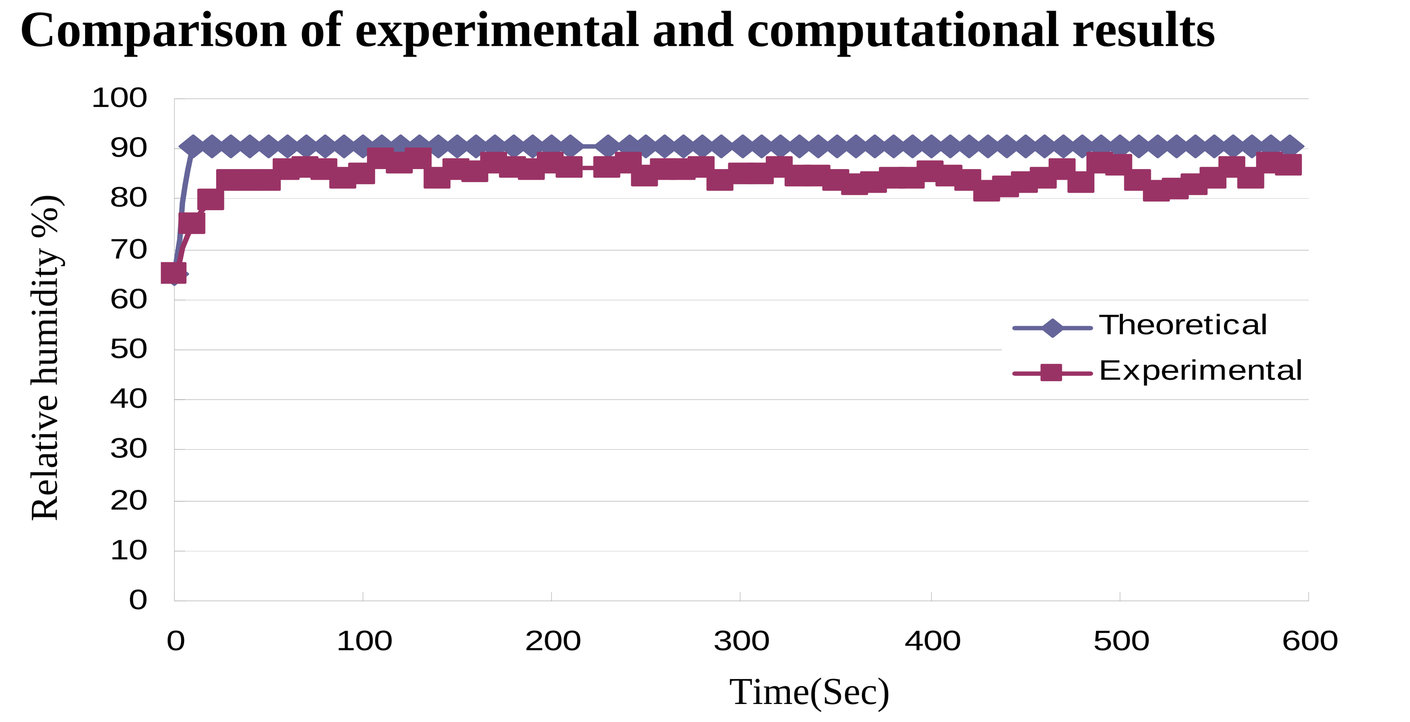

Fig. 4 Theoretical prediction of relative humidity at the nanofiber mats surface in comparison with experimental measurements

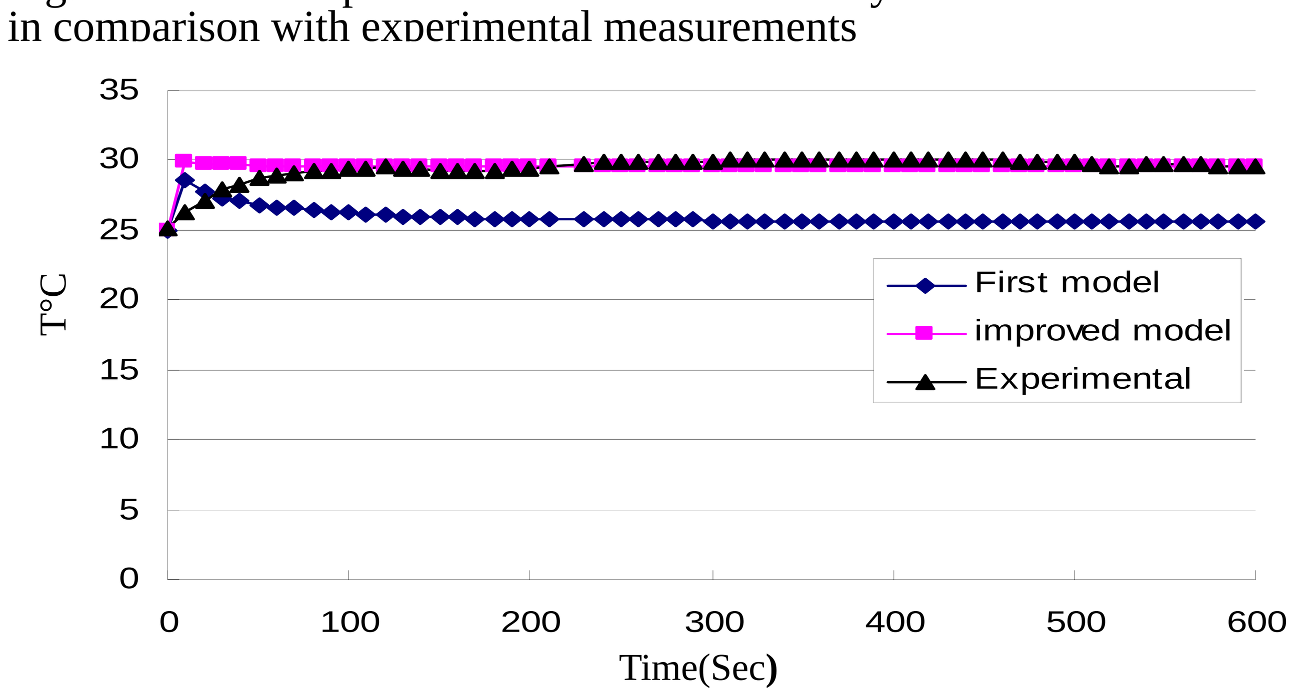

Fig. 5 Theoretical prediction of temperature at the nanofiber mats surface in comparison with experimental measurements

Conclusion

Nanofiber mats with high rates of water vapor diffusion and low air permeability are promising candidates for protective clothing applications.