PC 31. Heat and Mass Transfer Through a Firefighter Protective Vest - Numerical Analysis of Materials with Heterogeneous Permeability

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Abstract

Developing more efficient firefighter protective clothing is a crucial step towards advancing safety equipment, ensuring better protection against the rising risks of burn injuries and enhancing overall performance in increasingly hazardous fire environments. A recent innovation in firefighter safety is a vest designed to be worn over standard thermal protective clothing, aiming to improve both thermal comfort and safety [1]. While this vest has shown promising performance, its non-uniform material properties [2] can lead to localized zones of water vapor saturation, potentially compromising thermal efficiency.

This study presents a numerical analysis of heat and moisture transport through the vest system, which consists of phase change material (PCM)-filled pouches embedded between textile layers and a perforated cork layer.

The analysis evaluates the impact of PCM layer permeability, as well as the number, diameter, and spatial distribution of perforations, on both thermal and evaporative resistances. Two modeling approaches were adopted: a two-dimensional model assessing both impermeable and permeable pouches, and a three-dimensional model incorporating a permeable PCM configuration.

Results indicate that thermal resistance increases with larger perforation diameters and reduced perforation density, while evaporative resistance is maximized with smaller, fewer perforations. Although both two- and three-dimensional simulations reveal consistent trends, discrepancies in absolute values underscore the limitations of the two-dimensional approximation. As expected, the increase of the permeability of the PCM layer significantly enhances the evaporative performance of the multilayer system. This study highlights the critical role of material and structural design in optimizing the thermal and evaporative performance of firefighter protective gear.

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References

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