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Numerical and Experimental Investigation of Heat Transfer and Convective Flow Patterns between Semi-Transparent Horizontal Insulating Screen Layers

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Extended Abstract

Climate control systems in buildings and greenhouses are energy intensive, reducing cost-efficiency and increasing pollution. Using glazing and insulation materials like blinds, thermal screens, or photovoltaic films can provide consistent indoor conditions and conserve energy. The thermal properties of building glazing have been studied theoretically and experimentally for several decades [1-4]. For example, various aspects of multiple pane windows have been addressed in recent studies [5], indicating that a large amount of energy can be saved by using double or triple glazing for buildings, depending on local external climatic conditions.

In this study, an enhanced algorithm for calculating heat transfer through semi-transparent screens was developed and validated via published data and in-site experiments to analyze the thermal properties of different screen materials and their combinations under more realistic conditions. The proposed algorithm allows us to simplify the computational method described in [3,4] employing linearization of a nonlinear system, which is solved by inverting a tridiagonal matrix. Overall heat transfer coefficients (U-values) for single and multiple thin screens were calculated numerically and measured using the hot-box method [6]. The building insulating materials such as glass, polymers, aluminum films, and selected commercial thermal screens were examined. The cross-validated results indicated good agreement between calculated, measured, and previously published results demonstrating the abilities of the method to predict new data for materials and their combinations that have not yet been estimated. It is found that the heat transfer coefficient is affected by external and gap convective heat fluxes.

Following these results, the computational fluid dynamic model has been developed considering cavity geometry cooled at the top (Rayleigh-Benard convection) with single and double layers of thermal screens. The simulations have been carried out to test different commercial screen configurations under various ambient conditions. The results show significant variations in U-value in response to variations in weather parameters and the use of single or double-layer greenhouse covers. It was confirmed that low-emissivity materials have a more significant effect on reducing the U-value than insulating materials with IR-absorbing properties. The approach is valid for investigating the performance of thermal insulation in different enclosures, glazing in buildings, or moveable thermal screens in greenhouses.

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