PRACTICAL IMPLICATIONS OF OPTIMIZING THERMOELECTRIC WINDOWS

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ABSTRACT

One of the significant emerging applications of multidisciplinary design optimization (MDO) techniques is in the area of energy efficient building systems. In this research, the focus is on the design and optimization of energy efficient windows for residential or commercial use. Current state-of-the-art multi-pane windows can be considered passive, relying primarily on the low thermal conductivity of the gas between their panes to reduce the heat transfer. The novel concepts of this work are based on prior work by Prof. Achille Messac.

In this research, we pursue the novel idea of actively changing the thermodynamics of the window's air gap, such that the heat transfer that takes place through the window is desirable, rather than detrimental. This novel window design uses externally supplied energy to affect a change in the thermodynamics and is therefore an “active” window. Such windows can have significant economic and environmental benefits. Three new “active” window designs will be outlined and an optimized. All three of these windows use thermoelectric units (TE) in a unique manner to alter the heat flow characteristics of a window.

The Active Thermal Insulator (ATI) is a specially designed window that is expected to actively compensate for the heat gains or losses that occur through it. This window design has a thin film photovoltaic (PV) module integrated into the outer pane, which powers the TE units embedded in the frame of the window. The other two designs focus on changing the temperature, and the heat flow, in the air gap of a multi-pane window by recirculating the air in a TE units. In all of these designs, the TE units enforce heat flow in the direction opposite to that of the natural flow in order to minimize the net heat gain, or lost, through the window. Two different heat sinks geometries were considered to aid the heat transfer to and from the TE units.

The designer relied heavily on optimization tools and techniques to provide insight into the characteristics of each of these designs. Through the use of advanced optimization techniques the ATI design was improved substantially over traditional windows, between a 54% and a 67% improvement. This improvement reduces the load on traditional air conditioning devices and the associated consumption of fossil fuels.

The side-channel recirculating design was analyzed in *FLUENT* and optimized in MATLAB for 12 monthly conditions in three locations. The results from FLUENT were expensive to compute, an expense that became onerous in the optimization process. To reduce the computational expense, a surrogate model was implemented. Extended radial basis functions were used to create a locally accurate model to aid the optimization. The results show that the side-channel window is beneficial in both heating and cooling climates.