Numerical Analysis of the Thermal Resistance of a Multi-Layer Reflective Insulation Material Enclosed by Cavities under Varied Angles

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Introduction: This poster presents a numerical analysis on the thermal resistance of a sample, consisting of two cavities surrounding a Multi-Layer Reflective Insulation (MLRI) material, under various angles (α) and for downward and upward heat flows.

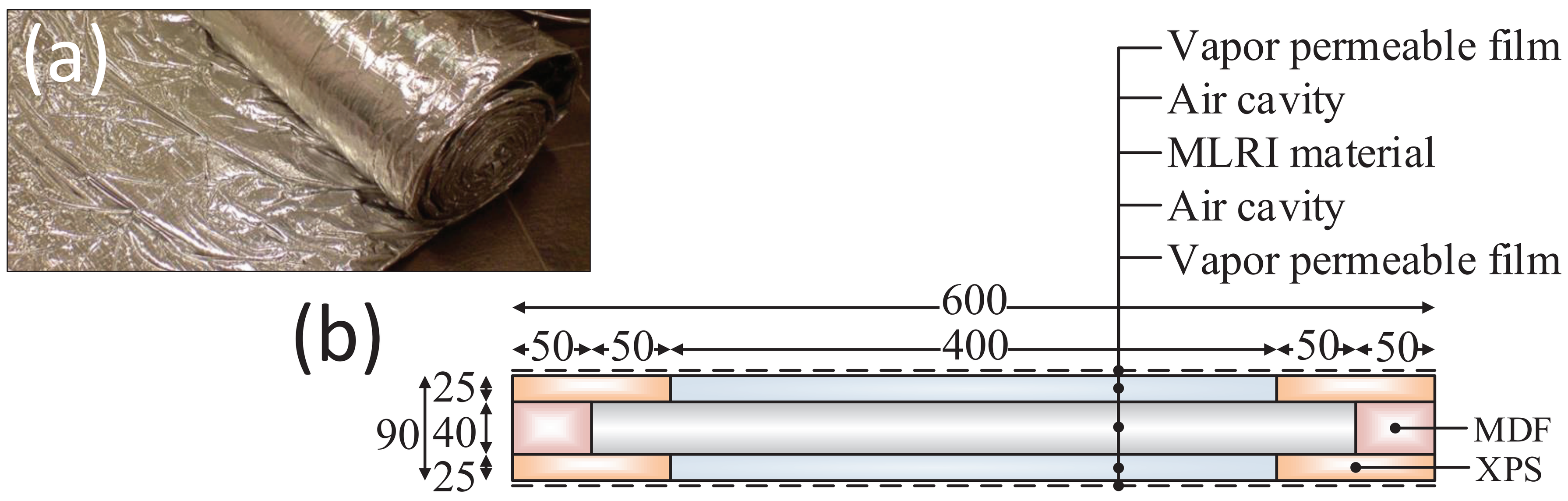

Figure 1. (a) A MLRI material; (b) A schematic cross-section of the sample.

Computational Methods: In the applied Laminar Flow module, the Navier Stokes equations for an incompressible flow a time-dependent system were defined for air by:

$$\rho_{air}\frac{\partial u}{\partial t}+\rho_{air}(u\cdot\nabla)u=-p\nabla+\nabla\cdot\mu(\nabla u+(\nabla u)^T)+F$$

$$\frac{\partial\rho_{air}}{\partial t}+\nabla\cdot u\rho_{air}=0$$

In turn, the equations in the Heat Transfer module n were defined for material by:

$$\rho_n c_n\frac{\partial T}{\partial t}+\nabla\cdot(-k_n\nabla T)=-\rho_n c_n u\cdot\nabla T$$

The Boussinesq approximation was applied and air was considered as an ideal gas:

$$\rho_{air}=\rho_{ref}\beta_p\left(T_{air}-T_{ref}\right)$$

Consecutively, F is defined as:

$$F=\begin{bmatrix}x\\y\end{bmatrix};\ x=-\rho_{air}g(\sin\alpha);\ \ y=-\rho_{air}g(\cos\alpha)$$

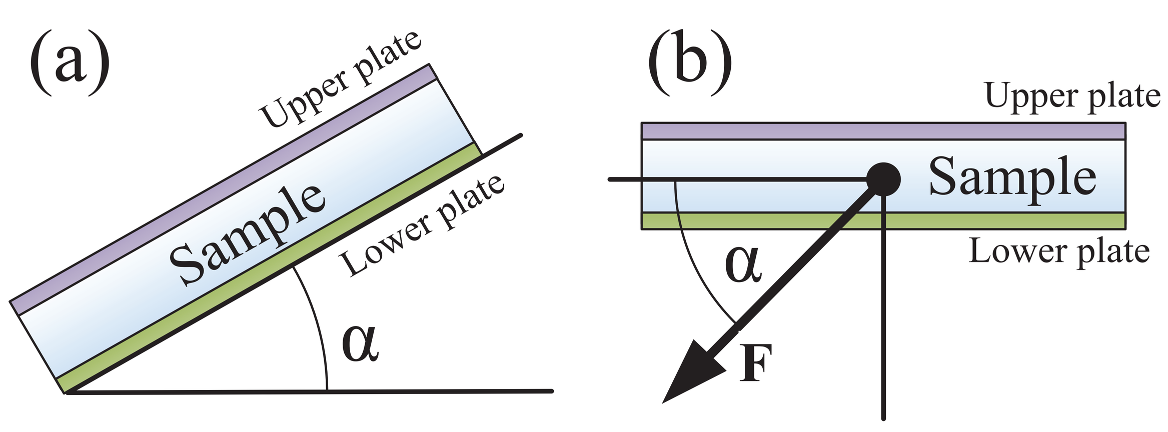

Figure 2. (a) The angle of the sample; (b) The angle of the sample translated to F.

Results: The heat transfer by radiation in both cavities was greatly reduced by the highly reflective surfaces of the MLRI material. Meanwhile, convective heat transfer gained a more dominant role on the heat transfer through the sample since the radiative heat transfer in the cavities is highly decreased.

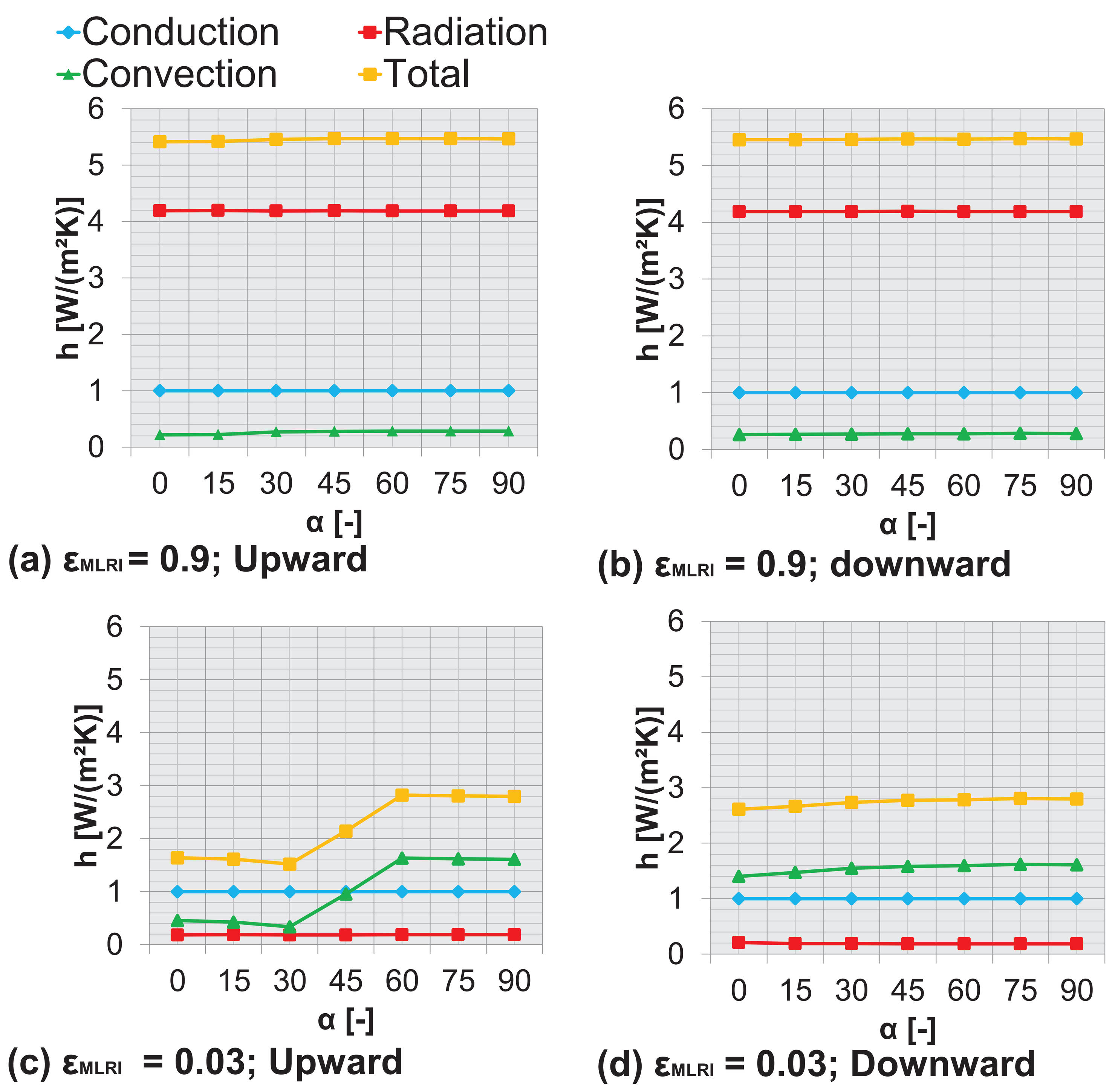

Figure 3. The heat transfer coefficient for each heat transfer mechanism and the total heat transfer per angle for the upward heat flux and downward heat flux for an ε_{MLRI} of respectively (a & b) 0.9 and (c & d) 0.03.

Conclusions: For practical application, MLRI materials are probably best placed in the floor beneath a building so that the highest thermal resistance is attained, since convective heat transfer is minimized due to the upward heat flow.

References:

1. H. Dillon, A. Emery and A. Mescher, "Benchmark comparison of natural convection in a tall cavity," *Proceedings of the COMSOL Conference 2009 Boston*, 2009.