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

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Abstract

In the current building industry, several manufactures of insulation materials offer customers Multi-Layer Reflective Insulation (MLRI) materials as an alternative to more commonly used insulation materials. MLRI materials are composed out of multiple layers of diverse materials, depending per type and manufacturer. An example of MLRI material is illustrated in Figure 1. While commonly used insulation materials try to minimize thermal conduction, MLRI materials also minimize thermal radiation. Therefore, common insulation materials do not require a cavity to function properly, but MLRI materials need to be adjacent to one of two cavities to maximize thermal resistance. Conversely, several manufactures claimed that their MLRI product may have extremely high thermal resistance when it is correctly applied in a façade. In addition, these MLRI materials are currently applied on a large scale in the sloping roofs of domestic houses. In the current standard ISO 6946:2007 only calculation rules for a cavity adjacent to a reflecting layer in the horizontal or vertical position are provided. Since there is no comprehensive standard, there is uncertainty about the thermal performance of MLRI materials under additional angles, both for downward and upward heat flows. Therefore the claims of the manufactures were questioned and investigated with numerical simulation, using COMSOL Multiphysics® 4.2, and were compared with heat flow measurements.

This work presents several simulations in which the thermal performance of the cavities surrounding a MLRI material under various angles and for downward and upward heat flows is analyzed. An older test model created in COMSOL Multiphysics® 3.5 is presented in Figure 2. In summary, related literature on heat transfer in facade cavities and the results from these simulations, compared with heat flow measurements and literature are presented. The heat flow measurements were conducted with a standardized instrument to determine the thermal conductivity of insulation materials.

The simulations demonstrate that MLRI indeed can reach high thermal resistance values when placed under certain angles, while at different angles the thermal resistance value of the sample can be substantial lower. Still, the values presented by the manufacturer of the used MLRI material do no correlate with the data from the numerical models and is higher as the found thermal resistance values. The heat transfer by radiation in both cavities is highly reduced, by the

highly reflective surfaces of the MLRI material. Meanwhile, convective heat transfer has a more dominant effect on the heat transfer through the sample, since the radiation in the cavities is highly decreased. The results of this study provide additional understanding of the heat transfer mechanics in a façade in which a cavity with MLRI material is applied. Moreover, these simulations suggest that 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. In sloping roofs, however, the convective heat transfer is higher thereby reducing the thermal resistance.

Figures used in the abstract

Figure 1: An example of a Multi-Layer Reflective Insulation material.

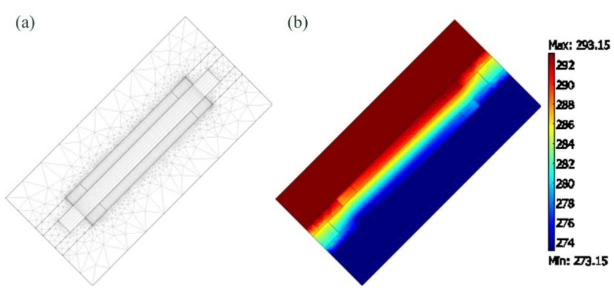

Figure 2: A test model of the MLRI material surrounded by two cavities, under 45 degrees with an upward heat flow (created in COMSOL Multiphysics® 3.5): (a) The mesh; (b) The temperature distribution in [K].