BUILD SIMUL (2012) 5: 337 – 344
DOI 10.1007/s12273-012-0064-9

Detailed numerical simulation of coupled heat transfer by conduction, natural convection and radiation through double honeycomb walls

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Abstract

The aim of the present work is to study numerically 2-D steady state coupled heat transfer by conduction, free convection and infra-red radiation through two honeycomb walls separated by a vertical air layer. Airflow in both holes and separating air layer is laminar. The limiting vertical sides of the double honeycomb wall are assumed to be isothermal but at different temperatures while the upper and lower horizontal surfaces of the structure are insulated. The FVM method and the SIMPLE algorithm are used to solve numerically the equations of conservation of mass, momentum and energy in both air filled cavities and solid partitions. It is found that the global heat flux across the entire wall varies almost linearly with the difference between the outside and the inside temperatures. Based on this linear thermal behaviour, appropriate overall heat exchange coefficients are derived. These coefficients can be used easily in practice to predict the global heat transfer across the studied honeycomb walls without solving the detailed and complex equations that govern the different heat transfer mechanisms. Effect of the thermal conductivity of the construction material on the overall heat transfer through double honeycomb walls is studied.

Keywords

double honeycomb walls,
vertical air layer,
conduction,
natural convection,
radiation,
overall thermal conductance

Article History

Received: 7 May 2011
Revised: 21 May 2012
Accepted: 4 July 2012

1 Introduction

Actually, double honeycomb walls are widely used as buildings envelop components in several countries particularly in North Africa and Middle East. This is due to their efficiency in reducing both heat transfer and noise and minimizing heating and air-conditioning loads.

The heat exchanges through the honeycomb walls are made simultaneously by free convection in the air filled cavities, infra-red radiation between their internal sides and heat conduction in the surrounding solid partitions. Because of the coupling between the three heat transfer mechanisms in studied honeycomb walls, it is necessary to use a detailed model to solve simultaneously the complex and non linear governing equations to obtain accurate simulation results and good thermal behaviour analysis.

The problem of the coupling between the processes of heat transfer was the subject of the lot of works in the literature and the majority of them are fundamental studies on the effects of conduction and/or radiation on natural convection in enclosures. These works are very numerous to be quoted here. Exhaustive bibliographic reviews of the coupled heat transfer by convection, conduction and/or radiation in hollow structures were made in previous works (Ait-Taleb et al. 2008a, b; Abdelbaki et al. 2001; Abdelbaki and Zrikem 1999). Furthermore, it is well known that, in convection–radiation coupling problems, the studies must be performed on real situations where both real geometric parameters and thermal excitations must be specified instead of the dimensionless parameters. For example, in a differentially heat square cavity, the effective values of both cavity dimension and sides temperature must be specified instead of the Rayleigh number because of the participation of radiation heat transfer.

For the reasons cited above, it is more interesting to limit the present bibliographic review to the studies which touch directly to the problem of coupled heat transfer in alveolar components of building walls. Al-Hazmy

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