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Quasi-isotropic laminated phase-change material system

K. Darkwa *

Applied Energy and Environmental Engineering Group, School of Architecture, Design and Built Environment, Nottingham Trent University, Burton Street, Nottingham NG1 4BU, UK

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Abstract

A composite quasi-isotropic laminated PCM system, based on two geometric configurations, has been evaluated theoretically for application in buildings. The results show significant increases in the rate of heat transfer in the triangular formation over the square type. There is however need for further optimisation and development of this technique with heat-enhancing materials.

Keywords: Quasi-isotropic; Phase-change material; Thermal-energy storage

1. Introduction

The growing trends of energy consumptions in the building sector have intensified the need for appropriate and effective technological solutions. One potential concept, which has attracted considerable research and development over the past decade, is the integration of phase-change materials (PCMs) into fabrics of buildings. It has been reported in various publications [1–7] that PCMs could help reduce energy consumptions in buildings through various techniques and applications.

However, due to heat transfer and integration problems, the application of PCMs are yet to become commercially viable in buildings. There are also life-cycle limitations associated with repeated melting and freezing of PCMs, which result in void formation, and

* Tel.: +44 1158482557; fax: +44 1158486140.
E-mail address: kojo.darkwa@ntu.ac.uk

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Nomenclature

k	thermal conductivity (W/mk)
L	latent heat of fusion (J/kg/K)
T	temperature (°C)
t	time (s)

Subscripts

i	intial
l	liquid
m	melting
o	outside
s	solid

degradation of thermal-energy storage/release capability of PCM wallboards. In this regard, investigations, such as Velraj et al. [8] have evaluated a composite wall board system and achieved an increase in thermal conductivity, but did recognise the need for the PCM fractions to be reduced and re-arranged in a matrix form in order to minimise heat diffusion time. Koschenz and Lehmann [9] thermally evaluated an activated PCM ceiling panel, but found the thermal response to be below the anticipated target. Darkwa and Kim [10] numerically analysed an encapsulated neuron-composite PCM system for improving heat-transfers at the moving boundary layers in PCMs but did experience a multidimensional heat-transfer profiling. Further studies covering two integrated methods of PCMs, i.e. randomly mixed-PCM and laminated PCM have been conducted with the laminated technique achieving better heat-transfer performances [11,12]. There was however a lower rate of heat transfer than the anticipated target and this was partly attributed to the bonding effect of the adhesive material on the thermal characteristics of the PCM and inadequate lamination process.

The two methods have also been simulated in a passively-designed room and found the laminated PCM-wallboard increases the minimum room-temperature at night by over 2 °C and is a more efficient way of utilizing latent heat [13,14]. The general conclusions were that the laminated PCM boards possess the greatest potential for heating and cooling applications in buildings, but further investigations were necessary.

One key finding was that effective spatial-distribution of PCMs could minimise temperature gradients and ultimately increase the effective thermal-conductivity and heat-transfer rates in laminated PCM drywalls. This is based on the fact that during the phase-change process, the interface surfaces of a PCM become wet by the compound driving out all air pockets in the interface, and thus eliminating the interface resistance component of the thermal impedance. Also, since the thermal impedance of the material is proportional to the thickness of the material in the interface and inversely proportional to thermal conductivity, it is necessary to have the minimum thickness of material that completely fills the interface after phase change and with the highest possible thermal conductivity. It should therefore be possible to select the orientations of the heat-enhancing material and tailor it to the properties of the laminated sheet to ensure a better thermal-performance. This study is intended to model and simulate the spatial-distribution concept of PCM for thermal evaluation.