International Communications in Heat and Mass Transfer 66 (2015) 233–239

Contents lists available at ScienceDirect

International Communications in Heat and Mass Transfer

journal homepage: www.elsevier.com/locate/ichmt

Experimental study of heat transfer enhancement of inserted LED lamp by the closed-cell aluminum-foam ceiling☆

Tzer-Ming Jeng *, Sheng-Chung Tzeng, Yu-Chuan Lin

Department of Mechanical Engineering, Chienkuo Technology University, 500 Changhua, Taiwan, ROC

ARTICLE INFO

Available online 26 June 2015

Keywords:
Closed-cell aluminum foams
Heat transfer
LED lamp
Ceiling

ABSTRACT

This work systematically studied the heat transfer characteristics of the porous green building materials. The base materials of these porous green building materials were closed-cell aluminum foams. When the LED lamp is inserted into this porous material, the porous materials may enhance the heat transfer capacity of the heat sink of LED lamp due to their high thermal conductivity. Total four kinds of test heat sinks were employed: (1) Model A—the copper-alloy powder and composite-graphite heat sink with the annular aluminum-alloy conductive base; (2) Model B—the aluminum-alloy powder and composite-graphite heat sink with the annular aluminum-alloy conductive base; (3) Model C—the composite-graphite heat sink with the annular aluminum-alloy conductive base and copper-foam fins; and (4) Model D—the aluminum-alloy heat sink of the Philips LED lamp (Model no.: MASTER LED PAR38 MV). The results showed that the height of the present ceiling's upper space was not the sensitive parameter for heat transfer. Therefore, lower ceiling's upper space is suitable for installing. Among various heat sinks, Model D heat sink had the lowest total thermal resistance. The thermal resistance of the Model D heat sink inserting into the closed-cell aluminum-foam ceiling was only about 0.34 times of that inserting into the wooden ceiling. The other three heat sinks had the similar thermal resistances. The thermal resistances of those three heat sinks inserting into the closed-cell aluminum-foam ceiling were only about 0.33–0.39 times of those inserting into the wooden ceiling. This work demonstrates that the closed-cell aluminum-foam ceiling did help in the cooling of LED lamp.

1. Introduction

Public fire occurs frequently, causing huge loss of life and property. Thus, the most appropriate method of protecting safety of life and property is to enhance the fire rating of building materials. Accordingly, the government and nongovernmental organizations pay more attention to fire performance of public and interior decoration material. It is an inevitable tendency that the fire building material will be used widely. As porous metal materials have been developed rapidly in recent years, there is a variety of products. According to the separate or interconnected cells, the metal product can be divided into: (1) the porous metal material with separate distributed cell structure and (2) the porous metal material with interconnected cell structure. The former consists of closed-cell metal foam and filling hollow metal particles which is lightweight, rigid, high-strength, shock-absorptive, sound-proof and heat-insulated. In particular, the closed cell metal foam has high-strength mechanical properties and high melting-point temperature. Besides, the internal structure is filled with closed cells. The overall weight is light. It is suitably used as fire heat-insulated fire building material.

Raj and Daniel [1] used artificial neural network method to simulate compressive property of closed-cell aluminum foam, including maximum pressure, the elastic modulus and energy absorption capacity. The sensitive parameters included porosity, average cell diameter and length–width ratio of cells. Raj and Daniel [2] observed the effect of the microstructure on the compressive properties of the closed-cell aluminum foam. They found that greater length–width ratio can enhance the stability of the foam material, and the cell edge effect on the mechanical properties is greater than cell face effect. Idris et al. [3] pointed out that reducing the porosity of closed-cell aluminum foam and increasing its thickness can increase the capacity of withstanding maximum stress and absorbing energy. They also found that the non-isotropic is more significant when the foam material has lower porosity. Konstantinidis et al. [4] used 3D analysis models to predict mechanical properties of closed-cell aluminum foam and open aluminum foam under a compressive load. Cady et al. [5] evaluated temperature and strain rate effect on compressive properties of closed-cell aluminum foam under static and dynamic loads, and found that distortion of

☆ Communicated by W.J. Minkowycz.

* Corresponding author at: Department of Mechanical Engineering, Chienkuo Technology University, No. 1, Chieh Shou N Rd., 500 Chang Hua, Taiwan, ROC.
E-mail addresses: tm.jeng@msa.hinet.net, tmjeng@cc.ctu.edu.tw (T.-M. Jeng).

http://dx.doi.org/10.1016/j.icheatmasstransfer.2015.06.001
0735-1933/

Nomenclature

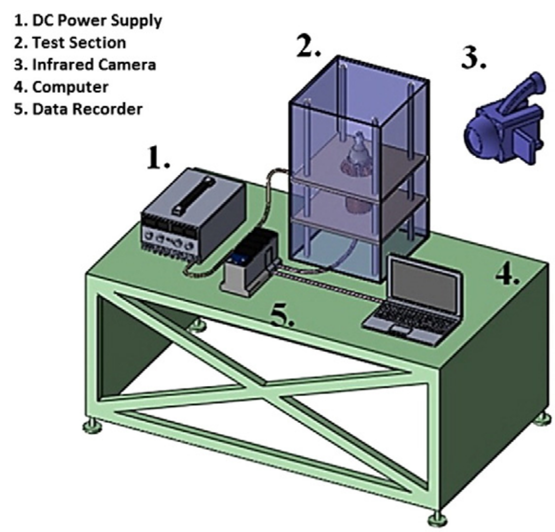
A	Surface area of film heater (m^2)
D	Diameter of film heater (m)
H	Height of the ceiling's upper space (m)
I	Electrical current (I)
k	Thermal conductivity (W/m/K)
R	Thermal resistance (°C/W)
T_0	Temperature of the ambient (°C)
T_w	Average temperature of the heating wall (°C)
t	Thickness of the ceiling (m)
V	Electrical voltage (V)
Q_t	Total input power (W)
Q_{Loss}	Heat loss (W)

closed-cell aluminum foam is strongly affected by temperature. Shen et al. [6] indicated that the mechanical properties of closed-cell aluminum foam are different at low strain rate and high strain rate. They also discussed change of energy absorption capacity of closed-cell aluminum foam energy at high strain rate, and proposed the relevant empirical model. Mu et al. [7] implemented quasi-static pressure testing of the closed-cell foam material. The results indicated that the cell shape and heterogeneous foam structure are the main reasons affecting the distortion pattern. Vodenitcharova et al. [8] used experimental method to investigate the response of cell shape and size on closed cell foam sheet on local deformation. Mukherjee et al. [9] explored the effect of cooling rate effect on formed structure and mechanical properties of closed-cell aluminum foam in fabrication, and they found that higher cooling rate is useful for the cell structure and enhancement of mechanical properties. Song et al. [10] investigated the three-dimensional dynamic failure behavior of closed-cell foam material, and found that adding irregularity of cell shape can improve the capabilities of closed-cell foam material to absorb energy. Xia et al. [11] discussed the compressive properties of closed-cell aluminum foam added with different manganese additives, and indicated that as compared to pure aluminum foam material, manganese foam material has higher hardness, compressive strength and energy absorption capability.

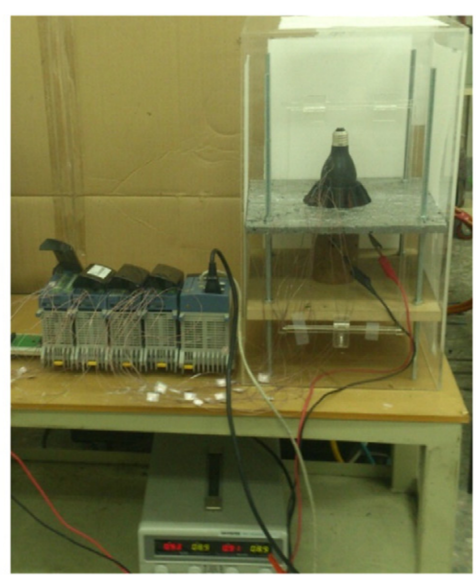
By reviewing the previous literature on closed-cell porous metal medium, most were focused on effect of the program (e.g., cooling rate) and additions (e.g., manganese) on the mechanical properties, or internal cell shape, size and porosity of closed-cell porous metal medium under static or dynamic load or different strain rates on the mechanical

Fig. 1. Installation diagram of LED lamp embedded in the ceiling.

Fig. 2. Schematic diagram of heat transfer for LED lamp embedded in the closed-cell aluminum-foam ceiling.



(a) Schematic diagram



(b) Physical photo

Fig. 3. Experimental setup.