



ELSEVIER

Available online at www.sciencedirect.com

SCIENCE @ DIRECT®

International Communications in Heat and Mass Transfer 32 (2005) 947–953

International Communications in
**HEAT and MASS
TRANSFER**

www.elsevier.com/locate/ichmt

Heat transfer correlations for open-cellular porous materials[☆]

Kouichi Kamiuto^{*}, San San Yee

Department of Mechanical and Energy Systems Engineering, Oita University, Dannoharu 700, Oita 870-1192, Japan

Available online 7 April 2005

Abstract

A general correlation for volumetric heat transfer coefficient between stream of air and open-cellular porous materials was derived utilizing experimental data obtained by several researchers. The derived correlation is written in form of $h_v = (A/D_s^{2-n})u^n$. Here, h_v denotes the volumetric heat transfer coefficient, A is the constant, n is the velocity exponent, u is the mean fluid velocity and D_s is the equivalent strut diameter of Dul'nev's unit cell for open-cell foam. The parameters, A and n , were determined by a least-square fit of the expression to the above-mentioned experimental data to give $A = 13.0$ and $n = 0.791$. Moreover, from the h_v – u correlation thus determined, the following Nusselt vs. Reynolds number heat transfer correlation was proposed: $Nu_s = 0.124(Re_s Pr)^{0.791}$, where Nu_s represents the Nusselt number defined by $h_v D_s^2 / k_f$, Re_s denotes the Reynolds number defined by $u D_s / \nu_f$, Pr is the Prandtl number, k_f is the thermal conductivity of fluid and ν_f is the kinetic viscosity of fluid. It is found that this correlation approximates 78.1% of the available experimental data with an error of less than $\pm 40\%$.

© 2005 Elsevier Ltd. All rights reserved.

Keywords: Open-cellular porous material; Volumetric heat transfer coefficient; Heat transfer correlation; Nusselt number; Reynolds number

1. Introduction

High-porosity open-cellular porous materials, consisting of pentagonal dodecahedron unit cells with open cell-walls as shown in Fig. 1(a), are recognized to be very promising as heat transfer elements of convection–radiation–converters, regenerative heat exchangers, combustor–incinerators and so forth

[☆] Communicated by K. Suzuki and S. Nishio.

^{*} Corresponding author.

E-mail address: kamiuto@cc.oita-u.ac.jp (K. Kamiuto).

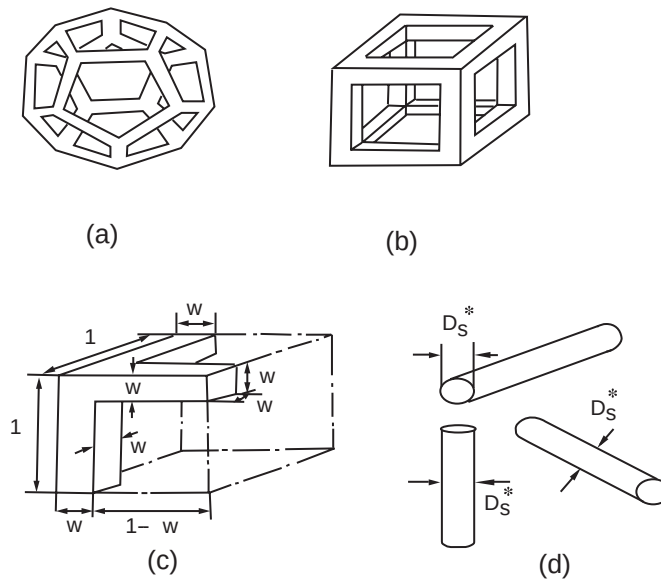


Fig. 1. Model systems for open-cellular porous materials: (a) perspective view, (b) unit cell model by Dul'nev, (c) rearranged unit cell model and (d) equivalent cylindrical struts derived from the unit cell model.

[1,2]. Thermal design and operation of these facilities require fundamental knowledge of the heat transfer characteristics of this kind of porous medium to be known.

When local thermal equilibrium between a fluid stream and the solid phase does not exist within a porous medium, a two-energy-equation model must be utilized as a heat transfer model: the volumetric heat transfer coefficient between a fluid stream and the solid phase h_v appears as parameter and must be prescribed beforehand as a function of relevant system parameters.

Considerable efforts to determine the volumetric heat transfer coefficient between air and open-cell foams [3–9] and to derive dimensionless heat transfer correlations have been made during the recent few decades, but a general Nusselt versus Reynolds number heat transfer correlation covering experimental data obtained by many researchers has not yet been established. To establish such a general heat transfer correlation, it is most important to select appropriate characteristic lengths of open-cellular porous materials. In the present paper, we propose use of an equivalent strut diameter of open-cell foam based on Dul'nev's unit cell model [10] as a representative characteristic length l and derive a Nusselt versus Peclet number correlation on the basis of the proposed equivalent strut diameter of open-cell foam.

2. Derivation of heat transfer correlations

To determine the volumetric heat transfer coefficient h_v , two kinds of experimental method have been adopted in literature: unsteady and steady methods. Almost all the previous studies have adopted the unsteady transient method called a single-blow method. In this method, transient temperature response of the solid phase of a porous medium suddenly exposed to a fluid stream with different temperature or response of exit fluid temperature of a porous medium subject to abrupt change in inlet fluid temperature are recorded and then inverse analyses of these data are conducted. On the other hand, there exist two

Download English Version:

<https://daneshyari.com/en/article/10392427>

Download Persian Version:

<https://daneshyari.com/article/10392427>

[Daneshyari.com](https://daneshyari.com)