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Numerical analysis of radiation effects in a metallic foam by means of the radiative conductivity model

Assunta Andreozzi [a], Nicola Bianco [a,*], Oronzio Manca [b], Vincenzo Naso [a]

[a] DETEC, Università degli Studi di Napoli Federico II, P.le Tecchio 80, 80125 Napoli, Italy
[b] DIAM, Seconda Università degli Studi di Napoli, Via Roma 29, 81031 Aversa (CE), Italy

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ABSTRACT

The aim of this work is the evaluation of the radiation contribution to the steady-state heat transfer in metallic foams by means of the radiative conductivity model. Because of the complexity of the structure, reference is made to a simplified physical radiative model, where the elementary cell of the foams is treated as a cubic cell. The contribution of the radiation heat transfer is investigated on a local basis. The local radiative conductivity has been used to evaluate the influence of radiative heat transfer in a two dimensional conductive-convective-radiative problem involving a forced fluid flow within a heated channel filled with a metallic foam. The effect of the solid emissivity and the foam porosity is pointed out for different foams.

1. Introduction

Porous media and metallic foams are widely used in heat transfer applications, because of their large ratio of the surface area to the volume as well as flow mixing capability enhanced by the tortuous pattern. Heat transfer in highly porous metallic foams, with particular attention to the radiation was widely investigated [1]. Heat and mass transfer characterization of foams requires the geometrical representation of their complex porous structure, which is needed for the direct pore-level numerical simulations [2,3]. Radiation heat transfer in metallic foams was studied in some recent works [4–6]. De Micco and Aldao [4,5] employed two different approaches: the former was based on the solution of a geometric model and the latter was derived from the experimental determination of the extinction coefficient. The extinction coefficient, the scattering albedo and the scattering phase function were evaluated by using simple predictive models in [6]. An approximated equation that predicts the solar transmittance of transparent honeycombs was presented by Hollands et al. [7]. The method accounted for scattering that occurs in such honeycombs by introducing diffuse components for both the reflectivity and the transmissivity of the honeycomb. Some papers report the evaluation of radiation contribution in metallic foams for TIM (Transparent Insulation Materials) [8–13]. TIM can be useful solar energy materials and the transparent honeycomb has certain important advantages. Suehrcke et al. [10] designed a simple guarded hot-plane apparatus for the measurement of heat transfer through a transparent insulation. The apparatus was used to measure the heat transfer through a transparent corrugated sheet and a honeycomb transparent insulation. Glicksman et al. [11] analyzed the contribution of radiation heat transfer to the overall conductivity of foam insulations by measuring the absorption and scattering coefficients and presented a heat transfer model using Rosseland equation. Kaushika and Arulanantham [12,13] formulated a physical model to evaluate the radiation heat transfer in transparent honeycomb insulating materials, that accounts for refraction, reflection, absorption, and scattering. Different shape models of foams were proposed in the aforementioned papers. A simplified tetrakaidecahedron shape to model the metallic foam was assumed in [14–16]. Zhao et al. [14] measured the effective thermal conductivity of a high temperature metal foam produced via the sintering route in the range 300–800 K. The spectral transmittance and reflectance of FeCrAlY foams were measured and a numerical model based on the effective continuum medium approach was developed by Zhao et al. [15]. An analytical model based on fundamental foam parameters was presented in [16]. A simple cubic cell model was used to capture the behavioural trends of radiative energy flow in the highly porous cellular foams.

The aim of this paper is the evaluation of a local radiative conductivity in metal foams by means of the model presented in Zhao et al. [16]. The local radiative conductivity has been used to evaluate the influence of radiative heat transfer in a two dimensional conductive-convective-radiative problem involving a forced fluid flow within a heated channel filled with a metallic foam.

* Corresponding author. Tel.: +39 0817682645; fax: +39 0812390364.
E-mail addresses: assunta.andreozzi@unina.it (A. Andreozzi), nicola.bianco@unina.it (N. Bianco), oronzio.manca@unina2.it (O. Manca), vincenzo.naso@unina.it (V. Naso).

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