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Local Thermal Non-Equilibrium Investigation on Natural Convection in Horizontal Channel Heated from Above and Partially Filled with Aluminum Foam

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Abstract

The configuration of two horizontal parallel walls, with heated upper plate and open cavities, gets considerable attention in many thermal engineering applications. In this work, a numerical investigation on steady state natural convection in a horizontal channel partially filled with a porous medium and heated at uniform heat flux from above is carried out. The local thermal non-equilibrium (LTNE) hypothesis is invoked. A three-dimensional model is realized and solved by means of the ANSYS-FLUENT code. Results are presented in terms of velocity and temperature fields and profiles, and they show that the use of porous medium improves the heat transfer in the channel due to the aluminum foam high conductivity.

Keywords: Metal foam; heat transfer; natural convection; LTNE; horizontal channel.

1. Introduction

In natural convection applications, the configuration of two horizontal parallel walls, with heated upper plate and open cavities, gets considerable attention in many thermal engineering applications, such as cooling of electronic components and devices, chemical vapor deposition systems and solar energy systems.

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In this work, a numerical investigation on steady state natural convection in a horizontal channel partially filled with a porous medium and heated at uniform heat flux from above is carried out in LTNE conditions. The flow motion is strongly affected by the location of the heated surface, positioned on the upper or the lower wall of the horizontal channel [1-7]. Secondary flows are induced by buoyancy force due to the heating of the cavity walls, hence the local heat transfer increases [2-4, 6]. The onset point of the secondary flows delineates the region after which the two-dimensional laminar flow becomes three-dimensional and a transition motion of the flow from laminar to turbulent is observed [5-6]. The main flow shows a "C" loop behavior very close to the flow inside open-ended channels and open cavities [5, 8]. The main flaw in natural convection is caused by the low heat exchanged between flow and walls, and one of the technique to enhance the heat transfer is expanding the exchange surfaces. Porous media provided with high thermal conductivity, like metal foams, are an adequate method of heat transfer enhancement due to their large surface area to volume ratio and to intense mixing of the flow [9]. In [7, 10], natural convection in high porosity metal foams heated from below is studied numerically and experimentally. In [11], the design of aluminum foam was experimentally built and the calibration was done comparing the results of a flat plate with literature data and the agreement resulted excellent. The investigated foams had a pore density of 10 and 20 PPI and the bonding of the foam was performed employing a single epoxy or via brazing. A numerical simulation investigates steady laminar incompressible non-Darcian natural convection heat transfer in an enclosed cavity that is filled with a fluid-saturated porous medium and the two-equation model is used to separately account for the local fluid and solid temperature [11, 12]. Numerical results of laminar fully developed natural convection in an inclined channel partially filled with metal foam are studied in [13]. An experimental investigation of air natural convection in horizontally-positioned copper metallic foams with open cells is performed in [14]: results show that the porosity influence on the heat transfer performance is more remarkable when the pore density is higher, and natural convection in the copper foam weakens its thermal resistance and enhances its heat transfer performance. The natural convection on metallic foam-sintered plate at different inclination angles is experimentally studied in [15]. A numerical investigation of the natural convection heat transfer in a rectangular cavity filled with a heat-generating porous medium by adopting the local thermal non-equilibrium (LTNE) model is reported in [16].

Studies on partially opened cavities filled with porous media and investigations on partially filled horizontal channels with porous media are reported in [17-21].

In this work, a numerical investigation on steady state natural convection in a horizontal channel partially filled with a porous medium and heated from above is carried out. A three-dimensional model is realized and solved by means of the ANSYS-FLUENT code, in LTNE conditions. The computational domain is made up of the principal channel and two lateral extended reservoirs at the open vertical sections. Furthermore, a porous plate is considered near the upper heated plate and it fills the channel partially. Channel partially filled with metal foam configuration is compared to the configuration without foam.

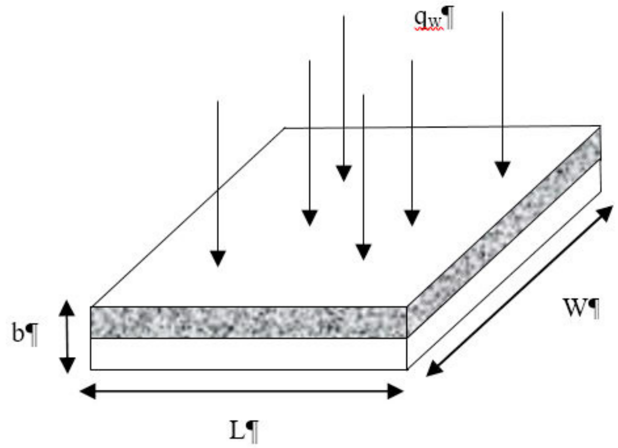

Fig. 1. Physical Domain.