International Communications in Heat and Mass Transfer 38 (2011) 110–118

Contents lists available at ScienceDirect

International Communications in Heat and Mass Transfer

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

Numerical modeling of natural convection in an open cavity with two vertical thin heat sources subjected to a nanofluid ☆

Amir Houshang Mahmoudi, Mina Shahi *, Abed Moheb Shahedin, Neda Hemati

Department of Mechanical Engineering, Faculty of Engineering, Semnan University, Semnan, Iran

ARTICLE INFO

Available online 18 November 2010

Keywords:
Natural convection
Numerical study
Open cavity
Heat source
Nanofluid

ABSTRACT

This paper presents a numerical study of natural convection cooling of two heat sources vertically attached to horizontal walls of a cavity. The right opening boundary is subjected to the copper–water nanofluid at constant low temperature and pressure, while the other boundaries are assumed to be adiabatic. The governing equations have been solved using the finite volume approach, using SIMPLE algorithm on the collocated arrangement. The study has been carried out for the Rayleigh number in the range $10^4 \leq Ra \leq 10^7$, and for solid volume fraction $0 \leq \varphi \leq 0.05$. In order to investigate the effect of heat source location, three different placement configurations of heat sources are considered. The effects of both Rayleigh numbers and heat source locations on the streamlines, isotherms, Nusselt number are investigated. The results indicate that the flow field and temperature distributions inside the cavity are strongly dependent on the Rayleigh numbers and the position of the heat sources. The results also indicate that the Nusselt number is an increasing function of the Rayleigh number, the distance between two heat sources, and distance from the wall. In addition it is observed that the average Nusselt number increases linearly with the increase in the solid volume fraction of nanoparticles.

1. Introduction

Natural convection in open cavities has a wide range of industrial applications and has been studied extensively in the literature [1–7]. Some applications are solar thermal receivers, energy-saving household refrigerators, and electronic cooling, etc. Most of researchers considered natural convections inside open ended enclosures in contact with pure fluid. However, there are no studies concerning the cooling process in open cavities filled by nanofluid. In recent years, nanofluids have attracted more attention for cooling in various industrial applications. Such fluids consist of suspended nanoparticles which have a better suspension stability compared to millimeter or micrometer sized ones. Use of metallic nanoparticles with high thermal conductivity will increase the effective thermal conductivity of these types of fluid remarkably. Since nanofluid consists of very small sized solid particles, therefore in low solid concentration it is reasonable to consider nanofluid as a single phase flow [8]. So, it is needed to present a brief review including cavities filled by nanofluids. A numerical study of natural convection of copper–water nanofluid in a two–dimensional enclosure was conducted by Khanafer et al. [9]. The nanofluid in the enclosure was assumed to be in single phase. It was found in any given Grashof number, heat transfer in the enclosure increased with the volumetric fraction of the copper nanoparticles in water. Ho et al. [10] presented two–dimensional numerical simulation of buoyancy-driven convection in the enclosure filled with alumina-water nanofluid. The effects of adopting different formulas for the effective viscosity and thermal conductivity have been identified. A significant difference was found in the effective dynamic viscosity enhancement calculated from considered formulas other than increment of thermal conductivity. Santra et al. [11] numerically investigated the laminar natural convection heat transfer in a differentially heated square cavity filled with copper–water nanofluid. They considered a two parameter power law model for an incompressible non-Newtonian fluid. Oztop et al. [12] investigated the natural convection heat transfer in partially heated enclosures. Their studies have been carried out for different water based nanofluids. Other researches have been conducted that simulate the natural convection heat transfer using nanofluid in the other geometrical configurations [13–18].

Literature reviews show that laminar natural convection on an open cavity with a heat source has interesting applications in cooling of electronic equipment. Jaluria [19] studied numerically the three-dimensional conjugate heat transfer in a rectangular duct with two discrete flush-mounted heat sources in the context of cooling of electronic equipments.

The present study conducts a numerical study of laminar natural convection heat transfer to copper–water nanofluid from two identical

☆ Communicated by W.J. Minkowycz

* Corresponding author. University of Semnan, Central organization, Molavi Blvd, Saadi Sq. ,Semnan, Iran.
E-mail address: mina.shahi@gmail.com (M. Shahi).

0735-1933/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.icheatmasstransfer.2010.09.009