Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 105 (2015) 388 – 397

Procedia Engineering

www.elsevier.com/locate/procedia

6th BSME International Conference on Thermal Engineering (ICTE 2014)

Effect of tilt angle on pure mixed convection flow in trapezoidal cavities filled with water-Al_2O_3 nanofluid

Mahmudul Hasan Hasib*, Md. Saddam Hossen, Sumon Saha

Department of Mechanical Engineering, Bangladesh University of Engineering and Technology, Dhaka 1000, Bangladesh

Abstract

A numerical study is carried out to investigate the effect of tilt angle of the cavity on mixed convection heat transfer inside two different lid-driven trapezoidal cavities; one having heated wall on short base and another having heated wall on long base. In this investigation, the top wall is maintained at isothermal cold temperature, which is moving in its own plane at a constant speed while a constant high temperature is provided at the bottom surface of the cavity. The cavity is assumed to be filled with water-Al_2O_3 nanofluid. The governing Navier–Stokes and thermal energy equations and boundary conditions are non-dimensionalised and are solved using Galerkin finite element method. Attention is paid in the present study on the pure mixed convection regime at Richardson number, Ri = 1 where the natural and the forced convection are equally dominated. Parametric investigations are carried out by taking base wall tilt angle from 0^o to 45^o with a step of 15^o and also varying Reynolds numbers from 0.1 to a maximum order of 10^4 with the corresponding Grashof numbers varying from 0.01 to a maximum order of 10^8 for Ri = 1. Simulations are carried out by considering both plain fluid (water) and nanofluid with 10% solid-volume fraction of nanoparticles. Flow and heat transfer characteristics are explained using streamline and isotherm contours, and the variation of average Nusselt number of the heated wall and average fluid temperature of the cavity are analysed for different tilt angles.

Peer-review under responsibility of organizing committee of the 6th BSME International Conference on Thermal Engineering (ICTE 2014)

Keywords: mixed convection; nanofluid; Richardson number; trapezoidal cavity; Nusselt number.

* Corresponding author. Tel.: +88 - 019 -1479 - 6443;
E-mail address: hasib_67@yahoo.com

Peer-review under responsibility of organizing committee of the 6th BSME International Conference on Thermal Engineering (ICTE 2014)
doi:10.1016/j.proeng.2015.05.024

1. Introduction

Mixed convection is the process of heat transfer including both natural and forced convection, which bears a great importance due to its wide applications such as cooling of electronic devices, lubrication technologies, heating and drying technologies, food processing, float glass production, flow and heat transfer in solar ponds, thermal hydraulics of nuclear reactors, dynamics of lakes, crystal growing, metal coating, reservoirs and cooling ponds, materials processing and so on.

There have been numerous studies in the past on mixed convective flow in lid-driven cavities. However, majority of these investigations considered the cases of simple geometry like square, rectangular or triangular cavities. Only a few studies considered the configuration of lid-driven trapezoidal cavities for mixed convection problems [1-5]. These cavities can be divided into two categories based on the length of the top and the bottom walls. Hossain *et al.* [1], Chowdhury *et al.* [2], Hasan *et al.* [3] and Mamun *et al.* [4] considered mixed convection inside a lid-driven trapezoidal cavity having heated wall on the short base. On the other hand, Bhattacharya *et al.* [5] performed investigation on lid-driven trapezoidal cavity with heated long base. Among these works, only Mamun *et al.* [4] showed the effect of cavity tilt angle on mixed convection heat transfer. Recently, Cheng [6] only pointed out the combined effect of Reynolds and Grashof numbers on pure mixed convection flow in a lid-driven square cavity. However, to the best of the authors' knowledge, no attention has been paid to investigate the effect of tilt angle on pure mixed convection flow inside the lid-driven trapezoidal cavity filled with nanofluid.

Nanofluid, after gaining popularity in various industrial applications, has become one of the effective means for the enhancement of convective heat transfer. This is because metallic nanoparticles such as copper, aluminum, silver, silicon, etc., with higher thermal conductivity improve the thermo-physical properties of the mixture of conventional base fluids like water, ethylene glycol, etc. Although many researchers such as Tiwari and Das [7], Talebi *et al.* [8], Abu-Nada and Chamkha [9] and Salari *et al.* [10] carried out investigations on mixed convection inside a lid-driven square cavity filled with nanofluid, a similar analysis inside a trapezoidal cavity is still missing. Therefore, the main objective of the present study is to present the influence of the cavity tilt angle of two different trapezoidal cavities filled with water-Al_2O_3 nanofluid on pure mixed convective flow condition. The combined effects of Reynolds and Grashof numbers on the characteristics of mixed convection heat transfer are also revealed via streamline and isotherm plots, and the variation of average Nusselt number and average fluid temperature of the cavity.

2. Problem formulation

Two lid-driven trapezoidal cavities with different base and top walls but equal domain area are considered in the present study. The schematic diagrams of these cavities along with their co-ordinate system are shown in Figs. 1 (a)

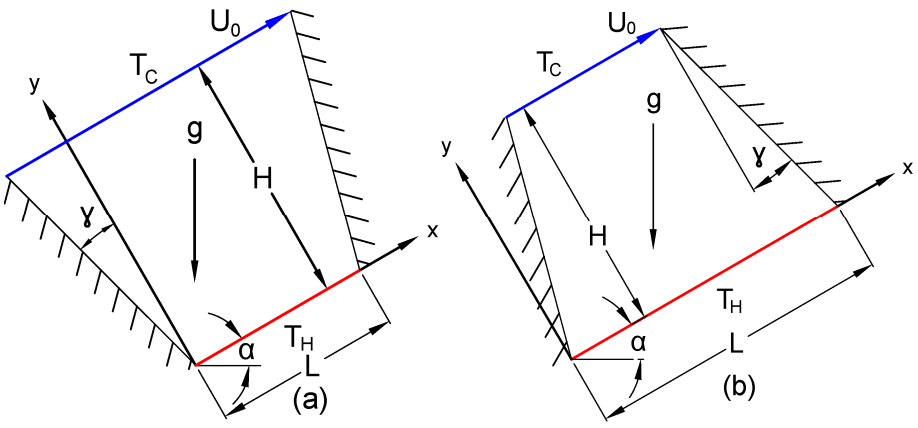

Fig. 1. Schematic representation of trapezoids having heated wall on (a) short base and (b) long base.