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Conjugate natural convection in air filled tube inserted a square cavity ☆

Hakan F.Oztop [a,b,*], Zaiguo Fu [c,d,**], Bo Yu [d], Jinjia Wei [e]

[a] Department of Mechanical Engineering, Technology Faculty, Firat University, TR-23119, Elazig, Turkey
[b] Department of Mech. Engineering, College of Engineering, King Saud University, Riyadh, Saudi Arabia
[c] Petroleum engineering college, Yangtze University, Jingzhou 434023, PR China
[d] Beijing Key Laboratory of Urban Oil and Gas Distribution Technology, China University of Petroleum-Beijing, Beijing 102249, PR China
[e] State Key Lab. of Multiphase Flow in Power Engineering, Xi'an Jiaotong University, Xi'an, PR China

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ABSTRACT

Numerical analyses of fluid flow and heat transfer due to buoyancy forces in a tube inserted square cavity filled with fluid were carried out by using control volume method in this study. The cavity was heated from the left wall and cooled from the right isothermally and horizontal walls were adiabatic. A circular tube filled with air was inserted into the square cavity. The case that the inside and outside of the tube were filled with the same fluid (air) was examined. Varied solid materials were chosen as the tube wall. Results were obtained for different Rayleigh numbers ($Ra=10^4$, 10^5 and 10^6), thermal conductivity ratio of the fluid to the tube wall ($k=0.1$, 1 and 10) and different location centers of the tube (c ($0.25\le x\le 0.75$, $0.25\le y\le 0.75$)). Comparison with benchmark solutions of the natural convection in a cavity was performed and numerical results gave an acceptable agreement. It was found that varied location of the tube center can lead to different flow fields and heat transfer intensities which are also affected by the value of Rayleigh number.

1. Introduction

Thermally driven fluid flow and heat transfer in differentially heated cavity have wide application areas in thermal engineering such as electronic equipment, solar collectors, oil storage, building heating, heat exchangers etc. Wide and excellent reviews on these applications can be found in the studies of De Vahl Davis and Jones [1], Catton [2] and Oztop et al. [3]. The topic of these studies is mostly on natural convection in cavities bounded by solid walls with zero thickness.

A divider can be located inside the cavity to control fluid flow and heat transfer in some applications. These can be found in the studies of Tong and Gerner [4], Turkoglu and Yucel [5], Nishimura et al. [6] and Ho and Yih [7]. They made numerical studies on natural convection in cavities with partition. Kahveci [8], Dzodzo et al. [9] and Khan and Yaho [10] investigated the effects of partition on the laminar natural convection heat transfer and fluid flow by numerical simulation and experiment. Also in present the author's earlier study [11], the natural convection heat transfer in an enclosure fully divided with a partition filled with different fluids was investigated. All of these studies show that the partition can be used as a control element for heat transfer and fluid flow. Here, the most important parameter is dimensionless thermal conductivity between partition and fluid.

Another application of conjugate problem in cavities is insertion of the body inside the enclosure with different temperature boundary conditions. In this context, Asan [12] studied the natural convection problem in an annulus between two isothermal concentric square ducts. The inner duct is heated and the outer one is cooled with constant temperature. Stream function-vorticity formulation was applied and control volume integration solution technique is adopted in this study. He found that the influence of dimension ratio on average Nu number differs in significance for inner and outer squares. Ha et al. [13] carried out two-dimensional unsteady natural convection inside an enclosure with a square body. They reported an unsteady flow and temperature fields when the Rayleigh number is high. Ha and Jung [14] conducted a numerical study of conjugate heat transfer of natural convection in a cubic enclosure with a centered cubic heat-conducting heat generating body. Dong and Li [15] studied the conjugate natural convection for a model of enclosure with high thickness ceiling and inserted solid circular body. The solid body is heated isothermally. They tested the effects of thermal conductivity ratios on heat and fluid flow. Varol et al. [16] solved the problem of natural convection in a triangular enclosure with inserted solid body under different thermal boundary conditions using finite difference method. Other similar studies can be found in Refs. [17–26].

In this study, conjugate natural convection heat transfer in a tube inserted square cavity was presented. A tube with finite thickness was inserted into cavities at different locations. This case may be referred to a pipe system in a conduit at motionless or very low fluid velocity. The

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* Correspondence to: H.F. Oztop, Department of Mechanical Engineering, Technology Faculty, Firat University, TR-23119, Elazig, Turkey. Tel.: +90 424 2370000x4356; fax: +90 424 241 5526.
E-mail addresses: hfoztop1@gmail.com, hOztop.v@ksu.edu.sa (H. F.Oztop), fuzaiguo2009@hotmail.com (Z. Fu).

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