International Communications in Heat and Mass Transfer 38 (2011) 263–274

Contents lists available at ScienceDirect

International Communications in Heat and Mass Transfer

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

Mixed convection heat transfer in a differentially heated square enclosure with a conductive rotating circular cylinder at different vertical locations☆

Salam Hadi Hussain, Ahmed Kadhim Hussein *

Mechanical Engineering Department, College of Engineering, Babylon University, Babylon Province, Iraq

ARTICLE INFO

Available online 18 December 2010

Keywords:
Mixed convection
Rotating circular cylinder
Enclosure
Conduction
Vertical cylinder locations
Finite volume

ABSTRACT

In this investigation, a numerical simulation using a finite volume scheme is carried out for a laminar steady mixed convection problem in a two-dimensional square enclosure of width and height (L), with a rotating circular cylinder of radius ($R = 0.2$ L) enclosed inside it. The solution is performed to analyze mixed convection in this enclosure where the left side wall is subjected to an isothermal temperature higher than the opposite right side wall. The upper and lower enclosure walls are considered adiabatic. The enclosure under study is filled with air with Prandtl number is taken as 0.71. Fluid flow and thermal fields and the average Nusselt number are presented for the Richardson numbers ranging as 0, 1, 5 and 10, while Reynolds number ranging as 50, 100, 200 and 300. The effects of various locations and solid–fluid thermal conductivity ratios on the heat transport process are studied in the present work. The results of the present investigation explain that increase in the Richardson and Reynolds numbers has a significant role on the flow and temperature fields and the rotating cylinder locations have an important effect in enhancing convection heat transfer in the square enclosure. The results explain also, that the average Nusselt number value increases as the Reynolds and Richardson numbers increase and the convection phenomenon is strongly affected by these parameters. The results showed a good agreement with further published works.

1. Introduction

Steady state convection heat transfer from a rotating cylinder to its surrounding enclosure is a subject of practical importance. This type of thermally driven flow is encountered in numerous applications especially in some building service situations, when a pipe carrying a hot water passes through an enclosure formed by structural components of the building, rotating-tube heat exchangers, and the drilling of oil wells. The function of the outer surface of the enclosure is to reduce the heat transfer from the inner rotating hot cylinder or to save the inner body in harsh outdoor environment. In recent years, the flow around a rotating circular cylinder is considered a fundamental fluid mechanics problem of great interest. It has potential relevance to a huge number of practical applications such as submarines, off shore structures, pipelines etc. Several numerical and experimental methods have been developed to investigate enclosures with and without rotating or stationary obstacle because these geometries have great practical engineering applications. Chang et al. [1] made a numerical analysis for natural convective heat transfer in an irregular two-dimensional enclosure formed by an inner square cylinder and an outer circular envelope. They also performed an experimental investigation to verify some of the numerical results. Glapke and Afsaw [2] presented some results for natural convection in a circular enclosure with an inner hexagonal concentric cylinder in the Rayleigh number range of 10^2 to 10^5. In their work, the velocity component in computational coordinate and that in physical coordinate were adopted as the primary independent variables. Elepano and Oosthuizen [3], studied natural convective flow in an enclosure containing a heated cylinder and a cooled upper surface numerically. They used stream function–vorticity formulation and the finite element technique to solve the governing equations. Oosthuizen and Paul [4], studied numerically, two-dimensional free convective flow in an enclosure which has a heated half-cylinder, kept at uniform high temperature. The enclosure has a horizontal upper and lower walls and inclined side walls. The side walls are kept at uniform temperatures and the top surface was considered adiabatic. They concluded that, when the flow in the enclosure was symmetrical about the vertical center-line of the enclosure, the dimensionless height of the enclosure was the only geometric parameter that had a significant effect on the mean heat transfer rate from the half-cylinder at a given Rayleigh number. Fu et al. [5] studied numerically natural convection of an enclosure by a rotating circular cylinder near a hot wall using a finite element method. They showed that the rotating cylinder direction had an important effect in enhancing natural convection heat transfer in the enclosure. Fu and Tong [6], numerically studied the flow structures and heat transfer characteristics of a heated cylinder oscillating transversely. They showed that

☆ Communicated by W.J. Minkowycz.

* Corresponding author.
E-mail addresses: salamphd1974@yahoo.com (S.H. Hussain), ahmedkadhim74@yahoo.com (A.K. Hussein).

0735-1933/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.icheatmasstransfer.2010.12.006