Mathematical and Computer Modelling 54 (2011) 2880–2888

Contents lists available at SciVerse ScienceDirect

Mathematical and Computer Modelling

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

Transient free-convective flow of reactive viscous fluid in vertical tube

Basant K. Jha, Ahmad K. Samaila *, Abiodun O. Ajibade

Department of Mathematics, Ahmadu Bello University, Zaria, Nigeria

ARTICLE INFO

Article history:
Received 16 March 2011
Received in revised form 5 July 2011
Accepted 7 July 2011

Keywords:
Transient free-convective flow
Reactive viscous fluid
Vertical tube

ABSTRACT

The problem of fully-developed transient free-convection flow of viscous reactive fluid in a vertical tube is analyzed both analytically and numerically. The study reports the effect of several operating parameters on the flow hydrodynamics and thermal characteristics. The solutions for transient state velocity and temperature fields are obtained by implicit finite difference method. To check the accuracy of the numerical solution steady-state solutions for temperature field and velocity field are obtained by using perturbation series method. Skin-friction and Nusselt number at the surface of tube are determined. The significant results from this study are that both velocity and temperature increase with the increase in the value of reactant consumption parameter and non-dimensional time until they reach steady-state value. The results also indicate that it takes longer time to attain steady-state in the case of water than air. During the course of computation, it was observed that the analytical and numerical solutions agree very well at large value of time.

1. Introduction

The investigation of free-convective flows is a classical problem in fluid dynamics and heat transfer with significance for a variety of engineering applications. These applications include nuclear reactor, solid matrix heat exchanger, porous flat plate collectors, oil recovery, dispersion of chemical contaminants in various processes, nuclear waste material, grain storage and drying and many others [1]. Also, free-convective flow is likely to find wider use as it could provide the flow mechanism in some types of solar heating and ventilating passive systems [2].

There has been greatly increased interest and research activity in free-convective flow problems. Singh et al. [3] reviewed these research activities. Jha et al. [4] investigated transient free-convective flow in a vertical channel due to symmetric heating of channel walls in the presence of temperature dependent heat sinks. The literature on the topic of free-convective flow in vertical channels is well surveyed by Joshi [5], Paul et al. [6], and Jha [7]. Also, work on free-convective flow due to symmetric and asymmetric heating has been reported by many investigators Miyatake and Fuzii [8]. Oosthuizen [9] considered numerical study of laminar free convective flow through a vertical open partially heated plane duct. Similarly, Pollard and Oosthuizen [10] considered the effect of free convection flow through open ended pipes. A numerical simulation of air in a channel-chimney system heated symmetrically at uniform heat flux is carried out by Andreozzi et al. [11]. Bianco et al. [12] investigated natural convection in vertical convergent and symmetrically heated channels by taking radiation effect into consideration. In an another article, Langelloto et al. [13] presented numerical investigation of natural convection in a convergent vertical channel in order to study the thermal and fluid dynamics behavior of the transient regime in this configuration.

Related works in natural convection research is the finding of new configurations to improve heat transfer or the analysis of standard configurations to determine optimal geometrical parameters in order to achieve a better heat transfer rate [14–17]. Recently, Jha and Ajibade [18] studied the transient natural convection flow between vertical parallel plates

* Corresponding address: Department of Mathematics, Usmanu Danfodiyo University, Sokoto, Nigeria. Tel.: +234 8036120027.
E-mail addresses: basant777@yahoo.co.uk (B.K. Jha), askamba2003@yahoo.co.uk (A.K. Samaila), olubadey2k@yahoo.com (A.O. Ajibade).

0895-7177/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.mcm.2011.07.008