ARTICLE IN PRESS
Ain Shams Engineering Journal (2015) xxx, xxx–xxx

Ain Shams University
Ain Shams Engineering Journal
www.elsevier.com/locate/asej
www.sciencedirect.com

MECHANICAL ENGINEERING

Effect of magnetic field on unsteady natural convective flow of a micropolar fluid between two vertical walls

Hari R. Kataria [a], Harshad R. Patel [b,*], Rajiv Singh [a]

[a] Department of Mathematics, Faculty of Science, The M.S. University of Baroda, Vadodara, India
[b] Applied Science & Humanities Department, Sardar Vallabhbhai Patel Institute of Technology, Vasad, India

Received 28 March 2015; revised 2 August 2015; accepted 28 August 2015

KEYWORDS
Micropolar fluid;
Vertical walls;
Unsteady flow;
Magnetic field

Abstract We study theoretically the boundary layer flow of an incompressible micropolar fluid under uniform magnetic field and motion takes place due to the buoyancy force between vertical walls. The governing unsteady boundary layer momentum, angular momentum and energy equations of micropolar fluid are nondimensionalized and solved numerically. Analytic result for steady state case is also discussed. The effects of magnetic parameter (M), vortex viscosity parameter (R), Prandtl number (Pr) and material parameter (b) on velocity, micro-rotation and Temperature profiles are discussed through several figures.

1. Introduction

Recently, the study of micropolar fluid has attracted many scholars as Navier–Stokes equations of Newtonian fluids cannot effectively describe the characteristics of fluid with suspended particles. Erigen [1] first introduced the theory of micropolar fluid and this theory is useful in explaining the characteristics of certain fluids such as liquid crystals, suspensions and animal blood. Chamkha [2] and Abdulaziz [3], studied the fully developed free convection of a micropolar fluid in vertical channel. Si [4] and Bég [5] have studied homotopy analysis solution for micropolar fluid flow through a porous medium. Rashidi [6], has studied Heat Convection in Magnetized Micropolar Fluid by Using Modified Differential Transform Method. Sadri [7] has discussed about Semi Analytical Solution of Boundary-Layer Flow of a Micropolar Fluid through a Porous Channel. Siddangoudaa [8] studied Squeezing Film Characteristics for Micropolar Fluid between Porous Parallel Stepped Plates.

Convection flow arises in many physical situations such as in the cooling of nuclear reactors and environmental heat transfer processes amongst others. It is of three types namely free, mixed and force. Amongst them, the problems of magneto hydrodynamic free convective flow in a porous medium have drawn considerable attentions of several researchers in various scientific and technological applications such as

* Corresponding author. Tel.: +91 9727413159.
E-mail addresses: hrkrmaths@yahoo.com (H.R. Kataria), harshadpatel2@gmail.com (H.R. Patel), Singhrajiv.bhu@gmail.com (R. Singh).
Peer review under responsibility of Ain Shams University.

Production and hosting by Elsevier

http://dx.doi.org/10.1016/j.asej.2015.08.013
2090-4479 © 2015 Faculty of Engineering, Ain Shams University. Production and hosting by Elsevier B.V.

Please cite this article in press as: Kataria HR et al., Effect of magnetic field on unsteady natural convective flow of a micropolar fluid between two vertical walls, Ain Shams Eng J (2015), http://dx.doi.org/10.1016/j.asej.2015.08.013

Nomenclature

b	material parameter
g	acceleration due to gravity
L	distance between two vertical walls
m	temperature ratio
M	magnetic parameter
Pr	Prandtl number
R	vortex viscosity parameter
t	time in non-dimensional form
t'	time
T'_c	temperature of the wall at $y' = L$
T'_h	temperature of the wall at $y' = 0$
T'_m	initial temperature of the fluid
u	fluid velocity in non-dimensional form
u'	velocity of fluid
y	dimensionless co-ordinate perpendicular to the walls
y'	co-ordinate perpendicular of the walls
ω	dimensionless angular velocity
j	micro-inertia density
κ	vortex viscosity
μ	dynamic viscosity

Greek symbols

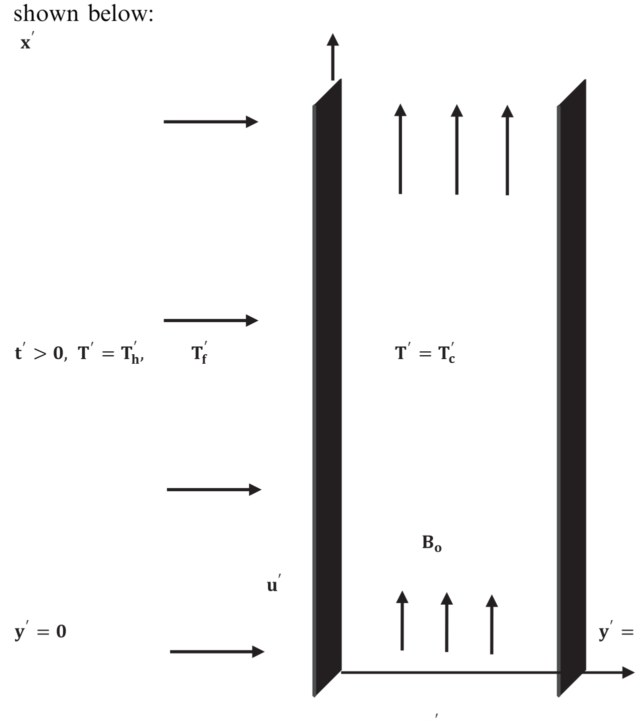
θ	temperature of the fluid in non-dimensional form
v	kinematic viscosity of the fluid

pumps, flow meters, generators, accelerators, plasma jet engines, and magnetic control of molten iron flow in steel industry and industrial processes in metallurgy and material processing, in chemical industry, industrial power engineering and nuclear engineering. Special mention can be made, for instance, to the experiments on liquid metal flows in MHD channels performed by Hartmann [9]. Rashidi [10] has studied Unsteady Two-Dimensional and Axisymmetric Squeezing flows between Parallel Plates. Siddiqui [11] considered Homotopy Analysis Method to the Unsteady Squeezing Flow between Circular Plates. Singh [12] discussed on MHD Free Convective Flow Past a Semi-infinite Vertical Permeable wall. Hamad [13], Uddin [14] and Khan [15] have studied MHD natural convection flow on a nanofluid in different physical conditions then Khan [16] obtained the solution of unsteady two-dimensional and axisymmetric squeezing flow between parallel plates. Kataria [17] has studied induced magnetic field effects on mixed convection. Narayana [18], Oahimire [19], Olajuwon [20] and Prakash [21] have studied effect of hall current and radiation on MHD flow of a micropolar fluid. Mahmoud [22] has obtained the solution of MHD flow of a micropolar fluid over a stretching surface with heat generation and slip velocity. Bég [23] has studied nanofluid convection boundary layers from an isothermal spherical body in a permeable regime. Freidoonimehr [24] and Vendabai [25] have studied free convective MHD flow past a permeable stretching vertical surface in a nano-fluid then Borrelli [26] obtained the solution of Magneto convection of a micropolar fluid in a vertical channel.

In most of the research works, case of asymmetric or symmetric thermal condition is studied in the absence of magnetic field. In this paper, we have analysed effect of magnetic field on unsteady natural convective flow and micro rotation between infinitely long vertical walls for asymmetric/symmetric wall temperatures.

2. Basic equations and description of the problem

Consider the unsteady free-convective flow of an electric conductive micro-polar fluid between two insulated vertical walls separated by a distance L apart subjected to a uniform transverse magnetic field. The coordinate system is chosen such that x' measures the distance along the walls and y' measures the distance normal to it. Initially, the temperatures of walls and the fluid are same says T'_f. When time $t' > 0$, the temperature of the walls at $y' = 0$ and $y' = L$ is instantaneously raised and lowered to T'_h and T'_c respectively such that $T'_h > T'_c$ which is there after maintained constant. A constant uniformly distributed transverse magnetic field of strength B_0 is applied in the y'-direction. Physical model and coordinate system are shown below:



The transversely applied magnetic field and magnetic Reynolds number are very small and hence the induce magnetic field is negligible. No electrical field is assumed to exist and both viscous and magnetic dissipations are neglected. The hall effects, the viscous dissipation and the joule heating terms are also neglected. Under above assumptions and taking into account the Boussinesq and boundary layer approximations, momentum, angular momentum and energy equations of micropolar fluid can be expressed as follows:

Please cite this article in press as: Kataria HR et al., Effect of magnetic field on unsteady natural convective flow of a micropolar fluid between two vertical walls, Ain Shams Eng J (2015), http://dx.doi.org/10.1016/j.asej.2015.08.013