ARTICLE IN PRESS

Alexandria Engineering Journal (2016) xxx, xxx–xxx

HOSTED BY

ELSEVIER

Alexandria University

Alexandria Engineering Journal

www.elsevier.com/locate/aej
www.sciencedirect.com

ORIGINAL ARTICLE

Diffusion-thermo effect with hall current on unsteady hydromagnetic flow past an infinite vertical porous plate

J.R. Pattnaik [a,*], G.C. Dash [b], S. Singh [a]

[a] Department of Mathematics, Padmanava College of Engineering, Rourkela 769002, Odisha, India
[b] Department of Mathematics, Siksha 'O' Anusandhan University, Bhubaneswar 751030, Odisha, India

Received 20 May 2016; revised 18 August 2016; accepted 25 August 2016

KEYWORDS

Hydromagnetic;
Hall current;
Chemical and thermal diffusion;
Dufour effect

Abstract An unsteady hydromagnetic flow past an infinite vertical porous plate has been analyzed to show the effect of an additional cross transport phenomenon, i.e. heat flux caused by concentration gradient in addition to the heat flux caused by temperature gradient. The effect of magnetic field on the fluid temperature and the heat transfer between fluid and wall is of considerable importance affecting the flow. Further, Hall current, an additional electric current density so generated perpendicular to both applied electric field and magnetic field has been taken into consideration in the present study. Moreover, the Dufour effect has been considered in energy equation leaving the equations of thermal diffusion and mass diffusion coupled. The coupled non-linear equations are solved by applying a special function $Hh_n(x)$. The effects of flow parameters are shown with the help of graphs and tables. A phenomenal observation, i.e. a radical change is marked near the plate in respect of Dufour number in the presence of suction. Further, it is to note that suction induces backflow in conjunction with opposing buoyancy forces. Hall current contributes to greater skin friction at the bounding surface.

1. Introduction

There are many flows which arise from difference in concentration or temperature alone. Atmospheric flows, at all scales, are driven appreciably by both temperature and H_2O concentration differences. There are many interesting aspects of such flows. The flow characteristics of such flows are characterized by two transport parameters, i.e. Prandtl and Schmidt numbers.

The Soret effect or thermophoresis is a phenomenon observed in mixtures of mobile particles where the different particles exhibit different responses to the cause of a temperature gradient. The term Soret effect most often applies to aerosol mixtures, but may also commonly refer to the phenomenon in all phases of matter. It has been used in commercial precipitators for applications similar to electrostatic precipitators, manufacturing of optical fiber in vapor deposition processes. It is also used to separate different polymers particles in fluid flow. Gebhart and Pera [1] studied the laminar flows which

* Corresponding author.
E-mail address: jrp_bapi@rediffmail.com (J.R. Pattnaik).

Peer review under responsibility of Faculty of Engineering, Alexandria University.

http://dx.doi.org/10.1016/j.aej.2016.08.027
1110-0168

Nomenclature

a	suction or blowing parameter
B	magnetic induction vector
C	dimensionless fluid concentration
C'	dimensional concentration in the fluid
C_p	specific heat at constant pressure
C_s	concentration susceptibility
C'_w	concentration of the fluid near the plate
C'_∞	concentration of the fluid far away from the plate
C_0	constant
D_m	mass diffusivity
D_u	Dufour parameter
e	charge of an electron
E	electric field vector
$f(\eta), g(\eta)$	dimensionless stream function
g	acceleration due to gravity
G_c	mass Grashof number
G_r	thermal Grashof number
J	current density vector
k	thermal conductivity of the fluid
K_0	constants
K_T	thermal diffusion ratio
M	magnetic parameter
$m = w_e\tau_e$	Hall parameter
m_e	mass of an electron
N	buoyancy ratio parameter
n_e	electron number density
P_e	electron pressure
P_r	Prandtl number
S_c	Schmidt number
t	dimensionless time
t'	dimensional time
T	dimensionless temperature of the fluid
T'	dimensional temperature
T'_w	constant temperature of the plate
T'_∞	temperature of the fluid far away from the plate
T_0	constant
u	x component of velocity
u'	velocity of the fluid in the x' - direction
U_0	characteristic velocity of the plate
V	velocity vector
w	z component of velocity
w_e	electron frequency
x', y'	co-ordinate axes along and perpendicular to the plate

Greek symbols

α	positive constant
β	volumetric coefficient of thermal expansion
β^*	volumetric coefficient of expansion with concentration
η	similarity variable
μ	coefficient of viscosity
ν	kinematic viscosity
ρ	fluid density
σ	electric conductivity
τ_e	electron collision time

arise in fluid due to the interaction of the gravity forces and density differences caused by the simultaneous diffusion of thermal energy of chemical species, neglecting the thermal diffusion (Soret) and diffusion thermo (Dufour) effects because the level of concentration is very low. Sparrow et al. [2,3] and Sparrow [4] analyzed the free convection flow with Soret–Dufour effects. Their work was confined to non-conducting flow without magnetic field. The Dufour effect is found to be of considerable order of magnitude such that it cannot be neglected (Eckert and Drake [5]). Kafoussias and Williams [6] have studied thermal-diffusion and diffusion-thermo effects on mixed free and forced convective and mass transfer boundary layer flow with temperature dependent viscosity. Anghel and Takhar [7] have studied Dufour effects and Soret effects on free convection boundary layer over a vertical surface embedded in porous medium. Ahmed [8] had studied MHD convection with Soret and Dufour effect in a three dimensional flow past an infinite vertical plate. Recently, Beg et al. [9] have studied chemically reacting mixed convective heat and mass transfer along inclined and vertical plates considering Soret and Dufour effect. More recently, Jha and Ajibade [10] have studied the heat and mass transfer aspect of the flow of a viscous incompressible fluid in a vertical channel considering the Dufour effect. The Dufour effect has been studied in free convective flow of visco-elastic fluid in a vertical channel by Mishra et al. [11]. The diffusion thermo effect has been considered on the fully developed laminar flow with uniform plate temperature and concentration.

Very recently, Mahdy and Ahmed [12] studied the laminar magnetohydrodynamic thermosolutal Marangoni convection along a vertical surface in the presence of the Soret and Dufour effects. They found that, both temperature and concentration gradient at the wall increase as the thermosolutal surface tension ratio increases. The effects of heat and mass transfer on two-dimensional unsteady MHD free convection flow past a vertical porous plate in a porous medium in the presence of thermal radiation under the influence of Dufour and Soret effects have been studied by Vedavathi et al. [13]. They reduced the governing nonlinear partial differential equations to the coupled nonlinear ordinary differential equations by the similarity transformations and then solved the resulting equations numerically using shooting method along with Runge-Kutta method. Srinivasacharya et al. [14] investigated the influence of thermophoresis on mixed convection heat and mass transfer flow over a vertical wavy surface in a porous medium with variable viscosity and variable thermal conductivity.

There exists a large number of constitutive equations describing irreversible processes in the form of linear relationships between fluxes and driving forces. For example, Fourier's law is relating heat-flow to temperature gradient; Fick's law is relating flow of matter of a species in a multicomponent system to its concentration gradient; Newton's law is relating shearing force to velocity gradient, etc. In all these cases we see a simple linear dependence of a flow on some conjugated forces. However, this simple relationship does not always hold. As early as 1801, Rouss carried out an experiment that showed that the

Please cite this article in press as: J.R. Pattnaik et al., Diffusion-thermo effect with hall current on unsteady hydromagnetic flow past an infinite vertical porous plate, Alexandria Eng. J. (2016), http://dx.doi.org/10.1016/j.aej.2016.08.027