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Full Length Article

Chemically reactive and naturally convective high speed MHD fluid flow through an oscillatory vertical porous plate with heat and radiation absorption effect

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ABSTRACT

This paper concerns with the modelling of an unsteady natural convective and higher order chemically reactive magnetohydrodynamics (MHD) fluid flow with the effect of heat and radiation absorption. The flow is generated through a vertical oscillating porous plate. Boundary layer approximations is carried out to establish a flow model which represents the time dependent momentum, energy and diffusion balance equations. Before being solved numerically, the governing partial differential equations (PDEs) were transformed into a set of nonlinear ordinary differential equation (ODEs) by using non-similar technique. A very efficient numerical approach solves the obtained nonlinear coupled ODEs so called Explicit Finite Difference Method (EFDM). An algorithm is implemented in Compaq Visual Fortran 6.6a as a solving tool. In addition, the stability and convergence analysis (SCA) is examined and shown explicitly. The advantages of SCA is its optimizes the accuracy of system parameters such as Prandtl number (P_r) and Schmidt number (S_c).The velocity, temperature and concentration fields in the boundary layer region are studied in detail and the outcomes are shown in graphically with the influence of various pertinent parameters such as Grashof number (G_r), modified Grashof number (G_r), magnetic parameter (M), Darcy number ($\mathrm{D_a}$),Prandtl number (P_r), Schmidt number (S_c), radiation (R), heat sink (Q),radiation absorption (Q_1), Eckert number (E_c), Dufour number ($\mathrm{D_u}$),Soret number (S_r), Schmidt number (S_c), reaction index (P) and chemical reaction (K_r). Furthermore, the effect of skin friction coefficient (C_f), Nusselt number (N_u) and Sherwood number (S_h) are also examined graphically.

1. Introduction

During the recent years, Magnetohydrodynamic (MHD) natural convection heat and mass transfer flow [1–10] is of significant attention in geophysics, engineering and industrial technology due to its wide range technical fields. This study finds numerous applications in industrial manufacturing processes such as the aerodynamic extrusion of plastic sheets, liquid metal fluids, biological transportation, oil reservoirs, geothermal systems, high-temperature plasmas, energy storage units, heat insulation and metal and polymer extrusion and micro MHD pumps etc. MHD flow through porous media is a major area of research for its wide range applications such as thermal energy storage devices, ground water systems, electronic cooling, boilers and nuclear process systems etc. Researchers are also interested in expanding their investigation on infinite vertical insulated porous plate [11], inclined porous plate [12], vertical porous plate [13–16], semi-infinite vertical porous plate [17] and vertical moving porous plate [18] etc.

In many chemical engineering and hydrometallurgical practices, it is required to investigate the influence of chemical reaction on heat and mass transfer flow because of the growing need for chemical reactions. This study is further plays outstanding role industries such as chemical industry, power and cooling industry for the applications of evaporation, flow in a desert cooler, energy transfer in a cooling tower, drying etc. Devi et al. [19] investigated chemical reaction effects on heat and mass transfer MHD boundary layer laminar type flow over a wedge considering suction/injection. Kandasamy et al. [20] studied chemical reactive MHD flow through a stretching surface with the effect of thermal stratification and heat source. The study of MHD temperature dependent

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Nomenclature

$B_{\circ}$	magnetic component
C_f	skin-friction
C_p	specific heat at constant pressure
D_a	Darcy number
D_m	coefficient of mass diffusivity
D_u	Dufour number
E_c	Eckert number
G_r	Grashof number
G_c	modified Grashof number
$K^{/}$	permeability of the porous medium
Kr	chemical reaction parameter
ke	mean absorption coefficient
N_u	local Nusselt number
P_r	Prandtl number
qr	unidirectional radiative heat flux
$Q1^{*}$	radiation absorption
$Q_{\circ}$	heat absorption quantity
S_c	Schmidt number
S_h	Sherwood number
S_r	Soret number
$U_{\circ}$	uniform velocity
u, v	velocity components
x, y	Cartesian co-ordinates

Greek symbols

σ	thermal conductivity
ρ	density of the fluid
μ	dynamic viscosities
ν	kinematic viscosity
β	thermal expansion co-efficient
β^{*}	concentration expansion co-efficient
κ	thermal conductivity
σs	Stefan-Boltzmann constant

viscosity and thermal diffusive flow with Hall and ion-slip currents with the influence of chemical reaction was carried out by Elgazery [21].The analysis of a first-order chemical reaction on MHD thermosolutal Marangoni convection flow was examined by Zhang and Zheng [22]. This field of study is still getting a lot of attention in recent years [23–31] for controlling the hydrodynamics behaviour of the fluid flow.

The fluid flow rising from the field of temperature and material difference is further applied in biochemical engineering, chemical engineering, geothermal reservoirs, aeronautics and astrophysics. The effect of presence of radiation absorption on the fluid flow is very significant from the scientific point of view. An example is arisen of this application in the planetary atmosphere where there is radiation absorption from nearby stars. Further industrial applications can be encompassed such as oil reservoirs, heat insulation, catalytic reactors, reactor safety, geothermal systems etc. Ibrahim et al. [32] reported the effect of radiation absorption on transient MHD free convection flow. Rubio Hernández [33] analysed a Network numerical analysis on unsteady MHD fluid flow through a porous medium with the influence of radiation absorption. Satya Narayana [34] investigated radiation absorption effects on MHD micropolar fluid flow in a rotating system. A study of free convective boundary layer flow with an aligned magnetic field in presence of radiation absorption was carried out by Reddy et al. [35]. The study of motion of fluids of magnetic field and thermal radiation effect on heat and mass transfer of air flow near a moving infinite plate with a constant heat sink has been studied by Arifuzzaman et al. [36] with Perturbation technique. The combined action of bouncy forces due to both thermal and mass diffusion in the presence of thermal radiation and chemical reaction are observed in nuclear reactor safety, solar collectors and combustion technique. Momentum boundary layer and thermal boundary layer presentation with the streamlines and isotherms has been studied by Rana et al. [37] in effect of radiation on unsteady MHD free convective flow past an exponentially accelerated inclined plate. A few more recent studies [38–41] can also be found where the radiation absorption parameter has a significant importance.

In many engineering applications including strength of radioactive materials, reactor safety analysis, spent nuclear fuel, fire and combustion, metal waste etc., it is very important to understand the effects of heat generation. This parameter is significant in numerous physical difficulties dealing with chemically reactive process and drives several phenomena (temperature distribution, particle deposition rate etc.) involve natural convection. The heat generation effects, MHD, heat and mass transfer flow has been studied by several researchers [42–47]. Recently, Reddy et al. [48] reported heat generation/absorption effects on MHD convective fluid flow (Al_2O_3–water and TiO_2–water nanofluids) past a stretching sheet in porous media. Srinivasa and Eswara[49] investigated the effect of heat generation on transverse magnetic-convective flow of an incompressible and electrically conducting fluid near an isothermal truncated cone. More recently, an analytical study MHD three-dimensional Oldroyd-B nanofluid flow with the effect of presence of heat generation/absorption is carried out by Hayat et al. [50]. Venkateswarlu and Satya Narayana [52] studied heat transfer flow of a nanofluid in a rotating system with the effect of radiation absorption and chemical reaction. Babu et al. [53] investigated the influence of radiation absorption on MHD transient free convection flow of a micropolar fluid through a porous medium of variable permeability over a vertical moving porous flat plate.

To the best of the author's knowledge, the study of transient MHD natural convective and chemically reactive high-speed fluid flow through an oscillatory vertical porous plate in presence of heat and radiation absorption has remained unexplored. Therefore, this phenomenon is addressed in this study. The results have been reported so far for MHD single-phase flow whilst hydrodynamic studies on high speed flow are reported only rarely. Application for high speed MHD are specially use in flow in the blanket (porous medium) of a nuclear fusion reactor, liquid metal MHD different phase flow power-generating etc. In the present investigation, the basic equation was derived, analysing the utmost MHD effects on flow momentum and energy transfer. For this reason, MHD term was also imposed in the thermal boundary layer equation. Theoretical solution for the effect of magnetic field on small convection-generating conditions was encompassed. The specific aims of this article are listed below:

To study the problem of unsteady chemically reactive fluid flow through a semi-infinite vertical porous plate with influence of thermal radiation, thermal and mass diffusion and radiation absorption, following steps have been carried out:

a) To solve the governing flow model including time dependent momentum, energy and diffusion balance equations numerically using well-known explicit finite difference method (EFDM).
b) Explicitly analyses the stability and convergence analysis (SCA) for optimizing the numerical value of flow parameters