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Soret Effect And Effect Of Radiation On Transient Mhd Free Convective Flow Over A Vertical Plate Through Porous Media

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Abstract: *The present paper is concerned to analyze the radiation, Magneto hydrodynamic and soret effects on unsteady flow heat and mass transfer characteristics in a viscous, incompressible and electrically conduction fluid over a semi-infinite vertical porous plate through porous media the porous plate is subjected to a transverse variable suction velocity. The transient, non linear and coupled dimensionless governing equations for this investigation are solved analytically using perturbation technique about a small parameter* ε *. the effects of governing parameters on the flow variables are discussed graphically.*
Keywords: *Soret effect, MHD, Radiation and rarefaction parameter.*

I. Introduction

Thermal radiation in fluid dynamics has become a significant branch of the engineering sciences and is an essential aspect of various scenarios in mechanical, aerospace, chemical, environmental, solar power and hazards engineering. For some industrial applications such as glass production and furnace design and in space technology applications such as cosmic flight aerodynamics rocket, propulsion systems, plasma physics and spacecraft re-entry aerothermodynamics which operate at higher temperatures, radiation effects can be significant. The effect of radiation on MHD flow and heat transfer problem has become more important industrially. Singh and ShwetaAgarwal [1] studied the Heat transfer in a second grade fluid over an exponentially stretching sheet through porous medium with thermal radiation and elastic deformation under the effect of magnetic field. Makinde and Ogulu [2] studied the effect of thermal radiation on the heat and mass transfer flow of a variable viscosity fluid past a vertical porous plate permeated by a transverse magnetic field.

In recent years, the problems of free convective heat and mass transfer flows through a porous medium under the influence of magnetic field have been attracted the attention of a number of researchers because of their possible applications in many branches of science and technology, such as transportation cooling of re-entry vehicles and rocker boosters, cross-hatching on ablative surfaces and film vaporization in combustion chambers. Magnetohydrodynamics is currently undergoing a period of great enlargement and differentiation of subject matter. In light of these applications, steady MHD free convective flow past a heated vertical flat plate has been studied by many researchers such as Gupta [3], Lykoudis [4] and Nanda and Mohanty [5]. Chaudhary and Sharma [6] considered combined heat and mass transfer by laminar mixed convection flow from a vertical surface with induced magnetic field.

In recent years, the problems of free convective heat and mass transfer flows through a porous medium under the influence of magnetic field have been attracted the attention of a number of researchers because of their possible applications in many branches of science and technology, such as its applications in transportation cooling of re-entry vehicles and rocket boosters, cross-hatching on ablative surfaces and film vaporization in combustion chambers. Magnetohydrodynamics is currently undergoing a period of great enlargement and differentiation of subject matter. In light of these applications, steady MHD free convective flow past a heated vertical flat plate has been studied by many researchers such as Gupta [7], Lykoudis [8] and Nanda and Mohanty [9]. Chaudhary and Sharma [10] considered combined heat and mass transfer by laminar mixed convection flow from a vertical surface with induced magnetic field.

Due to the importance of Soret (thermal-diffusion) effects for the fluids with very light molecular weight as well as medium molecular weight. The Soret effect arises when the mass flux contains a term that depends on the temperature gradient. Bhavana et al [11] proposed the Soret effect on unsteady MHD free convective flow over a vertical plate in presence of the heat source. Anand Rao et al. [12] explained the Soret and Radiation effects on unsteady MHD free convective flow past a vertical porous plate.

The objective of the present study is to investigate the effect of various parameters like soret number, thermal grashof number, mass grashof number, rarefaction parameter, magnetic field parameter, radiation parameter, suction parameter onconvective heat transfer along an inclined plate embedded in porous medium. The governing non-linear partial differential equations are first transformed intodimensionless form and thus resulting non-similar set of equations has been solved using the perturbation technique. results are presented graphically and discussed quantitatively for parameter values of practical interest from physical point of view.

II. Mathematical Analysis

The unsteady two dimensional MHD free convective flow of a viscous incompressible, electrically conducting and radiating fluid in an optically thin environment past an infinite heated vertical porous plate embedded in a porous medium in presence of thermal and concentration buoyancy effects . Let the x-axis be taken in vertically upward direction along the plate and y axis is normal to the plate. It is assumed that there exist a homogeneous chemical reaction of first order with constant rate *K* between the diffusing species and the fluid uniform magnetic field is applied in the direction perpendicular to the plate. The viscous dissipation and the Joule *r* heating effects are assumed to be negligible in the energy equation. The transverse applied magnetic field and magnetic Reynolds number are assumed to be very small, so that the induced magnetic field is negligible [22] . Also it is assumed that there is no applied voltage, so that the electric field is absent. The concentration of the diffusing species in the binary mixture is assumed to be very small in comparison with the other chemical species, which are present, and hence the Soret and Dufour effects are negligible and the temperature in the fluid flowing is governed by the energy concentration equation involving radiative heat temperature. Under the above assumptions as well as Boussinesq's approximation, the equations of conservation of mass, momentum, energy and concentration governing the free convection boundary layer flow over a verticalporous plate in porous medium can be expressed as:

$$\frac{\partial v^{'}}{\partial y^{'}} = 0 \tag{1}$$

$$\frac{\partial u^{'}}{\partial t^{'}} - v_0(1+\varepsilon A e^{nt})\frac{\partial u^{'}}{\partial y^{'}} = g\beta(T^{'}-T^{'}_{\infty}) + g\beta^{*}(C^{'}-C^{'}_{\infty}) + v\frac{\partial^2 u^{'}}{\partial y^{'2}} - \frac{\sigma\beta_0^2}{\rho}u^{'} - \frac{v}{k^{'}}u^{'} \tag{2}$$

$$\rho C_p\left[\frac{\partial T^{'}}{\partial t^{'}} - v_0 v_0(1+\varepsilon A e^{nt})\frac{\partial T^{'}}{\partial y^{'}}\right] = k\frac{\partial^2 T^{'}}{\partial y^{'2}} - \frac{\partial q^{'}_r}{\partial y^{'}} \tag{3}$$

$$\frac{\partial C^{'}}{\partial t^{'}} - v_0(1+\varepsilon A e^{nt})\frac{\partial C^{'}}{\partial y^{'}} = D\frac{\partial^2 C^{'}}{\partial y^{'2}} - D_T\frac{\partial T^{'}}{\partial y^{'2}} \tag{4}$$

Where $g, T^{'}, C^{'}, B_0, D, \sigma.k, C_p, v, \beta, \beta_e, q^{'}$ and Kr are acceleration due to gravity, fluid temperature, species concentration, magnetic field, chemical molecular diffusivity, electrical conductivity, thermal conductivity, specific heat constant pressure, kinematic viscosity, density, coefficient of volume expansion for heat transfer, volumetric coefficient of expansion with species concentration, radiative heat flux and soret effect parameter repectively.

The corresponding boundary conditions of the problem are

$$u^{'} = L^{'}\left(\frac{\partial u^{'}}{\partial y^{'}}\right), \qquad T^{'} = T^{'}_w + \left(T^{'}_w - T^{'}_{\infty}\right)e^{i\varpi^{'}t^{'}} \qquad C^{'} = C^{'}_w + \left(C^{'}_w - C^{'}_{\infty}\right)e^{i\varpi^{'}t^{'}} \qquad \text{at} \quad y^{'} = 0$$

$$u^{'} \to 0, \qquad T^{'} \to T^{'}_{\infty}, \qquad C^{'} \to C^{'}_{\infty} \quad \text{at} \quad y^{'} \to \infty \tag{5}$$

Where $T^{'}_w$ and $T^{'}_{\infty}$ is the temperature at the wall and infinity, $C^{'}_w$ and $C^{'}_{\infty}$ is the species concentration at the wall and infinity respectively.

By using Rosseland approximation the radiative heat flux $q^{'}_r$ is given by

$q^{'}_r = \dfrac{4\sigma_s}{3k_e}\dfrac{\partial T^{'4}_w}{\partial y^{'}}$ where σ_s is the Stefan Boltzmann constnt and k_e is the mean absorption coefficient.

By expanding $T^{'4}_w$ in to the taylors series about $T^{'}_{\infty}$ which after neglecting higher order terms takes the form $T^{'4}_w \cong 4T^{'3}_{\infty}T^{'}_w - 3T^{'4}_{\infty}$

From the equation of continuity (1), it is clear that the suction velocity at the plate is either a constant or a function of time only. Hence, the suction velocity normal to the plate is assumed to be in the form

$$v^{'} = -v_0(1+\varepsilon A e^{i\varpi^{'}t^{'}}) \tag{6}$$

We now introduce the following non-dimensional quantities in to the equations (1) to (5)

The governing equations (2) to (4) can be rewritten in the non-dimensional form as follow

$$\frac{1}{4}\frac{\partial u}{\partial t}-(1+\varepsilon Ae^{\text{int}})\frac{\partial u}{\partial y}=\frac{\partial^2 u}{\partial y^2}+Gr\,\theta+Gc\,\varphi-(M+k)u \tag{8}$$

$$\frac{1}{4}\frac{\partial \theta}{\partial t}-(1+\varepsilon Ae^{\text{int}})\frac{\partial \theta}{\partial y}=\frac{1}{pr}\left(1+\frac{4}{3R}\right)\frac{\partial^2 \theta}{\partial y^2} \tag{9}$$

$$\frac{1}{4}\frac{\partial \varphi}{\partial t}-(1+\varepsilon Ae^{\text{int}})\frac{\partial \varphi}{\partial y}=\frac{1}{Sc}\frac{\partial^2 \varphi}{\partial y^2}-S_0\frac{\partial^2 \theta}{\partial y^2} \tag{10}$$

The transformed boundary conditions are

$$u=h\frac{\partial u}{\partial y},\quad \theta=1+\varepsilon e^{i\varpi t}\quad \phi=1+\varepsilon e^{i\varpi t}\quad \text{at}\quad y=0$$

$$u\to 0,\quad \theta\to 0\quad \phi\to 0\quad \text{at}\quad y\to\infty \tag{11}$$

III. Solution Of The Problem

The equations (8) to (10) are coupled, non linear partial differential equations and these cannot be solved in closed form. However, these equations can be reduced to a set of ordinary differential equations, which can be solved analytically. So this can be done, when the amplitude of oscillations (ε <<1) is very small, we can assume the solutions of flow velocity u, temperature field and concentration in the neighborhood of the plate as :

$$\theta_0^{''}+\Pr\left(1+\frac{4}{3R}\right)\theta_0^{'}=0 \tag{13}$$

$$\theta_1^{''}+\Pr\left(1+\frac{4}{3R}\right)\theta_1^{'}-i\omega\Pr\left(1+\frac{4}{3R}\right)\theta_1/4=-2A\Pr\left(1+\frac{4}{3R}\right)\theta_0^{'} \tag{14}$$

$$u_0^{''}+u_0^{'}-(M+k)u_0=-Gr\,\theta_0-Gc\,\varphi_0 \tag{15}$$

$$u_1^{''}+u_1^{'}-((M+k)+i\omega/4)u_1=-Gr\,\theta_1 \tag{16}$$

$$\varphi_0^{''}+\varphi_0^{'}Sc=-ScSo\,\theta_0^{''} \tag{17}$$

$$\varphi_1^{''}+\varphi_1^{'}-\frac{i\omega}{4}Sc\,\varphi_1=-\theta_1^{''}ScS\;0+AScC\;_0^{'} \tag{18}$$

Where prime denotes differentiation with respect to y. The corresponding boundary conditions are

$$u_0=1,\quad u_1=1,\quad \theta_0=1,\quad \theta_1=1,\quad \phi_0=1,\quad \phi_1=1\quad \text{at}\quad y=0$$

$$u_0\to 0,\quad u_1\to 0,\quad \theta_0\to 0,\quad \theta_1\to 0,\quad \phi_0\to 0,\quad \phi_1\to 0\quad \text{at}\quad y\to\infty \tag{19}$$

The solutions of the equations (13) to (18) under the boundary conditions (19) are

$$\theta_0(y)=e^{-m_2 y}$$
(20)

$$\phi_0(y)=A_2e^{-m_4 y}-A_1e^{-m_2 y}$$
(21)

$$u_0(y)=e^{-m_5 y}+A_3e^{-m_2 y}+A_4e^{-m_4 y}+A_5e^{-m_2 y} \tag{22}$$

$$\theta_1(y)=e^{-m_7 y}+A_6e^{-m_2 y}$$
(23)

$$\phi_1(y)=e^{-m_8 y}++A^7e^{-m_7 y}+A_8e^{-m_4 y}+A_9e^{-m_2 y}$$
(24)

$$u_1(y)=A_{10}e^{-m_7 y}-A_{11}e^{-m_2 y} \tag{25}$$

The skin-friction, Nusselt number and Sherwood number are important physical parameters for this type of boundary layer flow. these parameters can be defined and determined as follows.

Knowing the velocity field, the skin friction at the plate can be obtained, which in non- dimensional form is given by

$$C_f = \left(\frac{\partial u}{\partial y}\right)_{y=0} = \left(\frac{\partial u_0}{\partial y} + \varepsilon e^{nt}\frac{\partial u_1}{\partial y}\right)_{y=0}$$

$$= -m_5 - m_2 A_3 - m_4 A_4 + m_2 A_5 + \varepsilon e^{nt}(-m_7 A_{10} - m_2 A_{11})$$

Knowing the temprature field, the rate of heat transfer coefficient can be obtained, which in the non-dimensional form, in terms of the Nusselt number, is given by

$$Nu = -\left(\frac{\partial \theta}{\partial y}\right)_{y=0} = -\left(\frac{\partial \theta_0}{\partial y} + \varepsilon e^{nt}\frac{\partial \vartheta_1}{\partial y}\right)_{y=0}$$

$$= -(m_2 + \varepsilon e^{nt}(m_7 + m_2 A_6))$$

Knowing the concentration field, the rate of mass transfer coefficient can be obtained, which in the nono-dimensional form, in terms of the sherwood number is given by

$$Sh = -\left(\frac{\partial \phi}{\partial y}\right)_{y=0} = -\left(\frac{\partial \phi_0}{\partial y} + \varepsilon e^{nt}\frac{\partial \phi_1}{\partial y}\right)_{y=0}$$

$$= -m_4 A_2 - m_2 A_1 + \varepsilon e^{nt}(m_8 - A_7 m_7 - m_4 A_8 - m_2 A_9)$$

IV. Results And Discussions

The effects of governing parameters like so ret number, grash of number, radiation parameter and with respect to time have been presented in respective graphs. here we consider the foreign species Sc=0.22, wt=pi/2.

Figure 1 shows the effect of modified Grashof number Gm on velocity U. it is observed that an increase in the modified Grashof numbers Gm on velocity profile, that is , the fluid motion is accelerated for increasing the permeability of the medium. Figure 2 shows the effect of radiation parameter N on velocity U. The figure 3 displays that an increase in the radiation parameter N lead to the decrease of the fluid motion. Fig.6 indicates the behavior of soret effect parameter and it shows the increase in velocity as the increase in soret. Fig.4. It is noticed that an increase in the velocity with an increasing time Fig.5 illustrates the concentration profiles for different values of soret. It is observed that concentration decreases as the increase in soret. Fig.6 has been plotted to depict the variation of temperature profiles for different values of radiation parameter by fixing other physical parameters. From this Graph we observe that temperature decrease with increase in the radiation parameter *R.*

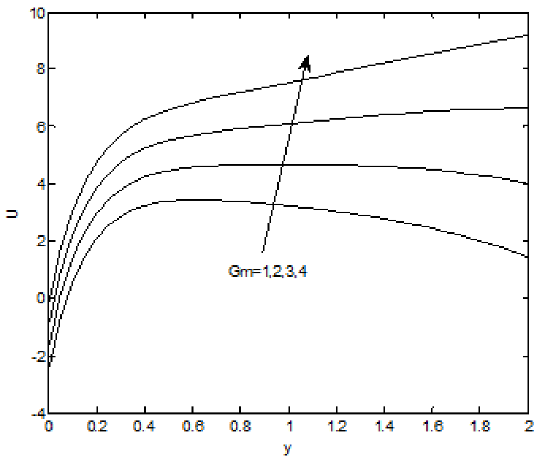

Figure 1: Effect of modified Grash of number Gm on velocity.

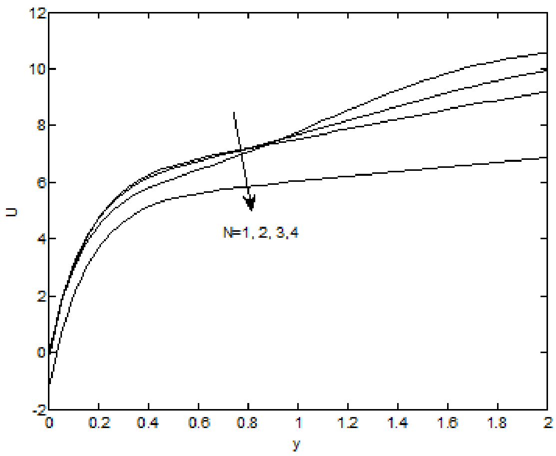

Figure 2 Effect of radiation parameter N on Velocity profile.

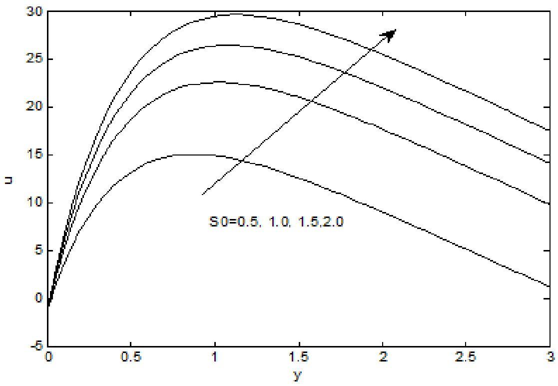

Fig-3. Velocity profiles for different values of Soret effect.

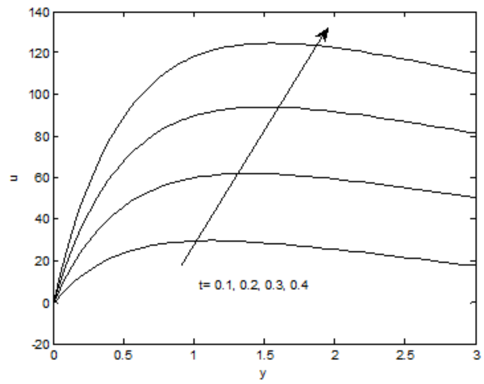

Fig-4. Velocity profiles for different values of time.

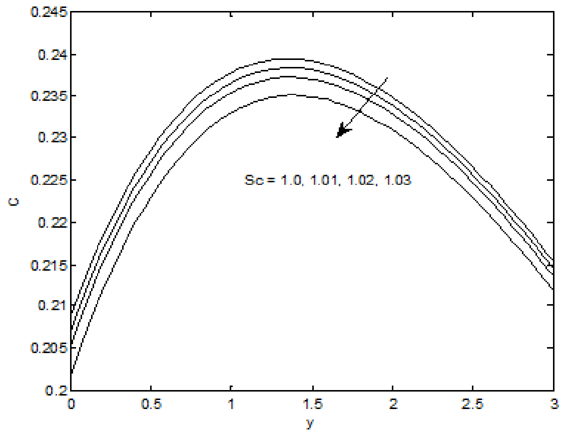

Fig-5. concentration profiles for different values soret number.

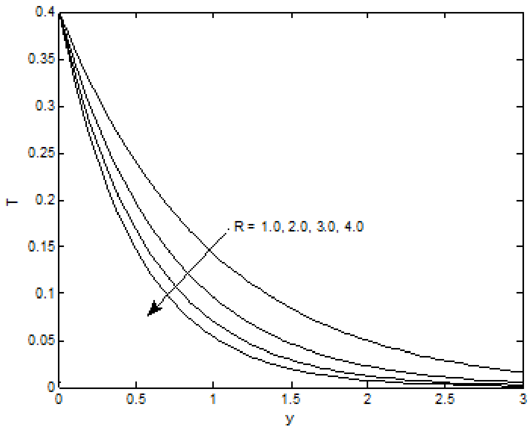

Fig-6. Temprature profiles for different values of Radiation parameter.

Appendix

$m_1 = 0$	$m_2 = -\Pr(1 + \frac{4}{3R})$	$m_3 = 0$
$m_4 = -Sc$	$m_5 = \frac{-1 + \sqrt{1 + 4(M + k)}}{2}$	$B = \Pr(1 + \frac{4}{3R})$
$m_6 = \frac{-B + \sqrt{B^2 + i\omega B}}{2}$	$m_7 = \frac{-B - \sqrt{B^2 + i\omega B}}{2}$	$m_8 = \frac{-1 + \sqrt{1 - i\omega Sc}}{2}$
$m_9 = \frac{-1 + \sqrt{1 + (4(M + k) + i\omega}}{2}$	$A_1 = -\frac{ScSom_2^2}{m_2^2 + m_2 Sc}$	$A_2 = 1 + A_1$
$A_3 = -\frac{Gr}{m_2^2 + m_2 - (m + K)}$	$A_4 = -\frac{GcA_2}{m_4^2 - m_4 - (m + K)}$	$A_5 = -\frac{GcA_1}{m_2^2 - m_2 - (m}$
$A_6 = -\frac{2Am_2 B}{m_2^2 + Bm_2 - \frac{i\omega B}{4}}$	$A_7 = -\frac{ScSom_7^2}{m_7^2 - m_7 - \frac{i\omega}{4} Sc}$	$A_8 = -\frac{AScm_4 A_2}{m_4^2 - m_4 - \frac{i\omega}{4}}$

$A_9 = -\dfrac{AScm_2 A_2}{m_2^2 - m_2 - \dfrac{i\omega}{4}Sc}$	$A_{10} = -\dfrac{Gr}{m_7^2 + m_7 - ((M + k) + \dfrac{i\omega}{4})Sc}$	
$A_{11} = -\dfrac{Gr}{m_2^2 + m_2 - ((M + k) + \dfrac{i\omega}{4})Sc}$		

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