Effect of Radiation on Free Convection Heat and mass Transfer Flow Through Porous Medium in a Vertical Channel With Heat Absorption/Generation and Chemical Reaction

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ABSTRACT:

The present paper analyses a solution for the transient free flow oa a viscous and incompressible fluid between two vertical walls as a result of heta and mass transfer. The perturbation technique ahs been used to find the solutions for the velocity and temprature fgields by solving the governing partial differential equations. The temperature of the one plate is assumed to be fluctuating. The effcets of the various parametrs entering into the problem, on the velocity and the temprature are depivted graphically. The impact of various parameters (Da, Rv, Pr, Rnad S) on velocity and temperature fields are shown graphically. The expressions for skin friction at both walls are also obtained.

Key words: *Vertical channel., porous medium, heat generation and chemical reaction.*

INTRODUCTION:

There are many transport processes in nature and in many industries where flows with free convection currents caused by the temprature difference are affected by the differences in concentarion or material constitutions. In a number of engineering appliactions foreign gases are injected to attain more efficiency, the advantage being the reduction in wall shaer stress, the mass transfer conductance or the rate of heat transfer.

Heat and mass transfer in a porous medium is prevalent in nature many man made technological processes. in consequence the theory of flow through porous media emerged as a vibrant discipline of intensive research activity. Free convective flow past a vertical plate has been studied extensively by Ostrich (1). Free convective heat transfer due to the simultaneous action of buoyancy and induced magnetic force was investigated by Sparrow and Cess (2).

An excellent summary of applications is given by Huges and Young[3]. Raptis[4] studied mathematically the case of time varying two dimensional natural convective flow of an incompressible, electrically conducting fluid along an infinite vertical porous plate embedded in a porous medium. Helmy(5) analyzed MHD unsteady free convection flow past a vertical porous plate embedded in porous medium. Elabashbeshy[6] studied heat and mass transfer along a vertical plate in the presence of magnetic field. Chamkha[7] analyzed an unsteady, MHD convective, viscous incompressible, heat and mass transfer along a semi-infinite vertical porous plate in the presence of transverse magnetic field, thermal and concentration buoyancy effects.

The study of heat generation or absorption in moving fluids is important in view of several physical problems, such as fluids undergoing exothermic or endothermic chemical reactions. in many chemical engineering processes, there does occur chemical reaction between a foreign mass and the fluid in which the plate is moving. These take place in numerous industrial applications viz., polymer production, manufacturing the of ceramics or glass ware and food processing. Sharma et.al[8] have discussed in detail the effect of variable thermal conductivity in MHD fluid flow over a stretching sheet considering heat source and sink parameter. Chamkha and Khaled[9] investigated the problem of coupled heat and mass transfer by magneto hydrodynamic free convection from an inclined plate in the presence of internal heat generation or absorption.

The effects of chemical reaction and radiation absorption on free convective flow through a porous medium with a variable suction in the presence of uniform magnetic field were studied by Sudheer Babu and Satyanarayana [10]. Ahmed and Alam Sarker [11] presented the problem of a steady two - dimensional natural convective flow of a viscous incompressible and electrically conducting fluid past a vertical impermeable flat plate in the presence of a uniform transverse magnetic field. Saravana et al. [12] studied the effects of mass transfer on the MHD viscous flow past an impulsively started infinite vertical plate with constant mass flux.

The main goal here is to study the effcts of radiation on free convection steady fully developed flow through porous medium in a vertical channel.The closed form solutions for velocity, temperature, skin friction and concentration are presented. The effects of pertinent parameters on fluid flow and heat and mass transfer characteristics are studied in detail. this work is presented as follows.

MATHEMATICAL FORMULATION:

The free convection flow of a viscous incompressible fluid has been considered in a porous region bounded by two vertical walls. The viscous and Darcy resistances are taken into account to model the momentum transfer in the porous region by taking permeability of the medium as constant . The x' axis is taken along one of the vertical plate while y' axis taken normal to the plate. The temperature of one plate is high enough to induce radiative heat.

under the usual Boussinesq's approximation the natural convection flow is governed by following equations of conservation of momentum, thermal energy and concentration in non-dimensional forms.

$$\frac{\partial u}{\partial t} = Rv\frac{\partial^2 u}{\partial y^2} - \frac{u}{Da} + Gr\overline{\ } + GmC \quad (1)$$

$$\Pr\frac{\partial\overline{\ }}{\partial t} = \frac{\partial^2\overline{\ }}{\partial y^2} - (R^2 + S)\overline{\ } \quad (2)$$

$$Sc\frac{\partial C}{\partial t} = \frac{\partial^2 c}{\partial y^2} + Kr(C - C_\infty) \quad (3)$$

In non-dimensionalization, following quantities have been used

$$Da = \frac{K}{h^2}\ , \quad Rv = \frac{\text{«}_{eff}}{\text{«}_f}\ , \quad y = \frac{y'}{h}\ , \quad u = \frac{u'}{h}\ , \quad R^2 = \frac{4\sim^2 h^2}{k}\ , \quad - = \frac{(T'-T_c')}{(T_w'-T_c')}\ , \quad n = \frac{n'h^2}{v}\ , \quad t = \frac{t'v}{h^2}$$

$$C = \frac{(C'-C_c')}{(C_w'-C_c')}\ , \quad Gr = g \ ^*v(T_w'-T_c')\frac{h^3}{v_f^2}\ , \quad R^2 = \frac{Q_0 h^2}{k}\ , Gm = g \ (C_w'-C_c')\frac{h^3}{v_f^2}\ , \quad \Pr = \frac{\text{«}_f C_p}{k}\ ,$$

$$Sc = \frac{v}{D} \qquad (4)$$

Where R, radiation parameter, S heat generation/absorption parameter, Da Darcy number, Rv ratio of viscosities, ~ radiation/absorption coefficient, u' is the velocity components in y' directions respectively. K is the permeability of the porous medium «_{eff} , effective viscosity of the fluid, «_f dynamic viscosity of the fluid, v_f kinematic viscosity of the fluid, u' fluid velocity, g acceleration due to gravity, coefficient of thermal expansion of the temperature of the fluid density, k is the thermal conductivity of the fluid, D thermal diffusivity of the fluid, ° is density T' and T_c' are the respective temperature of the fluid and cold wall, C' and C_c' are the respective concentration of the fluid and cold wall and C_p is the specific heat at the constant pressure.

The boundary conditions for above set of equations in none-dimensional form are obtained as

$$u(y,t) = 1\ , \ ^-(y,t) = 1 + \text{£}e^{nt}\ , \ C(y,t) = 1 \qquad \text{at} \quad y=0$$

$$u(y,t) = 0\ , \ ^-(y,t) = 0\ , \ C(y,t) = 0 \qquad \text{at} \quad y=1 \qquad (5)$$

SOLUTION OF THE PROBLEM:

Equation 1,2 and 3 are second order coupled partial differential equations. We apply the regular perturbation method to solve them since $\text{£} << 1$, therefore fluid velocity, temperature and concentration can be expanded as follows:

$$u(y,t) = u_0(y) + \text{£}e^{\text{int}}u_1(y) + o(E^2)............$$

$$^-(y,t) = ^-{}_0(y) + \text{£}e^{\text{int}}{}^-{}_1(y) + o(E^2)............$$

$$C(y,t) = C_0(y) + \text{£}e^{\text{int}}C_1(y) + o(E^2)............ \qquad (6)$$

Substituting the values from Equation (6) in to equation (1), (2) and (3) neglecting the coefficients of $o(E^2)$, we obtain the following equations

$$Rv\frac{d^2u_0}{dy^2} - \frac{u_0}{Da} + Gr^-{}_0 + GmC_0 = 0 \qquad (7)$$

$$Rv\frac{d^2u_1}{dy^2}-(\frac{1}{Da}+n)u_1+Gr\overline{\;}_1+GmC_1=0 \qquad (8)$$

$$\frac{d^2\overline{\;}_0}{dy^2}-(R^2+S)\overline{\;}_0=0 \qquad (9)$$

$$\frac{d^2\overline{\;}_1}{dy^2}-(R^2+S+n\,\mathrm{Pr})\overline{\;}_1=0 \qquad (10)$$

$$\frac{d^2C_0}{dy^2}+KrC_0=0 \qquad (11)$$

$$\frac{d^2C_1}{dy^2}-(Kr+Scn)C_1=0 \qquad (12)$$

The corresponding boundary conditions are as follows:

$$u_0=1,\quad u_1=1,\quad \overline{\;}_0=1,\quad \overline{\;}_1=1,\quad C_0=1,\quad C_1=1 \qquad \text{at} \quad y=0$$

$$u_0=0,\quad u_1=0,\quad \overline{\;}_0=0,\quad \overline{\;}_1=0,\quad C_0=0,\quad C_1=0 \qquad \text{as} \quad y\to\infty \qquad (13)$$

By solving equations (7) to (12) subject to boundary conditions (13) the solutions $u_0(y)$, $u_1(y)$, $\overline{\;}_0(y)$, $\overline{\;}_1(y)$, $C_0(y)$, and $C_1(y)$, are obtained as follows.

$$u_0(y)=e^{-m_5y}+A_1e^{-m_3y}+A_2e^{-m_1y}$$

$$u_1(y)=e^{-m_6y}+A_3e^{-m_4y}+A_4e^{-m_2y}$$

$$\overline{\;}_0(y)=e^{-m_3y}$$

$$\overline{\;}_1(y)=e^{-m_4y}$$

$$C_0(y)=e^{-m_1y}$$

$$C_1(y)=e^{-m_2y}$$

From the above equations $u(y)$, $\overline{\;}(y)$, and $C(y)$, are obtained as follows.

$$u(y)=e^{-m_5y}+A_1e^{-m_3y}+A_2e^{-m_1y}+£e^{nt}(e^{-m_6y}+A_3e^{-m_4y}+A_4e^{-m_2y})$$

$$\overline{\;}(y)=e^{-m_3y}+£e^{nt}(e^{-m_4y})$$

$$C(y) = e^{-m_1 y} + £e^{nt}(e^{-m_2 y})$$

where the expressions for the constants are given in the appendix.

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

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

$$= - \quad m_5 + m_3 A_1 - m_1 A_2 + £e^{nt}(-m_6 + m_4 A_3 + m_2 A_4)$$

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

$$Nu = -\left(\frac{\partial \bar{\ }}{\partial y}\right)_{y=0} = -\left(\frac{\partial \bar{\ }_0}{\partial y} + £e^{nt}\frac{\partial g_1}{\partial y}\right)_{y=0}$$

$$= -(m_3 + £e^{nt} m_4)$$

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

$$Sh = -\left(\frac{\partial C}{\partial y}\right)_{y=0} = -\left(\frac{\partial C_0}{\partial y} + £e^{nt}\frac{\partial C_1}{\partial y}\right)_{y=0}$$

$$= - m_1 + £e^{nt}(m_2)$$

APPENDIX:

$$m_1 = \pm\sqrt{Kr}\ , \quad m_2 = \pm\sqrt{Kr + Scn}\ , \quad m_3 = \pm\sqrt{R^2 + S}\ , \quad m_4 = \pm\sqrt{R^2 + S + n\Pr}\ , \quad m_5 = \pm\sqrt{\frac{1}{DaRv}}\ ,$$

$$m_6 = \pm\sqrt{\frac{\frac{1}{Da} + n}{Rv}}\ , \quad A_1 = -\frac{Gre^{m3y}}{Rvm_3{}^2 - \frac{1}{da}}\ , \quad A_2 = -\frac{Gmm_1 e^{m3y}}{Rvm_1{}^2 - \frac{1}{da}}\ , \quad A_3 = -\frac{Grm_4 e^{m4y}}{Rvm_4{}^2 - (\frac{1}{Da} + n)}$$

$$A_4 = -\frac{Gmm_4 e^{m2y}}{Rvm2^2 - (\frac{1}{Da} + n)}$$

RESULTS AND DISCUSSIONS:

In order to understand the physical importance of the flow between the two plates, calculations have been carried out for velocity, temperature, concentration and skin friction. Effects for different values of Darcy number(Da), ratio of viscosities(Rv), Grashof number(Gr), radiation parameter (R) absorption/generation parameter (S) and chemical reaction parameter (Kr)on velocity and temperature profiles between plate y=0 and p[late y=1, are shown graphically while all other parameters are kept constant.

The velocity profiles are shown in figures 1 to 4 different values of Darcy number (Da), ratio of viscosities (Rv), Grashof number (Gr), Modified Grashof number(Gm), Radiation parameter (R) and absorption/generation parameter (s) while all other parameters are kept constant. It ios noticed that the velocity of fluid increases with the increase of Da and Gr while decreases with the increase of Rv and R. Interpreting physically, Increase in the permeability parameter K increases the flow which leads to increase in velocity. velocity decreases due to the increase of Rv for all values of da, which is due to the high effective viscosity of the porous medium to that of fluid viscosity. it is observed there is a fall in velocity in the presence of high thermal radiation.

Figure 5 and 6 represents the temperature profiles for different values of radiation parameter R and heat generation/absorption parameter S, while all the parameters are kept constant. it is observed from the figures that the temperature decreases with the increase of radiation parameter R and Heat generation/absorption parameter S.

Fig-7. Concentration profiles for different values of n it is observed that concentration decreases with the increase in n. Fig-8. Concentration profiles for different values of Sc it is observed that concentration decreases with the increase in Schmidt number.

CONCLUSION:

The fully developed free convection heat and mass transfer flow between two vertical plates through porous medium has been investigated. Perturbation technique is used to solve the equations. It is observed that velocity of fluid increases with increase of darcy number (Da), Grashof number (Gr) while decreases with increase of radiation parameter (R), ratio of viscoities (Rv) and Heat generation/absorption parameter (S). It is also obtained that temperature decreases with increase of radiation parameter (R) and heat generation/absorption parameter (S). Further, it is found that radiation causes to decrease the rate of heat transfer to the fluid thereby reducing the effct of natural convection. The rate of flow decreases with an increase of radiation.

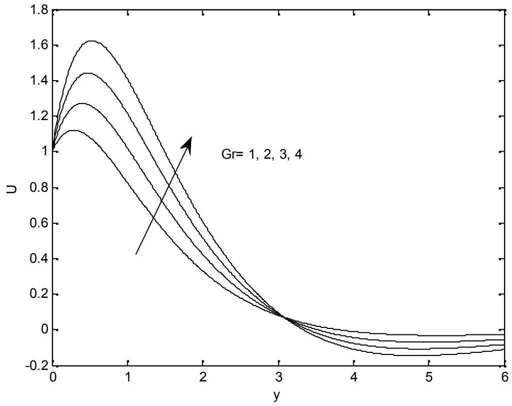

Fig.1: Effects of Grashof number on velocity profiles.

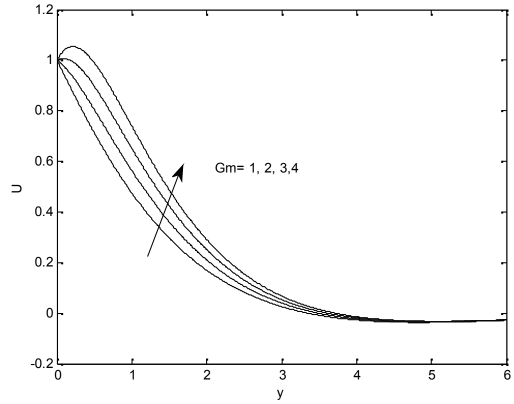

Fig:2 Effects of modified Grashof number on velocity profiles

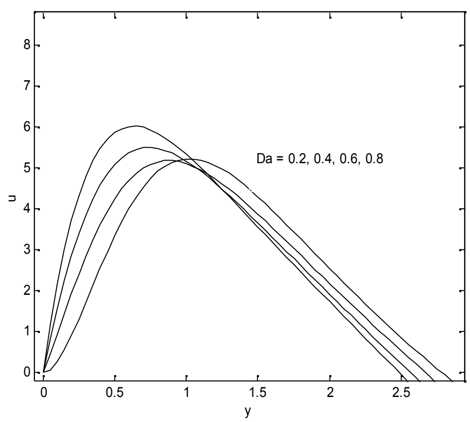

Fig.3: Effects of Darcy number on velocity profiles.

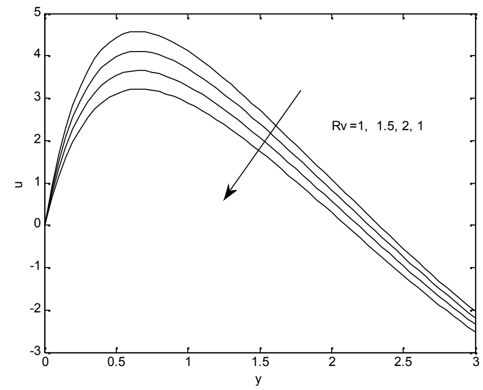

Fig.4: Effects Rv number on velocity profiles.

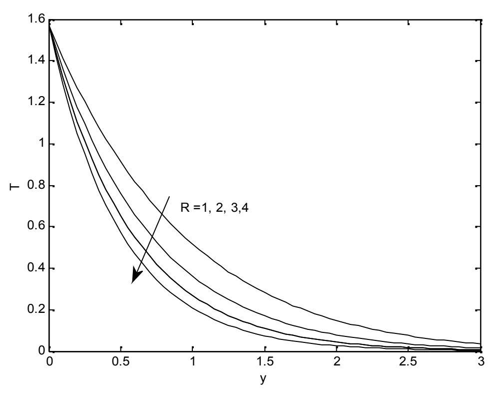

Fig-5. Temprature profiles for different values of Radiation parameter.

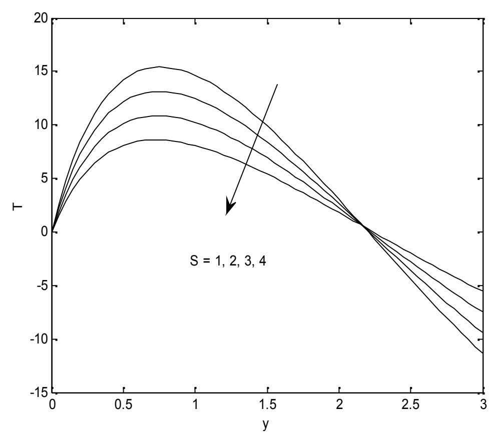

Fig-6. Temprature profiles for different values of S.

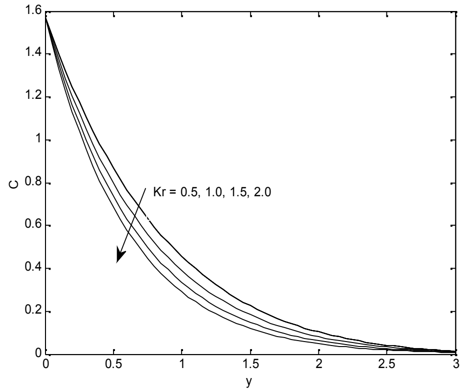

Fig-7, concentration profiles for different values of chemical reaction parameter.

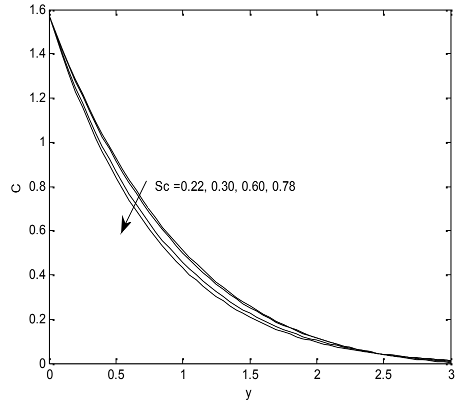

Fig-8. concentration profiles for different values Schmidt number

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