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Radiation And Chemical Reaction Effects on Unsteady Flow Past an Accelerated Infinite Vertical Plate with Variable Temperature and Uniform Mass Diffusion Through a Porous Medium

Ch. Shashi Kumar[1], P. Govinda Chowdary[2], P. Sarada Devi[3], V. Nagaraju[4]

[1]Department of Mathematics, VNR Vignana Jyothi Institute of Engineering & Technology, Hyderabad, TS-500090, India.

[2,4]Department of Basic Sciences and Humanities, Vignan Institute of Technology and Science, Deshmukhi (V), Pochampally (M), Yadadri-Bhuvanagiri (Dist), T.S-508284, India.
Email: chowdary.ratp@gmail.com

[3]Department of Mathematics, Malla Reddy Engineering College (Autonomous), Maisammaguda, Hyderabad-500100, India, Email: sarada.chakireddy@gmail.com

Abstract

The aim of the present analysis is to study the effect of radiation and chemical reaction unsteady flow of an incompressible viscous fluid past a uniformly accelerated infinite vertical porous plate through the porous medium taking into an account of the presence of the variable temperature, uniform mass diffusion with heat and mass transfer of the dimensionless governing partial differential equations. The velocity, temperature, concentration, skin friction, rate of heat transfer and Sherwood number are shown graphically various parameters involving in the problem.

Keywords: Radiation, Chemical reaction, Vertical plate, Variable temperature, Porous medium

INTRODUCTION

The effect of a chemical reaction depends on whether the reaction is homogenous or heterogeneous. This depends on whether the reaction occurs at an interface or as a single phase volume reaction. In well – mixed systems, if it takes place at an interface, the reaction is heterogeneous; and homogeneous if it takes place in solution. In view of the above some of the authors studied, in view of the above some of the authors are carried out Ch Kesavaiah et. al. [1] explained the effects of the chemical reaction and radiation absorption on an unsteady MHD convective heat and mass transfer flow past a semi-infinite vertical permeable moving plate embedded in a porous medium with heat source and suction, Das et. al. [2] expressed radiation effects on flow past an impulsively started vertical infinite plate, Muthucumaraswamy and Lakshmi [3] shows that first order chemical reaction effects on exponentially accelerated vertical plate with variable mass diffusion in the presence of thermal radiation, Chenna Kesavaiah and Sudhakaraiah [4] implemented the effects of heat and mass flux to MHD flow in vertical surface with radiation absorption, El-Hakiem [5] shows that MHD oscillatory flow on free convection-radiation through a porous medium with constant suction velocity, Karunakar Reddy et. al. [6] exhibited MHD heat and mass transfer flow of a viscoelastic fluid past an impulsively started infinite vertical plate with chemical reaction, Makinde and Mhone [7] demonstrated heat transfer to MHD oscillatory flow in a channel filled with porous medium, Raju [8] reviled MHD chemically reacting viscoelastic fluid past an impulsively started infinite vertical plate with heat and mass transfer effect, Gowri and Selvaraj [9] carried out of fluid performance of unsteady MHD parabolic flow past an accelerated vertical plate in the presence of rotation through Porous medium, Dilip Jose and Selvaraj [10] shows that the convective heat and mass transfer effects of rotation on parabolic flow past an accelerated isothermal vertical plate in the presence of chemical reaction of first order.

However, flow through a porous medium has been of significant interest in recent years particularly among geophysical fluid dynamicity. Examples of natural porous media are beach sand, stand stone, limestone, rye bread, wood, the human lung, bile duct, gall bladder with stones and in small blood vessels. Influence of MHD and radiation effects on oscillatory flow through a porous medium with constant suction velocity has been studied by Chenna Kesavaiah and Satyanarayana [11] has been considered MHD and Diffusion Thermo effects on flow accelerated vertical plate with chemical reaction, Sami Ul Haq et. al. [12] studied general solution for unsteady MHD natural convection flow with arbitrary motion of the infinite vertical plate embedded in porous medium, Srinathuni Lavanya and Chenna Kesavaiah [13] has been considered heat transfer to MHD free convection flow of a viscoelastic dusty gas through a porous medium with chemical reaction, Rajput and Gaurav Kumar [14] carried out the effects of radiation and chemical reaction on MHD flow past a vertical plate with variable temperature and mass diffusion, Adekeye et. al. [15] motivated study on numerical analysis of the effects of selected geometrical parameters and fluid properties on MHD natural convection flow in an inclined elliptic porous enclosure with localized heating, Chenna Kesavaiah et. al. [16] shows that the natural convection heat transfer oscillatory flow of an elastico-viscous fluid from vertical plate, Rout and Pattanayak [17] intended their work through chemical reaction and radiation effect on MHD flow past an exponentially accelerated vertical plate in presence of heat source with variable temperature embedded in a porous medium, Islam and Ahmed [18] expressed the effect of thermal diffusion and chemical reaction on MHD free convective flow past an infinite isothermal vertical plate with heat source.

The study of magneto hydrodynamics with mass and heat transfer in the presence of radiation and diffusion has attracted the attention of a large number of scholars due to diverse applications. In astrophysics and geophysics, it is applied to study the stellar and solar structures, radio propagation through the ionosphere, etc. In engineering we find its applications like in MHD pumps, MHD bearings, etc. Combined heat and mass transfer problems with chemical reaction are of importance in many processes and have, therefore, received a considerable amount of attention in recent years. In processes such as drying, evaporation on the surface of a water, energy transfer in a wet cooling tower and the flow in a desert cooler, heat and mass transfer occur simultaneously. Possible applications of this type of flow can be found in many industries. For example, in the power industry, one of the methods of generating electric energy is directly from a moving conducting fluid. The effects of radiation on MHD flow and heat transfer problem have become more important in industries. At high operating temperature, radiation effect can be quite significant. Many processes in engineering areas occur at high temperature and knowledge of radiation heat transfer becomes very important for the design of the pertinent equipment. Nuclear power plants, gas turbines and the various propulsion devices for aircraft, missiles, satellites and space vehicles are examples of such engineering areas. Such information noted some of the authors by Mallikarjuna Reddy et. al. [19] explained the effects of radiation and thermal diffusion on MHD heat transfer flow of a dusty viscoelastic fluid between two moving parallel plates, Muthucumaraswamy and Radhakrishnan [20] shows that the chemical reaction effects on flow past an accelerated vertical plate with variable temperature and mass diffusion in the presence of magnetic field, Ch Kesavaiah et. al. [21] has been studied radiation and mass transfer effects on moving vertical plate with variable temperature and viscous dissipation, Venkateswarlu and Satya Narayana [22] has been considered chemical reaction and radiation absorption effects on the flow and heat transfer of a nanofluid in a rotating system, Chenna Kesavaiah and Venkateswarlu [23] shows that the chemical reaction and radiation absorption effects on convective flows past a porous vertical wavy channel with travelling thermal waves, Venkateswarlu and Narayana [24] motivated study on variable wall concentration and slip effects on MHD nanofluid flow past a porous vertical flat plate, Chenna Kesavaiah et. al. [25] studied radiative MHD Walter's Liquid-B flow past a semi-infinite vertical Plate in the presence of viscous dissipation with a heat source. Earlier the related work discussed by different authors from [26-40]

The aim of the present analysis is to study the effect of radiation and chemical reaction unsteady flow of an incompressible viscous fluid past a uniformly accelerated infinite vertical porous plate through the porous medium taking into an account of the presence of the variable temperature.

FORMULATION OF THE PROBLEM

The unsteady flow of an incompressible viscous fluid which is initially at rest past an infinite vertical plate with variable temperature through a porous medium is considered. The flow is assumed to be in $x-$direction which takes vertical plate in the upward direction. The $y-$axis is taken to be normal to the plate. Initially the plate and the fluid are in same temperature T' with the same concentration C' level at all points shown in figure (1). At time $t' > 0$ the plate accelerated with velocity $u' = \frac{u_0^3 t'}{\nu}$ in its own plane. The plate temperature is raised to T'_w and the level of concentration near the plate is raised to C'_w linearly with the time t.

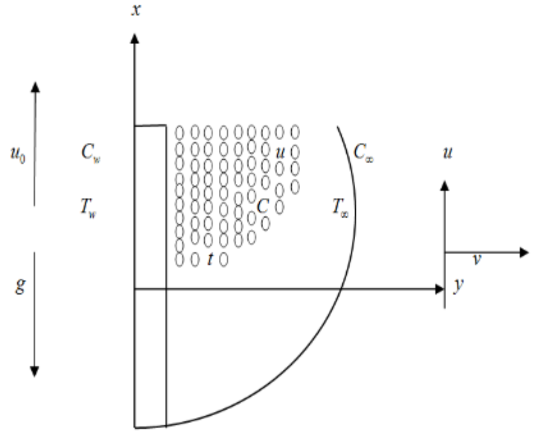

Figure (1): Physical model of the problem

Then by Boussinesq's approximation the unsteady flow is governed by the following equations:

$$\frac{\partial u'}{\partial t'} = g\beta\left(T' - T'_\infty\right) + g\beta^*\left(C' - C'_\infty\right) + \nu\frac{\partial^2 u'}{\partial y'^2} - \frac{\nu}{K'_1}u' \qquad (1)$$

$$\rho c_p \frac{\partial T'}{\partial t'} = \kappa\frac{\partial^2 T'}{\partial y'^2} - \frac{\partial q_r}{\partial y} \qquad (2)$$

$$\frac{\partial C'}{\partial t'} = D\frac{\partial^2 C'}{\partial y'^2} - Kr'\left(C' - C'_\infty\right) \qquad (3)$$

With the following initial and boundary conditions for the fluid flow problem are given below

$$u = 0, T' = T'_\infty, C' = C'_\infty \quad \forall \; y \;\&\; t' \le 0$$

$$\left.\begin{aligned} u' &= \frac{u_0^3 t'}{\nu}, \\ T' &= T'_\infty + \left(T'_w - T'_\infty\right)At', \\ C' &= C'_\infty + \left(C'_w - C'_\infty\right)At' \end{aligned}\right\} \text{at } y = 0 \;\&\; t'>0 \; (4$$

$$u \to 0, T' \to T'_\infty, C' \to C'_\infty \quad as \;\; y \to \infty$$

)

The following dimensionless variables and parameters of the problem are

$$\left.\begin{aligned} &U = \frac{u'}{u_0},\; t = \frac{t' u_0{}^2}{\nu},\; Y = \frac{y' u_0}{\nu},\; \theta = \frac{T' - T'_\infty}{T'_w - T'_\infty} \\ &C = \frac{C' - C'_\infty}{C'_w - C'_\infty},\; \frac{1}{K} = \frac{k' u_0^2}{\nu^2},\quad F = \frac{4\nu I^*}{\rho C_p u_0^2} \\ &Gr = \frac{g\beta\nu\left(T'_w - T'_\infty\right)}{u_0^3}, Sc = \frac{\nu}{D},\; \Pr = \frac{\mu C_p}{k} \\ &Gm = \frac{\beta' g\nu\left(C'_w - C'_\infty\right)}{u_0^3},\qquad Kr = \frac{Kr'\nu}{u_0^2} \end{aligned}\right\} (5)$$

Then an equations (1) – (3) leads to

$$\frac{\partial U}{\partial t} = Gr\;\theta + Gc\;C + \frac{\partial^2 U}{\partial Y^2} - KU \qquad (6)$$

$$\frac{\partial \theta}{\partial t} = \frac{1}{\Pr}\frac{\partial^2 \theta}{\partial Y^2} - F\theta \qquad (7)$$

$$\frac{\partial C}{\partial t} = \frac{1}{Sc}\frac{\partial^2 C}{\partial Y^2} - Kr\,C \qquad (8)$$

The relevant initial and boundary conditions in non- dimensional form are given by

$$\begin{aligned} &U = 0, \theta = 0, C = 0 \quad \forall\; Y \le 0, \&\; t \le 0 \\ &U = t, \theta = t, C = t \quad \text{at} \;\; Y = 0,\; \&\, t > 0 \quad (9) \\ &U \to 0,\; \theta \to 0, C \to 0\; Y \to \infty \quad t > 0 \end{aligned}$$

METHOD OF SOLUTION

Equation (6) - (8) are coupled, non – linear partial differential equations and these cannot be solved in closed – form using the initial and boundary conditions (9). However, these equations can be reduced to a set of ordinary differential equations, which can be solved analytically. This can be done by representing the velocity, temperature and concentration of the fluid in the neighbourhood of the fluid in the neighbourhood of the plate as

$$\begin{aligned} U(y,t) &= U_0(y) + U_1(y)e^{nt} \\ \theta(y,t) &= \theta_0(y) + \theta_1(y)e^{nt} \\ C(y,t) &= C_0(y) + C_1(y)e^{nt} \end{aligned} \qquad (10)$$

Substitute equation (10) in to the equations (6), (7) and (8) the set of ordinary differential equations are the following form

$$U_0'' - KU_0 = -Gr\,\theta_0 - Gm\,C_0 \qquad (11)$$

$$U_1'' - (K + nt)U_1 = -Gr\,\theta_1 - Gm\,C_1 \qquad (12)$$

$$\theta_0'' - F\Pr\theta_0 = 0 \qquad (13)$$

$$\theta_1'' - (F + nt)\Pr\theta_1 = 0 \qquad (14)$$

$$C_0'' - KrSc\,C_0 = 0 \qquad (15)$$

$$C_1'' - (Kr + nt)Sc\,C_1 = 0 \qquad (16)$$

The exact solution for the fluid velocity $U(y,t)$, fluid temperature $\theta(y,t)$ and species concentration $C(y,t)$ are obtained and expressed from equations from (11) - (16) in the following form:

$$\begin{aligned} U(y,t) &= A_1\, e^{-\sqrt{F\Pr}\;y} + A_2\, e^{-\sqrt{KrSc}\;y} + A_3\, e^{-\sqrt{K}\;y} \\ \theta(y,t) &= t\, e^{-\sqrt{F\Pr}\;y} \\ C(y,t) &= t\, e^{-\sqrt{KrSc}\;y} \end{aligned}$$

Skin-friction

$$\left(\frac{\partial U}{\partial y}\right)_{y=0} = -\sqrt{F\Pr}A_1 - \sqrt{Kr\,Sc}\,A_2 - \sqrt{K}A_3$$

Nusselt number

$$\left(\frac{\partial \theta}{\partial y}\right)_{y=0} = -t\sqrt{F\Pr}$$

Sherwood number

$$\left(\frac{\partial C}{\partial y}\right)_{y=0} = -t\sqrt{Kr\ Sc}$$

RESULTS AND DISCUSSION

The results are shown graphically for various parameters thermal Grashof number(Gr), modified Grashof number(Gc), Prandtl number$(\Pr)$, Schmidt number(Sc), Radiation parameter(F), Permeability parameter(K), Chemical reaction parameter (Kr) and time(t). In this observation the values of the Prandtl number are chosen to represents air $(\Pr = 0.71)$ and water $(\Pr = 7.0)$; Schmidt number are chosen to represents oxygen $(Sc = 0.60)$, Ammonia $(Sc = 0.78)$, Carbon Dioxide $(Sc = 0.94)$, Ethy benzene $(Sc = 2.0)$. The velocity profiles shown from figures (2) – (8); the velocity profiles different values of time$(t = 0.2, 0.4, 0.6, 0.8)$ is predicted in figure (2); it is clearly shown that the velocity increases with increasing values of time. The velocity profiles for different values of radiation parameter $(F = 1, 2, 3, 4)$ is presented in figure (3), it is observed that the velocity decrease with the increasing values of permeability parameter. For various values of thermal Grashof number and modified Grashof number $(Gr = 1, 2, 3, 4; Gc = 1, 2, 3, 4)$ are give an exhibition of the velocity profiles in figure (4) and (5), we noticed that the velocity increase with increasing values of thermal Grashof number as well as modified Grashof number. Figures (6) and (7) shown velocity profiles for different values of chemical reaction parameter$(Kr = 1, 2, 3, 4)$ and Schmidt number$(Sc = 0.60, 0.78, 0.94, 2)$, it is observed that an increasing values of chemical reaction parameter and Schmidt number the velocity decreases. The velocity profiles observed for different values of Prandtl number$(\Pr = 0.78, 0.9, 1, 7)$ are shown in figure (8), it is clear that the velocity decreases with increasing values of Prandtl number. The temperature profiles are shown from figures (9) – (11). From figures (9) and figure (10) observed that the temperature profiles for different values of Prandtl number$(\Pr = 0.78, 0.9, 1, 7)$ and radiation parameter$(F = 1, 2, 3, 4)$, we observed that an increasing Prandtl number and radiation parameters the temperature profiles decreases in both the parameters. Figure (11) displays the temperature profiles for different values of time $(t = 0.2, 0.4, 0.6, 0.8)$ indicates that the temperature profiles increases with increases with time. The concentration profiles are shown from figures (12) – (14). From figures (12) and figure (13) observed that the concentration profiles for different values of chemical reaction parameter $(Kr = 1, 2, 3, 4)$ and Schmidt number $(Sc = 0.60, 0.78, 0.94, 2)$ we observed that an increasing Prandtl number the concentration profiles decreases in both the parameters. Figure (14) displays the concentration profiles for different values of time $(t = 0.2, 0.4, 0.6, 0.8)$ indicates that the concentration profiles increases with increases with time. The skin friction coefficient shown in figure (15) for various values of radiation parameter $(F = 1, 2, 3, 4)$ versus thermal Grashof number (Gr) which is clear that an increasing values of radiation parameter the skin friction coefficient decreases. The rate of heat transfer shown in figure (16) for different values of radiation parameter $(F = 1, 2, 3, 4)$ versus Prandtl number $(\Pr)$, it shows that an increases in Prandtl number the Nusselt number decreases. From figure (18) observed that Sherwood number for different values of Schmidt number $(Sc = 0.60, 0.78, 0.94, 2)$ versus chemical reaction parameter (Kr), we observed that an increasing Schmidt number the Sherwood number decreases.

Conclusions:

We noticed that the

- Velocity increase with increasing values of thermal Grashof number as well as modified Grashof number.
- The velocity profiles for different values of Schmidt number, it is observed that increasing values of Schmidt number the velocity decreases.
- The velocity profiles for different values of chemical reaction parameter and Schmidt number, it is observed that an increasing values of chemical reaction parameter the velocity decreases.

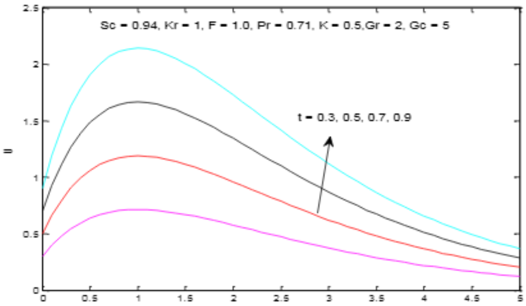

Figure (2): Velocity profiles for different values of t

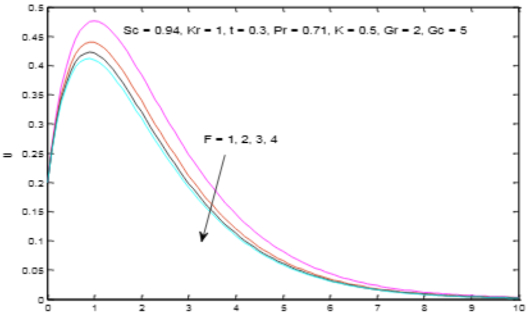

Figure (3): Velocity profiles for different values of F

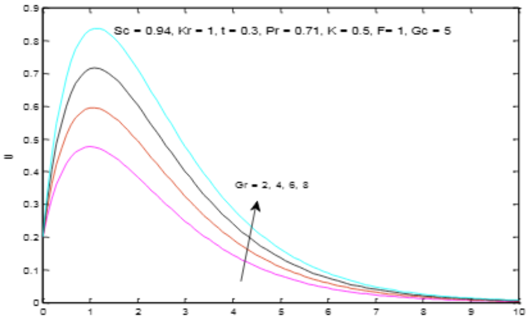

Figure (4): Velocity profiles for different values of Gr

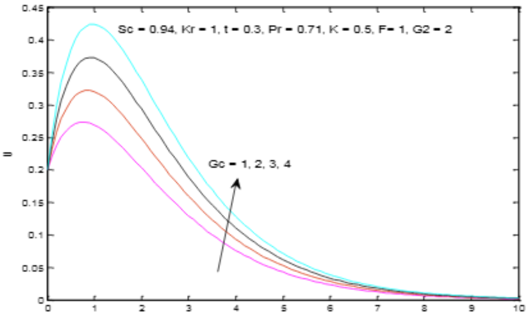

Figure (5): Velocity profiles for different values of Gc

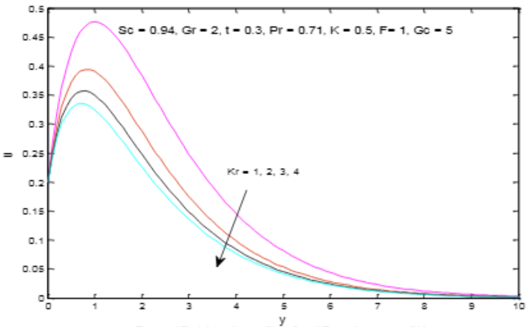

Figure (6): Velocity profiles for different values of Kr

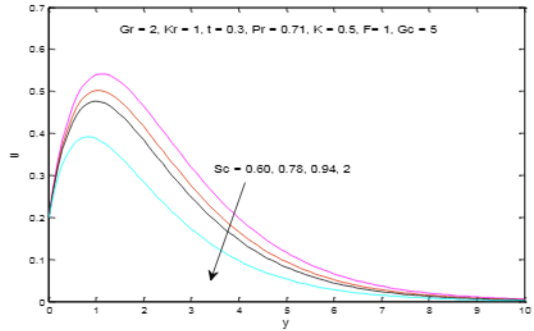

Figure (7): Velocity profiles for different values of Sc

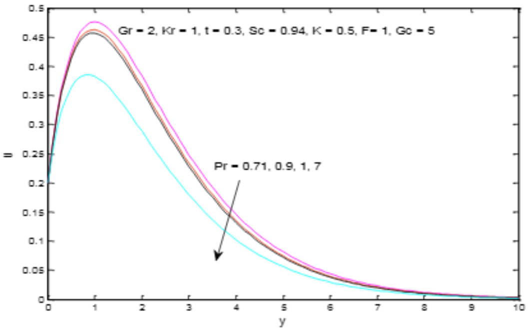

Figure (8): Velocity profiles for different values of Pr

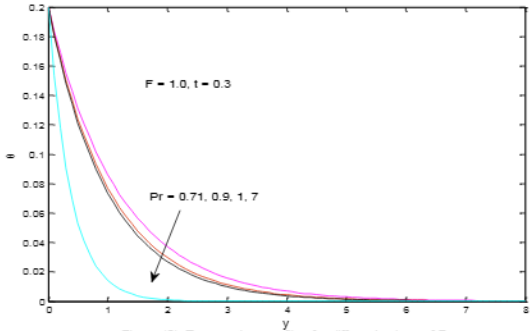

Figure (9): Temperature profiles for different values of Pr

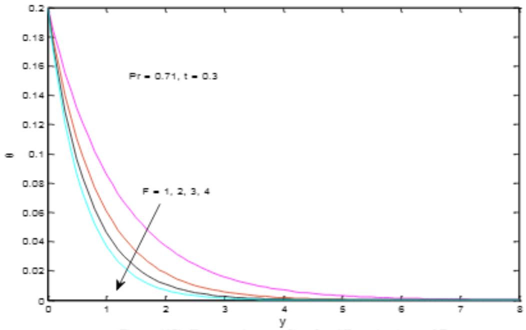

Figure (10): Temeprature profiles for different values of F

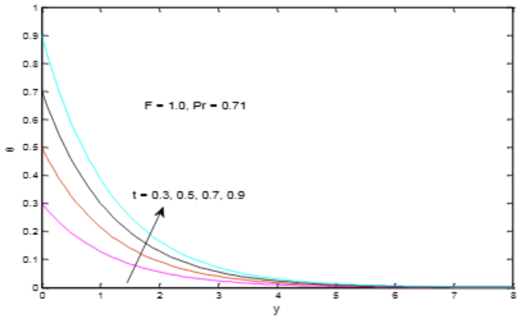

Figure (11): Temperature profiles for different values of t

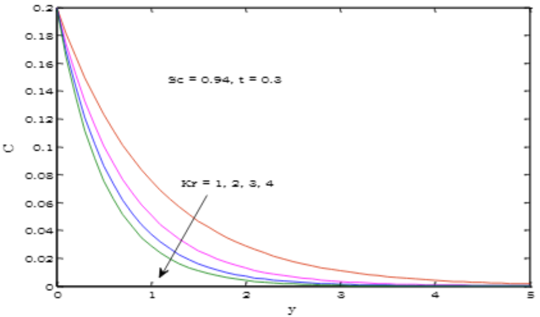

Figure (12): Concentration profiles for different values of Kr

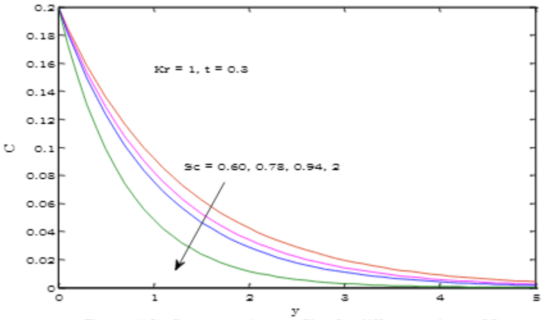

Figure (13): Concentration profiles for different values of Sc

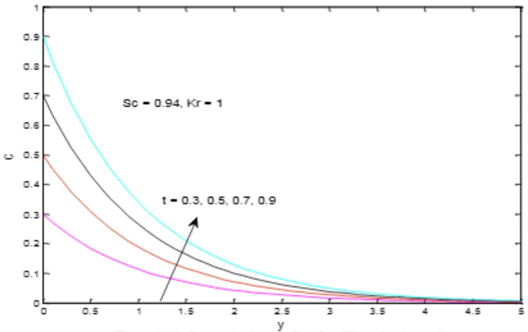

Figure (14): Concentration profiles for different values of t

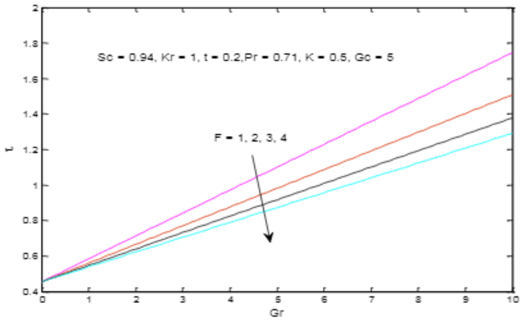

Figure (15): Skin friction for different values of F

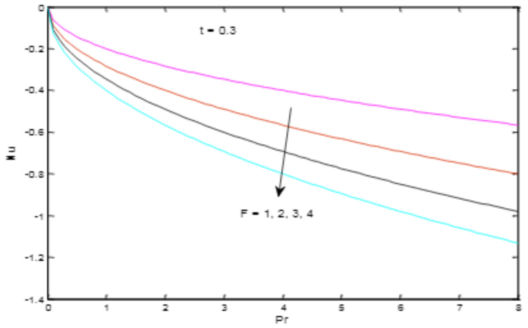

Figure (16): Nusselt number for different values of F

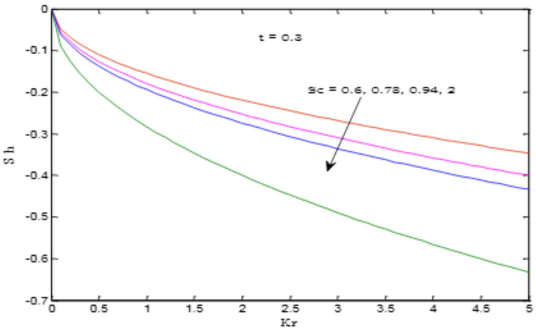

Figure (17): Sherwood number for different values of Sc

APPENDIX

$$A_1 = \frac{Gr\,t}{F\,\mathrm{Pr} - K}, A_2 = \frac{Gc\,t}{KrSc - K}$$

$$A_3 = \left(t - A_1 - A_2\right)$$

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