Chemical reaction effect on MHD flow over vertical surface through porous medium

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Abstract

The present paper intended to analyze the effect of diffusion - thermo (Dufour) on MHD free convective heat and mass transfer two-dimensional steady boundary layer flow of a viscous incompressible electrically conducting fluid through a porous medium with variable permeability over a vertical surface in the presence of first order chemical reaction and oscillatory suction. The resultant governing boundary layer equations are highly nonlinear and coupled form of partial differential equations which are solved analytically using two-term harmonic and non-harmonic function. The effects of different physical parameters on the velocity, temperature and concentration fields as well as skin friction are discussed in detail. The results are presented graphically by using MatLab.

Keywords: MHD, porous medium, chemical reaction, vertical surface

1. Introduction

A porous medium can be defined as a material consisting of solid matrix with an interconnected void. In recent years, the investigation of flow of fluids through porous media has become an importance topic due to the recovery of crude oil from the pores reservoir rocks. Typical examples of application involving such systems include catalytic and chromatographic reactions, packed absorption and distillation towers, ion exchange columns, packed filters, pebble type heat exchanger, geothermal operation, chemical engineering (absorption, filtration), petroleum reservoirs (rocks and soils), cement and ceramics, hydrology, filtration, mechanics (acoustics, geo mechanics, soil mechanics, rock mechanics), geo sciences (hydrogeology, petroleum, geology, geophysics), biology, bio – physics and material science. With the growing importance of non- Newtonian fluids is modern technology and industries, the thermal instability, thermal solution instability and Rayleigh-Taylor instability, problems of Walters (model B) fluid and couple stress fluid are desirable. The definition of the porosity of the porous medium can be given as the ratio of pore volume to the total volume of a given sample of material. A complete graduation exists from large force easily, accessible fluids to very small opening minerals that are caused by minor lattice imperfection. In view of the above some of the authored concentrated (SRINATHUNI LAVANYA et.al. 2017) presented heat transfer to MHD free convection flow of a viscoelastic dusty gas through a porous medium with chemical reaction, (VENKATESWARLU et.al. 2020) Showed Chemical reaction and radiation absorption effects on convective flows past a porous vertical wavy channel with travelling thermal waves, (CHENNA KESAVAIAH, 2020) analyzed radiative flow of MHD Jeffery fluid over a stretching vertical surface in a porous medium, (OMOWAYE et.al. 2015) Considered Dofour and Soret effects on steady MHD convective flow of a fluid in a porous medium with temperature dependent viscosity: Homotopy analysis approach, (DURSUNKAYA et.al. 1992) observed Diffusion thermo and thermal diffusion effects in transient and steady natural convection form a vertical surface.

In most of the investigation of heat and mass transfer process it is found that Soret and Dufour effects are neglected on the behalf of smaller order of their magnitude, the effects described by Fourier and Ficks. If the density difference occurs in flow regime these effects are applicable. The Dufour effect is the energy flux due to a mass concentration gradient occurring as a coupled effect of irreversible process. It is reciprocal phenomenon to the Soret effect. The concentration gradient results in a temperature change. For binary liquid mixtures, the Dufour effect is usually considered negligible, whereas in binary gas mixtures the effect can be significant. Dufour effect on the bifurcation behaviour of convective flow intensity, vertical heat current, and concentration mixing. The Dufour – induced changes in the bifurcation topology and the existence regimes of stationary and travelling –wave convection is elucidated. However, both effects become significant when the species having lower density than the surrounding liquids are introduced at surface of fluid medium. Also, such effects play a vital role in the field of geosciences, oceanography, chemical engineering and air pollution. Considering all the above (MOORTHY et.al. 2012) studied Soret and Dufour effects on natural convection flow past a vertical surface in a porous medium with variable viscosity, (SRINATHUNI LAVANYA et.al. 2014) presented radiation and Soret effects to MHD flow in vertical surface with chemical reaction and heat generation through a porous medium, (CH KESAVAIAH et. al. 2013) studied effects of radiation and free convection currents on unsteady Couette flow between two vertical parallel plates with constant heat flux and heat source through porous medium, (GBADEYAN et.al. 2018) Considered Soret and Dufour effects on heat and mass transfer in chemically reacting MHD flow through a wavy channel, (MABOOD et.al. 2015) Observed MHD stagnation point flow and transfer impinging on stretching sheet with chemical reaction and transpiration, (TASAWAR HAYAT et.al. 2018) presented Numerical investigation of MHD flow with Soret and Dufour effect.

The fundamental concept of behind magnetohydrodynamic (MHD) is that magnetic fields can induce currents in a moving conductive fluid, which in turn polarizes the fluid and reciprocally changes the magnetic field itself. The set of equations that describe MHD are combination of Navier-Stokes equation of fluid dynamics and Maxwell's equations of electromagnetism. These differential equations must solve simultaneously either analytically or numerically. The applications of magnetohydrodynamic (MHD) fluid flow in different geometries relevant to human body parts in an interesting and important scientific area due to its applications in medical sciences; hot gas ionize (atoms comprising gas collide with high energy); solar wind and flares (interacts with magnetosphere, interacts with earth's magnetic field) arise in astrophysics, sensors (base motion environment characterization), engineering and biomedical sciences (such as magnetic drug targeting, magnetic devices for cell separation, adjusting blood flow during surgery). In particular the magnetic fields play an essential role in forming the sun and stars. Due to these leading benefits, the researchers are continuously examining the MHD flows. (CHENNA KESAVAIAH et.al. 2013) considered MHD and Diffusion Thermo effects on flow accelerated vertical plate with chemical reaction, (CH KESAVAIAH et. al. 2012) analyzed radiation and mass transfer effects on moving vertical plate with variable temperature and viscous Dissipation, (CHENNA KESAVAIAH et.al. 2019) discussed radiation effects on transient MHD free convective flow over a vertical porous plate with heat source, (CHENNA KESAVAIAH et.al. 2019) analyzed Radiation and chemical reaction effects on MHD accelerated inclined plate with variable temperature, (SRINATHUNI LAVANYA et.al. 2017) analyzed radiation effects on MHD natural convection heat transfer flow from spirally enhanced wavy channel through a porous medium, (CHENNA KESAVAIAH et.al. 2014) presented effects of heat and mass flux to MHD flow in vertical surface with radiation absorption, (JENA et.al. 2018) Chemical reaction effect on MHD viscoelastic fluid flow over vertical stretching sheet with heat source/sink, (TRIPATHY et.al. 2015) studied chemical reaction effects on MHD free convective surface over a moving vertical plate through porous medium, for more information we refereed Applied Numerical Methods by (CARNAHAN et.al. 1996).

In many chemical engineering processes, the chemical reaction do occur between mass and fluid in which plate is moving. These processes take place in numerous industrial applications such as polymer production, manufacturing of ceramics or glassware and food processing. In the light of the fact that, the combination of 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 at the surface of a water body, 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, among the methods of generating electricity is one in which electrical energy is extracted directly from the moving conducting fluid. In view of the above some of the authors studies, (RAJPUT et.al. 2011) discussed radiation and chemical reaction effect on free convection MHD flow through a porous medium bounded by vertical surface, (REDDY et. al. 2013) considered chemical reaction and radiation effects on MHD free convection flow through a porous medium bounded by a vertical surface with constant heat and mass flux, (SUDERSHAN REDDY et. al. 2012) studied radiation and chemical reaction effects on free convection MHD flow through a porous medium bounded by vertical surface,

In view of the above the main objective of the present paper investigation is the effect of diffusion - thermo (Dufour) on MHD free convective heat and mass transfer two-dimensional steady boundary layer flow of a viscous incompressible electrically conducting fluid through a porous medium with variable permeability over a vertical surface in the presence of first order chemical reaction and oscillatory suction. The resultant governing boundary layer equations are highly nonlinear and coupled form of partial differential equations which are solved analytically using two-term harmonic and non-harmonic function. The effects of different physical parameters on the velocity, temperature and concentration fields as well as skin friction are discussed in detail.

2. Formulation of the Problem

We considered the steady, two - dimensional laminar, incompressible flow of a chemically reacting, viscous fluid on a continuously moving vertical surface in the presence of a uniform magnetic field and Dufour effect, uniform heat and mass flux effects issuing a slot and moving with uniform velocity in a fluid at rest. Let $x-axis$ be taken along the direction of motion of the surface in the upward direction and $y-axis$ is normal to the surface are shown in figure (1).

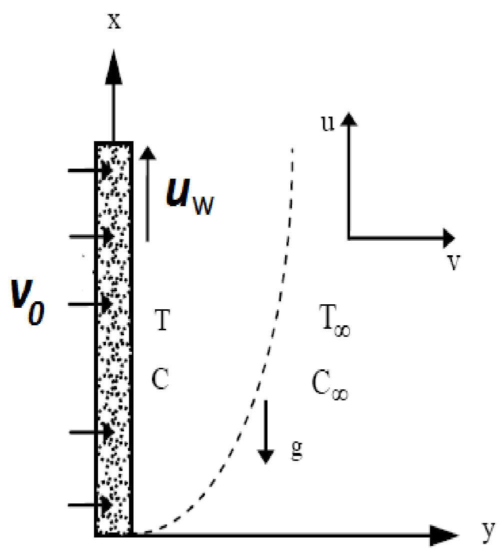

Figure (1): Geometry of the problem

The temperature and concentration levels near the surface are raised uniformly. The induced magnetic field, viscous dissipation is assumed to be neglected. Now, under the usual Boussinesq's approximation, the flow field is governed by the following equations.

Continuity equation

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \tag{1}$$

Momentum equation

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=g\beta\left(T'-T'_\infty\right)+g\beta^*\left(C'-C'_\infty\right)+\nu\frac{\partial^2 u}{\partial y^2}-\frac{\sigma B_0^2}{\rho}-\frac{\nu}{K_p}u \tag{2}$$

Energy equation

$$\rho C_p\left(u\frac{\partial T'}{\partial x}+v\frac{\partial T'}{\partial y}\right)=k\frac{\partial^2 T'}{\partial y^2}+\frac{D_M K_T}{C_s C_p}\frac{\partial^2 C'}{\partial y^2} \tag{3}$$

Diffusion equation

$$u\frac{\partial C'}{\partial x}+v\frac{\partial C'}{\partial y}=D\frac{\partial^2 C'}{\partial y^2}-Kr'\left(C'-C'_\infty\right) \tag{4}$$

The initial and boundary conditions

$$u = u_w, v = -v_0\, const, < 0, \frac{\partial T}{\partial y} = -\frac{q}{k}, \frac{\partial C}{\partial y} = -\frac{j''}{k} \quad at \quad y = 0$$
$$u \to 0, T \to T'_\infty, C \to C'_\infty \qquad as \;\; y \to \infty \tag{5}$$

Where u, are velocity components in x and y directions respectively. g is the acceleration due to gravity, β is volumetric coefficient of thermal expansion, β^* is the volumetric coefficient of expansion with concentration, is the temperature of the fluid, C' is the species concentration, T'_w is the wall temperature, C'_w is the concentration at the plate, T'_∞ is the free steam temperature far away from the plate, C'_∞ is the free steam concentration in fluid far away from the plate, ν is the kinematic viscosity, Du is the species diffusion coefficient, Kr is the chemical reaction parameter. The term is assumed to be the amount of heat generated or absorbed per unit volume. Q_0 is a constant, which may take on either positive or negative values. When the wall temperature T'_w exceeds the free steam temperature T'_∞, the source term represents the heat source $Q_0 > 0$ when and heat sink when $Q_0 < 0$. The first term and second term on the right hand side of the momentum equation (2) denote the thermal and concentration buoyancy effects respectively.

In order to write the governing equations and the boundary conditions the following non-dimensional quantities are introduced.

$$Y = \frac{y v_o}{\nu}, U = \frac{u}{u_w},, k = \frac{K_p v_0^2}{\nu^2}, T = \frac{T' - T'_\infty}{\left(\frac{q\nu}{k v_0}\right)},, C = \frac{C' - C'_\infty}{\left(\frac{j''\nu}{k v_0}\right)}, M = \frac{\sigma B_0^2 \nu}{\rho}, Sc = \frac{\nu}{D}$$
$$Gr = \frac{\nu g \beta \left(\frac{q\nu}{k v_0}\right)}{u_w v_0^2}, Du = \frac{D_M K_T j''}{c_s c_p \nu q \rho C_p} Gc = \frac{\nu g \beta^* \left(\frac{j''\nu}{k v_0}\right)}{u_w v_0^2}, Kr = \frac{Kr'\nu}{v_0^2}, \Pr = \frac{\mu C_p}{k} \tag{6}$$

In view of (6) the equations (2) – (4) are reduced to the following non-dimensional form

$$\frac{d^2U}{dY^2} + \frac{dU}{dY} - \left(M + \frac{1}{k}\right)U = -GrT - GrC \tag{7}$$

$$\frac{d^2T}{dY^2} + \Pr\frac{dT}{dY} = -Du\Pr\frac{d^2C}{dY^2} \tag{8}$$

$$\frac{d^2C}{dY^2} + Sc\frac{dC}{dY} - KrSc\,C = 0 \tag{9}$$

Corresponding initial and boundary conditions in non-dimensional form are

$$\begin{aligned} &U = 1, \frac{\partial T}{\partial Y} = -1, \frac{\partial C}{\partial Y} = -1 \quad at \quad Y = 0 \\ &U \to 0, T \to 0, C \to 0 \quad as \quad Y \to \infty \end{aligned} \tag{10}$$

where Gr is the thermal Grashof number, Gc is the solutal Grashof number, M is the magnetic parameter, k is the permeability parameter, Pr is the fluid Prandtl number, Du is the Dufour number , Sc is the Schmidt number and Kr is the chemical reaction parameter.

3. Method of Solution

The study of ordinary differential equations (7), (8) and (9) along with their initial and boundary conditions (10) have been solved by using the method of ordinary linear differential equations with constant coefficients. We get the following analytical solutions for the velocity, temperature and concentration

$$U = (Z_1 + Z_3)e^{m_2 y} + Z_2 e^{m_4 y} + Z_4 e^{m_6 y}$$

$$T = Q_1 e^{m_2 y} + Q_2 e^{m_4 y}$$

$$C = -\frac{1}{m_2} e^{m_2 y}$$

3.1. Skin friction

$$\tau = \left(\frac{\partial U}{\partial y}\right)_{y=0} = m_2 (Z_1 + Z_3) + m_4 Z_2 + m_6 Z_4$$

3.2. Nusselt number

$$Nu = \left(\frac{\partial T}{\partial y}\right)_{y=0} = m_2 Q_1 + m_4 Q_2$$

3.3. Sherwood number

$$Sh = \left(\frac{\partial C}{\partial y}\right)_{y=0} = -1$$

4. Results and Discussion

In order to analyze the results are carried out for various values of thermal Grashof number (Gr), solutal Grashof number (Gc), magnetic parameter (M), permeability parameter (k), Prandtl number $(\Pr)$, Dufour number (Du), Schmidt number (Sc) and Chemical reaction parameter (Kr). **Fig. (2) and (3)** reveals that the velocity variation with parameters Grashof number (Gr) and modified Grashof number (Gc), from this figures it is found that the fluid velocity increases with increases in Gr, Gc. It is because that increase in the values Gr, Gc has the tendency to increase the thermal and mass buoyancy effect. This gives rise to an increase in the induced flow transport. The effect of the chemical reaction parameter (Kr) has shown **fig. (4).** It should be mentioned that the case studied relates to a destructive chemical reaction. In fact, as the chemical reaction parameter increases, a considerable reduction in the velocity occurs, and the presence of the peak indicates that the maximum velocity takes place in the fluid body close to the surface, but not at the surface itself. It is evident that an increase in this parameter significantly alters the concentration boundary layer thickness but does not change the momentum one. From **fig. (5)** Observed the velocity of the fluid decreases with the increase of the magnetic parameter (M) values. It is because the application of the transverse magnetic field will result in a resistive type (Lorentz similar to the drag force which tends to resist the fluid flow and thus reducing its velocity. Also, the boundary layer thickness decrease with an increase in the magnetic parameter. We also had seen that velocity profiles decrease with the increase of magnetic effect indicating that the magnetic field trends to retard the motion of the fluid. The magnetic field may control the flow characteristics. The velocity profiles describe in **fig. (6)** For various values of Schmidt number (Sc), it is clear that increases in Schmidt number the velocity decreases. **Fig. (7)** Depicts that the velocity profiles for different values of Prandtl number $(\Pr)$. It is observed that increase in the value of Prandtl number results in decrease in the velocity profile. The Dufour number (Du) signifies the contribution of the concentration gradients to the thermal energy flux in the flow. It seen that Dufour number increases there is monotonic increases in the velocity which shown in **fig. (8).** The velocity profiles observed in **fig. (9)** for various values of Porosity parameter (K), from this figure it is clear that increases in Porosity parameter the velocity increases. From **fig. (10),** it is observed that the temperature for conducting air $(\Pr = 0.71)$ is higher than that of water $(\Pr = 7.0)$ it is because of the fact that thermal conductivity of the fluid decreases with increasing values of $\Pr$ resulting decreases in thermal boundary layer thickness. Physically, thermal diffusivity exceeds momentum diffusivity, i.e., heat will diffuse quickly than momentum. Temperature observed to be squeezing closer and closer to wall as Prandtl number increases. This implies that fluid is highly conductive when $\Pr \le 1$ so that heat from surface diffuses faster than for large $\Pr$ fluids. Therefore, in conducting flows, Prandtl number can be used to enhance cooling rate. The temperature profiles for Dufour number (Du) shown in **fig. (11),** it is clear that Dufour parameter as increases, the temperature of the flow field decreases at the all points in flow region. The effect of concentration profiles for different values of chemical reaction parameter (Kr) illustrated in **fig. (12),** it is found that the concentration decreases as chemical reaction parameter. **Fig. (13)** Describes the behaviour of various values of Schmidt number (Sc) on concentration profiles. The Schmidt number characterizes the ratio of thickness of viscous of the mass diffusivity. The Schmidt number quantifies concentration boundary layers. It is observed that an increases Schmidt number causes the species concentration and its boundary layer thickness to decrease significantly.

5. Conclusions:

We analysed the effect of diffusion - thermo (Dufour) on MHD free convective heat and mass transfer two-dimensional steady boundary layer flow of a viscous incompressible electrically conducting fluid through a porous medium with variable permeability over a vertical surface in the presence of first order chemical reaction and oscillatory suction. The governing unsteady boundary layer problems are solved numerically.

The main conclusions of this study are as follows:

1. Velocity profiles of the fluid increases with increasing values of Grashof number.
2. Velocity profiles of the fluid increases with increasing values of modified Grashof number.
3. Velocity profiles of the fluid increases with increasing values of Dufour number
4. Velocity profiles of the fluid increases with increasing values of porous permeability number.
5. The velocity profiles decreases with increasing values of chemical reaction.
6. The velocity profiles decreases with increasing values of magnetic field. So magnetic field can effectively be used to control the flow.
7. The velocity profiles decreases with increasing values of Schmidt number.
8. The velocity profiles decreases with increasing values of Prandtl number.
9. Temperature profiles decreases with increases in Dufour number and Prandtl number.
10. Concentration profiles decreases with increasing values of Schmidt number and chemical reaction parameter.
11. Skin friction increases with increasing values of porous permeability parameter versus Grashof number.

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Appendix

$$\beta = \left(M + \frac{1}{K} \right),\ m_2 = -\left(\frac{Sc + \sqrt{Sc^2 + 4KrSc}}{2} \right),\ m_4 = -\left(\Pr \right),\ m_6 = -\left(\frac{1 + \sqrt{1 + 4\beta}}{2} \right)$$

$$Q_2 = -\left(\frac{1 + Q_l m_2}{m_2} \right), Q_1 = \left(\frac{Du \Pr m_2}{m_2^2 + \Pr m_2} \right)\ Z_1 = -\left(\frac{GrQ_1}{m_2^2 + m_2 - \beta} \right), Z_2 = -\left(\frac{GrQ_2}{m_4^2 + m_4 - \beta} \right)$$

$$Z_3 = \frac{1}{m_2} \left(\frac{Gc}{m_2^2 + m_2 - \beta} \right), Z_4 = \left(1 - Z_1 - Z_2 - Z_3 \right)$$

Reference

CARNAHAN, B., LUTHER, H. A., WIKES, J. O. (1996): Applied Numerical Methods, John Wiely & Sons, New York, USA

CH KESAVAIAH., D, SATYANARAYANA., P. V. AND SUDHAKARAIAH, A. (2013): Effects of radiation and free convection currents on unsteady Couette flow between two vertical parallel plates with constant heat flux and heat source through porous medium, International Journal of Engineering Research, 2 (2):113-118

CH KESAVAIAH., D, SATYANARAYANA., P. V., GIREESH KUMAR., J S VENKATARAMANA (2012): Radiation and mass transfer effects on moving vertical plate with variable temperature and viscous Dissipation, International Journal of Mathematical Archives, 3 (8): 3028-3035

CHENNA KESAVAIAH, D. (2020): Radiative flow of MHD Jeffery fluid over a stretching vertical surface in a porous medium, Zeichen Journal, Vol. 6 (3), pp. 39-53, 2020

CHENNA KESAVAIAH, D., SUDHAKARAIAH, A. (2014): Effects of Heat and Mass Flux to MHD Flow in Vertical Surface with Radiation Absorption, Scholars Journal of Engineering and Technology, 2(2B): 219-2250

CHENNA KESAVAIAH., D, CHANDRAPRAKASH., D. (2019): Radiation and chemical reaction effects on MHD accelerated inclined plate with variable temperature, Adalya Journal, 8 (8): 346-365

CHENNA KESAVAIAH., D, SATYANARAYANA., P. V. (2013): MHD and Diffusion Thermo effects on flow accelerated vertical plate with chemical reaction, Indian Journal of Applied Research, 3 (7): 310-314, 2013

CHENNA KESAVAIAH., D, CHANDRAPRAKASH., D, MD EJA AHMED (2019): Radiation effects on transient MHD free convective flow over a vertical porous plate with heat source, Journal of Information and Computational Science, 9 (12): 535-550

DURSUNKAYA, Z., WOREK, W. M. (1992): Diffusion thermo and thermal diffusion effects in transient and steady natural convection form a vertical surface, Int. J Heat Mass Transfer, 35: 2060-2065

GBADEYAN, J. A., OYEKUNLE, T. L, FASOGBON, P. F. (2018): Soret and Dufour effects on heat and mass transfer in chemically reacting MHD flow through a wavy channel, Journal of Taibah University for Science, 12 (5),:631-651

JENA, S., MISHRA, S. R. (2018): Chemical reaction effect on MHD viscoelastic fluid flow over vertical stretching sheet with heat source/sink, Ain Shams Engineering Journal, 9 (4):1205-1213

MABOOD, F., KHAN, W., ISMAIL., A. I. (2015): MHD stagnation point flow and transfer impinging on stretching sheet with chemical reaction and transpiration, Chem. Eng., J., 273:430-437

MOORTHY., M. B. K., SENTHILVADIVU, K. (2012): Soret and Dufour effects on natural convection flow past a vertical surface in a porous medium with variable viscosity, Journal of Applied Mathematics

OMOWAYE, A. J., FAGBADE, A. I., AJAYI, A. O. (2015): Dofour and Soret effects on steady MHD convective flow of a fluid in a porous medium with temperature dependent viscosity: Homotopy analysis approach, Journal of the Nigerian Mathematical Society, 34: 343-360

SRINATHUNI LAVANYA, CHENNA KESAVAIAH, D. (2017): Heat transfer to MHD free convection flow of a viscoelastic dusty gas through a porous medium with chemical reaction, International Journal of Pure and Applied Researches, 3 (1): 43 - 56

SRINATHUNI LAVANYA, CHENNA KESAVAIAH., D. (2017): Radiation effects on MHD natural convection heat transfer flow from spirally enhanced wavy channel through a porous medium, International Journal on Future Revolution in Computer Science & Communication Engineering , 3 (10): 130-140

SRINATHUNI LAVANYA., CHENNA KESAVAIAH, D. (2014): Radiation and Soret effects to MHD Flow in vertical surface with chemical reaction and heat generation through a porous medium, International Journal of Computational Engineering Research, 04 (7): 62-73

TASAWAR HAYAT, TEHREEM NASIR., MUHAMMAD IJAZ KHAN., AHMED ALSAEDI. (2018): Numerical investigation of MHD flow with Soret and Dufour effect, Results in Physics, 8:1017-1022

TRIPATHY, R. S., DASH, G. C., MISHRA, S. R., BAAG, S., (2015): Chemical reaction effects on MHD free convective surface over a moving vertical plate through porous medium, Alexandria Engineering Journal, 54: 673-679

VENKATESWARLU, B., CHENNA KESAVAIAH, D. (2020): Chemical reaction and radiation absorption effects on convective flows past a porous vertical wavy channel with travelling thermal waves, International Journal of Fluid Mechanics Research, 2020, accepted

RAJPUT., U. S., SURENDRA KUMAR. (2011): discussed radiation and chemical reaction effect on free convection MHD flow through a porous medium bounded by vertical surface, International Journal of Mathematical Archive, 2: 12, 2660 – 2669

REDDY., T.S., RAJU., M. C., VARMA., S. V. K. (2013): Chemical reaction and radiation effects on MHD free convection flow through a porous medium bounded by a vertical surface with constant heat and mass flux, Journal of Computation and Applied Research in Mechanical Engineering, 3: no.1, 53-62

SUDERSHAN REDDY., G., RAMANA REDDY., G.V., JAYARAMI REDDY., K. (2012) studied radiation and chemical reaction effects on free convection MHD flow through a porous medium bounded by vertical surface, Advances in Applied Science Research, 3: no. 3, 1603-1610

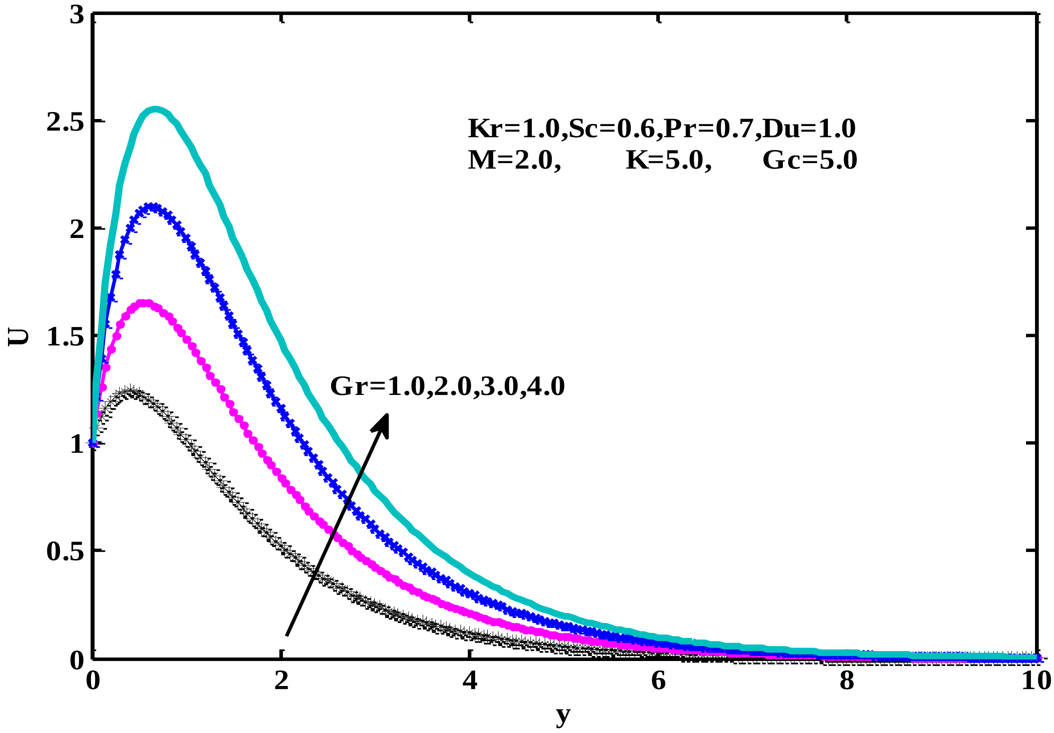

Figure (2): Velocity Profiles for different values of Gr

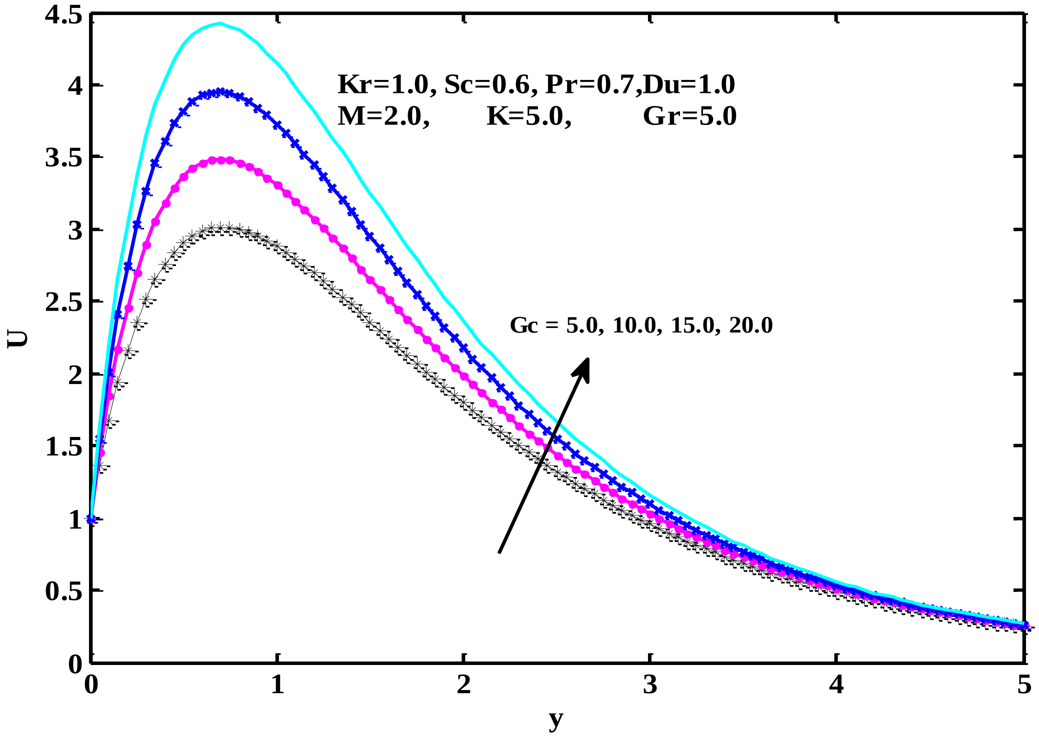

Figure (3): Velocity Profiles for different values of Gc

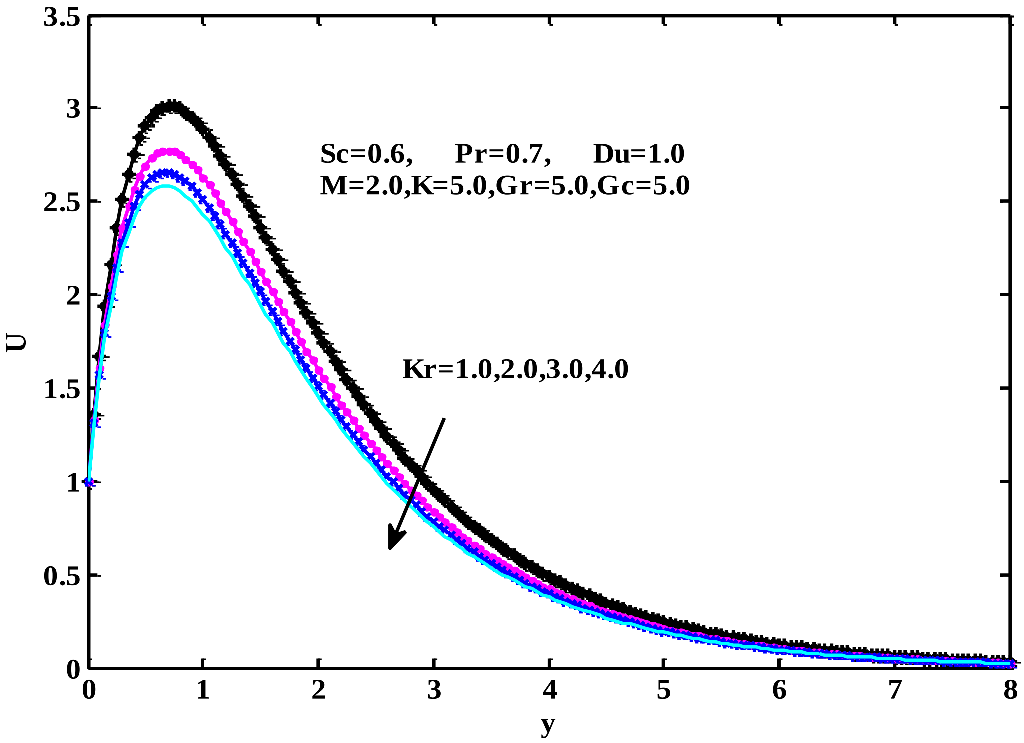

Figure (4): Velocity Profiles for different values of Kr

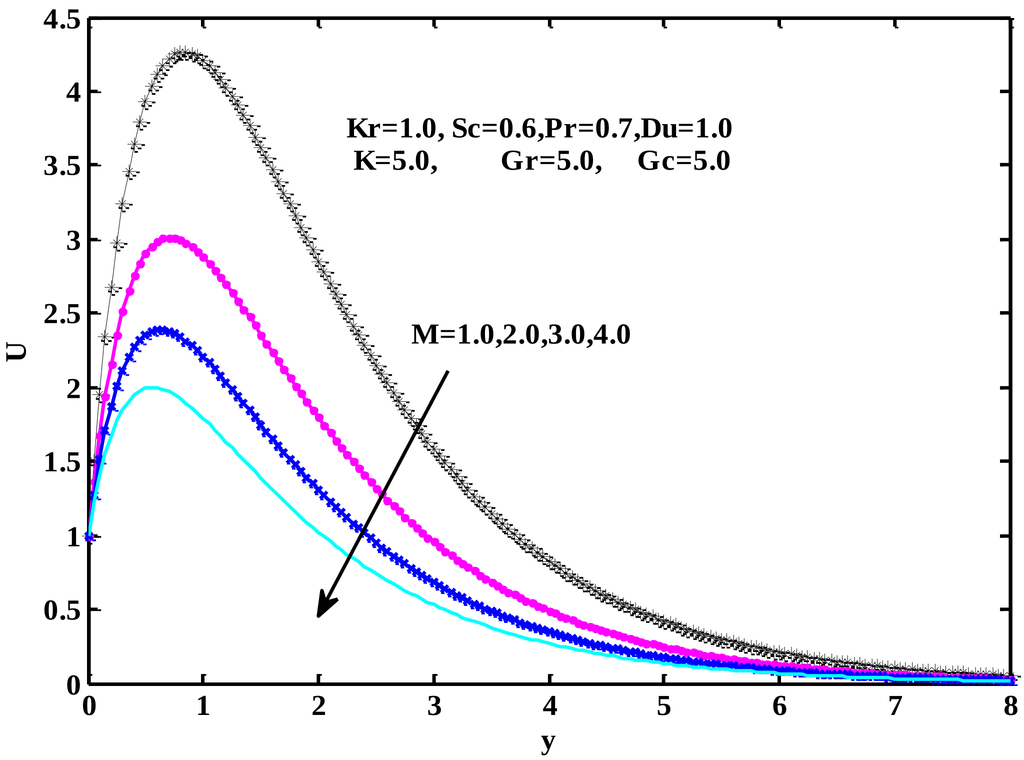

Figure (5); Velocity profiles for different values of M

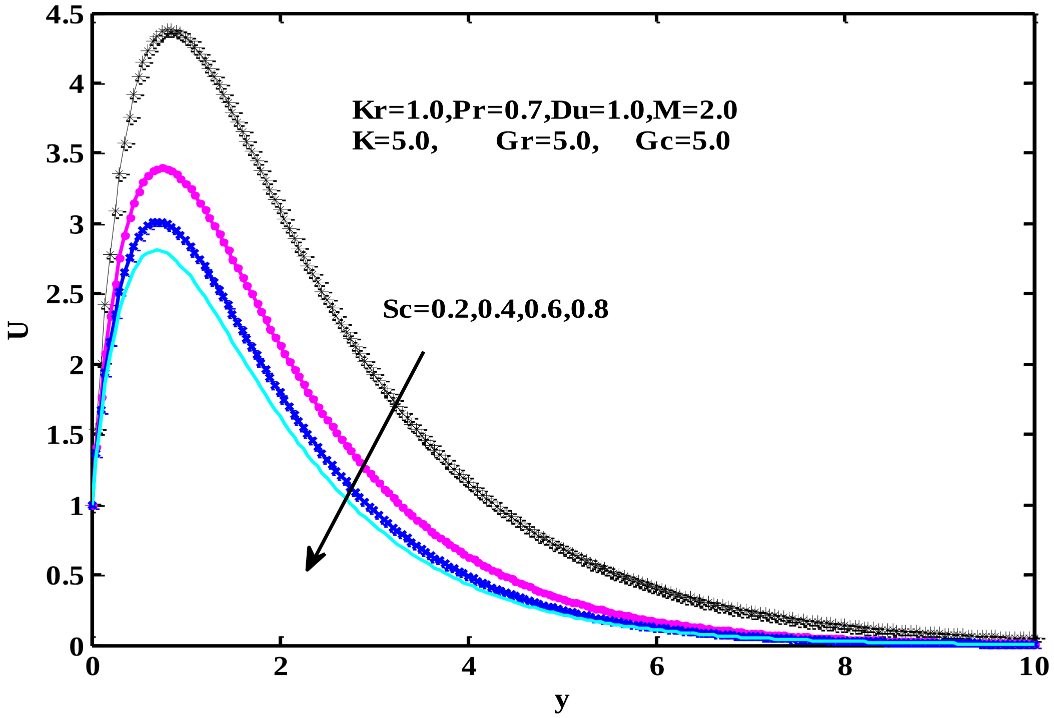

Figure (6): Velocity Profiles for different values of Sc

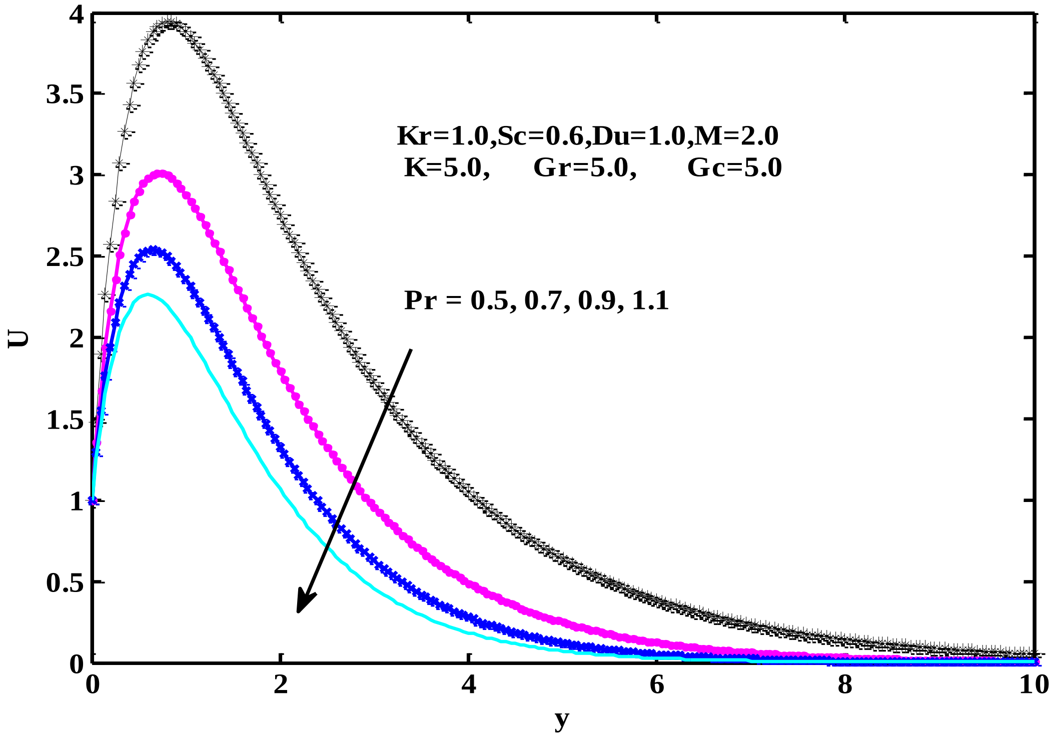

Figure (7): Velocity Profiles for different values of Pr

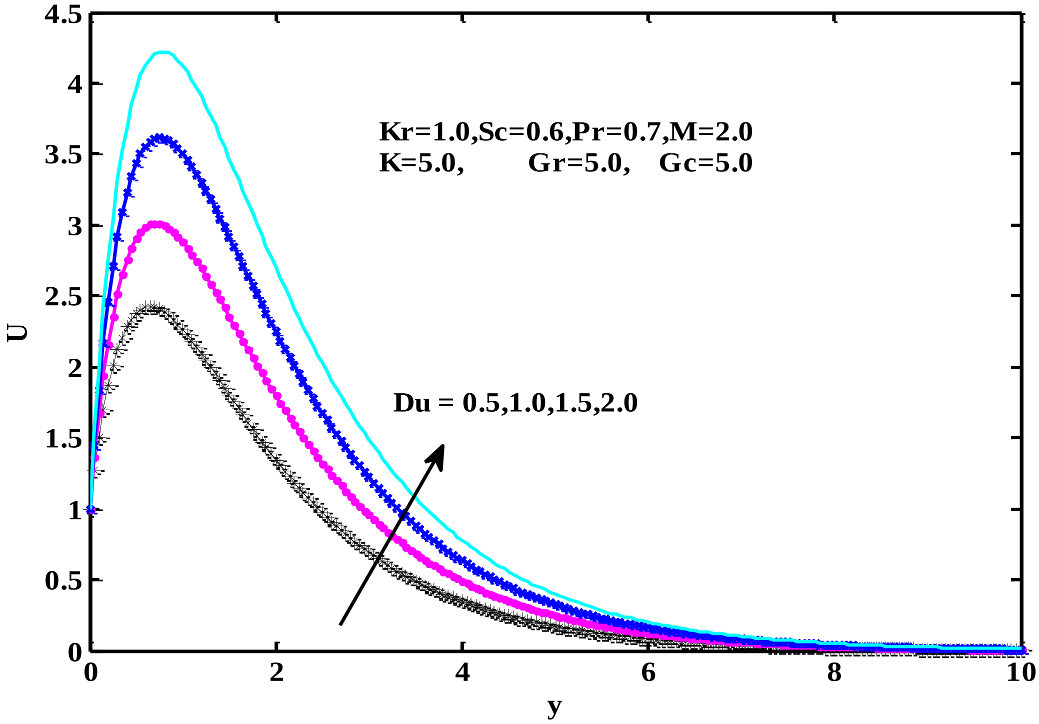

Figure (8): Velocity Profiles for different values of Du

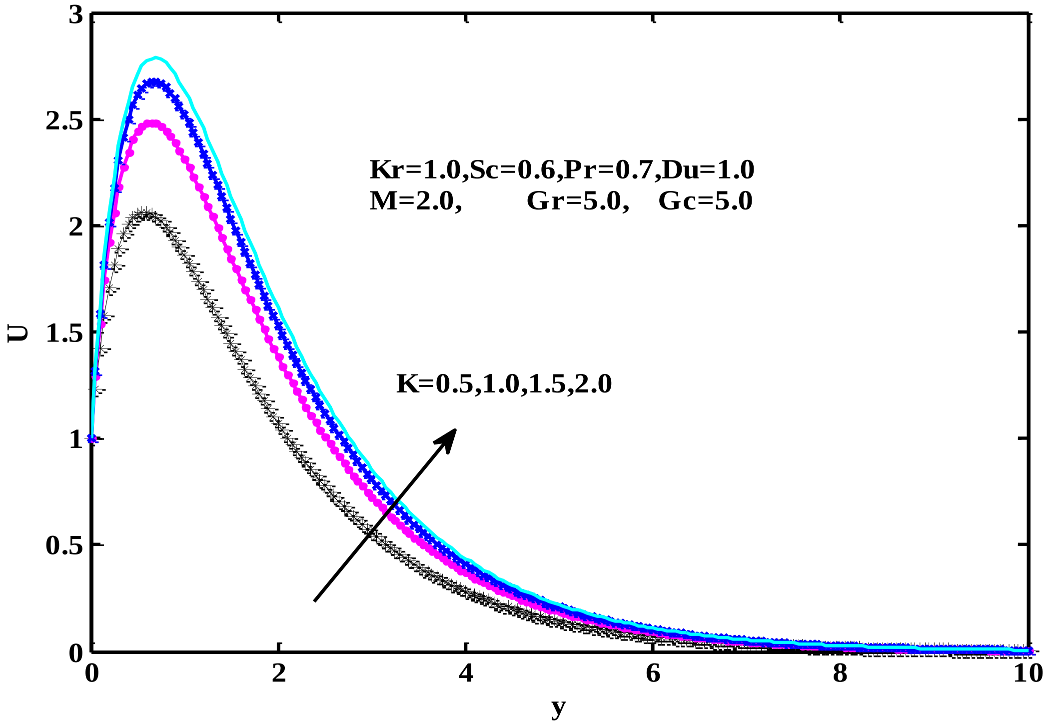

Figure (9): Velocity Profiles for different values of K

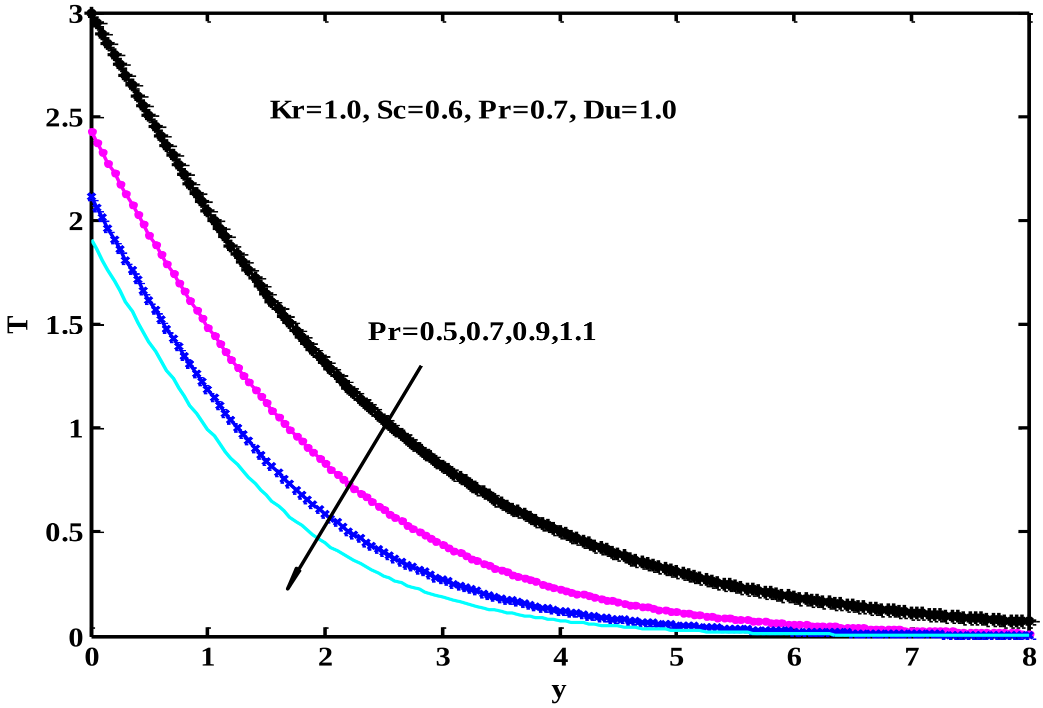

Figure (10): Temeprature Profiles for different values of Pr

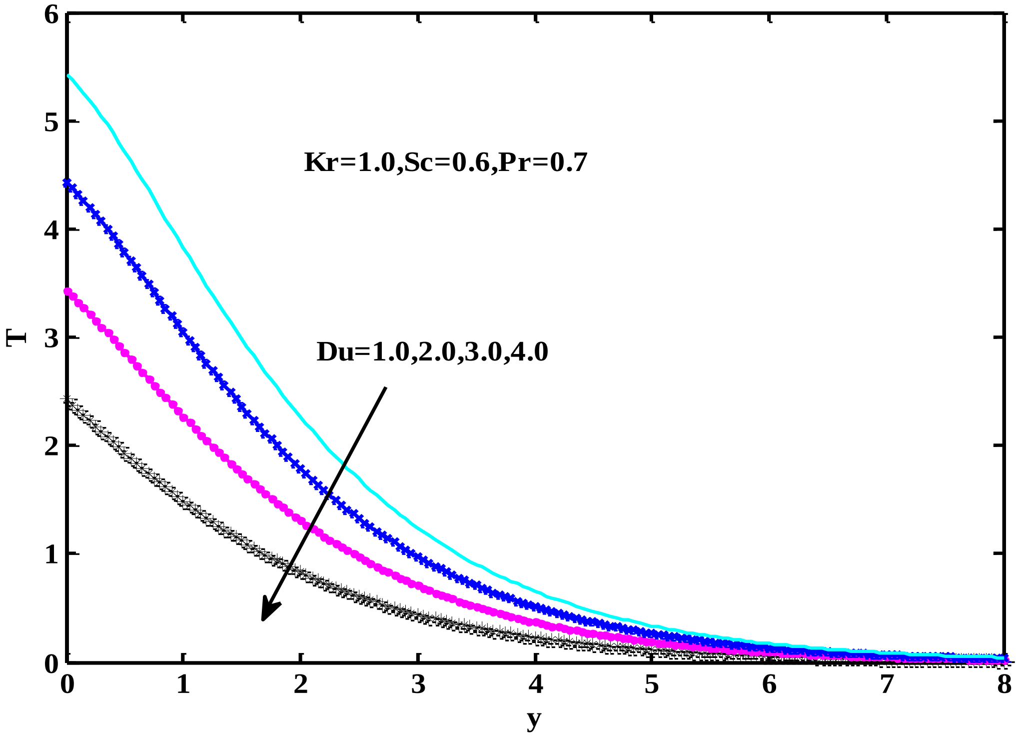

Figure (11): Temperature profiles for different values of Du

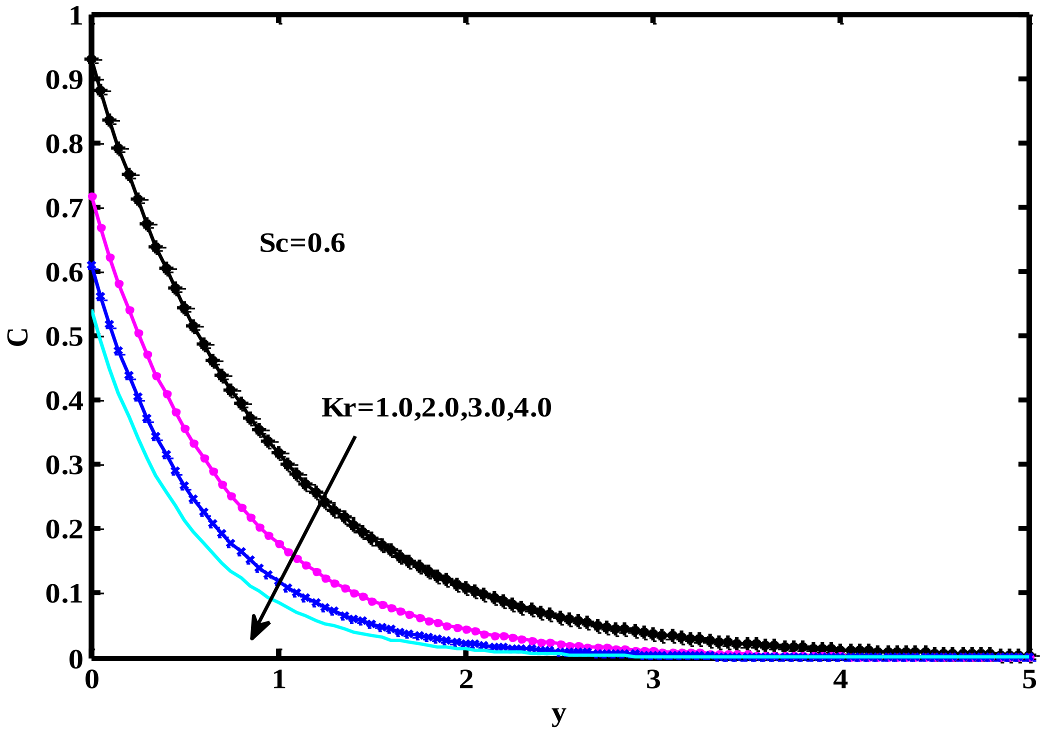

Figure (12): Concentration profiles for different values of Kr

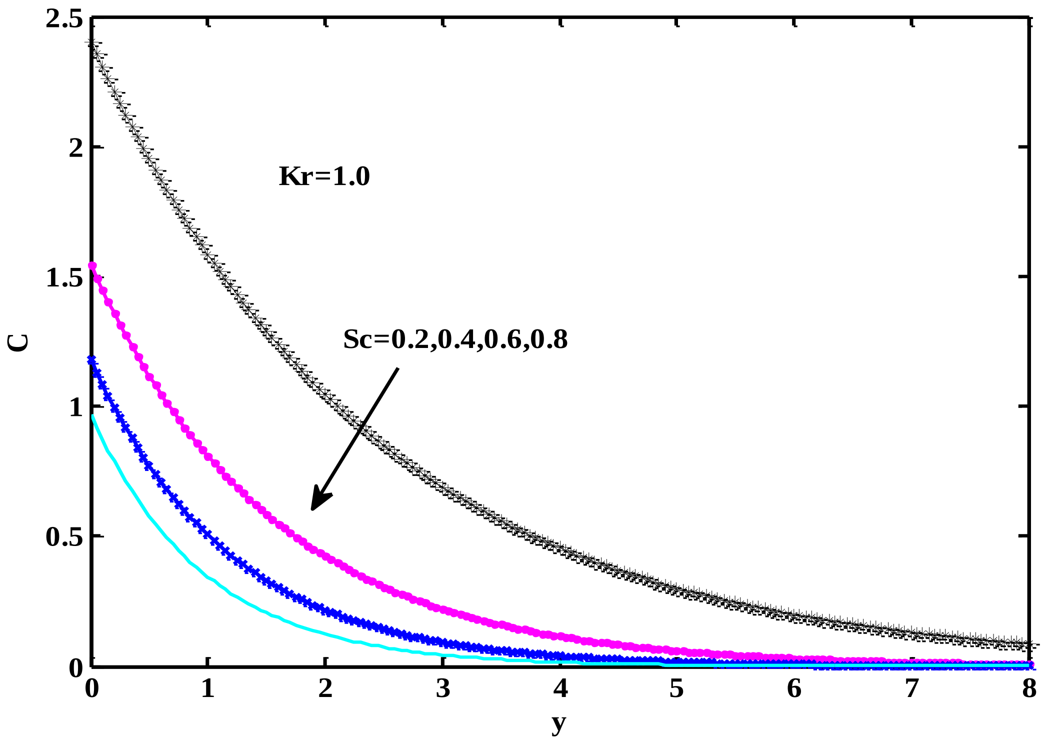

Figure (13): Concentration profiles for different values of Sc

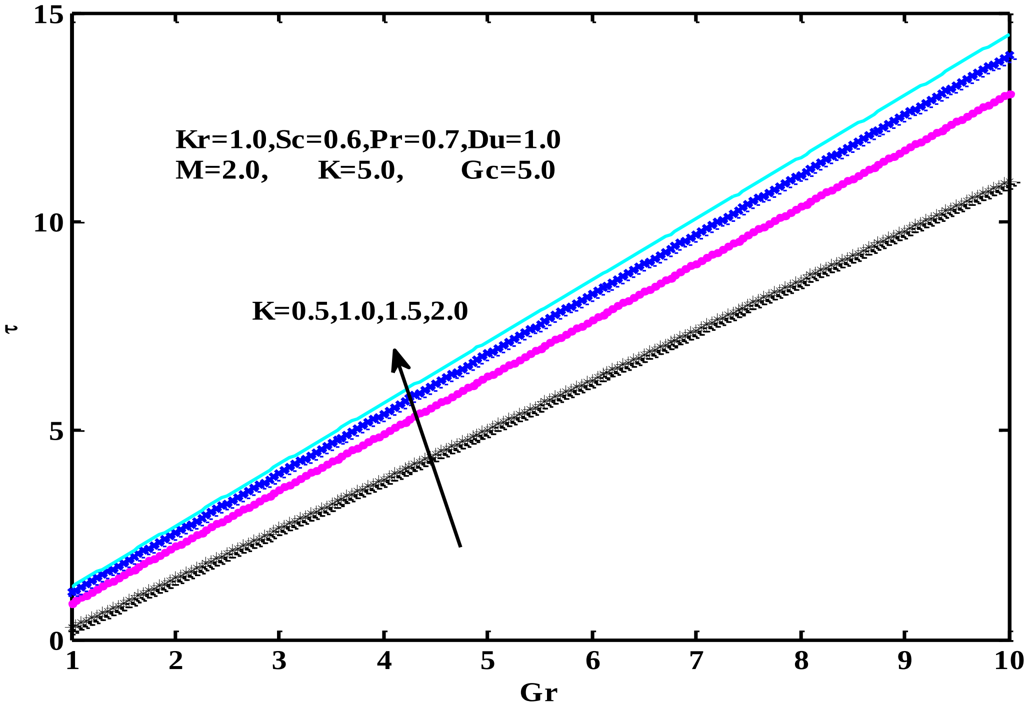

Figure (14): Skin friction for different values of K versus Gr