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Heat transfer analysis of hybrid nano-fluid through porous medium

D. Vidyanadha Babu[a]
[a]**QIS College of Engineering and Technology, Ongole, A.P**

Corresponding author.
Correspondence: D Vidyanadh Babu
E-mail:idyanadha.d@qiscet. edu.in.com

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Abstract
The main focus of this paper is to use water based hybrid nanofluid in place of ordinary fluid in porous medium to improve thermal properties. This paper deals with the effect of MHD and chemical reaction on a hybrid nanofluid through porous medium with suction/injection. We also studied the effects of MHD, heat source, suction/injection and chemical reaction influences on a hybrid nanofluid. Two types of nano particles namely copper (Cu) and Aluminum oxide (Al2O3) are suspended in base fluid (water) to form the hybrid nanofluid. Similarity transformations are used to change ordinary differential equations to partial equations, and then solved solved by perturbation method. Numerical investigation is carried out to test Skin friction, heat and mass transfer coefficient for different geometrical parameters.

1. Introduction

The Heat flow analysis mainly depends on enhancement of thermal properties of the fluid. That's why our concentration focus the improving techniques.. One of such technique is to suspend nano particles to the working fluid. Choi [1] was the first person to find the enhancement in thermal conductivity. Later Dae-Hawang [2] extended this thermal conductivity property to nanofluids for application of heat transfer fluids. Tran et al.[3] started preparation of nanofluids using laser ablation in liquid technique. Heat transfer through a vertical plate in a porous medium observed by Cheng P et al.[5]. In dealing with sustainable energy Hunt [6] described the heat exchangers. Masuda et al.,[7] explained the alteration of thermal conductivity and viscosity of liquid by dispersing ultra-fine particles in aluminum oxide , silicon oxide and titanium oxide. Convective transport in nanofluid is explained by Buongiorno [9]. Brownian diffusion of particle with hydro dynamic interaction is explained clearly Bachelor [10] in his paper. The coagulation, deposition, diffusion and thermo-phoresis of small particles in a laminar tube flow is explained clearly Walker[11] and Pratsinis et al.[12].Nanofluid will give a high quality absorption applications in solar collectors. The comparison between environmental and economic analysis of conventional nanofluid solar hot water technology is explained by Octanicar [13].Tyagi et al.[14] predicted the efficiency of a low temperature nanofluid based direct absorption solar collector. Buongioorno et al.[15] find the usage of nanofluids in nuclear reactors. He concentrated in enhancing the heat transfer done by nanofluids in nuclear reactors. Different nanofluid applications in heat exchanger is given by Huminic et al.[16]. Effect of thermal radiation and viscous dissipation on Powell-Eyring nano-fluid with variable thickness was studied by Vidyanadha babu and Suryanarayana Reddy [17].

Main intention of any researchers in the field of heat and mass transfer is to find different techniques to enhance the thermal characteristics. This desire is fulfilled up to certain extent when we considered nanofluid, but when hybrid nanofluids is the fluid to get better result in this regard. We have obtained better result. Comparing to the base fluid and nanofluid congaing single nanoparticle, thermal efficiencies are higher in hybrid nanofluids. Azwadi.,et..al[19] explained the preparation process and various factors which affect the performance of hybrid nanofluids in his paper. Siddiki,et.al.,[20] in his work he find the recent development in the enhancement of characteristics in heat transfer analysis through hybrid nanofluids. Based on the value of the viscosity Minea[21] in his paper analayzed hybrid nanofluids numerically by taking copper, cuprous oxide and Magnesium oxide etc. Toghraie et al.,[22] analyzed the relation between thermal conductivity and volume fraction with respect to temperature in Zno and TiO2 with EG hybrid nanofluid. Devi and Devi [23] studied two dimensional MHD hybrid nanofluid flow with suction by taking copper, alumina with water as base fluid. Iqbal et al., [24] studied the hall current and thermal radiation effects of the hybrid nan fluids Oscillating vertical channel. With respect to Ag and HEG by taking water as base fluid Zainal et al.,[25] find the effect of hybrid nanofluid in horizontal circular pipe with constant heat flux. Hayat and Nadeem [26] studied the heat transfer enhancement with Ag-Cuo /water hybrid nanofluid. The entropy generation analysis in MHD mixed convection of hybrid nanofluid in an open cavity with horizontal channel containing an adiabatic obstacle was studied by Hussain et al.,[27]. Afrand et al.,[28] studied the effect of temperature and nanoparticles concentration on rheological behavior of Fe3O4, Ag /EG hybrid nanofluid. The Hydro dynamic flow of copper and alumina/ water hybrid nanofluid in porous channel by Das et al.,[29]. Hong et al.,[30]studied the impact of surfactants and ultrasonication time on the stability and thermo physical properties of hybrid nanofluids. The stability, thermal conductivity and viscosity of Graphene (GnPs) and Titanium oxide (TiO2) in a mixture of distilled water and ethylene glycol (DW/EG) were determined. There is a significant improvement (23.74%) in thermal conductivity of nanofluid at 600C and 0.1 wt% with both temperature and concentration of nano particles. Viscosity of both mono and hybrid nanofluids showed about nearly 6% of difference at 0.1 wt % concentration and 400C working temperature. Nirmala P. Ratchagar et al.,[31] explained the hall current effect in oscillatory flow of a couple stress fluid in an inclined channel. Sharmam et al.,[32] studied the combined effect of viscous dissipation and Joule heating on unsteady MHD Flow and heat transfer over a stretching sheet saturated in porous medium.

Hence, the object of the present paper is to analyze the chemical reaction effect on an unsteady magneto hydrodynamic flow of a hybrid nanofluid past a moving vertical semi-infinite plate with constant heat source through porous medium. This is extension of the work done by Vidyanadha Babu [33] in his paper Unsteady MHD free convection flow in casson nano fluid through porous medium with suction and heat source In this study we have considered copper (Cu) and Aluminum oxide (Al2O3). The governing boundary layer equations have been transformed to a two-point boundary value problem in similarity variables and the resultant problem is solved numerically using perturbation technique. The influence of velocity, temperature, concentration profile on different governing parameter are analyzed graphically.

2. Mathematical Formulation

Some the unsteady convection hybrid nanofluid flow past a vertical permeable semi-infinite plate in presence of heat source and suction/injection is considered. In the flow direction x-axis is taken and normal to the surface y-axis is considered. B0, the external magnetic field is taken along y-axis. The fluid is rest initially and the initial temperature is T_w' after that the plate started to move with a velocity U_0 with harmonic fluctuate temperature. Induced magnetic field is negligible when compared to the external magnetic field. The hybrid fluid is water based with two types of nano particles copper and aluminum oxide. The suspended nano particles are in thermal equilibrium and no slip occurs between them. With these assumptions the governing equations of the considered flow are given by Tiwari and Das [18] in dimensional form is given by

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

$$\rho_{hnf}\left(\frac{\partial u'}{\partial t'} + v'\frac{\partial u'}{\partial y'}\right) = \mu_{hnf}\frac{\partial^2 u'}{\partial y'^2} + (\rho\beta_T')_{hnf} g(T'-T_\infty') + (\rho\beta_C')_{hnf} g'\left(C'-C_\infty'\right) - \sigma_{hnf}B_0^2 u' - \frac{u'}{K'} \tag{2}$$

$$\frac{\partial T'}{\partial t'} + v'\frac{\partial T'}{\partial y'} = \alpha_{hnf}\frac{\partial^2 T'}{\partial y'^2} - \frac{Q'(T'-T_\infty')}{(\rho c_p)_{hnf}} \tag{3}$$

$$\frac{\partial C'}{\partial t'} + v'\frac{\partial C'}{\partial y'} = D_{hnf}\frac{\partial^2 C'}{\partial y'^2} + k_r\left(C'-C_\infty'\right) \tag{4}$$

With the initial and boundary conditions are as follows

$$\begin{aligned} &t' < 0, u'(y',t') = 0, \quad T' = T_\infty' \text{and} \quad C' = C_\infty' \ \text{ at } y = 0 \\ &t' \geq 0, u'(y',t') = U_0, \ T' = T_w' + \left(T_w' - T_\infty'\right) \in e^{iw't'} \\ &C' = C_w' + (C_w' - C_\infty') \in e^{iw't'} \ \text{ at } y = 0 \\ &u' \ (y',t') = 0, \quad T' = T_\infty' \text{and} \quad C' = C_\infty' \quad \text{ at } y = \infty \end{aligned} \tag{5}$$

Hybrid nanofluid characteristics are derived from the following relations.

$$(\rho\beta)_{hnf} = (1-\varphi_2)(\rho\beta)_f\left[(1-\varphi_1) + \varphi_1\left(\frac{(\rho\beta)_{s1}}{(\rho\beta)_f}\right)\right] + \varphi_2(\rho\beta)_{s2}$$

$$(\rho c_p)_{hnf} = (1-\varphi_2)(\rho c_p)_f\left[(1-\varphi_1) + \varphi_1\left(\frac{(\rho c_p)_{s1}}{(\rho c_p)_f}\right)\right]$$

K_f, K_s are thermal conductivity of the base fluid and of the solid . σ is electrical conductivity of the fluid

and B_0 is the strength of magnetic field applied in the y direction. c_p is the specific heat, K_T is thermal conductivity. Q is the quantity of the heat, T is the temperature, and β_T coefficient of thermal expansion, β_c coefficient of mass expansion, K is porous medium permeability coefficient.
Solving equation (1) we may get, v'=-v0 (7)

Where v0 is the normal velocity at the plate, If v0>0 it is suction and if v0 < 0 then it is injection. Now introducing non dimensional variables as follows.

$$u = \frac{u'}{U_0}, \; y = \frac{U_0\, y'}{\nu_f}, \; t = \frac{U_0^2 t'}{a}, \quad \theta = \frac{T' - T'_\infty}{T'_\omega - T'_\infty}, \quad Q = \frac{Q' \nu_f^2}{k_f U_0^2}, \; P_r = \frac{\nu_f}{\alpha_f}$$

$$C = \frac{C' - C'_\infty}{C'_\omega - C'_\infty}, \quad M = \frac{\sigma B_0^2}{\rho_f U_0^2}, S = \frac{V_0}{U_0}, \quad R = \frac{16 T_\infty^3 \sigma^*}{3k^*}, K = \frac{\rho_f U_0^2 k'}{\nu_f}$$

$$G_r = \frac{(\rho\beta)_{nf}\, g\, \nu_f}{\rho_f U_0^2}\left(T'_\omega - T'_\infty\right), \quad G_c = \frac{(\rho\beta')_{nf}\, g\, \nu_f}{\rho_f U_0^2}\left(T'_\omega - T'_\infty\right) \quad (8)$$

Substituting equation (8) in equations (2), (3) and (4) we get

$$A\left(\frac{\partial u}{\partial t} - S\frac{\partial u}{\partial y}\right) = D\frac{\partial^2 u}{\partial y^2} - \left(M + \frac{1}{K}\right) u + BG_r\,\theta + B' G_r\, C \quad (9)$$

$$C\left(\frac{\partial \theta}{\partial t} - S\frac{\partial \theta}{\partial y}\right) = \frac{1}{P_r}\left(E\,\frac{\partial^2 \theta}{\partial y^2} - Q\theta\right) \quad (10)$$

$$\frac{\partial C}{\partial t} - S\frac{\partial C}{\partial y} = \frac{1}{S_c}\frac{\partial^2 C}{\partial y^2} + K_r\, C \quad (11)$$

The dimensionless boundary conditions are

$$t' < 0, u = 0, \quad \theta = 0 \text{ and } \quad C = 0 \quad \text{at } y = 0$$
$$t' \geq 0, u = 1, \theta = 1{+}\epsilon\, e^{iwt} \text{ and } C = 1{+}\epsilon\, e^{iwt} \text{ at } y = 0 \quad (12)$$
$$u = 0, \theta = 0 \text{ and } C = 0 \text{ at } y = \infty$$

3. Method of Solution

The Equations (12) to (14) are solved by perturbation method by considering the following solution

$$u(y,t) = u_0(y) + \epsilon\; u_1(y)\, e^{iwt}$$
$$\theta(y,t) = \theta_0(y) + \epsilon\; \theta_1(y)\, e^{iwt}$$
$$C(y,t) = C_0(y) + \epsilon\; C_1(y)\, e^{iwt}$$

In view of the above equations (9) to (11) and equating the harmonic and non-harmonic terms, we obtain

$$D\frac{\partial^2 u_0}{\partial y^2} + AS\frac{\partial u_0}{\partial y} - \left(M + \frac{1}{K}\right) u_0 = -BG_r\theta_0 - BG_cC_0 \quad (13)$$

$$D\frac{\partial^2 u_1}{\partial y^2} + AS\frac{\partial u_1}{\partial y} - \left(M + \frac{1}{K} + iAw\right) u_1 = -BG_r\theta_1 - BG_cC_1 \quad (14)$$

$$E\,\frac{\partial^2 \theta_0}{\partial y^2} + CSP_r\frac{\partial \theta_0}{\partial y} - Q\theta_0 = 0 \quad (15)$$

$$E\,\frac{\partial^2 \theta_1}{\partial y^2} + CSP_r\frac{\partial \theta_1}{\partial y} - (Q + iCP_r w)\theta_1 = 0 \quad (16)$$

$$\frac{\partial^2 C_0}{\partial y^2} + SS_c\frac{\partial C_0}{\partial y} + S_cK_rC_0 = 0 \quad (17)$$

$$\frac{\partial^2 C_1}{\partial y^2} + SS_c\frac{\partial C_1}{\partial y} + S_c(K_r - iw)C_1 = 0 \quad (18)$$

With boundary conditions

$$t' < 0, \; u_0 = 1, u_1 = 0, \quad \theta_0 = 1, \theta_1 = 1 \text{ and } \quad C_0 = 1, C_1 = 1 \quad \text{at } y = 0$$
$$t' \geq 0, \; u_0 = 0, u_1 = 0, \quad \theta_0 = 0, \theta_1 = 0 \text{ and } \quad C_0 = 0, C_1 = 0 \quad \text{at } y = 0 \quad (19)$$
$$u = 0, \quad \theta = 0 \text{ and } C = 0 \quad \text{at } y = \infty$$

Solving equation (17) and (18)

$$u = A_1 e^{-m_3 y} + A_2 e^{-m_4 y} + A_3 e^{-m_5 y}$$

$$\theta = e^{-m_3 y} {+}\epsilon\; e^{iwt} e^{-m_4 \theta}$$
$$C = e^{-m_1 y} {+}\epsilon\; e^{iwt} e^{-m_2 \theta}$$

The Skin friction coefficient (τ) at the plate is given by

$$\tau = (\partial u/\partial y)_{y=0} = -m_3 A_1 - m_4 A_2 - m_5 A_3$$

The Heat transfer coefficient (Nu)

$$Nu = (\partial\theta/\partial y)_{y=0} = -m_1 - m_2 \in e^{iwt}$$

The Mass transfer coefficient (Sh)

$$Sh=(\partial C/\partial y)_{y=0} = (-m_3 B_1 - (m_1 + 2)B_2)s+\in (-m_4 B_3 - (m_2+2) B_4)\, e^{iwt}$$

Where

$$m_1 = \frac{-SS_c \pm \sqrt{(SS_c)^2 - 4S_cK_r}}{2E} \qquad m_2 = \frac{-SS_c \pm \sqrt{(SS_c)^2 - 4S_c(K_r - iw)}}{2E}$$

$$m_3 = \frac{-csp_r \pm \sqrt{(csp_r)^2 + 4EQ}}{2E} \qquad m_4 = \frac{-csp_r \pm \sqrt{(csp_r)^2 + 4E(Q + icp_r w)}}{2E}$$

$$m_5 = \frac{-As \pm \sqrt{(As)^2 + 4D\left(M + \frac{1}{k}\right)}}{2D} \qquad A_1 = \frac{-(BG_r)}{Dm_3^2 - Asm_3 - \left(M + \frac{1}{k}\right)}$$

$$A_2 = \frac{-(BG_c)}{Dm_4^2 - Asm_4 - \left(M + \frac{1}{k}\right)} \qquad A_3 = \frac{(BG_r)}{Dm_3^2 - Asm_3 - \left(M + \frac{1}{k}\right)} + \frac{(BG_c)}{Dm_4^2 - Asm_4 - \left(M + \frac{1}{k}\right)}$$

4. Results and Discussions:

Hybrid nanofluid flow with mixed convection is studied for analytical solutions in a channel under effect of MHD and porosity. Graphical illustrations are made for effect of different parameters on concentration, temperature and velocity of the hybrid nanofluid. For the graphical presentation, the thermo-physical properties for base fluid and nanoparticles are taken from the Table 1.

Material	$\rho(kg/m^3$	$C_p(J/\,kgK)$	$K(W/mK)$	$\beta X10^{5-6}(K^{-1})$	$\sigma(s/m$
Pure Water	997.1	4179	0.613	21	$5.5X10^{-6}$
Sodium alginate	989	4175	0.6376	21	$5.5X10^{-6}$
Copper(ϕ_1)	8933	385	401	1.67	$5.96X10^7$
Alumina(ϕ_2)	3970	765	40	0.85	3.5x107
TiO_2	4250	686.2	8.9538	0.9	2.38x106

Table 1: Thermo physical properties of base fluid and nano particles

Fig: 1 depicts the velocity profiles for different values of Grashof number (Gr). It is observed that the Grashof number Gr increases the velocity field increases. This is because of the increasing the strength of the flow and the ratio of the thermal buoyancy force to the viscous hydrodynamic force. Fig: 2 presents the velocity profiles for different values of the magnetic parameter. It is observed that the magnetic parameter increases, then velocity profile decreases this is because an increase in applied magnetic field strength causes greater interaction between the fluid motion and magnetic field and hence an increase in Lorentz force , since this force opposes the buoyancy force velocity will be decreased. Fig:3 shows the velocity profile change with the change of Grashof number Gc. the velocity increases with the increase of the Grashof number which agrees with the natural phenomena because of buoyancy force assist the flow. Figs:4 represent the velocity profile for different values of chemical reaction parameter (Kr). It is noticed that the chemical reaction increases in velocity decreases due to the fact that increase in chemical reaction parameter Kr gives rise to an increase in viscosity of fluid which means velocity boundary layer thickness decreases. Fig:5 Shows that the effect of velocity profiles for different values of Schmidt number (Sc). It is observed that the Schmidt number increases, the velocity profiles decreases because Schmidt number is a dimensionless number defined as the ratio of momentum diffusivity and mass diffusivity, and is used to characterize the fluid flows in which there are simultaneous momentum and mass diffusion convection processes. Fig:6 revealed that increasing Suction parameter (S) accelerates the velocity of the fluid in case of suction and injection. It is evident from this figure that the velocity is higher in case of injection than suction. Fig:7 depicts the temperature profile for different values of the heat source parameter (Q). It is noticed that an increase in the heat source parameter S the velocity increases but both trends are observed in the temperature profiles. Fig:8 shows the effect suction/injection parameter(S) on the temperature profiles. It is observed that temperature of the fluid increases with increasing values of S respectively. It is seen that temperature increase due to injection but decreases due to suction parameter. In case of suction, the fluid at ambient conditions is brought closer to the surface and reduces the thermal boundary layer thickness. The same principle operates but in reverse direction in case of injection. The effects suction/injection parameter (S) on the concentration distribution are shown graphically in Fig:9. From this, it can be noticed that concentration of the fluid increases with suction and injection.Fig:11 shows that the effect of concentration profiles for different values of Schmidt number (Sc). It is observed that the Schmidt number increases, concentration profile decreases because Schmidt number is a dimensionless number defined as the ratio of momentum diffusivity and mass diffusivity, and is used to characterize the fluid flows in which there are simultaneous momentum convection processes.

5.Conclusion:

In this research work, the influence of MHD and chemical reaction on hybrid nanofluid through porous medium with suction /injection is studied. The resulting governing equations were solved by the perturbation technique. From the study, the following remarks can be summarized.

1. Fluid velocity increases with increasing Grashoff parameter(Gr), modified Grashoff parameter(Gc) and suction parameter(S), Permeability parameter number (K) and volume solid fraction of the nano particles(φ) while a reverse effect in the velocity distribution for Magnetic parameter (M), chemical reaction parameter (Kr) and Schmidt parameter(Sc) is observed.
2. Fluid temperature decreases with increasing, suction parameter(s), Magnetic parameter (M) and heat source parameter (Q) where as reverse effect is observed in case of suction parameter(s) and heat source parameter is observed.
3. Fluid concentration decreases with increasing, Magnetic parameter (M), chemical reaction parameter(Kr) , and Schmidt parameter(Sc) and reverse effect is observed in case of suction parameter(s) and is observed

5. Graphs:

Fig1. Velocity profile for different values of Gr

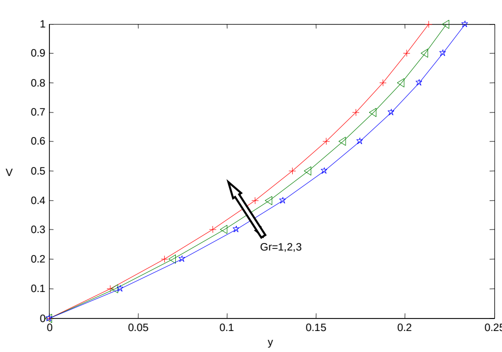


Fig2. Velocity profile for different values of M

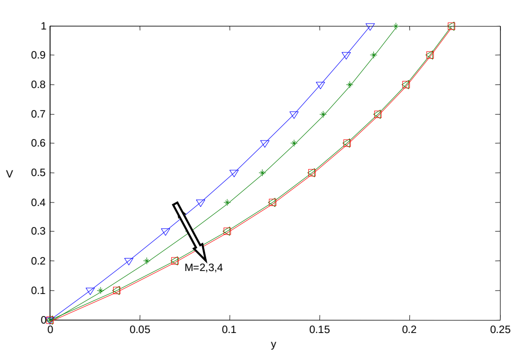


Fig3. Velocity profile for different values of Gc

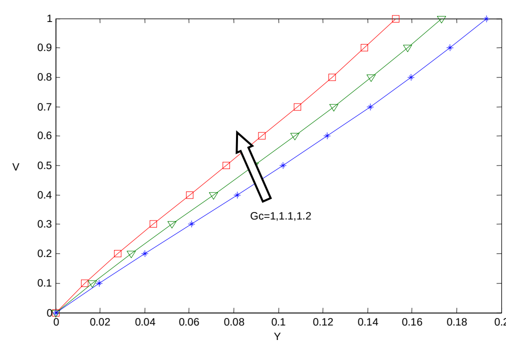


Fig4. Velocity profile for different values of Kr

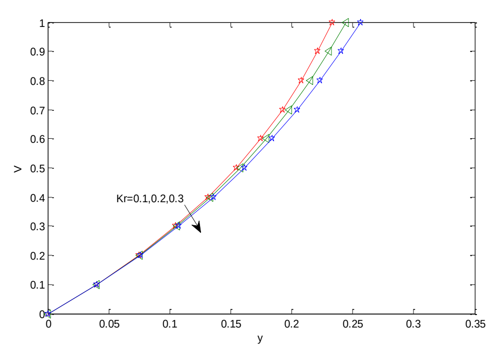


Fig5. Velocity profile for different values of Sc

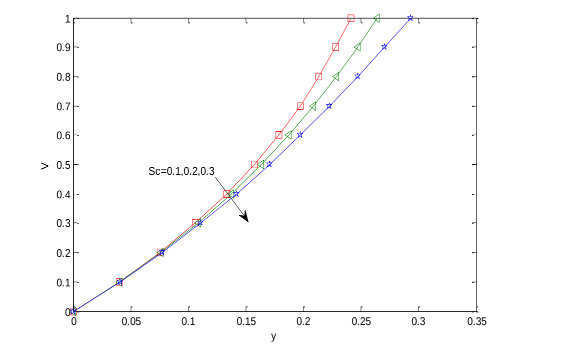


Fig6. Velocity profile for different values of S

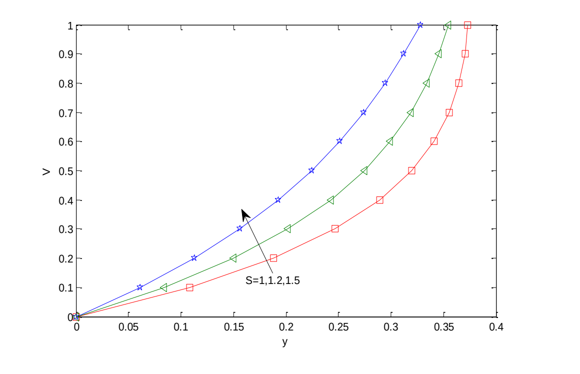


Fig7.Temperature profile for different values of Q

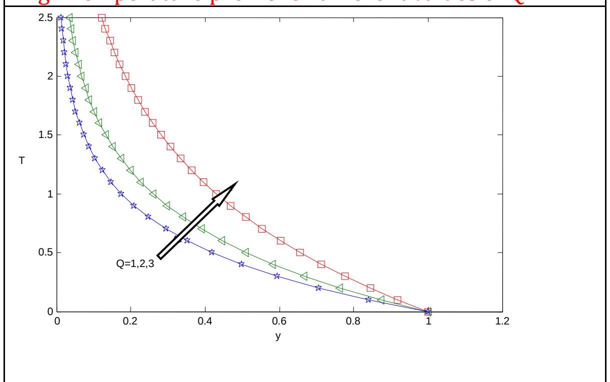


Fig8.Temperature profile for different values of S

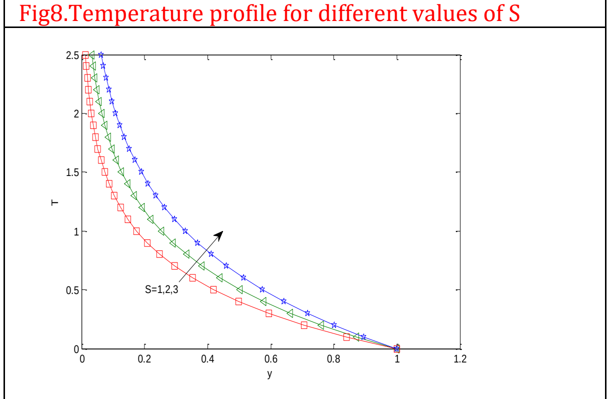


Fig9.Concentration profile for different values of S

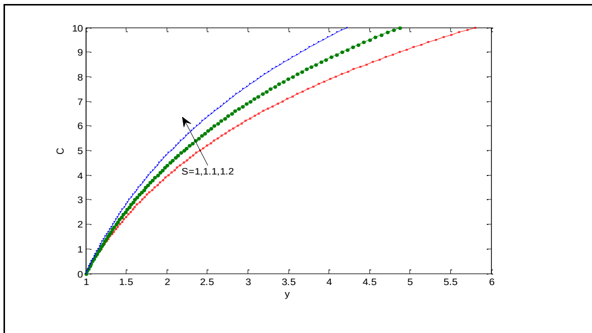


Fig10.Concentration profile for different values of Kr

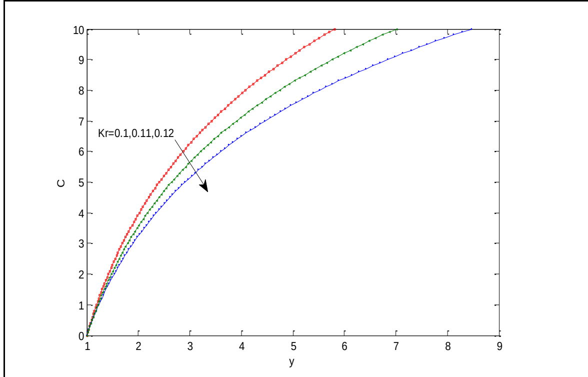
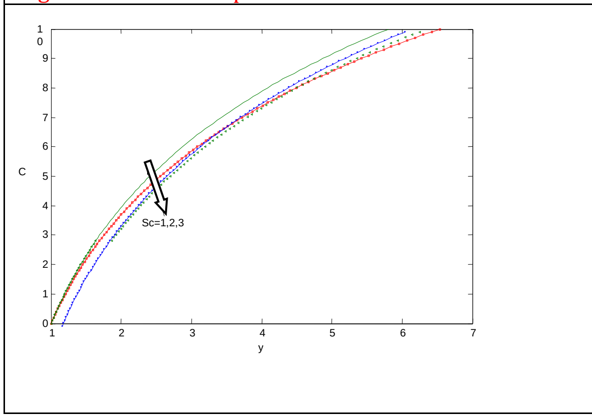


Fig11.Concentration profile for different values of Sc



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