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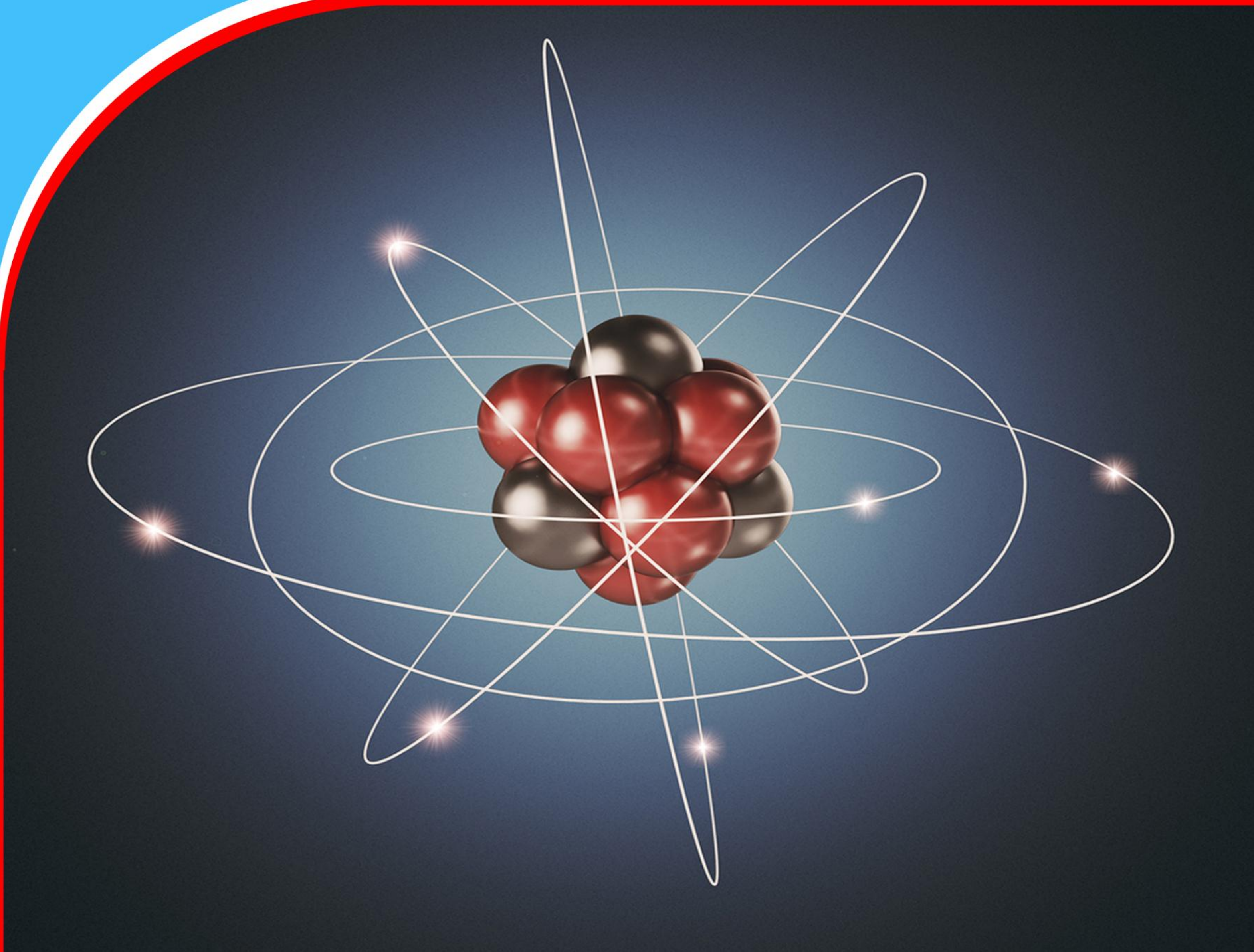

EFFECT OF CHEMICAL REACTION ON MIXED CONVECTION FLOW OF AN EXOTHERMIC FLUID IN A VERTICAL POROUS CHANNEL

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EFFECT OF CHEMICAL REACTION ON MIXED CONVECTION FLOW OF AN EXOTHERMIC FLUID IN A VERTICAL POROUS CHANNEL

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ABSTRACT

In this paper, Effect of chemical reaction on mixed convection flow of an exothermic fluid in a vertical porous channel is considered. The dimensionless ordinary differential equations were solved using differential transformation method (DTM) to obtain the expression of velocity, temperature and concentration from momentum, energy and mass equations. The effect of Skin friction, Nusselt number and Sherwood number with various parameters on velocity, temperature and concentration are presented and discussed. The result indicated that the velocity, temperature and concentration increases with the increase in suction/injection and mixed convection parameters.

Key words: *Differential Transformation Method, Chemical reaction, Heat Mass Transfer*

1. INTRODUCTION

In many transport processes and industrial applications, transfer of heat mass occurs simultaneously as a result of combined buoyancy effects of thermal diffusion and diffusion of chemical species. Unsteady natural convection of heat mass transfer is of great importance in designing control systems for modern free convection heat exchangers. More recently, Barik and Dash [2] have studied Free Convection Heat and Mass Transfer MHD Flow in a Vertical Porous Channel in the Presence of Chemical Reaction, Jha and Ajibade [8] have studied the heat mass transfer aspect of the flow of a viscous incompressible fluid in a vertical channel considering the Dufour effect. Soundalgekar and Akolkar [11] studied the effect of free convection currents and mass transfer on flow past a vertical oscillating plate. In nature, flow occurs due to density differences caused by temperature as well as chemical composition gradients. Therefore, it warrants the simultaneous consideration of temperature difference as well as concentration difference when heat mass transfer occurs simultaneously. It has been found that an energy flux can be created not only by temperature gradients but by composition gradients also. This is called Dufour effect. If, on the other hand, mass fluxes are created by temperature gradients, it is called the Soret effect.

The analysis of natural convection heat mass transfer near a moving vertical plate has received much attention in recent times due to its wide application in engineering and technological processes. There are applications of interest in which combined heat mass transfer by natural convection occurs between a moving material and ambient medium, such as the design and operation of chemical processing equipment, design of heat exchangers, transpiration cooling of a surface, chemical vapour deposition of solid layer, nuclear reactor and many manufacturing processes like hot rolling, hot extrusion, wire drawing, continuous casting and fiber drawing. Ghosh et al. [6] studied the effects of mass transfer on a steady free convection flow past a semi-infinite vertical plate by the similarity method and it was assumed that the concentration level of the diffusing species in fluid medium was very low. This assumption enabled them to neglect the diffusion-thermo and thermal-diffusion effects as well as the interfacial velocity at the wall due to species diffusion. Following this assumption, Das *et al.* [4] investigated mixed convective magnetohydrodynamic flow in a vertical channel filled with nanofluids.

Heat transfer related processes plays a major role in the devices used and produce by all the major industrial sectors such as car radiators, solar collectors, various components of power plants and even spacecraft. The optimal insulation thickness in the walls and roofs of the houses, on hot water or steam pipes, or on water heaters is again determined on the basis of a heat transfer analysis with economic consideration. Yunus [12]

In view of the applications of mixed convection and mass transfer flow in a vertical channel many researchers contributed in this area, some of them are: Pop *et al.* [10] investigated numerically by using implicit finite difference scheme, the effect of heat generated by an exothermic reaction on the fully developed mixed convection flow in a vertical channel. Ahmad and Jha [1] investigated Steady/Unsteady natural convection flow of reactive viscous fluid in a vertical annulus. Isah and Jha [7] investigate steady-state natural convection flow in an annulus with thermal radiation. Mass transfer is often coupled to additional transport processes for instance in industrial cooling towers.

These towers couple heat transfer to mass transfer by allowing hot water to flow in contact with hotter air and evaporate as it absorbs heat from the air. Ferdos and Qasem [5] investigated the effect of order chemical reaction on a boundary layer flow with heat and mass transfer over a linearly stretching sheet. Chamkha *et al.* [3] discussed the effects of Joule heating, chemical reaction and thermal radiation on unsteady hydromagnetic natural convection boundary layer flow with heat mass transfer of a micro polar fluid from a semi-infinite heated vertical porous plate in the presence of a uniform transverse magnetic field.

Flow of an electrically conducting fluid within porous and non-porous media has received considerable attention of several researchers during past few decades due to its overwhelming and important applications in many areas of science and engineering which includes geophysics, astrophysics, electronics, aeronautics, metallurgy, chemical and petroleum engineering, etc. Keeping in view the importance of this fluid flow, several researchers investigated unsteady hydromagnetic natural convection flow of an electrically conducting fluid past bodies with different geometries under different initial and boundary conditions. Hydromagnetic natural convection flow of radiating and non-radiating fluid with heat mass transfer in porous and non-porous media is studied by several researchers due to its varied and wide applications in astrophysics, geophysics, aeronautics, electronics, metallurgy, chemical and petroleum industries. Makinde and Sibanda [9] studied MHD mixed convection heat mass transfer flow past a vertical porous plate embedded in a porous medium with constant heat flux.

2. FORMULATION

The fluid has a uniform vertical upward stream wise velocity distribution U_o at the channel entrance. We assume that inside the channel the heat is supplied to the surrounding fluid by an exothermic surface reaction at temperature T and concentration C, The governing equations in dimensional form can be written as

$$V\frac{d^2U'}{dy^{2}{'}}+g\beta(T'-T_0^{'})+g\beta(C'-C_0^{'})-\frac{1}{\rho}\frac{dp'}{dx^{'}}=0 \quad (1)$$

$$\alpha\frac{d^2T'}{dv^2}+Qk_0ae^{\frac{-E}{RT'}}=0 \quad (2)$$

$$\frac{dc'}{dy'}=D\frac{d^2c'}{dy^{2}{'}}-R(C'-C_0^{'})^n \quad (3)$$

Subject to boundary conditions

$$\{\ U(0)=0,\ U(L)=0,\ T(0)=T_1,\ T(L)=T_2,\ C(0)=C_1,\ C(L)=C_2\ \} \quad (4)$$

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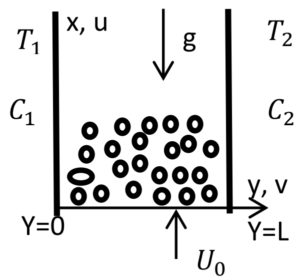
Where Q is the exothermic factor, ρ is the density, V is the kinematic viscosity, β is the Coefficient of thermal expansion, g is the acceleration of gravity, α is the thermal diffusivity, D is the effective diffusion coefficients, R is a constant of first order chemical reaction, T_0 is the reference temperature and C_0 is the reference concentration. We assume $T_0 = \frac{T_1+T_2}{2}$, and $C_0 = \frac{C_1+C_2}{2}$

2.1 Physical geometry and coordinate system

Then we introduce the following dimensionless variables.



$$\left.\begin{array}{l} X = \dfrac{x'}{\mathrm{Re}\,L}, \quad y = \dfrac{y'}{L}, \quad U(y) = \dfrac{U'}{U_0}, \quad P(x) = \dfrac{p'}{\rho U_0^2}, \quad U = \dfrac{u'v}{g\beta h^2 (T_w - T_0)} \\ C = \dfrac{c - c_0'}{\mathrm{R}\, c_0^2 / E}, \quad \mathrm{Re} = \dfrac{U_0 L}{V}, \quad S_c = \dfrac{v}{D}, \quad K_c c = \dfrac{K_c c * h^2}{v}, \quad \theta = \dfrac{T - T_0'}{\mathrm{R}\, T_0^2 / E} \end{array}\right\} \tag{5}$$

Substituting (5) into (1 to 3) we have the following differential equations

$$\frac{d^2U}{dy^2} + \lambda\left[\theta + NC\right] = \gamma \tag{6}$$

$$\frac{d^2\theta}{dy^2} + Ke^{\theta} = 0 \tag{7}$$

$$\frac{dc}{dy} = \frac{1}{S_c}\frac{d^2c}{dy^2} - K_c c \tag{8}$$

Subject to the boundary conditions

$U = 0, \Theta = \gamma_t, C = \gamma_c, Y=0,$ (9)

$U = 0, \Theta = -\gamma_t, C = -\gamma_c, Y=1,$

where λ, N, γ, K, γ_t, γ_c, Sc and K_c are mixed convection parameters, sustention parameter, pressure term, Frank-Kamenetskii number, symmetric wall temperature and concentration, Schmidt number and chemical reaction parameter respectively which are defined as

$$\left.\begin{array}{l} \lambda = \frac{Gr}{\mathrm{Re}}, \quad \gamma = \frac{dp}{dx}, \quad \gamma_t = \frac{T_1 - T_0}{\mathrm{R}T_0^2/E}, \quad \gamma_c = \frac{C_1 - C_0}{\mathrm{R}C_0^2/E}, \quad K_c c = \frac{K_c c * h^2}{v}, \\ K = \frac{EQK_0 aL^2}{RT_0^2\alpha} e^{-E/RT_0}, \quad N = \frac{\beta_c(c_w - c_0)}{\beta_T(T_w - T_0)}, S_c = \frac{v}{D} \end{array}\right\} \quad (10)$$

3. METHOD OF SOLUTION

Equations (6) to (8) subject to (9) are solved analytically by using DTM. The expression of velocity, temperature and concentration respectively are displayed below

From equation (7)

$$\theta'' + Ke^{\theta} = 0 \quad (11)$$

From equation (11)

$$\theta'' = -Ke^{\theta} \quad (12)$$

$$(k+1)(k+2)G(k+2) = \frac{-R(1)^k}{k!} \quad (13)$$

$$G(k+2) = \frac{-R(1)^k}{(k+1)(k+2)k!} \quad (14)$$

where G(0) = γ_t, G(1) = B and substitute R with K

From equation (14) when k = 0;

$$G(2)=\frac{-R}{2!}=\frac{-K}{2!} \tag{15}$$

When k = 1,

$$G(3)=\frac{-R}{(2)(3)1!}=\frac{-R}{3!}=\frac{-K}{3!} \tag{16}$$

When k = 2,

$$G(4)=\frac{-R}{(3)(4)2!}=\frac{-R}{4!}=\frac{-K}{4!} \tag{17}$$

When k = 3

$$G(5)=\frac{-R}{(4)(5)3!}=\frac{-R}{5!}=\frac{-K}{5!} \tag{18}$$

By generalization, $\theta=\sum_{k=0}^{\infty}G(k)y^k$ (19)

Then $\theta = G(0) + G(1)y + G(2)y^2 + G(3)y^3 + \dots$ (20)

Then, from equation (9) where θ = - γ_t at y = 1.

$$\theta=\gamma_t+By-\frac{K}{2!}y^2-\frac{K}{3!}y^3-\frac{K}{4!}y^4-\frac{K}{5!}y^5+\dots \tag{21}$$

From equation (8)

$$\frac{\partial c}{\partial y}=\frac{1}{S_c}\frac{\partial^2 c}{\partial y^2}-K_c c \tag{22}$$

We take $\frac{\partial c}{\partial y}=\frac{dc}{dy}, \quad \frac{\partial^2 c}{\partial y^2}=\frac{d^2 c}{dy^2},$

Then,

$$\frac{dc}{dy}=\frac{1}{S_c}\frac{d^2 c}{dy^2}-K_c c \tag{23}$$

Multiply (23) through by S_c

$$S_c\frac{dc}{dy}=\frac{d^2 c}{dy^2}-S_c K_c c \tag{24}$$

$$\frac{d^2 c}{dy^2}=S_c\frac{dc}{dy}+S_c K_c c \tag{25}$$

Let $\frac{d^2 c}{dy^2}=C'', \frac{dc}{dy}=C'$

$$C''=S_c(C')+S_c(K_c c) \tag{26}$$

Apply differential transformation method DTM, subject to boundary conditions

$$\{C(1) = -\gamma_c\ , C(0) = \gamma_c\ , H(0) = \gamma_c\ , H(1) = D\} \tag{27}$$

$$(k+1)(k+2)H(k+2) = S_c\left[(k+1)H(k+1)\right] + S_cK_cc \quad (28)$$

$$H(k+2) = \frac{S_c\left[(k+1)H(k+1)\right]}{(k+1)(k+2)} + \frac{S_cK_cc}{(k+1)(k+2)} \quad (29)$$

When k = 0, from equation (29)

$$H(2) = \frac{S_c\left[H(1)\right]}{2} + \frac{S_cK_c}{2} = \frac{S_c(D)}{2} + \frac{S_cK_c}{2} = \frac{S_c(D+K_c)}{2} \quad (30)$$

When k = 1,

$$H(3) = \frac{S_c\left[H(2)\right]}{3} + \frac{S_cK_cc}{6} = \frac{S_c\left[2H(2)+K_cc\right]}{6}$$

$$= \frac{S_c\left[2\left[\frac{S_c(D+K_cc)}{2}\right]+K_cc\right]}{6} = \frac{S_c\left[S_c(D+K_cc)+K_cc\right]}{6} \quad (31)$$

When k=2,

$$H(4) = \frac{S_c\left[H(3)\right]}{4} + \frac{S_cK_cc}{12} = \frac{S_c\left[3H(3)+K_cc\right]}{12}$$

$$= \frac{S_c\left[3\left[\frac{S_c\left[S_c(D+K_cc)+K_cc\right]}{6}\right]+K_cc\right]}{12} = \frac{S_c\left[\frac{S_c\left[S_c(D+K_cc)+K_cc\right]}{2}+K_cc\right]}{12}$$

$$= \frac{S_c\left[S_c[S_c(D+K_cc)]+K_cc\right]}{24} + \frac{K_cc}{12} = \frac{S_c\left[S_c^{\,2}(D+K_cc)+S_cK_cc+2K_cc\right]}{24} \quad (32)$$

When k = 3,

$$H(5)=\frac{S_c\left[H(4)\right]}{5}+\frac{S_cK_cc}{20}=\frac{S_c\left[4H(4)+K_cc\right]}{20}$$

$$=\frac{S_c\left[4\left[\frac{S_c\left[S_c^{2}(D+K_cc)+S_cK_cc+2K_cc\right]}{24}\right]+K_cc\right]}{20}=\frac{S_c\left[\frac{S_c\left[S_c^{2}(D+K_cc)+S_cK_cc+2K_cc\right]}{6}+K_cc\right]}{20}$$

$$=\frac{S_c\left[S_c\left[S_c^{2}(D+K_cc)+S_cK_cc+2K_cc\right]+6K_cc\right]}{120}=\frac{S_c\left[S_c^{3}(D+K_cc)+S_c^{2}K_cc+2S_cK_cc+6K_cc\right]}{120}$$

(33)

By generalization, $C(y)=\sum_{n=0}^{\infty}H(k)y^{k}$ (34)

C(y) = H(0) + H(1)y + H(2) y^2 + H(3) y^3 + H(4) y^4 + H(5) y^5 + … (35)

From equation (27) we let, C(1) = - γ_c, H(0) = γ_c , H(1) = D.,

$$C(y)=\gamma_c+Dy+\frac{S_c(D+K_cc)}{2}y^2+\frac{S_c\left[S_c(D+K_cc)+K_cc\right]}{6}y^3+\frac{S_c\left[S_c^{2}(D+K_cc)+S_cK_cc+2K_cc\right]}{24}y^4+\frac{S_c\left[S_c^{3}(D+K_cc)+S_c^{2}K_cc+2S_cK_cc+6K_cc\right]}{120}y^5+\ldots$$

(36)

From equation (6)

$$U''+\lambda\left[\theta+NC\right]=\gamma$$

$$U''=\gamma-\lambda\left[\theta+NC\right] \tag{37}$$

By applying DTM we have U(1)=0, U(0) = 1

$$(k+1)(k+2)F(k+2)=\gamma-\lambda\left[G(k)+NH(k)\right] \tag{38}$$

$$F(k+2)=\frac{\gamma-\lambda\left[G(k)+NH(k)\right]}{(k+1)(k+2)} \tag{39}$$

Let F(0) = 0, F(1) = M and G(0) = γ_t , G(1) =B, (40)

U(1) = 0 Then, H(1) = D, H(0) = γ_c (41)

From temperature and concentration respectively

When k= 0, from equation (39)

$$F(2)=\frac{\gamma-\lambda\left[G(0)+NH(0)\right]}{2}=\frac{\gamma-\lambda\left[\gamma_t+N\gamma_c\right]}{2} \tag{42}$$

When k=1,

$$F(3)=\frac{\gamma-\lambda\left[G(1)+NH(1)\right]}{6}=\frac{\gamma-\lambda\left[B+ND\right]}{6} \tag{43}$$

When k=2,

$$F(4)=\frac{\gamma-\lambda\left[G(2)+NH(2)\right]}{12}=\frac{\gamma-\lambda\left[\frac{-K}{2}+N\left[\frac{S_c(D+K_cc)}{2}\right]\right]}{12}$$

$$=\frac{2\gamma-\lambda\left[-K+N\left[S_c(D+K_cc)\right]\right]}{24} \tag{44}$$

When k=3,

$$F(5)=\frac{\gamma-\lambda\left[G(3)+NH(3)\right]}{20}=\frac{\gamma-\lambda\left[\frac{-K}{6}+N\left[\frac{S_c[S_c(D+K_cc)+K_cc]}{6}\right]\right]}{20}$$

$$=\frac{6\gamma-\lambda\left[-K+N\left[S_c{}^2(D+K_cc)+S_cK_cc\right]\right]}{120} \tag{45}$$

By Generalization, $U(y)=\sum_{k=0}^{\infty}F(k)y^k$ (46)

U(y) = F(0) + F(1)y + F(2) y^2 + F(3) y^3 + F(4) y^4 + F(5) y^5 + … (47)

$$U(y)=0+My+\frac{\gamma-\lambda\left[\gamma_t+N\gamma_c\right]}{2}y^2+\frac{\gamma-\lambda\left[B+ND\right]}{6}y^3+\frac{2\gamma-\lambda\left[-K+N\left[S_c(D+K_cc)\right]\right]}{24}y^4+\frac{6\gamma-\lambda\left[-K+N\left[S_c{}^2(D+K_cc)+S_cK_cc\right]\right]}{120}y^5+\ldots$$

$$U(y)=My+\frac{\gamma-\lambda\left[\gamma_t+N\gamma_c\right]}{2}y^2+\frac{\gamma-\lambda\left[B+ND\right]}{6}y^3+\frac{2\gamma-\lambda\left[-K+N\left[S_c(D+K_cc)\right]\right]}{24}y^4+\frac{6\gamma-\lambda\left[-K+N\left[S_c{}^2(D+K_cc)+S_cK_cc\right]\right]}{120}y^5$$

(48)

3.1 Influence of Skin friction, Nusselt number and Sherwood number

From equation (48) which is the velocity, we obtain the expression of Skin friction as follows

Then,

$$U(y) = My + \frac{\gamma - \lambda[\gamma_t + N\gamma_c]}{2} y^2 + \frac{\gamma - \lambda[B + ND]}{6} y^3 + \frac{2\gamma - \lambda\left[-K + N\left[S_c(D + K_c c)\right]\right]}{24} y^4 + \frac{6\gamma - \lambda\left[-K + N\left[S_c^{\ 2}(D + K_c c) + S_c K_c c\right]\right]}{120} y^5$$

Then,

$$\frac{dU}{dy} = M + (\gamma - \lambda[\gamma_t + N\gamma_c])y + 3\left(\frac{\gamma - \lambda[B + ND]}{6}\right)y^2 + 4\left(\frac{2\gamma - \lambda\left[-K + N\left[S_c(D + K_c c)\right]\right]}{24}\right)y^3 + 5\left(\frac{6\gamma - \lambda\left[-K + N\left[S_c^{\ 2}(D + K_c c) + S_c K_c c\right]\right]}{120}\right)y^4 \tag{49}$$

$$\frac{dU}{dy} = M + (\gamma - \lambda[\gamma_t + N\gamma_c])y + \left(\frac{\gamma - \lambda[B + ND]}{2}\right)y^2 + \left(\frac{2\gamma - \lambda\left[-K + N\left[S_c(D + K_c c)\right]\right]}{6}\right)y^3 + \left(\frac{6\gamma - \lambda\left[-K + N\left[S_c^{\ 2}(D + K_c c) + S_c K_c c\right]\right]}{24}\right)y^4 \tag{50}$$

From equation (49)

$$\left.\frac{dU}{dy}\right|_{y=0} = M \tag{51}$$

$$\left.\frac{dU}{dy}\right|_{y=1} = M + \left(\gamma - \lambda\left[\gamma_t + N\gamma_c\right]\right) + \left(\frac{\gamma - \lambda\left[B + ND\right]}{2}\right) + \left(\frac{2\gamma - \lambda\left[-K + N\left[S_c(D + K_c c)\right]\right]}{6}\right) + \left(\frac{6\gamma - \lambda\left[-K + N\left[S_c^{\,2}(D + K_c c) + S_c K_c c\right]\right]}{24}\right) \tag{52}$$

From equation (21) we obtain the rate of heat transfer (Nusselt Number) at the plate y = 0 and y = 1, as follows

$$\theta = \gamma_t + By - \frac{K}{2!}y^2 - \frac{K}{3!}y^3 - \frac{K}{4!}y^4 - \frac{K}{5!}y^5 + \ldots$$

$$\frac{d\theta}{dy} = B - 2\frac{K}{2}y - 3\frac{K}{6}y^2 - 4\frac{K}{24}y^3 - 5\frac{K}{120}y^4 \tag{53}$$

$$\frac{d\theta}{dy} = B - Ky - \frac{K}{2}y^2 - \frac{K}{6}y^3 - \frac{K}{24}y^4 \tag{54}$$

$$\left.\frac{d\theta}{dy}\right|_{y=0} = B \tag{55}$$

$$\left.\frac{d\theta}{dy}\right|_{y=1} = \left(B - K - \frac{K}{2} - \frac{K}{6} - \frac{K}{24}\right) \tag{56}$$

From equation (36) we obtain the rate of mass transfer (Sherwood Number) at the plate y = 0 and y = 1, as follows

$$C(y)=\gamma_c+Dy+\frac{S_c(D+K_c c)}{2}y^2+\frac{S_c\left[S_c(D+K_c c)+K_c c\right]}{6}y^3$$
$$+\frac{S_c\left[S_c{}^2(D+K_c c)+S_c K_c c+2K_c c\right]}{24}y^4+\frac{S_c\left[S_c{}^3(D+K_c c)+S_c{}^2K_c c+2S_c K_c c+6K_c c\right]}{120}y^5$$

$$\frac{dC}{dy}=D+2\left(\frac{S_c(D+K_c c)}{2}\right)y+3\left(\frac{S_c\left[S_c(D+K_c c)+K_c c\right]}{6}\right)y^2$$
$$+4\left(\frac{S_c\left[S_c{}^2(D+K_c c)+S_c K_c c+2K_c c\right]}{24}\right)y^3+5\left(\frac{S_c\left[S_c{}^3(D+K_c c)+S_c{}^2K_c c+2S_c K_c c+6K_c c\right]}{120}\right)y^4$$

(57)

$$\frac{dC}{dy}=D+S_c(D+K_c c)y+\left(\frac{S_c\left[S_c(D+K_c c)+K_c c\right]}{2}\right)y^2$$
$$+\left(\frac{S_c\left[S_c{}^2(D+K_c c)+S_c K_c c+2K_c c\right]}{6}\right)y^3+\left(\frac{S_c\left[S_c{}^3(D+K_c c)+S_c{}^2K_c c+2S_c K_c c+6K_c c\right]}{24}\right)y^4$$

(58)

$$\left.\frac{dC}{dy}\right|_{y=0}=D \quad (59)$$

$$\left.\frac{dC}{dy}\right|_{y=1}=D+S_c(D+K_c c)+\left(\frac{S_c\left[S_c(D+K_c c)+K_c c\right]}{2}\right)$$
$$+\left(\frac{S_c\left[S_c{}^2(D+K_c c)+S_c K_c c+2K_c c\right]}{6}\right)+\left(\frac{S_c\left[S_c{}^3(D+K_c c)+S_c{}^2K_c c+2S_c K_c c+6K_c c\right]}{24}\right)$$

(60)

4. RESULTS AND DISCUSSION

The ordinary differential equations (6 to 8) Subject with boundary conditions (9) are solved analytically using differential transformation method to obtain the equations of temperature, concentration and velocity respectively some of the nondimensional parameters that govern the flow are (λ) is the mixed convection parameter, (γ) is the constant pressure gradient, (γ_t) is the constant temperature parameter, (γ_c) is the wall concentration parameter, (K_c) is the chemical reaction parameter, (Sc) is the Schmidt number, (N) is the sustentation parameter and (K) is the Frank-Kamenetskii number. For the purpose of discussion the following parameters are fixed throughout the calculation except where otherwise stated,

K = 0.5, K_c = 0.1, S_c = 0.22, γ_c = 0.1, γ_t = 0.1, λ = 100, γ = 0.1, N = 0.01

The velocity profiles are illustrated in Figure 1 to Figure 3 for different values of (γ_t = 0.1, 0.5, 1.0, 1.5), (γ_c = 0.1, 0.5, 1.0, 1.5) and (K = 0.5, 1.0, 1.5, 2.0). While temperature profile are illustrated in Figure 4 and Figure 5 for different values of (γ_t = 0.1, 0.5, 0.9, 1.4), (K = 0.5, 1.0, 1.5, 2.0) and concentration profile are illustrated in Figure 6 and Figure 7 for different values of (γ_c = 0.1, 0.5, 1.0, 1.5), (K_c = 0.1, 0.5, 1.0, 1.5).

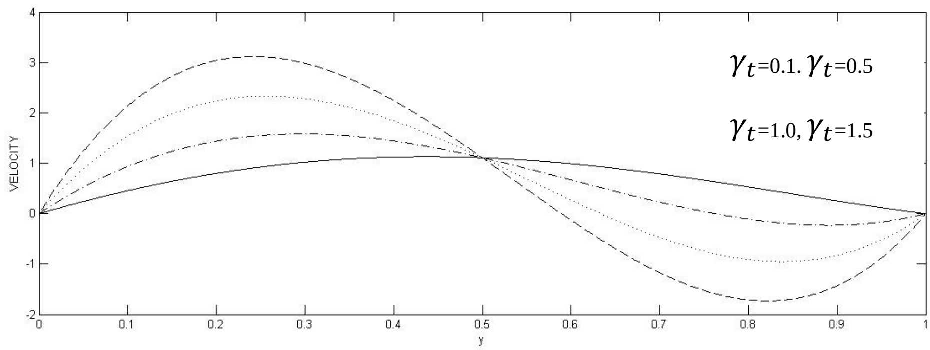


Figure 1. Velocity profile with different values of γ_t

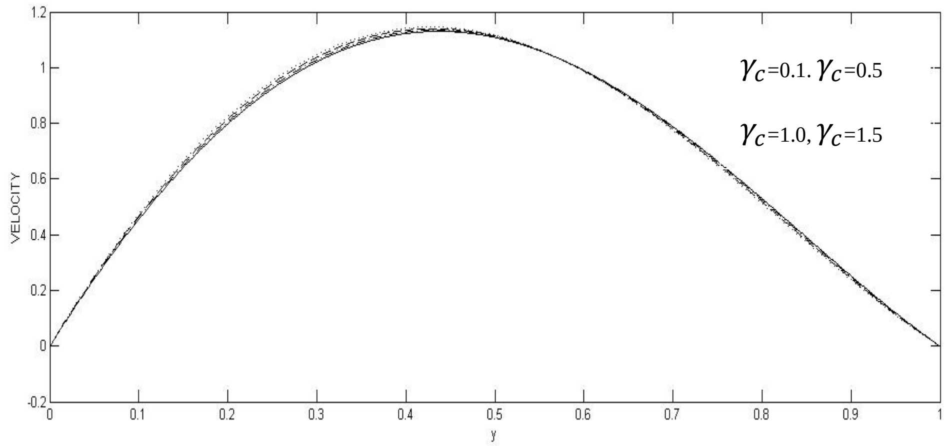


Figure 2. Velocity profile with different values of γ_c

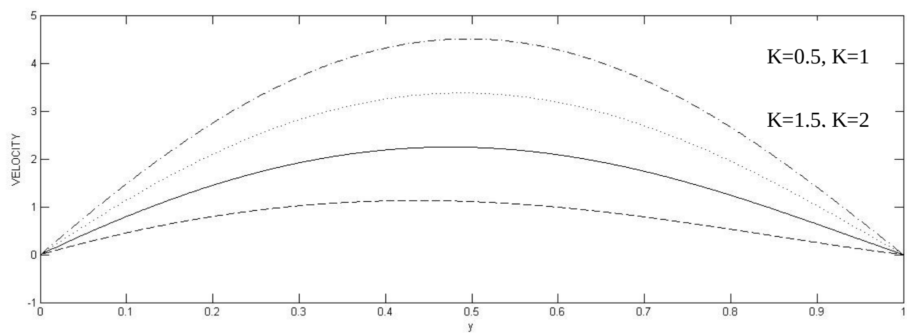


Figure 3.Velocity profile with different values of K

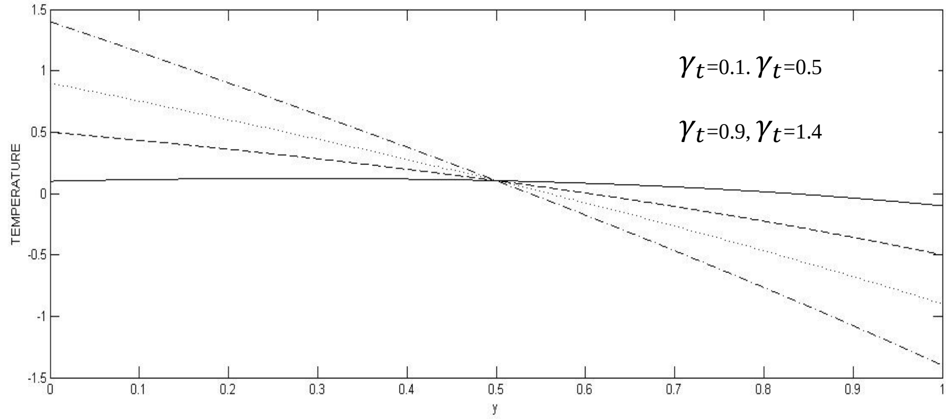


Figure 4. Temperature profile with different values of γ_t

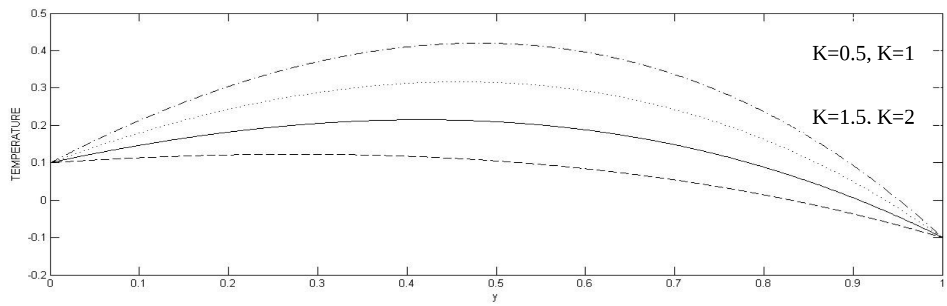


Figure 5. Temperature profile with different values of K

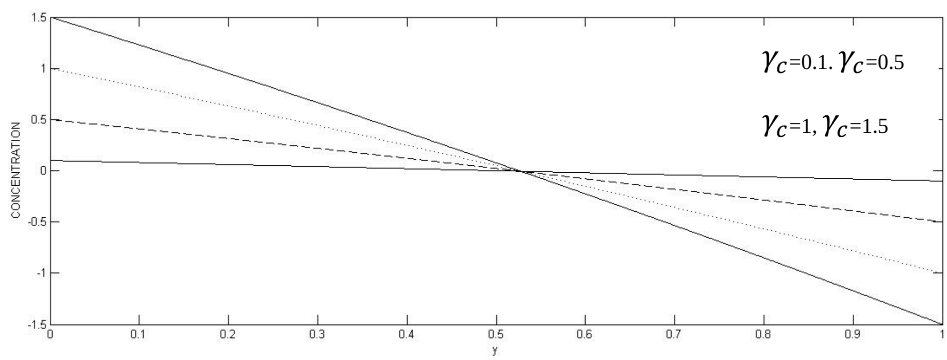


Figure 6. Concentration profile with different values of γ_c

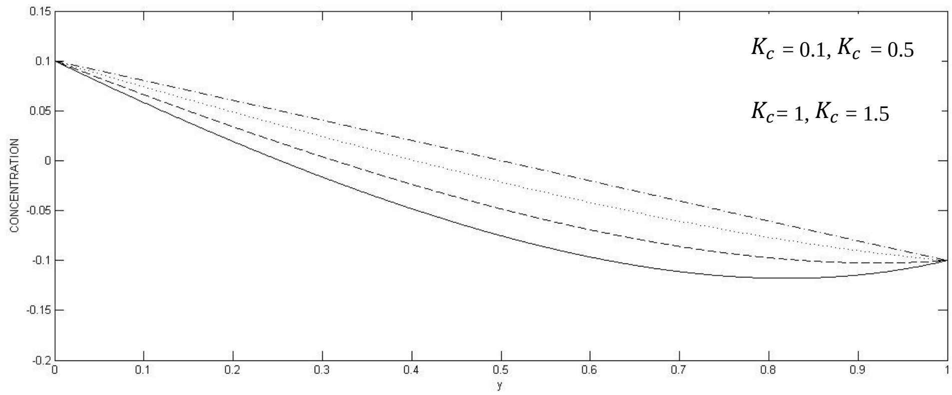


Figure 7. Concentration profile with different values of K_c

Figure 1 to Figure 7 exhibit the influence of (γ_t), (γ_c) and (K) on temperature and velocity profiles, it is observed from these Figures that, increasing K, γ_t and γ_c lead to significant increase in the temperature and velocity profiles, as expected since an increase in λ and γ_t lead to the significant increase in the strength of the reaction and heating of the channel wall. Thus, correspondingly increases the temperature within the fluid and consequently increases the fluid velocity.

Table 1. Influence of γ_t on Skin friction (C_f) and Nusselt number (Nu)

γ_t	$\frac{dU}{dy}_{y=0}$	$\frac{dU}{dy}_{y=1}$	$\frac{d\theta}{dy}_{y=0}$	$\frac{d\theta}{dy}_{y=1}$
0.1	5.0756	-2.2155	0.1583	1.0125
0.5	11.7422	4.4511	-0.6417	0.2125
1.0	20.0756	12.7845	-1.6417	-0.7875
1.5	28.4089	21.1178	-2.6417	-1.7875

Table 2. Influence of γ_c on Skin friction (C_f) and Sherwood number (Sh)

γ_c	$\frac{dU}{dy}_{y=0}$	$\frac{dU}{dy}_{y=1}$	$\frac{dC}{dy}_{y=0}$	$\frac{dC}{dy}_{y=1}$
0.1	5.0756	-2.2155	-0.1956	-0.1940
0.5	5.1495	-2.1563	-0.9108	-1.0852
1.0	5.2420	-2.0823	-1.8048	-2.1992
1.5	5.3344	-2.0082	-2.6988	-3.3133

Table 3. Influence of K on Skin friction (C_f) and Nusselt number (Nu)

K	$\frac{dU}{dy}_{y=0}$	$\frac{dU}{dy}_{y=1}$	$\frac{d\theta}{dy}_{y=0}$	$\frac{d\theta}{dy}_{y=1}$
0.5	5.0756	-2.2155	0.1583	1.0125
1.0	8.5478	-6.2433	0.5167	2.2250
1.5	12.0200	-10.2711	0.8750	3.4375
2.0	15.4922	-14.2989	1.2333	4.6500

Table 4. Influence of K_c on Sherwood number (Sh)

K_c	$\frac{dC}{dy}_{y=0}$	$\frac{dC}{dy}_{y=1}$
0.1	-0.1956	-0.1940
0.5	-0.2626	-0.0787
1.0	-0.3464	0.0653
1.5	-0.4302	0.2094

The effect of K, γ_t, γ_c and K_c on Skin friction, rate of heat (Nusselt number) and Mass transfer equation (Sherwood number) are provided on table 1 to 4 it is interesting to note from table 1 that the Skin friction is increasing with an increase in γ_t at the plate y = 0 and y = 1, while the rate of heat transfer (Nusselt number) decreases with increase in γ_t from table 2 it show that the Skin friction increases slowly with increase in γ_c at y = 0 and y = 1, while Sherwood number decreases slowly at y = 0 and y = 1 with increase in γ_c.

Table 3 Revealed that Skin friction and Nusselt number both increases with increase of (K) except at the upper plate of Skin friction while the velocity is decreasing. It also observed from table 4 that the influence of (K_c) decreases concentration as the values of (K_c) increases at the lower plate, while reverse is the case at the upper plate.

5. CONCLUSION

The study investigated the steady-state of heat mass transfer on the effect of chemical reaction on mixed convection flow of an exothermic fluid in a vertical porous channel with symmetric wall temperature and concentration. The governing equations are solved by using Differential transformation method. The expression of velocity, temperature, concentration, Skin friction, rate of heat and mass transfer (Nusselt and Sherwood number) has been presented. The numerical simulation with aid of matlab software shows graphically that flow formation strongly depend on the mixed convection parameter, Frank-Kamenetskii parameter, symmetric wall temperature and concentration. It was found in this research that, there is an excellent agreement with Pop *et al.* (2010). It is found that multiple solutions exist for velocity, temperature and concentration. From the research conducted, it is concluded that:

i. The temperature increases with the increase in γ_t and K.
ii. The concentration increases with increase in γ_c and suppresses as K_c increases.
iii. The velocity increases with increase in γ_t, γ_c and K.
iv. The effect of γ_t, γ_c is to increase the Skin friction while K increases the flow at lower plate and suppresses it at upper plate. Morealso, the effect of γ_t is to decrease the Nusselt number and K is to increase it as in the case of Sherwood number K_c is to enhance the flow at the plate y = 1, but decreases at y = 0.

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