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Effects of Chemical Reaction and Jeffery Fluid on MHD Unsteady Heat and Mass Transfer Due to the Ramped Temperature

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ABSTRACT
This research work was numerically prepared to investigate the impact of Jeffery fluid and chemical reaction on unsteady (MHD) heat mass transfer free-convective past an infinite vertical plate. The research used appropriate dimensional quantities in transforming the dimensional, coupled, non-linear boundary layer partial differential equations into non-dimensional form. Finite element method (FEM) was employed to find the Numerical solution of the dimensionless governing differential equations. The expressions of velocity, temperature, concentration, skin friction, Nusselt number as well as Sherwood number were obtained and discussed using line graph. From the result obtained, it was shown that velocity profile gets enlarged with the increase of porosity parameter K, ratio of mass transfer parameter N, Eckert number Ec and Jeffery fluid parameter β, while reverse is the case for the Magnetic parameter M, and Prandtl number Pr. Temperature profile magnifies with the increase porosity parameter K, ratio of mass transfer parameter N Eckert number Ec, while reverse is the case for Magnetic parameter M, and Prandtl number Pr. Concentration profile gets lowered by increasing the value Schmidt parameter Sc and chemical reaction parameter K_r. Jeffery fluid parameter β has enhancing effect on skin friction at both $y = 0$and $y = 1$, while reverse is the case for Chemical Reaction parameterK_r. Rising the Jeffery fluid parameter β reduces the Nusselt number at $y = 0$ and reverse is the case for chemical reaction parameterK_r and opposite behavior is seen at $y = 1$. Finally chemical reaction parameterK_r does not have any significant effects on Sherwood number at y=0 and y=1. While Schmidt number reduces the Sherwood numberSc at y=0 and intensifies it at y=1

I. INTRODUCTION

Jeffery fluid is categorized as non-Newton fluid, simply because it does not obey the Newton's law of viscosity. And since it does not obey Newton's law of viscosity that it means that ratio of shear stress to the shear rate is not constant and is dependent on the shear rate. Non-Newton fluid possesses both properties of viscosity and elasticity. Many researchers have turned their attention and interest in carrying out research works on non-Newton fluid because of its applications in geophysics, biological sciences, and petroleum and chemical industries. Non Newton's fluid is exemplified as Honey, ketchup, certain oils, toothpaste, paints, apple sauce, foams, soaps, sugar solution pastes, clay coating, lubricants etc. Differential, integral and rate types are the three types of non-Newton fluids (Tasawar, Samira, Mustafa & Ahmed, 2016). Rate type is anexample of Jeffery fluid which depicts linear viscoelastic effect of fluid.The study of heat and mass transfer under the influence of chemical reaction has also received wide spread attention as a result of the application it has in areas of science and engineering. This phenomenon is applied in human transpiration, nuclear power plants, cooling of nuclear reactors, chemical industries and petroleum industries.

Nirmala (2020) examined the influence ofa Jeffery fluid on MHD heat and mass transferin a vertical channel in the presence of Hall current and wall slip condition. Similarly, the influence of Jeffrey fluid on MHD electrically conducting-heat absorbing through a vertical permeable moving plate fixed in a porous medium was studied by (Venkateswarlu&Keshava, 2019). Furthermore, the effect of first order chemical reaction on unsteady MHD free convective two immiscible fluid flows with heat and mass transfer was analyzed by (Joseph, Daniel, Ayuba&Agaie, 2017). Additionally,Dharmaiah, Prakash, Balamurugan, and Vedavathi (2017) studied the influence of

Chemical reaction and Radiation Absorption on MHD free convective heat and mass transfer flow of a Nano-fluid bounded by a semi-infinite flat plate with Diffusion thermo(Dufour). The investigations of the influence of induced magnetic field on an unsteady two dimensional incompressible free was carried out by (Odelu, Adigoppula&Naresh, 2019). Moreover, Siti-Nur and Anati (2019) studied theeffects heat and mass transfer of steady magnetohydrodynamics of dusty Jeffrey fluid past an exponentially stretching sheet in the presence of thermal radiation. Sridhar and Ramesh (2019) analyzed combined influence of thermal radiation and heat sources on peristaltic flow of a conducting Jeffrey fluid in a vertical porous channel.

The analysis of the effect of heat transfer to MHD Oscillatory flow of Jeffrey fluid in a channel filled with porous material was carried out by Danjuma,Abubakar, Ibrahim andMurtala (2019) and reported that, the velocity profile gets diminished with the rising of Dacy number, Grashof number and Jeffrey fluid parameter analyzed. Moreover,Eswara, Renuka, Mahesh and Krishna (2018) analyzes the effects of heat and mass transfer flow of Jeffrey fluid through a vertical deformable porous stratum and discovered that the velocity profile and the temperature profile gets reduced for higher values of Jeffrey parameter. Imran,Fizza, Khana, andTlili (2018) studied the exact analysis of non-Newtonian fluid. They stated that increasing the value of Jeffrey parameter and fractional parameter, fluid flow can also be higher and lessens with increase of chemical reaction parameter. Eswara, Sreenadhand Sumalatha (2017) analyzed the unsteady flow of an incompressible Jeffrey fluid past a semi-infinite vertical plate with time dependent suction and found that the velocity profile is boosting with increase values of thermal of Jeffrey parameter and concentration profile get lowered with the increase of chemical reaction parameter.

Krishna (2016) studied the effects of heat and mass transfer on MHD Couette flow of a Jeffrey fluid in a porous channel with heat source and chemical reaction and stated that, the velocity profile is increasing with the increase of Jeffery fluid parameter and decreasing with the increasing chemical reaction parameter and heat source parameter. Mustapha, Yale, Murtala and Abubakar (2020) studied the effect of suction/injection on unsteady MHD Oscillatory flow of Jeffrey fluid with heat source/sink through porous medium under slip condition and found that the velocity profile and skin friction diminished with increasing of and fluid parameter. Dastagiri, Venkateswarlu and Keshava (2020) studied the MHD flow of Jeffrey fluid of an electrically conducting-heat absorbing through a vertical permeable moving plate fixed in a porous medium with a uniform diagonal Magnetic field and reported that that the increasing the Jeffrey fluid parameter leads to the lowering of velocity. Ge-JiLe, Mubbashar, Farooq, Ijaz Khan,Adila and Imran (2021) investigated the two-phase flow of MHD Jeffrey fluid in the presence of porous media through horizontal walls and found that the Jeffrey fluid parameter show variations in behavior against velocity and temperature field for all considered flow phenomenon.

The present study originated from the work of Prabhakar (2016) who studied the effects of heat and mass transfer on an unsteady free convection flow of viscous dissipative fluid past an infinite vertical porous plate under the influence of a uniform magnetic field applied normal to the plate. This study adopted and extended the Prabhakar's model by incorporating the Jeffery fluid and chemical reaction parameter on magneto-hydrodynamics (MHD) unsteady heat and mass transfer free convective past an infinite vertical plate. Furthermore, the study employed the validated finite element method (FEM) in finding numerically solution of governingpartial differential equations. Theexpressions of velocity, temperature, concentration, skin friction, Nusselt number as well as Sherwood were obtained and discussed using line graph.

Formulation of the Problem

Consider an unsteady free convection flow of an incompressible electrically conducting fluid past an infinite vertical porous plate.

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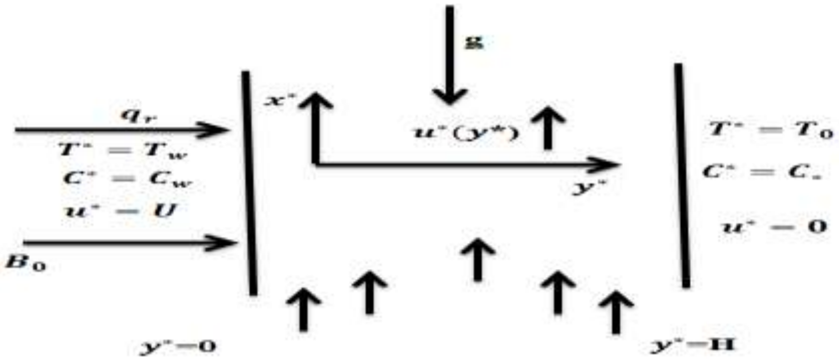

Figure 1: Geometry of the Problem

Let the x* -axis be taken along the plate in the vertically upward direction and the y* - axis is taken normal to the plate. A uniform magnetic field of intensity H_0 is applied transversely to the plate. The induced magnetic field is ignored as the magnetic Reynolds number of the flow is taken to be very small. Initially, the temperature of the plate T^* and the fluid T_w^* are assumed to be the same. The concentration of species at the plate C_w^* and C_0^* are assumed to be the same. At time t*>0, the plate temperature is changed to T_w^*, which is then maintained constant, causing convection currents to flow near the plate and mass is supplied at a constant rate to the plate. Under these conditions the flow variables are functions of time y* and t* alone. The problem is governed by the following equations:

$$\frac{\partial u^*}{\partial t^*} = \left(\frac{1}{1+\beta}\right)\frac{\partial^2 u^*}{\partial y^{*2}} + g\beta(T^* - T_\alpha^*) + g\beta^\bullet (C^* - C_0^*) - \frac{\sigma\mu_e^2 H_0^2 u^*}{\rho} - \frac{\nu u^*}{K^*} \quad (1)$$

$$\rho C_p \frac{\partial T^*}{\partial t^*} = k\frac{\partial^2 T^*}{\partial y^{*2}} + \mu\left[\frac{\partial u^*}{\partial y^*}\right]^2 \quad (2)$$

$$\frac{\partial C^*}{\partial t^*} = D_M \frac{\partial^2 C^*}{\partial y^{*2}} - K_r C^* \quad (3)$$

The corresponding initial and boundary conditions are:

$$\begin{bmatrix} t^* \le 0,\ u^* = 0,\ T^* = T_\alpha, C^* = C_\alpha \ \ for\ \ all\ \ y^* \\ t^* > 0, u^* = 0,\ T^* = T^*{}_w,\ C^* = C_w^*\ \ at\ \ y^* = 0 \\ u^* = 0, T^* \to T_\alpha{}^*,\ C^* \to C_\alpha^*\ \ as\ \ y^* = \alpha \end{bmatrix} \quad (4)$$

To transform the dimensional governing partial differential equations and their there boundary conditions into non-dimensional form, we now introduce the following non- dimensional quantities:

$$\left.\begin{array}{l}
U_0=(vg\beta\Delta T)^{1/3},\quad L=\left(\frac{g\beta\Delta T}{v^2}\right)^{-1/3}\quad T_R=\frac{(g\beta\Delta T)^{-2/3}}{v^{-1/3}}\\
\Delta T=T_w^*-T_\infty^*,\quad t=\frac{t^*}{T_R},\quad y=\frac{y^*}{L},\\
u=\frac{u^*}{U_0},\quad K=\frac{K^*}{vT_R},\quad \theta=\frac{T^*-T_0}{T_w^*-T_0},\quad \phi=\frac{C^*-C_0}{C_w^*-C_0}\\
Pr=\frac{\mu C_P}{k},\quad Sc=\frac{v}{D_m},\quad Ec=\frac{U_0^2}{C_P\Delta T},\\
N=\frac{\beta^\bullet(C_w^*-C_\infty^*)}{\beta(T_W^*-T_\infty^*)},\quad M=\frac{\sigma\mu_0^2H_0^2T_R}{\rho}
\end{array}\right] \tag{5}$$

Applying equations (5) into (1) - (4) then the following governing partial differential equations and their boundary conditions in non-dimensional form are obtained.

$$\frac{\partial u}{\partial t}=\left(\frac{1}{1+\beta}\right)\frac{\partial^2 u}{\partial y^2}+Gr\theta+N\phi-(M+\frac{1}{K})u \tag{6}$$

$$Pr\frac{\partial\theta}{\partial t}=\frac{\partial^2\theta}{\partial y^2}+Ec\left(\frac{\partial u}{\partial y}\right)^2 \tag{7}$$

$$Sc\frac{\partial\phi}{\partial t}=\frac{\partial^2\phi}{\partial y^2}-K_r\phi \tag{8}$$

$$\left.\begin{array}{l}
t\le 0,\ u=0,\theta=0,\phi=0\ \ for\ \ all\ \ y\\
For\ t>0: u=0,\theta=1,\phi=1\quad at\ \ y=0\\
u=0,\theta\to 0,\phi\to 0\quad at\ \ y=\alpha
\end{array}\right\} \tag{9}$$

Method of the Solution

Finite element method (Galerkin's approach) was found to be suitable in finding the numerical solution of equations (6) – (8) under the boundary conditions (9).

Now applying Galerkin's finite element method for equation (6) over the element $e\ y_i\le y\le y_j$ we have:

$$\int_{y_i}^{y_i}\left\{N^T\left[\left(\frac{1}{1+\beta}\right)\frac{\partial^2 u}{\partial y^2}-\frac{\partial u}{\partial t}-u(M+\frac{1}{K})+N\phi+\theta\right]\right\}dy=0 \tag{10}$$

Equation (10) is reduced to:

$$\int_{y_i}^{y_i}\left\{N^T\left[M_2\frac{\partial^2 u}{\partial y^2}-\frac{\partial u}{\partial t}-M_1u+P\right]\right\}dy=0 \tag{11}$$

Where $M_1=M+\frac{1}{K}$ and $P=\theta+N\phi$ and $M_2=\left(\frac{1}{1+\beta}\right)$

Applying integration by part to equation (11) to get:

$$[M_2 N^T \frac{\partial u}{\partial t}]_{y_i}^{yj} - \int_{y_i}^{y_i} M_2 \frac{\partial N^T}{\partial y}\frac{\partial u}{\partial y} dy - \int_{y_i}^{y_i} N^T \frac{\partial u}{\partial t} dy - M_1 \int_{y_i}^{y_i} N^T u dy + P \int_{y_i}^{y_i} N^T dy = 0 \quad (12)$$

Neglecting the first term of equation (12) we have:

$$\int_{y_i}^{y_i} M_2 \frac{\partial N^T}{\partial y}\frac{\partial u}{\partial y} dy + \int_{y_i}^{y_i} N^T \frac{\partial u}{\partial t} dy + M_1 \int_{y_i}^{y_i} N^T u dy - P \int_{y_i}^{y_i} N^T dy = 0 \quad (13)$$

Let $u^{(e)} = u_i N_i + u_j N_j$ Þ $u^{(e)} = [N][u]^T$ be a linear piecewise approximation solution over the two nodal element $e, (y_i \le y \le y_j)$ where $u^{(e)} = [u_i \; u_j]$, $N = [N_i N_j]$ also u_i *and* u_j are the velocity component at the i^{th} and j^{th} nodes of the typical element (e) $(y_i \le y \le y_j)$ furthermore, N_i and N_j are called basis (or shape) functions which are defined as follows:

$$N_i = \frac{y_j - y}{y_j - y_i}, \; N_j = \frac{y - y_i}{y_j - y_i}$$

Applying the above on equation (13) and simplify to have:

$$M_2 \int_{y_i}^{y_i} \begin{bmatrix} N_i'N_i' & N_i'N_j' \\ N_i'N_j' & N_j'N_j' \end{bmatrix} \begin{bmatrix} u_i \\ u_j \end{bmatrix} dy + \int_{y_i}^{y_i} \begin{bmatrix} N_iN_i & N_iN_j \\ N_iN_j & N_jN_j \end{bmatrix} \begin{bmatrix} \dot{u}_i \\ \dot{u}_j \end{bmatrix} dy + M_1 \int_{y_i}^{y_i} \begin{bmatrix} N_iN_i & N_iN_j \\ N_iN_j & N_jN_j \end{bmatrix} \begin{bmatrix} u_i \\ u_j \end{bmatrix} dy - P \int_{y_i}^{y_i} \begin{bmatrix} N_i \\ N_j \end{bmatrix} dy = 0$$

(14)

Equation (14) is also simplified to have:

$$\frac{M_2}{l}\begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix}\begin{bmatrix} u_i \\ u_j \end{bmatrix} + \frac{l}{6}\begin{bmatrix} 2 & 1 \\ 1 & 2 \end{bmatrix}\begin{bmatrix} \dot{u}_i \\ \dot{u}_j \end{bmatrix} + \frac{M_1 l}{6}\begin{bmatrix} 2 & 1 \\ 1 & 2 \end{bmatrix}\begin{bmatrix} u_i \\ u_j \end{bmatrix} - \frac{lP}{2}\begin{bmatrix} 1 \\ 1 \end{bmatrix} = 0 \quad (15)$$

Where $l = y_j - y_i = h$ and prime and dot indicates differentiation with respect to y and t respectively. Assembling the equations for the two consecutive elements $y_{i-1} \le y \le y_i$ and $y_i \le y \le y_{i+1}$ the following is obtained:

$$\frac{M_2}{l^2}\begin{bmatrix} 1 & -1 & 0 \\ -1 & 2 & -1 \\ 0 & -1 & 1 \end{bmatrix}\begin{bmatrix} u_{i-1} \\ u_i \\ u_{i+1} \end{bmatrix} + \frac{1}{6}\begin{bmatrix} 2 & 1 & 0 \\ 1 & 4 & 1 \\ 0 & 1 & 2 \end{bmatrix}\begin{bmatrix} \dot{u}_{i-1} \\ \dot{u}_i \\ \dot{u}_{i+1} \end{bmatrix} + \frac{M_1}{6}\begin{bmatrix} 2 & 1 & 0 \\ 1 & 4 & 1 \\ 0 & 1 & 2 \end{bmatrix}\begin{bmatrix} u_{i-1} \\ u_i \\ u_{i+1} \end{bmatrix} - \frac{P}{2}\begin{bmatrix} 1 \\ 2 \\ 1 \end{bmatrix} \quad (16)$$

Now consider the row corresponding to the node i to zero with $l = h$, from equation (16) the difference schemes reads:

$$\frac{M_2}{h^2}(-u_{i-1} + 2u_i - u_{i+1}) + \frac{1}{6}(-\dot{u}_{i-1} + 4\dot{u}_i + \dot{u}_{i+1}) \frac{M_1}{6}(u_{i-1} + 4u_i + u_{i+1}) = P \quad (17)$$

Using the trapezoidal rule on (17), the following system of equations in Crank-Nicolson method is obtained as:

$$A_1u_{i-1}^{n+1} + A_2u_i^{n+1} + A_3u_{i+1}^{n+1} = A_4u_{i-1}^{n} + A_5u_i^{n} + A_6u_{i+1}^{n} + P^* \tag{18}$$

Similarly applying the same method to solve (7) and (8) we have:

$$B_1q_{i-1}^{n+1} + B_2q_i^{n+1} + B_3q_{i+1}^{n+1} = B_4q_{i-1}^{n} + B_5q_i^{n} + B_6q_{i+1}^{n} + Q^* \tag{19}$$

$$C_1\phi_{i-1}^{n+1} + C_2\phi_i^{n+1} + C_3\phi_{i+1}^{n+1} = C_4\phi_{i-1}^{n} + C_5\phi_i^{n} + C_6\phi_{i+1}^{n} + R^* \tag{20}$$

Where:

$$A_1 = 2 - 6M_2r + rM_1h^2, \quad A_2 = 8 + 12M_2r + rM_1h^2, \quad A_3 = 2 - 6M_2r + rM_1h^2$$

$$A_4 = 2 + 6M_2r - rM_1h^2, \quad A_5 = 8 - 12M_2r - 4rrM_1h^2, \quad A_6 = 2 + 6M_2r - rM_1h^2$$

$$B_1 = Pr - 3r, \quad B_2 = 4Pr + 6r, \quad B_3 = Pr - 3r \quad B_4 = Pr + 3r, B_5 = 4Pr - 6r, \quad B_6 = Pr + 3r$$

$$C_1 = Sc - 3r, \quad C_2 = 4Sc + 6r, \quad C_3 = Sc - 3r$$

$$C_4 = Sc + 3r, \quad C_5 = 4Sc - 6r, \quad C_6 = Sc + 3r$$

$$P^* = 12rh^2(\theta_i^n + N\phi_i^n), \quad Q^* = 6r\,Pr\,Ec\left(\left[\frac{\partial u}{\partial y}\right]^2 - R\theta\right) \text{ and } R^* = -6rh^2ScK_r$$

Where $r = \frac{k}{h^2}$ and h and k are the mesh size along y direction and time direction respectively. Index i represents space and j signifies to the time. In equations (18), (19) and (20), taking $i = 1(1)n$ and using the initials and boundary conditions (9), the following system of equations is obtained:

$$A_iX_i = B_i \; i = 1(1)n$$

Where A_i matrices of are order n and X_i and B_i are column matrices having n components. The solution of the system of equation are obtained using Thomas algorithm for velocity, temperature and concentration. For various parameters the results are computed and p resented graphically. The skin friction, Nusselt number and Sherwood number are important physical parameters for this type boundary layers flow if thevalues velocity, temperature and concentration are known

The skin-friction at the plate is given in non-dimensional form as:

$$\tau = \left[\frac{\partial u}{\partial y}\right]_{y=0,1} \tag{21}$$

The rate of heat transfer coefficient can be obtained in the terms of Nusselt number in non-dimensional form as:

$$N_u = -\left[\frac{\partial \theta}{\partial y}\right]_{y=0,1} \tag{22}$$

The rate of mass transfer coefficient cab be obtained in terms of Sherwood number in non-dimensional as:

$$S_h = -\left[\frac{\partial \phi}{\partial y}\right]_{y=0,1}$$

II. RESULTS AND DISCUSSIONS

Finite element method (Galerkin's approach) was employed to find the numerical solution of dimensionless governing coupled non-linear differential equations which were represented by equations (6) to (8) using the

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boundary conditions (9). In order to analyze the effect of chemical and Jeffery fluid on MHD unsteady heat transfer due to the ramped temperature. The graph of velocity profile (u), the temperatureprofiles(θ) and concentration profile (ϕ) was plotted against y for different values of Prandtl number $\Pr$, Jeffery fluid parameterβ, Eckert number EcSchmidt number Sc, Chemical reaction parameterK_r, magnetic parameter M, porosity parameter K, Buoyancy effect parameterr_t ratio of mass transformation (N). The study has chosen and adopted the values of the following parameters: $\Pr = 0.71$ $K_r = 1$ $\beta = 1$, $Ec = 1$, $Sc = 0.2$, $M = 1$, $K = 1$ and $N = 1$ to be default values to be used under this study. The velocity, temperature, and concentration profiles were presented in the following figures:

Velocity Profile

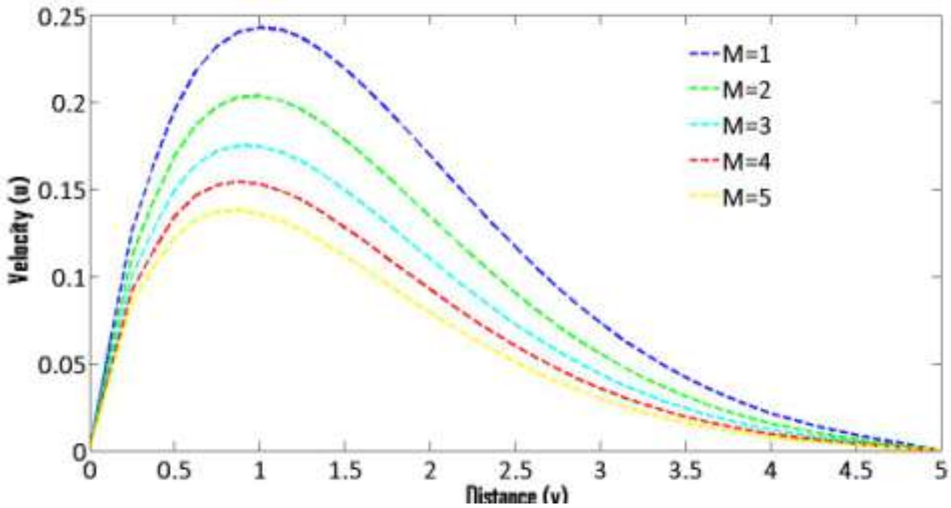

Figure 1: Effect of M on velocity profile

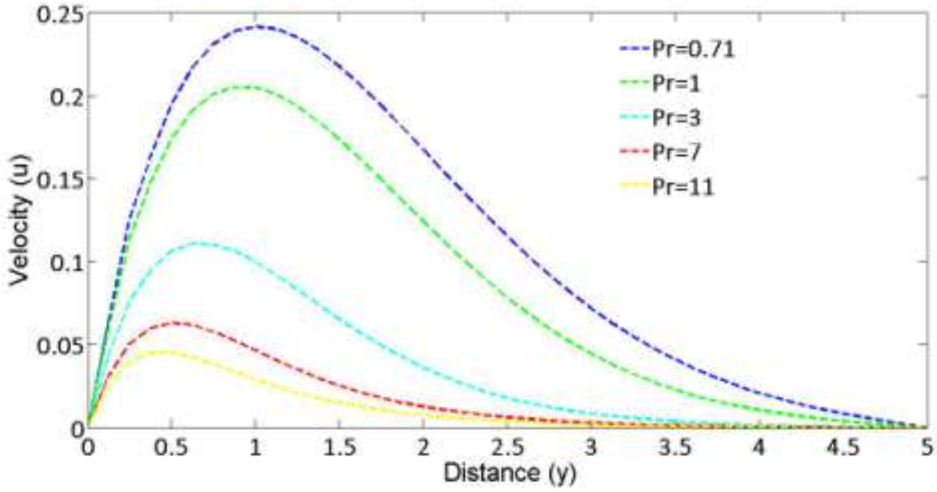

Figure 2: Effect Pr on velocity profile

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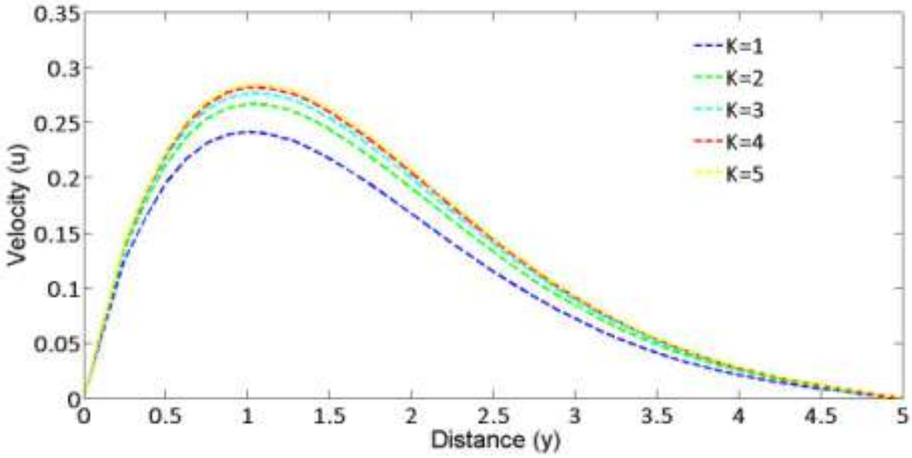

Figure 3: Effect of K on velocity profile

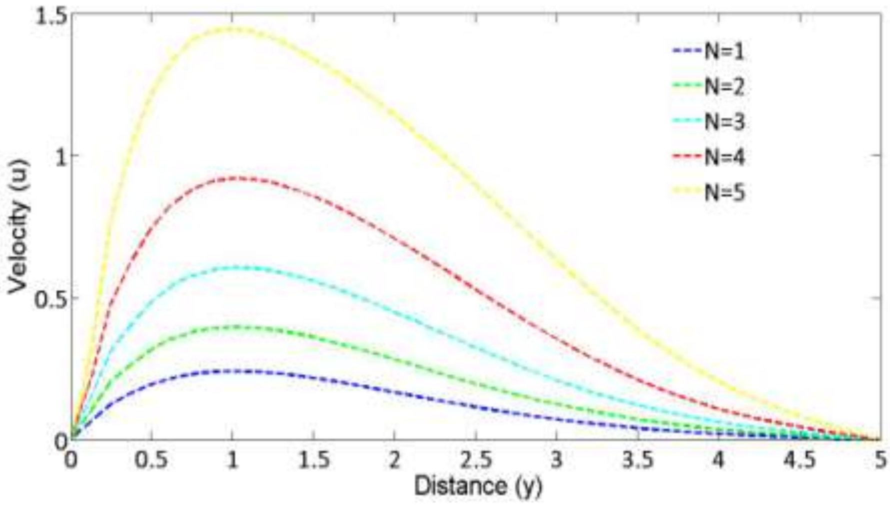

Figure 4: Effect of N on velocity profile

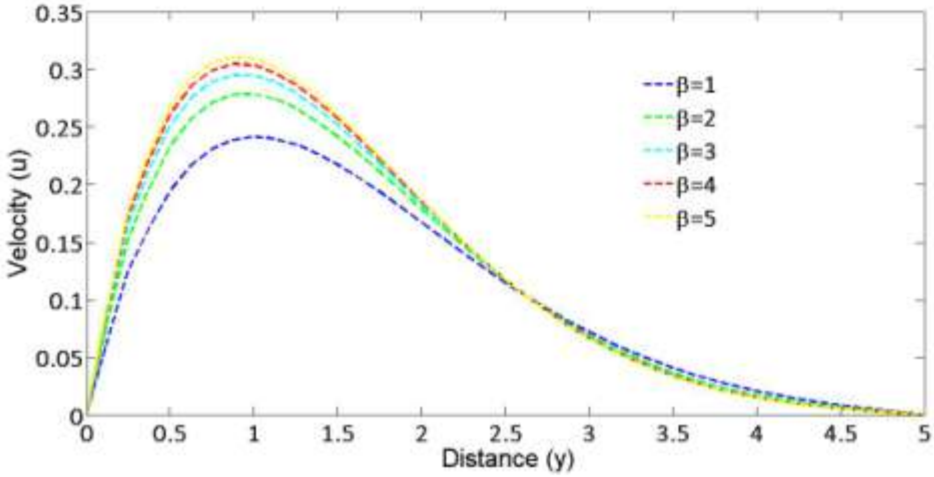

Figure 5: Effect of β on velocity profile

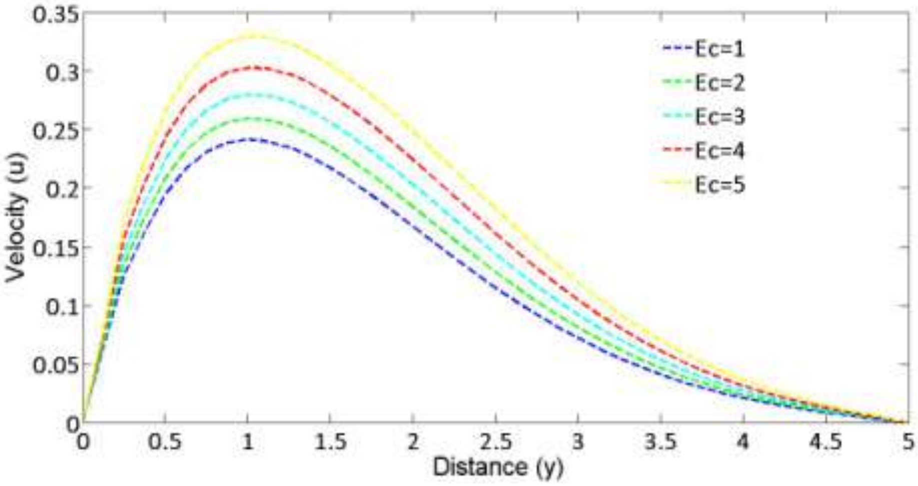

Figure 6: Effect the different values Ecvelocity profile

Figure 1&2 exhibit the effects ofmagnetic parameter M and Prandtl number Pr on velocity profile. From the two figures it is observed that the velocity profile gets diminished at all point of the flow field by increasing the values of magnetic parameter M and Prandtl number Pr. Magnetic parameter normally produces resistive force, which acts opposite direction to the fluid motion. While the opposite behavior is seen in **Figure 3** gives as result of increasing porosity parameter K on fluid velocity.

Figure 4, 5 & 6 reveal the influence of the ratio of mass transfer parameter N, Jeffery fluid parameterβ andEckert number Ec respectively on the fluid velocity. It is observed that the fluid velocity gets enhanced by increasing the values of ratio of mass transfer parameter N and Jeffery fluid parameterβ and Eckert number Ec .

Temperature Profile

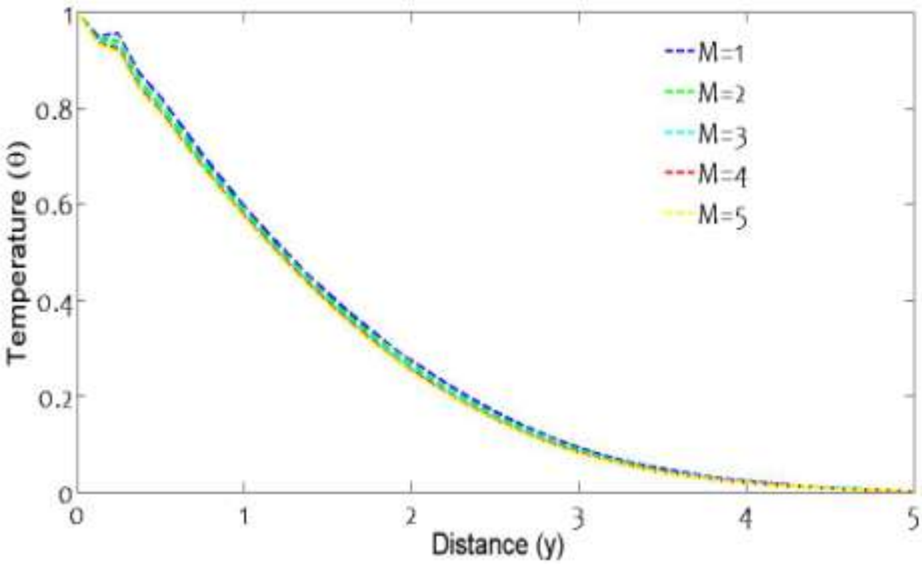

Figure 7: EffectM on temperature profile

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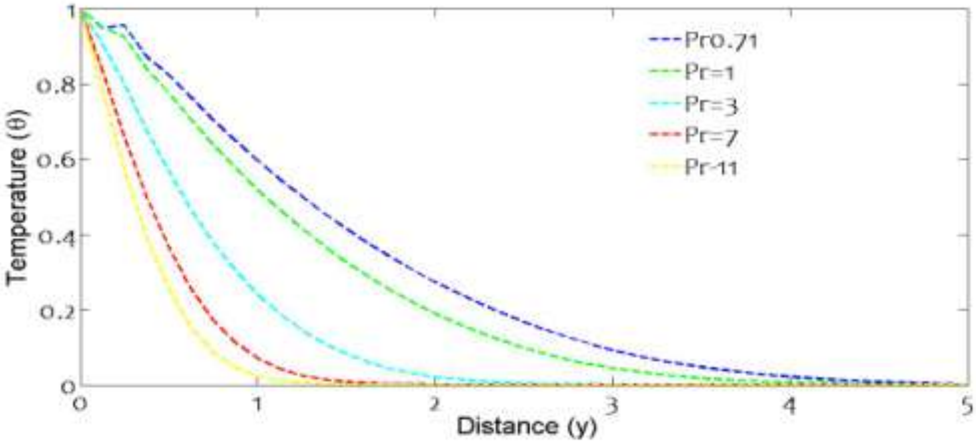

Figure 8: Effect Pr on temperature profile

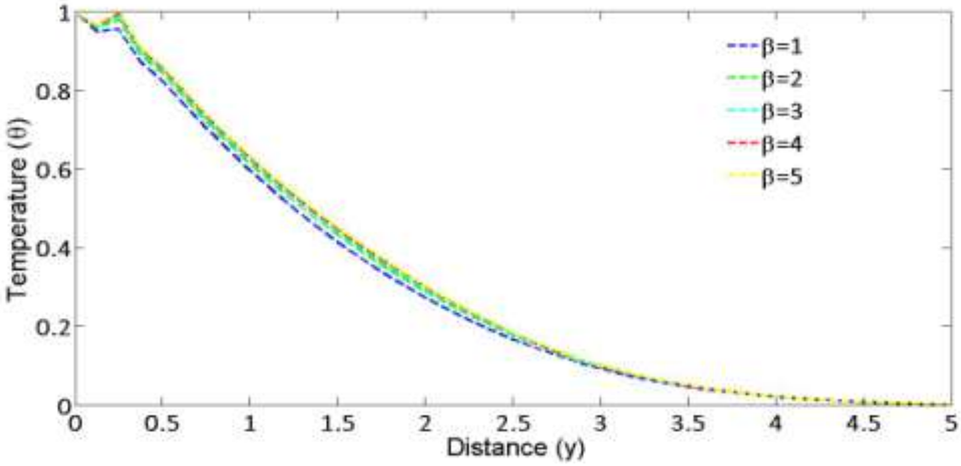

Figure 9: Effect β and on temperature profile

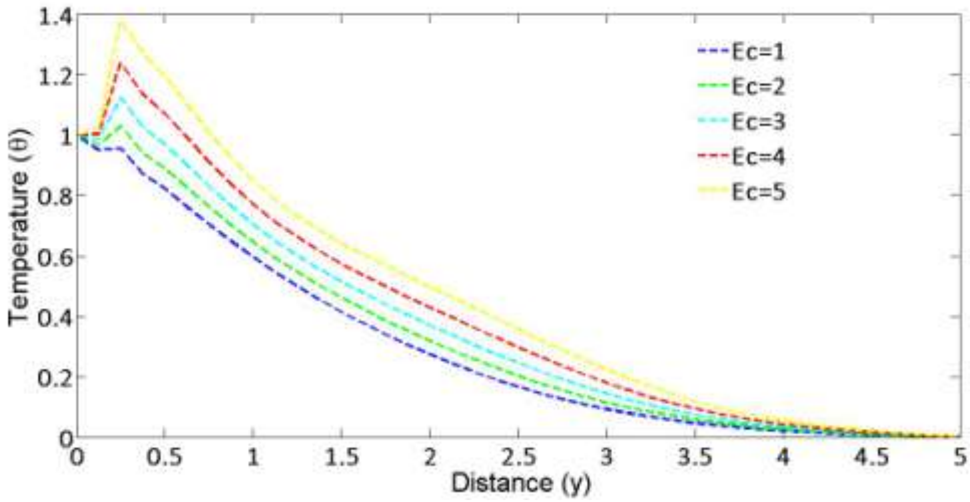

Figure 10: Effect Ec on temperature profile

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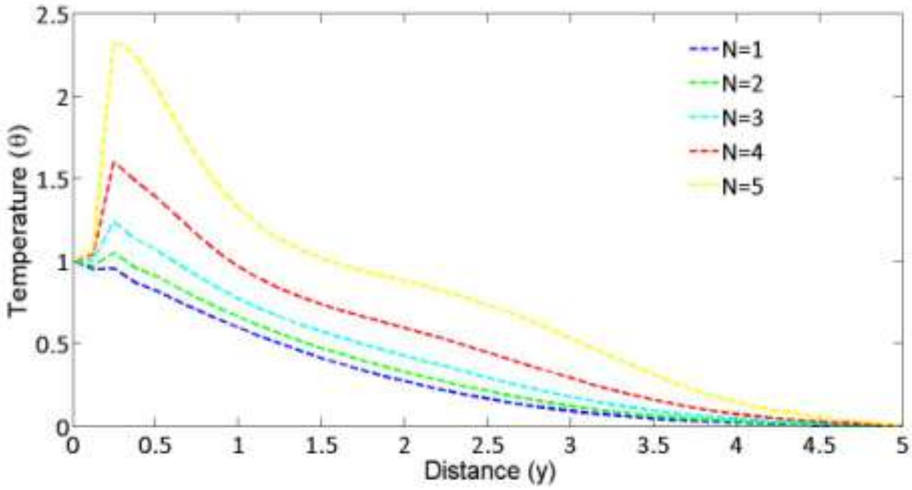

Figure 11: Effect N on temperature profile

Figure 7&8 depict the influence of magnetic field parameter M and Prandtl numberPr on fluid temperature respectively. From the both figures it is clearly seen that, the fluid temperature gets reducedby increasing the values of magnetic field parameter M and Prandtl numberPr. While reverse is the case in **Figure 9** by increasing the value of Jeffery fluid parameter β.

Similarly, **Figure 10 &11** displays the effects of Eckert number Ec and ratio of mass transfer parameter N on fluid temperature respectively. From the both figures it is clearly observed that temperature profile gets enlarged by increasing the values of Eckert number Ec and ratio of mass transfer parameter N

Concentration Profile

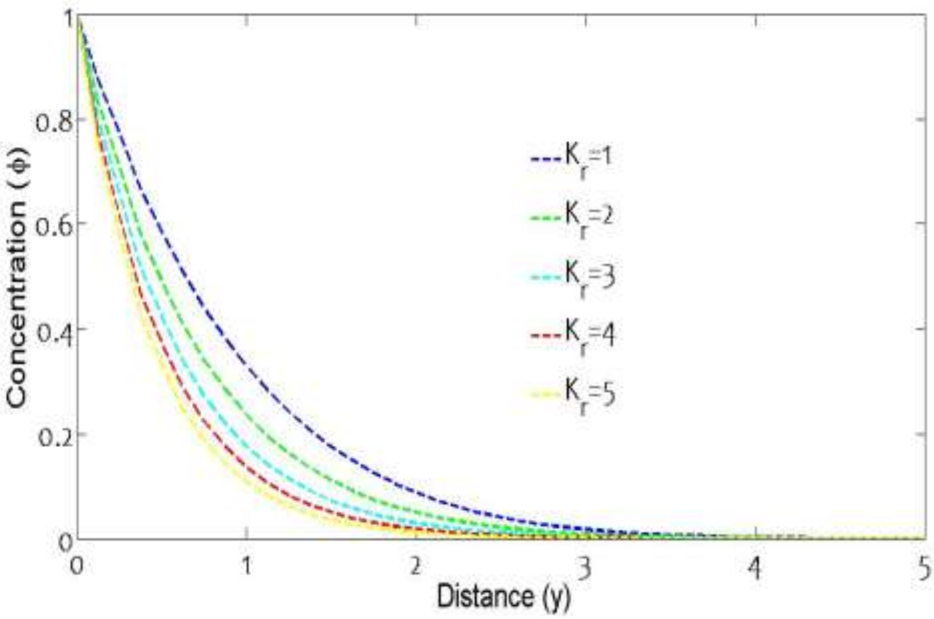

Figure 12: Effect of K_r on temperature profile

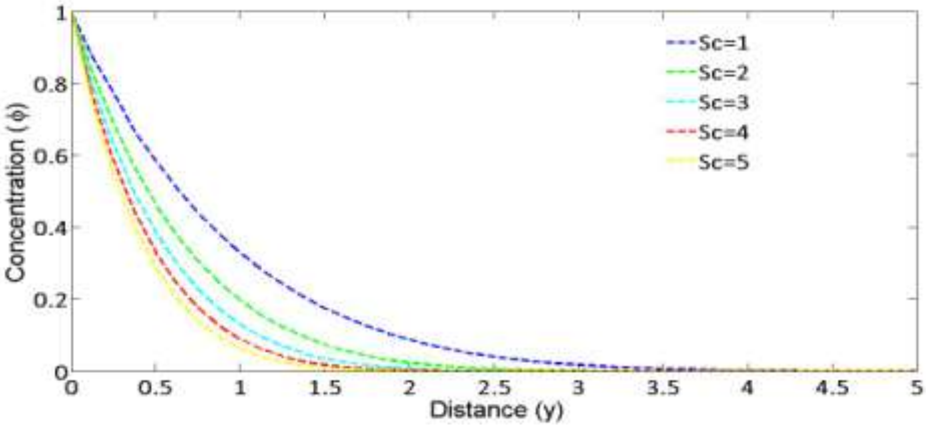

Figure 13: Effect of Sc on temperature profile

Figure 12 and 13 depicts the influence of Schmidt number Sc and chemical reaction parameter βon concentration profile. From both figures it is seen that, the fluid temperature get condensedby increasing the values of magnetic field and chemical reaction parameter β

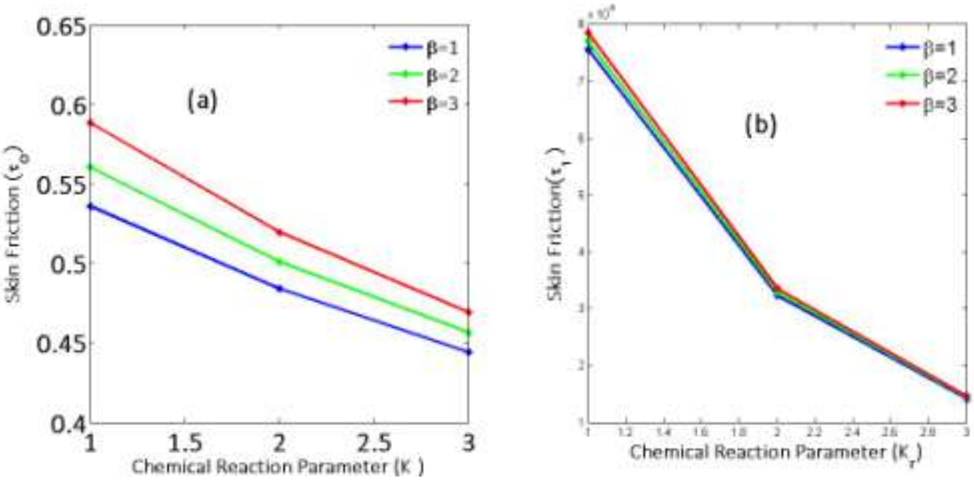

Figure 14(a) & 14(b): Effect β and K_r on Skin friction

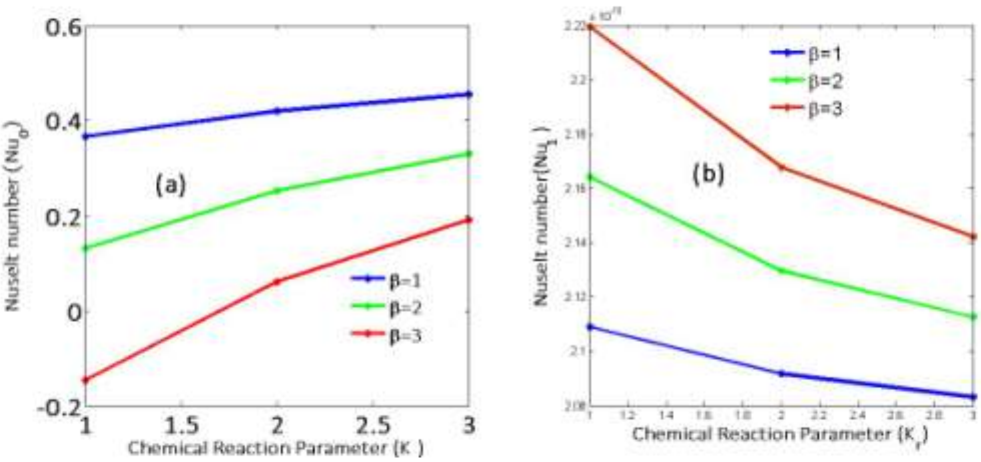

Figure 15(a) &15(b):effect βand $K_r$on Nusselt number

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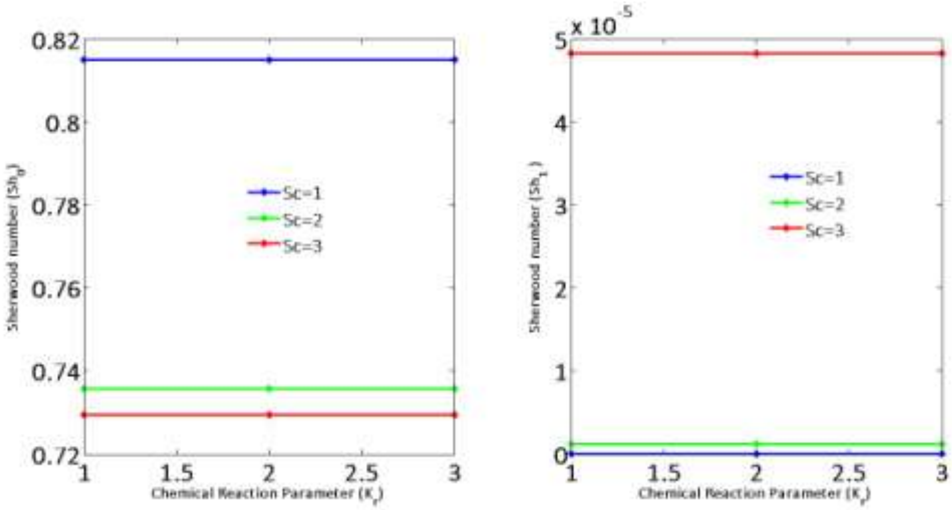

Figure 16(a) &16(b):effect Sc and K_r on Sherwood number

Figure 14(a) and 14(b) depicts the effect Jeffery fluid parameterβ and chemical Reaction parameter K_r on the fluid skin friction. It is shown that, rising Jeffery fluid parameter β has enhancing effect on skin friction in both figures. While reverse is the for Chemical Reaction parameterK_r. Similarly **Figure 15(a) and 15(b)** displays the same effects on Nusselt number. It is observed that in **Figure15(a)** rising the Jeffery fluid parameterβ reduces the Nusselt number andreverse is the case for chemical reaction parameter β. In **Figure 15(b)**Nusselt number magnifieswith increasing Jeffery fluid parameter β and reverse is the case for chemical reaction parameterK_r. Additionally, **figure 16(a) and 16(b)** show the effect Schmidt number and chemical reaction parameter. From the figures it is seen that chemical reaction parameter has no any significant effects on Sherwood number. While Schmidt number reduces the Sherwood number in figure **16 (a)** and intensifies it in **figure 16(b)**

III. CONCLUSION

In this research paper, numerical investigations of the effects of chemical reaction and Jeffery fluid on MHD unsteady heat and mass transfer due to ramped temperature has carried out. The governing coupled non-linear partial differential equations were numerically using finite element method (Galerkin's approach). From the investigations the following conclusions were made:

i. Velocity profile gets magnified with the increase of porosity parameter K, ratio of mass transfer parameter N, Eckert number Ec and Jeffery fluid parameter β, while reverse is the case for the increase of Magnetic parameter M, and Prandtl number Pr.

ii. Temperature profile enlarges with the increase porosity parameter K, ratio of mass transfer parameter N Eckert number Ec while reverse is the case for Magnetic parameter M, and Prandtl number Pr.

iii. Concentration profile gets lowered by increasing the value Schmidt parameter Sc and chemical reaction parameterK_r.

iv. Jeffery fluid parameter β has enhancing effect on skin friction at both $y = 0$ and$y = 1$. While reverse is the for chemical reaction parameterK_r

v. Rising the Jeffery fluid parameter β reduces the Nusselt number and reverse is the case for chemical reaction parameter β at $y = 0$. Nusselt number magnifies with increasing parameter β and reverse is the case for chemical reaction parameterK_r at $y = 1$

vi. Chemical reaction parameter does not have any significant effects on Sherwood number at y=0 and y=1. While Schmidt number reduces the Sherwood number at y=0 and intensifies itat y=1

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