Radiation and Soret Effects On Unsteady MHD Flow Past A Parabolic Started Vertical Plate in the Presence of Chemical Reaction With Magnetic Dissipation Through A Porous Medium.

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Abstract: ***The numerical solutions of a Radiation and Soret effects on unsteady MHD flow past a parabolic started vertical plate in the presence of chemical reaction with Ohmic heating through a porous medium are analyzed. The dimensionless governing equations are solved using finite difference method and the effects of various physical parameters like Radiation parameter (R), Permeability parameter(K), Thermal Grashoff number(Gr),Modified Grashoff number(Gc),Soret number (Sr) and the Eckert number (Ec) etc. are studied using numerical results. The local skin friction coefficient (τ), the Nusselt number (Nu), and rate of mass transfer (Sh) are also observed, using the numerical results which are presented as tables.***

Keywords: Radiation parameter, permeability parameter, Eckert number, Ohmic heating, finite difference, Soret number.

1. Introduction

The study of simultaneous heat and mass transfer in the presence of MHD plays an important role in petroleum industries, geophysics, meteorology, electrical power generation, solar power technology and nuclear engineering. It also finds applications in many engineering problems such as magneto hydrodynamic generator, plasma studies, in the study of geological formations, in exploration and thermal recovery oil. In recent years hydro magnetic flows and heat transfer have become more important because of numerous applications, for example, metallurgical processes in cooling of continuous strips through a quiescent fluid, thermonuclear fusion, aerodynamics. At high operating temperature, the radiation effect can be quite significant, see M.Sivaiah et al. [1]. Molla et al.[2], Akther and Alim[3] and Miraj et al.[4] investigated the radiation effect on free convection flow from an isothermal sphere with constant wall temperature, constant heat flux and in the presence of heat generation, respectively. Pop et al.[5] studied results for the problem of free convection boundary layer flow along a vertical surface in a porous medium with Newtonian heating.

Heat transfer effects on impulsively started an infinite vertical plate in the presence of magnetic field was presented by Soundalgekar et al.[6]. Agrawal et al.[7] obtained free convection due thermal and mass diffusion in laminar flow of an accelerated infinite vertical in the presence of magnetic field. Rajesh Kumar et al.[8] have offered exact solution of hydro magnetic flow on moving vertical surface with prescribed uniform heat flux. Chambre and Young [9] have investigated a first order chemical reaction in the neighborhood of a horizontal plate. Das et al.[10] analyzed mass transfer effects on moving isothermal vertical plate in the presence of chemical reaction using Laplace transform technique.

Muthucumaraswamy et al. [11] studied heat and mass transfer effects on the flow past an accelerated vertical plate with variable mass diffusion in the absence of thermal diffusion. Muralidharan et al.[12] investigated the thermal radiation on linearly accelerated vertical plate with variable temperature. Sundar Raj et al.[13] discussed an unsteady flow past an accelerated infinite vertical plate with uniform ass diffusion. The exact solutions, of a radiative flow past an accelerated vertical plate with variable temperature and uniform mass diffusion are discussed by Muralidharan and Muthucumaraswamy [14]. The obtained exact solutions using Laplace transform techniques and the effects of various physical parameters discussed using numerical results. Mohammed Ibrahim et al.[15] proposed the radiation and chemical reaction effects on MHD free convection flow past a moving vertical plate. Muthucumaraswamy et al.[16] analyzed hydromagnetic flow past a parabolic started vertical plate in the of homogeneous chemical reaction of first order.

Therefore, the main aim of the present paper is to analyze the Radiation and Soret effects on unsteady MHD flow past a parabolic started vertical plate in the presence of chemical reaction with Ohmic heating through a porous medium. The dimensionless governing equations are solved using finite difference method and the effects of various physical parameters are presented through graphs and tables.

2. Mathematical Formulae

The effects of Radiation and Soret on unsteady MHD free convection flow of an electrically conducting incompressible viscous fluid over parabolic started vertical plate in the presence of Ohmic heating through porous medium is considered under the following assumptions:

1. The x^* - axis is taken along the plate in the vertically upward direction and the y^*- axis is taken normal to the plate.
2. The viscous fluid is taken to be electrically conducting and fills the porous half space $y^* > 0$.
3. A uniform magnetic field of strength B_o is applied in the y^*-direction transversely to the plate. The applied magnetic field is assumed to be strong enough so that the induced magnetic field due to the fluid motion becomes weak and can be neglected.
4. Initially, both the fluid and the plate are at rest with constant temperature T_∞^* and constant concentration C_∞^*. At time $t^* > 0.$, the plate is started with a velocity $u^* = u_0\, t^{*2}$ in its own plane against gravitational field and the temperature from the plate is raised to T_w and concentration level near the plate are also raised to C_w^*.

In view of the above assumptions, as well as of the using a Boussineq's approximation, the governing equations reduce as

$$\frac{\partial u^*}{\partial t^*} = \nu \frac{\partial^2 u^*}{\partial y^{*2}} - \left(\frac{\sigma B_0^2}{\rho} + \frac{\nu}{K^*}\right) u^* + g\,\beta_T\left(T^* - T_\infty^*\right) + g\,\beta_C\left(C^* - C_\infty^*\right) \tag{1}$$

$$\rho\, C_P \frac{\partial T^*}{\partial t^*} = \kappa \frac{\partial^2 T^*}{\partial y^{*2}} - \frac{\sigma \beta_0^2}{\rho\, C_P}\left(u^*\right)^2 - \frac{\partial q_r}{\partial y^*} \tag{2}$$

$$\frac{\partial C^*}{\partial t^*} = D\frac{\partial^2 C^*}{\partial y^{*2}} - K_1\left(C^* - C_\infty^*\right) + \frac{D\,\kappa_T}{T_m}\frac{\partial^2 T^*}{\partial y^{*2}} \tag{3}$$

$$u^*\left(y^*, 0\right) = 0,\quad T^*\left(y^*, 0\right) = T_\infty^*,\quad C^*\left(y^*, 0\right) = C_\infty^* \qquad y^* < 0$$

$$\left.\begin{array}{l} u^*\left(0, t^*\right) = u_0, T^*\left(0, t^*\right) = T_\infty^* + \left(T_w^* - T_\infty^*\right)At^*, C^*\left(0, t^*\right) = C_\infty^* + \left(C_w^* - C_\infty^*\right)At^* \end{array}\right\} \quad t^* > 0$$

$$u^*\left(\infty, t^*\right) = 0,\quad T^*\left(\infty, t^*\right) = T_\infty^*,\quad C^*\left(\infty, t^*\right) = C_\infty^* \tag{4}$$

The equations (1) to (3) transformed to the following dimensionless form

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial y^2} - \left[M - \frac{1}{k} \right] u + Gr\ \theta + Gc\phi \tag{5}$$

$$\frac{\partial \theta}{\partial t} = \frac{1}{\Pr}\frac{\partial^2 \theta}{\partial y^2} - \frac{R}{\Pr}\theta - M\,E\,u^2 \tag{6}$$

$$\frac{\partial \phi}{\partial t} = \frac{1}{Sc}\frac{\partial^2 \phi}{\partial y^2} - Kr\theta + Sr\phi \tag{7}$$

The corresponding initial and boundary conditions in dimensionless form are as follows

$$t \le 0\ :\ u = 0,\quad \theta = 0,\quad C = 0 \quad for\ all\ y \tag{8}$$

$$t > 0 \quad \left\{ \begin{array}{ll} u = t^2,\quad \theta = t,\quad C = t & for\ y = 0 \\ u \to 0,\quad \theta \to 0,\quad C \to 0 & as\ y \to \infty \end{array} \right.$$

3. Finite Difference Technique

Using the finite difference technique, the governing equations for the problem are

$$\frac{u(i+1, j) - u(i, j)}{\Delta t} = \frac{u(i+1, j) - 2u(i, j) + u(i-1, j)}{\Delta y^2} - \left[M - \frac{1}{K} \right] u(i, j) + Gr\ \theta(i, j) + Gc\ \phi(i, j) \tag{9}$$

$$\frac{\theta(i+1, j) - \theta(i, j)}{\Delta t} = \frac{1}{\Pr}\frac{\theta(i+1, j) - 2\theta(i, j) + \theta(i-1, j)}{\Delta y^2} - \frac{R}{\Pr}\theta(i, j) - M\,E\left[\ u(i, j)\ \right]^2 \tag{10}$$

$$\frac{\phi(i+1, j) - \phi(i, j)}{\Delta t} = \frac{1}{Sc}\frac{\phi(i+1, j) - 2\phi(i, j) + \phi(i-1, j)}{\Delta y^2} - Kr\phi(i, j) + Sr(\phi(i+1, j) - 2\phi(i, j) + \phi(i-1, j)) \tag{11}$$

The initial and boundary conditions are represented as

$$u(i, 0) = 0,\quad \theta(i, 0) = 0,\quad \phi(i, 0) = 0 \qquad for\ all\ i$$

$$u(0,\ j) = t^2,\quad \theta(0,\ j) = t,\quad \phi(0,\ j) = t \qquad for\ all\ i$$
$$u(i,\ j) \to 0,\qquad \theta(i,\ j) \to 0,\quad \phi(i,\ j) \to 0 \qquad for\ all\ j \tag{12}$$

The suffixes, i corresponds to y and j corresponds to t and $\Delta t = t(j+1) - t(j)$ and $\Delta y = y(i+1) - y(i)$.

From the velocity, temperature, and concentration fields, the expressions for skin friction coefficient, the rate of heat transfer coefficient in terms of Nusselt number, and the rate of mass transfer in terms of Sherwood number are derived using

$$\tau = \left(\frac{\partial u}{\partial y}\right)_{y=0} \quad (13) \qquad Sh = -\left(\frac{\partial \phi}{\partial y}\right)_{y=0} \quad (15)$$

$$Nu = -\left(\frac{\partial \theta}{\partial y}\right)_{y=0} \quad (14)$$

4. Stability Analysis

The computations are carried out for different values of the various physical parameters. The procedure is repeated until the steady state. During computation Δt was chosen as 0.001. These computations are carried out for Pr= 0.71,1,7 and11 and Ec=-6,-2, 2, 6.To judge the accuracy of the convergence of the finite difference scheme, the same program was run with the Δt=0.0009, 0.00125 and no significant change was observed. Hence, we conclude the finite difference scheme is stable and convergent.

5. Results and Discussions

The system of dimensionless equations (9),(10) and (11) subject to the boundary conditions (12) were solved numerically using finite difference technique and analyzed the effects of various physical parameters like Permeability parameter(K), Radiation parameter(R),Eckert number(Ec),time(t) and Soret number(Sr) are presented through graphs and tables. The velocity profiles, for Radiation parameter(R), Permeability parameter(K), Eckert number(Ec), time(t) and Soret number(Sr) are obtained through the graphs 1 to5.

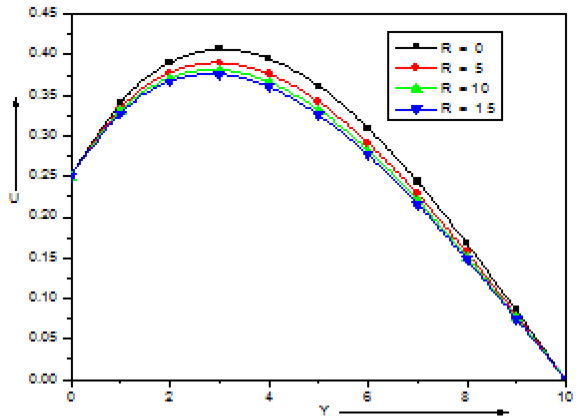

Fig. 1 Velocity profiles for R variation

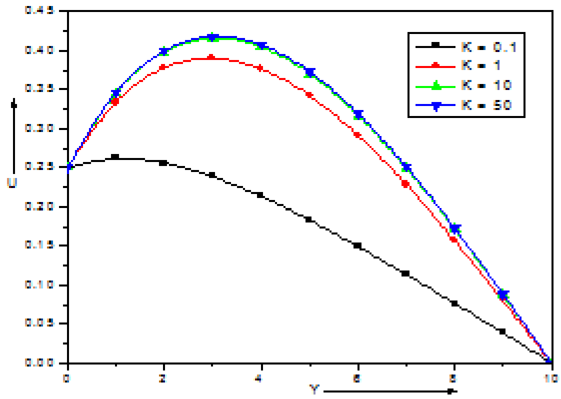

Fig. 2 Velocity profiles for K variation

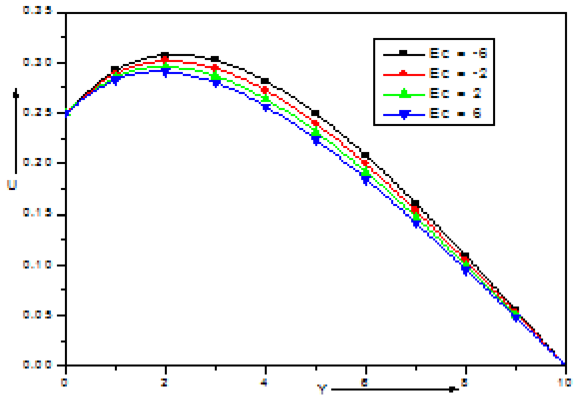

Fig. 3 Velocity profiles for Ec variation

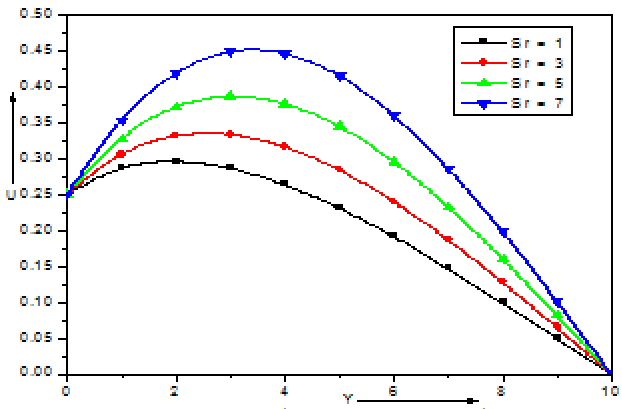

Fig. 4 Velocity profiles for Sr variation

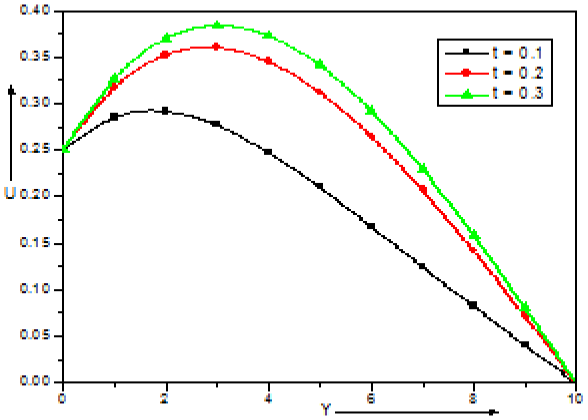

Fig. 5 velocity profiles for t variation

In the figure 1, the effect of the Rradiation parameter (*R*) is given. The presence of radiation is to increase the velocity. The increase of velocity distribution with the porosity (K) is given in the figure 2. This can be reduced with the holes of the porous medium is decreased. The velocity rises to maximum in the middle of the boundary layer but decreases sharply with the increase of the porosity and boundary layer. This effect is noted from the figure 2. The variation of velocity profiles for different values of Eckert number (Ec) are shown in figure 3, it is clearly observed that, as Eckert number increases, velocity decreases. The variation of velocity of the flow field with different values of Soret numbers is presented in the figure 5. The increase of velocity distribution is noticed from the figure5. From the figure 5, the increase of velocity is observed with the increase of time (t).

The considerable variation in the temperature of the flow with variation of parameters like Radiation parameter (R), Soret number (Sr), Eckert number (Ec) and time (t) are presented though figures (6) to (9).

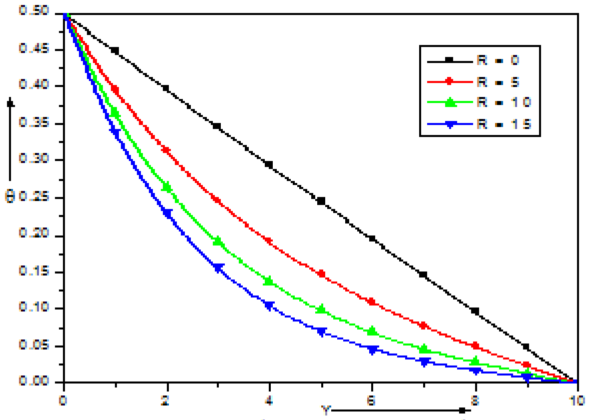

Fig. 6Temperature profiles for R variation

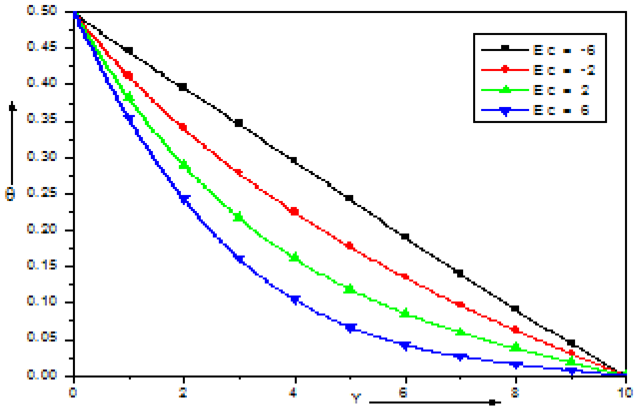

Fig. 7 Temperature profiles for Ec variation

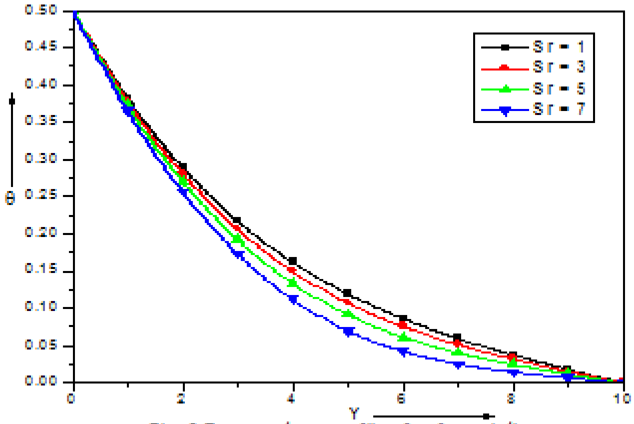

Fig. 8 Temperature profiles for Sr variation

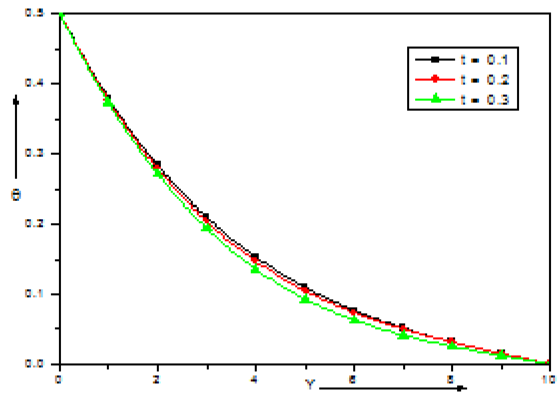

Fig. 9 Temperature profiles for t variation

The Radiation parameter increases the temperature in the boundary layer is decrease. This effect can be observed from the figure 6. Figure 7 shows that the temperature decreases with increase in Eckert number Ec. The decrease of the temperature distribution with the increase of Soret number can be seen from the figure 8. Figure 9 depicts that the temperature distribution decreases with increase in time. The important discrepancy in the concentration of the flow with variation of parameters like radiation parameter (R), Soret number (Sr), Eckert number(Ec) and time (t) are presented though figures (10) to (13).

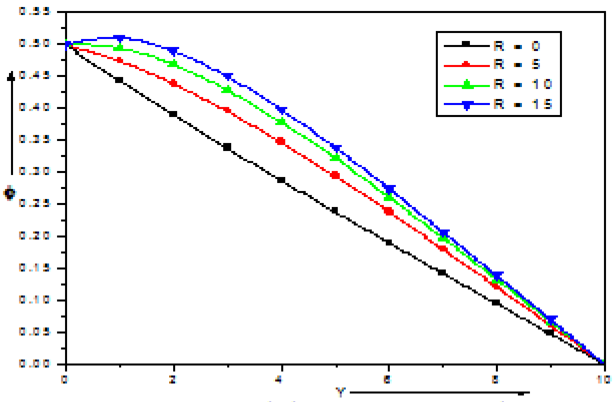

Fig. 10 Concentration profiles for R variation

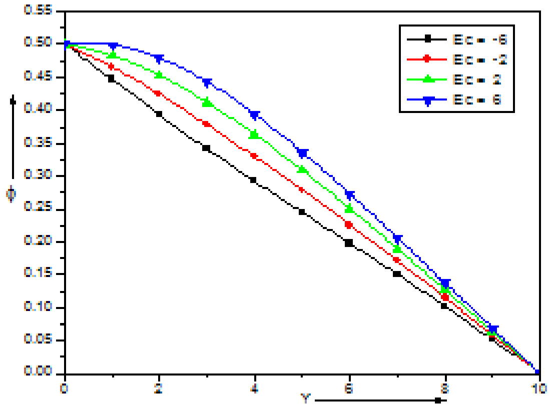

Fig. 11 Concentration profiles for Ec variation

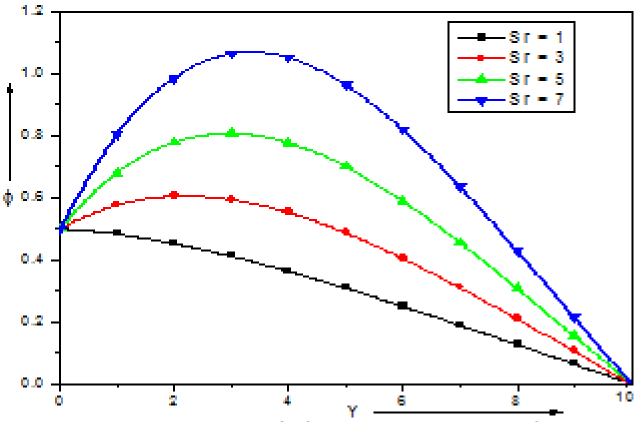

Fig. 12 Concentration profiles for Sr variation

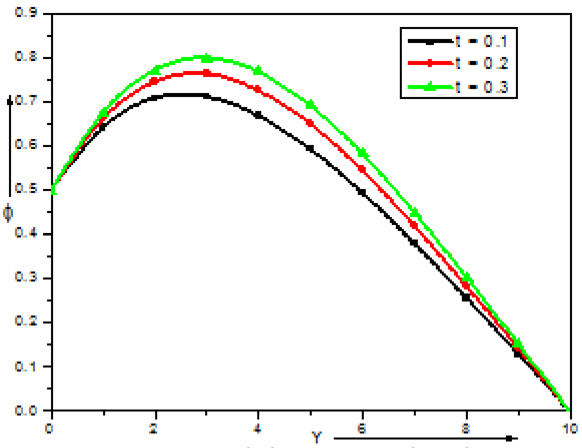

Fig. 13 Concentration profiles for t variation

The concentration profiles increases with an increase in radiation parameter, Eckert number, Soret number and time are presented in figures 10, 11, 12 and 13.The changes in Shear stress(τ), the rate of heat transfer in terms of the Nusselt number (Nu), and the rate of mass transfer in terms of the Sherwood number (Sh) are also derived in terms of the given system parameters. The results are shown in table.

Table 1

R	K	Ec	Sr	Skin	Nusselt	Sherwood
5	1	-6	1	1.042335	-1.148262	-.1957788
10	1	-6	1	1.004689	-1.584783	7.879004E-02
5	10	-6	1	1.165576	-1.148796	-.1955384
5	1	6	1	.4833942	-1.63574	.0884254
5	1	-6	5	.9304757	-1.411208	2.211152

From the table-I, the increase in radiation parameter causes the decrease in Shear stress, the rate of heat transfer and increase in the rate of mass transfer. With an increase permeability parameter the Shear stress, the rate of heat transfer increases and the rate of mass transfer decrease. The shear stress and the rate heat transfer decrease and the rate of mass transfer increase are observed with the increase in Eckert number. The increase in Soret number results in increase in shear stress, the rate of heat transfer and the rate mass transfer.

6. Conclusions

The numerical solution of Radiation and Soret effects on unsteady MHD flow past a parabolic started vertical plate in the presence of Ohmic heating through porous medium. The dimensionless governing equations are solved using finite difference method and the effects of various physical parameters are presented through graphs and tables and conclude that

1) The velocity profiles increase with an increase of K, Sr, t and decrease with an increase in R, Ec.
2) The increase of R, Ec, Sr,t results the decrease in temperature profiles.
3) The increase in R, Ec, Sr, t causes the decrease in concentration profiles.
4) The increase in radiation parameter results in the decrease in skin friction, Nusselt number and increase in Sherwood number.
5) With an increase of Permeability parameter and the skin friction, Nusselt number increases and Sherwood number decreases.
6) The skin friction and Nusselt number decrease and eventually Sherwood number increase with the increase in Eckert number.
7) The increase in Soret number results in the increase in skin friction, Sherwood number and Nusselt number.

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