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Unsteady MHD Heat and Mass Transfer Flow of a Radiating Fluid past an Accelerated Inclined Porous Plate in Presence of Hall Current with Chemical Reaction

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ABSTRACT
In this paper an investigation has been performed to analyse the combined influence ofradiation and Hall current for MHD free convective mass and heat transfer flow phenomenonfor a radiate fluid flow along a slanted permeable sheet with hall current having heat source and thermal diffusion in presence of chemical reaction. The solutions for velocity, temperature and concentration fieldare obtained by applying Laplace transform method. The articulations for skin friction, Nusselt number and Sherwood number are additionally determined. The characteristics and behaviour of fluid velocity, temperature and mass are presented graphicallyfor different pertinent physical parameters.

Keywords*:* Hall Current; Thermal Radiation; Heat and Mass Transfer; chemical reaction; Thermal Diffusion; Accelerated Inclined Porous Plate.

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I. INTRODUCTION

The studies related to boundary layer flow, heat and mass transfer over an inclined plate has generated much interest from astrophysical science, renewable energy systems and also hypersonic aerodynamics researchers at least for twodecades. There has been a renewed interest in analysing MHD flow and heat transfer in porous medium due to the influence of magnetic fields on the boundary layer flow control and on the performance of many systems using electrically conducting fluids. Moreover, this type of flow finds applications in many engineering and scientific problems such asplasma studies, MHD generators,MHD pumps, nuclear reactors, geothermal energy extractions and MHD bearing.

In many applications for the study of MHD with heat and mass transfer such as energy production, conversion, Refrigeration, membrane filtration, drying, ovens, air-conditioning, stoves, toaster Cooling of electronic equipment, materials processing, Manufacturing, welding, soldering, casting, laser machining Automobiles, aircraft design, weather, absorption, climate, evaporation, distillation etc. and the many engineering devices using conducting fluids of electrically, namely, generators in MHD, jet engines in plasma, accelerators in MHD, flow-meters in MHD, nuclear reactors, pumps in MHD, etc.

In industries, many transport processes exist in which heat and mass transfer takes place simultaneously as a result of combined buoyancy effect of thermal diffusion and diffusion through chemical species. The phenomenon of heat and mass transfer frequently exist in chemically processed industries such as food processing and polymer production. Free convection flow involving coupled heat and mass transfer occurs frequently in nature. For this flow, the driving forces arise due to the temperature and concentration variations in the fluid. For example, in atmospheric flows, thermal convection resulting from heating of the earth by sunlight is affected by differences in water vapour concentration. The study of effects of magnetic field on free convection flow is important in liquid-metals, electrolytes and ionized gases. The combined effects of convective heat and mass transfer on the flow of a viscous, incompressible and electrically conducting fluid has many engineering and geophysical applications such as in geothermal reservoirs, drying of porous solids, thermal insulation, and enhanced oil recovery, cooling of nuclear reactor and underground energy transports. Rapits and Singh [1] studied the effects of uniform transverse magnetic field on the free convection flow of an electrically conducting fluid past an infinite vertical plate for the classes of impulsive and uniformly accelerated motions of the plate. Duwairi and Al-Kablawi [2] formulated and analysed the MHD conjugative heat transfer problem from vertical surfaces embedded in saturated porous media. Seddeek [3] analysed the effect of variable viscosity and magnetic field on the flow and heat transfer past a continuously moving porous plate. Abdelkhalek [4] investigated the effects of mass transfer on steady two-dimensional laminar MHD mixed convection flow. Chowdhury and Islam [5] presented a theoretical analysis of a MHD free convection flow of a visco-elastic fluid adjacent to a vertical porous plate. Singh [6] studied heat and mass transfer in MHD boundary layer flow past an inclined plate with viscous dissipation in porous medium. Rajesh and Vijaya kumar verma [7] analysed radiation and mass transfer effects on MHD free convection flow past an exponentially accelerated vertical plate with variable temperature.

The influence of magnetic field on viscous incompressible flow of electrically conducting, radiative reactive fluid through porous medium associated with heat and mass transfer playing a key role in different areas of science and technology. The convective hence at and mass transfer flow in porous medium find several applications in many branches of science and technology like chemical industry, cooling of nuclear reactions. MHD power generators, geothermal energy extractions processes, petroleum engineering etc.Takhar and Ram [8] have studied MHD free convection flow of water through a porous medium. MHD free convection near a moving vertical plate in the presence of thermal radiation is studied by Das and Das [9]. The effects of variable thermal conductivity and heat source/sink on MHD flow near a stagnation point on a linearly stretching sheet are studied by Sharma and Singh [10]. Chen [11] considered the problem of combined heat and mass transfer of electrically conducting fluid in MHD natural convection adjacent to a vertical surface with ohmic heating. The influence of a uniform transverse magnetic field on the motion of an electrically conducting fluid past a stretching sheet was investigated by Pavlov [12], Chakravarty and Gupta [13], Andersson [14], Andersson et al. [15]. Alam et al. [16] studied the combined effect of viscous dissipation and Joule heating on steady MHD free convective heat and mass transfer flow of a viscous incompressible fluid past a semi-infinite inclined radiate isothermal permeable moving surface in the presence of thermophoresis.

In most cases, the Hall term was ignored in applying Ohm's law as it has no marked effect for small and moderate values of the magnetic field. However, the current trend for the application of MHD is towards a strong magnetic field, so that the influence of electromagnetic force is noticeable [17]. Under these conditions, the Hall current is important and it has a marked effect on the magnitude and direction of the current density and consequently on the magnetic force term. Attia [18] has studied the influence of the Hall current on the velocity and temperature fields of an unsteady flow of a conducting Newtonian fluid between two infinite non-conducting horizontal parallel stationary and porous plates. Unsteady MHD free convection flow past an exponentially accelerated vertical plate with mass transfer, chemical reaction and thermal radiation was examined by Raju et al. [19]. MHD three dimensional Couette flow past a porous plate with heat transfer was considered by Ravikumar et al. [20]. Radiation and mass transfer effects on a free convection flow through a porous medium bounded by a vertical surface were considered by Raju et al. [21].Unsteady MHD radiative and chemically reactive free convection flow near a moving vertical plate in porous medium was investigated by Reddy et al. [22]. Seth et al. [23] studied heat and mass transfer effects on unsteady MHD natural convection flow of a chemically reactive and radiating fluid through a porous medium past a moving vertical plate with arbitrary ramped temperature. MHD free convection heat and mass transfer flowover a vertical porous plate in a rotating system with hall current, heat source and suction was discussed by Iva et al.[24]. Sarma et al. [25] investigated effects of hall current; rotation and Soret effects on MHD free convection heat and mass transfer flow past an accelerated vertical plate through a porous medium. Kataria et al. [26] were discussed heat and mass transfer in magnetohydrodynamic (MHD) Casson fluid flow past over an oscillating vertical plate embedded in porous medium with ramped wall temperature. Vijayaragavan et al. [27] studied the Influence of thermal diffusion effects on unsteady MHD free convection flow past an exponentially accelerated inclined plate with ramped wall temperature. Obulesu et al.[28] was examined the Hall Current Effects on MHD Convective Flow Past A Porous Plate with Thermal Radiation, Chemical Reaction and Heat Generation /Absorption.Ali et al. [29] discussed the conjugate effects of heat and mass transfer on MHD free convection flow over an inclined plate embedded in a porous medium.G. S. Seth et al. [30] studied the Soret and Hall effects on unsteady MHD free convection flow of radiating and chemically reactive fluid past a moving vertical plate with ramped temperature in rotating system.Hari Krishna et al. [31] studied the Effects of

Radiation and Chemical Reaction on MHD Flow Past an Oscillating Inclined Porous Plate with Variable Temperature and Mass Diffusion. Saidulu et al. [32]Role of Magnetic Field on Natural Convective Towards a Semi- Infinite Vertically Inclined Plate in Presence of Hall Current with Numerical Solutions: A Finite Difference Technique.Bhandari et al. [33] studiednumerical solution through mathematical modelling of unsteady MHD flow past a semi-infinite vertical moving plate with chemical reaction and radiation.

Reddy et al. [34] was discussedunsteady MHD Free Convection Flow of a Viscoelastic Fluid Past a Vertical Porous Plate, International Journal of Dynamics of Fluids.Usman et al. [35] studied Heat and Mass Transfer along Vertical Channel in Porous Medium with Radiation Effect and Slip Condition.Raju et al. [36]discussedConvective Ramped Wall Temperature and Concentration Boundary Layer Flow of a Chemically Reactive Heat Absorbing and Radiating Fluid over a Vertical Plate in Conducting Field with Hall Current. Sheri et al.[37] discussed the hall current and chemical reaction effects on free convective flow past an accelerated moving vertical plate with ramped temperature: fem.Srinivasaet al. [38]studied chemically reacting fluid flow induced by an exponentially accelerated infinite vertical plate in a magnetic field and variable temperature via LTT and FEM. Jain [39] analysed Combined Influence of Hall Current and Soret Effect on Chemically Reacting Magnetomicropolar Fluid Flow from Radiative Rotating Vertical Surface with Variable Suction in Slip-Flow Regime. The effects of hall current, radiation and rotation on natural convection heat and mass transfer flow past a moving vertical plate was investigated by Seth et al.[40].MultivariateJeffrey fluid flow past a vertical plate through porous medium was analysed by Dastagiri et al. [41]. Motivated by the above studies in this article an attempt is made to examine the conjugate influence of heat and mass transfer process of time dependent Newtonian fluid in the presence of chemical reaction and Hall current.

The aim of the present investigation is to analyse the effects of chemical reaction,Hall current and radiation of MHD unsteady free convection heat and mass transfer flow of a viscous, electrically conducting incompressible fluid near an infinite accelerated inclined plate embedded in porous medium which moves with time dependent velocity under the influence of uniform magnetic field, applied normal to the plate. A general exact solution of the governing partial differential equation is obtained by using Laplace transform technique.

II. FORMULATION OF THE PROBLEM

Consider unsteady free convection heat and mass transfer flow of a viscous incompressible and electrically conducting fluid along an infinite non-conducting accelerated inclined plate with an acute angle α through a porous medium. The x^* direction is taken along the leading edge of the inclined plate and y^* is normal to it and extends parallel to x^*axis. A magnetic field of strength B_0 is introduced to the normal to the direction to the flow.

Initially for time $t^* \leq 0$, the plate and the fluid are maintained at the same constant temperature T_∞^* in a stationary condition with the same species concentration C_∞^* at all points.Subsequently $(t^* > 0)$, the plate is assumed to be accelerating with a velocity $U_0 f(t^*)$ in its own plane along the x^* -axis, instantaneously the temperature of the plate and the concentration are raised to T_w^* and C_w^* respectively, which are hereafter regarded as constant. The flow of the fluid is assumed to be in the direction of the x^*-axis, so the physical quantities are functions of the space co-ordinate y^* and time t^* only. Taking into consideration the assumption made above, in accordance with the usual Boussinesq's approximation, the governing equations for unsteady free convective boundary layer flow of viscous incompressible and electrical conducting fluid along infinite accelerated inclined plate through a porous medium with hall current, radiation, chemical reaction and thermal diffusion in two dimensional flow can be expressed as:

Momentum equation:

$$\frac{\partial u^*}{\partial y^*} = \nu \frac{\partial^2 u^*}{\partial y^{*2}} + g\beta_T (T^* - T_\infty^*)\cos\alpha + g\beta_C (C^* - C_\infty^*)\cos\alpha - \frac{\sigma B_0^2}{\rho(1+m^2)} u^* - \frac{\nu u^*}{k^*} \qquad (1)$$

Energy Equation:

$$\frac{\partial T^*}{\partial t^*} = \frac{k^*}{\rho C_p}\frac{\partial^2 T^*}{\partial y^{*2}} - \frac{1}{\rho C_p}\frac{\partial q_r}{\partial y^*} - Q^*(T^* - T_\infty^*) \qquad (2)$$

Concentration equation:

$$\frac{\partial C^*}{\partial t^*} = D_M \frac{\partial^2 C^*}{\partial y^{*2}} - D_T \frac{\partial^2 T^*}{\partial y^{*2}} - Kr^*(C^* - C_\infty^*) \qquad (3)$$

Where u^* velocity, T^* is the temperature, C^* is the species concentration and g is the acceleration due to gravity.
The initial and boundary conditions corresponding to the present problem are

$$\left.\begin{array}{l} u^*(y^*,t^*) = 0, T^*(y^*,t^*) = T_w^*, C^*(y^*,t^*) = C_\infty^*, \ \ for \ \ y^* \ge 0 \ \ and \ \ t^* \le 0 \\ u^*(0,t^*) = U_0 e^{a_0^* t^*}, T^*(0,t^*) = T_w^*, C^*(0,t^*) = C_w^* \ \ for \ \ t^* \le 0 \\ u^* \to 0, T^* \to T_\infty^*, C^* \to C_w^*, \ \ as \ \ y^* \to \infty \ \ and \ \ for \ \ t^* \ge 0 \end{array}\right\} \qquad (4)$$

The radiative heat flux q_r^* is given by

$$\frac{\partial q_r^*}{\partial y^*} = 4(T^* - T_\infty^*) I^* \qquad (5)$$

Where, $I^* = \int_0^\infty K_{\lambda w} \frac{\partial e_{b\lambda}}{\partial T^*} d\lambda$ is absorption coefficient and $e_{b\lambda}$ is Plank function.
To reduce the above equations into non-dimensional form for convenience, let us introduce the following dimensionless variables and parameters:

$$\left.\begin{array}{l} u_0 = \dfrac{u^*}{U_0}, y = \dfrac{U_0 y^*}{\nu}, t = \dfrac{U_0{}^2 t^*}{\nu}, \theta = \dfrac{T^* - T_\infty^*}{T_W^* - T_\infty^*}, C = \dfrac{C^* - C_\infty^*}{C_W^* - C_\infty^*}, \\ \Pr = \dfrac{\nu \rho C_p}{k^*}, Sc = \dfrac{\nu}{D_M}, M = \dfrac{\sigma B_0^2 \nu}{\rho U_0{}^2}, Gr = \dfrac{\nu g \beta_T (T_W^* - T_\infty^*)}{U_0{}^3}, \\ Gm = \dfrac{\nu g \beta_c (C_W^* - C_\infty^*)}{U_0{}^3}, S_0 = \dfrac{(T_W^* - T_\infty^*) D_T}{\nu (C_W^* - C_\infty^*)}, k = \dfrac{U_0{}^2 k^*}{\nu^2}, \\ \gamma = \dfrac{\nu k_1^*}{U_0{}^2}, Q = \dfrac{Q^* \nu}{U_0{}^2}, F = \dfrac{4 I^* \nu}{\rho C_p U_0{}^2}, a_0 = \dfrac{a_0^* \nu}{U_0{}^2}, w = \dfrac{w^* \nu}{U_0{}^2}, \\ M_1 = \dfrac{M}{1+m^2}, N = \dfrac{1}{k} + M_1, Kr = \dfrac{Kr^* \nu^2}{D_m U_0{}^2} \end{array}\right\} \qquad (6)$$

where Gr is the thermal Grashof number, Gm is the is the mass Grashof number, k is the permeability parameter, M is the magnetic parameter, m is the hall current parameter, Pr is Prandtl number, Sc is Schmidt number, β_T is thermal expansion coefficient, β_C is concentration expansion coefficient a_0^* is dimensional accelerating parameter and other physical variables have their usual meanings.

With the help of (6), the governing equations (1) to (3) reduce to

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial y^2} + Gr(\cos\alpha)\theta + Gm(\cos\alpha)C - Nu \qquad (7)$$

$$\frac{\partial^2\theta}{\partial y^2}-\Pr\left\{\frac{\partial\theta}{\partial t}+(F+Q)\theta\right\}=0 \qquad (8)$$

$$\frac{\partial^2 C}{\partial y^2}-Sc\frac{\partial C}{\partial t}-ScS_0\frac{\partial^2\theta}{\partial y^2}=KrC \qquad (9)$$

The corresponding initial and boundary conditions in non-dimensional form are:

$$\left.\begin{aligned}&u(y,t)=0,\theta(y,t)=0,C(y,t)=0 \ \ for \ \ y\geq 0 \ \ and \ \ t\leq 0\\&u(0,t)=e^{a_o t},\theta(0,t)=1,C(0,t)=1 \ \ for \ \ t\leq 0\\&u\to 0,\theta\to 0,C\to 0, \ \ as \ \ y\to\infty \ \ and \ \ for \ \ t>0\end{aligned}\right\} \qquad (10)$$

III. SOLUTION OF THE PROBLEM

In order to obtain the analytical solutions of the system of differential equations (7) to (9), we shall use the Laplace transform technique. Applying the Laplace transform (with respect to time t) to equations (7) to (9) and boundary conditions (10), we get

$$\bar{\theta}=exp(-y\sqrt{\Pr}\sqrt{s+S_1}) \qquad (11)$$

$$\begin{aligned}\bar{C}=&\frac{1}{s}exp(-y\sqrt{Scs+Kr})-\frac{m_6}{s+m_7}exp(-y\sqrt{Scs+Kr})-\frac{m_9}{s}exp(-y\sqrt{Scs+Kr})\\&-\frac{m_9}{s+m_7}exp(-y\sqrt{Scs+Kr})+\frac{m_6}{s+m_7}exp(-y\sqrt{\Pr}\sqrt{s+S_1})+\frac{m_9}{s}exp(-y\sqrt{\Pr}\sqrt{s+S_1})\\&-\frac{m_9}{s+m_7}exp(-y\sqrt{\Pr}\sqrt{s+S_1}) \qquad (12)\end{aligned}$$

$$\begin{aligned}\bar{u}=&\frac{1}{s-a_0}exp(-y\sqrt{s+N})-\frac{m_{23}}{s}exp(-y\sqrt{s+N})+\frac{m_{23}}{s+m_{22}}exp(-y\sqrt{s+N})\\&-\frac{m_{25}}{s}exp(-y\sqrt{s+N})+\frac{m_{25}}{s+m_{15}}exp(-y\sqrt{s+N})-\frac{m_{26}}{s+m_{15}}exp(-y\sqrt{s+N})\\&+\frac{m_{26}}{s+m_7}exp(-y\sqrt{s+N})-\frac{m_{27}}{s}exp(-y\sqrt{s+N})\end{aligned}$$

$$+\frac{m_{27}}{s+m_{15}}exp(-y\sqrt{s+N})+\frac{m_{28}}{s+m_{15}}exp(-y\sqrt{s+N})$$
$$-\frac{m_{28}}{s+m_{7}}exp(-y\sqrt{s+N})-\frac{m_{29}}{s+m_{7}}exp(-y\sqrt{s+N})$$
$$+\frac{m_{29}}{s+m_{20}}exp(-y\sqrt{s+N})-\frac{m_{30}}{s}exp(-y\sqrt{s+N})$$
$$+\frac{m_{30}}{s+m_{20}}exp(-y\sqrt{S+N})+\frac{m_{31}}{s+m_{7}}exp(-y\sqrt{s+N})$$
$$-\frac{m_{31}}{s+m_{20}}exp(-y\sqrt{s+N})+\frac{m_{23}}{s}exp(-y\sqrt{\Pr}\sqrt{s+S_1})-\frac{m_{23}}{s+m_{22}}exp(-y\sqrt{\Pr}\sqrt{s+S_1})$$
$$+\frac{m_{25}}{s}exp(-y\sqrt{Scs+Kr})-\frac{m_{25}}{s+m_{15}}exp(-y\sqrt{Scs+Kr})$$
$$+\frac{m_{26}}{s+m_{15}}exp(-y\sqrt{Scs+Kr})-\frac{m_{26}}{s+m_{7}}exp(-y\sqrt{Scs+Kr})$$
$$+\frac{m_{27}}{s}exp(-y\sqrt{Scs+Kr})-\frac{m_{27}}{s+m_{15}}exp(-y\sqrt{Scs+Kr})$$
$$-\frac{m_{28}}{s+m_{15}}exp(-y\sqrt{Scs+Kr})-\frac{m_{28}}{s+m_{7}}exp(-y\sqrt{Scs+Kr})$$
$$\frac{m_{29}}{s+m_{7}}\frac{1}{s}exp(-y\sqrt{\Pr}\sqrt{s+S_1})-\frac{m_{29}}{s+m_{20}}\frac{1}{s}exp(-y\sqrt{\Pr}\sqrt{s+S_1})$$
$$+\frac{m_{30}}{s}exp(-y\sqrt{\Pr}\sqrt{s+S_1})-\frac{m_{30}}{s+m_{20}}exp(-y\sqrt{\Pr}\sqrt{s+S_1})$$
$$-\frac{m_{31}}{s+m_{7}}\frac{1}{s}exp(-y\sqrt{\Pr}\sqrt{s+S_1})+\frac{m_{31}}{s+m_{20}}\frac{1}{s}exp(-y\sqrt{\Pr}\sqrt{s+S_1})............(13)$$

Then, inverting equations (11) to (13) in the usual way by using the inverse Laplace transform technique we get the general solution of the problem for the temperature $\theta(y,t)$, the species concentration $C(y,t)$ and velocity $u(y,t)$ for $t>0$ in the non-dimensional form as

$$\theta=\frac{1}{2}\left[e^{-y\sqrt{\Pr s_1}}erfc\left(\frac{y\sqrt{\Pr}}{2\sqrt{t}}-\sqrt{s_1t}\right)+e^{y\sqrt{\Pr s_1}}erfc\left(\frac{y\sqrt{\Pr}}{2\sqrt{t}}+\sqrt{s_1t}\right)\right]\text{..............................}(14)$$

$$C=\frac{1}{2}\left[e^{-y\sqrt{Kr}}erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}}-\sqrt{z_1t}\right)+e^{y\sqrt{Kr}}erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}}+\sqrt{z_1t}\right)\right]$$
$$-\frac{m_6e^{-m_7t}}{2}\left[e^{-y\sqrt{ScZ_2}}erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}}-\sqrt{Z_2t}\right)+e^{y\sqrt{ScZ_2}}erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}}+\sqrt{Z_2t}\right)\right]$$
$$-\frac{m_9}{2}\left[e^{-y\sqrt{Kr}}erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}}-\sqrt{z_1t}\right)+e^{y\sqrt{Kr}}erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}}+\sqrt{z_1t}\right)\right]$$
$$+\frac{m_9e^{-m_7t}}{2}\left[e^{-y\sqrt{ScZ_2}}erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}}-\sqrt{Z_2t}\right)+e^{y\sqrt{ScZ_2}}erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}}+\sqrt{Z_2t}\right)\right]$$
$$+\frac{m_6e^{-m_7t}}{2}\left[e^{-y\sqrt{\Pr(S_1-m_7)}}erfc\left(\frac{y\sqrt{\Pr}}{2\sqrt{t}}-\sqrt{(S_1-m_7)t}\right)+e^{y\sqrt{\Pr(S_1-m_7)}}erfc\left(\frac{y\sqrt{\Pr}}{2\sqrt{t}}+\sqrt{(S_1-m_7)t}\right)\right]$$
$$+\frac{m_9}{2}\left[e^{-y\sqrt{\Pr S_1}}erfc\left(\frac{y\sqrt{\Pr}}{2\sqrt{t}}-\sqrt{S_1t}\right)+e^{y\sqrt{\Pr S_1}}erfc\left(\frac{y\sqrt{\Pr}}{2\sqrt{t}}+\sqrt{S_1t}\right)\right]$$
$$-\frac{m_9e^{-m_7t}}{2}\left[e^{-y\sqrt{\Pr(S_1-m_7)}}erfc\left(\frac{y\sqrt{\Pr}}{2\sqrt{t}}-\sqrt{(S_1-m_7)t}\right)+e^{y\sqrt{\Pr(S_1-m_7)}}erfc\left(\frac{y\sqrt{\Pr}}{2\sqrt{t}}+\sqrt{(S_1-m_7)t}\right)\right]\text{........}(15)$$

And velocity distribution as a function of two variable is of the form

$$u(y,t)=\frac{e^{a_ot}}{2}\left[e^{-y\sqrt{a_o+N}}erfc\left(\frac{y}{2\sqrt{t}}-\sqrt{(a_o+N)t}\right)+e^{y\sqrt{a_o+N}}erfc\left(\frac{y}{2\sqrt{t}}+\sqrt{(a_o+N)t}\right)\right]$$
$$+\frac{m_{23}}{2}\left[e^{-y\sqrt{N}}erfc\left(\frac{y}{2\sqrt{t}}-\sqrt{Nt}\right)+e^{y\sqrt{N}}erfc\left(\frac{y}{2\sqrt{t}}+\sqrt{Nt}\right)\right]$$
$$+\frac{m_{23}e^{-m_{22}t}}{2}\left[e^{-y\sqrt{N-m_{22}}}erfc\left(\frac{y}{2\sqrt{t}}-\sqrt{(N-m_{22})t}\right)+e^{y\sqrt{N-m_{22}}}erfc\left(\frac{y}{2\sqrt{t}}+\sqrt{(N-m_{22})t}\right)\right]$$
$$+\frac{m_{25}}{2}\left[e^{-y\sqrt{N}}erfc\left(\frac{y}{2\sqrt{t}}-\sqrt{Nt}\right)+e^{y\sqrt{N}}erfc\left(\frac{y}{2\sqrt{t}}+\sqrt{Nt}\right)\right]$$
$$+\frac{m_{25}e^{-m_{15}t}}{2}\left[e^{-y\sqrt{N-m_{15}}}erfc\left(\frac{y}{2\sqrt{t}}-\sqrt{(N-m_{15})t}\right)+e^{y\sqrt{N-m_{15}}}erfc\left(\frac{y}{2\sqrt{t}}+\sqrt{(N-m_{15})t}\right)\right]$$

$$+\frac{m_{26}e^{-m_{15}t}}{2}\left[e^{-y\sqrt{N-m_{15}}}erfc\left(\frac{y}{2\sqrt{t}}-\sqrt{(N-m_{15})t}\right)+e^{y\sqrt{N-m_{15}}}erfc\left(\frac{y}{2\sqrt{t}}+\sqrt{(N-m_{15})t}\right)\right]$$
$$+\frac{m_{26}e^{-m_{7}t}}{2}\left[e^{-y\sqrt{N-m_{7}}}erfc\left(\frac{y}{2\sqrt{t}}-\sqrt{(N-m_{7})t}\right)+e^{y\sqrt{N-m_{7}}}erfc\left(\frac{y}{2\sqrt{t}}+\sqrt{(N-m_{7})t}\right)\right]$$
$$+\frac{m_{27}}{2}\left[e^{-y\sqrt{N}}erfc\left(\frac{y}{2\sqrt{t}}-\sqrt{Nt}\right)+e^{y\sqrt{N}}erfc\left(\frac{y}{2\sqrt{t}}+\sqrt{Nt}\right)\right]$$
$$+\frac{m_{27}e^{-m_{15}t}}{2}\left[e^{-y\sqrt{N-m_{15}}}erfc\left(\frac{y}{2\sqrt{t}}-\sqrt{(N-m_{15})t}\right)+e^{y\sqrt{N-m_{15}}}erfc\left(\frac{y}{2\sqrt{t}}+\sqrt{(N-m_{15})t}\right)\right]$$
$$+\frac{m_{28}e^{-m_{15}t}}{2}\left[e^{-y\sqrt{N-m_{15}}}erfc\left(\frac{y}{2\sqrt{t}}-\sqrt{(N-m_{15})t}\right)+e^{y\sqrt{N-m_{15}}}erfc\left(\frac{y}{2\sqrt{t}}+\sqrt{(N-m_{15})t}\right)\right]$$
$$+\frac{m_{28}e^{-m_{7}t}}{2}\left[e^{-y\sqrt{N-m_{7}}}erfc\left(\frac{y}{2\sqrt{t}}-\sqrt{(N-m_{7})t}\right)+e^{y\sqrt{N-m_{7}}}erfc\left(\frac{y}{2\sqrt{t}}+\sqrt{(N-m_{7})t}\right)\right]$$
$$+\frac{m_{29}e^{-m_{7}t}}{2}\left[e^{-y\sqrt{N-m_{7}}}erfc\left(\frac{y}{2\sqrt{t}}-\sqrt{(N-m_{7})t}\right)+e^{y\sqrt{N-m_{7}}}erfc\left(\frac{y}{2\sqrt{t}}+\sqrt{(N-m_{7})t}\right)\right]$$
$$+\frac{m_{29}e^{-m_{20}t}}{2}\left[e^{-y\sqrt{N-m_{20}}}erfc\left(\frac{y}{2\sqrt{t}}-\sqrt{(N-m_{20})t}\right)+e^{y\sqrt{N-m_{20}}}erfc\left(\frac{y}{2\sqrt{t}}+\sqrt{(N-m_{20})t}\right)\right]$$
$$+\frac{m_{30}}{2}\left[e^{-y\sqrt{N}}erfc\left(\frac{y}{2\sqrt{t}}-\sqrt{Nt}\right)+e^{y\sqrt{N}}erfc\left(\frac{y}{2\sqrt{t}}+\sqrt{Nt}\right)\right]$$
$$+\frac{m_{30}e^{-m_{20}t}}{2}\left[e^{-y\sqrt{N-m_{20}}}erfc\left(\frac{y}{2\sqrt{t}}-\sqrt{(N-m_{20})t}\right)+e^{y\sqrt{N-m_{20}}}erfc\left(\frac{y}{2\sqrt{t}}+\sqrt{(N-m_{20})t}\right)\right]$$
$$+\frac{m_{31}e^{-m_{7}t}}{2}\left[e^{-y\sqrt{N-m_{7}}}erfc\left(\frac{y}{2\sqrt{t}}-\sqrt{(N-m_{7})t}\right)+e^{y\sqrt{N-m_{7}}}erfc\left(\frac{y}{2\sqrt{t}}+\sqrt{(N-m_{7})t}\right)\right]$$
$$+\frac{m_{31}e^{-m_{20}t}}{2}\left[e^{-y\sqrt{N-m_{20}}}erfc\left(\frac{y}{2\sqrt{t}}-\sqrt{(N-m_{20})t}\right)+e^{y\sqrt{N-m_{20}}}erfc\left(\frac{y}{2\sqrt{t}}+\sqrt{(N-m_{20})t}\right)\right]$$
$$+\frac{m_{23}}{2}\left[e^{-y\sqrt{\Pr}\sqrt{s_1}}erfc\left(\frac{y\sqrt{\Pr}}{2\sqrt{t}}-\sqrt{s_1t}\right)+e^{y\sqrt{\Pr}\sqrt{s_1}}erfc\left(\frac{y\sqrt{\Pr}}{2\sqrt{t}}+\sqrt{s_1t}\right)\right]$$
$$+\frac{m_{23}e^{-m_{22}t}}{2}\left[e^{-y\sqrt{\Pr}\sqrt{N-m_{22}}}erfc\left(\frac{y}{2\sqrt{t}}-\sqrt{(N-m_{22})t}\right)+e^{y\sqrt{\Pr}\sqrt{N-m_{22}}}erfc\left(\frac{y}{2\sqrt{t}}+\sqrt{(N-m_{22})t}\right)\right]$$
$$+\frac{m_{25}}{2}\left[e^{-y\sqrt{Kr}}erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}}-\sqrt{Z_1t}\right)+e^{y\sqrt{Kr}}erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}}+\sqrt{Z_1t}\right)\right]$$

$$
\begin{aligned}
&-\frac{m_{25}e^{-m_{15}t}}{2}\left[e^{-y\sqrt{ScZ_3}}erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}}-\sqrt{Z_3t}\right)+e^{y\sqrt{ScZ_3}}erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}}+\sqrt{Z_3t}\right)\right]\\
&+\frac{m_{26}e^{-m_{15}t}}{2}\left[e^{-y\sqrt{ScZ_3}}erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}}-\sqrt{Z_3t}\right)+e^{y\sqrt{ScZ_3}}erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}}+\sqrt{Z_3t}\right)\right]\\
&-\frac{m_{26}e^{-m_7t}}{2}\left[e^{-y\sqrt{ScZ_2}}erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}}-\sqrt{Z_2t}\right)+e^{y\sqrt{ScZ_2}}erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}}+\sqrt{Z_2t}\right)\right]\\
&+\frac{m_{27}}{2}\left[e^{-y\sqrt{Kr}}erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}}-\sqrt{Z_1t}\right)+e^{y\sqrt{Kr}}erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}}+\sqrt{Z_1t}\right)\right]\\
&-\frac{m_{27}e^{-m_{15}t}}{2}\left[e^{-y\sqrt{ScZ_3}}erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}}-\sqrt{Z_3t}\right)+e^{y\sqrt{ScZ_3}}erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}}+\sqrt{Z_3t}\right)\right]\\
&-\frac{m_{28}e^{-m_{15}t}}{2}\left[e^{-y\sqrt{ScZ_3}}erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}}-\sqrt{Z_3t}\right)+e^{y\sqrt{ScZ_3}}erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}}+\sqrt{Z_3t}\right)\right]\\
&+\frac{m_{28}e^{-m_7t}}{2}\left[e^{-y\sqrt{ScZ_2}}erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}}-\sqrt{Z_2t}\right)+e^{y\sqrt{ScZ_2}}erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{t}}+\sqrt{Z_2t}\right)\right]\\
&+\frac{m_{29}e^{-m_7t}}{2}\left[e^{-y\sqrt{\Pr}\sqrt{N-m_7}}erfc\left(\frac{y\sqrt{\Pr}}{2\sqrt{t}}-\sqrt{(N-m_7)t}\right)+e^{y\sqrt{\Pr}\sqrt{N-m_7}}erfc\left(\frac{y\sqrt{\Pr}}{2\sqrt{t}}+\sqrt{(N-m_7)t}\right)\right]\\
&+\frac{m_{29}e^{-m_{20}t}}{2}\left[e^{-y\sqrt{\Pr}\sqrt{N-m_{20}}}erfc\left(\frac{y\sqrt{\Pr}}{2\sqrt{t}}-\sqrt{(N-m_{20})t}\right)+e^{y\sqrt{\Pr}\sqrt{N-m_{20}}}erfc\left(\frac{y\sqrt{\Pr}}{2\sqrt{t}}+\sqrt{(N-m_{20})t}\right)\right]\\
&+\frac{m_{30}}{2}\left[e^{-y\sqrt{\Pr S_1}}erfc\left(\frac{y\sqrt{\Pr}}{2\sqrt{t}}-\sqrt{S_1t}\right)+e^{y\sqrt{\Pr S_1}}erfc\left(\frac{y\sqrt{\Pr}}{2\sqrt{t}}+\sqrt{S_1t}\right)\right]\\
&+\frac{m_{30}e^{-m_{20}t}}{2}\left[e^{-y\sqrt{\Pr}\sqrt{N-m_{20}}}erfc\left(\frac{y\sqrt{\Pr}}{2\sqrt{t}}-\sqrt{(N-m_{20})t}\right)+e^{y\sqrt{\Pr}\sqrt{N-m_{20}}}erfc\left(\frac{y\sqrt{\Pr}}{2\sqrt{t}}+\sqrt{(N-m_{20})t}\right)\right]\\
&+\frac{m_{31}e^{-m_7t}}{2}\left[e^{-y\sqrt{\Pr}\sqrt{N-m_7}}erfc\left(\frac{y\sqrt{\Pr}}{2\sqrt{t}}-\sqrt{(N-m_7)t}\right)+e^{y\sqrt{\Pr}\sqrt{N-m_7}}erfc\left(\frac{y\sqrt{\Pr}}{2\sqrt{t}}+\sqrt{(N-m_7)t}\right)\right]\\
&+\frac{m_{31}e^{-m_{20}t}}{2}\left[e^{-y\sqrt{\Pr}\sqrt{N-m_{20}}}erfc\left(\frac{y\sqrt{\Pr}}{2\sqrt{t}}-\sqrt{(N-m_{20})t}\right)+e^{y\sqrt{\Pr}\sqrt{N-m_{20}}}erfc\left(\frac{y\sqrt{\Pr}}{2\sqrt{t}}+\sqrt{(N-m_{20})t}\right)\right] ....(16)
\end{aligned}
$$

Skin-friction

The quantities of physical interest are the skin-friction due to velocity is given by

$$\tau = \left(\frac{\partial u}{\partial y}\right)_{y=0}$$

$$= \frac{e^{a_0 t}}{2}\left[\frac{2}{\sqrt{\pi t}}\exp(-(a_0+N)t) + \sqrt{a_0+N}\left[erfc\sqrt{(a_0+N)}t - erfc\left(-\sqrt{(a_0+N)}t\right)\right]\right] +$$

$$+\frac{m_{23}}{2}\left[\frac{2}{\sqrt{\pi t}}\exp(-Nt) + \sqrt{N}\left(erfc(\sqrt{N}t) - erfc\left(-\sqrt{N}t\right)\right)\right]$$

$$+\frac{m_{23}e^{-m_{22}t}}{2}\left[\frac{2}{\sqrt{\pi t}}e^{-(N-m_{22})t} + \sqrt{N-m_{22}}\left(erfc(\sqrt{(N-m_{22})}t) - erfc\left(-\sqrt{(N-m_{22})}t\right)\right)\right]$$

$$+\frac{m_{25}}{2}\left[\frac{2}{\sqrt{\pi t}}\exp(-Nt) + \sqrt{N}\left(erfc(\sqrt{N}t) - erfc\left(-\sqrt{N}t\right)\right)\right]$$

$$+\frac{m_{25}e^{-m_{15}t}}{2}\left[\frac{2}{\sqrt{\pi t}}e^{-(N-m_{15})t} + \sqrt{N-m_{15}}\left(erfc(\sqrt{(N-m_{15})}t) - erfc\left(-\sqrt{(N-m_{15})}t\right)\right)\right]$$

$$+\frac{m_{26}e^{-m_{15}t}}{2}\left[\frac{2}{\sqrt{\pi t}}e^{-(N-m_{15})t} + \sqrt{N-m_{15}}\left(erfc(\sqrt{(N-m_{15})}t) - erfc\left(-\sqrt{(N-m_{15})}t\right)\right)\right]$$

$$+\frac{m_{26}e^{-m_{7}t}}{2}\left[\frac{2}{\sqrt{\pi t}}e^{-(N-m_{7})t} + \sqrt{N-m_{7}}\left(erfc(\sqrt{(N-m_{7})}t) - erfc\left(-\sqrt{(N-m_{7})}t\right)\right)\right]$$

$$+\frac{m_{27}}{2}\left[\frac{2}{\sqrt{\pi t}}\exp(-Nt) + \sqrt{N}\left(erfc(\sqrt{N}t) - erfc\left(-\sqrt{N}t\right)\right)\right]$$

$$+\frac{m_{27}e^{-m_{15}t}}{2}\left[\frac{2}{\sqrt{\pi t}}e^{-(N-m_{15})t} + \sqrt{N-m_{15}}\left(erfc(\sqrt{(N-m_{15})}t) - erfc\left(-\sqrt{(N-m_{15})}t\right)\right)\right]$$

$$+\frac{m_{28}e^{-m_{15}t}}{2}\left[\frac{2}{\sqrt{\pi t}}e^{-(N-m_{15})t} + \sqrt{N-m_{15}}\left(erfc(\sqrt{(N-m_{15})}t) - erfc\left(-\sqrt{(N-m_{15})}t\right)\right)\right]$$

$$+\frac{m_{28}e^{-m_{7}t}}{2}\left[\frac{2}{\sqrt{\pi t}}e^{-(N-m_{7})t} + \sqrt{N-m_{7}}\left(erfc(\sqrt{(N-m_{7})}t) - erfc\left(-\sqrt{(N-m_{7})}t\right)\right)\right]$$

$$+\frac{m_{29}e^{-m_{7}t}}{2}\left[\frac{2}{\sqrt{\pi t}}e^{-(N-m_{7})t} + \sqrt{N-m_{7}}\left(erfc(\sqrt{(N-m_{7})}t) - erfc\left(-\sqrt{(N-m_{7})}t\right)\right)\right]$$

$$+\frac{m_{29}e^{-m_{20}t}}{2}\left[\frac{2}{\sqrt{\pi t}}e^{-(N-m_{20})t} + \sqrt{N-m_{20}}\left(erfc(\sqrt{(N-m_{20})}t) - erfc\left(-\sqrt{(N-m_{20})}t\right)\right)\right]$$

$$+\frac{m_{30}}{2}\left[\frac{2}{\sqrt{\pi t}}\exp(-Nt) + \sqrt{N}\left(erfc(\sqrt{N}t) - erfc\left(-\sqrt{N}t\right)\right)\right]$$

$$+\frac{m_{30}e^{-m_{20}t}}{2}\left[\frac{2}{\sqrt{\pi t}}e^{-(N-m_{20})t}+\sqrt{N-m_{20}}\left(erfc(\sqrt{(N-m_{20})t})-erfc\left(-\sqrt{(N-m_{20})t}\right)\right)\right]$$
$$+\frac{m_{31}e^{-m_7t}}{2}\left[\frac{-2}{\sqrt{\pi t}}e^{-(N-m_7)t}+\sqrt{(N-m_7)}\left(erfc(\sqrt{(N-m_7)t})-erfc\left(-\sqrt{(N+m_7)t}\right)\right)\right]$$
$$+\frac{m_{31}e^{-m_{20}t}}{2}\left[\frac{-2}{\sqrt{\pi t}}e^{-(N-m_{20})t}+\sqrt{(N+m_{20})}\left(erfc(\sqrt{(N-m_{20})t})-erfc\left(-\sqrt{(N-m_{20})t}\right)\right)\right]$$
$$+\frac{m_{23}}{2}\left[\frac{2\sqrt{\Pr}}{\sqrt{\pi t}}\exp(-S_1t)+\sqrt{\Pr S_1}\left(erfc(\sqrt{S_1t})-erfc\left(-\sqrt{S_1t}\right)\right)\right]$$
$$+\frac{m_{23}e^{-m_{22}t}}{2}\left[\frac{2\sqrt{\Pr}}{\sqrt{\pi t}}e^{-(N-m_{22})t}+\sqrt{\Pr(N-m_{22})}\left(erfc(\sqrt{(N-m_{22})t})-erfc\left(-\sqrt{(N-m_{22})t}\right)\right)\right]$$
$$+\frac{m_{25}}{2}\left[\frac{2\sqrt{Sc}}{\sqrt{\pi t}}\exp(-z_1t)+\sqrt{Kr}\left(erfc(\sqrt{z_1t})-erfc\left(-\sqrt{z_1t}\right)\right)\right]$$
$$-\frac{m_{25}e^{-m_{15}t}}{2}\left[\frac{2\sqrt{Sc}}{\sqrt{\pi t}}\exp(-Z_3t)+\sqrt{ScZ_3}\left(erfc(\sqrt{Z_3t})-erfc\left(-\sqrt{Z_3t}\right)\right)\right]$$
$$+\frac{m_{26}e^{-m_{15}t}}{2}\left[\frac{2\sqrt{Sc}}{\sqrt{\pi t}}\exp(-Z_3t)+\sqrt{ScZ_3}\left(erfc(\sqrt{Z_3t})-erfc\left(-\sqrt{Z_3t}\right)\right)\right]$$
$$-\frac{m_{26}e^{-m_7t}}{2}\left[\frac{2\sqrt{Sc}}{\sqrt{\pi t}}\exp(-Z_2t)+\sqrt{ScZ_2}\left(erfc(\sqrt{Z_2t})-erfc\left(-\sqrt{Z_2t}\right)\right)\right]$$
$$+\frac{m_{27}}{2}\left[\frac{2\sqrt{Sc}}{\sqrt{\pi t}}\exp(-z_1t)+\sqrt{Kr}\left(erfc(\sqrt{z_1t})-erfc\left(-\sqrt{z_1t}\right)\right)\right]$$
$$-\frac{m_{27}e^{-m_{15}t}}{2}\left[\frac{2\sqrt{Sc}}{\sqrt{\pi t}}\exp(-Z_3t)+\sqrt{ScZ_3}\left(erfc(\sqrt{Z_3t})-erfc\left(-\sqrt{Z_3t}\right)\right)\right]$$
$$-\frac{m_{28}e^{-m_{15}t}}{2}\left[\frac{2\sqrt{Sc}}{\sqrt{\pi t}}\exp(-Z_3t)+\sqrt{ScZ_3}\left(erfc(\sqrt{Z_3t})-erfc\left(-\sqrt{Z_3t}\right)\right)\right]$$
$$+\frac{m_{28}e^{-m_7t}}{2}\left[\frac{2\sqrt{Sc}}{\sqrt{\pi t}}\exp(-Z_2t)+\sqrt{ScZ_2}\left(erfc(\sqrt{Z_2t})-erfc\left(-\sqrt{Z_2t}\right)\right)\right]$$
$$+\frac{m_{29}e^{-m_7t}}{2}\left[\frac{2\sqrt{\Pr}}{\sqrt{\pi t}}e^{-(N-m_7)t}+\sqrt{\Pr(N-m_7)}\left(erfc(\sqrt{(N-m_7)t})-erfc\left(-\sqrt{(N-m_7)t}\right)\right)\right]$$

$$+\frac{m_{29}e^{-m_{20}t}}{2}\left[\frac{2\sqrt{\Pr}}{\sqrt{\pi t}}e^{-(N-m_{20})t}+\sqrt{\Pr(N-m_{20})}\left(erfc(\sqrt{(N-m_{20})t})-erfc\left(-\sqrt{(N-m_{20})t}\right)\right)\right]$$

$$+\frac{m_{30}}{2}\left[\frac{2\sqrt{\Pr s_1}}{\sqrt{\pi t}}\exp(-z_1t)+\sqrt{Prs_1}\left(erfc(\sqrt{s_1t})-erfc\left(-\sqrt{s_1t}\right)\right)\right]$$

$$+\frac{m_{30}e^{-m_{20}t}}{2}\left[\frac{2\sqrt{\Pr}}{\sqrt{\pi t}}e^{-(N-m_{20})t}+\sqrt{\Pr(N-m_{20})}\left(erfc(\sqrt{(N-m_{20})t})-erfc\left(-\sqrt{(N-m_{20})t}\right)\right)\right]$$

$$+\frac{m_{31}e^{-m_7t}}{2}\left[\frac{2\sqrt{\Pr}}{\sqrt{\pi t}}e^{-(N-m_7)t}+\sqrt{\Pr(N-m_7)}\left(erfc(\sqrt{(N-m_7)t})-erfc\left(-\sqrt{(N-m_7)t}\right)\right)\right]$$

$$+\frac{m_{30}e^{-m_{20}t}}{2}\left[\frac{2\sqrt{\Pr}}{\sqrt{\pi t}}e^{-(N-m_{20})t}+\sqrt{\Pr(N-m_{20})}\left(erfc(\sqrt{(N-m_{20})t})-erfc\left(-\sqrt{(N-m_{20})t}\right)\right)\right].........(17)$$

Nusselt number

An important phenomenon in this study is to understand the effects of t, Pr on the Nusselt number. In non-dimensional form, the rate of heat transfer is given by

$$Nu=-\left(\frac{\partial\theta}{\partial y}\right)_{y=0}=\frac{-1}{2}\left[\frac{2\sqrt{\Pr}}{\sqrt{\pi t}}e^{-s_1t}+\sqrt{\Pr s_1}\left(erfc\left(\sqrt{s_1t}\right)-erfc\left(-\sqrt{s_1t}\right)\right)\right]............(18)$$

Sherwood Number

Another important physical quantities of interest is the Sherwood number which in non-dimensional form is

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

$$=-\frac{1}{2}\left[\frac{2\sqrt{Sc}}{\sqrt{\pi t}}e^{-z_1t}+\sqrt{Kr}\left(erfc\left(\sqrt{z_1t}\right)-erfc\left(-\sqrt{z_1t}\right)\right)\right]$$

$$-\frac{m_6e^{-m_7t}}{2}\left[\frac{2\sqrt{Sc}}{\sqrt{\pi t}}e^{-z_2t}+\sqrt{z_2Sc}\left(erfc\left(\sqrt{z_2t}\right)-erfc\left(-\sqrt{z_2t}\right)\right)\right]$$

$$+\frac{m_9}{2}\left[\frac{2\sqrt{Sc}}{\sqrt{\pi t}}e^{-z_1t}+\sqrt{Kr}\left(erfc\left(\sqrt{z_1t}\right)-erfc\left(-\sqrt{z_1t}\right)\right)\right]$$

$$-\frac{m_9e^{-m_7t}}{2}\left[\frac{2\sqrt{Sc}}{\sqrt{\pi t}}e^{-z_2t}+\sqrt{z_2Sc}\left(erfc\left(\sqrt{z_2t}\right)-erfc\left(-\sqrt{z_2t}\right)\right)\right]$$

$$-\frac{m_6 e^{-m_7 t}}{2}\left[\frac{2\sqrt{\Pr}}{\sqrt{\pi t}}e^{-(s_1-m_7)t}+\sqrt{\Pr(s_1-m_7)}\left(erfc\left(\sqrt{(s_1-m_7)t}\right)-erfc\left(-\sqrt{(s_1-m_7)t}\right)\right)\right]$$
$$-\frac{m_9}{2}\left[\frac{2\sqrt{\Pr}}{\sqrt{\pi t}}e^{-s_1 t}+\sqrt{\Pr s_1}\left(erfc\left(\sqrt{s_1 t}\right)-erfc\left(-\sqrt{s_1 t}\right)\right)\right]$$
$$+\frac{m_9 e^{-m_7 t}}{2}\left[\frac{2\sqrt{\Pr}}{\sqrt{\pi t}}e^{-(s_1-m_7)t}+\sqrt{\Pr(s_1-m_7)}\left(erfc\left(\sqrt{(s_1-m_7)t}\right)-erfc\left(-\sqrt{(s_1-m_7)t}\right)\right)\right].....(19)$$

IV. RESULTS AND DISCUSSION

The system of transformed differential equations (7) - (9) subject to the boundary conditions (10) is solved using Laplace transform technique. To understand the physical phenomenon and flow behaviour of the problem, we have computed the expression for velocity (u) ,temperature profile (θ) , Concentration (C), Skin friction (τ) , rate of heat transfer in the form of Nusselt Number and rate of mass transfer in the form of Sherwood number for different values of Prandtl number Pr, magnetic field parameter M ,Hall current parameter (m) ,Grashof number (Gr) , modified Grashof number (Gm) ,Schmidt number (Sc) ,permeability parameter (k) ,Soret number (S_0) ,radiation parameter (F) ,Heat source parameter (Q) and inclination angle (α) .The consequences of relevant parameters on the flow field are broken down and discuss with the help of graphs of velocity profiles, temperature profiles, concentration profiles, Skin-friction coefficient, Nusselt number and Sherwood number.

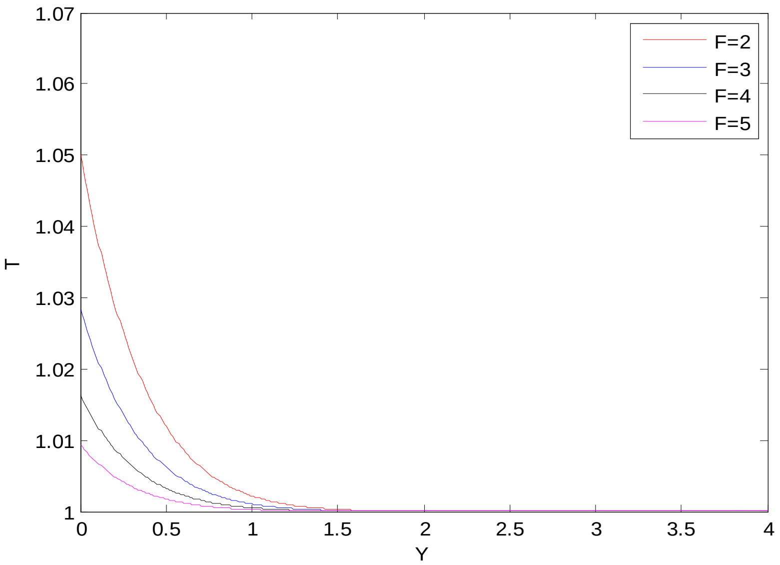

Fig: 1 Effect of temperature distribution over radiation parameter

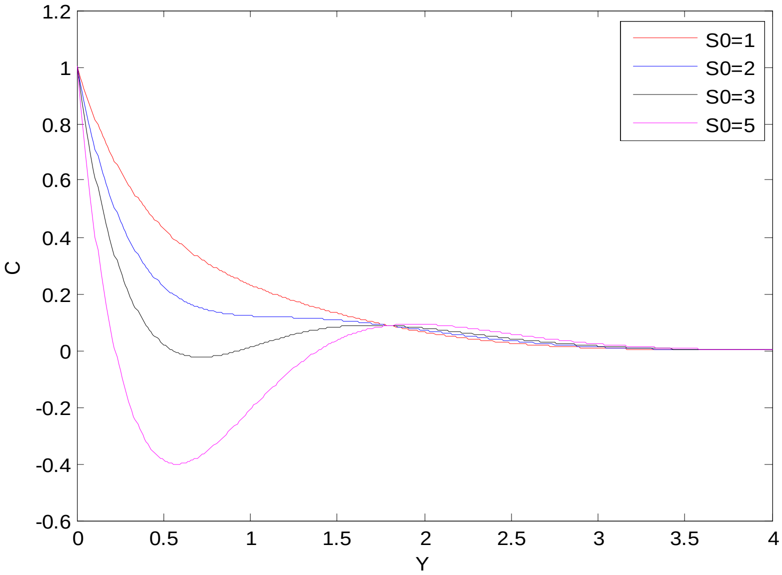

Fig: 2 Effect of concentration distribution over Soret number

Fig: 1 depicts temperature distribution over radiation parameter. Fig: 2 depict concentration distribution over Soret number. From Fig: 2, it is observed that for aiding flow, concentration of the fluid increases with increase in Soret number. Soret number is the ratio of temperature difference to the concentration. Hence, the bigger Soret number stands for a larger concentration difference and precipitous gradient.

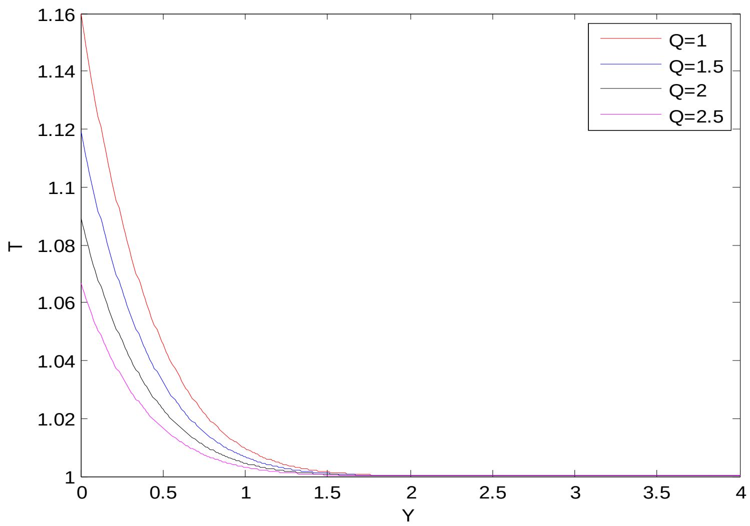

Fig: 3 Effectsof temperature distribution over Heat source parameter

Fig: 3 depict temperature distribution over Heat source parameter. This figure illustrates the influence of heat source parameter (Q) on temperature profiles. It is observed that the temperature of the fluid decreases with increase in the values of the heat source. The increases of Heat source parameter increase the thermal radiation parameter. The results show that the temperature profile increases with increase in the thermal radiation parameter and hence there would be an increase of thermal boundary layer thickness.

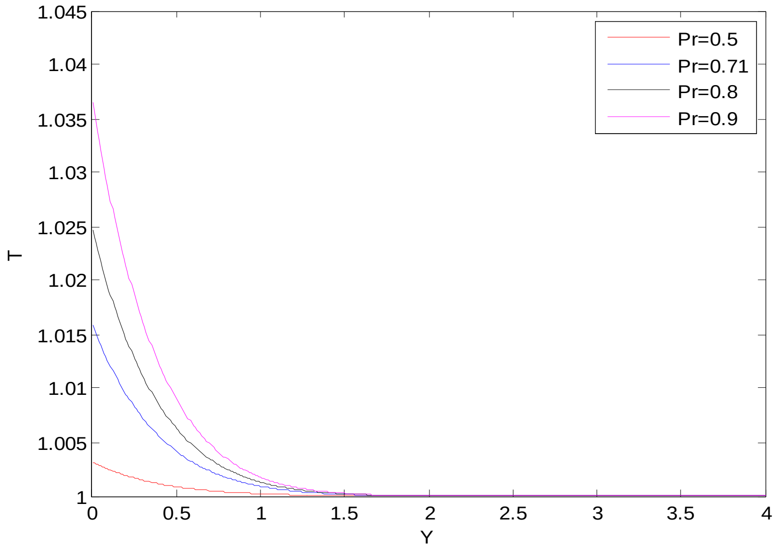

Fig-4 Effect of Temperature distribution over Prandtl number

It is found that the temperature decreases as the Prandtl number (Pr) increases. Physically, the increase of Pr means the decrease of thermal conductivity of fluid. From Figure 4, it is observed that an increase Prandtl number increases the thermal boundary layer thickness and as a result the surface temperature of the plate increases.

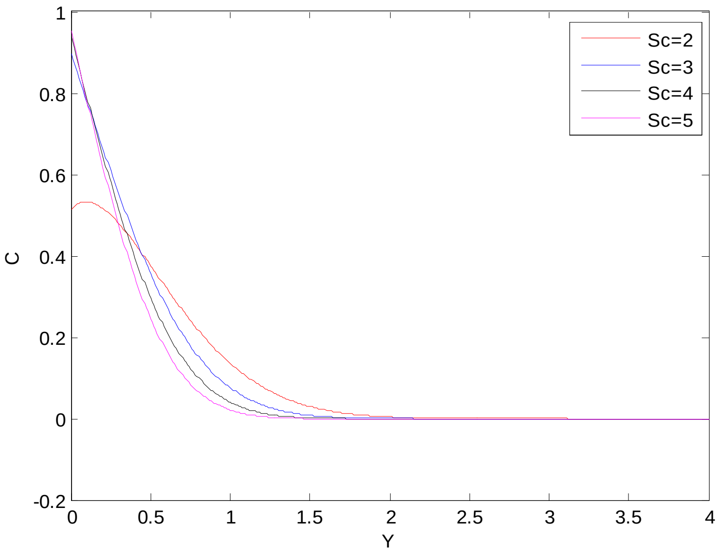

Fig: 5 Effect of Concentration distribution over Schmidt number

V. CONCLUSIONS

A general analytical solution for the problem of Hall current , radiation effects in addition of chemical reaction on MHD free convective heat and mass transfer flow past an accelerated inclined porous plate with thermal diffusion have been determined using Laplace transform technique. The expressions for Velocity, temperature, concentration, Skin friction, the rate of heat transfer in the form of Nusselt number and the rate of mass transfer in the form of Sherwood number have been derived and discussed in details through graphs. From the study the following conclusions can be drawn:

- The temperature decreases with increase in values of Pr and F .
- The temperature decreases with increase in values of Q .

- The Concentration increases with increase in S_0, while it decreases with increase in Sc .

VI. NOMENCLATURE

t^* : Time
α : Anglemade by accelerated inclined angle through a porous media
x^* : Direction along the edge of inclined plate
y^* : Normal to edge
T_w^* : Walltemperature
C_w^* : Wall concentration
T_∞^* : Constant temperature ina stationary condition ata point
C_∞^* : Constantconcentration ina stationary condition ata point
q_r^* : Radiative heat flux
I^* : Absorption coefficient
$e_{b\lambda}$: plank function
Gr : Thermal Grashof number
Gm : Solutal Grashof number
K : Permeability parameter
M : Magnetic field parameter
m : Hall current parameter
Pr : Prandtl number
Sc : Schmidt number
β_T : Thermal expansion coefficient
β_C : Concentrationexpansioncoefficient
a_0^* : Dimensionalaccelerating parameter
τ : Skin friction coefficient
Nu : Nusselt number
Sh : Sherwood number
u : Velocity distribution
θ : Temperatureprofile
C : Concentration
S_0 : Soret number
F : Radiationparameter
Q : Heat sourceparameter
α : inclination angle
Kr : Chemical reaction parameter

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