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Heat Absorption And Soret Effects On An Unsteady Natural Convective Flow Past An Exponentially Accelerated Plate

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Abstract: Analyzation has been accomplished to examine the consequences of soret and heat absorption on a free unsteady convective flow with mass and heat transfer of a viscous, electrically conducting and incompressible fluid over a vertical plate which is exponentially accelerated. The plate is accelerated exponentially in its plane with a velocity $\bar{\bar{u}} = u_0\, e^{\bar{\bar{a}}\,\bar{\bar{t}}}$ at time $\bar{\bar{t}} > 0$ and at the same time the level of temperature near the plate raises to $\overline{\overline{T_w}}$, with constant mass flux. The boussinesq's dimensionless equations are figured out by the method of Laplace transforms in closed form. The results of these flow parameters on profiles of temperature, concentration, are presented in graphs and the effects of surface heat transfer rate $\left[\frac{\partial\theta}{\partial y}\right]_{y=0}$ and surface mass transfer rate $\left[\frac{\partial c}{\partial y}\right]_{y=0}$ are discussed through tables.

Index Terms - **Heat absorption, mass flux, convection, unsteady.**

I. Introduction

Mass and heat transfer field play a substantial part in various branches of engineering. The mechanism of heat transfer involved in air pre-heaters, economizers, heat exchangers, internal combustion engines and so on. And this analysis is made in electric motors, transformers, to avoid material damage due to hot spots and generators, etc., Mass transfer involved in desorption, distillation, absorption, sublimation, humidification etc.,

In the mein of a chemical reaction, the leads of mass transfer moving in reverse or parallel to a free stream on a flat continuous plate was analyzed by Bhattacharyya[1] . Mass and heat transfer effects in elastic viscous fluid past a vertical transfinite plate which is started impulsively with Hall Effect was discussed by Chaudhary and kumar [2]. Anil kumar et.al [3] presented consequences of soret, dufour, hall current and rotation on MHD natural convective heat and mass transfer flow past an accelerated vertical plate through a porous medium. Kavitha and Selviraj [4] were reported the consequences of Rotation and Dufour Impact on Unsteady Flow Past a Parabolic Accelerated Vertical Plate with Uniform Temperature and Mass Diffusion. Seth et.al [5] investigated, Natural convection flow past an exponentially accelerated vertical ramped temperature plate with Hall effects and heat absorption. Shankar goud and Dharmendar Reddy [6] have been studied the Chemical reaction and Soret effect on an unsteady MHD heat and mass transfer fluid flow along an infinite vertical plate with radiation and heat absorption. Chemical Radiation and Soret Effects on Unsteady MHD Convective Flow of Jeffrey Nanofluid Past an Inclined Semi-Infinite Vertical Permeable Moving Plate was presented by Venkateswararaju et.al [7].

The intention of this delivered analysis is the effects of soret and heat absorption on an unsteady free convectional flow over a vertical plate accelerated exponentially with heat and mass transfer of an incompressible, viscous and electrically conducting fluid are investigated. The variations of several arguments involved in this flow on profiles of temperature, concentrations and their gradients are discussed.

II Mathematical formulation

Heat absorption and soret effects on an unsteady natural convectional flow of an incompressible, electrically conducting and viscous fluid past a vertical transfinite plate started impulsively with constant temperature and uniform mass flux are analyzed. In the direction vertically upward, axis-$\bar{\bar{x}}$ is assumed along the plate and axis-$\bar{\bar{\mathcal{Y}}}$ is considered normal to the plate. Presuming initially in the stationary condition that, the fluid and the plate at all points are maintained the same temperature $\overline{\overline{\mathbb{T}_\infty}}$ with concentration$\overline{\overline{C_\infty}}$. The plate is accelerated exponentially in its plane with a velocity $u_0\, e^{\bar{\bar{a}}\,\bar{\bar{\mathfrak{t}}}}$ for time $\bar{\bar{\mathfrak{t}}} > 0$. At the same time, the temperature level raises to $\overline{\overline{\mathbb{T}_w}}$ near the plate and with constant mass flux. Therefore, all the physical invariants are in terms of $\bar{\bar{\mathcal{Y}}}$ and $\bar{\bar{\mathfrak{t}}}$ only i.e, those are free from $\bar{\bar{x}}$ because the chosen transfinite plate is in the $\bar{\bar{x}}$ direction. With the boussinesq's approximation, governing equations for this unsteady flow are

$$\rho c_p \frac{\partial \bar{\bar{\mathbb{T}}}}{\partial \bar{\bar{\mathfrak{t}}}} = \kappa \frac{\partial^2 \bar{\bar{\mathbb{T}}}}{\partial \bar{\bar{\mathcal{Y}}}^2} - Q_0\left(\bar{\bar{\mathbb{T}}} - \overline{\overline{\mathbb{T}_\infty}}\right) \tag{1}$$

$$\frac{\partial \bar{\bar{\mathbb{C}}}}{\partial \bar{\bar{\mathfrak{t}}}} = D \frac{\partial^2 \bar{\bar{\mathbb{C}}}}{\partial \bar{\bar{\mathcal{Y}}}^2} + \frac{D_m K_T}{T_m} \frac{\partial^2 \bar{\bar{\mathbb{T}}}}{\partial \bar{\bar{\mathcal{Y}}}^2} \tag{2}$$

With the conditions

$$\left.\begin{array}{lll} \bar{\bar{\mathfrak{t}}} \le 0: & \bar{\bar{\mathbb{T}}} = \overline{\overline{\mathbb{T}_\infty}},\ \bar{\bar{\mathbb{C}}} = \overline{\overline{\mathbb{C}_\infty}} & for\ all\ \bar{\bar{\mathcal{Y}}} \\ \bar{\bar{\mathfrak{t}}} > 0: & \bar{\bar{\mathbb{T}}} = \overline{\overline{\mathbb{T}_w}},\ \frac{\partial \bar{\bar{\mathbb{C}}}}{\partial \bar{\bar{y}}} = -\frac{m}{D} & for\ \bar{\bar{\mathcal{Y}}} = 0 \\ & \bar{\bar{\mathbb{T}}} \to \overline{\overline{\mathbb{T}_\infty}},\ \bar{\bar{\mathbb{C}}} \to \overline{\overline{\mathbb{C}_\infty}} & as\ \bar{\bar{\mathcal{Y}}} \to \infty \end{array}\right\} \tag{3}$$

And the introduced dimensionless measures are

$$\left.\begin{array}{l} t = \frac{\bar{\bar{t}} u_0^2}{\nu},\ \mathcal{Y} = \frac{\bar{\bar{\mathcal{Y}}} u_0}{\nu},\ \Pr = \frac{\mu c_p}{\kappa},\ Sc = \frac{\nu}{D},\ a = \frac{\bar{\bar{a}}\nu}{u_0^2}, \\ \theta = \frac{\bar{\bar{\mathbb{T}}} - \overline{\overline{\mathbb{T}_\infty}}}{\overline{\overline{\mathbb{T}\mathbb{T}_w}} - \overline{\overline{\mathbb{T}_\infty}}},\ \mathbb{C} = \frac{\bar{\bar{\mathbb{C}}} - \overline{\overline{\mathbb{C}_\infty}}}{\left(\frac{m\nu}{D u_0}\right)},\ \varphi = \frac{Q_0 \nu}{\rho c_p u_0^2},\ Sr = \frac{D_m K_T\left(\overline{\overline{\mathbb{T}_w}} - \overline{\overline{\mathbb{T}_\infty}}\right)}{\nu T_m \left(\frac{m\nu}{D u_0}\right)} \end{array}\right\} \tag{4}$$

By using equation (4), the equations (1) and (2) reduced into the following non-dimensional form:

$$\frac{\partial \theta}{\partial t} = \frac{1}{P_r} \frac{\partial^2 \theta}{\partial \mathcal{Y}^2} - \varphi\, \theta \tag{5}$$

$$\frac{\partial \mathbb{C}}{\partial t} = \frac{1}{S_c} \frac{\partial^2 \mathbb{C}}{\partial \mathcal{Y}^2} + Sr \frac{\partial^2 \theta}{\partial \mathcal{Y}^2} \tag{6}$$

And also by using (5), the considerations in (4) reduces to

$$\left.\begin{array}{lll} \mathfrak{t} \le 0: & \theta = 0,\ \mathbb{C} = 0 & \forall \mathcal{Y} \\ \mathfrak{t} > 0: & \theta = 1,\ \frac{\partial \mathbb{C}}{\partial \mathcal{Y}} = -1 & for\ \mathcal{Y} = 0 \\ & \theta \to 0,\ \mathbb{C} \to 0 & as\ \mathcal{Y} \to \infty \end{array}\right\} \tag{7}$$

III Solution of the problem

With the conditions (7) the dimensionless ruled equations (5) and (6) are resolved by the method of Laplace transforms, and hence the exact solutions of temperature, concentration and velocity are given by

$$\theta(\mathcal{Y}, \mathfrak{t}) = M_1 \tag{8}$$

$$\mathbb{C}(\mathcal{Y}, \mathfrak{t}) = \frac{1}{\sqrt{Sc}} M_3 + \frac{h\sqrt{Pr}}{Sc}\left(P_1 M_2 + M_7 + P_2 M_3 + P_3 M_4 + P_3 M_5\right) - \frac{h}{b}\left(\varphi M_1 - (\varphi - b) M_6\right) \tag{9}$$

Nusselt Number:

The nusselt number in dimensionless form, from the temperature gradient in terms of surface rate of heat transfer is

$$Nu = -\left[\frac{\partial\theta}{\partial y}\right]_{y=0} \tag{10}$$

From (8) and (10), we get

$$Nu = \sqrt{\varphi\, Pr}erf\left(\sqrt{\varphi \mathfrak{t}}\right) + \sqrt{\frac{Pr}{\pi \mathfrak{t}}}\, e^{\varphi \mathfrak{t}} \tag{11}$$

Sherwood Number:

The sherwood number in non-dimensional form, from the concentration gradient in terms of the surface rate of mass transfer is

$$Sh = -\left[\frac{\partial \mathbb{C}}{\partial y}\right]_{y=0} \tag{12}$$

From (9) and (12), we get

$$Sh = \frac{h\sqrt{Pr}}{Sc^{\frac{3}{2}}}\left[\frac{P_1}{\sqrt{\pi \mathfrak{t}}} + P_2 + be^{-b\mathfrak{t}}(-2P_3)\right] + \frac{h\sqrt{Pr}}{b}\left[\varphi^{3/2}erf\sqrt{\varphi \mathfrak{t}} - (\varphi - b)^{\frac{3}{2}}e^{-b\mathfrak{t}}erf\sqrt{(\varphi - b)\mathfrak{t}} + b\frac{e^{-\varphi \mathfrak{t}}}{\sqrt{\pi \mathfrak{t}}}\right]$$

(13)

Where

$$M_1 = \frac{1}{2}\left[erfc\left(\frac{y\sqrt{Pr}}{2\sqrt{\mathfrak{t}}} - \sqrt{\varphi \mathfrak{t}}\right)e^{-y\sqrt{Pr}\sqrt{\varphi}} + erfc\left(\frac{y\sqrt{Pr}}{2\sqrt{\mathfrak{t}}} + \sqrt{\varphi \mathfrak{t}}\right)e^{y\sqrt{Pr}\sqrt{\varphi}}\right]$$

$$M_2 = \frac{1}{\sqrt{\pi \mathfrak{t}}}\, e^{-\frac{y^2 Sc}{4\mathfrak{t}}},\ M_4 = \frac{1}{\sqrt{\pi \mathfrak{t}}}\, e^{-\frac{y^2 Sc}{4\mathfrak{t}}} - i\sqrt{b}\, e^{i\sqrt{bSc}\,y - b\mathfrak{t}}\, erfc\left(i\sqrt{b\mathfrak{t}} + \frac{y\sqrt{Sc}}{2\sqrt{\mathfrak{t}}}\right)$$

$$M_3 = 2\sqrt{\frac{\mathfrak{t}}{\pi}}\, e^{-\frac{y^2 Sc}{4\mathfrak{t}}} - y\sqrt{Sc}\, erfc\left(\frac{y\sqrt{Sc}}{2\sqrt{\mathfrak{t}}}\right),$$

$$M_5 = \frac{1}{\sqrt{\pi \mathfrak{t}}}\, e^{-\frac{y^2 Sc}{4\mathfrak{t}}} + i\sqrt{b}\, e^{-i\sqrt{bSc}\,y - b\mathfrak{t}}\, erfc\left(-i\sqrt{b\mathfrak{t}} + \frac{y\sqrt{Sc}}{2\sqrt{\mathfrak{t}}}\right)$$

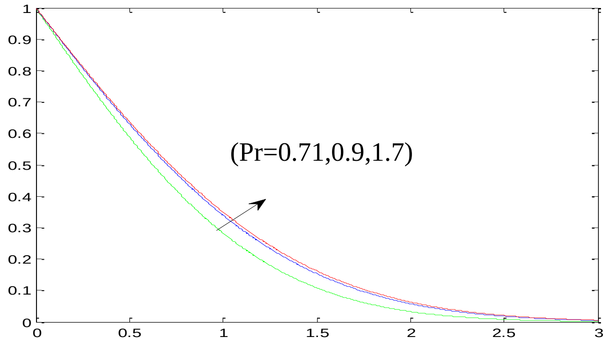
$$M_6 = \frac{e^{-b\mathfrak{t}}}{2}\left[erfc\left(\frac{y\sqrt{Pr}}{2\sqrt{\mathfrak{t}}} - \sqrt{(\varphi - b)\mathfrak{t}}\right)e^{-y\sqrt{Pr}\sqrt{\varphi - b}} + erfc\left(\frac{y\sqrt{Pr}}{2\sqrt{\mathfrak{t}}} + \sqrt{(\varphi - b)\mathfrak{t}}\right)e^{y\sqrt{Pr}\sqrt{\varphi - b}}\right]$$

$$M_7 = \frac{e^{-b\mathfrak{t}}}{2}\left[erfc\left(\frac{y}{2\sqrt{\mathfrak{t}}} - \sqrt{-b\mathfrak{t}}\right)e^{-y\sqrt{-b}} + erfc\left(\frac{y}{2\sqrt{\mathfrak{t}}} + \sqrt{-b\mathfrak{t}}\right)e^{y\sqrt{-b}}\right]$$

IV. RESULTS AND DISCUSSION

The variations of respective measures viz., Schmidt number (Sc), soret number (Sr), Prandtl number (Pr), parameters of heat absorption (∅) and time (t) of this present flow. Effects of these parameters are shown graphically in figures and tables. These resolutions show the effects of various arguments on profiles of concentration and temperature distributions and their gradients.

For respective values of various arguments, the temperature consequences for both hydrogen and water vapor are presented in figures 1 and 2.from these figures, it is noticed that, with the increase of heat absorption and prandtl number, the temperature decreases. And the consequences of different arguments for various values on concentration for both hydrogen and water vapor are shown in figures 3-6. from the figures 3,5, 6 it is identified that there is an increase in temperature with the increase of prandtl number, soret effect and heat absorption. The concentration profile for various evaluates of Sc is presented in figure 4. It is observed that concentration raises with the raise of Sc near the plate and moving away from the plate concentration falls with a point of separation.



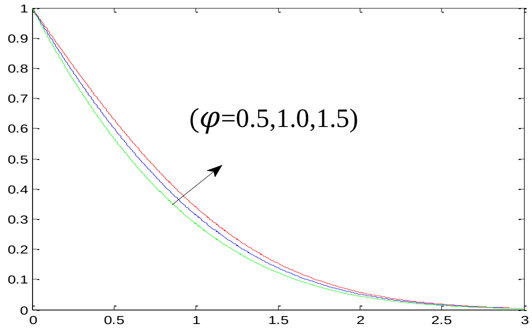
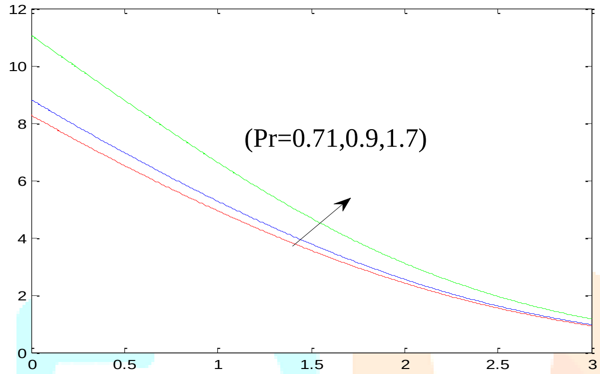


Fig.1., Results of Pr on temperature for different Fig.2., consequences of φ on temperature for

Values of Pr, φ=0.5, $\mathfrak{t}$=0.4 different values of φ, Pr=0.71, $\mathfrak{t}$=0.4



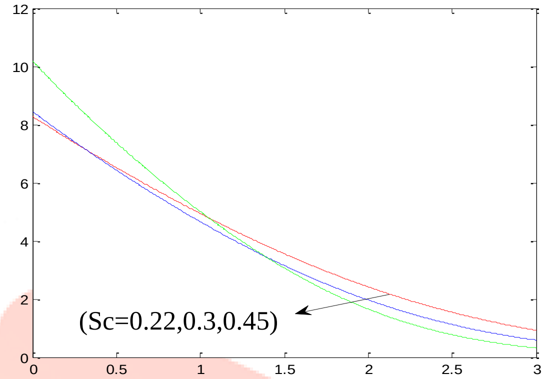
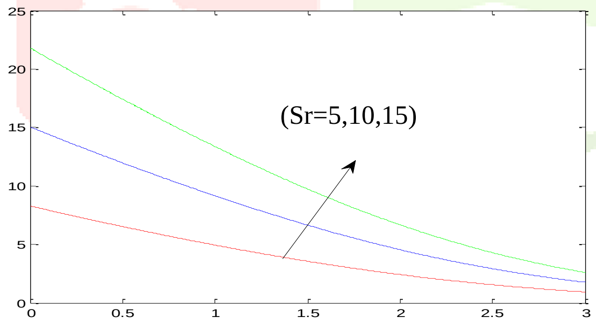


Fig.3., Leads of concentration for several values Fig.4., results of Sc on concentration for different

of Pr,Sc=0.22,Sr=5, φ=0.5, $\mathfrak{t}$=0.4 values of Sc, Pr=0.71,Sr=5, φ=0.5, $\mathfrak{t}$=0.4



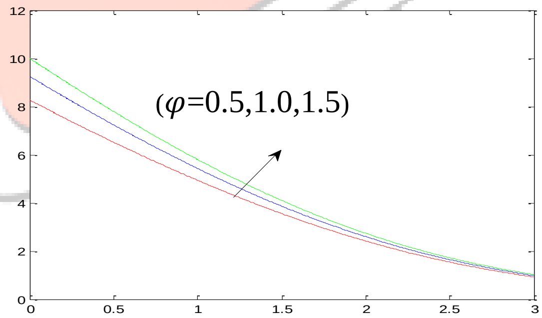


Fig.5., Leads of Sr on concentration for different Fig.6., Effect of concentration for different values

values of Sr,Sc=0.22,φ=0.5, Pr=0.71, $\mathfrak{t}$=0.4 of φ,Sc=0.22,Sr=5, Pr=0.71, $\mathfrak{t}$=0.4

The consequences of gradients of concentration, temperature in terms of Sherwood number and nusselt number are discussed through the following tales.

Table 4.1:

Pr	Sc	Sr	φ	t	sherwood number
0.71	0.22	5	0.5	0.4	7.661395373415637 + 3.782340967547664i
0.9	0.22	5	0.5	0.4	8.499931407091678 + 2.783427344101957i
1.71	0.22	5	0.5	0.4	11.337942015268434 + 1.313750763275343i
0.71	0.3	5	0.5	0.4	6.861709932655733 + 5.914425946733506i
0.71	0.45	5	0.5	0.4	6.074951327767980 + 12.461844759625430i
0.71	0.22	10	0.5	0.4	14.322790746831274 + 7.564681935095329i
0.71	0.22	15	0.5	0.4	20.984186120246910 + 11.347022902642992i
0.71	0.22	5	1	0.4	10.565224599596316 + 3.176920580366037i
0.71	0.22	5	1.5	0.4	12.825948945373815 + 2.745491180860314i

Table 4.2:

Pr	φ	t	Nusselt Number
0.71	0.5	0.4	0.89705641
0.9	0.5	0.4	1.009977815
1.71	0.5	0.4	1.392158344
0.71	1	0.4	1.033680793
0.71	1.5	0.4	1.162363
0.71	0.5	0.6	0.789077959
0.71	0.5	0.8	0.730922699

Table 4.1 shows the effects of Sherwood number for different values of several measurements Pr, Sr, φ and Sc. As Pr, Sr and φ raises, Sherwood number also raises and it falls with the raise of Sc.

Table 4.2 shows the leads of Nusselt number for various values of several measurements Pr, φ and t. As Pr and φ raises, nusselt number also raises and it falls with the raise in t.

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Appendix:

$$h = \frac{Sr.Sc\,.Pr}{(Pr-Sc)},\; b = \frac{\varphi Pr}{(Pr-Sc)},\; P_1 = -\frac{(\varphi-b)^{3/2}}{b^2},\; P_2 = \frac{\varphi^{3/2}}{b}\;,\; P_3 = \frac{P_1}{2}$$