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THERMAL AND MASS STRATIFICATION EFFECTS ON UNSTEADY FLOW PAST AN ACCELERATED INFINITE VERTICAL PLATE WITH VARIABLE TEMPERATURE AND EXPONENTIAL MASS DIFFUSION IN POROUS MEDIUM

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This study looks at how thermal and mass stratification affect the unsteady flow past an infinitely fast-moving vertical plate when the temperature is changing and there is exponential mass diffusion in a porous medium. By applying the Laplace transformation method, we determine the solutions to the equations that govern the system for the case of unitary Prandtl and Schmidt numbers. Graphical representations of the concentration, temperature, and velocity profiles, as well as the Nusselt Number, Sherwood number, and the Skin friction are provided to facilitate discussion of the cause of the different variables. To see the effects of thermal and mass stratification on the fluid flow, we compare the classical solution (Fluid with out stratification) with the primary solution (Fluid with the stratification) by using graph. The combined effects of the two stratification lead to a quicker approach to steady states. The outcomes can be helpful for heat exchange design and other engineering applications.

Keywords: *Unsteady flow; Porous Medium; Thermal Stratification; Mass Stratification; Accelerated plate*

PACS: 47.55.P-, 44.25.+f, 44.05.+e, 47.11.-j

NOMENCLATURE

α	Thermal Diffusivity
β	Volumetric Coefficient of Thermal Expansion
β^*	Volumetric Coefficient of Expansion with Concentration
γ	Thermal Stratification Parameter
ν	Kinematic Viscosity
τ	Non-Dimensional Skin-Friction
θ	Non-Dimensional Temperature
ξ	Mass Stratification Parameter
A, a, a'	Constant
C	Non-Dimensional Concentration
C'	Species fluid concentration
C'_∞	Concentration of the fluid far away from the Plate
C'_w	Concentration at the Plate
D	Mass Diffusion Coefficient
Da	Darcy number
F	Non-Dimensional Mass Stratification Parameter
g	Acceleration due to gravity
Gc	Mass Grashof Number
Gr	Thermal Grashof Number
Pr	Prandtl Number
S	Non-Dimensional Thermal Stratification Parameter
t	Non-Dimensional Time
T'	Temperature of the fluid
t'	Time
T'_∞	Temperature of the fluid far away from the Plate
T'_w	Temperature at the Plate
U	Non-Dimensional Velocity
u'	Velocity of the fluid in x' direction
u_0	Acceleration of the Plate
y	Non-Dimensional Coordinate which is Normal to the plate
y'	Coordinate which is Normal to the Plate

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1. INTRODUCTION

Many fields, including geology, thermal hydraulics, combustion, and environmental engineering, are profoundly affected by the phenomenon of mass and heat movement in porous material. The discovery of new energy sources has sparked a growing interest in the challenge of controlling the flow of mass and heat through porous materials. The focus of this work is to investigate the influences of thermal and mass stratification on the dynamics of unstable flow across an infinite vertical plate moving at high speed through a material that is permeable with changing temperature and exponential mass diffusion. Analytical approaches are applied to determine the solutions to the problem's governing equations. The outcomes are carefully examined and discussed. The paper also sheds light on the relevant physical processes that control the flow's behavior.

Natural convection of MHD mass and heat transport, when a chemical reaction is present was explored by Hemant Poonia and R.C. Chaudhary [1] through the use of an infinitely accelerated plate in a porous material that is positioned vertically. A. Selvaraj and E. Jothi [2] studied MHD and the absorption of radiation of a stream of fluid passing a vertical plate moving at an exponentially increasing rate, when warmth and mass diffuse exponentially across a porous material, and the influences of the source of heat on these variables. R.K. Deka and B.C. Neog [3] conducted research to find a precise solution to the problem of natural convection movement that fluctuates in one dimension passing an endless vertically accelerated plate while the plate was immersed in a thick fluid with layers of different temperatures. Researchers Kumar A.V., S.V.K. Varma, and R. Mohan [4] studied how the chemical processes and radiation affect the flow of MHD free convection through a plate that is vertical and accelerating at an exponential rate, where both the temperature and the rate of mass diffusion were variable. Using a porous materials and a magnetic field, Mondal S., Parvin S., and Ahmmed S. [5] examined the impact of chemical processes and radiation on the transfer of mass in unstable natural convection flow across an infinite perpendicular plate moving at an exponential pace. The unstable, incompressible, one-dimensional natural convective flow across an indefinitely rotating vertical cylinder with combined buoyancy effects of mass and heat transfer along with thermal and mass stratification was investigated by Deka R.K. and Paul A. [6]. Muthucumaraswamy R. and Visalakshi V. [7] investigated the impact of heat radiation on the motion of a fluid with a high viscosity and low compressibility through a vertically infinite plate moving at an exponential rate, subject to a homogeneous mass diffusion and changeable temperature. Rajesh V., Varma S.V.K. [8] did a study to find out how heat radiation affects the flow of natural convection over an infinitely long perpendicular plate that is speed up exponentially in a magnetic field and with mass transfer. Rajesh V. and S. Varma [9] considered the impact of a heat source on MHD flow. The flow was studied as it went through a porous medium at several temperatures and past an exponentially accelerating vertical plate. R.S. Nath and R.K. Deka [18] looked into how thermal stratification affected a fluid's ability to pass through an infinite vertical plate while experiencing a first-order chemical reaction.

Since no studies have been conducted on the impact of mass and thermal stratification on an infinite vertical plate started by an impulse in a porous material with exponential mass diffusion and temperature change, we were inspired to fill this area of knowledge.

2. MATHEMATICAL ANALYSIS

The fundamental equations of momentum, energy, and mass conservation are used to develop the system of equations that describes unsteady flow via a porous materials with exponential mass diffusion and fluctuating temperatures across an indefinitely accelerated vertical plate. Fig. 1 depicts the problem's physical layout. We assume a Cartesian coordinate system to discuss the flow problem where the infinite plate is to be the $x'-axis$, and the $y'-axis$ to be transverse to it. At the start, the fluid and plate are both at the identical temperature, T'_∞ , and the concentration, C'_∞ , is uniform across the entire surface. At time t', the plate began to speed up with a velocity of $u' = u_0 t'$ in its own path. The plate's temperature grew in a linear fashion with time t', while the level of concentration close to the plate achieved a value $C'_\infty + (c'_w - c'_\infty)e^{a't'}$. Therefore, the following equations characterize the unsteady flow using the standard Boussinesq approximation:

$$\frac{\partial u'}{\partial t'} = g\beta(T' - T'_\infty) + g\beta^*(C' - C'_\infty) + \nu\frac{\partial^2 u'}{\partial y'^2} - \frac{\nu}{k'}u' \tag{1}$$

$$\frac{\partial T'}{\partial t'} = \alpha\frac{\partial^2 T'}{\partial y'^2} - \gamma u' \tag{2}$$

$$\frac{\partial C'}{\partial t'} = D\frac{\partial^2 C'}{\partial y'^2} - \xi u' \tag{3}$$

with the following initial and boundary Conditions:

$$\begin{array}{llll} u' = 0 & T' = T'_\infty & C' = C'_\infty & \forall y', t' \leq 0 \\ u' = u_0 t' & T' = T'_\infty + (T'_w - T'_\infty)At' & C' = C'_\infty + (C'_w - C'_\infty)e^{a't'} & \text{at } y' = 0, t' > 0 \end{array}$$

$$u' = 0 \qquad T' \to T'_\infty \qquad C' \to C'_\infty \qquad \text{as } y' \to \infty, t' > 0 \tag{4}$$

Non-Dimensional Quantities:

$$U = \frac{u'}{(u_0\nu)^{\frac{1}{3}}}, \quad t = \frac{t' u_0^{\frac{2}{3}}}{\nu^{\frac{1}{3}}}, \quad y = \frac{y' u_0^{\frac{1}{3}}}{\nu^{\frac{2}{3}}}, \quad \theta = \frac{T' - T'_\infty}{T'_w - T'_\infty}, \quad C = \frac{C' - C'_\infty}{C'_w - C'_\infty}, \quad Gr = \frac{g\beta(T'_w - T'_\infty)}{u_0}$$

$$Gc = \frac{g\beta^*(C'_w - C'_\infty)}{u_0}, \quad Pr = \frac{\nu}{\alpha}, \quad Sc = \frac{\nu}{D}, \quad a = \frac{\nu^{\frac{1}{3}} a'}{u_0^{\frac{2}{3}}}, \quad S = \frac{\gamma \nu^{\frac{2}{3}}}{u_0^{\frac{1}{3}}(T'_w - T'_\infty)}, \quad F = \frac{\xi \nu^{\frac{2}{3}}}{u_0^{\frac{1}{3}}(C'_w - C'_\infty)}$$

$$Da = \frac{k' u_0^{\frac{2}{3}}}{\nu^{\frac{4}{3}}}$$

where, $A = \left(\frac{u_0^2}{\nu}\right)^{\frac{1}{3}}$ is the constant.

Using the non-dimensional quantities, equation (1) to (3) reduces to

$$\frac{\partial U}{\partial t} = Gr\theta + GcC + \frac{\partial^2 U}{\partial y^2} - \frac{1}{Da}U \tag{5}$$

$$\frac{\partial \theta}{\partial t} = \frac{1}{Pr}\frac{\partial^2 \theta}{\partial y^2} - SU \tag{6}$$

$$\frac{\partial C}{\partial t} = \frac{1}{Sc}\frac{\partial^2 C}{\partial y^2} - FU \tag{7}$$

Boundary and initial conditions in dimensionless form are:

$$\begin{array}{llll} u = 0 & \theta = 0 & C = 0 & \forall y, t \leq 0 \\ u = t & \theta = t & C = e^{at} & \text{at } y = 0, t > 0 \\ u = 0 & \theta \to 0 & C \to 0 & \text{as } y \to \infty, t > 0 \end{array} \tag{8}$$

3. METHOD OF SOLUTION

The Laplace Transform is implemented to find the solutions of the coupled equations mentioned above. Using Laplace transform technique for Pr=Sc=1 and with the help of (8), equation (5) to (7) reduces to,

$$\frac{d^2\overline{U}}{dy^2} - \left(s + \frac{1}{Da}\right)\overline{U} + Gr\overline{\theta} + Gc\overline{C} = 0 \tag{9}$$

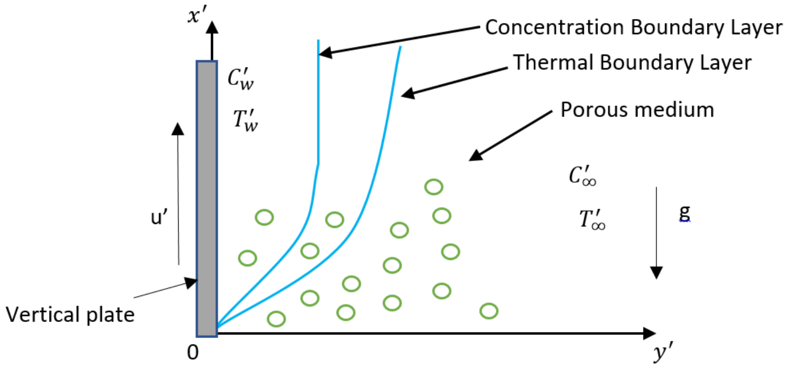

Figure 1. Physical model of the problem

$$\frac{d^2\overline{\theta}}{dy^2} - s\overline{\theta} = S\overline{U} \tag{10}$$

and

$$\frac{d^2\overline{C}}{dy^2} - s\overline{C} = F\overline{U} \tag{11}$$

Where 's' is the Parameter for the Laplace transform and $\overline{U}$, $\overline{\theta}$ and $\overline{C}$ are the Laplace transform of U, Θ and C respectively.

Now this set of differential equations were solved using boundary and initial conditions and taking inverse Laplace technique we obtained the expression for velocity, concentration and temperature as follows:

$$U = \frac{1}{B-R}\left\{Bh_1(B) - Rh_1(R)\right\} - \frac{Gr}{B-R}\left\{h_1(B) - h_1(R)\right\} - \frac{Gc}{B-R}\left\{h_2(B) - h_2(R)\right\} \tag{12}$$

$$\begin{aligned} C = {} & \frac{SGre^{at}}{2BR}\left[e^{-2\eta\sqrt{at}}erfc\left(\eta - \sqrt{at}\right) + e^{2\eta\sqrt{at}}erfc\left(\eta + \sqrt{at}\right)\right] - \frac{FGrt}{BR}\left[\left(1+2\eta^2\right)erfc(\eta) - \frac{ye^{-\eta^2}}{\sqrt{\pi t}}\right] \\ & + \frac{F}{B-R}\left\{h_1(B) - h_1(R)\right\} - \frac{FGr}{BR(B-R)}\left\{Rh_1(B) - Bh_1(R)\right\} \\ & - \frac{FGc}{BR(B-R)}\left\{Rh_2(B) - Bh_2(R)\right\} \end{aligned} \tag{13}$$

and

$$\begin{aligned} \theta = {} & \frac{FGct}{BR}\left[\left(1+2\eta^2\right)erfc(\eta) - \frac{ye^{-\eta^2}}{\sqrt{\pi t}}\right] - \frac{SGce^{at}}{2BR}\left[e^{-2\eta\sqrt{at}}erfc\left(\eta - \sqrt{at}\right) + e^{2\eta\sqrt{at}}erfc\left(\eta + \sqrt{at}\right)\right] \\ & + \frac{S}{B-R}\left\{h_1(B) - h_1(R)\right\} - \frac{SGr}{BR(B-R)}\left\{Rh_1(B) - Bh_1(R)\right\} \\ & - \frac{SGc}{BR(B-R)}\left\{Rh_2(B) - Bh_2(R)\right\} \end{aligned} \tag{14}$$

Where,

$$B = \frac{\frac{1}{Da} + \sqrt{\frac{1}{Da^2} - 4(SGr + FGc)}}{2}, \quad R = \frac{\frac{1}{Da} - \sqrt{\frac{1}{Da^2} - 4(SGr + FGc)}}{2},$$

$$\eta = \frac{y}{2\sqrt{t}}, \quad BR = SGr + FGc, \quad B + R = \frac{1}{Da}, \quad B - R = \sqrt{\frac{1}{Da^2} - 4(SGr + FGc)}$$

Also h_i's are inverse Laplace's transforms given by

$$h_1(P) = L^{-1}\left\{\frac{e^{-y\sqrt{s+P}}}{s^2}\right\} \quad and \quad h_2(P) = L^{-1}\left\{\frac{e^{-y\sqrt{s+P}}}{s-a}\right\}$$

3.1. Classical Case $(S = 0, F = 0)$

For classical solution, we first put $\gamma = 0$ in equation (2) and $\xi = 0$ in equation (3). After that they are non-dimensionalized by using same group of dimensionless parameters. Thus the solutions of concentration, temperature and velocity are obtained as follows:

$$C^* = \frac{e^{at}}{2}\left[e^{-2\eta\sqrt{at}}erfc\left(\eta - \sqrt{at}\right) + e^{2\eta\sqrt{at}}erfc\left(\eta + \sqrt{at}\right)\right] \tag{15}$$

$$\theta^* = t\left[\left(1+2\eta^2\right)erfc(\eta) - \frac{ye^{-\eta^2}}{\sqrt{\pi t}}\right] \tag{16}$$

$$\begin{aligned} U^* = {} & \left(1 - \frac{Gr}{B+R}\right)h_1(B+R) - \frac{Gc}{(B+R)}h_2(B+R) + \frac{Gr.t}{B+R}\left[\left(1+2\eta^2\right)erfc(\eta) - \frac{ye^{-\eta^2}}{\sqrt{\pi t}}\right] \\ & + \frac{Gc\ e^{at}}{2(B+R)}\left\{e^{-2\eta\sqrt{a.t}}erfc\left(\eta - \sqrt{a.t}\right) + e^{2\eta\sqrt{a.t}}erfc\left(\eta + \sqrt{a.t}\right)\right\} \end{aligned} \tag{17}$$

3.2. Skin-Friction

Non-dimensional determinations of the plate's skin friction (relative to momentum transfer) is given by:

$$\tau = -\frac{dU}{dy}\bigg|_{y=0}$$

So, using the expression of velocity profile in equation (12) we get,

$$\begin{aligned}\tau \;=\; & \frac{1}{B-R}\left[t\left(B^{3/2}\,erf\left(\sqrt{B.t}\right)-R^{3/2}\,erf\left(\sqrt{R.t}\right)+\frac{B.e^{-B.t}-R.e^{-R.t}}{\sqrt{\pi t}}\right)\right.\\ & \left.+\frac{\sqrt{B}erf\left(\sqrt{B.t}\right)-\sqrt{R}erf\left(\sqrt{R.t}\right)}{2}\right]-\frac{Gr}{B-R}\left[t\left(\sqrt{B}\,erf\left(\sqrt{B.t}\right)-\sqrt{R}\,erf\left(\sqrt{R.t}\right)\right.\right.\\ & \left.\left.+\frac{e^{-B.t}-e^{-R.t}}{\sqrt{\pi t}}\right)+\frac{erf\left(\sqrt{B.t}\right)}{2\sqrt{B}}-\frac{erf\left(\sqrt{R.t}\right)}{2\sqrt{R}}\right]-\frac{Gc}{B-R}\left[e^{a.t}\left(\sqrt{a+B}\,erf\left(\sqrt{(a+B)t}\right)\right.\right.\\ & \left.\left.-\sqrt{a+R}\,erf\left(\sqrt{(a+R)t}\right)\right)+\frac{e^{-B.t}-e^{-R.t}}{\sqrt{\pi t}}\right] \qquad (18)\end{aligned}$$

Similarly the expression of skin friction for Classical case is given by -

$$\begin{aligned}\tau^* = -\frac{dU^*}{dy}\bigg|_{y=0} \;=\; & \left(1-\frac{Gr}{B+R}\right)\left[t\sqrt{B+R}\,erf\left(\sqrt{(B+R)t}\right)+\frac{te^{-(B+R)t}}{\sqrt{\pi t}}\right.\\ & \left.+\frac{erf\left(\sqrt{(B+R)t}\right)}{2\sqrt{B+R}}\right]+\frac{2Gr}{(B+R)}\sqrt{\frac{t}{\pi}}\\ & -\frac{Gc}{(B+R)}\left[e^{a.t}\sqrt{a+B+R}\,erf\left(\sqrt{(a+B+R)t}\right)+\frac{e^{-(B+R)t}}{\sqrt{\pi t}}\right]\\ & +\frac{Gc}{(B+R)}\left[e^{a.t}\sqrt{a}\,erf\left(\sqrt{at}\right)+\frac{1}{\sqrt{\pi t}}\right] \qquad (19)\end{aligned}$$

3.3. Nusselt Number

Non-dimensional determinations of the plate's Nusselt number (relative to heat transfer) is given by:

$$Nu = -\frac{d\theta}{dy}\bigg|_{y=0}$$

So, using expression of temperature in equation (14) we get,

$$\begin{aligned}Nu \;=\; & \frac{2FGc}{BR}\sqrt{\frac{t}{\pi}}-\frac{SGc}{BR}\left[e^{at}\sqrt{a}\,erf\left(\sqrt{at}\right)+\frac{1}{\sqrt{\pi t}}\right]+\frac{S}{B-R}\left[t\left(\sqrt{B}\,erf\left(\sqrt{B.t}\right)\right.\right.\\ & \left.\left.-\sqrt{R}\,erf\left(\sqrt{R.t}\right)+\frac{e^{-B.t}-e^{-R.t}}{\sqrt{\pi t}}\right)+\frac{1}{2}\left(\frac{erf\left(\sqrt{B.t}\right)}{\sqrt{B}}-\frac{erf\left(\sqrt{R.t}\right)}{\sqrt{R}}\right)\right]\\ & -\frac{SGr}{BR(B-R)}\left[t\left(R\sqrt{B}\,erf\left(\sqrt{B.t}\right)-B\sqrt{R}\,erf\left(\sqrt{R.t}\right)+\frac{R.e^{-B.t}-B.e^{-R.t}}{\sqrt{\pi t}}\right)\right.\\ & \left.+\frac{1}{2}\left(\frac{R.erf\left(\sqrt{B.t}\right)}{\sqrt{B}}-\frac{B.erf\left(\sqrt{R.t}\right)}{\sqrt{R}}\right)\right]-\frac{SGc}{BR(B-R)}\left[\frac{R.e^{-B.t}-B.e^{-R.t}}{\sqrt{\pi t}}\right.\\ & \left.+e^{at}\left\{R\sqrt{a+B}\,erf\left(\sqrt{(a+B)t}\right)-B\sqrt{a+R}erf\left(\sqrt{(a+R)t}\right)\right\}\right] \qquad (20)\end{aligned}$$

Similarly the expression of nusselt number for Classical case is given by -

$$Nu^* = -\frac{d\theta^*}{dy}\bigg|_{y=0} = 2\sqrt{\frac{t}{\pi}}$$

3.4. Sherwood Number

In non-dimensional form, expression for the Sherwood number (relative to mass transfer) is given by,

$$Sh = -\frac{dC}{dy}\bigg|_{y=0}$$

So, using expression of concentration in equation (13) we get,

$$\begin{aligned}
Sh \quad = \quad & \frac{SGr}{BR}\left[e^{at}\sqrt{a}\ erf(\sqrt{at}) + \frac{1}{\sqrt{\pi t}}\right] - \frac{2FGr}{BR}\sqrt{\frac{t}{\pi}} \\
& + \frac{F}{B-R}\left[t\left(\sqrt{B}\ erf(\sqrt{B.t}) - \sqrt{R}\ erf(\sqrt{R.t}) + \frac{e^{-B.t} - e^{-R.t}}{\sqrt{\pi t}}\right)\right. \\
& \left. + \frac{1}{2}\left(\frac{erf(\sqrt{B.t})}{\sqrt{B}} - \frac{erf(\sqrt{R.t})}{\sqrt{R}}\right)\right] \\
& - \frac{FGr}{BR(B-R)}\left[t\left(R\sqrt{B}\ erf(\sqrt{B.t}) - B\sqrt{R}\ erf(\sqrt{R.t}) + \frac{R.e^{-B.t} - B.e^{-R.t}}{\sqrt{\pi t}}\right)\right. \\
& \left. + \frac{1}{2}\left(\frac{R.erf(\sqrt{B.t})}{\sqrt{B}} - \frac{B.erf(\sqrt{R.t})}{\sqrt{R}}\right)\right] - \frac{FGc}{BR(B-R)}\left[\frac{R.e^{-B.t} - B.e^{-R.t}}{\sqrt{\pi t}}\right. \\
& \left. + e^{at}\left\{R\sqrt{a+B}\ erf(\sqrt{(a+B)t}) - B\sqrt{a+R}\ erf(\sqrt{(a+R)t})\right\}\right]
\end{aligned} \tag{21}$$

Similarly the expression of Sherwood number for Classical case is given by -

$$Sh^* = -\frac{dC^*}{dy}\bigg|_{y=0} = e^{at}\sqrt{a}\ erf(\sqrt{at}) + \frac{1}{\sqrt{\pi t}}$$

4. RESULT AND DISCUSSIONS

We computed numerical values of temperature, concentration, velocity, Nusselt number, Skin friction, and Sherwood Number from the solutions obtained in the sections that came before this one, for a variety of values of the physical parameters Gr, Gc, S, F, Da and time t. This allowed us to get a better understanding of the physical significance of the problem. In addition to this, we showed them using graphs, which can be found in Figures 2 through 22.

The velocity profile with and without stratification for various values of S, F, Gr, Gc, Da and time (t) are shown in the Figures 2 to 6. A stratified fluid is observed to move more slowly than a comparable volume of unstratified fluid. The velocity diminishes as the values of S and F, which represent the temperature and mass stratification, are raised. The increase in velocity is proportional to the rise in thermal Grashof number (Gr) and mass Grashof number (Gc). The rise in velocity is caused by an increase in buoyancy forces. With time, the classical velocity keeps on rising, but in the presence of stratification, it stabilises. All of these results were found to be similar to those obtained by Deka RK and Paul A. [6]. Figure 6 clearly shows that the velocity grows up with the growing Darcy number(Da). The reason behind this is that a higher Darcy number indicates a more permeable porous material, which in turn reduces the resistance to the flow of the fluid and increases its velocity.

The temperature and concentration profile (with stratification and with no stratification) against y for various values of S, F, Gr, Gc, Da and t are depicted graphically in Figures 7 to 16. Diagrams show that at the plate, the concentration and temperature are at their highest, and as time progresses, they decline toward zero. Concentration reduces with rising F but increases with rising S, and temperature rises with rising F but drops with rising S. Compared to the non-stratified fluid, the stratified fluid has been found to have lower concentration and temperature. As the thermal and mass Grashof numbers (Gr and Gc) go up, it is also evident that both concentration and temperature fall. In the absence of stratification, the traditional concentration and temperature also increase gradually over time. From Figures 9 and 14 it is seen that as Darcy number(Da) grow up, temperature and concentration fall down.

For a set of variables governing the mass and temperature stratification, Figures 17, 19, and 21 shows the time-dependent pattern of the momentum transfer rate, the Nusselt number, and the rate of mass transfer, including the classical case. While skin friction steadily decreases for an unstratified fluid, it approaches a steady state for a stratified one and as the temperature and mass stratification parameters rise, so does skin friction. Plate and fluid interaction generates skin friction. More extreme differences in fluid temperature or density from the plate surface are observed when the thermal or mass stratification parameter rises. Skin friction increases as a result of increased fluid interaction with a plate as a result of a change in fluid temperature or density. The Nusselt number increases over time, and the Sherwood number initially drops before rising again. Also with the increase in S, Nusselt number increases but it decreases as mass stratification parameter (F) increases and the result is opposite for Sherwood number. Skin friction decrease as Gr and Gc increases. All of these results were earlier predicted by Deka RK and Paul A. [6]. However, the Nusselt and Sherwood numbers are decreases with increasing Gc but increases as Gr increase.

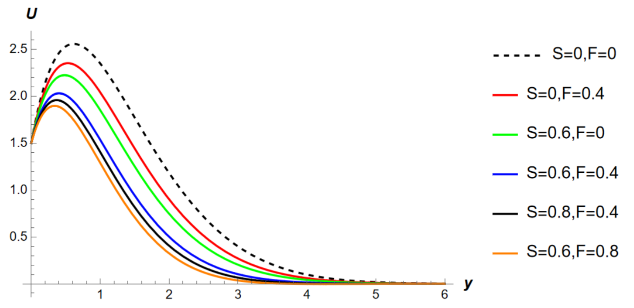

Figure 2. Influences of S and F on velocity profile for $Gr = 5, Gc = 5, Da = 1, a = 0.1, t = 1.5$

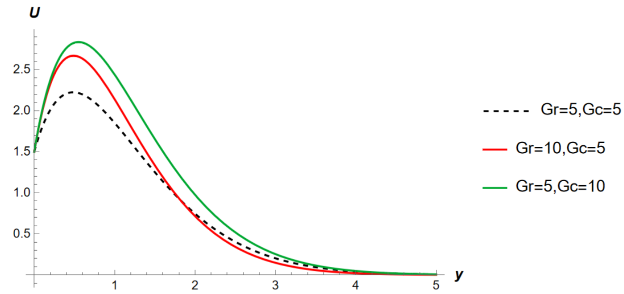

Figure 3. Influences of Gr and Gc on velocity profile for $S = 0.4, F = 0.2, Da = 1, a = 0.1, t = 1.5$

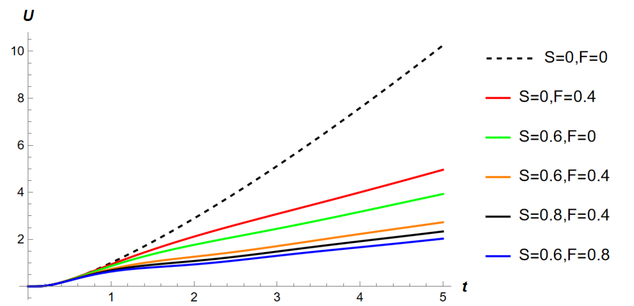

Figure 4. Influences of S and F on velocity profile against time for $Gr = 5, Gc = 5, y = 1.4, Da = 1, a = 0.1$

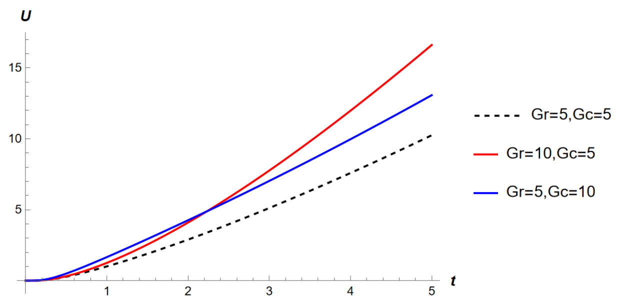

Figure 5. Influences of Gr and Gc on velocity against time for $S = 0.4, F = 0.2, Da = 1, y = 1.4, a = 0.1$

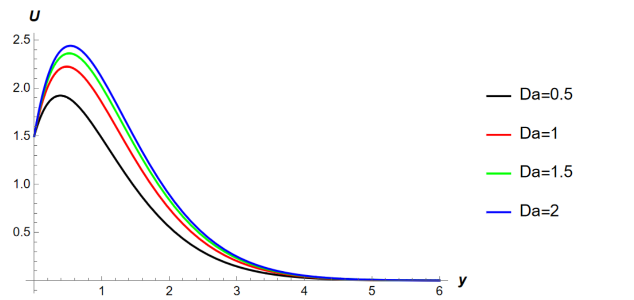

Figure 6. Influences of Da on velocity profile for $Gr = 5, Gc = 5, S = 0.4, F = 0.2, a = 0.1, t = 1.5$

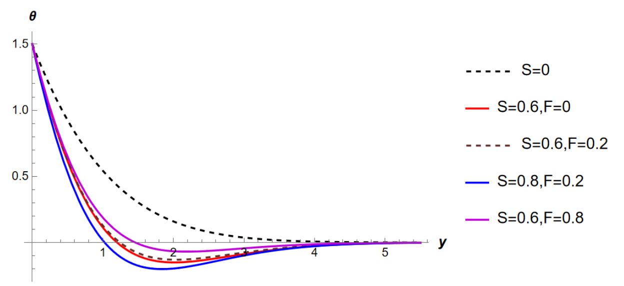

Figure 7. Influences of S and F on temperature profile for $Gr = 5, Gc = 5, t = 1.5, Da = 1, a = 0.1$

5. CONCLUSION

Based on the results derived from the preceding discussion, the following are the conclusions of this study:

(i) As S and F grow, velocity drops, while rises with Gr, Gc and Da. Compared to unstratified fluid, the speed of thermally and mass-stratified fluid is slower.

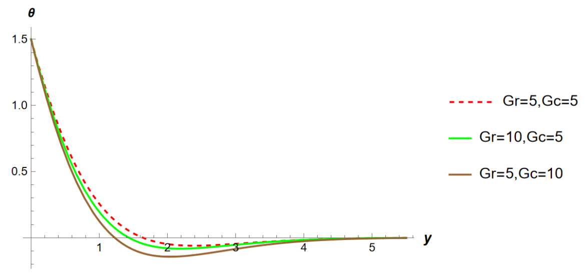

Figure 8. Influences of Gr and Gc on temperature for $S = 0.4, F = 0.2, a = 0.1, Da = 1, t = 1.5$

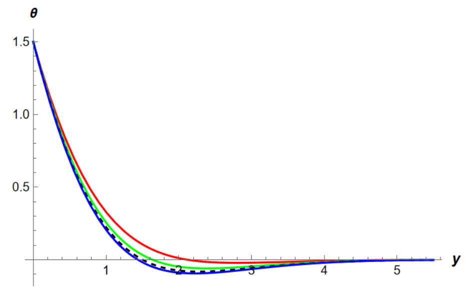

Figure 9. Influences of Da on temperature for $S = 0.4, F = 0.2, a = 0.1, t = 1.5, Gr = 5, Gc = 5$

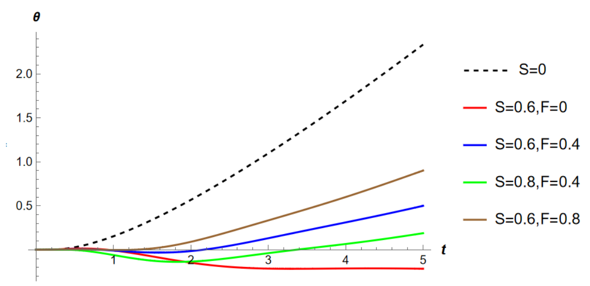

Figure 10. Influences of S and F on temperature profile against time for $Gr = 5, Gc = 5, Da = 1, y = 1.4, a = 0.1$

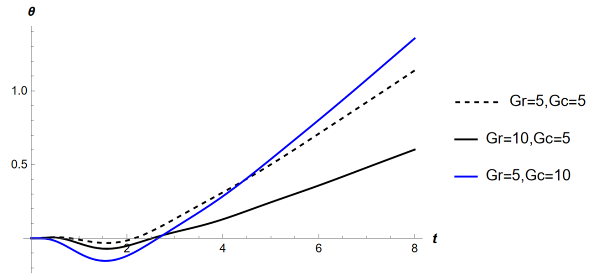

Figure 11. Influences of Gr and Gc on temperature profile for $S = 0.4, F = 0.2, Da = 1, y = 1.4, a = 0.1$

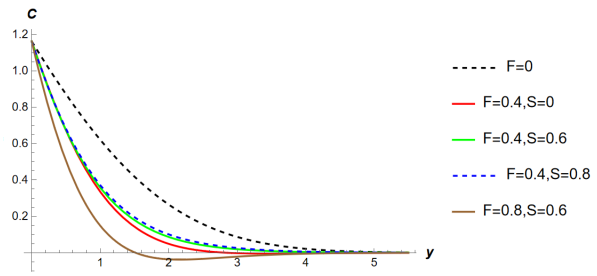

Figure 12. Influences of S and F on concentration profile for $Gr = 5, Gc = 5, t = 1.5, a = 0.1, Da = 1$

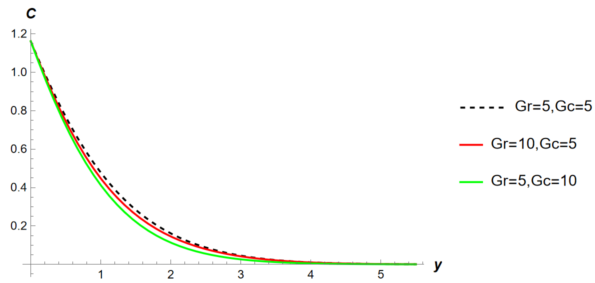

Figure 13. Influences of Gr and Gc on concentration for $S = 0.4, F = 0.2, a = 0.1, Da = 1, t = 1.5$

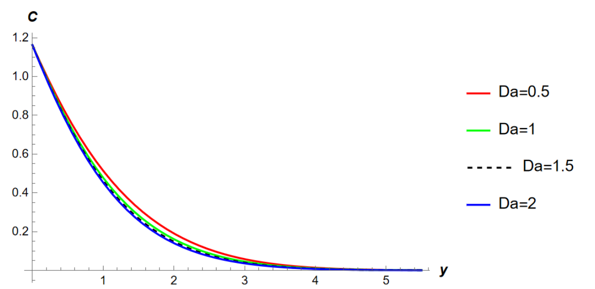

Figure 14. Influences of Da on concentration profile for $S = 0.4, F = 0.2, a = 0.1, Da = 1, t = 1.5, Gr = 5, Gc = 5$

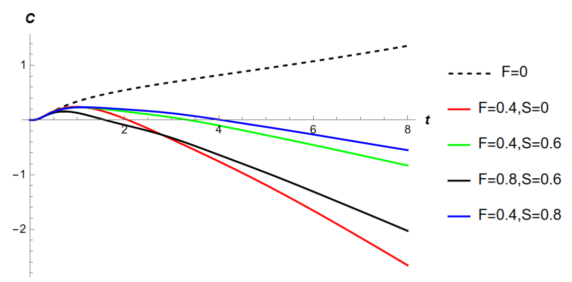

Figure 15. Influences of S and F on concentration against time for $Gr = 5, Gc = 5, a = 0.1, Da = 1, y = 1.4$

(ii) Increasing Gr, and Gc causes temperature and concentration to drop. The temperature falls as S rise and rises as F rise, the result is opposite for concentration. Fluid that is stratified has a lower temperature and concentration than fluid that is not stratified.

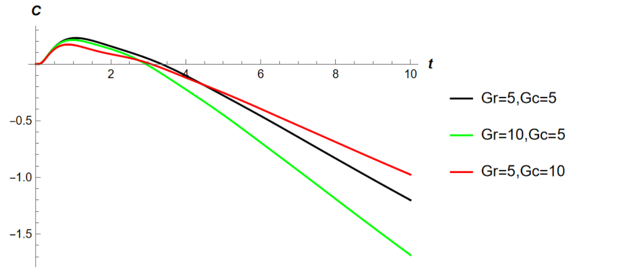

Figure 16. Influences of Gr and Gc on concentration against time for $S = 0.4, \quad F = 0.2, \quad y = 1.4, \quad a = 0.1, \ Da = 1$

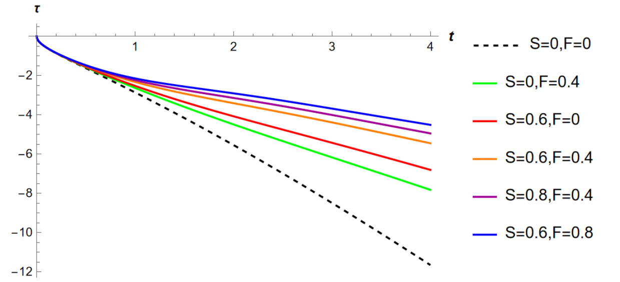

Figure 17. Influences of S and F on Skin friction for $Gr = 5, \quad Gc = 5, a = 0.1, \quad Da = 1$

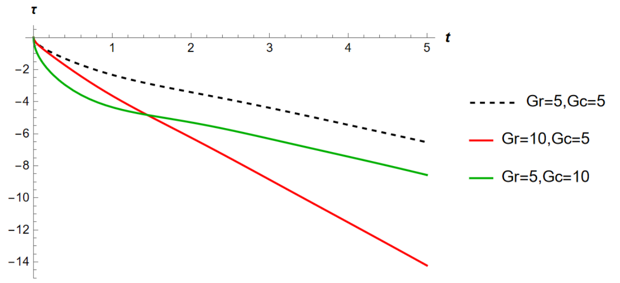

Figure 18. Influences of Gr and Gc on Skin friction for $S = 0.4, F = 0.2, a = 0.1, Da = 1$

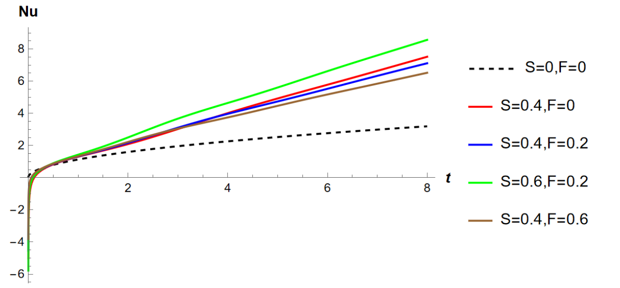

Figure 19. Influences of S and F on Nusselt number for $Gr = 5, Gc = 5, a = 0.1, Da = 1$

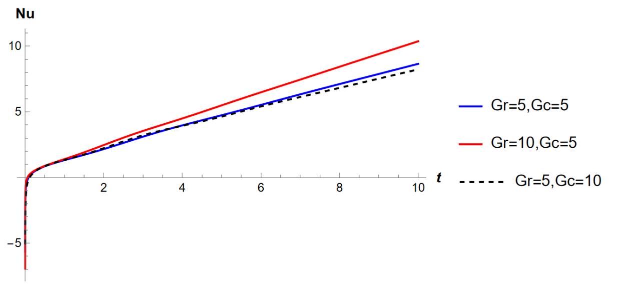

Figure 20. Influences of Gr and Gc on Nusselt number for $S = 0.4, F = 0.2, Da = 1, a = 0.1$

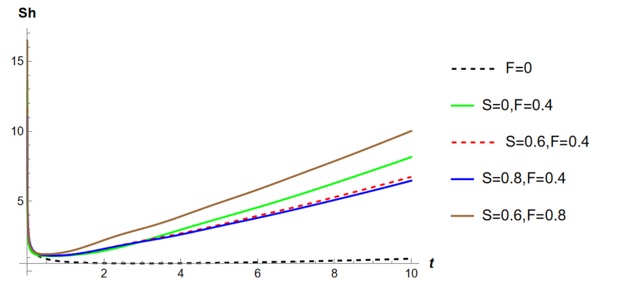

Figure 21. Influences of S and F on Sherwood number for $Gr = 5, Gc = 5, Da = 1, a = 0.1$

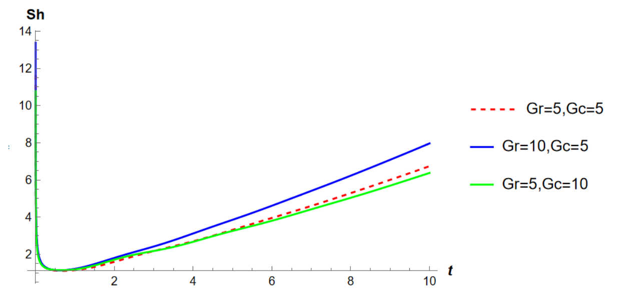

Figure 22. Influences of Gr and Gc on Sherwood number for $S = 0.4, F = 0.2, a = 0.1, Da = 1$

(iii) When stratification is present, the velocity, temperature, and concentration progressively stabilise, whereas without it, they continue to increase gradually with time. A more rapid approach to steady states is achieved due to the cumulative impacts of the two stratification.

(iv) It is shown that, unlike in the classical condition, skin friction approaches a fixed value as time progresses for stratified fluid. When S and F are both high, skin friction rises. Additionally, as Gr and Gc grow, skin friction decreases.

(v) Increasing the thermal stratification value leads to a greater Nusselt number, whereas increasing the mass stratification parameter causes a decline in the Nusselt number; however, the inverse is true for the Sherwood number. Increasing Gc reduces the Nusselt number and the Sherwood number, but increasing Gr raises them.

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ВПЛИВ ТЕРМІЧНОЇ ТА МАСОВОЇ СТРАТИФІКАЦІЇ НА НЕСТАЦІОНАРНИЙ ПОТІК ПОВЗ ПРИСКОРЕНУ НЕСКІНЧЕННУ ВЕРТИКАЛЬНУ ПЛАСТИНУ ЗІ ЗМІННОЮ ТЕМПЕРАТУРОЮ ТА ЕКСПОНЕНЦІАЛЬНОЮ МАСОВОЮ ДИФУЗІЄЮ В ПОРИСТОМУ СЕРЕДОВИЩІ

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У цьому дослідженні розглядається, як термічна та масова стратифікація впливає на нестаціонарний потік повз вертикальну пластину, що нескінченно швидко рухається, коли температура змінюється та відбувається експоненціальна дифузія маси в пористому середовищі. Застосовуючи метод перетворення Лапласа, ми визначаємо розв'язки рівнянь, що керують системою, для випадку унітарних чисел Прандтля та Шмідта. Графічне представлення профілів концентрації, температури та швидкості, а також числа Нуссельта, числа Шервуда та поверхневого тертя надаються для полегшення обговорення причин різних змінних. Щоб побачити вплив термічної та масової стратифікації на потік рідини, ми порівнюємо класичне рішення (рідина без стратифікації) з первинним рішенням (рідина з стратифікацією) за допомогою графіка. Комбінований ефект двох стратифікацій призводить до швидшого наближення до стійких станів. Результати можуть бути корисними для проектування теплообміну та інших інженерних застосувань.

Ключові слова: *нестабільний потік; пористе середовище; термічна стратифікація; масове розшарування; прискорена пластина*