Research Article

Performance of Dufour Effect on Unsteady MHD Flow past through Porous Medium an Exponentially Accelerated Inclined Vertical plate with Variable Temperature and Mass Diffusion

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Abstract:
The objective of this study is to the effect of Dufour along unstable MHD stream over an exponentially accelerated started inclined plate through porous medium by variable temperature and mass diffusion. The governing equations occupied in the current study and also the set of non-dimensional partial differential equations are solved by the Laplace-transform technique. The velocity profile , temperature profile, concentration profile have been considered for distinct parameters as warm Grashof value, mass Grashof value, Prandtl value, Dufour value, hypnotic field parameter, Schmidt value and time. The impacts of boundaries are demonstrated graphically for various boundaries. The velocity profiles increases when the value of Dufour value, Magnetic parameter, Schmidt value and also time are decreased and also mass Grashof number, Prandtl number are increased

Key Words: MHD, Dufour effect, Porous medium, inclined plate, exponentially , mass diffusion.

1.INTRODUCTION

The investigation of the unstable hydromagnetic physical convection heat and mass transfer flow of solid bodies past the viscous, incompressible and electrostatic fluid with different geometries embedded in microscopic and non-porous media has been the focus of extensive research over the past few decades for its diverse causes and has a wide series of usages in science and engineering such as border layer control, geothermal energy extraction, advanced recuperation of oil based commodities and gases, metal controlled thermo- nuclear reactors and more. In crystal formation, in reservoir engineering, in the study of the dynamics of an ocean's hot and salty springs, grain storage, and high- performing separation for buildings. Movement of moisture via air in fiber and granular protections, heat trade among soil and environment, reasonable warmth stockpiling beds, geothermal energy systems etc.

Cheng et.al [2] have discussed the Soret and Dufour impacts on the boundary limit cover stream due for characteristic displacement warm and mass exchange all over a descending face vertical cone in a porous medium filled with Newtonian liquids with steady wall temperature and concentration. A likeness examination is done, and the acquired comparative conditions are explained by cubic spline comparision method. Hayat et.al [3] presented the Soret and Dufour impacts on the magnetohydrodynamic movement of the Casson fluid over a stretched surface. The important conditions are first inferred, and the arrangement is built by the homotopic methodology. The combination of the series solution is examined.

Mansour et.al [4] Ananalys is presented to investigate the effects of chemical reaction, thermal layer, Soret value and Dufour value on MHD free convective heat and mass transfer of a viscous, incompressible and electrically directing liquid on a vertical extending surface inserted in an immersed porous medium by a fourth order Runge-Kutta scheme through the shooting method. Motsa et.al [5] On the beginning of convection in a permeable layer within the sight of Dufour and (Soret and Dufour) impacts in twofold diffusive (warm and solutal angles forced) convection in a liquid soaked permeable medium. It was discovered that, on account of fixed unsteadiness, the Soret impact had a balancing out impact though the Dufour impact was destabilizing. The cross diffusion impacts were found to have no impact on over solidness. In the restricting situation when the Soret and Dufour boundaries were set to be equivalent to zero the outcomes introduced in this investigation diminished to those detailed in past examinations on related twofold diffusive convective stream.

Pal et.al [6] study is MHD varied convection along with the related action of Soret and Dufour on heat and mass transfer of a power-law liquid across an inclined plate in a porous medium within the sight of variable warm conduction, warm radiation, synthetic response in numerical model. Prakash et.al [7] considered it is intended to consider diffusion thermo and radiation impacts on MHD free convection stream past an indiscreetly begun limitless vertical plate with variable temperature over permeable medium within the sight of slanting used attractive field. The dimensionless administering conditions are tackled utilizing Laplace change procedure. Also, the arrangements are communicated as far as exponential and corresponding error functions.

2. MATHEMATICAL FORMULATION

An unstable thick incompressible MHD stream among two equal electrically not the lead plates slanted on edge α as of vertical is thought of x axis pointed the plate and z regular towards it. A cross over attractive field B_0 of uniform quality is used along the stream. At first it takes viewed as that the plate just as the liquid is at a similar heat temperature T_∞. The species concentration in the liquid is chosen as C_∞. At time t > 0 the plate begins touching by velocity u = $u_0\exp(at)$, and the plate temperature is raised to T_w. The concentration C close to the plate is raised straightly regarding time. Along these lines, under the above suppositions, the stream modular is as under:

$$\frac{\partial u}{\partial t} = g\beta Cos\alpha(T - T_\infty) + g\beta^* Cos\alpha(C - C_\infty) + \nu\frac{\partial^2 u}{\partial z^2} - \frac{\sigma B_0^2 u}{\rho} - \frac{\nu u}{K} \qquad (1)$$

$$\rho C_p\frac{\partial T}{\partial t} = k\frac{\partial^2 T}{\partial z^2} + \frac{D_m K_T}{C_s C_p}\frac{\partial^2 C}{\partial z^2} \qquad (2)$$

$$\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial z^2} \qquad (3)$$

Along with the basic and limit constrains:

$$\begin{aligned}
&t \le 0 \quad u = 0,\quad T = T_\infty \quad C = C_\infty \quad \text{for each value of z}\\
&t > 0 \quad u' = u_0\exp(at),\ T = T_\infty + (T_w - T_\infty)\frac{u_0{}^2 t}{\nu},\\
&C = C_\infty + (C_w - C_\infty)\frac{u_0{}^2 t}{\nu} \quad \text{at } z = 0\\
&u \to 0,\ T \to T_\infty,\ C \to C_\infty \quad \text{as} \quad z \to \infty
\end{aligned} \qquad (4)$$

where u is the fluid velocity , g - the gravity of acceleration, β - volumetric coefficient of thermal extension, t - time, T - the fluid temperature, T_∞- the temperature of the plate at z → ∞, β^* - volumetric coefficient of concentration extension, C - species fluid concentration, ν - viscosity of kinematic, z - the co-ordinate axis to the normal plates, ρ - density, C_p − the specific heat at stable pressure, C_s – susceptibility due to Concentration, k - thermal conductivity of liquid, D - mass dispersion coefficient, D_m - effective mass diffusion rate, T_w – plate temperature at z = 0, C_w - plate - species concentration at z = 0, B_0 - the identical magnetic field, σ - electrically conduction and α – angle of inclination from vertical. The resulting non-dimensional amounts are presented with change conditions (1), (2), and (3) into dimensionless structure:

$$\begin{aligned}
&\bar{z} = \frac{z u_0}{\nu},\ \bar{t} = \frac{t u_0{}^2}{\nu},\ \bar{u} = \frac{u}{u_0},\ \theta = \frac{T - T_\infty}{T_w - T_\infty},\ \bar{C} = \frac{C - C_\infty}{C_w - C_\infty},\\
&S_c = \frac{\nu}{D},\ M = \frac{\sigma B_0{}^2\nu}{\rho u_0{}^2},\ \bar{K} = \frac{K u_0{}^2}{\nu^2},\ G_r = \frac{g\beta\nu(T_w - T_\infty)}{u_0^3},\\
&P_r = \frac{\mu C_p}{k},\quad G_c = \frac{g\beta^*\nu(C_w - C_\infty)}{u_0^3},\ \mu = \nu\rho\\
&D_f = \frac{D_m K_T(C_w - C_\infty)}{\nu C_S C_P(T_w - T_\infty)},\ \bar{a} = \frac{a\nu}{u_0{}^2}
\end{aligned} \qquad (5)$$

where $\bar{u}$ is non-dimensional velocity, $\bar{t}$ non-dimensional time, P_r - Prandtl value, S_c - Schmidt value, G_r- thermally Grashof number, G_c - mass Grashof value, θ – non-dimensional temperature, $\bar{C}$ – non-dimensional concentration, μ - the co-efficients of viscosity, $\bar{a}$ – non-dimensional accelerated parameter, $\bar{K}$ − $fluid$ permeable parameter and D_f - Dufour value, K_T -ratio of thermal diffusion and M - the magnetic variable parameter.

$$\frac{\partial\bar{u}}{\partial\bar{t}} = \frac{\partial^2\bar{u}}{\partial\bar{z}^2} + G_r\theta + G_c\bar{C} + \frac{\partial^2 q}{\partial z^2} - m\bar{u} - \frac{\bar{u}}{K} \qquad (6)$$

$$\frac{\partial\theta}{\partial\bar{t}} = \frac{1}{P_r}\frac{\partial^2\theta}{\partial\bar{z}^2} + D_f\frac{\partial^2\bar{C}}{\partial\bar{z}^2} \qquad (7)$$

$$\frac{\partial\bar{C}}{\partial\bar{t}} = \frac{1}{S_c}\frac{\partial^2\bar{C}}{\partial\bar{z}^2} \qquad (8)$$

Across the using below limit conditions

$$\left.\begin{array}{l} \bar{t} \leq 0: \quad \bar{u} = 0, \quad \theta = 0, \quad \bar{C} = 0 \text{ for all } \bar{z} \\ \bar{t} > 0: \quad \bar{u} = e^{\bar{a}\bar{t}}, \quad \theta = \bar{t}, \quad \bar{C} = \bar{t} \text{ at } \bar{z} = 0 \\ \bar{u} \to 0, \quad \theta \to 0, \quad \bar{C} \to 0 \quad \text{as} \quad \bar{z} \to \infty \end{array}\right\} \qquad (9)$$

Getting the above mentioned equations

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial z^2} + G_r Cos\alpha\, \theta + G_c Cos\alpha\, C - \text{mu} - \frac{u}{K} \qquad (10)$$

$$\frac{\partial \theta}{\partial t} = \frac{1}{P_r}\frac{\partial^2 \theta}{\partial z^2} + D_f\, \frac{\partial^2 C}{\partial z^2} \qquad (11)$$

$$\frac{\partial C}{\partial t} = \frac{1}{S_c}\frac{\partial^2 C}{\partial z^2} \qquad (12)$$

With the initial and limit constrains

$$\left.\begin{array}{l} t \leq 0: \quad u = 0, \quad \theta = 0, \quad C = 0 \quad \text{for all } z \\ t > 0: \quad u = e^{at}, \quad \theta = t, \quad C = t \quad \text{at } z = 0 \\ u \to 0, \quad \theta \to 0, \quad C \to 0 \quad \text{as} \quad z \to \infty \end{array}\right\} \qquad (13)$$

Non-dimensional quantities are stated in the classification.

3. METHOD OF SOLUTION

For the results of equations (10), (11) and (12) within the limit conditions (13) are found by the Laplace transform technique. The solution obtained is as under

$$\theta = t\,[(1 + 2\eta^2 P_r)erfc\,(\eta\sqrt{P_r}) - \frac{2\eta\sqrt{P_r}}{\sqrt{\pi}} e^{-\eta^2 P_r}]$$

$$- t[(1 + 2\eta^2 S_c)erfc\,(\eta\sqrt{S_c}) - \frac{2\eta\sqrt{S_c}}{\sqrt{\pi}} e^{-\eta^2 S_c}]$$

$$C = t[(1 + 2\eta^2 S_c)erfc\,(\eta\sqrt{S_c}) - \frac{2\eta\sqrt{S_c}}{\sqrt{\pi}} e^{-\eta^2 S_c}]$$

$$u = \frac{e^{at}}{2}[\exp(-2\eta\sqrt{(a+m+\tfrac{1}{k})t})\text{erfc}(\eta - \sqrt{(a+m+\tfrac{1}{k})t}) +$$

$$\exp(2\eta\sqrt{(a+m+\tfrac{1}{k})t})\text{erfc}(\eta + \sqrt{(a+m+\tfrac{1}{k})t})]$$

$$+ \frac{G_r\, cos\alpha}{2(1-P_r)(b+d)^2}[\exp(-2\eta\sqrt{(m+\tfrac{1}{k})t})\text{erfc}(\eta - \sqrt{(m+\tfrac{1}{k})t}) +$$

$$\exp(2\eta\sqrt{(m+\tfrac{1}{k})t})\text{erfc}(\eta + \sqrt{(m+\tfrac{1}{k})t})]$$

$$+ \frac{G_r\, cos\alpha}{(1-P_r)(b+d)}[\exp(-2\eta\sqrt{(m+\tfrac{1}{k})t})\text{erfc}(\eta - \sqrt{(m+\tfrac{1}{k})t})(\frac{t}{2} - \frac{\eta\sqrt{t}}{2\sqrt{(m+\frac{1}{k})}}) +$$

$$\exp(2\eta\sqrt{(m+\tfrac{1}{k})t})\text{erfc}(\eta + \sqrt{(m+\tfrac{1}{k})t})(\frac{t}{2} + \frac{\eta\sqrt{t}}{2\sqrt{(m+\frac{1}{k})}})]$$

$$- \frac{G_r\, cos\alpha}{(1-P_r)(b+d)^2}\frac{e^{(b+d)t}}{2}[\exp(-2\eta\sqrt{(b+d+m+\tfrac{1}{k})t})\text{erfc}(\eta - \sqrt{(b+d+m+\tfrac{1}{k})t}) +$$

$$\exp(2\eta\sqrt{(b+d+m+\frac{1}{k})t}\,)\text{erfc}(\eta+\sqrt{(b+d+m+\frac{1}{k})t}\,)]$$

$$-\frac{G_r D_f P_r S_c cos\alpha}{2(S_c-P_r)(1-S_c)(c+f)^2}[\exp(-2\eta\sqrt{(m+\frac{1}{k})t}\,)\text{erfc}(\eta-\sqrt{(m+\frac{1}{k})t}\,)+$$

$$\exp(2\eta\sqrt{(m+\frac{1}{k})t}\,)\text{erfc}(\eta+\sqrt{(m+\frac{1}{k})t}\,)]$$

$$-\frac{G_r D_f P_r S_c cos\alpha}{(S_c-P_r)(1-S_c)(c+f)}[\exp(-2\eta\sqrt{(m+\frac{1}{k})t}\,)\text{erfc}(\eta-\sqrt{(m+\frac{1}{k})t}\,)(\frac{t}{2}-\frac{\eta\sqrt{t}}{2\sqrt{(m+\frac{1}{k})}})+$$

$$\exp(2\eta\sqrt{(m+\frac{1}{k})t}\,)\text{erfc}(\eta+\sqrt{(m+\frac{1}{k})t}\,)\,(\frac{t}{2}+\frac{\eta\sqrt{t}}{2\sqrt{(m+\frac{1}{k})}})]$$

$$+\frac{G_r D_f P_r S_c cos\alpha}{(S_c-P_r)(1-S_c)(c+f)^2}\frac{e^{(c+f)t}}{2}[\exp(-2\eta\sqrt{(c+f+m+\frac{1}{k})t}\,)\text{erfc}(\eta-\sqrt{(c+f+m+\frac{1}{k})t}\,)+$$

$$\exp(2\eta\sqrt{(c+f+m+\frac{1}{k})t}\,)\text{erfc}(\eta+\sqrt{(c+f+m+\frac{1}{k})t}\,)]$$

$$+\frac{G_c cos\alpha}{2(1-S_c)(c+f)^2}[\exp(-2\eta\sqrt{(m+\frac{1}{k})t}\,)\text{erfc}(\eta-\sqrt{(m+\frac{1}{k})t}\,)+$$

$$\exp(2\eta\sqrt{(m+\frac{1}{k})t}\,)\text{erfc}(\eta+\sqrt{(m+\frac{1}{k})t}\,)]$$

$$+\frac{G_c cos\alpha}{(1-S_c)(c+f)}[\exp(-2\eta\sqrt{(m+\frac{1}{k})t}\,)\text{erfc}(\eta-\sqrt{(m+\frac{1}{k})t}\,)(\frac{t}{2}-\frac{\eta\sqrt{t}}{2\sqrt{(m+\frac{1}{k})}})+$$

$$\exp(2\eta\sqrt{(m+\frac{1}{k})t}\,)\text{erfc}(\eta+\sqrt{(m+\frac{1}{k})t}\,)(\frac{t}{2}+\frac{\eta\sqrt{t}}{2\sqrt{(m+\frac{1}{k})}})]$$

$$-\frac{G_c cos\alpha}{(1-S_c)(c+f)^2}\frac{e^{(c+f)t}}{2}[\exp(-2\eta\sqrt{(c+f+m+\frac{1}{k})t}\,)\text{erfc}(\eta-\sqrt{(c+f+m+\frac{1}{k})t}\,)+$$

$$\exp(2\eta\sqrt{(c+f+m+\frac{1}{k})t}\,)\text{erfc}(\eta+\sqrt{(c+f+m+\frac{1}{k})t}\,)]$$

$$-\frac{G_r cos\alpha}{(1-P_r)(b+d)^2}\,erfc(\eta\sqrt{P_r})-\frac{G_r cos\alpha}{(1-P_r)(b+d)}t\,[(1+2\eta^2 P_r)erfc\,(\eta\sqrt{P_r})-\frac{2\eta\sqrt{P_r}}{\sqrt{\pi}}e^{-\eta^2 P_r}]$$

$$+\frac{G_r cos\alpha}{(1-P_r)(b+d)^2}\frac{e^{(b+d)t}}{2}[\exp(-2\eta\sqrt{(P_r(b+d)t}\,)\text{erfc}(\eta\sqrt{P_r}-\sqrt{(b+d)t}\,)+$$

$$\exp(2\eta\sqrt{(P_r(b+d)t}\,)\text{erfc}(\eta\sqrt{P_r}+\sqrt{(b+d)t}\,)]$$

$$+\frac{G_r D_f P_r S_c cos\alpha}{(S_c-P_r)(1-S_c)(c+f)^2}erfc(\eta\sqrt{S_c})+\frac{G_r D_f P_r S_c cos\alpha}{(S_c-P_r)(1-S_c)(c+f)}t[(1+2\eta^2 S_c)erfc\,(\eta\sqrt{S_c})-\frac{2\eta\sqrt{S_c}}{\sqrt{\pi}}e^{-\eta^2 S_c}]$$

$$-\frac{G_r D_f P_r S_c cos\alpha}{(S_c-P_r)(1-S_c)(c+f)^2}\frac{e^{(c+f)t}}{2}[\exp(-2\eta\sqrt{(S_c(c+f)t}\,)\text{erfc}(\eta\sqrt{S_c}-\sqrt{(c+f)t}\,)+$$

$$\exp(2\eta\sqrt{(S_c(c+f)t}\,)\text{erfc}(\eta\sqrt{S_c}+\sqrt{(c+f)t}\,)]$$

$$-\frac{G_c cos\alpha}{(1-S_c)(c+f)^2}\,erfc(\eta\sqrt{S_c})-\frac{G_c cos\alpha}{(1-S_c)(c+f)}t[(1+2\eta^2 S_c)erfc\,(\eta\sqrt{S_c})-\frac{2\eta\sqrt{S_c}}{\sqrt{\pi}}e^{-\eta^2 S_c}]$$

$$+\frac{G_c cos\alpha}{(1-S_c)(c+f)^2}\frac{e^{(c+f)t}}{2}[\exp(-2\eta\sqrt{(S_c(c+f)t}\,)\text{erfc}(\eta\sqrt{S_c}-\sqrt{(c+f)t}\,)+$$

$$\exp(2\eta\sqrt{(S_c(c+f)t}\,)\text{erfc}(\eta\sqrt{S_c}+\sqrt{(c+f)t}\,)]$$

4. RESULTS AND DISCUSSIONS

The velocity profile, temperature profile and concentration profile by the various variable parameter such as mass Grashof value Gc, thermal Grashof value Gr, magnetized parameter M, Dufour value Df, Prandtl value Pr, Schmidt value Sc also time t is displayed in images 1 to 10. It is noted that Velocity increased while Dufour value, Magnetic limit parameter, Schmidt value and also time are decreased. (Figure 1,3, 5,6). It is noted that the Velocity increased while mass Grashof value, Prandtl number are enlarged. (Figure 2, 4).It is noted that the temperature increased while time and Dufour value are expanded. (Figure 7, 8) It is noted that the concentration increased when Schmidt value is diminished.(Figure 9). It is noted that the concentration increased while time is extended.(Figure 10).

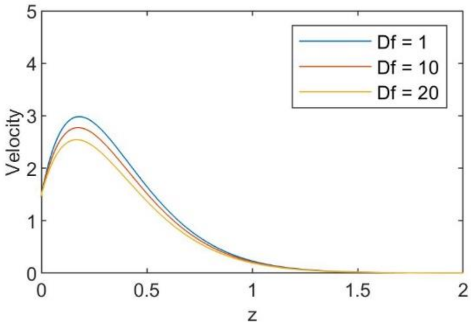


Fig.1. Velocity outcomes for distinct values of Df

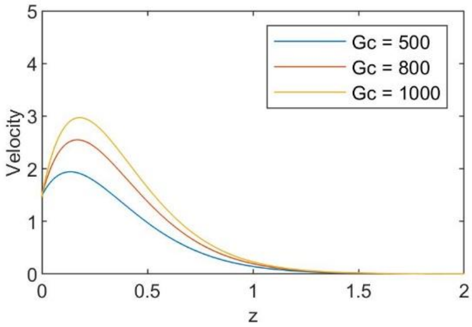


Fig.2. Velocity outcomes for distinct values of Gc

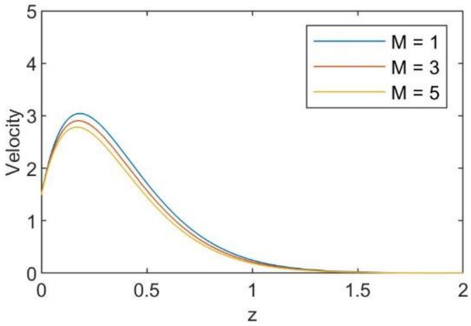


Fig.3.Velocity outcomes for distinct values of M

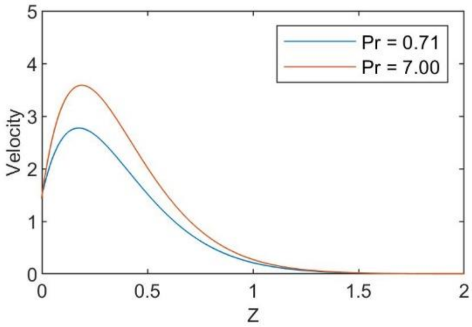
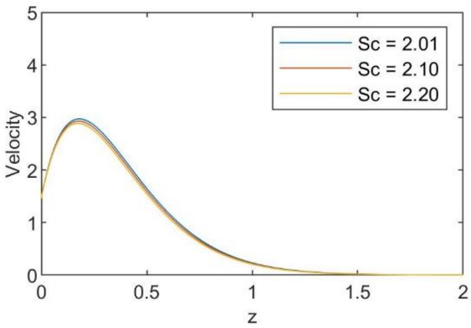


Fig.4. Velocity outcomes for distinct values of Pr



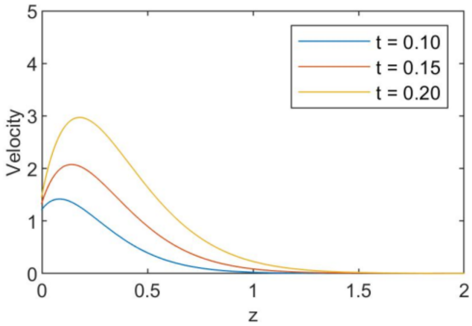
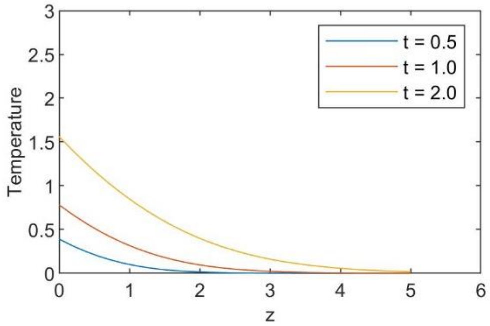


Fig.5. Velocity outcomes for distinct values of Sc

Fig.6. Velocity outcomes for distinct values of t



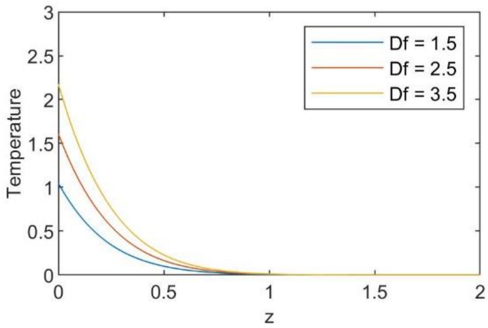
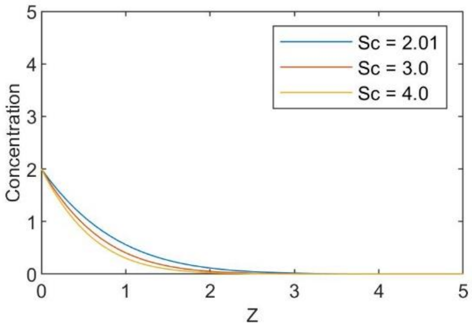


Fig.7.Temperature outcomes for distinct values of t

Fig.8.Temperature outcomes for distinct values of Df



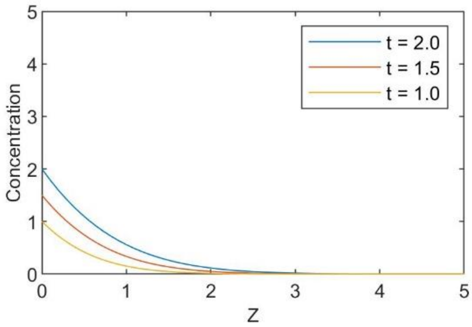


Fig.9. Concentration outcomes for distinct values of Sc

Fig.10. Concentration outcomes for distinct values of t

5. CONCLUSIONS

In that present review has been carried out to learn of Dufour effect on unstable mhd course through porous medium past an implusively begun slanted oscillating plate about variable temperature and mass dispersion. Answers for the ideal have been inferred by utilizing Laplace - change method. Certain results of the study are

(i) Velocity expands when Dufour value, Magnetic parameter, Schmidt value and time are decreased.
(ii) Velocity raises when mass Grashof value, Prandtl value are increased.
(iii) Temperature increased when Dufour number and time are increased.
(iv) Concentration increased when Schmidt number is decreased
(v) Concentration increased when time is increased.

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