Available online at http://scik.org
J. Math. Comput. Sci. 11 (2021), No. 5, 6205-6215
https://doi.org/10.28919/jmcs/6104
ISSN: 1927-5307

DUFOUR EFFECT ON MHD FLOW PAST AN EXPONENTIALLY ACCELERATED VERTICAL PLATE THROUGH POROUS SYSTEM WITH VARIABLE TEMPERATURE AND MASS DIFFUSION

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Abstract: The purpose of this study is to examine the effect of Dufour on the exponentially accelerated plate past MHD flow through porous media with varying temperatures and constant mass distribution. The considered fluid conducts electricity. The set of dimensionless area differential equations is solved by using the Laplace transformation technique and by finding the value of velocity, temperature and concentration profiles. The outcomes are found by graphs for various boundaries such as warm Grashof value, mass Grashof value, Prandtl value, permeability parameter, Schmidt value, Dufour value, time, magnetic flux tendency and acceleration parameter. The velocity profile decreases by increasing the values of the magnetic parameter, radiation absorption, chemical reaction and thermal radiation. The temperature profile increases by increasing the values of the thermal radiation and the Dufour number.

Keywords: Dufour effect, Exponentially accelerated plate, Heat transfer, Mass transfer, MHD, Porous medium.

2010 AMS Subject Classification: 80A20.

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Received May 23, 2021

1. INTRODUCTION

The result of the magnetic area on insoluble, absorbing conductive liquid works a main part numerous purposes like glass industrial, control concession, paper manufacturing, garments, magnetic material handling and raw oil refining. In nature, any currents are produced by temperature contrasts and also concentration contrasts. In industry, there are several transport schemes for simultaneously transferring heat and mass effect of the combined buoyancy effect of thermal energy. Thus, steel coils, nuclear force plants, gas turbines and airplane, rockets, reactor plan, materials preparing, temperature dimensions and aerospace remote sensing, food handling and many other farming. In the event that the temperature of the encompassing liquid is high, the radiation impacts assume a significant job, and this condition is available in space innovation. In such cases, one must consider the joined impact of warm radiation and mass contrast.

Alam et.al [1] reviewed the Dufour and Soret impacts on unstable free convection and mass exchange stream past an indiscreetly begun endless vertical plate implanted in a permeable moderate affected by transverse attractive field. They saw that enormous Darcy value prompts the expansion of the speed and decline of the temperature and just as centralization of the stream liquid with limit layer. Babu et.al [2] have examined an accurate result for study compound response, dispersion thermo (Dufour impact) and radiation consequences for flimsy MHD free convective warmth and mass exchange stream past a impulsively begun limitless vertical plate with variable mass diffusion within the sight of realistic slanting attractive field. it is seen that skin-grinding increments by M in the two instances of freezing and warming of the plate because of upgraded Lorentz force which introduces extra energy in the limit layer.

Kumar et.al [3] have explored warm diffusion and radiation consequences for changeable free convection synthetically responding liquid stream past a quickened unending vertical plate with variable temperature and mass dispersion [4] affected by constant transverse attractive field when the attractive outlines of power are stable comparative with the liquid or to the plate concentrated in two events, (I) Attractive field stable at comparative with the liquid (K=0), (ii) Attractive field stable at comparative with the plate (K=1) has-been thought of. An overall careful arrangement of the non-dimensional overseeing incomplete variance condition is grown by the typical Laplace change method [5] with no limitation. The impact of stream boundaries on speed, temperature, focus, heat move and the pace of mass exchange [6] are concentrated however diagrams and tables. Rajput U. S et.al [7] talked about Dufour impact on MHD unstable free convection stream over an exponentially quickened plate done permeable moderate by varying temperature and consistent mass dispersion in a slanted attractive area. Reddy et.al [8] A consistent two-dimensional MHD free convection stream thick scattering liquid past a semi-unending moving vertical plate in a permeable medium with Soret and Dufour impacts is dissected. The governing fractional differential conditions are non-dimensionalized and changed into an arrangement of nonlinear customary differential likeness conditions, in a solitary autonomous variable η. The subsequent coupled, nonlinear conditions are explained under suitable changed limit conditions utilizing the Runge-Kutta fourth request with Shooting strategy. Calculations are performed for a wide scope of the governing stream boundaries.

2. MATHEMATICAL FORMULATION

We consider the progression of an unstable thick concentrated liquid. Plate electric non lead. The x-axis plate is brought upwards and z - axis is chosen as regular for it. A uniformly inclined hypnotic domain B_0 is directed to the plate by use α from the vertical. At first the liquid and plate similar temperatures T_∞ and the centralization of liquid C_∞. At time t > 0, the plate begins to move exponentially with speed u = $u_0 \exp(at)$, heat temperature of the plate is extended to T_w, and also the concentration of the liquid is extended to C_w. The governing conditions underneath standard Boussinesq's calculations are as the following:

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

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

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

Consider the problem described by

$$\left.\begin{array}{l} t \le 0 \quad u = 0, \quad T = T_\infty \quad C = C_\infty \quad \text{for each value of z} \\ t > 0 \quad u' = u_0 \exp(at), T = T_\infty + (T_w - T_\infty)\frac{u_0{}^2 t}{v}, \\ C = C_\infty + (C_w - C_\infty)\frac{u_0{}^2 t}{v} \quad \text{at } z = 0 \\ u \to 0, \ T \to T_\infty, \ C \to C_\infty \ when \quad z \to \infty \end{array}\right\} \quad (4)$$

where u is the velocity of the liquid, g - the acceleration over gravity, β – volumetric quantity of thermal extension, β^*- volumetric quantity of concentration extension, t – time, T - the heat temperature of the liquid, T_∞- the high temperature of the plate at z → ∞, C − concentration in the liquid, C_∞ - concentration at z → ∞ , v - the kinetic viscidness, ρ - the thickness, C_p – the particular heat at constant tension, k – thermal reaction of the liquid, K_T - thermal circulation ratio, D – the mass dispersion stable, D_m - the real mass diffused rate, T_w − the heat of the plate at z = 0, C_w - concentration at the plate at z = 0, C_s - Concentration exposure, B_0 − the constant magnetic area, σ – electric reaction and K - permissibility of the porous form. By utilizing the resulting non dimensional magnitudes, equalities (1), (2), and (3) as changed to non-dimensional structure.

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

Here $\bar{u}$ is dimensionless speed velocity, $\bar{t}$ dimensionless period, P_r - Prandtl value, S_c - Schmidt value, G_r- thermal Grashof value, G_c - mass Grashof value, θ – non-dimensional temperature, $\bar{C}$ -

dimensionless concentration, μ - the coefficient of thickness, $\bar{a}$ - dimensionless acceleration limit, $\bar{K}$ – permeability factor and D_f - Dufour number.

At that point typical is changed into non dimensional equalities

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

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

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

The initial and limit terms are

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

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial z^2} + G_r\theta + G_cC - \mathrm{mu} - \frac{u}{K} \tag{10}$$

$$\frac{\partial \theta}{\partial t} = \frac{1}{P_r}\frac{\partial^2 \theta}{\partial z^2} + D_f\ \frac{\partial^2 C}{\partial z^2} \tag{11}$$

$$\frac{\partial C}{\partial t} = \frac{1}{S_c}\frac{\partial^2 C}{\partial z^2} \tag{12}$$

With the initial and limit constrains

$$\left.\begin{array}{lllll} t \leq 0: & u = 0, & \theta = 0, & C = 0 & \text{for all } z \\ t > 0: & u = e^{at}, & \theta = t, & C = t & \text{at } z = 0 \\ & u \to 0, & \theta \to 0, & C \to 0 & \text{as } z \to \infty \end{array}\right\} \tag{13}$$

The non-dimensional quantities are stated in the classification.

3. METHOD OF SOLUTION

Now solutions (10), (11) and (12) of equations (13) below the limit terms are found by Laplace - transform method. The results for concentration C, liquid temperature θ and liquid velocity *u* are separately. The non-dimensional measures are identified.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

4. RESULTS AND DISCUSSION

The velocity, concentration and temperature are work out for distinct limits as Thermal grashof value (G_r), Mass grashof value (G_c), Prandtl value (P_r), Schmidt value (S_c), Permeability parameter (K), Magnetic field parameter(M), *A*cceleration parameter *(a)*, Dufour value (D_f) and Time (*t*). The ideals of the limit measured are G_r = 5, 10, G_c = 2,5, P_r = 0.30, 0.71, 7.10, S_c = 0.16, 0.30, 0.60, *K* = 0.2, 0.6, 1.0, M = 2, 4, 6, a = 1, 1.5, 2, D_f = 1, 3, 5 and *t* = 0.2, 0.4, 0.6 Figures 1, 2, 3, 4 and 8 show that velocity increases when a, D_f , G_r ,G_c , K *and t* are enlarged. Figures 5, 6 and 7 show that velocity decreases when M, S_c, P_r are increased. Figure 9 displays that concentration growths when t raised. Figure 10 shows that concentration decreases when S_c increased. Figure 11 and 12 show that temperature increases when t *and* D_f increased.

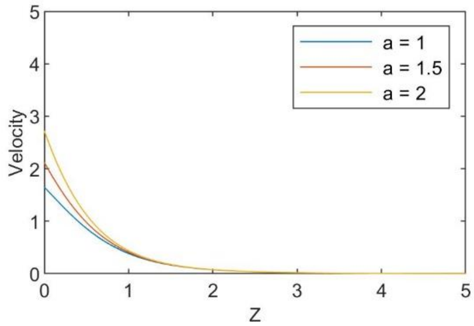

Fig.1.Velocity outcomes for various values of a

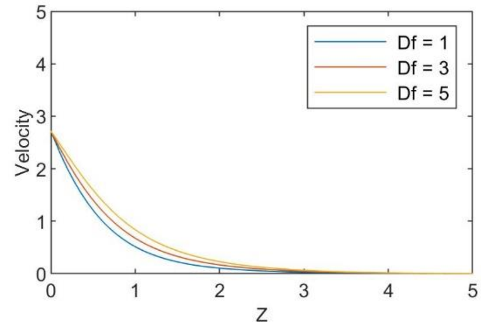

Fig.2.Velocity outcomes for various values of D_f

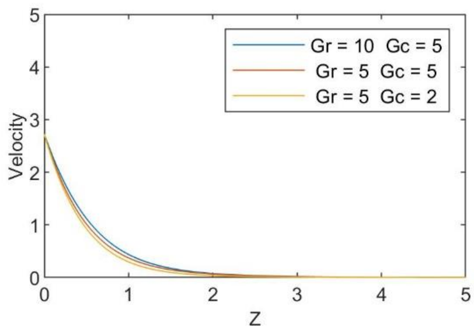

Fig.3.Velocity outcomes for various values of G_r, G_c

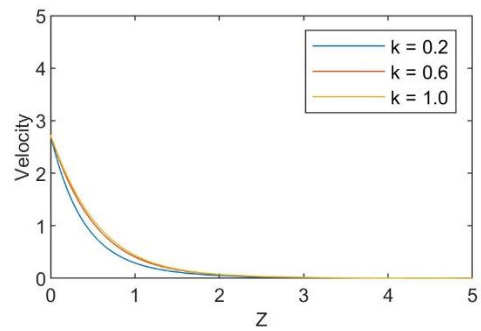

Fig.4.Velocity outcomes for various values of K

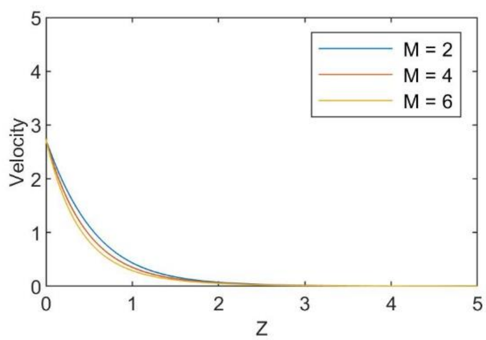

Fig.5.Velocity outcomes for various values of M

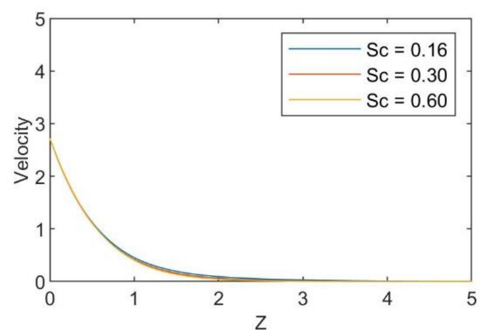

Fig.6.Velocity outcomes for various values of S_c

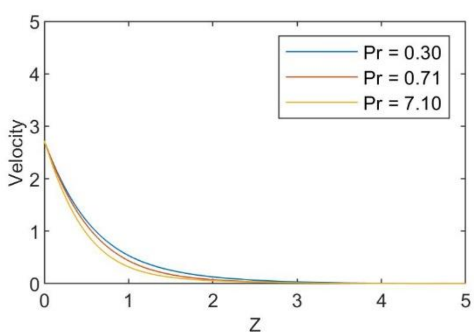

Fig.7.Velocity outcomes for various values of P_r

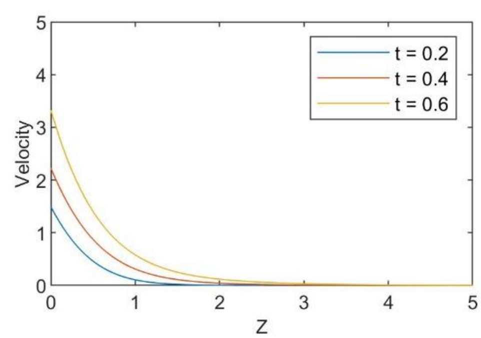

Fig.8.Velocity outcomes for various values of t

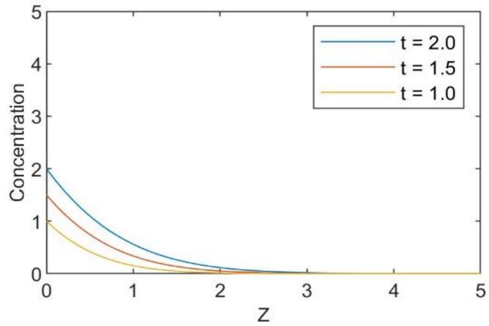

Fig.9.Concentration outcomes for various of t

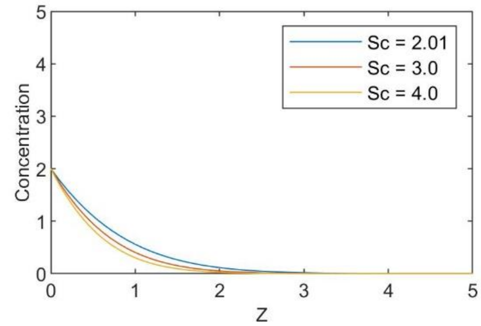

Fig.10.Concentration outcomes for various of S_c

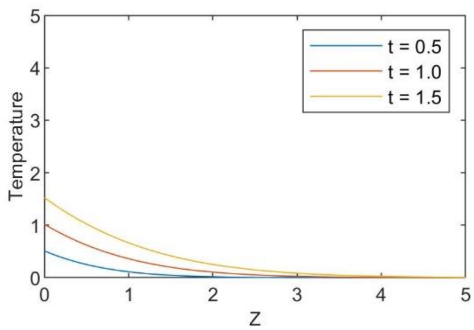

Fig.11.Temperature outcomes for various of t

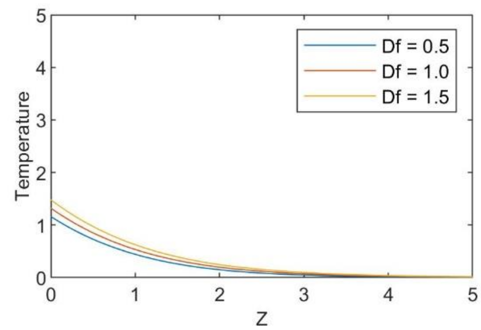

Fig.12.Temperature outcomes for various of D_f

5. CONCLUSIONS

In this paper a theoretical study has-been ensured to analysis of dufour effect on MHD flow past an exponentially accelerated vertical plate through porous system by variable temperature and mass diffusion. Explanations used for the equation has-been solved by utilizing Laplace - transform methods. Various of the results of the analysis are

(i) Increasing the values of a, D_f , G_r ,G_c , K and t increases the velocity of the liquid.

(ii) Expanding the ideals of M, S_c and P_r decreases the velocity of the liquid.

(iii) Rising the value of t increases the concentration of the fluid.

(iv) Increasing the value of S_c decreases the concentration of the liquid.

(v) Growing the value of D_f and t increases the temperature of the liquid.

CONFLICT OF INTERESTS

The author(s) declare that there is no conflict of interests.

REFERENCES

[1] M.S. Alam, M.M. Rahman, Dufour and Soret effects on MHD free convective heat and mass transfer flow past a vertical porous flat plate embedded in a porous medium, J. Naval Arch. Marine Eng. 2 (2005), 55-65.

[2] K.R. Babu, A.G.V. Kumar, S.V.K. Varma, Diffusion-thermo and radiation effects on MHD free convective heat and mass transfer flow past an infinite vertical plate in the presence of a chemical reaction of first order, Adv. Appl. Sci. Res. 3 (2012), 2446-2462.

[3] B.R. Kumar, T.S. Kumar, A.G. Kumar, Thermal diffusion and radiation effects on unsteady free convection flow in the presence of magnetic field fixed relative to the fluid or to the plate, Front. Heat Mass Transfer, 6 (2015), 12.

[4] S.R. Mohan, G.V. Reddy, S.V.K. Varma, Dufour and radiation absorption effects on unsteady mhd free convection casson fluid flow past an exponentially infinite vertical plate through porous medium, J. Emerging Technol. Innov. Res. 6 (2019), 485-512.

[5] R. Muthucumaraswamy, K.E. Sathappan, R. Natarajan, Mass transfer effects on exponentially accelerated isothermal vertical plate, Int. J. Appl. Math. Mech. 4 (2008), 19-25.

[6] V. Rajesh, S.V.K. Varma, Radiation and mass transfer effects on MHD free convection flow past an exponentially accelerated vertical plate with variable temperature, ARPN J. Eng. Appl. Sci. 4 (2009), 20-26.

[7] U.S. Rajput, N.K. Gupta, Dufour effect on unsteady free convection MHD flow past an exponentially accelerated plate through porous media with variable temperature and constant mass diffusion in an inclined magnetic field, Int. Res. J. Eng. Technol. 3 (2016), 2135-2140.

[8] M.G. Reddy, N.B. Reddy, Soret and Dufour effects on steady MHD free convection flow past a semi-infinite moving vertical plate in a porous medium with viscous dissipation, Int. J. Appl. Math. Mech. 6 (2010), 1-12.