28DUFOUR EFFECT ON RADIATIVE EFFECT FLOW AND HEAT TRANSFER OVER A VERTICALLY OSCILLATING POROUS FLAT PLATE EMBEDDED IN POROUS MEDIUM WITH OSCILLATING SURFACE TEMPERATURE

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ABSTRACT - *The Dufour effects on flow and heat transfer over a vertically oscillating porous flat plate embedded in porous medium with oscillating surface temperature is investigated in this paper. An analytic solutions of momentum, energy and concentration equations are obtained by Perturbation technique. The velocity, temperature and concentration profile is computed. The dimensionless skin friction co-efficient, Nusselt number and Sherwood number are also estimated. The transfer Gr, Grashof number for mass transfer Gm, Suction parameter S, Dufour number Du, Schmidt number Sc, Magnetic field parameter M and radiative parameter R on velocity, temperature and concentration profiles are analyzed through graphs.*

Keywords: **Radiation, Suction, Heat Flux, Oscillating Porous Plate, Dufour Effect.**

1. INTRODUCTION

A new dimension is added to the study of mixed convection flow past a stretching sheet embedded in a porous medium by considering the effect of thermal radiation. Thermal radiation effect plays a significant role in controlling heat transfer process in polymer processing industry. The quality of the final product depends to a certain extent on heat controlling factors. Also, the effect of thermal radiation on flow and heat transfer processes is of major important in the design of many advanced energy convection systems which operate at high temperature. Sasikumar and Govindarajan [1], discussed free convective MHD oscillating flow past parallel plates in a porous medium. Where the effects of various non dimensional parameters on velocity, temperature and concentration profiles have been analysed. The effect of magnetic field and convection on transient velocity, transient temperature and concentration when the plate is subjected to oscillatory velocity, temperature and concentration are increases. Radiation effects on MHD flow past an impulsively started vertical plate with variable heat and mass transfer is studied by Rajput and Kumar [2]. Balamurugan and Karthikeyan [3] discussed effects of radiation MHD oscillating flow through a porous medium boundary by two vertical porous plates in the presence of hall current and Dufour effect with homogeneous first order chemical reaction under the influence of uniform magnetic field and another plate is oscillating with uniform velocity. Soundalgekar [4] was the first to study Magneto hydrodynamic free convection flow past an infinite vertical plate oscillating in its own plane in case of an isothermal plate. The motion of a semi-infinite incompressible viscous fluid, caused by the oscillation of a plane vertical plate, has been studied in presence of free convection currents. Mansour [5] has studied the interaction of fre e convection with thermal radiation of the oscillating flow past a vertical plate. Soundalgekar and Takhar [6] have considered radiation effects on free convection flow past a semi-infinite vertical plate. Helmay [7] has investigated MHD unsteady free convection flow past a vertical porous medium plate. Radiation effects on unsteady MHD free convective heat and mass transfer flow of past a vertical porous plate embedded in a porous medium with viscous dissipation studied by Mohammad Ibrahim and Sankar reddy roja [8]. Sooraj pal singh [9] analyzed the effects of radiation on unsteady laminar free convection flow of an electrically conducting fluid along a porous hot vertical plate in the presence of heat source with mass transfer in rotating system was discussed. They found that primary velocity decreases with the increase in rotation velocity parameter, radiation parameter and time. Dufour and thermal radiation effects of Kuvshinski fluid on double diffusive and convective MHD heat and mass transfer flow past a porous vertical plate in the presence of radiation absorption is investigated by Lalitha, Varma, Manjulatha and Raju [10]. Arabaway [11], examined the effect of suction/ injection on a micropolar fluid past a continuously moving plate in the presence of radiation. The effects of thermal radiation on the flow past an oscillating plate with variable temperature have been studied by Pathak, Maheswari and Gupta [12]. The effect of radiation on various convection flows under different conditions have been studied by many researchers including Hussain and Thakar [13], Ahmed and Sarmah [14], Rajesh and Varma [15], Pal and Mondal, Samad,Rahman [16]. The present work is concerned with the Dufour effect on radaitive effect flow and heat transfer over a vertically oscillating porous flat plate embedded in porous medium with oscillating surface temperature. [17]Monika Miglani, Net Ram Garg, Mukesh Kumar Sharma (2016) Radiative effect on flow and heat transfer over a vertically oscillating porous flat plate embedded in porous medium with oscillating surface temperature. An analytic solutions of momentum, energy and concentration equations are obtained by perturbation technique.

2. MAHEMATICAL ANALYSIS

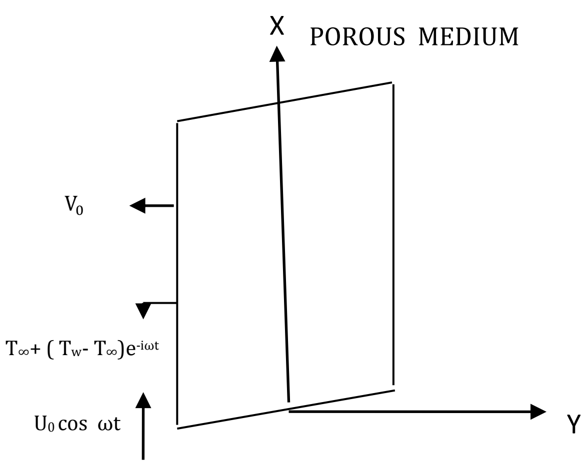

Fig. 1

We consider a two dimensional unsteady free convective flow and heat transfer through a vertical porous flat plate in the influence of radiative heat flux is considered. The axis of x is taken along the vertical plate and the axis of y is normal to the plate. The plate is oscillating in its own plane with a frequency of oscillation ω and mean velocity U_0. The temperature at the plate is also oscillating and the free stream temperature is constant T_∞. A constant suction velocity V_0 is applied at the oscillating porous plate. Since the plate is of semi infinite length therefore the variation along x-axis will be negligible as compared to the variation along y-axis.

$$\frac{\partial}{\partial x}(.) = 0 \qquad (1)$$

From the physical description the governing equations are,

Continuity Equation

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \qquad (2)$$

Momentum Equation

$$\frac{\partial u}{\partial t} + v\frac{\partial u}{\partial y} = -\frac{1}{\rho}\frac{\partial p}{\partial x} + \nu\frac{\partial^2 u}{\partial y^2} - \frac{\nu}{k}u - \sigma B_0^2 u \qquad (3)$$

Energy Equation

$$\frac{\partial T}{\partial t} + v\frac{\partial T}{\partial y} = \alpha\frac{\partial^2 T}{\partial y^2} - \frac{\alpha}{K}\frac{\partial q_r}{\partial y} + \frac{D_M K_T}{\rho C_P C_S}\frac{\partial^2 C}{\partial y^2} \qquad (4)$$

Species Equation

$$\frac{\partial C}{\partial t} + v\frac{\partial C}{\partial y} = D_M\frac{\partial^2 C}{\partial y^2} \qquad (5)$$

From physical description the governing equations (2) to (4) becomes,

$$\frac{\partial v}{\partial y} = 0 \qquad (6)$$

The suction parameter normal to the plate is, $\upsilon = -V_0$ (Constant), where υ is independent of y.

$$\frac{\partial u}{\partial t} - V_0\frac{\partial u}{\partial y} = g\beta(T - T_\infty) + g\beta^*(C - C_\infty) + \nu\frac{\partial^2 u}{\partial y^2} - \frac{\nu}{k}u - \sigma B_0^2 u \qquad (7)$$

$$\frac{\partial T}{\partial t} - V_0\frac{\partial T}{\partial y} = \alpha\frac{\partial^2 T}{\partial y^2} - \frac{\alpha}{K}\frac{\partial q_r}{\partial y} + \frac{D_M K_T}{\rho C_P C_S}\frac{\partial^2 C}{\partial y^2} \qquad (8)$$

$$\frac{\partial C}{\partial t} - V_0 \frac{\partial C}{\partial y} = D_M \frac{\partial^2 C}{\partial y^2} \tag{9}$$

Where, 'y' and 't' are the dimensional distance perpendicular to the plate and dimensional time respectively. 'u' is the components of the dimensional velocity along y. g is the acceleration due to gravity, β is the coefficient of thermal expansion, β^* is the coefficient of mass expansion, T is the dimensional temperature of the fluid near the plate, T_∞ is the dimensional free stream temperature, U_0 is the amplitude of oscillation of the plate, C is the dimensional Concentration of the fluid near the plate, C_∞ is the dimensional free stream concentration, υ is kinematic viscosity, σ is the fluid electrical conductivity, k is the permeability of the porous medium, B_0^2 is the magnetic induction, α is thermal diffusivity of the fluid, K thermal conductivity of the fluid, q_r is the radiative heat flux, D_M is the coefficient of chemical molecular diffusivity, and D_T is the coefficient of thermal diffusivity. The Roseland approximation for radiative heat flux is given by,

$$q_r = -\frac{4\sigma}{3\delta} \frac{\partial T^4}{\partial y} \tag{10}$$

Where σ and δ are the Stefen-Boltzmann constant and Mean absorption coefficient respectively. By neglecting the higher powers of Taylor's series expansion of T^4, we hav $T^4 \cong 4TT_\infty^3 - 3T_\infty^3$

The appropriate boundary conditions for velocity, temperature and concentration fields are as follows,

$$y = 0; u = U_0 \cos \omega t; T = T_\infty + (T_w - T_\infty)e^{-i\omega t}; \quad C = C_\infty + (C_w - C_\infty)e^{-i\omega t} \tag{11}$$

$$y \to \infty; u \to 0; T \to T_\infty; C \to C_\infty \tag{12}$$

We introduce the dimensionless variables as follows,

$$u^* = \frac{u}{U_0} \quad t^* = \frac{tU_0^2}{\nu} \quad y^* = \frac{yU_0}{\nu}$$

$$\Pr = \frac{\mu C_p}{k} \quad S = \frac{V_0}{U_0}$$

$$\omega^* = \frac{\nu\omega}{U_0^2} \quad Sc = \frac{\nu}{D_M} \quad Da = \frac{U_0^2}{\nu^2}$$

$$R = \frac{\delta K}{4\sigma T_\infty^3} \quad M^2 = \frac{\sigma B_0^2 \nu}{U_0^2}$$

$$\theta = \frac{T - T_\infty}{T_w - T_\infty} \quad \alpha = \frac{3R\Pr}{3R+4} \quad \phi = \frac{C - C_\infty}{C_w - C_\infty}$$

$$Gr = \frac{g\beta\gamma(T_w - T_\infty)}{U_0^3} \quad Gm = \frac{g\beta^*\gamma(C_w - C_\infty)}{U_0^3}$$

$$Df = \frac{D_M (C_w - C_\infty)}{\gamma(T_w - T_\infty)} \tag{13}$$

Where, *Pr* is the Prandtl number, *S* is the suction parameter, *Sc* is Schmidt number, *Da* is the Darcy number, *R* is the radiation parameter, *M* is the magnetic parameter, *Df* is the Dafour number, *Gr* is the Grashof number for heat transfer and *Gm* is the Grashof number for mass transfer. By using non-dimensional quantities (13), the equations (7) to (9) reduces to the following non-dimensional form,

$$\frac{\partial u^*}{\partial t^*} - S\frac{\partial u^*}{\partial y^*} = Gr\theta + Gm\phi + \frac{\partial^2 u}{\partial y^2} - \left(M^2 + \frac{1}{Da}\right)u^* \tag{14}$$

$$\alpha\frac{\partial \theta}{\partial t^*} - \alpha S\frac{\partial \theta}{\partial y^*} = \frac{\partial^2 \theta}{\partial y^{*2}} + Df\frac{\partial^2 \phi}{\partial y^{*2}} \tag{15}$$

$$\frac{\partial \phi}{\partial t^*} - S\frac{\partial \phi}{\partial y^*} = \left(\frac{1}{Sc}\right)\frac{\partial^2 \phi}{\partial y^{*2}} \tag{16}$$

The boundary conditions (11) and (12) in the dimensional form can be written as,

$$y^* = 0; u^* = \cos\omega^* t^*; \theta = e^{-i\omega^* t^*}; \phi = e^{-i\omega^* t^*} \tag{17}$$

$$y^* \to \infty; u^* \to 0; \theta \to 0; \phi \to 0 \tag{18}$$

Equations (14) to (16) are coupled non-linear partial differential equations and these equations can be solved in

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closed form. However, these equations can be reduced to a set of ordinary differential equations, which can be solved analytically. The suitable solutions for the equations are as follows,

$$u(y,t) = f_1(y)e^{i\omega t} + \bar{f}_1(y)e^{-i\omega t} \tag{19}$$

$$\theta(y,t) = g_1(y)e^{i\omega t} + \bar{g}_1(y)e^{-i\omega t} \tag{20}$$

$$\phi(y,t) = h_1(y)e^{i\omega t} + \bar{h}_1(y)e^{-i\omega t} \tag{21}$$

Where $f_1(y), \bar{f}_1(y), g_1(y), \bar{g}_1(y), h_1(y)$ and $\bar{h}_1(y)$ are unknowns to be determined.

Substituting (19) to (21) in equations (14) to (16) and equating harmonic and non- harmonic terms, we get the following set of ordinary differential equations.

$$f_1''(y) + Sf_1'(y) - \left(i\omega + \left(M^2 + \frac{1}{Da}\right)\right)f_1(y) = -(Gr(1+A_3)\exp(-A_2 y) + A_3\exp(-A_1 y) - Gm\exp(-A_1 y)) \tag{22}$$

$$\bar{f}_1'(y) + S(y)\bar{f}_1' + \left(i\omega - \left(M^2 + \frac{1}{Da}\right)\right)\bar{f}_1(y) = -(Gr(1+A_3)\exp(-A_2 y) + GrA_3\exp(-A_1 y) - Gm\exp(-A_1 y)) \tag{23}$$

$$g_1''(y) + S\alpha g_1'(y) - \alpha i\omega g_1(y) = -\alpha Dfh''(y) \tag{24}$$

$$\bar{g}_1''(y) + S\alpha\bar{g}_1'(y) + \alpha i\omega\bar{g}_1(y) = -\alpha Dfh''(y) \tag{25}$$

$$h_1''(y) + S.Sc.h_1'(y) - i\omega.Sch_1(y) = 0 \tag{26}$$

$$\bar{h}_1''(y) + S.Sc\bar{h}_1'(y) + Sc\cdot i\omega.\bar{h}_1(y) = 0 \tag{27}$$

Where, the primes denote the differentiation with respect to y. The corresponding boundary conditions can be written as,

$$y = 0;\ f_1 = \bar{f}_1 = \frac{1}{2};\ g_1 = 0;\ \bar{g}_1 = 1;\ h_1 = 0;\ \bar{h}_1 = 1 \tag{28}$$

$$y \to \infty;\ f_1 \to 0;\ \bar{f}_1 \to 0;\ g_1 \to 0;\ \bar{g}_1 \to 0;\ h_1 \to 0;\ \bar{h}_1 \to 0 \tag{29}$$

Applying the prescribed boundary conditions (28) and (29) to the equations (22) to (27) their solutions are as follows,

$$g_1(y) = 0 \tag{30}$$

$$\bar{g}_1(y) = (1+A_3)\exp(-A_2 y) - A_3\exp(-A_1 y) \tag{31}$$

$$h_1(y) = 0 \tag{32}$$

$$\bar{h}_1(y) = \exp(-A_1 y) \tag{33}$$

$$f_1(y) = \left(\frac{1}{2}\right)\exp(-A_4 y) \tag{34}$$

$$\bar{f}_1(y) = \left(\left(\frac{1}{2}\right) + A_6 - A_7 + A_8\right)\exp(-A_5 y) - A_6\exp(-A_2 y) + A_7\exp(-A_1 y) - A_8\exp(-A_1 y) \tag{35}$$

Substituting the determined unknowns (30) to (35) into the equations (19) to (20), the velocity, temperature and concentration distributions in the boundary layer becomes,

$$u(y,t) = \left(\begin{array}{l} \left(\left(\frac{1}{2}\right)\exp(-A_4 y)\right)e^{i\omega t} + \\ \left(\begin{array}{l} \left(\left(\frac{1}{2}\right) + A_6 + A_7 - A_8\right)\exp(-A_5 y) - A_6 \exp(-A_2 y) \\ + A_7 \exp(-A_1 y) - A_8 \exp(-A_1 y) \end{array} \right) e^{-i\omega t} \end{array} \right)$$

$$\theta(y.t) = ((1 + A_3)\exp(-A_2 y) - A_3(\exp - A_1 y))e^{-i\omega t}$$

$$\phi(y.t) = \exp(-A_1 y)e^{-i\omega t}$$

Where,

$$A_1 = \frac{S.Sc + \sqrt{(S\cdot Sc)^2 - 4Sc\cdot i\omega}}{2}$$

$$A_2 = \frac{\alpha S + .\sqrt{(S.\alpha)^2 - 4i\omega.\alpha}}{2}$$

$$A_3 = \frac{Df.\alpha}{A_1^2 + S.\alpha A_1 + i\omega.\alpha}$$

$$A_4 = \frac{S + \sqrt{S^2 + 4\left(i\omega + \left(M^2 + \frac{1}{Da}\right)\right)}}{2}$$

$$A_5 = \frac{S + \sqrt{S^2 - 4\left(i\omega - \left(M^2 + \frac{1}{Da}\right)\right)}}{2}$$

$$A_6 = \frac{Gr(1 + A_3)}{A_2^2 + SA_{21} + \left(i\omega - \left(M^2 + \frac{1}{Da}\right)\right)}$$

$$A_7 = \frac{Gm(A_3)}{A_1^2 + SA_1 + \left(i\omega - \left(M^2 + \frac{1}{Da}\right)\right)}$$

$$A_8 = \frac{Gm}{A_1^2 - SA_1 + \left(i\omega - \left(M^2 + \frac{1}{Da}\right)\right)}$$

Skin- Friction

The Skin-Friction at the plate, which in the non-dimensional form is given by

$$C_f = \left(\frac{\partial u}{\partial y}\right)_{y=0} = -\frac{1}{2}A_4 e^{i\omega t} + \left(\begin{array}{l} -A_5\left(\frac{1}{2} + A_6 - A_7 + A_8\right) + \\ A_2 A_6 + A_1 A_7 - A_1 A_8 \end{array} \right) e^{-i\omega t}$$

Nusselt Number

The non-dimensional co-efficient of heat transfer defined by Nusselt number is obtain and given by

$$Nu = -\left(\frac{\partial \theta}{\partial y}\right)_{y=0} = (A_2(1 + A_3) - A_1 A_3)e^{-i\omega t}$$

Sherwood Number

The non-dimensional co-efficient of heat transfer defined by Sherwood number is obtain and given by

$$Sh = -\left(\frac{\partial \phi}{\partial y}\right)_{y=0} = (A_1)e^{-i\omega t}$$

3.RESULT AND DISCUSSION

In order to get physical insight into the problem, we have calculated the velocity field, temperature field, concentration field, coefficient of skin friction C_f at the rate of heat transfer in terms of Nusselt number N_u and the rate of mass transfer in terms of Sherwood number $S_h$by assigning specific values to the different values to the parameters involved in the problem, viz., Magnetic field parameter M, Grashof number for heat transfer G_r, Suction parameter S, Darcy number Da, Prandtl number P_r, Radiative parameter R, Schmidt number S_c and Dufour number Du, time t. In the present study, the following default parametric values are adopted. G_r= 5.0, S= 0.5, M= 5, P_r= 1, R= 2.0, S_c= 0.03, D_f = 0.02, Da= 0.1, t=1.

The variation of velocity profiles with respect to the suction parameter S, From this Figure 1, It is observed that velocity decrease for the increasing values of Suction parameter for heat transfer S.

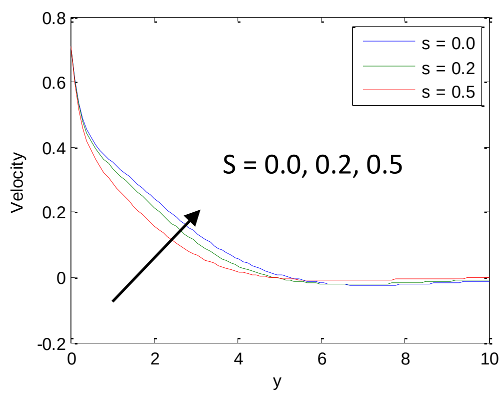

Fig 1. Velocity profiles for different values of s [G_r = 5, M = 5, R = 2, S_c = 0.3, D_f = 0.2, G_m = 3, t = 1, D_a = 0.1, P_r = 1, ωt = 3.14/4]

The variation of velocity profiles with respect to the positive value of Grashof number G_r, From this figure 2, It is observed that velocity increase for the increasing values of Grashof number for heat transfer G_r.

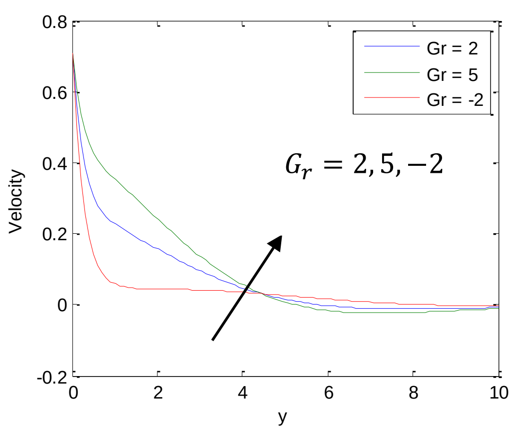

Fig 2.Velocity profiles for different values of Gr [G_r = 5, M = 5, R = 2,S_c = 0.3, D_a = 0.1, G_m = 3, s = 0.0, P_r = 1, t = 1, ω = 3.14/4]

The temperature profiles for different values of suction parameter S are plotted in Fig 3. The analytical results show that the positive values of suction parameter correspond to cooling of the plate increases temperature decrease

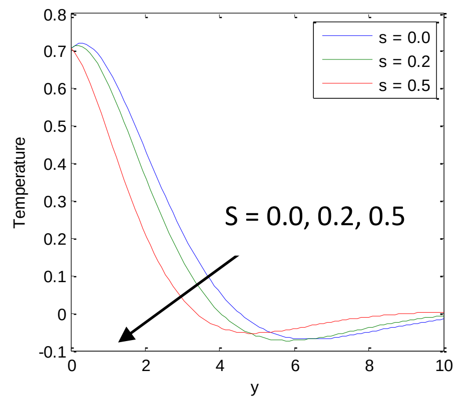

Fig 3. Temperature profiles for different values of S [S=2, t = 1, S_c = 0.3, D_f = 0.2, P_r = 1, ωt = 3.14/4]

The temperature profiles for different values of the Dufour number D_f, From this figure 4, The analytical results show that the effect of increasing values of Dufour number results in a increasing temperature.

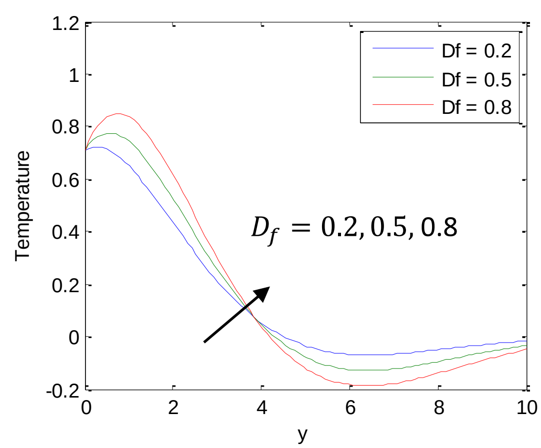

Fig4. Temperature profiles for different values of Du [t = 1, R = 2, S = 0.0, S_c = 0.03, P_r = 1, ωt = 3.14/4]

The concentration profiles for different values of Schmilt number S_c are plotted in Fig 5. The analytical results show that the effect of increasing Schmilt number decreases the concentration profile.

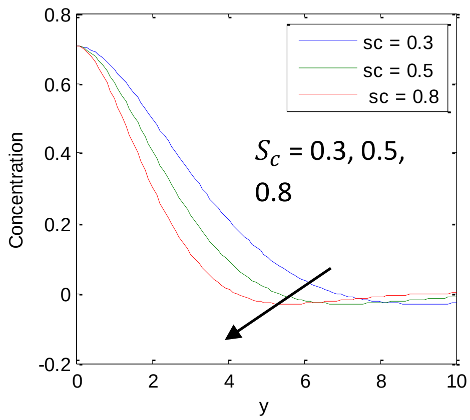

Fig 5. Concentration profiles for different values of S_c [s = 0, t = 1, ωt = 3.14/4]

For various values of suction parameter S, the concentration profile is plotted in Fig 6. Clearly as S increases, the concentration decreases.

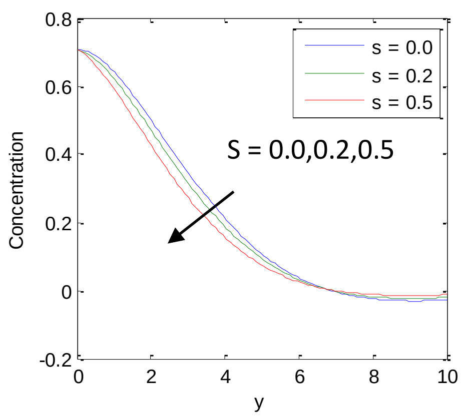

Fig 6. Concentration profiles for different values of S[t = 1, s_c = 0.3, ωt = 3.14/4]

4. CONCLUSION

The Dufour effects on flow and heat transfer over a vertically oscillating porous flat plate embedded in porous medium with oscillating surface temperature. The leading governing equations are solved analytically by perturbation method. We presented the results to illustrate the flow characteristics for the velocity, temperature and concentration and have shown how the flow fields are influenced by the material parameters of the flow problem. We can conclude from these results that ,An increase in G_r, and S increases the velocity field, while an increase in M, R, Da, P_r, and Du increases the velocity field. An increase in S increases the temperature distribution, while an increase in P_r, Sc, and Du decrease the temperature distribution. An increase in S, and Sc decreases the concentration distribution, while an increase in Dc decreases the concentration distribution.

5. REFERENCES

[1] Ahmed. N, and H. K. Saramah, The Radiation Effect on a Transient MHD Flow Mass Transfer Past an Impulsively Fixed Infinite Vertical Plate, International Journal of Applied Mathematics and Mechanics, Vol 5, No 5, pp 87-98. 2009.

[2] Balamurugan. K, and R.Karthikeyan, Radiation Effects of MHD Oscillatory Rotation Flow Through a Porous Medium Bounded by Two Vertical Porous Plate in the Presence of Hall. Vol 4, pp, 47-56. 2016.

[3] EI-Arabawy, H.A.M. Effects of Suction/ Injection on the Flow of a Micro Polar Fluid Post a Continuously Moving Plate in the Presence of Radiation. International Journal of Heat and Mass Transfer, 46, pp, 1471-1477. 2003.

[4] Helmay, K.A, MHD unsteady Free Convection Flow Past a Vertical Porous Plate. Vol 78, pp, 255-270. 1998.

[5] Hussain.M.A, and H.S.Takhar, Radiation Effect on Mixed Convection along a Vertical Plate in Presence of Heat Generation or Absorption, Journal of Heat Transfer, Vol 31, pp, 243-248. 1996.

[6] Lalitha.P, S.V.K.Varma, V.Manjulatha, V.C. Raju Dufour and Thermal Radiation Effects of Kuvshinski Fluid on Double Diffusive and Convective MHD Heat and Mass Transfer Flow Past a Porous Vertical Plate in the Presence of Radiation Absorption, Viscous Dissipation and Chemical Reaction. Journal of Progressive Research in Mathematics, pp, 995-1014. 2016

[7] Mansour, M.A. Radiation and Free Convection Effects on the Oscillatory Flow Past a Vertical Plate. Astrophysics and Space Science, Vol 166, pp, 269-275. 1990.

[8] Mohammed Ibrahim. S, Sankar Reddy. T, Roja. P, Radiation Effects on Unsteady MHD Free Convective Heat and Mass Transfer Flow Of Past a Vertical Porous Plate Embedded In a Porous Medium with Viscous Dissipation. International Journal of Innovative Research in Science, Engineering and Technology, Issue 11, Vol. 3. 2014.

[9] Rajesh.V, and S. V. K. Varma, Radiation Effects on MHD Flow Through a Porous Medium with Variable Temperature and Mass Diffusion, Vol 6, No. 11, pp, 39-57. 2010.

[10] Rajput.U.S, and S.Kumar, Radiation Effects on MHD Flow An Impulsively Started Vertical Plate with Variable Heat and Mass Transfer. Vol 8(1), pp, 66-85. 2011.

[11] Samad. A. M. D, and M. M. Rahman, Thermal Radiation Interaction with Unsteady MHD Flow Past a Vertical Porous Plate Immersed in a Porous Medium. Vol 3, No.1, pp, 7-14. 2006.

[12] Sasi kumar.J, A. Govindarajan, Free Convective MHD Oscillatory Flow Past Parallel Plates in a Porous Medium with Heat Source and Chemical Reaction. Vol 6, Issue 3. 2015.

[13] Sooraj Pal Singh., Effect Of Radiation On Unsteady Laminar Free Convective Flow Along A Porous Hot Vertical Plate In The Presence Of Heat Source With Mass Transfer In Rotating System. International Journal of Mathematical Archive. 4(8), pp, 303-311. 2013.

[14] Soundalgekar.V.M, Free Convection Effects on the Flow Past an Infinite Vertical Oscillating Plate. Vol 64, pp, 165-171. 1979.

[15] Soundalgekar, V.M and Takhar, H.S. Radiation Effects on Free Convection Flow Past a Semi-Infinite Vertical Plate, Modeling, Measurement and Control, B51, pp, 31-40. 1993.

[16] Pal.D and H. Mondal, Radiation Effects on Combined Convection over a Vertical Flat Plate Embedded in a Porous Medium of Variable Porosity, Vol 44, No. 2, pp, 133-144. 2009.

[17] Monika Miglani, Net Ram Garg, Mukesh Kumar Sharma (2016) Radiative effect on flow and heat transfer over a vertically oscillating porous flat plate embedded in porous medium with oscillating surface temperature. Open Journal of Fluid Dynamics. 119-129.