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Mass Diffusion Effect on Magneto Hydrodynamic (MHD) Unsteady Free Convective Flow with Viscous Dissipation and Radiation Absorption

P. Vijayakumari[1], K. Venkata Ramana[2,*], Kotha Gangadhar[1], and Ali J. Chamkha[3]

[1]*Department of Mathematics, Acharya Nagarjuna University Campus, Ongole 523001, Andhra Pradesh, India*
[2]*Department of Mathematics, Vardhaman College of Engineering, Kacharam, Shamshabad, Hyderabad 501218, Telangana, India*
[3]*Faculty of Engineering, Kuwait College of Science and Engineering, Doha District, 35004, Kuwait*

The current research analyzed unsteady viscous dissipation, comprehensive radiation absorption consequence on hydrodynamic free-convective movement on perpendicular porous plate beyond chemical reaction and heat generation. Doufour effect is also introduced to solve utilizing multiple perturbation law momentum, heat and mass fields of outcome are inspected through pertinent parameters. Doufour consequence and comprehensive thermal radiation enhances it tends to enhance in duel temperature. Skinfriction, Nusselt number is diminished when enhancing Prandtl number. Skinfriction, Sherwood number and Nusselt number are examined.

KEYWORDS: Doufour, Perturbation, MHD, Prandtl Number, Viscous Dissipation, Radiation.

1. INTRODUCTION

In engineering and technological applications free-convective movement of comprehensive incompressible viscous liquid occurs at high θ. Impact of radiation is lead to focused applications. The important applications are explored by the Impact of radiation. The organ systems and medical science takes a unbelievable importance in magneto science. Magnetic resources for bio-waste fluids transporting, targeting of magnetic drug, during surgery the regulation of the blood flow, gastro intestinal disorders are controlled by hydrodynamic field. magnetic endoscopy, treatment for cancer tumour and cell death by hyperthermia are the examples of MHD the out standing implications of MHD are in magnetic endoscopy, treatment of cancer tumour and cell death by the hyperthermia. When MHD is induced in to a magnetic field the conducting fluid is heighly. The resistive type of force is generated between induced currents and exerted magnetic field. Magnetic field is applied in many biological devices. Magnetically driven blood pump. Biological fluids flow affect the magnetically driven blood pump devices. Ramzan et al.[1] with duel stratification elaborates analytical outcomes of MHD Powell-Eyring nanofluid activation with duel stratification. Zeeshan et al.[2] used HAM procession in hydrodynamic nanofluid behaviour in a micro channel. Raja kumar et al.[3] illustrates the stable MHD mixed convective, comprehensive viscous dissipative Newtonian fluid movement beyond an unlimit perpendicular porous plate at the attention of soret impact. Raja kumar et al.[4] deliberates the Dufour constitution as well as thermal energy on detail unsteady hydrodynamic Walter's Liquid Model-B movement past beyond started unlimit perpendicular plate. Raja kumar et al.[5] illustrates deportment of liquid momentum, heat and mass. And also examined skin friction, Sherwood, Nusselt coefficients. Raja kumar et al.[6] illustrates the Dufour constitution and comprehensive thermal radiation enlarge it tends to enhance duel momentum and heat. An enlarge in duel chemical reactions, Schmidt coefficient, tends to diminishes in mass. Raja kumar et al.[7] deliberates the Dufour consequence, comprehensive viscous dissipation influences on detail Unsteady hydrodynamic free convective Newtonian liquid movement beyond vertical porous plate. Raja kumar et al.[8] illustrates the Radiation as well as viscous dissipation influences on Magnetohydrodynamic free convective movement past a semi-unlimit rotating porous plate. Hazarika and Ahmed[9] illustrates the distinct of viscosity on hdrodynamic convective flow beyond a non-isothermal perpendicular plate.

Role of Nano fluids to improve heat execution adding solid nanoparticles to the working fluids. Hazarika and Ahmed[10] discuss the influence of Skinfriction, nusselt coefficient and Sherwood coefficient. Hazarika et al.[11] investigated the chemical reaction of hydromagnetic movement by volume fraction and thermal diffusion. Hazarika and Ahmed[12] describes angular momentum is elevated

*Author to whom correspondence should be addressed.
Email: ramana.may@gmail.com
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surface of the detail sphere. Hazarika and Chamka[13] illustrates the consequence of nanoparticles identified in industry and engineering area. Hazarika et al.[14] investigate the constitutions of nanofluid momentum and heat expressions. Hazarika and Ahmed[15] plotted the nature of constants on micropolar liquid movement to velocity, micro-rotation and radial velocity. Hazarika and Chamka[16] describes the analytical model depends on the momentum, heat as well as pressure is improved non-linear partial constitution. Perfectancy of the processes are illustrated. Hazarika and Ahmed[17] describes the chemically reacting comprehensive viscous-liquid of a conducting gas beyond a perpendicular porous surface. Zueco et al.[18] investigated the 2-D detail unsteady free convective heat and mass movement be accelerate semi-unlimit perpendicular porous plate with comprehensive thermal diffusion in attention of hdrodnamic field, heat and Soret consequences accept into account the induced electrically conducting field. Ahmed et al.[19] illustrated non-linear hydromagnetic movement with heat and mass process attributes of an incompressible, Boussinesq's fluid beyond a perpendicular plate. Ahmed and Lopez-Gonzalez[20] describes the stable mixed convective movement of an incompressible, electrically-conducting liquid over an unlimit perpendicular porous plate with chemical reaction of single order. Ahmed et al.[21] analysed the upward Reynolds coefficient or magnetic coefficient upgrades the horizontal coefficient and diminishes the the skin-friction.

Connection between energy flux and θ gradient Fourier's law described by Fourier's and Fick's law are applied for the correlation of concentration gradient. The θ due to the composition gradient is termed to be the Dufour which is otherwise said to be diffusion thermos effect. Gbadeyan et al.[22] illustrated the uniform β_0 act transversely to the walls. Rasool et al.[23] solved the final equation through investigation of the numerical approach by uilizing RK45 with shooting approach. Nagaraju et al.[24] examined the annular region by cylinders with soret and dufour effect. Moorthy and Senthilvadivu[25] illustrated the heat and mass procedure attributes of natural convection beyond perpendicular surface in a porous medium. Arifuzzaman et al.[26] examined the unsteady upgrade order comprehensive chemically reactive hydrodynamic movement with the impact of heat absorption.

Current analysis is mass diffusion impact on MHD detail unsteady free convective movement with viscous dissipation and radiation absorption. This current attempt analytically using multiple perturbation law. Results for u, θ, ϕ fields are analyzed through pertinent parameters.

2. MATHEMATICAL FORMULATION

2D, unsteady, η-electrically conducting fluid, moving, porous plate with double-diffusive comprehensive thermal radiation, thermal diffusion is shown in Figure 1.

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- The x_a-direction is acts as porous plate in perpendicular direction and the y_a-direction flow acts as perpendicular way.
- Duel x_a and y_a are distances of porous plate, and t_a represents dimensional time. Where u_a, v_a represents dimensional velocities.
- $Q_0\left(T_a - T_{a_\infty}\right)$ is η per unit volume Q_0 is a constant. ($Q_0 \prec 0$ or $Q_0 \succ 0$)
- C_a, g_a are the dimensional C.
- Porous plate rotates with u_{a_p}, U_{a_∞}.

The unsteady flow is establishing by PDE:

Equation of momentum:

$$\frac{\partial v_a}{\partial y_a} = 0 \tag{1}$$

Equation of velocity:

$$\frac{\partial u_a}{\partial t_a} + v_a \frac{\partial u_a}{\partial y_a} = -\frac{1}{\rho}\frac{\partial p_a}{\partial x_a} + \vartheta \frac{\partial^2 u_a}{\partial {y_a}^2} + g\beta(T_a - T_{a_\infty}) + g\beta(C_a - C_{a_\infty}) - \frac{\vartheta}{K_a} u_a - \frac{\sigma}{\rho} B_0^2 u_a \tag{2}$$

Equation of energy:

$$\frac{\partial T_a}{\partial t_a} + v_a \frac{\partial T_a}{\partial y_a} = \frac{K}{\rho C_p}\frac{\partial^2 T_a}{\partial y_a^2} + \frac{D_m K_T}{C_s C_p}\left[\frac{\partial^2 C_a}{\partial y_a^2}\right] + \frac{Q_0}{\rho C_p}(T_a - T_{a_\infty}) - \frac{1}{K\rho C_p}\frac{\partial q_{a_\infty}}{\partial y_a} + \frac{\vartheta}{C_p}\left(\frac{\partial u_a}{\partial y_a}\right)^2 + R^*\left(C_a - C_{a_\infty}\right) \tag{3}$$

Equation of mass:

$$\frac{\partial C_a}{\partial t_a} + v^* \frac{\partial C_a}{\partial y_a} = D\frac{\partial^2 C_a}{\partial y_a^2} - K_r(C_a - C_{a_\infty}) \tag{4}$$

The boundary constitutions are:

$$\begin{aligned} u_a &= U_{a_p}, \quad T_a = T_{a_w} + \varepsilon(T_{a_w} - T_{a_\infty})e^{n_a t_a}, \\ C_a &= C_{a_w} + \varepsilon(C_{a_w} - C_{a_\infty})e^{n_a t_a} \quad \text{at} \quad y_a = 0 \\ U_a &= U_{a_\infty} = U_0(1 + \varepsilon e^{n_a t_a}),\ T_a \to T_{a_\infty}, \\ C_a &\to C_{a_\infty} \quad y_a \to \infty \end{aligned} \tag{5}$$

Where T_{a_w} represents wall-dimensional T, C_{a_w} represents concentration, C_{a_∞} represents free stream dimensional C, U_0, n_a represents constants.

$$v_a = -v_0(1 + \varepsilon A e^{n_a t_a}) \tag{6}$$

From the (1)

$$-\frac{1}{\rho}\frac{\partial p_a}{\partial x_a} = \frac{dU_{a_\infty}}{dt_a} + \frac{\vartheta}{k_a}U_{a_\infty} + \frac{\sigma}{\rho}B_0^2 U_{a_\infty} \tag{7}$$

By depleting Eq. (7) in (2) we get,

$$\frac{\partial u_a}{\partial t_a} + v_a \frac{\partial u_a}{\partial y_a} = \frac{dU_{a_\infty}}{dt_a} + \vartheta \frac{\partial^2 u_a}{\partial {y_a}^2} + g\beta(T_a - T_{a_\infty}) + g\beta(C_a - C_{a_\infty}) + \frac{\vartheta}{K_a}\left(U_{a_\infty} - u_a\right) + \frac{\sigma}{\rho}B_0^2\left(U_{a_\infty} - u_a\right) \tag{8}$$

The radiative heat flux utilizing Rosseland approximation is mentioned by

$$q_{a_r} = -\frac{4\sigma_{a_s}}{3k_{a_e}}\frac{\partial T_a^4}{\partial y_a} \tag{9}$$

$$T_a^4 \cong 4T_a T_\infty^3 - 3T_{a_\infty} \tag{10}$$

By depleting Eqs. (9) and (10) in (3), we get

$$\frac{\partial T_a}{\partial t_a} + v_a\frac{\partial T_a}{\partial y_a} = \frac{K}{\rho C_p}\frac{\partial^2 T_a}{\partial y_a^2} + \frac{D_m K_T}{C_s C_p}\left[\frac{\partial^2 C_a}{\partial y_a^2}\right] + \frac{Q_0}{\rho C_p}(T_a - T_{a_\infty}) + \frac{16\sigma_{a_s} {T_{a_\infty}}^3}{3\rho C_p k_{a_e}}\frac{\partial^2 T_a}{\partial {y_a}^2} + \frac{\vartheta}{C_p}\left(\frac{\partial u_a}{\partial y_a}\right)^2 + R_a\left(C_a - C_{a_\infty}\right) \tag{11}$$

Now, nondimensional Eq. are taken as:

$$u = \frac{u_a}{U_0},\quad v = \frac{v_a}{V_0},\quad U_\infty = \frac{U_{a_\infty}}{U_0},\quad y = \frac{V_0 y_a}{\vartheta},$$
$$U_p = \frac{u_{a_p}}{U_0},\quad t = \frac{V_0^2 t_a}{\vartheta},\quad K_a = \frac{K\vartheta^2}{V_0^2},\quad n_a = \frac{V_0^2 n}{\vartheta},$$
$$T_a = T_{a_\infty} + \theta(T_{a_w} - T_{a_\infty}),$$
$$C_a = C_{a_\infty} + \phi(C_{a_w} - C_{a_\infty}) \tag{12}$$

Substituting these boundary conditions in Eqs. (4), (8) and (11) and taking into Eq. (6) we get

$$\frac{\partial u}{\partial t} - (1 + \varepsilon A e^{nt})\frac{\partial u}{\partial y} = \frac{dU_\infty}{dt} + \frac{\partial^2 u}{\partial y^2} + Gr\theta + GmC + N(U_\infty - u) \tag{13}$$

$$\frac{\partial \theta}{\partial t} - (1 + \varepsilon A e^{nt})\frac{\partial \theta}{\partial y} = D_r\frac{\partial^2 C}{\partial y^2} + (\mathrm{Pr})^{-1}\left(1 + \frac{4R}{3}\right)\frac{\partial^2 \theta}{\partial y^2} + \eta\theta + Ec\left(\frac{\partial u}{\partial y}\right)^2 + RaC \tag{14}$$

$$\frac{\partial C}{\partial t} - (1 + \varepsilon A e^{nt})\frac{\partial C}{\partial y} = (Sc)^{-1}\frac{\partial^2 C}{\partial y^2} - K_r C \tag{15}$$

Initial and boundary conditions represented by Eq. (5) in dimension less form are:

$$\text{At } y = 0,\quad u = u_p,\quad \theta = 1 + \varepsilon e^{nt},\quad C = 1 + \varepsilon e^{nt}$$
$$\text{As } y \to \infty,\quad u = U_\infty,\quad \theta \to 0,\quad C \to 0 \tag{16}$$

where $Gr = (\vartheta\beta g(T_w^* - T_\infty^*))/(V_0^2 U_0)$, $Gm = (\vartheta\beta^* g(C_w^* - C_\infty^*))/(V_0^2 U_0)$, $M = (\sigma B_0^2)/(\rho V_0^2)$, $\eta = (\vartheta Q_0)/(\rho V_0^2 C_P)$, $D_r = (D_m K_T(C_w^* - C_\infty^*))/(\vartheta C_s C_p(T_w^* - T_\infty^*))$

$$N = M + \frac{1}{K},\quad \mathrm{Pr} = \frac{\rho\vartheta C_p}{k},\quad Ec = \frac{U_0^2}{C_p(T_w^* - T_\infty^*)},$$
$$R = \frac{4\sigma {T_\infty^*}^3}{k_e k},\quad Sc = \frac{\vartheta}{D},\quad Ra = \frac{R^*\vartheta(C_w^* - C_\infty^*)}{V_0^2(T_w^* - T_\infty^*)},$$
$$K_r = \frac{k_1\vartheta}{V_0^2} \tag{17}$$

3. METHOD OF SOLUTION

To obtain the solutions of the beyond scheme of PDE Eqs. (4), (8) and (11) under the boundary conditions (17), we assume the perturbation technique.

$$u = u_0(y) + \varepsilon e^{nt}u_1(y)$$
$$\theta = \theta_0(y) + \varepsilon e^{nt}\theta_1(y)$$
$$c = c_0(y) + \varepsilon e^{nt}c_1(y) \tag{18}$$

Effect of Eq. (18), Eqs. (13)–(15) are modified in to harmonic and nonharmonic terms, and abanding coefficients of higher order $o(\in^2)$, resultant Eqs to (u_0, θ_0, C_0), (u_1, θ_1, C_1) are

$$u_0'' + u_0' - Nu_0 = -N - Gr\theta_0 - GmC_0 \tag{19}$$

$$u_1'' + u_1' - (N + n)u_1 = -(N + n) - Au_0' - Gr\theta_1 - GmC_1 \tag{20}$$

$$(3 + 4R)\theta_1'' + 3\,\mathrm{Pr}\,\theta_1' - 3\,\mathrm{Pr}(n - \eta)\theta_1 = -3\,\mathrm{Pr}\,A\theta_0' - 6Ec\,\mathrm{Pr}\,u_0'u_1' - 3\,\mathrm{Pr}\,RaC_1 + D_r\phi_1''\,\mathrm{Pr} \tag{21}$$

$$(3 + 4R)\theta_0'' + 3\,\mathrm{Pr}\,\theta_0' + 3\,\mathrm{Pr}\,\eta\theta_0 = -3\,\mathrm{Pr}\,Ec\left(\frac{\partial u_0}{\partial y}\right)^2 - 3\,\mathrm{Pr}\,RaC_0 + D_r\phi_0''\,\mathrm{Pr} \tag{22}$$

$$C_0'' + ScC_0' - ScK_rC_0 = 0 \tag{23}$$

$$C_1'' + ScC_1' - Sc(K_r + n)C_1 = -ScAC_0' \tag{24}$$

The revised boundary conditions can be written as:

$$u_0 = U_p,\quad u_1 = 0,\quad \theta_0 = 1,\quad \theta_1 = 1,\quad C_0 = 1,$$
$$C_1 = 1 \quad \text{at} \quad y = 0$$
$$u_0 = 1,\quad u_1 = 1,\quad \theta_0 \to 0,$$
$$\theta_1 \to 0,\quad C_0 \to 0 \quad \text{as} \quad y \to \infty \tag{25}$$

Represented by the equations from (19)–(22) are nonlinear and the results are not possible. To remove nonlinearity, enlarge $u_0, u_1, \theta_0, \theta_1$. Initially we solve Eqs. (23) and (24) by utilising Eq. (25). Then we get

$$C_0 = e^{-R_1 y} \tag{26}$$

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$$C_1 = e^{-R_2 y}(1-N_1) + e^{-R_1 y} N_1 \tag{27}$$

Now, utilising multiparameter perturbation methodology and taking $Ec \prec\prec 1$,

$$\begin{aligned} u_0 &= u_{00} + Ec u_{01} + 0(\varepsilon)^2 \\ \theta_0 &= \theta_{00} + Ec\theta_{01} + 0(\varepsilon)^2 \\ u_1 &= u_{10} + Ec u_{11} + 0(\varepsilon)^2 \\ \theta_1 &= \theta_{10} + Ec\theta_{11} + 0(\varepsilon)^2 \end{aligned} \tag{28}$$

By applying Eq. (28) in (19)–(22), we get the following set of differential equations by neglecting those of $(Ec)^2$ and $0(\in)^2$.

$$u_{00}'' + u_{00}' - N u_{00} = -N - Gr\theta_{00} - GmC_0 \tag{29}$$

$$u_{01}'' + u_{01}' - N u_{01} = -Gr\theta_{01} \tag{30}$$

$$u_{10}'' + u_{10}' - (N+n)u_{10} = -(N+n) - Au_{00}' - Gr\theta_{10} - GmC_1 \tag{31}$$

$$u_{11}'' + u_{11}' - (N+n)u_{11} = -Au_{01}' - Gr\theta_{11} \tag{32}$$

$$(3+4R)\theta_{10}'' + 3\Pr\theta_{10}' - 3\Pr(n-\eta)\theta_{10} = -3A\Pr\theta_{00}' - 3\Pr RaC_1 + D_r\phi_{11}''\Pr \tag{33}$$

$$(3+4R)\theta_{11}'' + 3\Pr\theta_{11}' - 3\Pr(n-\eta)\theta_{11} = -3A\Pr\theta_{01} - 6\Pr u_{00}' u_{10}' \tag{34}$$

$$(3+4R)\theta_{00}'' + 3\Pr\theta_{00}' + 3\eta\Pr\theta_{00} = -3\Pr RaC_0 + D_r\phi_{00}''\Pr \tag{35}$$

$$(3+4R)\theta_{01}'' + 3\Pr\theta_{01}' + 3\eta\Pr\theta_{01} = -3\Pr(u_{00}')^2 \tag{36}$$

The boundary conditions are:

$$\begin{aligned} &u_{00} = u_p,\quad u_{01}=0,\quad u_{10}=0,\quad u_{11}=0,\quad \theta_{00}=1,\\ &\theta_{01}=1,\quad \theta_{10}=1,\quad \theta_{11}=1 \quad \text{at} \quad y=0\\ &u_{00}=1,\quad u_{01}=0,\quad u_{10}=0,\quad u_{11}=0,\quad \theta_{00}=0,\\ &\theta_{01}=0,\quad \theta_{10}=0,\quad \theta_{11}=0 \quad \text{at} \quad y\to\infty \end{aligned} \tag{37}$$

With the help of Eq. (37), solving Eqs. (29)–(36), we get

$$u_{00} = A_0 e^{-R_4 y} + N_3 e^{-R_3 y} + N_4 e^{-R_1 y} + 1 \tag{38}$$

$$\begin{aligned} u_{01} = {} & A_2 e^{-R_4 y} + N_{11} e^{-R_3 y} + N_{12} e^{-2R_4 y} + N_{13} e^{-2R_3 y} \\ & + N_{14} e^{-2R_1 y} + N_{15} e^{-(R_3+R_4)y} + N_{16} e^{-(R_1+R_3)y} \\ & + N_{17} e^{-(R_1+R_4)y} \end{aligned} \tag{39}$$

$$\begin{aligned} u_{10} = {} & A_4 e^{-R_6 y} + N_{21} e^{-R_1 y} + N_{22} e^{-R_2 y} + N_{23} e^{-R_3 y} \\ & + N_{24} e^{-R_4 y} + N_{25} e^{-R_5 y} + 1 \end{aligned} \tag{40}$$

$$\begin{aligned} u_{11} = {} & A_6 e^{-R_6 y} + N_{42} e^{-R_4 y} + N_{43} e^{-R_3 y} + N_{44} e^{-2R_4 y} \\ & + N_{45} e^{-2R_3 y} + N_{46} e^{-2R_1} + N_{47} e^{-(R_3+R_4)y} \\ & + N_{48} e^{-(R_1+R_3)y} + N_{49} e^{-(R_1+R_4)y} + N_{50} e^{-R_6 y} \\ & + N_{51} e^{-(R_2+R_4)y} + N_{52} e^{-(R_2+R_3)y} + N_{53} e^{-(R_3+R_6)y} \\ & + N_{54} e^{-(R_1+R_6)y} + N_{55} e^{-(R_1+R_5)y} + N_{56} e^{-(R_4+R_6)y} \\ & + N_{57} e^{-(R_4+R_5)y} + N_{58} e^{-(R_3+R_5)y} + N_{59} e^{-(R_1+R_2)y} \end{aligned} \tag{41}$$

$$\theta_{00} = (1-N_2)4e^{-R_3 y} + N_2 e^{-R_4 y} \tag{42}$$

$$\begin{aligned} \theta_{01} = {} & A_1 e^{-R_3 y} + N_5 e^{-2R_4 y} + N_6 e^{-2R_3 y} + N_7 e^{-2R_1 y} \\ & + N_8 e^{-(R_3+R_4)y} + N_9 e^{-(R_1+R_3)y} \\ & + N_{10} e^{-(R_1+R_4)y} \end{aligned} \tag{43}$$

$$\theta_{10} = A_3 e^{-R_5 y} + N_{18} e^{-R_1 y} + N_{19} e^{-R_2 y} + N_{20} e^{-R_3 y} \tag{44}$$

$$\begin{aligned} \theta_{11} = {} & A_5 e^{-R_6 y} + N_{26} e^{-(R_2+R_4)y} + N_{27} e^{-(R_3+R_4)y} + N_{28} e^{-2R_4 y} \\ & + N_{29} e^{-(R_4+R_6)y} + N_{30} e^{-(R_4+R_5)y} + N_{31} e^{-(R_1+R_3)y} \\ & + N_{32} e^{-(R_2+R_3)y} + N_{33} e^{-2R_3 y} + N_{34} e^{-(R_3+R_6)y} \\ & + N_{35} e^{-(R_3+R_5)y} + N_{36} e^{-2R_1 y} + N_{37} e^{-(R_1+R_2)y} \\ & + N_{38} e^{-(R_1+R_6)y} + N_{39} e^{-(R_1+R_5)y} + N_{40} e^{-R_3 y} \\ & + N_{41} e^{-(R_1+R_4)y} \end{aligned} \tag{45}$$

Velocity, temperature and concentration values are obtained by using the Eqs. (13)–(15) and they are as follows.

$$\begin{aligned} u(y,t) = {} & \begin{pmatrix} A_0 e^{-R_4 y} + N_3 e^{-R_3 y} + N_4 e^{-R_1 y} + 1 + EcA_2 e^{-R_4 y} \\ + EcN_{11} e^{-R_3 y} + EcN_{12} e^{-2R_4 y} + EcN_{13} e^{-2R_3 y} \\ + EcN_{14} e^{-2R_1 y} + EcN_{15} e^{-(R_3+R_4)y} + \\ Ec3N_{16} e^{-(R_1+R_3)y} + EcN_{17} e^{-(R_1+R_4)y} \end{pmatrix} \\ & + \in e^{nt} \begin{pmatrix} A_4 e^{-R_6 y} + N_{21} e^{-R_1 y} + N_{22} e^{-R_2 y} + N_{23} e^{-R_3 y} \\ + N_{24} e^{-R_4 y} + N_{25} e^{-R_5 y} + 1 + EcA_6 e^{-R_6 y} \\ + EcN_{42} e^{-R_4 y} + EcN_{43} e^{-R_3 y} + EcN_{44} e^{-2R_4 y} \\ + EcN_{45} e^{-2R_3 y} + EcN_{46} e^{-2R_1 y} \\ + EcN_{47} e^{-(R_3+R_4)y} \\ + EcN_{48} e^{-(R_1+R_3)y} + EcN_{49} e^{-(R_1+R_2)y} \\ + EcN_{50} e^{-R_6 y} + EcN_{51} e^{-(R_2+R_4)y} \\ + EcN_{52} e^{-(R_2+R_3)y} + EcN_{53} e^{-(R_3+R_6)y} \\ + EcN_{54} e^{-(R_1+R_6)y} + EcN_{55} e^{-(R_1+R_5)y} \\ + EcN_{56} e^{-(R_4+R_6)y} + EcN_{57} e^{-(R_4+R_5)y} \\ + EcN_{58} e^{-(R_3+R_5)y} + EcN_{59} e^{-(R_1+R_2)y} \end{pmatrix} \end{aligned} \tag{46}$$

$$\begin{aligned} \theta(y,t) = {} & \begin{pmatrix} (1-N_2)\, e^{-R_3 y} + N_2 e^{-R_1 y} + EcA_1 e^{-R_3 y} + EcN_5 e^{-2R_4 y} \\ + EcN_6 e^{-2R_3 y} + EcN_7 e^{-2R_4 y} + EcN_8 e^{-(R_3+R_4)y} \\ + EcN_9 e^{-(R_1+R_3)y} + EcN_{10} e^{-(R_1+R_4)y} \end{pmatrix} \\ & + \in e^{nt} \end{aligned}$$

$$\times\begin{pmatrix} A_3e^{-R_5y}+N_{18}e^{-R_1y}+N_{19}e^{-R_2y}+N_{20}e^{-R_3y} \\ +EcA_5e^{-R_6y}+EcN_{26}e^{-(R_2+R_4)y}+EcN_{27}e^{-(R_3+R_4)y} \\ +EcN_{28}e^{-2R_4y}+EcN_{29}e^{-(R_4+R_6)y}+EcN_{30}e^{-(R_4+R_5)y} \\ +EcN_{31}e^{-(R_1+R_3)y}+EcN_{32}e^{-(R_1+R_3)y}+EcN_{33}e^{-2R_3y} \\ +EcN_{34}e^{-(R_3+R_6)y}+EcN_{35}e^{-(R_3+R_5)y}+EcN_{36}e^{-2R_1y} \\ +EcN_{37}e^{-(R_1+R_2)y}+EcN_{38}e^{-(R_1+R_6)y} \\ +EcN_{39}e^{-(R_1+R_5)y}+EcN_{40}e^{-R_3y}+EcN_{41}e^{-(R_1+R_4)\,y} \end{pmatrix} \tag{47}$$

$$C\,(y,\ t)\ =\ e^{-R_1y}+\in e^{nt}\left(e^{-R_2y}\,(1-N_1)+e^{-R_1y}N_1\right) \tag{48}$$

Now we calculate τ_w, Nu, Sh as follows:

$$\tau_w=\frac{\partial u}{\partial y}|_{y=0}$$

$$=\begin{pmatrix} -R_4A_0-R_3N_3-R_1N_4-R_4EcA_2 \\ -R_3EcN_{11}-2R_4EcN_{12}-2R_3EcN_{13} \\ -2R_1EcN_{14}-(R_3+R_4)EcN_{15}-(R_1+R_3)EcN_{16} \\ -(R_1+R_4)EcN_{17} \end{pmatrix}$$

$$+\in e^{nt}$$

$$\times\begin{pmatrix} -R_6A_4-R_1N_{21}-R_2N_{22}-R_3N_{23}-R_4N_{24}-R_5 \\ N_{25}-R_6EcA_6-R_4EcN_{42}-R_3EcN_{43}-2R_4EcN_{44} \\ -2R_3EcN_{45}-2R_1EcN_{46}-(R_3+R_4)EcN_{47} \\ -(R_1+R_3)EcN_{48}-(R_1+R_2)N_{49}-R_6EcN_{50} \\ -(R_2+R_4)EcN_{51}-(R_2+R_3)EcN_{52} \\ -(R_3+R_6)EcN_{53}-(R_1+R_6)EcN_{54} \\ -(R_1+R_5)EcN_{55}-(R_4+R_6)EcN_{56} \\ -(R_4+R_5)EcN_{57}-(R_3+R_5)EcN_{58} \\ -(R_1+R_2)EcN_{59} \end{pmatrix} \tag{49}$$

$$Nu=\frac{\partial\theta}{\partial y}|_{y=0}$$

$$=\begin{pmatrix} -R_3(1-N_2)-R_1N_2-R_3EcA_1-2R_4EcN_5 \\ -2R_3EcN_6-2R_1EcN_7-(R_3+R_4)EcN_8 \\ -(R_1+R_3)EcN_9-(R_1+R_4)EcN_{10} \end{pmatrix}$$

$$+\in e^{nt}$$

$$\cdot\begin{pmatrix} -R_5A_3-R_1N_{18}-R_2N_{19}-R_3N_{20}-R_6EcA_5 \\ -(R_2+R_4)EcN_{26}-(R_3+R_4)EcN_{27} \\ -2R_4EcN_{28}-(R_4+R_6)EcN_{29}-(R_4+R_5) \\ \times EcN_{30}-(R_1+R_3)EcN_{31}-(R_1+R_3)EcN_{32} \\ -2R_3EcN_{33}-(R_3+R_6)EcN_{34}-(R_3+R_5) \\ \times EcN_{35}-2R_1EcN_{36}-(R_1+R_2)EcN_{37} \\ -(R_1+R_6)EcN_{38}-(R_1+R_5)EcN_{39} \\ -R_3EcN_{40}-(R_1+R_4)EcN_{41} \end{pmatrix} \tag{50}$$

$$Sh=\frac{\partial C}{\partial y}|_{y=0}=-R_1-\varepsilon e^{nt}R_2(1-N_1)-\varepsilon e^{nt}R_1N_1$$

4. RESULTS AND DISCUSSION

This segment follows the above section which established the Ra, viscous dissipation effects, thermal radiation, thermal diffusion, Doufour, MHD convective flow. $n=0.5$, $\in=0.2$, $A=0.5$, $u_p^*=0.5$, $D_r=0.5$, $t=1.0$.

K_r on u is explained in Figure 2. As the current of K_r significantly effects velocity portrait. In this process K_r enhances the decreasing trend is observed in current portrait. The presence abnormal output of the u occurs on the fluid.

Figure 3 illuminate the significance of M on resultant u, Magnetic field activation is observed in Figure 2. Input values are acts as a ramping way. Magnetic performance is diminished in u. An impact of magnetic field on the liquid which is electrically conducted gives resistive force known as Lorentz force. In boundary layer area fluid motion is go up.

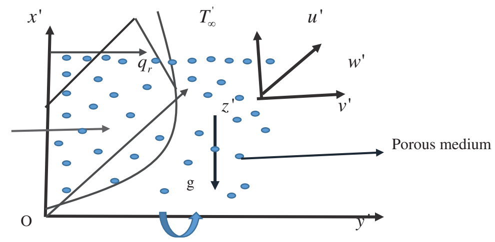

Fig. 1. Schematic diagramme.

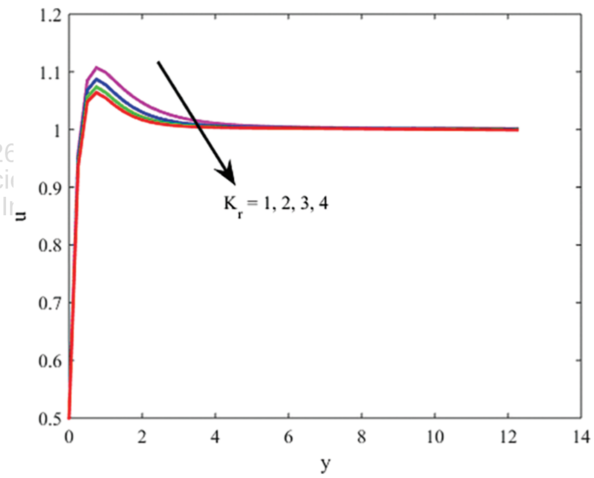

Fig. 2. Velocity portrait with K_r.

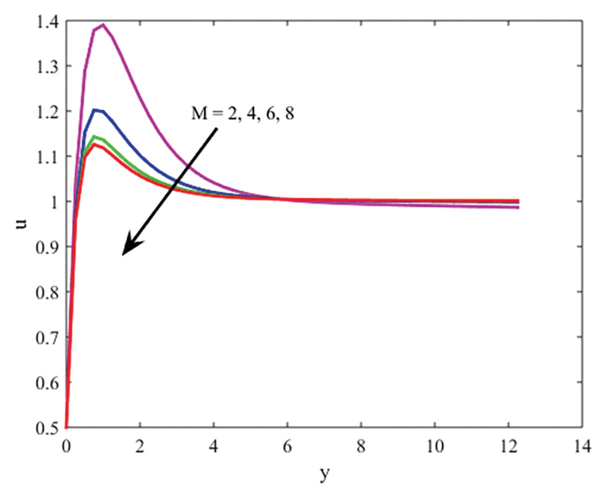

Fig. 3. Velocity portrait with M.

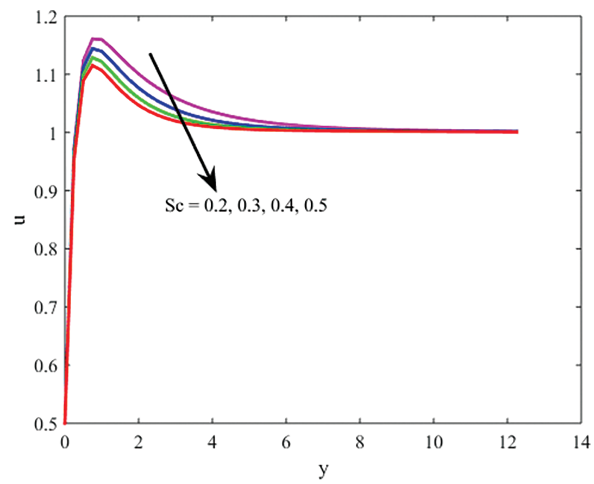

Fig. 4. Velocity portrait with Sc.

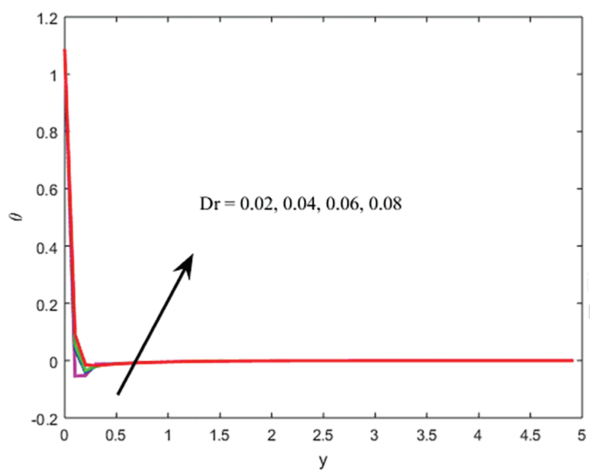

Fig. 5. Temperature portrait with D_r.

Various results of Sc impacts u is plotted in Figure 4. The outcome result of Sc enhanced when the values of Sc are increased. The outcomes of Sc the disparate species contains oxygen ($Sc = 0.60$) along with carbon dioxide ($Sc = 0.94$). The discrepancies in temperature with y for distinct outcomes in Dufour consequence D_r is illustrate in Figure 5. It reflects the enhancement in D_r the fluid θ is enhanced.

Figure 6 illustrates when enhancing in R causes the enhance in θ also. The fluid absorbs the heat which causes to enhance the θ with the boundary-layer thickness. It enhances in the R enhance in the interaction in the thermal boundary. In addition, huge impacts of R released large amount of heating to the nanofluid which enhances the nanofluid θ portrait.

Figure 7 deliberates the Pr performance on θ. Pr Augmenting give a decay to the profiles of θ. The material thermal conductivity is diminish for larger Prandtl values. At lower θ thermal conductivity act as equal performance

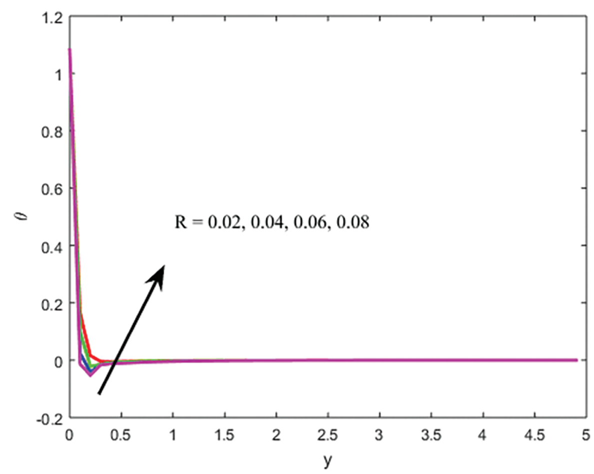

Fig. 6. Temperature portrait with R.

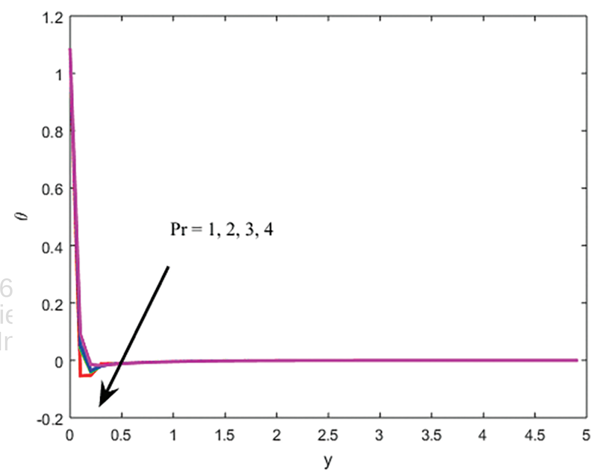

Fig. 7. Temperature portrait with Pr.

θ. The enlarger thermal relaxation time-based parameter augments the θ.

Figure 8 shows the enhancing behaviour of Sc when concentration is diminished. Figure 8 enplanes the

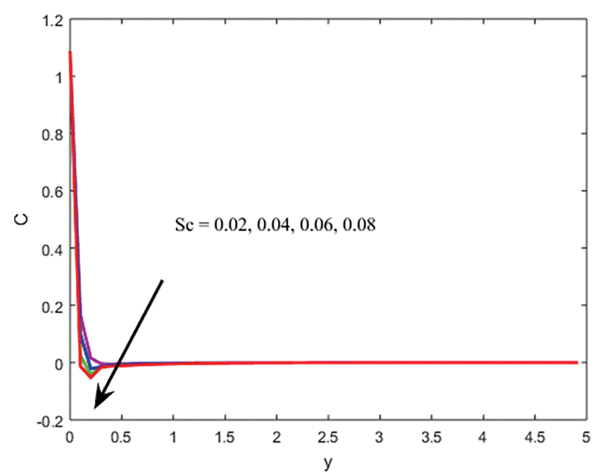

Fig. 8. Concentration portrait with Sc.

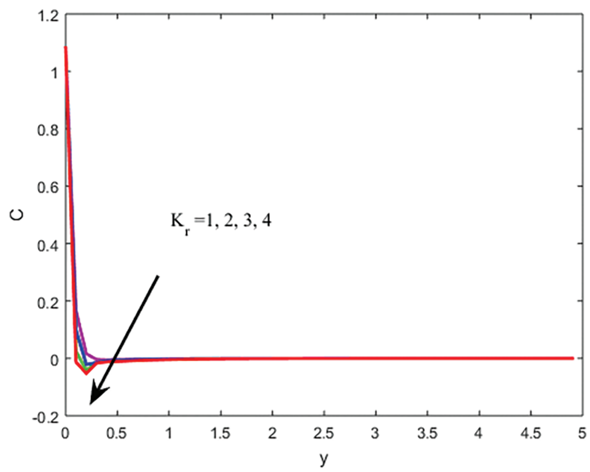

Fig. 9. Concentration portrait with K_r.

K_r concentration portrait, the behaviour of portrait is enhanced when C diminished. Figure 9 shows the diminishing output of K_r on concentration profile.

Table I portrays the consequence Pr, Sc, Ec, D_r, Ra, K_r, R on τ_w, Nu. Pr and Ra increases τ_w, Nu decreases. Sc and K_r enhances τ_w diminished, Nu is increased. We observed that increase in Ec, τ_w is diminished. R values are enhanced τ_w, Nu results are also increased and these points perceived form Table I.

4.1. Justification of Outcomes

Towards perfection of model, outcomes analogised with obtained data for momentum constitution in the instance of thermal diffusion consequence on hydrodynamic heat and mass transfer movement past a semi-infinite, porous plate with K_r Ref. [7], in the negligency of Ra and Ec. Remaining parameters are in constant position, we grabbed distinct outcomes for K_r. Obtained outcomes are conferred in Figure 2 and this association are in reliable accord.

Table I. Illustrates the impact of Pr, Sc, Ec, D_r, Ra, K_r, R on τ_w, Nu.

Pr	Sc	Ec	D_r	Ra	K_r	R	τ_w	Nu
1							4.7456	−9.3452
5							4.6231	−10.9876
7							4.5567	−19.0876
	0.61						5.0987	−7.1345
	0.81						4.9987	−7.0123
	0.94						4.9765	−6.9879
		0.001					4.7450	−7.9878
		0.003					4.7443	−7.9878
		0.005					4.7434	−7.9878
			0.01				4.9899	−9.9876
			0.02				4.9899	−9.9872
			0.03				4.9899	−9.9871
				5			4.6860	−7.7591
				10			4.6031	−7.9807
				20			4.4431	−8.0124
					0.2		4.7471	−7.5784
					2		4.1145	−7.5491
					2.5		4.0057	−7.5473
						0.01	4.7470	−7.5784
						0.02	4.7776	−5.8289
						0.03	4.8040	−5.0658

5. CONCLUSION

Main things are listed below

(1) Velocity behaviour is diminished in K_r, M, Sc.
(2) Temperature effect is increased in D_r, R.
(3) Concentration impact is diminished in Sc, K_r.
(4) τ_w is diminished when increasing $\Pr, Sc, Ec, Ra, K_r$.
(5) τ_w is enhanced when enhancing R.
(6) Nu is diminished when enhancing values of $\Pr, Ra$.
(7) Nu is enhanced when enhancing values of Sc, D_r, K_r, R.

NOMENCLATURE

B_0 Magnetic Component ($\mathrm{A \cdot m^{-1}}$)
C^* Dimensionless fluid concentration
C_w^* Concentration
C_∞^* Dimensionless concentration outside of the sheet
C_p Specific heat at constant pressure ($\mathrm{J \cdot Kg^{-1} \cdot k}$)
D_r Doufour number
Ec Eckert number
Gm Thermal Grashof number
Gr Mass Grashof number
g Acceletion due to gravity ($\mathrm{m \cdot s^{-2}}$)
g^* Acceletion due to gravity dimensional C
K_r Chemical reaction parameter ($\mathrm{m \cdot s^{-1}}$)
M Magnetic parameter
n^* minning
Pr Prandtl number
Q_0 Constant
Ra Radiation parameter
Sc Schmidt number
Sh Shearwood number
t^* Dimensional time
T_∞ Temperature outside of the boundary layer (k)
T_w^* Wall dimensional
U_0 Uniform velocity
U Dimensionless primary velocity
U_∞ Velocity outside of the boundary layer
u_p^*, u_∞^* Free stream velocity
u^*, v^* Dimensionless velocities
x^*, y^* Dimensions

Greek Symbols

β Fluid parameter
ν Kinematic viscosity ($\mathrm{m^2 \cdot s^{-1}}$)
ρ Density of the fluid ($\mathrm{Kg \cdot m^{-3}}$)
σ_ρ Electrical conductivity ($\sigma^{-1} \cdot \mathrm{m^{-1}}$)
σ Thermal conductivity ($\mathrm{m^2 \cdot s^{-1}}$)

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ε Arbitary constant
η Unit volume

Subscripts

$*$ Dimensionless properties
w Wall condition
∞ Free stream condition

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