International Journal of Engineering Trends and Technology
ISSN: 2231 – 5381 /doi:10.14445/22315381/IJETT-V69I10P220

Volume 69 Issue 10, 161-167, October, 2021

Original Article

MHD Rotating Flow Over a Semi-infinite Vertical Moving Plate With Oscillatory Effects

N. Ameer Ahammad[1], Abdulwahab Ali Mohammed Al Talea[2]

Department of Mathematics, Faculty of Science, University of Tabuk, 71491, Saudi Arabia.

[1]n.ameer1234r@gmail.com, [2]hoobba0599@gmailcom

Abstract - *The magnetohydrodynamic (MHD) free convective rotating flow of an incompressible fluid over a semi-infinite permeable moving plate by applying constant heat source, including diffusion thermo and radiation absorption, has been explored in this paper. The non-dimensional governing equations are solved by applying the Perturbation technique method to get the closed-form of solutions. Based on those outcomes, the expressions for shear stress and Nusselt number are evaluated. The effect of different parameters on the fluid flow is presented by the graphical representations. The computational values of the shear stress and Nusselt number at the surface are tabulated by the different implanted parameters. The resultant velocity diminishes with increasing in Hartmann number, Suction and Radiation parameters but amplifies with radiation absorption parameter and Dufour parameter. The suction parameter, along with the chemical reaction parameter, increases the Sherwood number. At the same time, the Nusselt number decreases with the increase in the Suction parameter, radiation absorption parameter, and Dufour parameter.*

Keywords — *Dufour effect, MHD flows, Radiation-absorption, Suction parameter, Porous medium.*

I. INTRODUCTION

The action of Coriolis force plays a vital role in viscous fluid flow in rotating channels due to its applications in various technological aspects. In various subjects like oceanography, meteorology, atmospheric science, and limnology depends on the concept of rotating fluids. Many researchers analyze the viscous fluid flow problems in rotating mediums under different conditions and configurations. Various problems of a viscous incompressible electrically conducting fluid along with rotation and magnetic field can be found in fluid engineering, astrophysics, and geophysics.

The study over a stretching sheet with visco-elasticity and heat transfer in a porous was reported by Abel and Veena [1]. The mass transfer flow through a porous medium was along with the effect of MHD, was highlighted by Abdel-Rahman [2]. Reddy. et al. [3] discussed the concept of Ohmic heating on MHD along with thermal and mass diffusion. Sharma et al. [4] investigated MHD flow past an accelerated vertical plate with radiation effect. Ahmed and Batin [5] reported the MHD flow through porous media with both thermal and mass diffusion. Mutuku-Njane and Makinde [6] reported that the MHD boundary layer flow of nanofluids over a permeable surface with Newtonian heating. Krishna et al. [9] carried their investigation on an unsteady MHD free convective flow between two vertical plates using Hall effects. Krishna and Chamkha [10] discussed the work with Hall effects along with ramped wall temperature and concentration of surface on unsteady MHD flow of second-grade fluid through the porous medium. Krishna and Chamkha [11] reported the squeezing flow of a water-based nanofluid between two parallel disks with MHD. Krishna and Reddy [12] highlighted their work by applying a uniform transverse magnetic field over an infinite vertical plate with heat source and chemical reaction on unsteady MHD free convection in a boundary layer flow of an electrically conducting fluid through the porous medium. Krishna and Subba Reddy [13] analyzed the simulation through a stumpy permeable porous medium with MHD forced convective flow. Krishna and Jyothi [14] examined the Hall effects on MHD Rotating flow of a viscoelastic fluid through a porous medium over an infinite oscillating porous plate with parameters, such as heat source and chemical reaction. Krishna [15] explored the impact of Hall and ion slip effects on unsteady MHD free convective rotating flow of Jeffrey's fluid with ramped wall temperature. Krishna and Swarnalathamma [16] discussed the MHD peristaltic flow of Williamson fluid with the effect of parameters inclined magnetic field with convective heat and mass transfer. Swarnalathamma and Krishna [17] investigated the peristaltic hemodynamic flow of couple stress fluid through a porous medium with parameters magnetic field and slip effect. Krishna and Reddy [18] explored their work on an infinite vertical oscillating porous plate with MHD free convective rotating flow of visco-elastic fluid along with chemical reaction. Krishna and Reddy [19] addressed their work on an unsteady MHD convective flow of second-grade fluid through a porous medium under the influence of temperature. Krishna et al. [20] studied the influence of heat and mass transfer in porous arteriole with unsteady MHD oscillatory flow of blood.

In this paper, we explore the work on MHD free convective flow of a nanofluid past a semi-infinite flat permeable porous plate with combined effects of diffusion thermo and radiation absorption. The profiles of velocity, temperature, concentration have depicted the graphs using Perturbation techniques. We also evaluated the parameters like skin friction, Nusselt number, and Sherwood number analytically and computationally.

II. Mathematical Method

We considered an infinite vertical permeable moving plate with a constant heat source with unsteady MHD convective rotating flow of an incompressible fluid past. Fig. 1 depicted the physical model where the plate is moving infinitely, and all the physical variables are functions of z and time t only. The governing equations for the flow are given by:

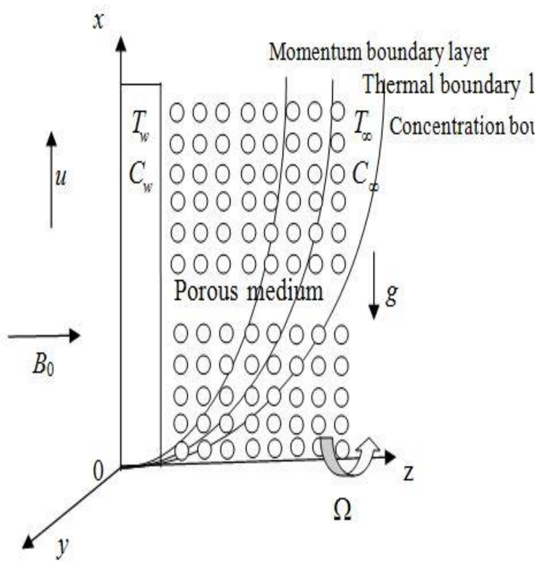

Figure. 1 Physical regime of the problem

$$\frac{\partial w}{\partial z} = 0 \qquad (1)$$

$$\frac{\partial u}{\partial t} + w\frac{\partial u}{\partial z} - 2\Omega v = \frac{\mu}{\rho}\frac{\partial^2 u}{\partial z^2} - \frac{\sigma B_0^2}{\rho}u - \frac{\mu}{k\rho}u + g\beta(T - T_\infty) \qquad (2)$$

$$\frac{\partial v}{\partial t} + w\frac{\partial v}{\partial z} + 2\Omega u = \frac{\mu}{\rho}\frac{\partial^2 v}{\partial z^2} - \frac{\sigma B_0^2}{\rho}v - \frac{\mu}{k\rho}v \qquad (3)$$

$$\frac{\partial T}{\partial t} + w\frac{\partial T}{\partial z} = \alpha\frac{\partial^2 T}{\partial z^2} - \frac{Q}{\rho c_\rho}(T - T_\infty) + Q_l(C - C_\infty) + \frac{D_m K_T}{C_s \rho C_\rho}\frac{\partial^2 C}{\partial z^2} \qquad (4)$$

$$\frac{\partial C}{\partial t} + w\frac{\partial C}{\partial z} = D_B\frac{\partial^2 C}{\partial z^2} - K_l(C - C_\infty) \qquad (5)$$

The related boundary conditions are given as :

$$u = 0, v = 0, T = T_\infty, C = C_\infty, t \leq 0 \qquad (6)$$

$$u = U_0, v = 0, T = T_w + (T_w - T_\infty)\varepsilon e^{i\omega t},$$

$$C = C_w + (C_w - C_\infty)\varepsilon e^{i\omega t}, t > 0 \; at \; z = 0 \qquad (7)$$

$$u = 0, v = 0, T = T_\infty, C = C_\infty, as z \to \infty \qquad (8)$$

Combining equations (2) and (3), let $q = u + iv$

$$\frac{\partial q}{\partial t} + w\frac{\partial q}{\partial z} + 2i\Omega q = \frac{\mu}{\rho}\frac{\partial^2 q}{\partial z^2} - \frac{\sigma B_0^2}{\rho}q - \frac{\mu q}{k\rho} + g\beta(T - T_\infty) \qquad (9)$$

We assumed the solution of Eq. (1) as $w = -W_0$ (10)

The normal velocity is represented by the constant $-W_0$ at the plate where ($W_0 > 0$) represents the positive suction ($W_0 > 0$) and ($W_0 < 0$) represents the negative for blowing injection. Considering the non-dimensional variables.

$$q* = \frac{q}{U_0}, z* = \frac{U_0 z}{v_f}, t* = \frac{U_0^2 t}{v}, \omega* = \frac{v\omega}{U_0^2}, \theta = \frac{T - T_\infty}{T_w - T_\infty},$$

$$\psi = \frac{(C - C_\infty)}{(C_w - C_\infty)}, M^2 = \frac{\sigma B_0^2 v}{\rho U_0^2},$$

$$Du = \frac{D_m K_T (C_w - C_\infty)}{k_f C_s (T_w - T_\infty)}, Q_L = \frac{Q_l (C_w - C_\infty)}{U_0^2 (T_w - T_\infty)},$$

$$Kr = \frac{K_l v}{U_0^2}, Pr = \frac{v}{\alpha}, Sc = \frac{v}{D_B},$$

$$R = \frac{2\Omega v}{U_0^2}, Q* = \frac{Q v^2}{K_f U_0^2}, S = \frac{W_0}{U_0}, K = \frac{k\rho U_0^2}{v^2},$$

$$Gr = \frac{g\beta v (T_w - T_\infty)}{U_0^3}$$

Using non-dimensional variables, the equations (9) and (4) – (5) with the boundary conditions (6) – (8), we get (Dropping asterisks)

$$\frac{\partial q}{\partial t} - S\frac{\partial q}{\partial z} = \frac{\partial^2 q}{\partial z^2} - \left(M^2 + 2iR + \frac{1}{K}\right)q + Gr\theta \qquad (11)$$

$$\frac{\partial \theta}{\partial t} - S\frac{\partial \theta}{\partial z} - Q_L\psi = \frac{1}{\Pr}\frac{\partial^2 \theta}{\partial z^2} - \frac{Q}{\Pr}\theta + \frac{\mathrm{Du}}{\Pr}\frac{\partial^2 \psi}{\partial z^2} \qquad (12)$$

$$\frac{\partial \psi}{\partial t} - S\frac{\partial \psi}{\partial z} = \frac{1}{Sc}\frac{\partial^2 \psi}{\partial z^2} - Kr\psi \qquad (13)$$

The boundary conditions be

$$q = 0, \theta = 0, \psi = 0 \; at \; t \leq 0 \qquad (14)$$

$$q = 1, \theta = 1 + \varepsilon e^{i\omega t}, \psi = 1 + \varepsilon e^{i\omega t},$$

$$at \; t > 0, z = 0 \qquad (15)$$

$$q = 0, \theta = 0, \psi = 0 \; as \; z \to \infty \qquad (16)$$

To solve the equations (11)-(13) with relevant boundary conditions (16)-(17) with the help of the perturbation technique($\varepsilon << 1$), the velocity, temperature, and concentration equations are assumed to be

$$q = q_0 + \varepsilon q_1 e^{i\omega t}, \qquad (17)$$

$\theta = \theta_0 + \varepsilon\theta_1 e^{i\omega t}$, (18)

$\psi = \psi_0 + \varepsilon\psi_1 e^{i\omega t}$ (19)

Equation (11) - (13) are reduced to

$\frac{d^2 q_0}{dz^2} + S\frac{dq_0}{dz} - \left(M^2 + 2iR + \frac{1}{K}\right) q_0 = -Gr\theta_0$ (20)

$\frac{d^2 q_1}{dz^2} - S\frac{dq_1}{dz} - \left(M^2 + \frac{1}{K} + i(2R+\omega)\right) q_1 = -Gr\theta_1$ (21)

$\frac{d^2\theta_0}{dz^2} - Pr\, S\frac{d\theta_0}{dz} - Q\theta_0 = -Du\frac{d^2\psi_0}{dz^2} - Pr\, Q_L\, \psi_0$ (22)

$\frac{d^2\theta_1}{dz^2} - Pr\, S\frac{d\theta_1}{dz} - (Q + Pr\, i\,\omega)\theta_1 = -Du\frac{d^2\psi_1}{dz^2} - Pr\, Q_L\, \psi_1$ (23)

$\frac{d^2\psi_0}{dz^2} + SSc\frac{d\psi_0}{dz} - KrSc\psi_0 = 0$ (24)

$\frac{d^2\psi_1}{dz^2} + SSc\frac{d\psi_1}{dz} - (i\omega + Kr)Sc\psi_1 = 0$ (25)

The boundary conditions (16) – (17) become

$q_0 = 1, q_1 = 0, \theta_0 = 1, \theta_1 = 1, \psi_0 = 1, \psi_1 = 1$

$at\ z = 0$ (26)

$q_0 = 0, q_1 = 0, \theta_0 = 0, \theta_1 = 0, \psi_0 = 0, \psi_1 = 0$

$at\ z \to \infty$ (27)

On solving equations (20) – (25) using the boundary conditions (26) - (27), we get

$q = B_5 e^{-m_5 z} + B_3 e^{-m_3 z} + B_4 e^{-m_1 z}$

$+\varepsilon(B_8 e^{-m_6 z} + B_6 e^{-m_4 z} + B_7 e^{-m_2 z})e^{i\omega t}$ (28)

$\theta = B_1 e^{-m_3 z} + A_1 e^{-m_1 z}$

$+\varepsilon(B_2 e^{-m_4 z} + A_2 e^{-m_2 z})e^{i\omega t}$ (29)

$\psi = e^{-m_1 z} + \varepsilon e^{-m_2 z} e^{i\omega t}$ (30)

The skin friction, Nusselt number, and Sherwood number at the plate in the dimensional form are,

$\tau = \left(\frac{\partial q}{\partial z}\right)_{z=0}, Nu = -\left(\frac{\partial \theta}{\partial z}\right)_{z=0}$

$and\ Sh = -\left(\frac{\partial \psi}{\partial z}\right)_{z=0}$ (31)

III. Results and Discussion

The present work is explored the magnetohydrodynamic (MHD) free convective rotating flow of an incompressible fluid over a semi-infinite permeable moving plate by applying a constant heat source, including the parameters diffusion thermo and radiation absorption. Applying the Perturbation technique, the outcome of the solution is the velocity, temperature, and concentration profiles are depicted in Figures.2–10. Tables 2–4 are represented the skin friction, Nusselt number, and Sherwood number for various parameters. The flow parameters' effects on velocity, temperature and concentration distributions, skin friction, the rate of heat transfer, and mass transfer coefficients have been discussed computationally. For computational intention, we are fixing up the values by $\varepsilon = 0.001, \omega = \pi/6$, $Pr = 0.71, Q = 2, Sc = 0.22$, while the remaining parameters are varied over a range.

The significance of Hartmann number M for velocity components is intercepted from Figure 2. The primary velocity *u* declines as the secondary velocity *v* augments as the Hartmann number increases. Both velocities *u* and *v* decline with the increase in value of *M*. Here, we observe the role of Lorentz force which is by the presence of the transverse magnetic field. Also from Figures (3 & 4) shows that the velocity components of fluid are enhanced by increasing *K* and Gr. In turn, we notice that the fluid speed is scrutinized in the whole fluid region due to the less permeability of *K* and Gr. It was noted from Figure.5, the velocity components *u* and *v*enhances with an increase in Du which results in the increase of thickness of hydrodynamic boundary layer thickness. It was determined from Figure.6 that the buoyancy force accelerates the flow while the heat is absorbed by the increase in Q_LWhich results in enhancement of velocity of the fluid. One can observe the predominance of conduction over radiation absorption results in enhancing the thickness of the momentum boundary layer. It was observed that by increasing the suction parameter *S*, the velocity of the fluid across the boundary layer diminishes, as shown in Figure 7. At the same time, the increase in rotation parameter R affects decreasing the magnitude of the velocity components *u* and *v*, as depicted in Figure 8.

Figure 9 depicts the temperature profiles against parameters Du, Q_L And *S*. The thermal boundary layer thickness arises with the presence of Du. By reducing the value of Du, the temperature was reduced, which was influenced by species gradients, which results in a decrease in temperature allows the boundary layer thickness to get cooled. But with the increase of Q_L We observe the enhancement of the temperature of the fluid. As the heat is absorbed, the buoyancy force accelerates the fluid flow, which results in the increase of temperature at the vicinity of the boundary, and later it retards around the fluid region as the value of *S* increases.

Figure 10 depicts the concentration boundary layer of the flow by reducing the species concentration and increasing the suction parameter results in a reduction of the solutal boundary layer thickness. At a certain point, we observe that the boundary growth stabilizes due to suction. The Kc reduces the concentration and in chemical molecular diffusivity by increasing Kc.

The computational results of the Skin-friction, Nusselt number, and Sherwood number were tabulated in Tables (2,3 & 4). Table 2 depicted that the skin friction enhanced with an increment in Gr, *K*, Q_L and Du, and declined with *M*, *R*, and *S*. The analysis of Nusselt number for various quantities *S*, Du and Q_L Are represented in Table 3. It is noted that the Nusselt number enhanced for various parameters *S*, Du and Q_L. The Sherwood number enhanced with the rise in *S* and Kr and, in turn, declined with an increase in time, which was given in Table 4. The results of Hamad and Pop [13] (Table 5) are in good agreement with our results.

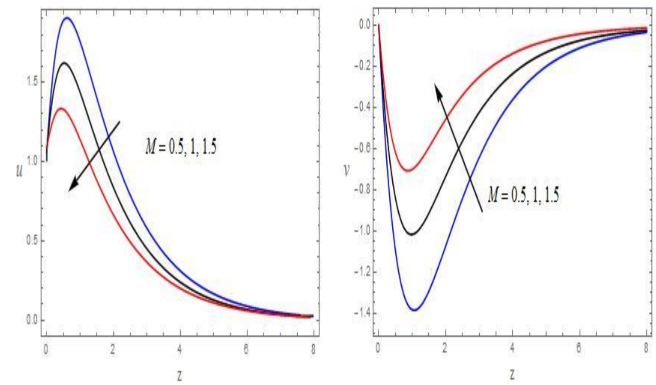

Figure 2 Velocity profiles against *M* with $K = 0.5$, $S = 1$, $Du = 1$, $Gr = 3$, $Q_L = 1$, $R = 0.5$

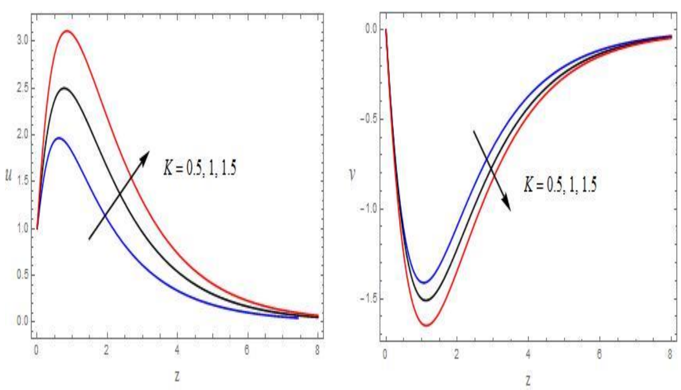

Figure. 3 Velocity profiles against *K* with $M = 0.5$, $S = 1$, $Du = 1$, $Gr = 3$, $Q_L = 1$, $R = 0.5$

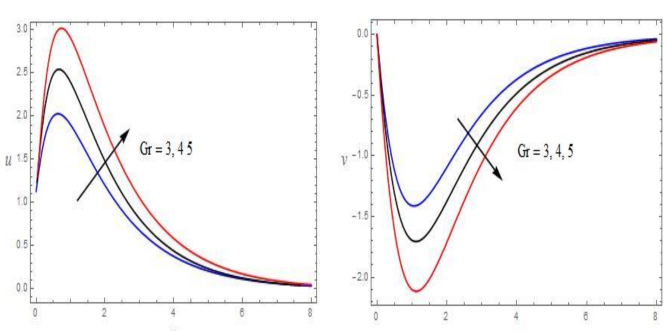

Figure 4 Velocity profiles against Gr with $M = 0.5$, $K = 0.5$, $S = 1$, $Du = 1$, $Q_L = 1$, $R = 0.5$

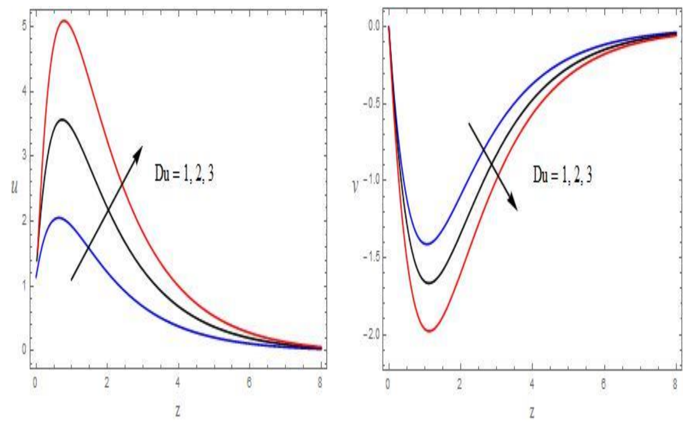

Figure 5 Velocity profiles against Du with $M = 0.5$, $K = 0.5$, $S = 1$, $Gr = 3$, $Q_L = 1$, $R = 0.5$

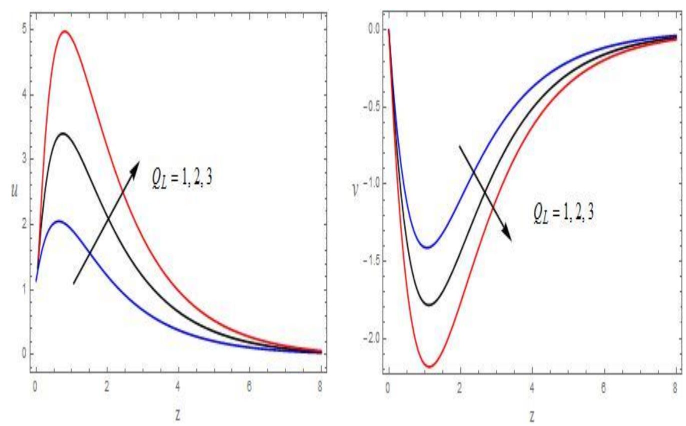

Figure 6 Velocity profiles against Q_L with $M = 0.5$, $K = 0.5$, $S = 1$, $Du = 1$, $Gr = 3$, $R = 0.5$

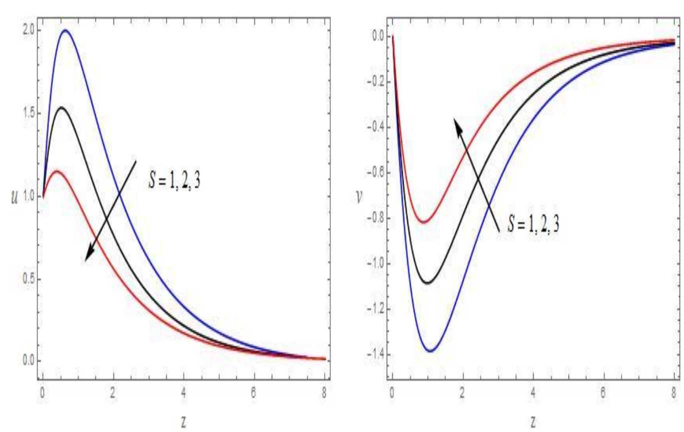

Figure 7 Velocity profiles against *S* with $M = 0.5$, $K = 0.5$, $Du = 1$, $Gr = 3$, $Q_L = 1$, $R = 0.5$

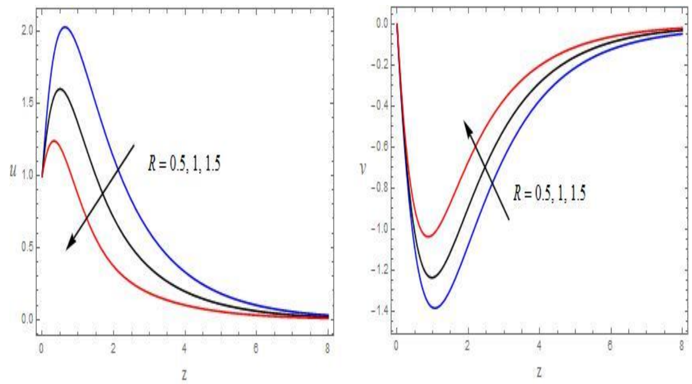

Figure 8 Velocity profiles against R with $M = 0.5$, $K = 0.5, Du = 1, Gr = 3, Q_L = 1, S = 1$

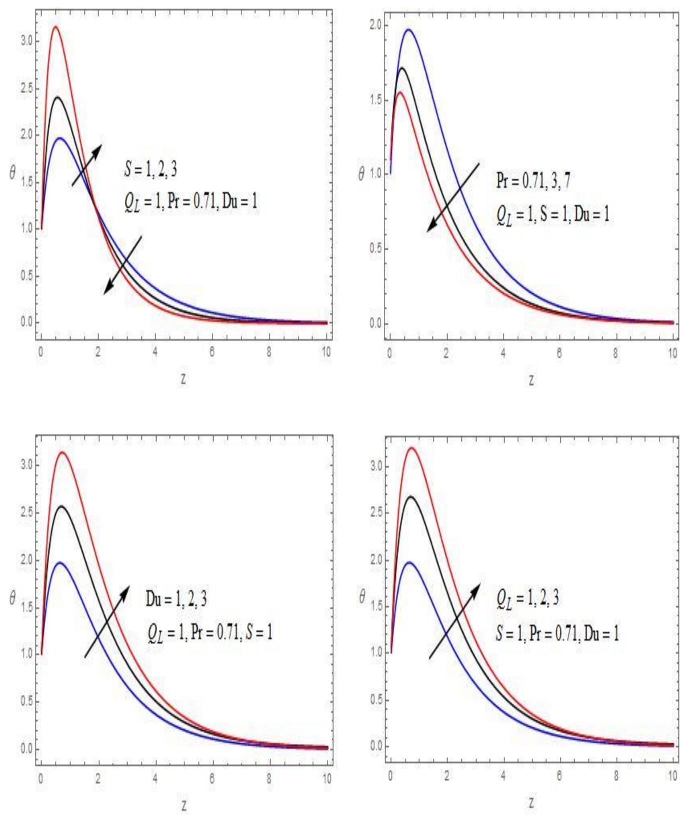

Figure 9 Temperature profiles with *S*, Pr, Du and Q_L

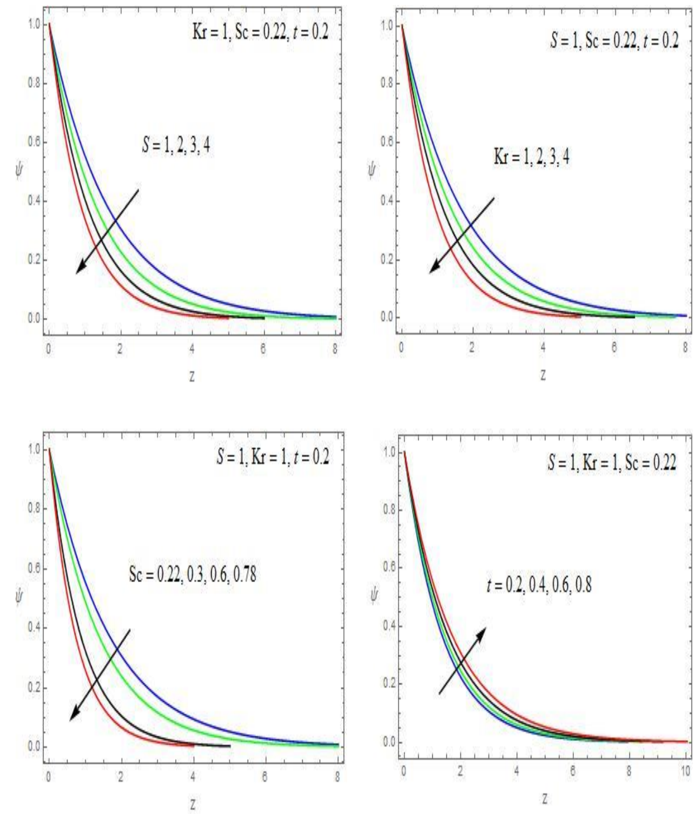

Figure 10 Concentration Profiles with *S*, Kr, Sc, and *t*

Table 2. Skin friction (τ)

M	K	Gr	Du	Q_L	S	R	τ
0.5	0.5	3	1	1	1	0.5	2.336584
1.0							2.114587
1.5							1.966587
	1						2.668954
	1.5						2.996889
		4					3.336589
		5					4.441587
			2				2.675874
			3				3.021478
				2			2.587995
				3			2.998564
					2		2.014895
					3		1.748895
						1	2.201451
						1.5	2.101158

Table 3. Nusselt number (Nu)

Du	*S*	Q_L	Nu
1	1	1	-0.855945
2			-0.996887
3			-1.225472
	2		-1.557845
	3		-2.655248
		2	-0.998574
		3	1.0988545

Table 4. Sherwood number (Sh)

S	Kr	*t*	Sh
1	2	0.2	0.788549
2			0.958774
3			1.225479
	3		0.895798
	4		1.147889
		0.4	0.788535
		0.6	0.788519

Table 5. Comparison of the results for Nusselt number (Nu) ($Du = Q_L = 0$)

S	*Q*	Hamad and Pop [13]	Present results
1	1	2.18785	2.18795
2		2.63198	2.63207
3		3.13033	3.13043
	2	2.92694	2.92702
	3	3.49707	3.49719

IV. CONCLUSIONS

The present article investigated the MHD free convective rotating flow of an incompressible fluid past a semi-infinite permeable moving plate. The analysis was carried out with respect to constant heat source along with parameters diffusion thermos, radiation absorption with oscillatory effects due to various parameters. The following conclusions are drawn:

- The resultant velocity diminishes with an increase in *M*, *S* and *R*and amplified with Q_L and Du.
- The thermal boundary layer thickness takes place because of Q_L and Du.
- The increase in Sand Kr reduces the concentration profile.
- The skin friction coefficient enhances owing to Grashof number Gr, permeability parameter *K*, radiation absorption parameter Q_L and Dufour parameter.
- The Nusselt number decreases with the increase in the values of the Suction parameter, radiation absorption parameter Q_L, and Dufour parameter Du.
- The suction parameter, along with the chemical reaction parameter, aid in the increase of Sherwood's number.

APPENDIX

$$A_1 = -\left(\frac{m_1^2 Du + Pr\,Q_L}{m_1^2 - Pr\,Sm_1 - Q}\right),$$

$$A_2 = -\frac{m_2^2 Du + Pr\,Q_L}{m_2^2 - Pr\,Sm_2 - (Q + i\omega Pr())}$$

$$B_1 = 1 - A_1, \qquad B_2 = 1 - A_2,$$

$$B_3 = -\frac{B_1 Gr}{m_3^2 - Sm_3 - (M^2 + 2iR + (1/K))},$$

$$B_4 = -\frac{A_1 Gr}{m_1^2 - Sm_1 - (M^2 + 2iR + (1/K))},$$

$$B_5 = 1 - B_3 - B_4,$$

$$B_6 = -\frac{B_2 Gr}{m_4^2 - Sm_4 - (M^2 + (1/K) + i(2R + \omega))},$$

$$B_7 = -\frac{A_2 Gr}{m_2^2 - Sm_2 - (M^2 + (1/K)) + i(2R + \omega)},$$

$$B_8 = -B_6 + B_7,$$

$$m_1 = \frac{SSc + \sqrt{(SSc)^2 + 4KrSc}}{2}, m_2 = \frac{SSc + \sqrt{(SSc)^2 + 4Sc(i\omega + Kr)}}{2},$$

$$m_3 = \frac{Pr\,S + \sqrt{(Pr\,S)^2 + 4Q}}{2}, m_4 = \frac{Pr\,S + \sqrt{(Pr\,S)^2 + 4(Q + i\omega Pr())}}{2}$$

$$m_5 = \frac{S + \sqrt{S^2 + 4\left(M^2 + (1/K) + 2iR\right)}}{2},$$

$$m_6 = \frac{S + \sqrt{S^2 + 4\left(i\omega + (M^2 + (1/K) + 2iR)\right)}}{2}$$

ACKNOWLEDGMENT

The athors extend their appreciation to the refrees for their valueable comments.

REFERENCES

[1] S. Abel, P.H.Veena, Visco-Elastic Fluid Flow and Heat Transfer in Porous Medium over a Stretching Sheet, Int. J of Non-Linear Mech, 33 (1998) 531-540.

[2] G.M. Abdel-Rahman, Thermal Diffusion and MHD Effects on Combined Free Forced Convection and Mass Transfer Flow of a Viscous Fluid Flow through a Porous Medium with Heat Generation. Chem. Engg and Tech,31 (2008) 554-559. http://dx.doi.org/10.1002/ceat.200700487

[3] N.A. Reddy, M.C. Raju and S.V.K. Varma, Thermo Diffusion and Chemical Effects with Simultaneous Thermal and Mass Diffusion in MHD Mixed Convection Flow with Ohmic Heating. J. Naval Arch and Marine Engg, 6(2009) 84-93.

[4] D. Sarma, N. Ahmed and H. Deka, MHD Free Convection and Mass Transfer Flow past an Accelerated Vertical Plate with Chemical Reaction in Presence of Radiation. Latin Amer App Res, 44 (2014) 1-8.

[5] S. Ahmed, and A. Batin, A. Magnetohydrodynamic Heat and Mass Transfer Flow with Induced Magnetic Field and Viscous Dissipative Effects. Latin Amer App Res, 44 (2014) 9-17.

[6] W.N. Mutuku-Njane, and O.D. Makinde, On Hydromagnetic Boundary Layer Flow of Nanofluids over a Permeable Moving Surface with Newtonian Heating. Latin Amer App Res, 44 (2014) 57-62.

[7] F.M. Abbasi FM, T. Hayat and F. Alsaadi, Peristaltic transport of magnetonanoparticles submerged in water: model for drug delivery system. Physica E; 68 (2015) 123–32.

[8] F.M. Abbasi FM, T. Hayat and F. Alsaadi, Hydromagnetic peristaltic transport of water-based nanofluids with slip effects through an asymmetric channel. Int J Mod Phys B, 29 (2015) 1–17.

[9] M.V.Krishna. G.S.Reddy and A.J. Chamkha, Hall effects on unsteady MHD oscillatory free convective flow of second grade fluid through porous medium between two vertical plates, Phys of Fluids, 3**0**, 023106, (2018). doi: 10.1063/1.5010863

[10] M.V.Krishna and A.J. Chamkha, Hall effects on unsteady MHD flow of second grade fluid through porous medium with ramped wall temperature and ramped surface concentration, Phys of Fluids, **30**, 053101 (2018),doi: 10.1063/1.5025542

[11] M.V.Krishna and A.J. Chamkha, Hall Effects on MHD Squeezing Flow of A Water-based Nanofluid between two Parallel disks, J. of Por. media, 21(13),(2018), 1345–1359. DOI:10.1615/JPorMedia.2018028721

[12] M.V.Krishna and M.G.Reddy, MHD Free Convective Boundary Layer Flow through Porous medium Past a Moving Vertical Plate with Heat Source and Chemical Reaction, Materials Today: Proce, 5 (2018) 91–98.

[13] https://doi.org/10.1016/j.matpr.2017.11.058.

[14] M.V.Krishna and G.S.Reddy, MHD Forced Convective flow of Non-Newtonian fluid through Stumpy Permeable Porous medium, Materials Today: Proce, 5 (2018) 175–183. https://doi.org/10.1016/j.matpr.2017.11.069.

[15] M.V.Krishna and K. Jyothi, K., Hall effects on MHD Rotating flow of a Visco-elastic Fluid through a Porous medium Over an Infinite Oscillating Porous Plate with Heat source and Chemical reaction, Materials Today: Proce,5,(2018), 367–380. https://doi.org/10.1016/j.matpr.2017.11.094.

[16] M.V.Krishna, Hall and ion slip impacts on unsteady MHD free convective rotating flow of Jeffreys fluid with ramped wall temperature. Int Comm Heat and Mass Trans, 119 (2020) 104927. https://doi.org/10.1016/j.icheatmasstransfer.2020.104927

[17] M.V. Krishna and B.V. Swarnalathamma, Convective Heat and Mass Transfer on MHD Peristaltic Flow of Williamson Fluid with the Effect of Inclined Magnetic Field,AIP Con Proce, 1728 (2016) 020461, DOI: 10.1063/1.4946512

[18] B.V. SwarnalathammaandM.V. Krishna, Peristaltic hemodynamic flow of couple stress fluid through a porous medium under the influence of magnetic field with slip effect AIP Con Proce, 1728, (2016) 020603. DOI: 10.1063/1.4946654.

[19] M.V.Krishna and M.G.Reddy, MHD free convective rotating flow of Visco-elastic fluid past an infinite vertical oscillating porous plate with chemical reaction, IOP Conf. Series: Mater Sci Engg.,149 (2016) 012217, DOI:10.1088/1757-899X/149/1/012217.

[20] Krishna.M.V., Reddy, G.S., Unsteady MHD convective flow of Second grade fluid through a porous medium in a Rotating parallel plate channel with temperature dependent source, IOP Conf. Series: Mater Sci Engg.,149 (2016) 012216, DOI**:** 10.1088/1757-899X/149/1/012216.

[21] M.V.Krishna, B.V.Swarnalathamma, and J. Prakash, Heat and mass transfer on unsteady MHD Oscillatory flow of blood through porous arteriole, Applications of Fluid Dynamics, Lect Notes in MecEngg, XXII, (2018) 207-224. Doi: 10.1007/978-981-10-5329-0_14.