JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Thermal Diffusion and Reactive Species Transport in Transient MHD Free Convection Flow over a Porous Vertical Plate with Nonlinear Radiation and Temperature-Dependent Heat Generation

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Abstract :

In the current century, research on the flow of fluids (liquids or gases) through porous media is extremely important due to the rate at which these fluids occur in nature and in newly emerging industries like the production of synthetic polymers and oil, as well as the wide range of applications in composition. Research on heat transfer and mass transfer of the fluid movement of lubricant across a permeable stratum is receiving a lot of attention from the fuel (such as petroleum) trade. A continuous solid phase with numerous voids or pores is known as porous media. The connectivity of the pores determines whether they are effective or ineffective. Porous media that have linked pores are permeable, while those that do not are impermeable. Porous media include things like clothing, paper, gravel, wicks, and sponges. In order to analyse stream waste in canal beds, one must be familiar with the fluid movement over porous media, which is necessary to valve ground water as of the subversive reservoirs in order to overcome the crisis caused by the monsoon breakdown in the rainfed areas. Because felts are employed in the paper production process to move the paper expanse through its various configuration and ventilation processes, fluid flow during absorbent stratum is also beneficial to the creation of paper. Heat and mass transfer combine to create flows across the majority of technology, industrial, and real-world scenarios. The rate of energy matter transfer is altered by variations in heat (mass) transmission. Heat and mass transfer are two common transfer processes in industry. Many chemical processes used in industries, such as the food and polymer processes, typically include simultaneous transfers of combined heat and mass.

MATHEMATICAL DESCRIPTION :

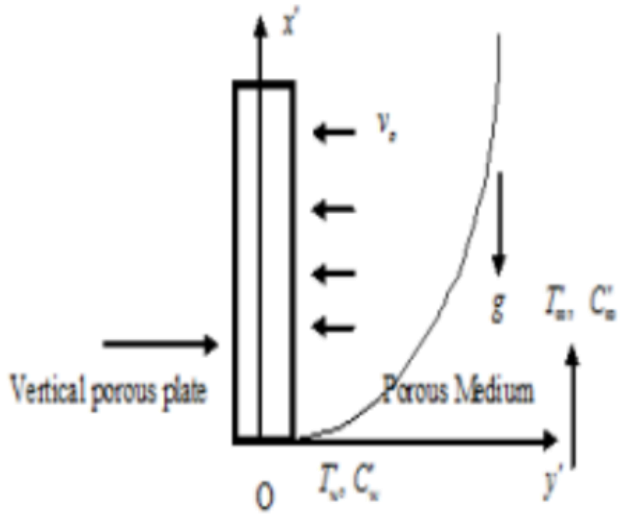

Fig. 1. Physical chart of flow model

Continuity Equation

$$\frac{\partial v'}{\partial y'}=0 \tag{1}$$

Momentum Equation

$$\frac{\partial u'}{\partial t'}+v'\frac{\partial u'}{\partial y'}=g\beta\left(T'-T'_\infty\right)+g\beta^{\square}\left(C'-C'_\infty\right)+v\frac{\partial^2 u'}{\partial y'^2}-\frac{v}{k(t)}u'-\frac{\sigma B_0^2}{\rho}u' \tag{2}$$

Energy Equation

$$\frac{\partial T'}{\partial t'}+v'\frac{\partial T'}{\partial y'}=\frac{\alpha}{\rho C_P}\frac{\partial^2 T'}{\partial y'^2}-\frac{1}{\rho C_P}\frac{\partial q_r}{\partial y'}+\frac{Q'}{\rho C_P}\left(T'-T'_\infty\right) \tag{3}$$

Concentration Equation

$$\frac{\partial C'}{\partial t'}+v'\frac{\partial C'}{\partial y'}=D\frac{\partial^2 C'}{\partial y'^2}-k_o\left(C'-C'_\infty\right)+D_1\frac{\partial^2 T'}{\partial y'^2} \tag{4}$$

Associated conditions of boundary layer flow of the problem are

$$\left.\begin{aligned} &u'=L_1\left(\frac{\partial u'}{\partial y'}\right),T'=T'_w,C'=C'_w \ \text{ at } y'=0\\ &u'\to 0.T'\to T'_-.C'\to C'_- \ \text{ as } \ v'\to\infty \end{aligned}\right\} \tag{5}$$

Here $L_1=\left(\frac{2-m_1}{m_1}\right)$ is the free mean path of fluid flow, where m_1 is the reflection of Maxwell's factor.

$$v'=-v'_0(1+\varepsilon e^{-nt}) \tag{6}$$

where $v'_0>0$ denotes the velocity related to suction component to plate. and n is a +Ve constant, while $v'_0>0$ indicates the velocity of blowing fluid flow towards state.

Here the fluid is considered to be optically slight with a fairly small density and radaitve heat flux was mentioned

$$\frac{\partial q_r}{\partial y'} = 4\left(T' - T'_\infty\right) I \tag{7}$$

here I represent the factor of absorption at the plate.

The Permeability k of the porous medium is mentioned in the form

$$k = k'_0 \tag{8}$$

Describe the necessary problem's non-dimensional quantities and variables as

$$\left.\begin{aligned} u &= \frac{u'}{v'_0}, y = \frac{y' v'_0}{v}, n = \frac{4\nu n'}{v'^2_0}, Gr = \frac{g\beta\nu\left(T'_w - T'_\infty\right)}{v'^3_0}, t = \frac{v'^2_0 t'}{4\nu}, M = \frac{\sigma B_0^2 \nu}{v'^{2\rho}_0}, \\ \phi &= \frac{T' - T'_\infty}{T'_w - T'_\infty}, K = \frac{k'_0 v'^2_0}{\nu^2}, R = \frac{4\nu I}{\rho C_p v'^2_0}, Sc = \frac{\nu}{D}, Q = \frac{Q'\nu}{v'^2_0\left(T'_w - T'_\infty\right)\rho C_p}, \\ P_r &= \frac{\rho C_p \nu}{\alpha}, \phi = \frac{C' - C'_\infty}{C'_w - C'_\infty}, \Gamma = \frac{k_o \nu}{v'^2_0}, Gc = \frac{g\beta^{\square}\nu\left(C'_w - C'_\infty\right)}{v'^3_0}, So = \frac{D_1\left(T'_w - T'_\infty\right)}{\left(C'_w - C'_\infty\right)\nu} \end{aligned}\right\} \tag{9}$$

In set of equations (5.2.2) -(5.2.4), we attain dimensionless outline of overriding equations as follows:

$$\frac{1}{4}\frac{\partial u}{\partial t} - (1+\varepsilon e^{-nt})\frac{\partial u}{\partial y} = Gr\theta + Gc\phi + \frac{\partial^2 u}{\partial y^2} - \left[M + \frac{1}{K}\right]u \tag{10}$$

$$\frac{1}{4}\frac{\partial \theta}{\partial T} - (1+\varepsilon e^{-nt})\frac{\partial \theta}{\partial y} = \frac{1}{\Pr}\frac{\partial^2 \theta}{\partial y^2} - R\theta + Q\frac{\partial \theta}{\partial y} \tag{11}$$

$$\frac{1}{4}\frac{\partial \phi}{\partial T} - (1+\varepsilon e^{-nt})\frac{\partial \phi}{\partial y} = \frac{1}{Sc}\frac{\partial^2 \phi}{\partial y^2} - \Gamma\phi + S_0\frac{\partial^2 \theta}{\partial y^2} \tag{12}$$

and boundary condition (5.2.5) trim down to

$$\left.\begin{aligned} u &= \mathrm{h}\left(\frac{\partial u}{\partial y}\right), T = 1.0, C = 1.0, \text{ at } y = 0 \\ u &\to 0.0, T \to 0.0, C \to 0.0, \text{ as } y \to \infty \end{aligned}\right\} \tag{13}$$

where $\mathrm{h} = \frac{L_1 v_0{}^{o\,2}}{\nu}$

SOLUTION METHODOLOGY :

The regular perturbation method is an analytical methodology that can be used to solve the non-linear ordinary differential equations (10)–(12) and the necessary BCs equation (13). The procedure outlined by Gersten and Gross must be followed in order to obtain the resolution. Consequently, the following form implicitly uses terms related to flow and thermal concentration.

$$u1(y,t) = u_0(y) + \varepsilon u_1(y) e^{-nt} + O\left(E^2\right) \tag{14}$$

$$\theta 1(y,t) = \theta_0(y) + \varepsilon\theta_1(y) e^{-nt} + O\left(E^2\right) \tag{15}$$

$$\phi 1(y,t) = \phi_0(y) + \varepsilon\phi_1(y) e^{-nt} + O\left(E^2\right) \tag{16}$$

Substituting above equations (14), (15), (16) in the equations (10),(11),(12) and comparing the coefficient of Harmonic and nonharmonic values, and neglect second order and above terms, we $O\left(E^2\right)$, we attain the subsequent set of ODEs.

$$u_0''+u_0'-M_1u_0=-Gr\theta_0-Gc\phi_0 \quad (17)$$

$$u_1''+u_1'-M_2u_1=-Gr\theta_1-Gc\phi_1-u_0' \quad (18)$$

$$\theta_0''+(1+Q)\Pr\theta_0'-R\Pr\theta_0=0 \quad (19)$$

$$\theta_1''+(1+Q)\Pr\theta_1'-\left(R-\frac{n}{4}\right)\Pr\theta_1=-\Pr\theta_O' \quad (20)$$

$$\phi_0''+Sc\phi_0'-Sc\Gamma\phi_0=-ScS_0\phi_0'' \quad (21)$$

$$\phi_1''+Sc\phi_1'-\left(\Gamma-\frac{n}{4}\right)Sc\phi_1=-ScS_0\phi_0'-ScS_0\theta_1'' \quad (22)$$

here $M_I=M+\frac{1}{K}$ and $M_2=M-\frac{1}{4}\square n+\frac{1}{K}$

The equations from (4) - (22) are 2nd order LDEs along constant factors. The required general paired equation solutions of these matching BCs, the equation (18) are,

$$\theta_0(y)=e^{-m_1y} \quad (23)$$

$$\phi_0=A_2e^{-m_2y}-A_1e^{-m_1y} \quad (24)$$

$$u_0=A_5e^{-m_3y}-A_4e^{-m_2y}+A_3e^{-m_1y} \quad (25)$$

$$\theta_1=-A_6e^{-m_4y}+A_6e^{-m_1y} \quad (26)$$

substituting the equations (16) and (18) in the equation (14), the momentum of the boundary field u(y,t) is,

$$\left.\begin{array}{l}u(y,t)=(A_5e^{-m_3y}-A_4e^{-m_2y}+A_3e^{-m_1y})\\+\varepsilon e^{-nt}(A_{16}e^{-m_6y}-A_{11}e^{-m_5y}+A_{12}e^{-m_4y}+A_{13}e^{-m_3y}-A_{14}e^{-m_2y}+A_{15}e^{-m_1y})\end{array}\right\} \quad (27)$$

substituting the equations (15) and (16) in the equation(14), temperature field $\phi(y,t)$ is,

$$\theta(y,t)=(e^{-m_1y})+\varepsilon e^{-nt}(-A_6e^{-m_4y}+A_6e^{-m_1y}) \quad (28)$$

Also substituting the equations (22) and (23) in the equation (16), the concentration field $\theta(y,t)$ is,

$$\phi(y,t)=(A_2e^{-m_2y}-A_1e^{-m_1y})+\varepsilon e^{-nt}(A_{10}e^{-m_5y}+A_7e^{-m_4y}+A_8e^{-m_2y}-A_9e^{-m_1y}) \quad (29)$$

Expressive the flow characteristic, the shearing stress at the plate can be

found, which in the dimensionless appearance (skin friction factor) is taken in the form by

The expression for friction factor (τ) at the plate is,

$$Cf=\left(\frac{du}{dy}\right)_{y=0}=\left(\frac{du_0}{dy}\right)_{y=0}+\varepsilon e^{-nt}\left(\frac{du_1}{dy}\right)_{y=0}=A_{17}+\varepsilon e^{-nt}A_{18} \quad (30)$$

Regarding to the thermal distribution, factor of heat transfer at the plate can be find, which is in dimensionless form it can be termed as Nusselt number, which is presented as

$$Nu=\left(\frac{d\theta}{dy}\right)_{y=0}=\left(\frac{d\theta_0}{dy}\right)_{y=0}+\varepsilon e^{-nt}\left(\frac{d\theta_1}{dy}\right)_{y=0}=-m_1+\varepsilon e^{-nt}A_{19} \quad (31)$$

RESULTS AND DISCUSSION :

In order to highlight the sound consequences of various regulating aspects such as Grashof number Gr, magnetic factor M, permeability of porous value K, Prandtl number Pr, radiation parameter R, heat generating factor Q, modified Grashof number Gc, Schmidt number Sc, destructive or constructive chemical reactor factor Γ, thermo-diffusion number and slip condition factor h on momentum of the flow distribution, thermal boundary distribution, and mass boundary distribution are examined graphs (1)–(14), adopted the values

Adopted the values *Gr = 10.0, Gc = 6.0, K = 1.0, M = 5.0, h = 1.0, Sc=0.22, R = 10.0, Γ = 2.0, Pr = 0.7, So=0.5, Q=0.3, and =0.01,* while observance further factors as constants.The velocity profile with variation in slip in slip factor h is shown in Fig. (1). The result of the flow's momentum is seen to be soaring near the plate, abating behind it, and reaching a stationary place on the other side of the plate. Figures (2) and (3) are made to demonstrate the manipulation of thermal Grashof number Gr and Grashof number for concentration Gc on flow of the flow as predictable momentum of flow improves with an enhancing value in slip coefficient factor h. It is clearly practical to significantly improve the flow distribution in order to raise Gr or Gc.The effects of radiative flux and heat-generating factor on the flow distribution are shown in Figures (6) and (7). Figures (8) and (9) show that the flow profile is not surplus with the enhancement of radiative flux factor R and heat generating source factor Q. Figures (10) and (11) show the momentum profile for a variety of significant destructive chemical reactor factor Γ and Soret number So. It is pragmatic that flow of the flow profile abatement as Prandtl number Pr or Schmidt number Sc enlarge. It is observed that when the destructive chemical reactor factor Γ increases, the flow rate falls, but when the Soret factor increases, the flow rate increases.

Fig. (12) highlights the manipulation of the Prandtl number Pr on the thermal boundary layer profile. The impact of heat generating factor Q and thermal radiative factor R on temperature is determined from Figures (13) & (14), and the temperature abatement with an amplification in Prandtl number Pr is concluded. It has been noted that when the thermal radiation factor R or heat source parameter Q rises, the temperature profile rises.

The tables (1) and (3) discuss variations in the skin friction factor, the rate of heat flux in the type of Nusselt number, and the rate of mass flow in the type of Sherwood number. Table (1) makes clear that increasing the values of Gr, Gc, and K results in an acceleration of the skin friction factor. Table (2) shows that the Nusselt number increases as Pr and Q values rise, but it decreases when R increases. Table (3) shows that as Sc, Γ, and So increase, the Sherwood number value increases.

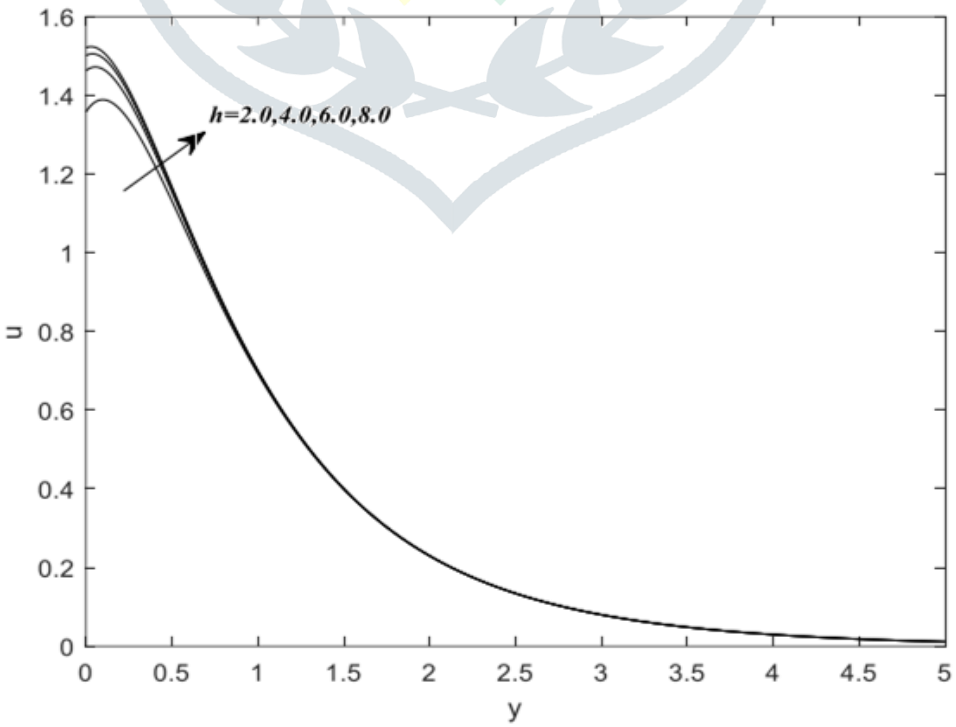

Fig. (1). The outlines of *u* w.r.to *y* for varies *h*

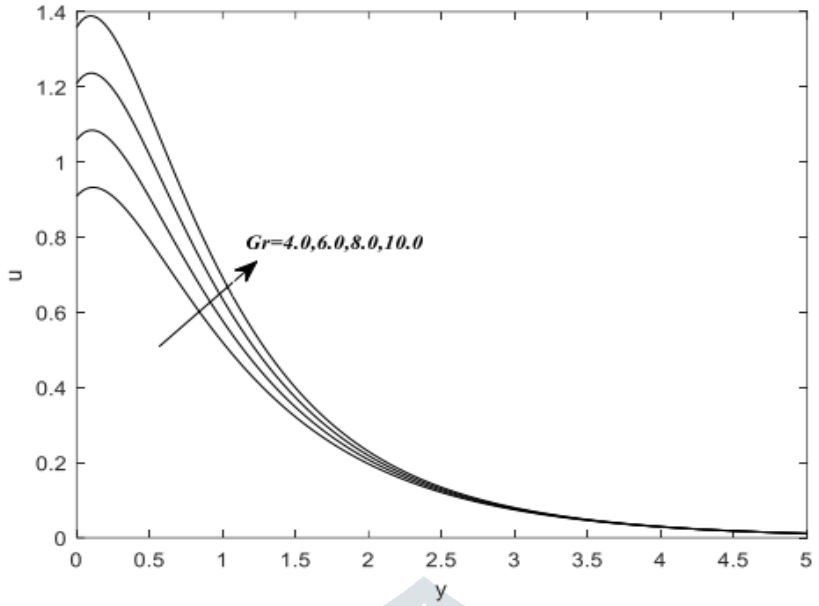

Fig. (2). The outlines of *u* w.r.to *y* for varies *Gr*

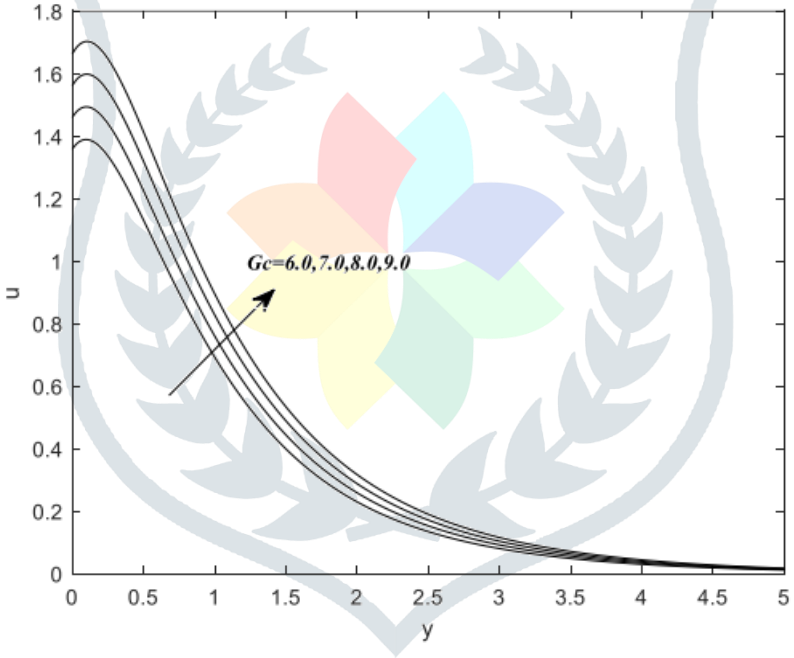

Fig. (3). The outlines of *u* w.r.to *y* for *Gc*

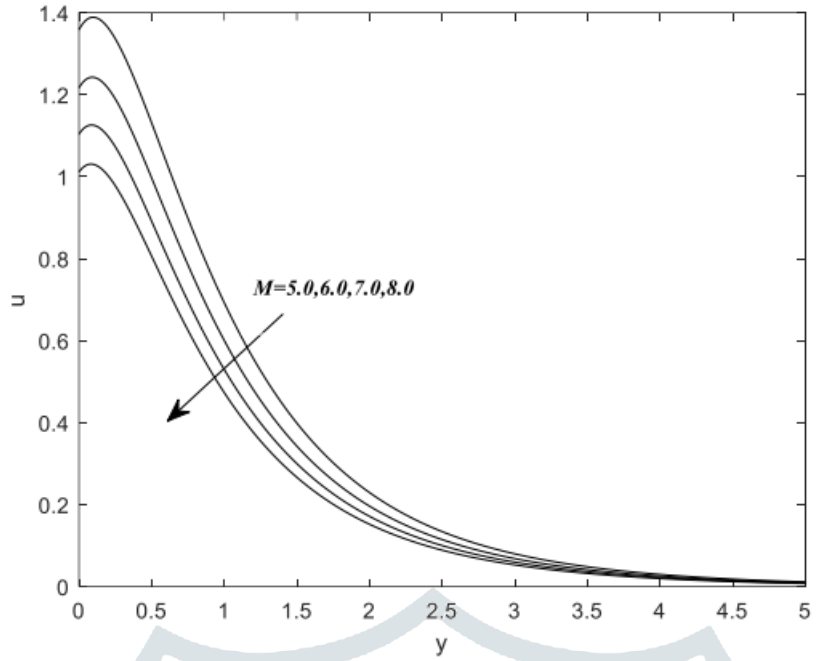

Fig. (4). The outlines of *u* w.r.to *y* for *M*

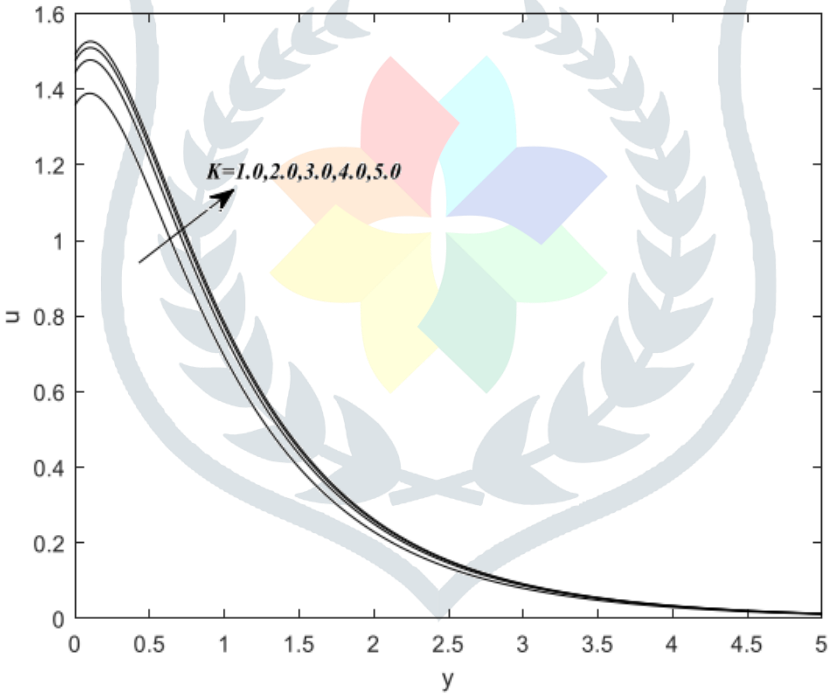

Fig. (5). The outlines of *u* w.r.to y for *K*

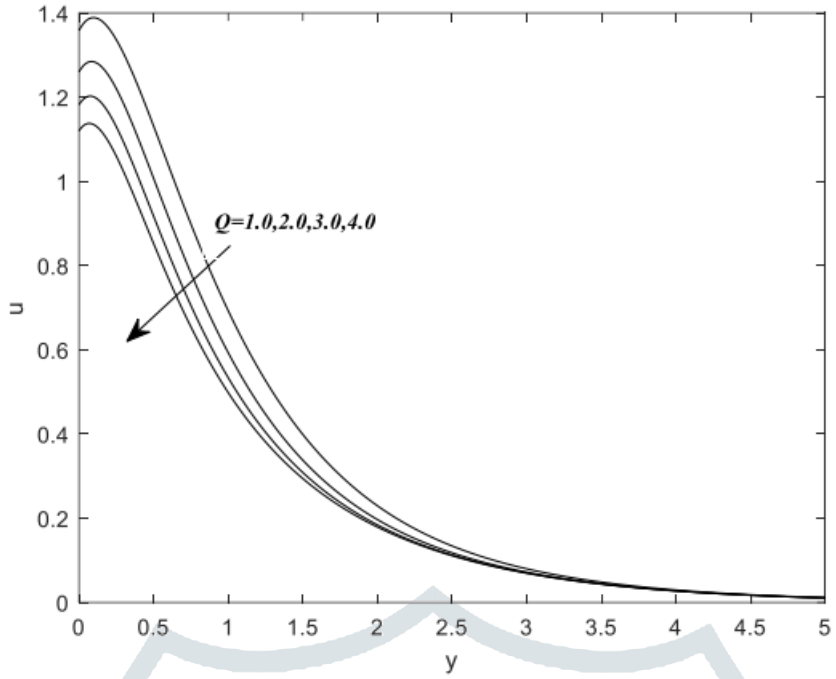

Fig. (6). The outlines of *u* w.r.to *y* for *Q*

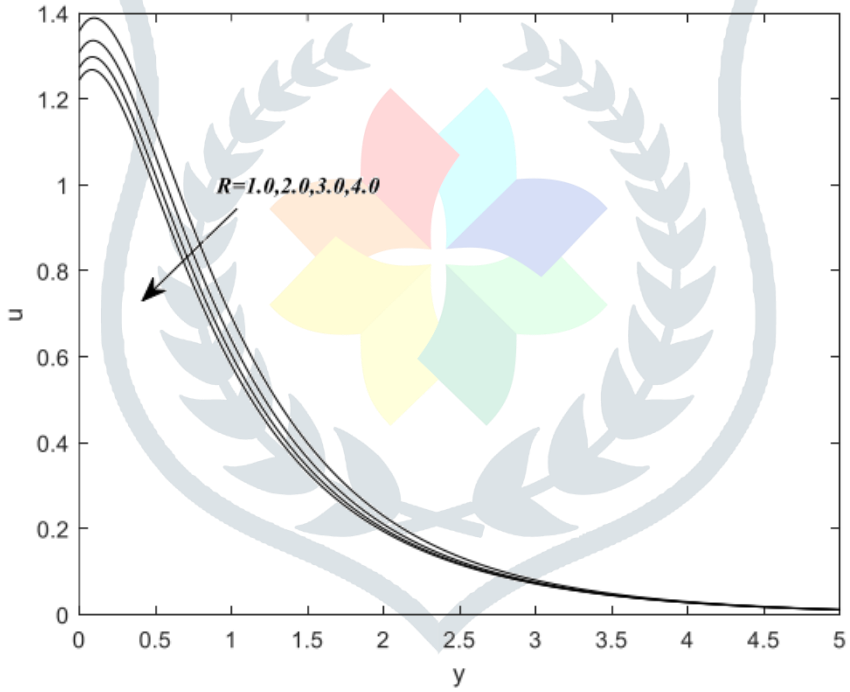

Fig. (7). The outlines of *u* w.r.to *y* for *R*

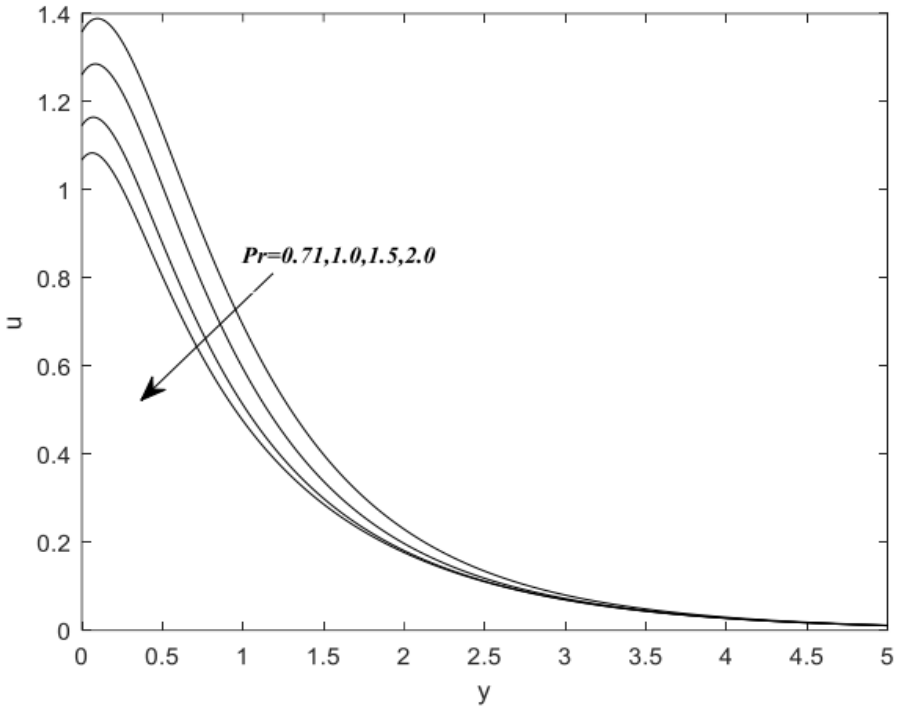

Fig. (8). The outlines of *u* w.r.to *y* for *Pr*

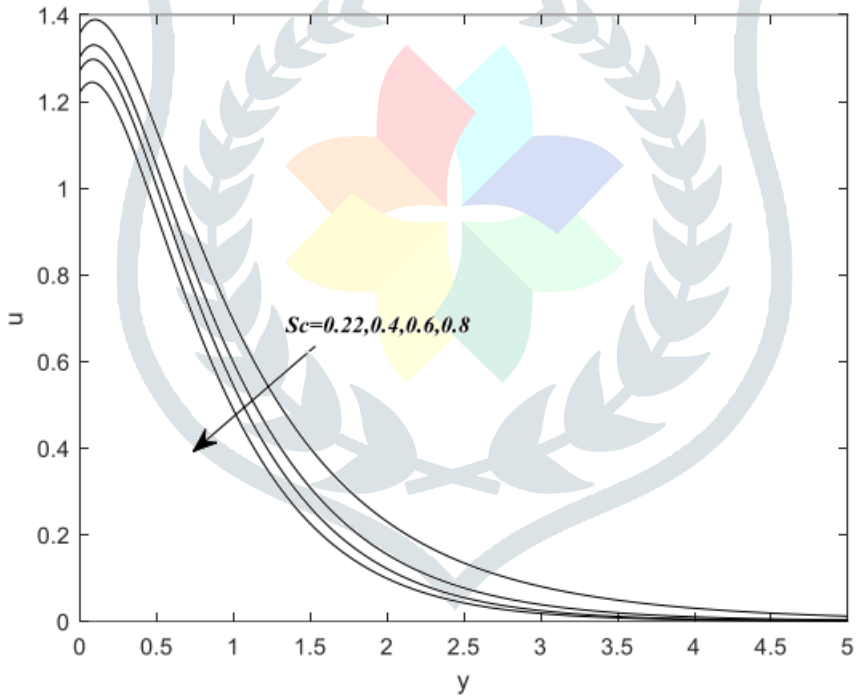

Fig. (9). The outlines of *u* w.r.to *y* for *Sc*

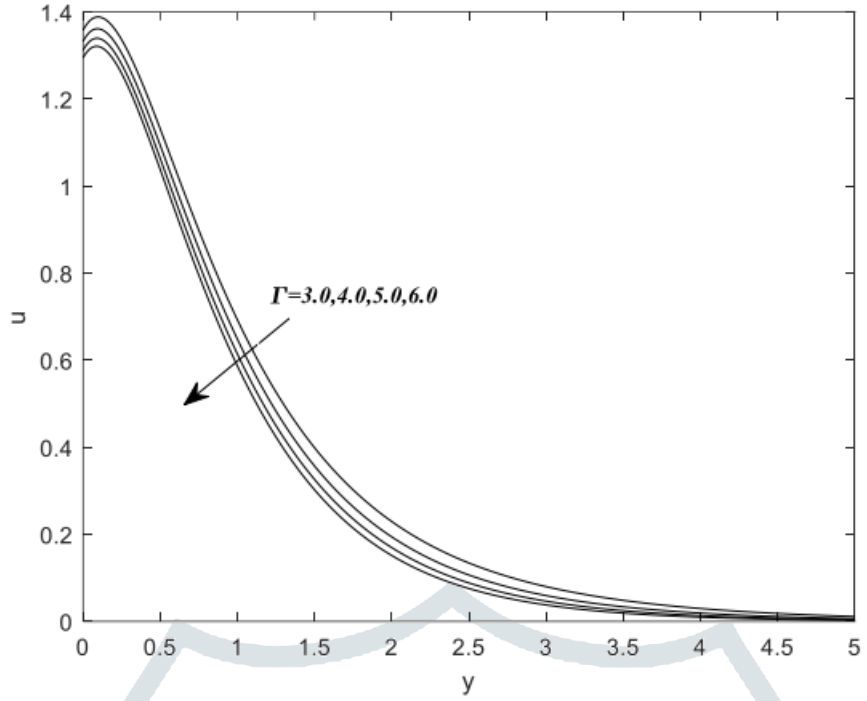

Fig. (10). The outlines of *u* w.r.to *y* for *Γ*

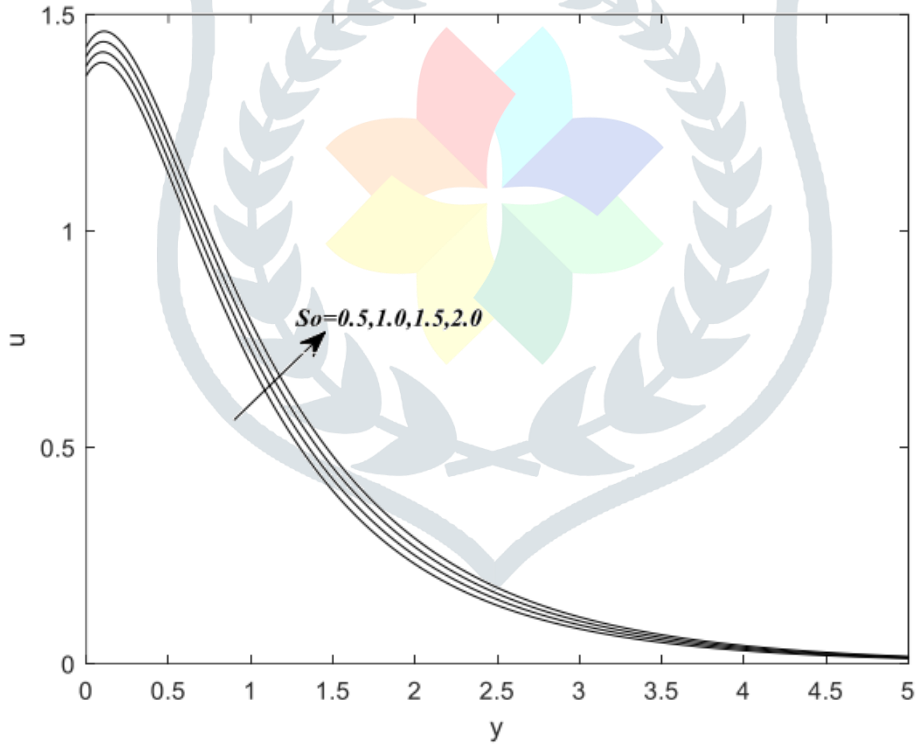

Fig. (11). The outlines of *u* w.r.to *y* for *So*

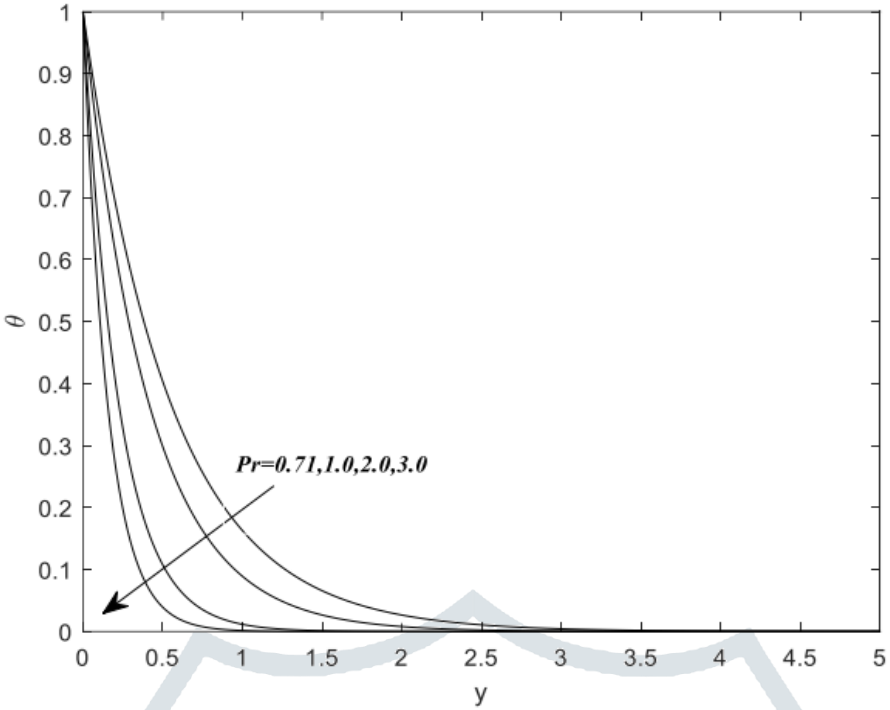

Fig. (12). The outlines of w.r.to *y* for *Pr*

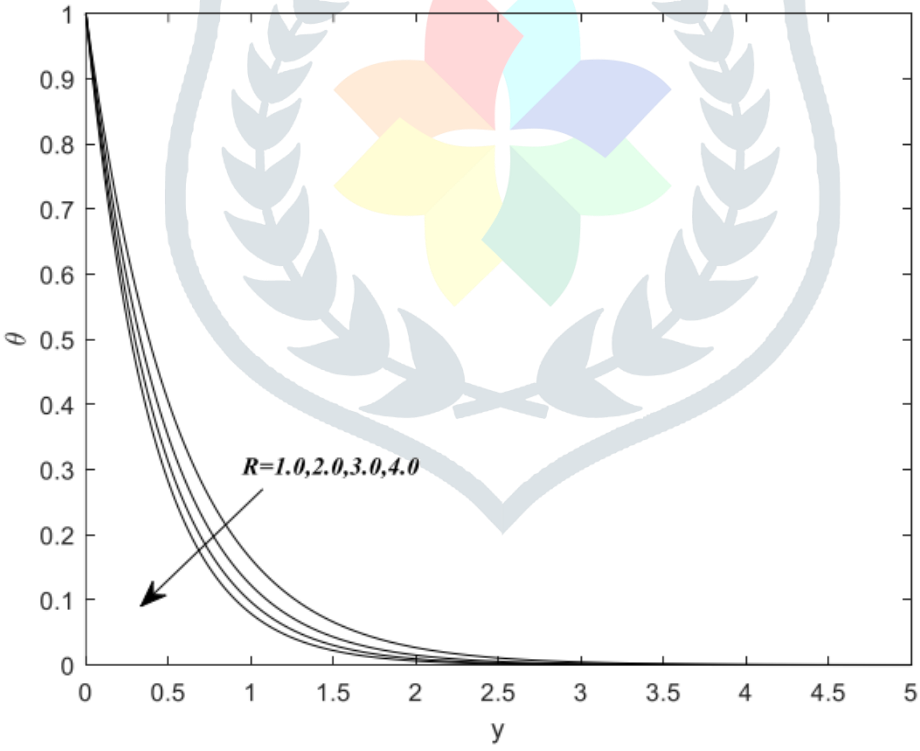

Fig. (13). The outlines of θ w.r.to *y* for R

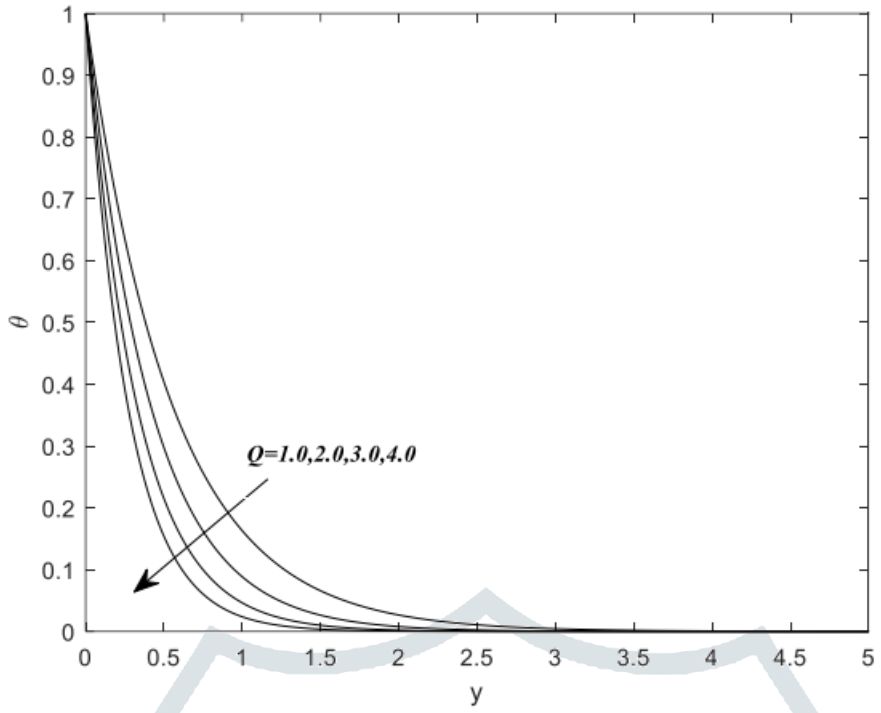

Fig. (14). The outlines of θ w.r.to *y* for Q

Table-1. Consequence of an assortment of bodily constraint on friction factor for *Pr = 0.7, Q = 1.0, R=10, Sc=0.22, Γ=2 and So=0.5.*

Gr	Gm	M	K	Cf	Nu	Sh
10	6.0	5.0	1.0	0.5885	-3.4692	-0.4449
12	6.0	5.0	1.0	0.6407	-3.4692	-0.4449
14	6.0	5.0	1.0	0.6929	-3.4692	-0.4449
10	8.0	5.0	1.0	0.6976	-3.4692	-0.4449
10	10.0	5.0	1.0	0.8067	-3.4692	-0.4449
10	6.0	6.0	1.0	0.5287	-3.4692	-0.444
10	6.0	7.0	1.0	0.4809	-3.4692	-0.4449

Tabl-2. Consequence of an assortment of bodily constraint on rate of heat flux for

Gr = 10.0, , M = 5.0, K = 1.0, Gc = 6.0, Sc = 0.22, Γ = 2.0 and So = 0.5

Pr	Q	R	Cf	Nu	Sh
0.71	1.0	10	0.5885	-3.4692	-0.4449
1.0	1.0	10	0.5553	-4.3190	-0.3530
1.5	1.0	10	0.5181	-5.6571	-0.2073
0.71	3.0	10	0.5513	-4.4413	-0.3397
0.71	5.0	10	0.5208	-5.5434	-0.2197
0.71	1.0	6	0.6174	-2.8944	-0.5067
0.71	1.0	8	0.6013	-3.1985	-0.4741

Table-3. Consequence of an assortment of bodily constraint on rate of mass flux *Gr=10, Gc=6, M=5, K=1, Pr = 0.71, Q=1 and R=10.*

Sc	*Γ*	*So*	*Cf*	*Nu*	*Sh*
0.22	2.0	0.5	0.5877	-3.4691	-0.4450
0.65	2.0	0.5	0.5512	-3.4691	-0.5635
0.93	2.0	0.5	0.5298	-3.4691	-0.6170
0.65	3.0	0.5	0.5723	-3.4691	-0.5999
0.65	4.0	0.5	0.5589	-3.4691	-0.7295
0.65	2.0	1.0	0.6075	-3.4691	-0.1157
0.66	2.0	1.5	0.6255	-3.4691	0.2138

CONCLUSIONS :

The characteristics of the Soret effects on the magnetic field over free convective flow via a vertical plate with thermal radiation, gradient, slip factor, thermal dependent heat generating factor, and destructive chemical parameter are described in this chapter. The perturbation approach is used to solve the consequential leading equations. The outcome is available for various important criteria. Comprehensive research on the various characteristics of flow, heat, and mass transmission is given up. The following are some noteworthy conclusions drawn from the results' figures and tables, While the overturn effect is observed for the permeability of the porous material Ko, an increase in the electrical field parameter M tends to reduce the flow distribution. When thermal radiation R is present, both the flow and the thermal boundary layer are reduced. A decrease in flow is typically associated with an increase in Schmidt number Sc or Prandtl number Pr. The skin-friction factor decreases with an increase in M, but the type of Gr, Gm, or Ko shows an opposite impact. Heat flow uplift rate as Prandtl number Pr increases. The fluid's concentration appears to decrease as the destructive chemical reactor factor and Schmidt number rise.

References :

1) Das, S.S., Sahoo, S.K. and Dash, G.C., (2006) Numerical solution of mass transfer effects on unsteady flow past an accelerated vertical porous plate with suction, *Bulletin of Malysie. Math.Sci. Soc*, Vol.29, No. 1, pp.33-42.

2) Chen, C.H., Yunlin and Taiwan., (2004) Heat and mass transfer in MHD flow by natural convection from a permeable inclined surface with variable wall temperature and concentration, *Acta Mechanica*, Vol. 172, No. 3-4, pp. 219- 235.

3) Masood, K., Ali, R., Shahzad, A., (2013) MHD Falkner-Skan flow with mixed convection and convective boundary conditions, *Walaiak J SciTechnol*, Vol. 10, No. pp.517-529.
4) Nasir Uddin, Md., Ali, M.A. and Chowdhury, M.M.K., (2014) Effect of conjugate heat and mass transfer on MHD mixed convective flow past inclined porous plate in porous medium, *International Journal of Mechanical, Industrial Science and Engineering*, Vol.8, No. 3, pp. 1870-1875.
5) Abdel Khalek, M.M., (2006) The skin friction in the MHD mixed convection stagnation point with mass transfer, *Int. Communications in Heat and Mass Transfer*, Vol. 33, No.2, pp. 249-258.
6) Kinyanjui, M., Kwanza, J.K. and Uppal, S.M., (2001) Magnetohydrodynamic free convection heat and mass transfer of a heat generating fluid past an impulsively started infinite vertical porous plate with Hall current and radiation absorption, *Energy Conversion and Management*, Vol. 42, No. 8, pp. 917–931.137

7) Suneetha, S., Bhaskar Reddy, N. and Ram Chandra Prasad, V., (2009) Radiation and mass transfer effects on MHD free convection flow past an impulsively started isothermal vertical plate with dissipation, *Thermal Science*, Vol. 13, No.2, pp. 171-181.
8) Aydi, O. and Kaya, A., (2009) MHD mixed convective heat transfer flow about an inclined plate, *Heat Mass Transfer*, Vol. 46, pp. 129-136.
9) Israel Cookey, C., Ogulu, A., Omubo-Pepple, V.M., (2003) The influence of viscous dissipation and radiation on unsteady MHD free convection flow past an infinite heated vertical plate in a porous medium with time dependent suction, *Int. J. Heat Mass Transfer*, Vol.46, No. 13, pp.2305-2311.
10) Muthucumaraswamy, R., Maheswari, J. and Pandurangan, J., (2008) Unsteady
11) MHD flow past an impulsively started semi-infinite vertical plate in the presence of chemical reaction, *Mathematics and Mathematical Sciences*, Vol. 4, No.1, pp.1-14.
12) Sudhir Babu, M., Satyanarayana, P.V., Sankar Reddy, T. and Uma
13) Maheshwara Reddy, D., (2011) Radiation and chemical reaction effects on an unsteady MHD convection flow past a vertical moving porous plate embedded in a porous medium with viscous dissipation, *Advances in Applied Science Research*,Vol.2, No.5, pp.226-239.
14) Pal, D. and Talukdar, B., (2010) Perturbation analysis of unsteady magneto hydrodynamic convective heat and mass transfer in a boundary layer slip flow past a vertical permeable plate with thermal radiation and chemical reaction, *Communications in Nonlinear Science and Numerical Simulation*,Vol.15,No. 7, pp.1813-1830.138
15) Sandeep, N., Vijaya Bhaskar Reddy, A. and Sugunamma, V., (2012) Effect of radiation and chemical reaction on Transient MHD free convective flow over a vertical plate through porous media, *Chemical and Process Engineering Research*, Vol.2, No.1, pp. 1-9.
16) Kumar, A.G., Varma, S.V.K. and Ram Mohan, M., (2012) Chemical reaction and radiation effects on MHD free convective flow past an exponentially accelerated vertical plate with variable temperature and variable mass diffusion, *Annals of Faculty Engineering Hunedoara, Tome X, Fascicule*,Vol.2, No.3, pp.195-202.
17) Anjali Devi, S.P. and Kandasamy, R., (2000) Effects of chemical reaction, heat and mass transfer on MHD flow past a semi-infinite plate, *Zeitschrift fur Angewandte Mathematik und Mechanik*, Vol.80, No.10, pp.697–701.
18) Ibrahim, F.S., Elai, A.M. and Bakr, A.A., (2008) Effects of chemical reaction and radiation absorption on the unsteady MHD free convection flow past a semi-infinite vertical permeable moving plate with heat source and suction, *Communications in Nonlinear Science and Numerical Simulation*,Vol.13,No. pp.1056-1066. Prakash, J., Vijaya Kumar, A.G., Madhavi, M. and Varma, S.V.K., (2014)
19) Effects of chemical reaction and radiation absorption on MHD flow of dusty Visco-elastic fluid, *applications and applied mathematics: an international journal*, Vol. 9, No. 1, pp.141-156.139

20) Muhammad, T., Alsaedi, A., Shehzad, S.A. and Hayat, T., (2017) A revised model for Darcy-Forchheimer flow of Maxwell nanofluid subject to convective boundary condition, *Chinese Journal of Physics*, Vol. 55, No.3, pp. 963-976.

21) Hayat, T., Muhammad, T., Alsaedi. And Alhuthali, M.s., (2015) Magneto hydrodynamic three-dimensional flow of visco-elastic nanofluid in the presence of non-linear thermal radiation", *Journal of Magnetism and Magnetic Materials*, Vol. 385, pp. 222-229.