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AN ANALYTICAL STUDY OF CHEMICAL REACTION EFFECT ON MHD FLOW IN A VERTICAL SURFACE FILLED WITH POROUS MEDIUM

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Abstract

The present paper an analytical study of chemical reaction effect on MHD flow of continuously moving vertical surface filled with a porous medium. The equations governing the flow field are solved by analytical method by using perturbation technique. The velocity, temperature, concentration profiles and skin friction have been evaluated for variation in the different governing parameters through graphs.

Keywords: Chemical reaction, MHD, Vertical surface, Perturbation technique

INTRODUCTION

Chemical reactions are of varying use in industries. Firstly, industries use galvanized products for manufacturing steel which is corrosion resistance. Industries also use electrolysis for manufacturing pure quality of goods and minerals. Industries use chemical reaction for extracting minerals from ores. Chemical reactions are used for reuse of by product if possible for making various compounds that may be useful for the industries, making lubricant which is use for the smooth performance of types of machinery, reuse of by product if possible and it also used for making various compounds that may be useful for the industries, lubricant, which is useful for the smooth performance of types of machinery. In view of the above some of the authors, Tsai and Huang [1] explained heat and mass transfer for Soret and Dufour's effects on Hiemenz flow through porous medium onto a stretching surface, Srinathuni Lavanya and Chenna Kesavaiah [2] observed that heat transfer to MHD free convection flow of a viscoelastic dusty gas through a porous medium with chemical reaction, Jeena et. al. [3] observed that chemical reaction effects on MHD viscoelastic fluid flow over a vertical stretching sheet with heat source/sink, Tripathy et. al. [4] has been studied chemical reaction effect on MHD free convective surface over a moving vertical plane through porous medium, Srinathuni Lavanya and Chenna Kesavaiah [5] considered radiation effects on MHD natural convection heat transfer flow from spirally enhanced wavy channel through a porous medium, Kafoussias and Williams [6] motivated study on thermal diffusion and diffusion thermo effects on mixed free forced convective and mass transfer boundary layer flow with temperature dependent viscosity, Chenna Kesavaiah and Satyanarayana [7] presented radiation absorption and Dufour effects to MHD flow in vertical surface, Sajid and Hayat [8] shows Influence of thermal radiation on the boundary layer flow due to an exponentially stretching sheet, Chenna Kesavaiah and Satyanarayana [9] reveals MHD and Diffusion Thermo effects on flow accelerated vertical plate with chemical reaction, Girish Kumar [10] exhibits chemical reaction effects on MHD flow of continuously moving vertical surface with heat and mass flux through porous medium.

Natural convection in a cavity saturated or partially filled with porous media is still one of the researcher's interests studying because it's a distinguishing tool to augment the heat transfer for some natural and engineering applications also it is used as exquisite isolation for other applications. The motion of fluid due to difference in density resulting from temperature gradients is the main rule of natural convection. The term (natural) comes from the absence of foreign effects such as mixer machine, compressor, pump, etc. The effect of a porous medium in natural convection has received widespread attention, especially in recent time. Bidin and Nazar [11] worked to improve numerical solution of the boundary layer flow over an exponentially stretching sheet with thermal radiation, Ch Kesavaiah et. al. [12] shows that the effects of the chemical reaction and radiation absorption on an unsteady MHD convective heat and mass transfer flow past a semi-infinite vertical permeable moving plate embedded in a porous medium with heat source and suction, Abolbashari et. al. [13] studied entropy analysis for an unsteady MHD flow past a stretching permeable surface in nanofluid, Chauhan et. al. [14] motivated study on radiation effects on natural convection MHD flow in a rotating vertical porous channel partially filled with a porous medium, Srinathuni Lavanya and Chenna Kesavaiah [15] explained on radiation and Soret effects to MHD flow in vertical surface with chemical reaction and heat generation through a porous medium, Khansila and Witayangkurn [16] expressed their views on visualization of natural convection in enclosure filled with porous medium by sinusoidally temperature on the one side, Chaudhary et. al. [17] motivated study on free convection effects on MHD flow past an infinite vertical accelerated plate embedded in porous media with constant heat flux, Chin et. al. [18] observe that effect of variable viscosity on mixed convection boundary layer flow over a vertical surface embedded in a porous medium, Troy et. al. [19] studies on uniqueness of flow of a second order fluid past a stretching sheet, Chenna Kesavaiah and Sudhakaraiah [20] done on effects of heat and mass flux to MHD flow in vertical surface with radiation absorption.

The behaviour of MHD's boundary layer momentum and heat transfer in the presence of an external magnetic field has been a hot issue in a variety of academic domains. Research in the field of nonlinear analysis is equally important from a theoretical standpoint. The use of numerical analysis in partial differential equations (PDEs) is ubiquitous in the study of MHD flow. No analytical solution can be found because of the nonlinearities in the governing equations, and the nonlinear equations are usually solved numerically with appropriate boundary conditions. Many researchers have long used various nonlinear analysis methods to handle nonlinear problems numerically or analytically and have looked at MHD flow and heat transfer on the extended or contracted surface from many theoretical and practical perspectives. Cogly et. al. [21] has been studied a Differential approximation for radiative transfer in a non-gray gas near equilibrium, Samad and Rahman [22] considered thermal Radiation interaction with unsteady MHD flow past a vertical porous plate immersed in a porous medium, Makinde and Mhone [23] expressed heat transfer to MHD oscillatory flow in a channel filled with porous medium, Chenna Kesavaiah and Devika [24] explained on free convection and heat transfer of a Couette flow an infinite porous plate in the presence radiation effect, Anwar Be'g et. al. [25] observe that numerical study of free convection magnetohydrodynamic heat and mass transfer from a stretching surface to a saturated porous medium with Soret and Dufour effects, Chenna Kesavaiah and Venkateswarlu [26] motivated study on chemical reaction and radiation absorption effects on convective flows past a porous vertical wavy channel with travelling thermal waves, Misirlioglu et. al. [27] studied free convection in a wavy cavity filled with a porous medium, Beithou et. al. [28] shows the effect of porosity on the free convection flow of non-Newtonian fluids along vertical plate embedded in a porous media. The same related investigations are studied by various authors from [29] to [40]

The present paper an analytical study of chemical reaction effects on MHD flow of continuously moving vertical surface filled with a porous medium. The velocity, temperature, concentration and skin friction have been evaluated for variation in the different governing parameters.

FORMULATION OF THE PROBLEM

Consider the steady, two - dimensional laminar, incompressible flow of a chemically reacting, viscous fluid on a continuously moving vertical surface in the presence of a uniform magnetic field, uniform heat and mass flux effects issuing a slot and moving with uniform velocity in a fluid at rest. Let $x-axis$ be taken along the direction of motion of the surface in the upward direction and $y-axis$ is normal to the surface. The temperature and concentration levels near the surface are raised uniformly. The induced magnetic field, viscous dissipation is assumed to be neglected. Now, under the usual Boussinesq's approximation, the flow field is governed by the following equations.

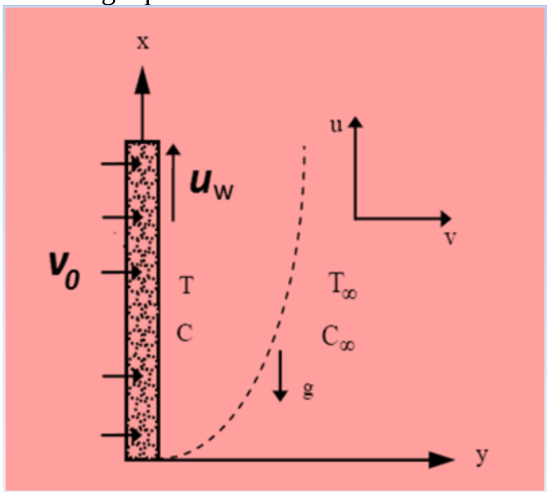

Figure (1): Flow configuration and coordinate system

Continuity equation

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \tag{1}$$

Momentum equation

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

Energy equation

$$\rho C_p\left(u\frac{\partial T'}{\partial x}+v\frac{\partial T'}{\partial y}\right)=k\frac{\partial^2 T'}{\partial y^2} \tag{3}$$

Diffusion equation

$$u\frac{\partial C'}{\partial x}+v\frac{\partial C'}{\partial y}=D\frac{\partial^2 C'}{\partial y^2}-Kr'\left(C'-C'_\infty\right) \tag{4}$$

The initial and boundary conditions

$$\left.\begin{aligned} & u=u_w, v=-v_0 \text{ constant}, <0, \\ & \frac{\partial T}{\partial y}=-\frac{q}{k}, \frac{\partial C}{\partial y}=-\frac{j''}{k} \end{aligned}\right\} at \quad y=0 \tag{5}$$

$$u\to 0, T\to T'_\infty, C\to C'_\infty \qquad as \quad y\to\infty$$

Where u, are velocity components in x and y directions respectively. g is the acceleration due to gravity, β is volumetric coefficient of thermal expansion, β^* is the volumetric coefficient of expansion with concentration, is the temperature of the fluid, C' is the species concentration, T'_w is the wall temperature, C'_w is the concentration at the plate, T'_∞ is the free steam temperature far away from the plate, C'_∞ is the free steam concentration in fluid far away from the plate, ν is the kinematic viscosity, D is the species diffusion coefficient, Kr is the chemical reaction parameter. The term is assumed to be the amount of heat generated or absorbed per unit volume. Q_0 is a constant, which may take on either positive or negative values. When the wall temperature T'_w exceeds the free steam temperature T'_∞, the source term represents the heat source $Q_0>0$ when and heat sink when $Q_0<0$. The first term and second term on the right hand side of the momentum equation (2) denote the thermal and concentration buoyancy effects respectively.

In order to write the governing equations and the boundary conditions the following non-dimensional quantities are introduced.

$$Y=\frac{y v_o}{\nu}, U=\frac{u}{u_w}, \Pr=\frac{\mu C_p}{k}, Sc=\frac{\nu}{D}$$

$$K=\frac{K_p v_0^2}{\nu^2},\ Kr=\frac{Kr'\nu}{v_0^2},\ M=\frac{\sigma B_0^2 \nu}{\rho}$$

$$Gr=\frac{\nu g\beta\left(\frac{q\nu}{k v_0}\right)}{u_w v_0^2}, Gc=\frac{\nu g\beta^*\left(\frac{j''\nu}{k v_0}\right)}{u_w v_0^2} \tag{6}$$

$$T=\frac{T'-T'_\infty}{\left(\frac{q\nu}{k v_0}\right)}, \qquad C=\frac{C'-C'_\infty}{\left(\frac{j''\nu}{k v_0}\right)}$$

In view of (6) the equations (2) – (4) are reduced to the following non-dimensional form

$$\frac{d^2U}{dY^2}+\frac{dU}{dY}-\left(M+\frac{1}{k}\right)U=-GrT-GrC \tag{7}$$

$$\frac{d^2T}{dY^2}+\Pr\frac{dT}{dY}=0 \tag{8}$$

$$\frac{d^2C}{dY^2}+Sc\frac{dC}{dY}-KrSc\,C=0 \tag{9}$$

The corresponding initial and boundary conditions in non-dimensional form are

$$U=1, \frac{\partial T}{\partial Y}=-1, \frac{\partial C}{\partial Y}=-1 \ at \ \ Y=0$$

$$U\to 0, T\to 0, C\to 0 \quad as \ \ Y\to\infty \tag{10}$$

The radiative heat flux q_r is given by equation (5) in the spirit of Cogly et.al [9]

$$\frac{\partial q_r}{\partial y} = 4\left(T - T_\infty\right) I \qquad (11)$$

where $I = \int_0^\infty K_{\lambda w} \frac{\partial e_{b\lambda}}{\partial T} d\lambda,\ K_{\lambda w} -$ is the absorption coefficient at the wall and $e_{b\lambda} -$ is Planck's function, I is absorption coefficient

Where Gr is the thermal Grashof number, $\Pr$ is the fluid Prandtl number, Sc is the Schmidt number and Kr is the chemical reaction parameter,

Method of solution

The study of ordinary differential equations (7), (8) and (9) along with their initial and boundary conditions (10) have been solved by using the method of ordinary linear differential equations with constant coefficients. We get the following analytical solutions for the velocity, temperature and concentration

$$U = L_1 e^{m_2 y} + L_2 e^{m_4 y} + L_3 e^{m_6 y}$$

$$T = -\frac{1}{m_2} e^{m_2 y}$$

$$C = -\frac{1}{m_4} e^{m_4 y}$$

Skin friction

$$\tau = \left(\frac{\partial U}{\partial y}\right)_{y=0} = m_2 L_1 + m_4 L_2 e^{m_4 y} + m_6 L_3$$

Nusselt number

$$Nu = \left(\frac{\partial T}{\partial y}\right)_{y=0} = -1$$

Sherwood number

$$Sh = \left(\frac{\partial C}{\partial y}\right)_{y=0} = -1$$

Appendix

$$m_2 = -\Pr; m_4 = -\left(\frac{Sc + \sqrt{Sc^2 + 4KrSc}}{2}\right)$$

$$m_6 = -\left(\frac{1 + \sqrt{1 + 4\beta}}{2}\right), \beta = \left(M + \frac{1}{K}\right)$$

$$L_1 = \frac{1}{m_2}\left(\frac{Gr}{m_2^2 + m_2 - \beta}\right), L_2 = \frac{1}{m_4}\left(\frac{Gr}{m_4^2 + m_4 - \beta}\right)$$

$$L_3 = \left(1 - L_1 - L_2\right)$$

RESULTS AND DISCUSSION

Set of numerical results is shown graphically in figures to illustrate the influence of physical parameters viz., Grashof number, Permeable parameter, Chemical reaction, Magnetic field parameter, Prandtl number and Schmidt number for velocity, temperature, concentration profiles and skin friction on two dimensional incompressible and chemically reacting flow of a viscous fluid on a continuously moving vertical plate in the presence of magnetic field. The thermal Grashof number represents here the effects of free convection currents and receives positive, zero or negative. **Figures (2) - (3)** we observe that an increase in Grashof number and Permeable parameter rise the velocity, but form **figures (4) - (7)** the reverse effects observed in the Chemical reaction parameter, Magnetic parameter, Prandtl number and Schmidt number. It is also observed form the **figure (8)** when increase the Prandtl number lead to decrease in temperature, as well as the concentration profiles shown for the parameters chemical reaction and Schmidt number in **figures (9) - (10)** it shown that the concentration profiles decrease with increasing the above parameters. **Figure (11)** shows that skin friction for magnetic parameter versus Grashof number, it is observed that an increase in magnetic parameter the skin friction decreases.

Conclusion:

An analytical study of chemical reaction effect on MHD flow of continuously moving vertical surface filled with a porous medium. The equations governing the flow field are solved by analytical method by using perturbation technique. Generally our results show that an increase in Grashof number and Permeable parameter raise the velocity.

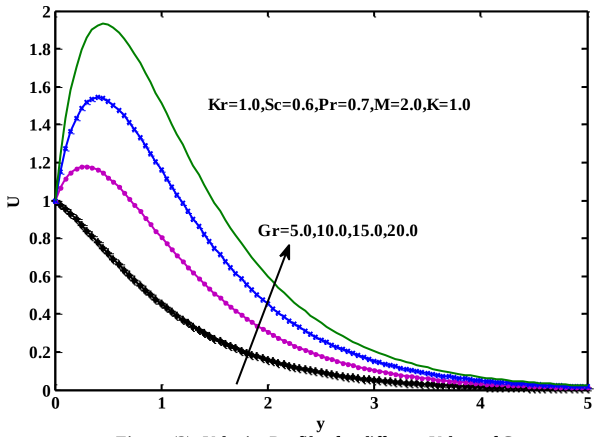

Figure (2): Velocity Profiles for different Values of Gr

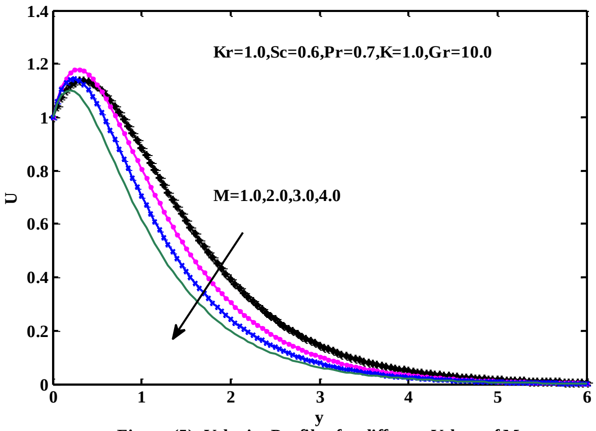

Figure (5): Velocity Profiles for different Values of M

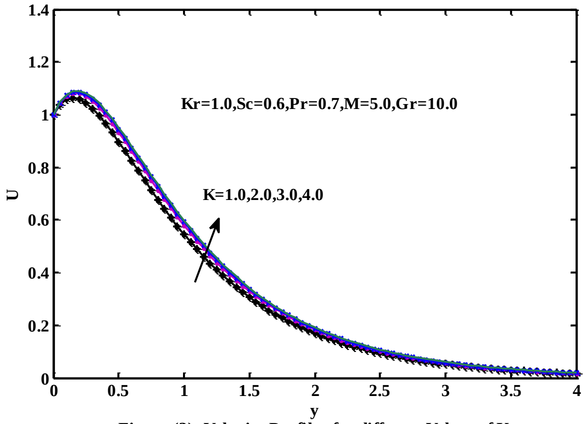

Figure (3): Velocity Profiles for different Values of K

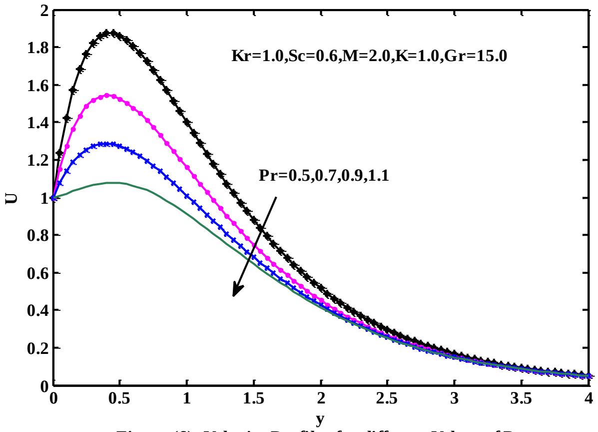

Figure (6): Velocity Profiles for different Values of Pr

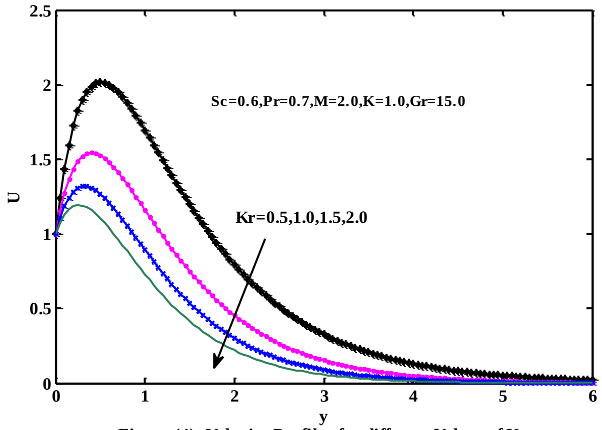

Figure (4): Velocity Profiles for different Values of Kr

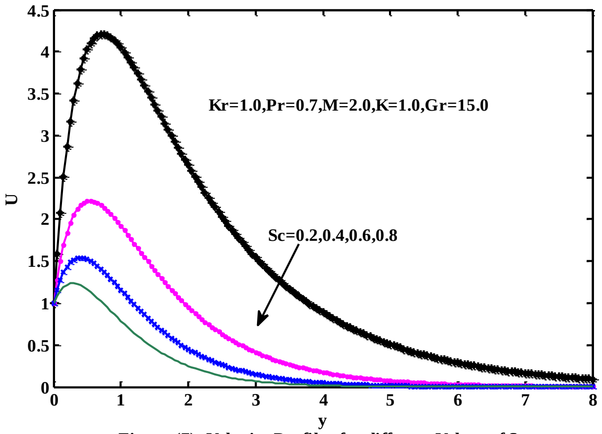

Figure (7): Velocity Profiles for different Values of Sc

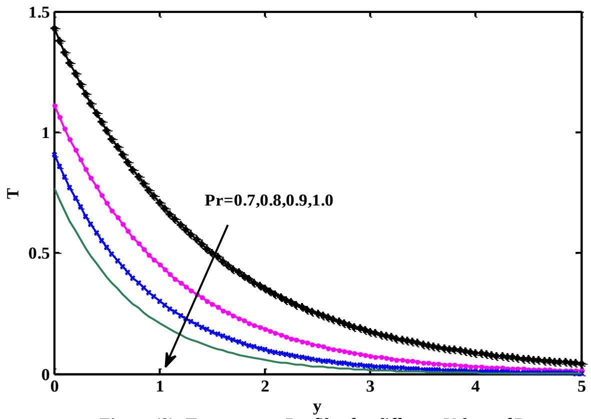

Figure (8): Temperature Profiles for different Values of Pr

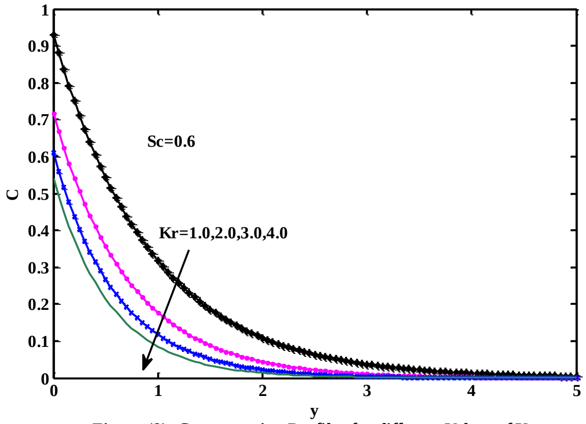

Figure (9): Concentration Profiles for different Values of Kr

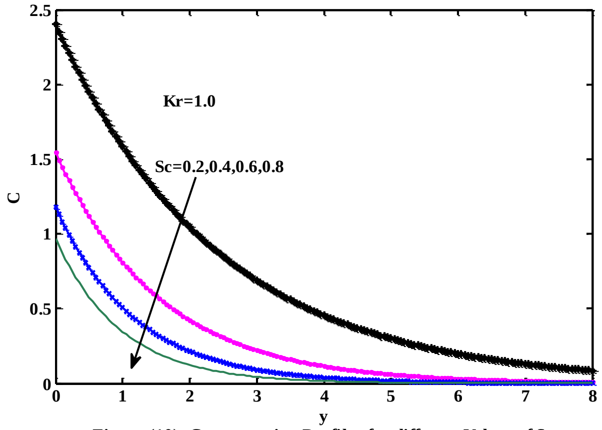

Figure (10): Concentration Profiles for different Values of Sc

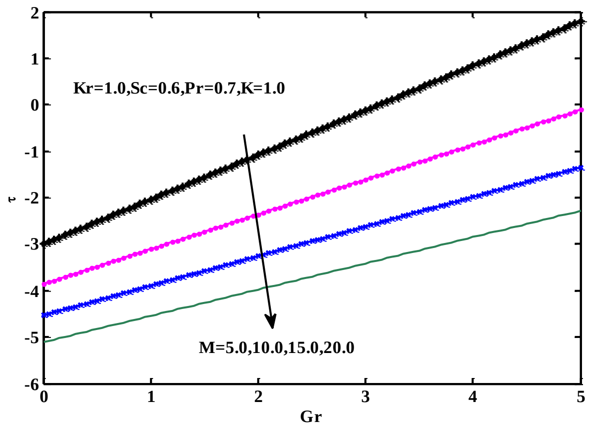

Figure (11): Skin friction for different values of M versus Gr

REFERENCES

[1] R. Tsai, J. S. Huang (2009): Heat and mass transfer for Soret and Dufour's effects on Hiemenz flow through porous medium onto a stretching surface, Int. J. Heat Mass Trasnf. Vol. 52, pp. 2399-2406

[2] Srinathuni Lavanya and D. Chenna Kesavaiah (2017): Heat transfer to MHD free convection flow of a viscoelastic dusty gas through a porous medium with chemical reaction, International Journal of Pure and Applied Researches, Vol. 3 (1), pp. 43 – 56

[3] S. Jeena, G. C. Dash and S. R. Mishra (2018); Chemical reaction effects on MHD viscoelastic fluid flow over a vertical stretching sheet with heat source/sink, Ain Shams Engineering Journal, Vol. 9, pp. 1205-1213

[4] R. S. Tripathy, G.C. Dash, S. R. Mishra and S. Baag (2015): Chemical reaction effect on MHD free convective surface over a moving vertical plane through porous medium, Alex. Eng. J. Vol. 54 (3), pp. 673-679

[5] Srinathuni Lavanya and D. Chenna Kesavaiah (2017): Radiation effects on MHD natural convection heat transfer flow from spirally enhanced wavy channel through a porous medium, International Journal on Future Revolution in Computer Science & Communication Engineering, Vol. 3(10), pp. 130-140

[6] N. G. Kafoussias and E.W. Williams (1995): Thermal diffusion and diffusion thermo

effects on mixed free forced convective and mass transfer boundary layer flow with temperature dependent viscosity, Int. J. Eng. Sci., Vol. 33, 1369-1384

[7] D.Chenna Kesavaiah and P V Satyanarayana (2014): Radiation absorption and Dufour effects to MHD flow in vertical surface, Global Journal of Engineering, Design and Technology, Vol 3(2), pp. 51-57

[8] M. Sajid and T. Hayat (2008): Influence of thermal radiation on the boundary layer flow due to an exponentially stretching sheet, Int. Comm. Heat Mass Trasf. Vol. 35, pp. 347-56

[9] D. Chenna Kesavaiah, P V Satyanarayana (2013): MHD and Diffusion Thermo effects on flow accelerated vertical plate with chemical reaction, Indian Journal of Applied Research, Vol. 3 (7), pp. 310-314

[10] J. Girish Kumar (2013): Chemical reaction effects on MHD flow of continuously moving vertical surface with heat and mass flux through porous medium, International Journal of science, Engineering and Technology Research, Vol. 2 (40), pp. 881-886

[11]B. Bidin and R. Nazar (2009): Numerical solution of the boundary layer flow over an exponentially stretching sheet with thermal radiation, Euro. J. Sci. Res., Vol. 33, pp. 710-717

[12]D. Ch Kesavaiah, P. V. Satyanarayana and S. Venkataramana (2011): Effects of the chemical reaction and radiation absorption on an unsteady MHD convective heat and mass transfer flow past a semi-infinite vertical permeable moving plate embedded in a porous medium with heat source and suction, Int. J. of Appl. Math and Mech. Vol. 7 (1), pp. 52-69

[13] M.H. Abolbashari, N. F. Nazari and M. M. Rashidi (2014): Entropy analysis for an unsteady MHD flow past a stretching permeable surface in nanofluid, Powder Technol., Vol. 267, pp. 256-267

[14] Chauhan, Dileep Singh and Priyanka Rastogi (2010): Radiation effects on natural convection MHD flow in a rotating vertical porous channel partially filled with a porous Medium. Applied Mathematical Science, 4 (13), pp. 648 – 655.

[15] Srinathuni Lavanya, D Chenna Kesavaiah (2014): Radiation and Soret Effects to MHD Flow in Vertical Surface with Chemical reaction and Heat generation through a Porous Medium, International Journal of Computational Engineering Research, Vol, 04, (7), pp. 62-73

[16] P. Khansila and S. Witayangkurn (2012): Visualization of natural convection in enclosure filled with porous medium by sinusoidally temperature on the one side, Applied Mathematical Sciences, Vol. 6 (97), pp. 4801-4812

[17] R. C. Chaudhary, M. C. Goyal and A. Jain (2009): Free convection effects on MHD flow past an infinite vertical accelerated plate embedded in porous media with constant heat flux, Matematicas Ensenanza Universitaria, Vol. 17 (2), pp. 73-82.

[18] K. E. Chin, R. Nazar, N. M. Arifin and I. Pop, (2007): Effect of variable viscosity on mixed convection boundary layer flow over a vertical surface embedded in a porous medium, International Communications in Heat and Mass Transfer, Vol. 34 (4), pp. 464-473

[19] W.C. Troy, E.A. Overman, H.G.B. Ermentrout and J.P. Keener (1987): Uniqueness of flow of a second order fluid past a stretching sheet, Quart. Appl. Math., Vol. 44, pp. 753-5

[20]D. Chenna Kesavaiah and A. Sudhakaraiah (2014): Effects of Heat and Mass Flux to MHD Flow in Vertical Surface with Radiation Absorption, Scholars Journal of Engineering and Technology, 2(2B), pp. 219-225

[21] A. C. Cogly, W. C. Vincentry and S. E. Gille (1968): A Differential approximation for radiative transfer in a non-gray gas near equilibrium, AIAA Journal, 6

[22]M. A. Samad and M. M. Rahman (2006): Thermal Radiation interaction with unsteady MHD flow past a vertical porous plate immersed in a porous medium, J. Naval

Architecture and Marine Eng., Vol. 3, pp. 7 – 14

[23] O.D. Makinde and P.Y. Mhone (2005): Heat transfer to MHD oscillatory flow in a channel filled with porous medium, Rom. Journ. Phys., Vol. 50, Nos. 9–10, pp. 931–938

[24] D. Chenna Kesavaiah and B. Devika (2020): Free convection and heat transfer of a Couette flow an infinite porous plate in the presence radiation effect, Journal of Xi'an University of Architecture & Technology, Vol. XII, (V), pp. 525-543

[25]O. Anwar Be'g, A.Y. Bakier, V.R. Prasad (2009): Numerical study of free convection magnetohydrodynamic heat and mass transfer from a stretching surface to a saturated porous medium with Soret and Dufour effects. Comput. Mater. Sci., Vol. 46, pp. 57-65

[26]D. Chenna Kesavaiah and B. Venkateswarlu (2020): Chemical reaction and radiation absorption effects on convective flows past a porous vertical wavy channel with travelling thermal waves, International Journal of Fluid Mechanics Research, Vol. 47 (2), pp. 153-169

[27]A. Misirlioglu, A. C. Baytas, and I. Pop (2005): Free convection in a wavy cavity filled with a porous medium, International journal of heat and mass transfer, Vol. 48 (9), pp. 1840-1850

[28]N. Beithou, K. Albayrak and A. Abdulmajeed (1998): Effect of porosity on the free convection flow of non-Newtonian fluids along vertical plate embedded in a porous media, Turkish J. of Eng. Envir. Sci. Vol. 22 (3), pp. 203-209.

[29]V Nagaraju, K Hemalatha and V Srihari Babu. (2018): Radiation effects on MHD convective heat and mass transfer flow past a semi-infinite vertical moving porous plate in the presence of chemical reaction, International journal of engineering sciences and research technology, 7(8), pp. 146-161.

[30]V Nagaraju, K Hemalatha and V Srihari Babu. (2019): MHD Viscoelastic Fluid flow Past an Infinite Vertical Plate in the Presence of Radiation and Chemical Reaction, International Journal of Applied Engineering Research, Volume 14(5), pp. 1062-1069.

[31]Omeshwar Reddy V, Neelima A and Thiagarajan S. (2019). "Finite difference solutions of MHD natural convective Rivlin-ericksen fluid flow past a vertically inclined porous plate in presence of thermal diffusion, diffusion thermo, heat and mass transfer effects." International Journal of Applied Engineering Research, 14(3): 703-716.

[32]Nagaraju V, Srihari Babu V and Srilakshmi Ch. (2022). "Numerical investigation of radiation effects on MHD convective heat and mass transfer flow past a semi-infinite vertical moving porous plate in the presence of chemical reaction." International Journal for Research in Applied Science & Engineering Technology, Vol. 10 (1): 1595-1607. https://doi.org/10.22214/ijraset.2022.40105.

[33]V Sri Hari Babu, Nagaraju Vellanki, G Rami Reddy, V. Omeswar Reddy. *(2021):* **"**Radiation and chemical reaction effects on mhd rotating fluid past a moving vertical plate.**"** Journal of Mathematical Control Science and Applications**,** 7(2*): 301-312.*

[34]Nagaraju Vellanki, Y.V. Seshagiri Rao, G. Rami Reddy, V Sri Hari Babu. (2021): "Radiation effect on unsteady free convection oscillatory couette flow through a porous medium with periodic wall temperature and heat generation." Journal of Mathematical Control Science and Applications, Vol 7(2):269-283.

[35]Omeshwar Reddy V, Y.V. Seshagiri Rao, K. Venugopal Reddy, Shivaleela G *(2021): "*Radiation and mass transfer effects on unsteady hydro magnetic free convection flow through porous medium past a vertical plate with heat flux." Journal of Mathematical Control Science and Applications, *7(2): 285-299.*

[36]Omeshwar reddy V, V.Nagaraju, Y.V. Seshagiri Rao. (2020). "Thermo diffusion, heat and mass transfer analysis of MHD viscoelasticf luid flow towards a vertically inclined plate by perturbation technique."

Journal of Mathematical Control Science and Applications, Vol 6(2):151-164.

[37]Nagaraju V,V Sri Hari Babu, G. Rami Reddy, Lakshmi Appidi. (2021). “A perturbation analysis for effects on chemical reaction and thermal radiation on temperature and concentration on MHD free convection flow past a vertical porous plate in the presence of and heat source parameter.” Journal of Mathematical Control Science and Applications, 7(2):253-267.

[38] Bang Chuol Nhial, V Sri Hari Babu, V. Nagaraju Vellanki, G. Y. Sagar (2022): ‘RADIATION AND MASS TRANSFER EFFECTS ON MHD FREE CONVECTION FLOW OVER AN INCLINED PLATE’, Journal of Positive School Psychology, Vol 6(5), pp.697-706.

[39]Bang Chuol Nhial, V. Nagaraju Vellanki, V Sri Hari Babu, G. Y. Sagar (2022): ‘ HALL CURRENT, ROTATION AND CHEMICAL REACTION EFFECTS ON MHD FREE CONVECTION FLOW PAST AN ACCELERATED VERTICAL PLATE THROUGH A POROUS MEDIUM’, Journal of Positive School Psychology, Vol 6(5),2022, pp.707-716.

[40]Y.Sunita Rani (2019) : ‘Jeffrey Fluid Behaviour on Oscillatory Couette Flow past Two Horizontal Parallel Plates in Presence of MHD and Radiative Heat Transfer‘ in ‘’International Journal of Innovative Technology and Exploring Engineering’’ ISSN: 2278-3075, Volume-8 Issue-11, September 2019.