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MHD mixed convective Micropolar Fluid flow over an exponentially stretching sheet with heat source and Mass transfer

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ABSTRACT

This present article investigates the problem of MHD mixed convective micropolar fluid flow with mass transfer over an exponentially stretching porous sheet. The flow governing equations have been altered as ODE with similarity transformation and then solved by finite differences method. To study controlling parameters of velocity, temperature and concentration profiles, all non-dimensional parameterssuch as Material constant K, magnetic parameter M, Prandtl number Pr, Heat source parameter S, Schmidt number Sc, and chemical reaction parameter γ are presented graphically. This investigation gives the understanding of thermal and chemical reactionbahaviours towards non-Newtonian fluids.

KEYWORDS: MHD, Mixed convection, ODE, finite difference method, non-Newtonian fluid

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1. INTRODUCTION

Recently, most of researchers have fascinated tremendous attention towards the theory of micropolar fluid and interest of extensive research has given towards the study of MHD micropolar fluid over a stretching sheet due to its industrial applications.Chaudaryet.al[1]investigated the heat and mass transfer processes on an unsteady flow of a micropolar fluid past through a porous medium bounded by a semi-infinite vertical plate.FaizAwadet.al[2]studied Dufour and Soret effects of a micropolar fluid in a horizontal channel. In the above article a couple of partial differential equations were solved analytically by Homotopy Analysis Method and numerically by bvp4c MATLAB. Mohamed Abd-El-aziz.et.al[3] discussed the effect of variable viscosity and variable thermal conductivity of an unsteady forced convective flow and heat transfer characteristics of a viscoelastic liquids film past on a horizontal stretching sheet in presence of viscous dissipation. Dakshinamoorthy.et.al[4] reported the steady, two-dimensional, boundary layer flow of an electrically conducting viscous incompressible fluid past in a continuously moving surface in presence of uniform transverse magnetic field. Kishoreet.al[5]presented MHD viscous incompressible fluid past in an oscillating vertical plate fixed in a porous medium in presence of variable heat and mass diffusion, radiation and viscous dissipation.

Further, Rojaet.al[6] investigated the effect of first-order homogeneous chemical reaction and thermal radiation on hydromagnetic free convective micropolar fluid flow through semi-infinite vertical moving porous plate. Rajasekaret.al[7]studied the influence of variable viscosity and thermal conductivity on an unsteady MHD, two-dimensional laminar viscous flow of an incompressible electrically conducting fluid past through a semi-infinite vertical plate with mass transfer processes. Shehzad.et.al[8] discussed MHD flow of Casson fluid over a porous stretching sheet in presence of a chemical reaction. Shitet.al[9]reported the influence of thermal radiation and temperature dependent viscosity on a free convective flow and mass transfer characteristics of an electrically conducting fluid over an isothermal stretching sheet. Yigit Aksoyet.al[10]analyzed the new techniques in perturbation iteration method for heat transfer problems. This new technique is practically applied in much nonlinear heat transfer and flow problems and is successfully implemented. Sankar Reddyet.al[11]discussed MHD flow of a micropolar fluid past in semi-infinite vertically moving porous plate fixed in a porous medium in presence of thermal radiation, thermal diffusion, and the first order homogeneous chemical reaction. Mohammed Abd El-Aziz[12] investigated the unsteady mixed convective flow of a viscous incompressible micropolar fluid close to a heated vertical surface with viscous dissipation where the buoyancy force assists or opposes the flow.

Moreover, Najwa Najibet.al[13] reported the stagnation point flow and mass transfer characteristics through a stretching/shrinking cylinder. Hayatet.al[14]discussed on steady magnetohydrodynamic (MHD) flow of viscous nanofluid over an permeable exponentially stretching surface in a porous medium with convective boundary condition. Lavanyaet.al[15]analyzed two-dimensional steady MHD free convective flow past in a vertical porous plate in a porous medium in presence of thermal radiation, chemical reaction. Bhim Sen Kalaet.al[16] discussed the influence of first-order chemical reaction and oscillatory suction on magnetohydrodynamic (MHD) flow of a viscous incompressible electrically conducting fluid through a porous medium in presence of transverse magnetic field. Prabir Kumar Kunduet.al[17] studied hydrodynamic free convective micropolar fluid flow in a rotating frame of reference with constant wall heat and mass transfer in a porous medium which was bounded by a semi-infinite porous plate. Abdul Rehman.et.al[18] analyzed the influence of natural convective heat transfer analysis for a steady boundary layer flow of an Eyring Powell fluid which was flowed through a vertical circular cylinder. Sethet.al[19] discussed unsteady hydromagnetic natural convective heat and mass transfer processes of a viscous incompressible, electrically conducting chemically reactive and optically thin radiating fluid past in an exponentially accelerated moving vertical plate with arbitrary ramped temperature fixed in a fluid-saturated porous medium.

Numerical analysis of a steady two-dimensional hydromagnetic stagnation point flow of an electrically conducting nanofluid past in a stretching surface with induced magnetic field was studied by Gireeshaet.al[20]. KhairyZaimiet.al[21] discussed the influence of partial slip on stagnation point flow and heat transfer processes towards a stretching vertical sheet and the problem was solved numerically by using the shooting method. Sheri Siva Reddyet.al[22]analyzed boundary layer analysis on an unsteady MHD free convective micropolar fluid flow past in a semi-infinite vertical porous plate with the presence of diffusion Thermo, heat absorption, and homogeneous chemical reaction. Shahirah Abu Bakeret.al[23] investigated a mathematical analysis of forced convective boundary layer stagnation-point slip flow in Darcy-Forchheimer porous medium through a shrinking sheet.Sahin.Ahmad.et.al[24]analyzed perturbation analysis of combined heat and mass transfer processes in MHD steady mixed convective flow of an incompressible, viscous, Newtonian, electrically conducting and chemical reacting fluid past over an infinite vertical porous plate in presence of the homogeneous chemical reaction of first order.

Shamshuddinet.al[25] discussed the heat and mass transfer processes on the unsteady incompressible MHD flow of chemically reacting micropolar fluid flow to a vertical porous plate fixed in a saturated homogeneous porous medium in presence of radiation effect and Joule heating. Okechiet.al[26]investigated the boundary layer analysis of viscous fluid flow induced by rapidly stretching curved surface with an exponential velocity. Aliet.al[27] investigated MHD boundary layer nanofluid flow along a moving wedge. Arunaet.al[28] studied parameterized perturbation method

(PPM) for the solution of nonlinear equations which was arising in heat transfer processes. Abid Hussananet.al[29] investigated a closed form solution for an unsteady free convective flow of a micropolar fluid past over a vertical plate oscillating in its own plane with a Newtonian heating condition. Sivakumar Narsuet.al[30]analyzed the effect of thermo diffusionin unsteady MHD combined convective boundary layer flow of a Kuvshinski fluid through vertical porous plate in slip flow regime.

A finite element computational analysis was done for MHD double-diffusive mixed convective micropolar fluid flow to a vertical porous plate fixed in the saturated porous medium by Shamshuddin.et.al[31]. Dulal palet.al[32] studied the double-diffusive heat and mass transfer processes of an oscillatory viscous electrically conducting micropolar fluid past over a moving plate with convective boundary condition and chemical reaction. Chandra sekaret.al[33] investigated MHD free convective flow past in an inclined porous stretching sheet with a presence of viscous dissipation and radiation effect. Sivakamiet.al[34]studied perturbation technique for an unsteady MHD free convective flow of two immiscible fluid in a horizontal channel with the influence of Dufour effect in presence of chemical reaction and heat source. Zahir Shahet.al[35]discussed micropolar nanofluid flow of Casson fluid past between the two rotating parallel plates with the influences of hall currents and thermal radiation. Motivation by the above studies, the novelty of present article extends the work of Anuradha[36] toMHD mixed convective micropolar fluid flow with mass transfer over an exponentially stretching porous sheet.

2. MATHEMATICAL FORMULATION

The steady two dimensional, incompressible,MHD mixed convective micropolar fluid flow through an exponentially stretching sheet is considered with heat source and chemical reaction.Assume that the sheet is being stretched with exponential velocity $U_w = ae^{x/L}$; a>0 ;a is a stretching constant. The physical configuration and Cartesian coordinate system are taken as follows: Leading edge of the sheet is located in the origin, considerable$x$ axis in positive direction and along the stretching sheet, positive y axis is normal to the stretching sheet,Cartesian coordinate axes (x, y, z) are with corresponding velocities (u, v, 0),the uniform magnetic field B_0 is applied towards the positive direction of y axis and dufour and soret effects are negligible in the concentration of mass. Under theBoussinesq and boundary layer approximation, the governing equations can be writtenas follows

Continuity Equation:

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

Momentum Equation:

$$u\frac{\partial u}{\partial x}+v\frac{\partial v}{\partial y}=U_{\infty}\frac{dU_{\infty}}{dx}+(\upsilon+\frac{k}{\rho})\frac{\partial^{2}u}{\partial y^{2}}+\frac{k}{\rho}\frac{\partial N}{\partial y}+\frac{\sigma B_{0}^{2}}{\rho}(U-u)\pm g\beta_{T}(T-T_{\infty})\pm g\beta_{C}(C-C_{\infty}) \qquad (2)$$

Angular momentum Equation:

$$u\frac{\partial N}{\partial x}+v\frac{\partial N}{\partial y}=\frac{\gamma}{\rho j}\frac{\partial^{2}N}{\partial y^{2}}-\frac{k}{\rho j}(2N+\frac{\partial u}{\partial y}) \qquad (3)$$

Energy Equation:

$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial x}=\frac{k}{\rho C_{p}}\frac{\partial^{2}T}{\partial y^{2}}+\frac{Q_{0}}{\rho C_{p}}(T-T_{\infty}) \qquad (4)$$

Concentration Equation:

$$u\frac{\partial C}{\partial x}+v\frac{\partial C}{\partial y}=D_{m}\frac{\partial^{2}C}{\partial y^{2}}-K_{r}(C-C_{\infty}) \qquad (5)$$

The corresponding boundary conditions of this model are

$$\begin{aligned}&u=U_{w},\ v=0,\ N=n(\frac{\partial v}{\partial x}-\frac{\partial u}{\partial y}),\ T=T_{w}(x),\ C=C_{w}(x)\quad at\quad y=0\\&u\to U_{\infty},\ \ N\to 0,\ \ T\to T_{\infty},\ \ C\to C_{\infty}\quad as\quad y\to\infty\end{aligned} \qquad (6)$$

Where g is the acceleration due to the gravity, β_C is Mass expansion coefficient, β_T is the thermal expansion coefficient, v is the kinematic viscosity, μ *is* the dynamic viscosity, ρ is the density,N is the microrotation,j is the micro inertia per unit mass, $\gamma$is the spin gradient viscosity, k is the vortex viscosity, T is the temperature in the boundary layer, C is the concentration in the boundary layer, L is the reference length, $D_m$is the modular diffusivity,

Assume that the exponential stretching sheet expression for U_∞, U_w , T_w and $C_w$from the stagnation point flow are defined as

$$U_{\infty}=ae^{\frac{x}{L}},\ \ U_{W}=be^{\frac{x}{L}},\ \ T_{w}=T_{\infty}+ce^{\frac{x}{L}},\ \ C_{w}=C_{\infty}+de^{\frac{x}{L}} \qquad (7)$$

The equations (1)- (5) with the boundary conditions (6) are transformed into ordinary differential equations by using similarity transformation. We introduce the following similarity variables and non-dimensional variables (8) to the equations (1)-(6), Equation (1) is satisfied byCauchy Riemann equations and the equations (2)-(5) becomes

$$\begin{aligned}&u=\frac{\partial\psi}{\partial y},v=-\frac{\partial\psi}{\partial x},u=ae^{\frac{x}{L}}f^{'}(\eta),v=-(\frac{\upsilon a}{2L})^{1/2}e^{\frac{x}{2L}}(f(\eta)+\eta f^{'}(\eta)),\\&N=a(\frac{a}{2\upsilon L})^{1/2}e^{\frac{3x}{2L}}M(\eta),\theta=\frac{T-T_{\infty}}{T_{W}-T_{\infty}},\eta=(\frac{a}{2\upsilon L})^{1/2}e^{\frac{x}{2L}}y,\varphi=\frac{C-C_{\infty}}{C_{w}-C_{\infty}}\end{aligned} \qquad (8)$$

where ψ(x,y) = the stream function.

$$f''' + \frac{1}{1+K}(ff'' - 2f'^2 + 2) + \frac{K}{1+K} g' + M(1 - f') + \lambda\theta + \delta\phi = 0 \tag{9}$$

$$g'' + \frac{1}{\Lambda}(fg' - 2f'g) - \frac{K\chi}{\Lambda \operatorname{Re}}(2g + f'') = 0 \tag{10}$$

$$\theta'' + \Pr(f\theta' - f'\theta) + \Pr S\theta = 0 \tag{11}$$

$$\varphi'' - Scf'\varphi + Scf\varphi' - Sc\gamma\varphi = 0 \tag{12}$$

The associated non-dimensional boundaryconditions becomes

$$\begin{array}{l} f(0) = 0, \quad f'(0) = \varepsilon, \quad f' \to 1 \quad as \quad \eta \to \infty \\ M(0) = -nf''(0), \quad M \to 0 \quad as \quad \eta \to \infty \\ \theta(0) = 1, \quad \theta \to 0 \quad as \quad \eta \to \infty \\ \varphi(0) = 1, \quad \varphi \to 0 \quad as \quad \eta \to \infty \end{array} \tag{13}$$

3. NUMERICAL PROCEDURE, RESULTS AND DISCUSSION

To solve this mathematical model, firstly, the given system of partial differential equations can betransformed into set of coupled non-linear boundary layer equations (9)-(12) with associated boundary condition (13) by using similarity transformation and then the equations (9)-(12) solved numerically by finite difference method. To study the flow characteristics and mixed convective parameters, the physical situation of non-dimensional parameters on velocity, temperature and concentration profiles are analyzed numerically and presented with the help of graphs. This study is extension of Anuradha(2018) for MHD mixed convective boundary layer flow of micropolar fluid along exponentially Stretchingsheetwithchemical reaction and heat source.The non-dimensional parameters such as Material constant K, magnetic parameter M, Prandtl number Pr, Heat source parameter S, Schmidt number Sc, and chemical reaction parameter γon velocity, temperature and concentration profiles are presented with help of graphs. For the depth of analysis, Assisting flow λ >1, δ >1 and Opposing flow λ <1, δ <1 are taken into account.

Figures 1-3 demonstrate the variation of Material constant K on temperature, concentration andvelocity profiles respectively. Increasing values of Material constant K decrease the velocity profile for both assisting and opposing flows.Whereas increasing values of Material constant K decrease the concentration and temperature profiles. This proves the impact that the thickness of thermal boundary layer has increased for assisting flow comparing with effect of opposing flow.

Figure 4-6 depict the effect of magnetic parameter M on temperature, concentration and velocity profiles respectively. Increasing values of magnetic parameter M reduce temperature and concentration profiles and increasing values of magnetic parameter M enhances the velocity field.

Figure 7 and 8 exhibit the effect of Prandtl number Pr and heat source parameterS on temperature profile respectively. Increment in the values of Prandtl number Pr decreases the temperature profile for both assisting and opposing flows. Increasing values of heatsource parameter S increase temperature profile which shows that increasing values of heat source parameter S increase the level of temperature for both flows in micropolar fluid.

Figures 9 and 10 illustrate the effect of Schmidt number Sc and chemical reaction parameter γ on concentration profile respectively. Increasing values of Schmidt number Sc and chemical reaction parameter γ reduces concentration profile. Increasing values of Schmidt number Sc improves the concentration level in micropolar fluid flow.

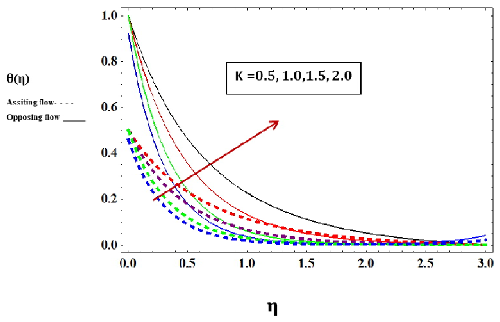

Figure.1.Influence of Material constant K on Temperature profile M=1,Pr =0.72, Re = 1, K=1, Sc=0.62, S=0.5

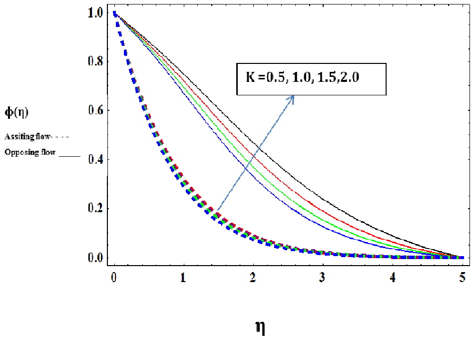

Figure.2.Influence of Material constant K on Concentration profile M=1,Pr =0.72, Re = 1, K=1, Sc=0.62, S=0.5

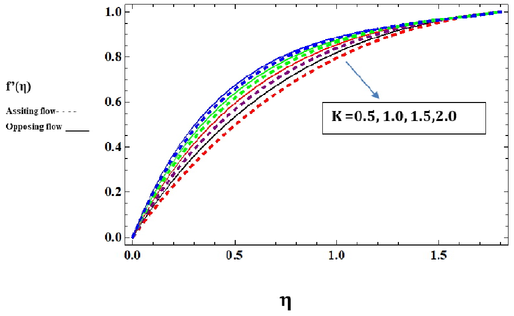

Figure.3.Influence of Material constant K on Velocity profile M=1,Pr =0.72, Re = 1, K=1, Sc=0.62, S=0.5

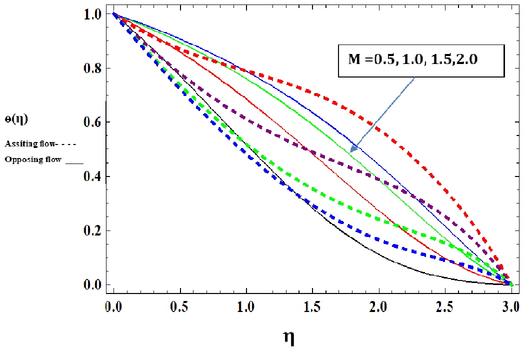

Figure.4.Influence of Magnetic parameter M on Temperature profile K=1,Pr =0.72, Re = 1, K=1, Sc=0.62, S=0.5

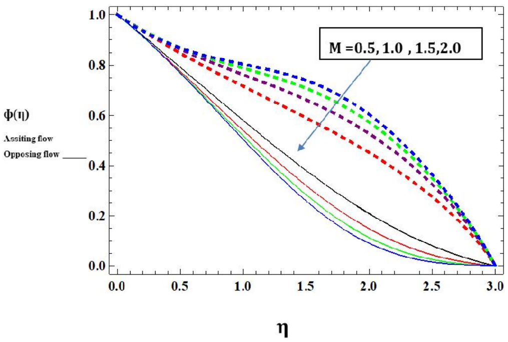

Figure.5.Influence of Magnetic parameter M on Concentration profile K=1,Pr =0.72, Re = 1, K=1, Sc=0.62, S=0.5

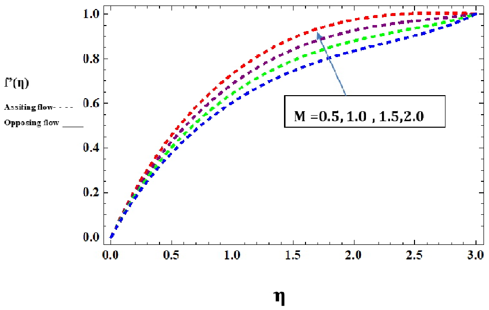

Figure.6.Influence of Magnetic parameter M on Velocity profile K=1,Pr =0.72, Re = 1, K=1, Sc=0.62, S=0.5

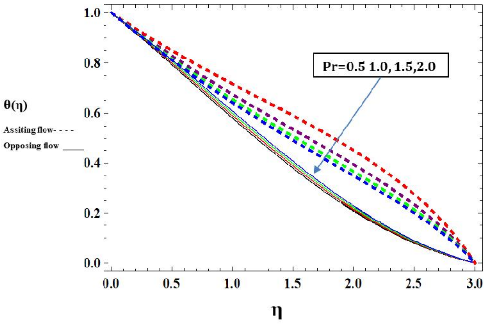

Figure.7.Influence of Prandtl number Pr on Temperature profile M=1, Re = 1, K=1, Sc=0.62, S=0.5,K=1

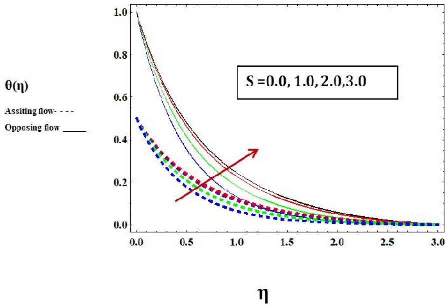

Figure.8.Infuence of Heat source parameter S on Temperature profile M=1, Re = 1, K=1, Sc=0.62, S=0.5,K=1

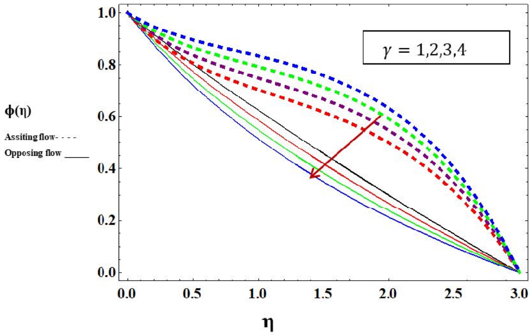

Figure.10.Influence of chemical reaction parameter γ on Concentration profile M=1,Pr =0.72, Re = 1, K=1, S=0.5

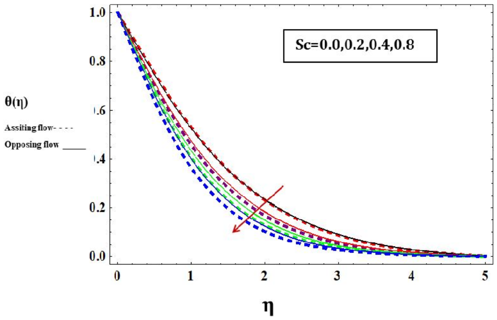

Figure.9.Influence of Schmidt number on Concentration profile M=1,Pr =0.72, Re = 1, K=1, K=1, S=0.5

4. CONCLUSION

This present article studied MHD mixed convective micropolar fluid flow with masstransfer and heat source over an exponentially stretching porous sheet. The conclusions are as follows:

- Increasing values of Material constant K decrease the velocity profile for both assisting and opposing flows. Whereas increasing values of Material constant K decrease the concentration and temperature profiles. This proves the impact that the thickness of thermal boundary layer has increased for assisting flow comparing with effect of opposing flow.
- Increasing values of magnetic parameter M reduce temperature and concentration profiles and increasing values of magnetic parameter M enhances the velocity field.
- Increment in the values of Prandtl number Pr decreases the temperature profile for both assisting and opposing flows. Increasing values of heat source parameter S increase temperature profile which shows that increasing values of heat source parameter S increase the level of temperature for both flows in micropolar fluid.
- Increasing values of Schmidt number Sc and chemical reaction parameter γ reduces concentration profile. Increasing values of Schmidt number Sc improves the concentration level in micropolar fluid flow.

REFERENCES

1. Chaudhary.R.C, Abhay Kumar Jha, Effects of chemical reaction on MHD micropolar fluid flow past a vertical plate in a slip-flow regime, Appl.Math, Mech.Engl. ed., 2008; 29(9):1179-1194.
2. FaizAwad and Precious Sibanda, Dufour and Soret effect on heat and mass transfer in a micropolar fluid in a horizontal channel, Wseas Transactions on heat and mass transfer, 2010; 3(5): 165-177.
3. Mohamed Abd El-Aziz The effect of variable fluid properties and Viscous dissipation on forced convection of viscoelastic liquids in a thin film over an unsteady stretching sheet, Canadian Journal of physics, 2010; 88(8):607-616.
4. Dakshinamoorthy.M, Geetha.P, Moorthy. M.B.K, Boundary layer flow and heat transfer over a continuous surface in the presence of Hydromagnetic field, Int.J of Mathematical Analysis, 2014; 18(38):1859-1872.
5. Kishore.PM, Rajesh.V, Vijayakumar Verma.S The effect of thermal radiation and viscous dissipation on MHD heat and mass diffusion flow past an oscillatory vertical plate embedded

in a porous medium with variable surface conditions, theoret. Appl.Mech, 2012; 39(2):99-125.

6. Roja.P, Sankar Reddy.T, Bhaskar Reddy. N, Double-diffusive Convection Radiation Interaction on unsteady MHD flow of a micropolar fluid over a vertical Moving porous embedded in a Porous Medium with heat Generation and Soret effects, the Int.Jour of Engg& science, 2012; 1(2): 201-214.
7. Rajasekhar. K, Ramana Reddy. G.V, Prasad. B.D.C.N., Unsteady MHD free convective flow past a semi-infinite vertical porous plate, IJMER, 2012; 2(5): 3123-3127.
8. Shehzad.S.A, Hayat.T, Qasim.M, and Asghar.S, Effects of mass transfer on MHD flow of Casson fluid with chemical reaction and suction, Brazilian Journal of Chemical Engg., 2013; 30(01): 187-195.
9. Shit G.C. and Halder R., Thermal radiation effects on MHD viscoelastic fluid flow over a stretching sheet with variable viscosity, Int. Jr. of Appl. Math. & Mech., 2012; 8(14): 14-36.
10. Yigit Aksoy, Mehmet PAkdemirle, Saeid Abbasbandy, Hakan Boyaci, New perturbation iterations solution for nonlinear heat transfer equations, Int.J.of Numerical Methods for Heat and Fluid Flow. Emerald Article, 2012; 22(7): 814-828.
11. Sankar Reddy. T, Mohammed Ibrahim. S, Sudhakara Reddy. A and Roja. P, Double-diffusive Convection-radiation interaction on Unsteady MHD flow of a micropolar fluid over a vertical moving porous plate embedded in a porous medium with chemical reaction and Soret effects, J of global research in Mathematical Archivers, 2013; 1(7): 72-87.
12. Mohamed Abd El-Aziz., Mixed convection flow of micropolar fluid from an unsteady stretching surface with viscous dissipation, J of the Egyptian Mathematical Society, 2013; 21(3): 385-394.
13. Najwa Najib, Norfifah Bachok, Norihan Md. Arifin and Anuar Ishak,(2014), Stagnation point flow and mass transfer with chemical reaction past a stretching/shrinking cylinder, Scientific Reports,4:4178/DOI:10.1038/srep04178.
14. Hayat.T., Imtiaz.M, Alsaedi. A and Mansoor. R, MHD flow of nanofluids over an exponentially stretching sheet in a porous medium with convective boundary conditions, Chin.Phys.B 2014;23(5): 054701.
15. Lavanya.B and Leela Ratnan. A., Dufour and Soret effect on steady MHD free convective flow past a vertical porous plate embedded in a porous medium with chemical reaction, radiation and heat generation and viscous dissipation, Advances in-app science Research, 2014; 5(1):127-142.

16. Bhim Sen Kala, Rawat.M.S Effect of chemical reaction and oscillatory suction on MHD flow through porous media in the presence of pressure, Int .J of Mathematical Archives, 2015;6(1):189-199.
17. Prabir Kumar Kundu, Kalidas. S. Jana, MHD micropolar fluid flow with thermal radiation and thermal diffusion in a rotating frame, Bulletin of the Malaysian Mathematical Sciences Society, 2015; 38(3): 1185-1205.
18. Abdul Rehman, Sallahuddin Achakzai, Sohail Nadeem, Saleem Iqbal, Stagnation point flow of Eyring Powell fluid in a vertical cylinder with heat transfer, J. of power technologies, 2016; 96(1): 57-62.
19. Seth. G.S, Sharma. R, and Kumbhakar. B., Heat and Mass Transfer effects on unsteady MHD natural convection flow of a chemically reactive and Radiating fluid through a porous medium past a moving vertical plate with Arbitrary Ramped temperature, Journal of Appl Fluid Mechanics, 2016;9(1): 103-117.
20. Gireesha. B.J, Mahanthesh. B, Shivakumara. I.S, Eshwarappa. K.M., Melting heat transfer in boundary layer stagnation-point flow of nanofluid toward a stretching sheet with the induced magnetic field, Engg science, and Tech, An International Journal, 2016; 19(1):331-321.
21. KhairyZaimi and AnuarIshak, Stagnation –point flow towards a stretching vertical sheet with slip effects, MDPI, Mathematics, 2016;4:27;doi:10.3390/math4020027.
22. Sheri Siva Reddy and Shamshuddin.MD, Diffusion-Thermo and Chemical Reaction effects on an unsteady MHD free convection flow in a Micropolar fluid, Theoretical and Applied Mechanics, 2016;43(1):117-131.
23. Shahirah Abu Bakar, Arifin.N.M, RoslindaNazar, Fadzilah Md ali., Forced Convection Boundary Layer Stagnation point flow in darcy-Forchheimer porous medium past a shrinking sheet, Frontiers in Heat and Mass Transfer(FHMT).7.38(2016).
24. Sahin Ahmed, Joaquin Zueco, Luis.M.Lopez-Gonzalez, Effects of chemical reaction, heat and mass transfer and viscous dissipation over an MHD flow in a vertical porous wall using perturbation method, International journal of heat and mass transfer, 2017;104:409-418.
25. Shamshuddin.M.D, Chamkha.A.J, ThirupathiThammaRaju.M.C., Computation of unsteady MHD Mixed convective heat and mass transfer in dissipative reactive micropolar flow considering Soret and Dufour effects, Frontiers in heat and mass transfer(FHMT), 2018; 10(15).
26. Okechi.N.F, Jalil.M, Asghar. S, Flow of Viscous fluid along an exponentially stretching curved surface, Result in physics, 2017;7: 2851-2854.

27. Ali.M, Alim.M.A, Nasrin.R, Alam.M.S.,(2017) Numerical Analysis of heat and mass transfer along a stretching wedge surface, http://dx.doi.org/10.3329/jname.v 14:2.30633.
28. Aruna.K, Geetha Vani.V, Ravi kanth.A.S.V, Solution of Nonlinear Equation arising in heat transfer through Parameterized perturbation method, Int.J.of pure and Appl Math, 2017;113(9):157-165.
29. Abid Hussanan, MohdZuki Salleh, Ilyas Khan, and Razman Mat Tahar, Unsteady free convection flow of a micropolar fluid with Newtonian heating closed form solution, Thermal Science, 2017; 21(6A):2312-2326.
30. Sivakumar Narsu and Rushi Kumar, Diffusion Thermo effects on unsteady MHD free convection flow of a Kuvshinski fluid past a vertical porous plate in slip flow regime, IOP Conf.series: Materials Science and Engineering 2017;263: 062016.
31. Shamshuddin.MD Heat and mass transfer on the unsteady MHD flow of chemically reacting Micropolar fluid with radiation and joule heating, Int.J of theoretical and Appl mathematics, 2017;3(3): 110-121.
32. Pal, D., Talukdar. B., Perturbation analysis of unsteady magnetohydrodynamic convective heat and mass transfer in a boundary layer slip flow past a vertical permeable plate with thermal radiation and chemical reaction. Commun. nonlinear Sci. Numer. Simul. 2010; 15:1813-1830.
33. Chandra Sekar. K.V, Manjula. V, Heat and mass transfer Analysis of steady MHD free convective fluid flow past an inclined stretching porous sheet with viscous dissipation and radiation, 2018, DOI;10.24247/ijmper feb2018039.
34. Sivakami.L, Govindrajan.A, Lakshmipriya. S, Dufour effects on unsteady MHD free convective flow of two immiscible fluid in a horizontal channel under chemical reaction and heat source, IOP conf.series: J. of Phys: Conf series 2018; 1000: 012001.
35. Zahir Shah, Saeed Islam, Hamza Ayaz, and SaimaKhan., Radiative heat and mass transfer analysis of the micropolar nanofluid flow of Casson fluid between two rotating parallel plates with an effect of hall current, J. Heat Transfer 2018;141(2): 022401.
36. Anuradha S and Punithavalli .R ‘ Investigation of chemical reaction on micropolar fluid over an exponentially stretching sheet’ International Journal of Engineering Sciences Paradigms and Researches (IJESPR) 2018;47(03): Quarter 03 :11-20