J. Comput. Appl. Res. Mech. Eng. Vol. 10. No. 2, pp. 497-509, 2021 *DOI: 10.22061/jcarme.2020.2599.1258*

SRTTU
Journal of Computational and Applied Research in Mechanical Engineering
jcarme.sru.ac.ir
JCARME
ISSN: 2228-7922

Research paper

Linear thermal radiation effects on MHD viscoelastic fluid flow through porous moving plate with first order chemical reaction, variable temperature, and concentration

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Article info:

Research history:

Received:	23/05/2017
Revised:	08/04/2020
Accepted:	10/04/2020
Online:	13/04/2020

Keywords:
Visco-elastic,
MHD,
Porous media,
Heat sink,
Radiation,
Chemical reaction,
Soret Number.

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Abstract

Due to the presence of rheological flow parameters and viscoelastic properties, non-Newtonian fluid structure is intricate and enticing to investigate. The flow has been made by considering variable temperature and radiation effects for the magnetohydrodynamic viscoelastic liquid past a moving vertical plate in a porous state. First order homogeneous chemical reaction, Soret number, variable temperature and concentration have been taken into account. The leading mathematical proclamation is handled analytically by perturbation strategy. The central aspiration of this work is to explore the consequences of sundry parameters on fluid flow, thermal boundary and concentration profiles. Diagram and tabular trends of the profiles are delineated with apropos parameters. Our sketches illustrate that the velocity profile exposes decelerate scenery with escalating M due to the Lorentz force in the opposite direction of flow. Temperature profile is getting accelerated owing to thermal radiation and concentration distribution is declined by boosting up the chemical reaction and Schmidt number. Diminishing nature of momentum boundary layer with Sc is also portrayed. Furthermore, at the end of this paper the effects of different parameters on skin fricition coefficient and local Nusselt number are investigated.

1. Introduction

Being multifaceted and having an ample scope of application in industry, non-Newtonian fluid flow has captured great attention by the current research community. The probe of non-Newtonian fluid nature turns out to be more strenuous as opposed to Newtonian fluid because the formerdoes not show a linear relationship between shear stress and strain.

Beard and Walters [1] first perceived the boundary layer analysis of idealized visco-elastic fluid. Natural convection flow between two vertical parallel plates was proposed by Singh et al. [2]. Sajid et al. [3] developed a fully mixed convection flow between two permeable vertical walls in visco-elastic. The importance of visco-elastic fluid flow in presence of different parameters has been studied by many authors [4-14]. Radiative dissipative MHD natural convection flow under the influence of heat source and sink was derived by Suneetha et al. [15].

Heat may be transferred from one space to another space without any intervening medium. This procedure is known as thermal radiation. Linear thermal radiation has a variety of applications in industry like polymer production, Nuclear reactors, thermal furnaces etc. Thermal radiation is a point of departure which is prolific in research in behalf of its applicability in fields like space technology and the schemes that hold high temperatures. Reddy et al. [16] studied the proposed magnetohydrodynamic free convection flow behaviour in a porous medium with constant heat and mass flux under thermal radiation and chemical reaction. Ahmed [17] and Sandeep [18] observed the nature of chemically reactive flow over a vertical plate under different background.

In current research prodigious attempt has been acclimated on heat source or sink in perspective of its essence in heat transfer analysis. Heat source/sink effects possession over moving fluid are imperative in outlook of more than a few bodily cases such as fluids undergo exo-thermic or endo-thermic substance response. In recent past, great care has been taken to audit the repercussion of chemical reaction and heat source (or sink) on different flow types [19-23]. The grasp on this subject assists to reconcile abundant biological problems. Considering the model of visco-elastic fluid, many scientists have solved problems of engineering interests viz. In the last few years, many investigations [24-36] have been accomplished regarding the ongoing work.

In most technology, in production and actual real-life situations, there exist flows which are combined by the heat and mass variation. The variation in heat (mass) transfer changes the rate of heat (mass) transfer. In industries, a lot of transfer process are real in which heat and concentration transfer takes position. The occurrence of heat transfer and mass transfer normally exists in many chemical procedures involved in industries namely food and polymer process, etc. Chemical reaction may be defined in two ways as homogeneous and heterogeneous process. It depends whether the action of chemical reactor takes in single or multiple phases. There are flows in countless science engineering and real-life problems that are caused by the difference in first order and higher order chemical reaction. The changes in the chemical reactor changes the rate of mass transfer. In industries, a huge number of applications exist where chemical procedures involved in industries, namely food and polymer process, etc. Stangle and Aksay [37] carried out an excellent theoretical work on blinder removal process by taking disordered porous materials. The stream of viscous flow because of exponentially accelerated isothermal sheet with chemical reaction was studied by Muthucumaraswamy et al. [38].

Soret defined as thermo-diffusion affect, for illustration, was utilized in isotope variation and combination of the fluids having nominal molecular load (Hydrogen, Helium) and of state molecular load (Nitrogen, Oxygen). Hari Mohan [39] presented the thermo diffusion influence on the rotator thermo solutal, over the vernonis kind of convection flow. Plattern and Charepeyer [40] represented the Soet effect of oscillatory flow in Bernard cell. Hydromagnetic field of natural convection flow of Water's memory with Suction, Soret and Heat sink was reported by Pavan Kumar et al. [41]. David Jacqmin [42] derived parallel flows with thermo-diffusion affect in slanted cylinders. Hurle and Jakeman [43] presented significance of the thermo-diffusion consequences on the Rayleigh-Jeffrey's systems.

In the light of the above studies, this segment of research intends to prove the consequences of heat generation or absorption and first order chemical reaction effects on laminar boundary layer flow through porous medium with thermal radiation, variable temperature and concentration. The dimensionless equations are then solved analytically using perturbation technique. The behaviors of numerous parameters on the physical quantities have been examined.

2. Mathematical descriptions

A two-dimensional unsteady MHD flow of an incompressible electrically conducting fluid over a semi-infinite vertical permeable moving plate permeable stretiching suface in presence of thermal radation is considered. The system of coordinate is taken in a way that *x*-axis is measured along the sheet and y-axis is orthogonal to it as presented in Fig. 1. Induced magnetic field is negligible as compared to the applied magnetic-field. The effects like non-linear radiative and variable thermal may be expected for affect of the heat transfer process in the equation of heat, while the variable molecular diffusivity is implicit to affect the mass transfer phenomenon. Assume that all the fluid regions are taken constant but not density variable. Under the above statement and considering Boussinesq estimates, the steady laminar leading equations of the flows of ccontinuity, momentum, heat and concentration for a flow, we assume that the equations are subjected to visco-elastic fluid flow proposed by Babu et al. [44]. In the absence of the gradient of pressure, one can obtain the following equations for mass, momentum energy and concentration

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

$$\frac{\partial u^*}{\partial y^*} + v^* \frac{\partial u^*}{\partial y^*} = \upsilon \frac{\partial^2 u^*}{\partial y^{*2}} - \left(\frac{\sigma B_0^2}{\rho} + \frac{\upsilon}{K^*} \right) u^* + g\beta_T (T^* - T_\infty) + g\beta_C (C^* - C_\infty) - k_0 \left(\frac{\partial^3 u^*}{\partial t^* \partial y^{*2}} + v^* \frac{\partial^3 u^*}{\partial y^{*3}} \right) \tag{2}$$

$$\frac{\partial T^*}{\partial t^*} + v^* \frac{\partial T^*}{\partial y^*} = \frac{k}{\rho C_p} \frac{\partial^2 T^*}{\partial y^{*^2}} - \frac{1}{\rho C_p} \frac{\partial q_r^*}{\partial y^*} - \frac{Q_0}{\rho C_p} \left(T^* - T_\infty \right) \tag{3}$$

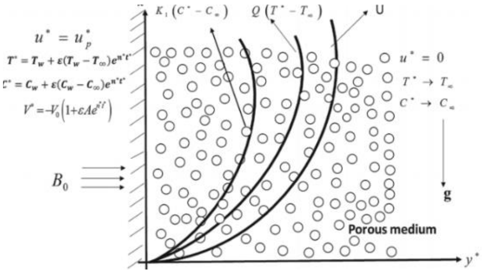

Fig. 1. Physical model of the problem.

$$\frac{\partial C^*}{\partial t^*} + v^* \frac{\partial C^*}{\partial y^*} = D \frac{\partial^2 C^*}{\partial y^{*^2}} - k_1 \left(C^* - C_\infty \right) + D_1 \frac{\partial^2 T^*}{\partial y^{*2}} \tag{4}$$

The boundary conditions for the above described model

$$u^* = u_{p^*}, \; T^* = T_w + \varepsilon \left(T_w - T_\infty \right) e^{n^* t^*},$$
$$C^* = C_w + \varepsilon \left(C_w - C_\infty \right) e^{n^* t^*}, \text{ at } \; y^* = 0$$
$$u^* = 0, \; T^* \to T_\infty, \; C^* \to C_\infty \text{ as } y^* \to \infty \tag{5}$$

It is unambiguous that in Eq. (1) the velocity of suction at the surface plate is time function. Presuming it yields into the form:

$$v^* = -V_0 (1 + \varepsilon A e^{n^* t^*}) \tag{6}$$

ε and A are small such that $\varepsilon \ll 1, A \ll 1$.

Acknowledging a self-siimilar solution of the form

$$u = \frac{u^*}{V_0}, u = \frac{v^*}{V_0}, \; y = \frac{V_0 y^*}{\upsilon}, \; t = \frac{V_0^2 y^*}{\upsilon}, \; u_p = \frac{u_p^*}{V_0},$$
$$n = \frac{n^* \upsilon}{V_0^2}, \; \theta = \frac{T^* - T_\infty}{T_w - T_\infty}, \; C = \frac{C^* - C_\infty}{C_w - C_\infty}, \tag{7}$$

the basic field Eqs. (2-4) can be expressed in non- dimensional form as

$$\frac{\partial u}{\partial t} - \left(1 + \varepsilon A e^{nt} \right) \frac{\partial u}{\partial y} = \frac{\partial^2 u}{\partial y^2} - \left(M + \frac{1}{K} \right) u + Gr\theta + GmC - E \left[\frac{\partial^3 u}{\partial t \partial y^2} - \left(1 + \varepsilon A e^{nt} \right) \frac{\partial^3 u}{\partial y^3} \right] \tag{8}$$

$$\frac{\partial\theta}{\partial t}-\left(1+\varepsilon Ae^{nt}\right)\frac{\partial\theta}{\partial y}=\frac{1}{\Pr}\frac{\partial^2\theta}{\partial y^2}-\left(Q+R\right)\theta \qquad (9)$$

$$\frac{\partial C}{\partial t}-\left(1+\varepsilon Ae^{nt}\right)\frac{\partial C}{\partial y}=\frac{1}{Sc}\frac{\partial^2 C}{\partial y^2}-KrC+So\frac{\partial^2\theta}{\partial y^2} \qquad (10)$$

$$u=u_p,\ \theta=1+\varepsilon e^{nt}\ ,\ C=1+\varepsilon e^{nt} \quad \text{at } y=0$$
$$u\to 0,\ \theta\to 0,\ C\to 0 \quad \text{as } y\to\infty \qquad (11)$$

$$Gr=\frac{\left(T_w-T_\infty\right)\beta_T g\upsilon}{V_0^{\,3}},\ Gm=\frac{\left(C_w-C_\infty\right)\beta_C g\upsilon}{V_0^{\,3}},$$
$$R=\frac{4\upsilon}{\rho C_p V_0^{\,2}},\ \Pr=\frac{\rho C_p\upsilon}{k},\ K=\frac{K^* V_0^{\,2}}{\upsilon^2},$$
$$Kr=\frac{K_1\upsilon}{V_0^{\,2}},\ Sc=\frac{\upsilon}{D},\ Q=\frac{\upsilon Q_0}{\rho C_p V_0^{\,2}},$$
$$So=\frac{D_1\left(T_w-T_\infty\right)}{\upsilon\left(C_w-C_\infty\right)} \quad E=\frac{k_0 V_0^{\,2}}{\upsilon^2} \qquad (12)$$

3. Problem's solution

Solutions of Eqs. (8-10) are reaped by regular and multi-parameter perturbation technique. E, ε and A are presumed small, such that $E<<1$ and $\varepsilon<<1$.
For getting solutions we introduce

$$\left.\begin{aligned} u(y,t)&=u_0(y)+\varepsilon e^{nt}u_1(y)+0(\varepsilon^2)\\ \theta(y,t)&=\theta_0(y)+\varepsilon e^{nt}\theta_1(y)+0(\varepsilon^2)\\ C(y,t)&=C_0(y)+\varepsilon e^{nt}C_1(y)+0(\varepsilon^2)\end{aligned}\right\} \qquad (13)$$

where, u_0, is the mean velocity, θ_0 is the mean temperature and C_0 is the mean concentration. Applying Eq. (13) into Eqs. (8-10), tallying non-harmonic and harmonic statement to above location, after neglecting coefficient of ε^2, we secure zero order

$$Eu_0'''+u_0''+u_0'-n_1u_0=-Gr\theta_0-GmC_0 \qquad (14)$$
$$\theta_0''+\Pr\theta_0'-n_3\Pr\theta_0=0 \qquad (15)$$
$$C_o''+ScC_0'-ScKrC_0=-ScSo\theta_0'' \qquad (16)$$

where $n_1=M+\frac{1}{K}$, $n_3=Q+R$

with

$$u_0=u_p,\theta_0=1,C_0=1, \quad \text{at } y=0$$
$$u_0\to 0,\theta_0\to,C_0\to 0, \quad \text{as } y\to\infty \qquad (17)$$

And first order

$$Eu_1'''+\left(1-nE\right)u_1''+u_1'-n_2u_1=-Gr\theta_1-GmC_1$$
$$-AEu_0'''-Au_0' \qquad (18)$$
$$\theta_1''+Sc\theta_1'-Scn_5\theta=-ASc\theta' \qquad (19)$$
$$C_1''+ScC_1'-Scn_5C_1=-AScC_0'-ScSo\theta_1'' \qquad (20)$$

where, $n_2=\left(M+\frac{1}{K}+n\right)$, $n_4=Q+R+n$,
$n_5=Kr+n$

with corresponding boundary conditions

$$u_1=0,\ \theta_1=1,\ C_1=1 \quad \text{at } y=0$$
$$u_1\to 0,\theta_1\to,C_1\to 0, \quad \text{as } y\to\infty \qquad (21)$$

Eqs. (14 and 18) are differential equations of 3rd order by virtue of visccoelastic paarameter. Since there are exclusively two accessible boundiry conditions, it necessitates an additional boundiry condition to novel solution.

$$\left.\begin{aligned} u_0\left(y\right)&=u_{00}(y)+Eu_{01}(y)+0(E^2)\\ u_1\left(y\right)&=u_{10}(y)+Eu_{11}(y)+0(E^2)\end{aligned}\right\} \qquad (22)$$

Put Eq. (22) in Eq. (14). Now compare the coefficient of first and zero order of E, Ne can procure

$$u_{00}''+u_{00}'-n_1u_{00}=-Gr\theta_0-G_mC_0 \qquad (23)$$
$$u_{01}''+u_{01}'-n_1u_{01}=-u_{00}''' \qquad (24)$$

The boundary conditions are

$$u_{00}=u_p,\ u_{01}=0, \quad \text{on } y=0$$
$$u_{00}\to 0,\ u_{01}\to 0, \quad \text{as } y\to\infty \qquad (25)$$

Put Eq. (22) in Eq. (18) and compare the coefficients of zero and first order of E,
we get

$$u_{10}''+u_{10}'-n_2u_{10}=-Gr\theta_{01}-G_mC_1-Au_{00}' \qquad (26)$$
$$u_{11}''+u_{11}'-n_2u_{11}=-Au_{00}''-Au_{01}'-u_{10}'''+nu_{10}'' \qquad (27)$$

with

$$u_{10}=0,\ u_{11}=0 \quad \text{on } y=0$$

$$u_{10} \to 0\,, u_{11} \to 0 \qquad \text{as} \quad y \to \infty \tag{28}$$

Using the Eq. (25 and 28), one can solve the Eq. (23), Eq. (24), Eq. (26), and Eq. (27) in order to obtain

$$u_{00} = A_7 e^{-m_5 y} - A_5 e^{-m_3 y} - A_6 e^{-m_1 y}$$

$$u_{01} = A_{11} e^{-m_6 y} + A_8 e^{-m_5 y} - A_9 e^{-m_3 y} - A_{10} e^{-m_1 y}$$

$$u_{10} = A_{17} e^{-m_7 y} + A_{12} e^{-m_5 y} - A_{13} e^{-m_4 y} - A_{14} e^{-m_3 y} - A_{15} e^{-m_2 y} - A_{16} e^{-m_1 y}$$

$$u_{11} = A_{25} e^{-m_8 y} + A_{18} e^{-m_7 y} + A_{19} e^{-m_6 y} + A_{20} e^{-m_5 y} - A_{21} e^{-m_4 y} - A_{22} e^{-m_3 y} - A_{23} e^{-m_2 y} - A_{24} e^{-m_1 y}$$

$$u_0(y) = u_{00}(y) + E u_{01}(y)$$

$$u_0(y) = \left(A_7 e^{-m_5 y} - A_5 e^{-m_3 y} - A_6 e^{-m_1 y}\right) + E\left(A_{11} e^{-m_6 y} + A_8 e^{-m_5 y} - A_9 e^{-m_3 y} - A_{10} e^{-m_1 y}\right)$$

$$u_1(y) = u_{10}(y) + E u_{11}(y)$$

$$u_1(y) = \begin{pmatrix} A_{17} e^{-m_7 y} + A_{12} e^{-m_6 y} - A_{13} e^{-m_4 y} \\ -A_{14} e^{-m_3 y} - A_{15} e^{-m_2 y} - A_{16} e^{-m_1 y} \end{pmatrix} + E\begin{pmatrix} A_{25} e^{-m_8 y} + A_{18} e^{-m_7 y} + A_{19} e^{-m_6 y} + A_{20} e^{-m_5 y} \\ -A_{21} e^{-m_4 y} - A_{22} e^{-m_3 y} - A_{23} e^{-m_2 y} - A_{24} e^{-m_1 y} \end{pmatrix}$$

$$u(y,t) = u_0(y) + \varepsilon e^{nt} u_1(y) \tag{29}$$

$$C(y,t) = \left(A_2 e^{-m_3 y} - A_1 e^{m_1 y}\right) + \varepsilon e^{nt}\left(A_4 e^{-m_4 y} + A_3 e^{-m_2 y}\right) \tag{30}$$

$$\theta(y,t) = e^{-m_3 y} + \varepsilon e^{nt}\left(A_4 e^{-m_4 y} + A_3 e^{-m_3 y}\right) \tag{31}$$

Non-dimensional skin friction coefficient heat transfer rate and mass transfer rates

$$\tau = \left(\frac{\partial u}{\partial y}\right)_{y=0} = \begin{bmatrix} \left(-m_5 A_7 + m_3 A_5 + m_1 A_6\right) \\ +E\begin{pmatrix} -m_6 A_{11} - m_5 A_8 + m_3 A_9 \\ +m_1 A_{10} \end{pmatrix} \end{bmatrix} - \varepsilon e^{nt} \begin{bmatrix} \begin{pmatrix} -m_7 A_{17} - m_5 A_{12} + m_4 A_{13} + m_3 A_{14} \\ +m_2 A_{15} + m_1 A_{16} \end{pmatrix} \\ +E\begin{pmatrix} -m_8 A_{25} - m_7 A_{18} - m_6 A_{19} \\ -m_5 A_{20} + m_4 A_{21} \end{pmatrix} \end{bmatrix} \tag{32}$$

$$Nu = -\left(\frac{\partial \theta}{\partial y}\right)_{(y=0)} = m_3 + \varepsilon e^{nt}\left(m_4 A_4 + m_3 A_3\right) \tag{33}$$

$$Sh = -\left(\frac{\partial C}{\partial y}\right)_{(y=0)} = \left(m_3 A_2 - m_1 A_1\right) + \varepsilon e^{nt}\left(m_4 A_4 - m_2 A_3\right) \tag{34}$$

4. Results and discussion

Eclectic evaluations have been reported graphically in all the sketches by allocating the values to the pertinent parameters by outlining the fluid flow structure. Extensive analytical computations are done for velocities, thermal and concentration distributions together with friction factor feature, Nusselt as well as Sherwood number for distinct standards of physical constraints which illustrate the structures of flow. Numirical conclusions are well establiished in Figs. 2-18 and additionally Tables 1-3. The problem composes of one independent variable (*y*), three dependent variables (*u*, *T*, *C*) with the *Gr = 10*, *Gm = 5.0*, *M = 0.2*, *K = 1.0*, *E = 0.01*, *Pr = 0.7*, *Q = 0.5*, *R = 0.2*, *Sc = 0.1*, *Kr = 2.0*, *A = 0.1*.

Figs. 2-3, illustrate the impact of the flow for heterogeneous values of *Gr* and *Gm*. The Grashof number for thermal is a sign of the virtual consequence of the heat buayancy (due to thickness differences) force to viscous hydrodynamic force in the border layer flow. The positive values of Grashof number *Gr* communicate to cooling of the plate by free convection. Heat is therefore conducted away from the vertical plate into the fluid which elevates thermal edge layer thickness and by this means rises the buoyancy force. It is also noticed that the momentary of the flow accelerates due to augmentation in the thermal buoyancy force. The Grashof number for concentration *Gm* defines the proportion of the species buoyancy force to the hydro dynamic viscous force. It is scrutinized that elevating Grashof number *Gm* results in the form of an improvement in the flow of the flow.

The influence of electrical conducting factor *M* and permeability of porous state *K* on flow profile for set ideals of other parameters is revealed in Figs. 4-5. It is observed that the flow is abatement by the elevating the values of conducting parameter *M*. Since, an applied conducting field acts as Lorentz's strength which reduces the flow of the flow. Fig. 3 is displayed to analyze conduct of flow profile against the permeability of porous state *K*. It further witnesses that uplifting the values of permeability of porous state *K* enhances the flow of model.

Fig. 6 and Fig. 13 display the dimensionless flow of the fluid and thermal boundary profiles for different values of *Pr*. These figures explore that the fluid flow and thermal boundary de-escalate with uplift in *Pr*. Because thermal diffusivity dwindles subjected to higher *Pr* observations, it elucidates downfall in the velocity and temperature. Figs. 7, 8, 14, 15 show the antecedent profiles for assorted values of *Q* and radiation *R*. The fluid flow and temperature profiles dwindle with the hike of *Q* and the fluid flow and temperature profiles are boosted up with the rise of *R*. Decelerating the nature of velocity with *Sc* is portrayed in Fig. 9.

The influence of visco-elastic parameter *E* and suction parameter *A* on velocity profiles has been illustrated in Fig .11 and Fig. 12. It can be identified that when *E* and *A* increase, the velocity profile increases. Fig. 16 and Fig. 17 depict the change of behavior of concentration profiles against y under the impact of *Kr*, *Sc* respectively. It is perceptible that raise in *Sc* contributes to downtrend of concentration of the fluid medium. Further, it is seen that *Sc* does not contribute much to the concentration field as we move far away from the boundary surface. Analogous effect is noted with chemical reaction parameter *Kr* on concentration profile.

Fig. 10 and Fig. 18 show the variation of flow and diffusion distribution to various values of Soret number *So*. It is notable from these graphs that elevating the values of *So*, increase velocity and concentration distribution.

The effects of Grashof value *Gr*, modified Grashof value *Gm*, magnetic parameter *M*, porosity parameter *K*, Prandtl value *Pr*, radiation parameter R, visco-elastic parameter *E*, suction parameter A, heat sink parameter Q, Schmidt value *Sc*, Soret number *So* and chemical reaction parameter *Kr* on the friction factor (*Cf*), Nusselt value (*Nu*) and Sherwood value (*Sh*) are represented in Tables 1-3.

From Table 1, it is perceptible that as *Gr* or *Gm* or *K* or *A* enhances, the friction factor uplifts, whereas the friction factor downtrends as *M* or *E* increases from Table 1. It is concluded that as R or Q or Pr escalates from Table 2, the friction factor and Nusselt number escalate. From Table 3, it is found that as Sherwood value escalates, when both the parameters Schmidt number *Sc* and chemical reactor accelerate, there is an opposite tend for Soret parameter *So*.

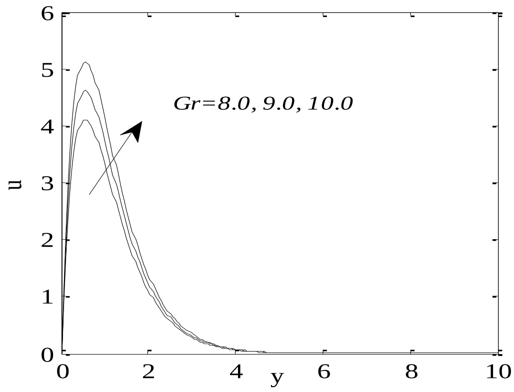

Fig. 2. Distribution of u for Gr .

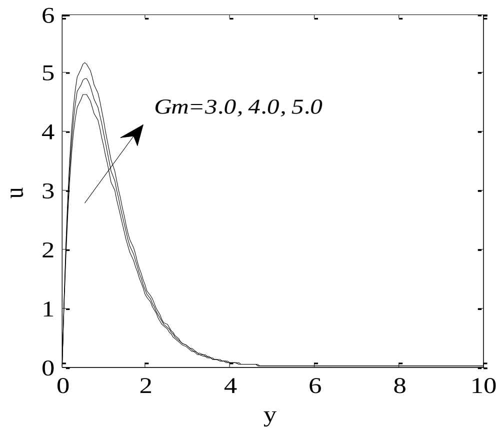

Fig. 3. Distribution of u for Gm .

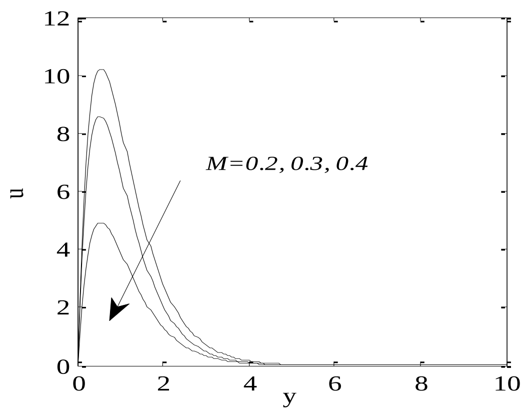

Fig. 4. Distribution of u for M .

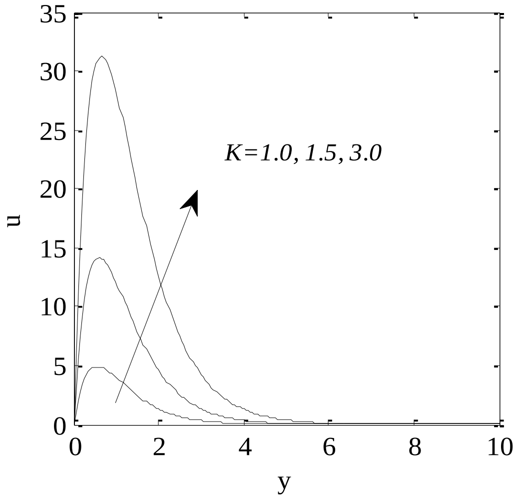

Fig. 5. Distribution of u for K .

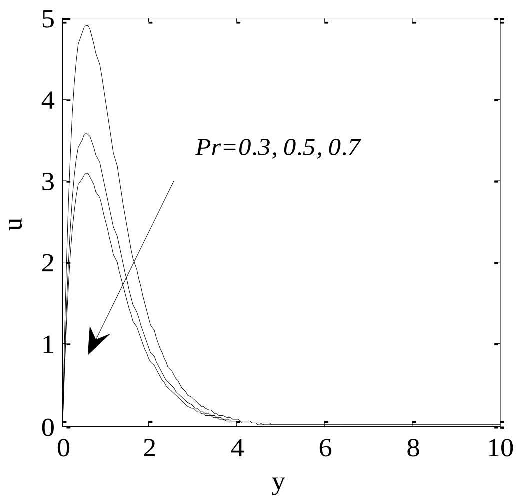

Fig. 6. Distribution of u for Pr .

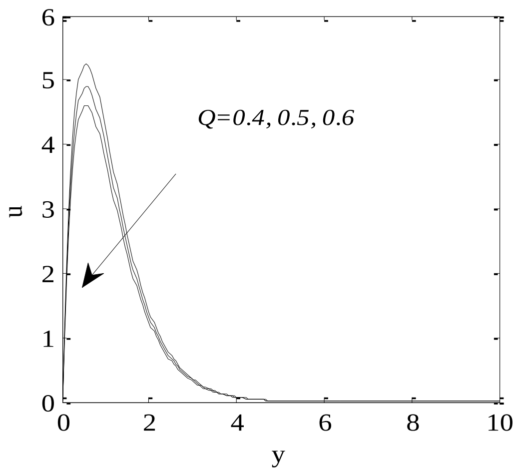

Fig. 7. Distribuation of u for Q .

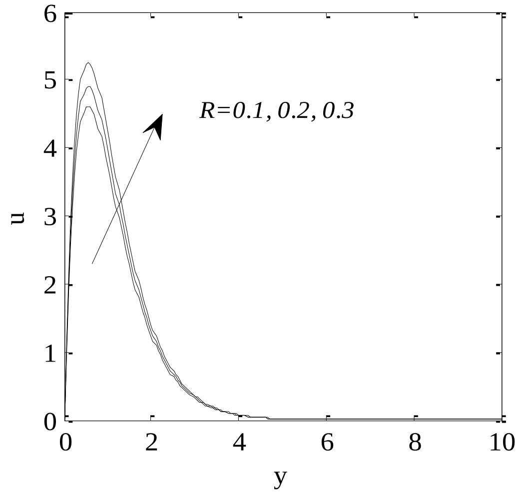

Fig. 8. Distribuation of u for R .

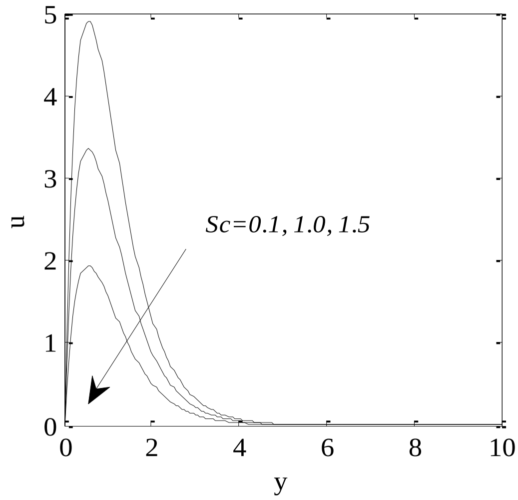

Fig. 9. Distribuation of u for Sc .

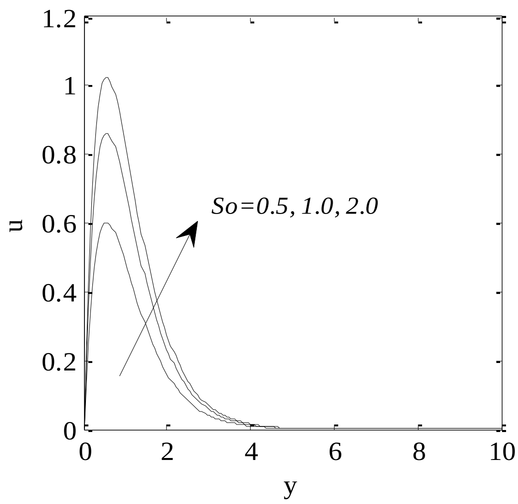

Fig. 10. Distribuation of u for So .

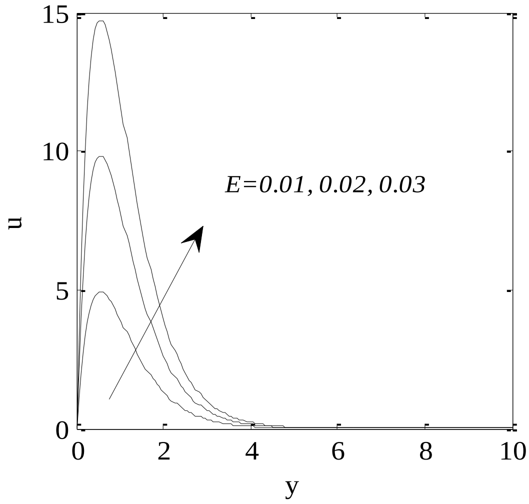

Fig. 11. Distribuation of u for *E*.

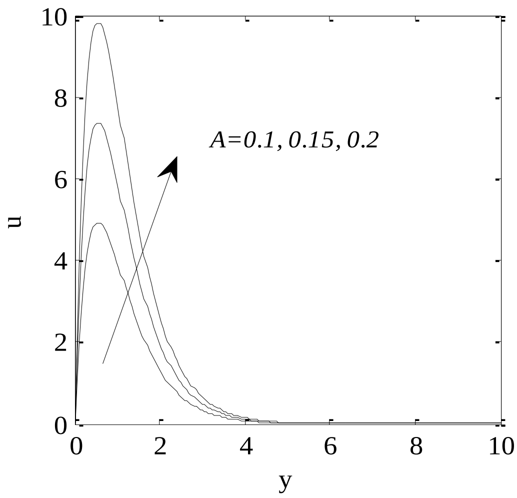

Fig. 12. Distribuation of u for A.

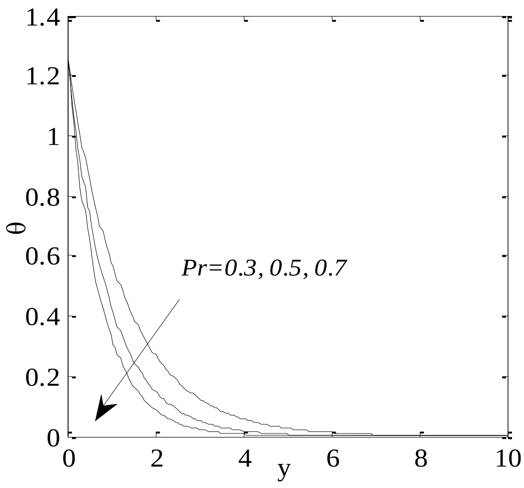

Fig. 13. Distribuation of θ for $\Pr$.

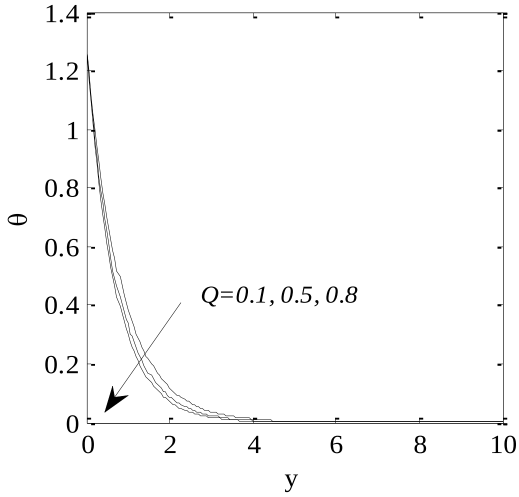

Fig. 14. Distribuation of θ for Q.

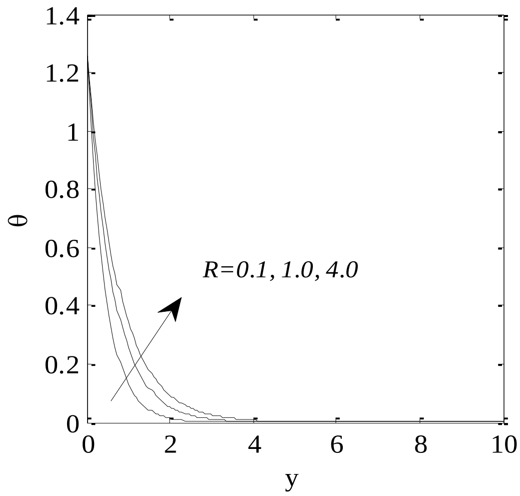

Fig. 15. Distribuation of θ for R.

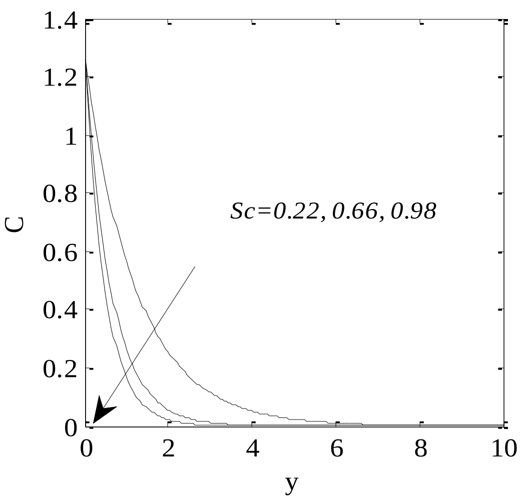

Fig. 16. Distribuation of C for Sc.

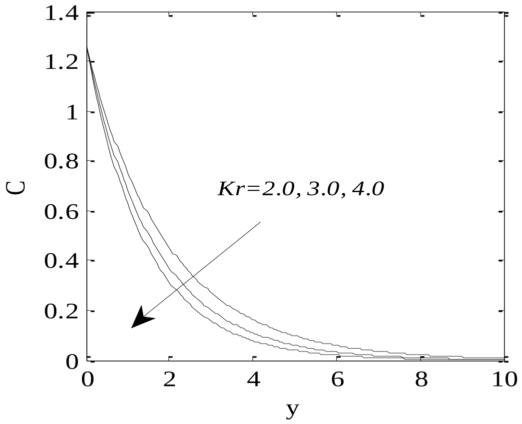

Fig. 17. Distribuation of C for Kr.

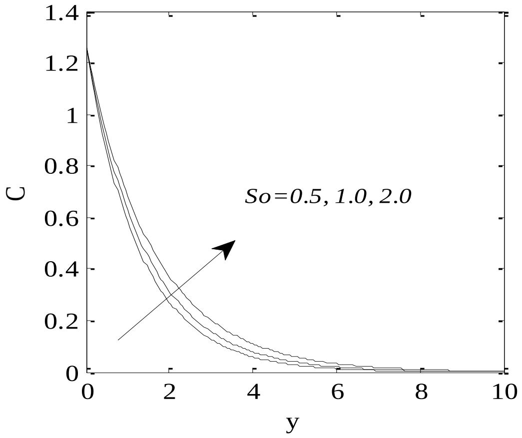

Fig. 18. Distribuation of C for So.

Table 1. Impact of different physical parameter on friction factor for $Pr = 0.7, Q = 0.0, R = 0.2$ $Sc = 0.1$, $Kr = 2.0$, So=0.5.

Gr	Gm	M	K	E	A	Cf
8.0	1.0	0.2	1.0	0.01	0.1	2.0115
9.0						2.2585
10.0						2.5055
	2.0					2.1408
	3.0					2.2702
		0.4				3.6009
		0.6				3.3221
			1.5			5.5941
			2.0			7.8830
				0.02		6.0344
				0.03		4.0230
					0.15	3.0172
					0.17	3.4195

Table 2. Impact of different physical parameter on friction factor and Nussselt value for $Gr = 8.0$ $Gm = K = 1.0, M = 0.2, Ec = 0.01, Kr = 2.0, Sc = A = 0.1, So = 0.5$.

Pr	R	Q	Cf	Nu
0.7	0.2	0.5	2.0115	5.7375
0.8			2.8576	1.3118
1.0			8.7732	3.3588
	0.8		3.8078	1.8848
	0.9		4.4935	1.9581
		1.0	3.3065	1.8110
		1.5	9.9184	2.1758

Table 3. Impact of different physical parameter on friction factor, Nussselt value and Sherwod value for $Gr = 8.0, Gm = 1.0, K = 1.0, M = 0.2, R = 0.2, Pr = 0.7$, $Ec = 0.01$, $Kr = 2.0$.

Sc	Kr	So	Cf	Nu	Sh
0.1	2.0	0.5	2.0115	5.7375	0.6432
0.3			2.0313	5.7375	1.2076
0.5			2.1053	5.7375	1.6467
	3.0		2.0124	5.7375	0.7667
	4.0		2.0146	5.7375	0.8714
		1.0	2.1126	5.7375	0.9125
		1.5	2.3120	5.7375	0.9512

5. Conclusions

In the present study, a mathematical framework has been evolved to simulate 2D unsteady magneto hydrodynamic flow of an incompressible electrically conducting fluid over a permeable moving plate through porous medium under the importance of thermal radiation and chemical reaction. The governed mathematical statement is handled analytically by perturbation technique. The governed mathematical statement is handled analytically by perturbation strategy. The obtained results have led to the following conclusions:

- Fluid velocity is enhancing reducing function of all parameters such as Grashaf number Gr, modified Grashaf number Gm, Permeability parameter K, Radiation parameter R, visco–elastic parameter E, and Suction parameter A.

- Thermal boundary distribution falls down against Pr or Q, while radiation parameter R enhances it.
- Presence of chemical reaction enhances the rate of mass transfer which is a desired consequence of the flow of reacting species.
- Friction factor downtrends when magnetic parameter is enlarged. Nussselt number enhances for huge values of Pr. By increasing Schmidt number or chemical reaction parameter Sherwod number progress.

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Appendix

$$m_1 = \frac{Sc + \sqrt{Sc^2 + 4ScKr}}{2},\ m_2 = \frac{Sc + \sqrt{Sc^2 + 4Scn_5}}{2},$$

$$m_3 = \frac{\Pr + \sqrt{\Pr^2 + 4\Pr n_3}}{2},\ m_4 = \frac{\Pr + \sqrt{\Pr^2 + 4\Pr n_4}}{2},$$

$$m_5 = \frac{1 + \sqrt{1 + 4n_1}}{2},\quad m_6 = \frac{1 + \sqrt{1 + 4n_1}}{2},$$

$$m_7 = \frac{1 + \sqrt{1 + 4n_2}}{2},\ m_8 = \frac{1 + \sqrt{1 + 4n_2}}{2},$$

$$A_1 = \frac{AScm_1}{m_1^2 - Scm_1 - Scn_5},\ A_2 = 1 - A_1,$$

$$A_3 = \frac{A\Pr m_3}{m_3^2 - \Pr m3 - \Pr n_4},\ A_4 = 1 - A_3,$$

$$A_5 = \frac{Gr}{m_3^2 - m_3 - n_1},\ A_6 = \frac{Gm}{m_1^2 - m_1 - n_1},$$

$$A_7 = u_p + A_5 + A_6,\ A_8 = \frac{A_7 m_5^3}{m_5^2 - m_5 - n_1},$$

$$A_9 = \frac{A_5 m_3^3}{m_3^2 - m_3 - n_1},\ A_{10} = \frac{A_6 m_1^3}{m_1^2 - m_1 - n_1},$$

$$A_{11} = A_{10} + A_9 - A_8$$

$$A_{12} = \frac{AA_7 m_5}{m_5^2 - m_5 - n_2},\ A_{13} = \frac{GrA_4}{m_4^2 - m_4 - n_2},$$

$$A_{14} = \frac{GrA_3 + AA_5 m_3}{m_3^2 - m_3 - n_2},\ A_{15} = \frac{GrA_2}{m_2^2 - m_2 - n_2},$$

$$A_{16}=\frac{GmA_1+AA_6m_1}{m_1^2-m_1-n_2},$$

$$A_{17}=A_{16}+A_{15}+A_{14}+A_{13}-A_{12},$$

$$A_{18}=\frac{m_7^3A_{17}+nA_{17}m_7^2}{m_7^2-m_7-n_2},\ A_{19}=\frac{AA_{11}m_6}{m_6^2-m_6-n_2},$$

$$A_{20}=\frac{AA_7m_5^3+AA_8m_5+A_{12}m_5^3+nA_{12}m_5^2}{m_5^2-m_5-n_2},$$

$$A_{21}=\frac{m_4^3A_{13}+nA_{13}m_4^2}{m_4^2-m_4-n_2},$$

$$A_{22}=\frac{AA_5m_3^3+AA_9m_3+A_{14}m_3^3+nA_{14}m_3^2}{m_3^2-m_3-n_2},$$

$$A_{23}=\frac{m_2^3A_{15}+nA_{15}m_2^2}{m_2^2-m_2-n_2},$$

$$A_{24}=\frac{AA_6m_1^3+AA_{10}m_1+A_{16}m_1^3+nA_{16}m_1^2}{m_1^2-m_1-n_2},$$

How to cite this paper:

K. Suneetha, S. M. Ibrahim, P. Vijaya Kumar and K. Jyothsna, "Linear thermal radiation effects on MHD viscoelastic fluid flow through porous moving plate with first order chemical reaction, variable temperature and concentration," *J. Comput. Appl. Res. Mech. Eng.*, Vol. 10, No. 2, pp. 496-509, (2021).

DOI: 10.22061/jcarme.2020.2599.1258

URL: https://jcarme.sru.ac.ir/?_action=showPDF&article=1218