THERMAL RADIATION HALL AND ION SLIP EFFECTS ON MHD CONVECTIVE FLOW OF ABSORBING SECOND GRADE FLUID

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***Abstract** :The thermal radiation, Hall and ion slip impacts on MHD natural convective rotating flow of micro-polar fluid past a semi-infinite vertical moving porous plate under the influence of uniform transverse magnetic field with convective boundary conditions have been investigated. The entire system is assumed to fluctuate in time with invariant frequency, therefore, the solutions of the boundary layer be of the oscillatory style. The non-dimensional governing equations are solved analytically through perturbation method and discussed computationally with references to pertinent parameters. For engineering curiosity, the shear stresses, Nusselt number and Sherwood number are obtained analytically, represented computationally in a tabular format as well as explained with respect to foremost parameters. It is concluded that, the resultant velocity is increased with an increasing in Hall and ion slip parameters throughout fluid region. The thermal and solutal buoyancy forces contribute to the resultant velocity ever-increasing to high. The temperature distribution is trim downs through an increasing in heat source parameter. The concentration is reduced with an increase in the chemical reaction parameter in the entire fluid region. Rotation parameter is to diminish the skin friction, whereas it is augmented through an increase of the Hall and ion slip effects.*

***Key words**: Hall and ion slip effect, Thermal Radiation, MHD, Second grade fluid.*

1. Introduction

A number of mathematical models have been proposed to explain the rheological behaviour of non-Newtonian fluids. Among these, a model which has been most widely used for non-Newtonian fluids, and is frequently encountered in chemical engineering processes, is the micro-fluid model. It has been successfully applied to non-Newtonian fluids experimentally. In modern decades, the investigation of heat and mass transfer through micro-polar fluids has been regarded comprehensively due to their assortment of industrial applications. The convective heat and mass transport through Newtonian and non-Newtonian fluids might be thoroughly utilized for polymer construction, these are fiber and granulated separation, geo-thermal regimes, wineglass-fiber and paper manufacture, refrigerating of metalized covers, geo-thermal repositories, thermal insulating material, strengthened oil rehabilitation, packing bed incentivized reactors etc.

The survey associated to free convective flow movement within the existence of temperature resource has drained substantial concentration of numerous investigators for the duration of last few decades, since of its extensive purpose in astrophysical disciplines and cosmical study etc. Those types of flows engage in recreation and vital function in chemical engineering, aero-space science and technology etc. The gyratory fluids are extre-mely imperative for the reason that of its happening in an assortment of expected phenomenon and technological requirements by the Coriolis force. The comprehensive regions of numerous sciences are full of a quantity of momentous and requisite characteristics of rotational fluids. Coriolis force effect is an essential than viscous and nonreactive forces. Moreover, strengths of magnetic and Coriolis are comparable in terrible nature.The time dependent fluctuating flows have numerous applications in a lot of domains such as chemical engineering, paper manufacturing and many other scientific and industrial fields.Asghar et al. [1] have researched the flow of a non-Newtonian fluid provoked owing toward the fluctuations for a absorbent plate. Choudhury and Das [2] explored the visco elastic magneto hydrodynamic (MHD) free convective flow in the course of permeable medium in the occurrence of radiation and chemical reaction phenomenon through heat and mass transportation. Deka et al. [3] have researched that a free convective consequences for MHD flow through an infinite perpendicular oscillating surface by constant heat discharge. Das et al. [4] have researched mass transportation effects on free convective MHD flow of a viscous fluid enclosed through a oscillating porous plate in the slip flow managed by heat source. The imperative investigation prepared by Hayat et al. [5] for the flow of a non-Newtonian fluid for a oscillating surface. Manna et al. [6] addressed results of radiation on time addicted MHD free convective flow over a fluctuating vertical porous plate entrenched in an absorbent medium through oscillating heat flux. Shen et al. [7] researched the Rayleigh-Stokes predicament for a temperature and comprehensive second order fluid through an important fragmentary derivative modeling. Singh and Gupta [8] studied free convective MHD flow of viscous fluid during a permeable medium enclosed along with a fluctu-ating porous plate in slip flow management through mass transportation. Jhansi Rani and Murthy [9] explored the radiation and absorption consequences on a time dependent con-vective flow through a semi-infinite, inclined porous plate embedded in a porous medium through the heat and mass transport. Veera Krishna et al. [10–13] researched the MHD flows for an incompressible, electrically conducting fluid in two-dimensional channels. The results of heat radiation on MHD nanofluid flow between two parallel rotating plates are premeditated through Sheikholeslami et al. [14]. Rashid et al. [15] explored a precise modeling for two dimensional stream wise transverse magnetic fluid flows with heat transfer around a porous obstacle. Ellahi et al. [16] addressed the blood flow of Prandtl liquid through tapered and stenosed arteries in permeable walls with magnetic field. Ellahi et al. [17] explored a new hybrid technique supported on pseudo-spectral colloca-tions inside the intellect of least-squares technique is used to scrutinize the MHD flow of non-Newtonian fluid. Oahimire and Olajuwon [18] addressed the effects of Hall current, chem-ical reaction and heat radiation on heat and mass transportation of MHD flow of a micro-polar liquid through a porous medium. Recently Veera Krishna et al. [19] explored heat and mass transportation on unsteady MHD fluctuating flow of blood through a porous arteriole.

Veera Krishna [20] discussed the MHD laminar flow of an elastico-viscous electrically conducting Walter's-B fluid through a cir-cular cylinder or a pipe. Veera Krishna et al. [21] discussed the heat and mass transfer on unsteady MHD oscillatory flow of second-grade fluid through a porous medium between two vertical plates, under the influence of fluctuating heat source/sink, and chemical reaction. With the enthusiasm from all the aforementioned, acknowl-edged efforts and specialized literature inquiry tolerated that,the scrutiny for the Hall and ion slip impacts on a unsteady laminar MHD convective rotating flow of heat generating or absorbing second grade fluid over a semi-infinite vertical moving permeable surface has not been inspected yet. Therefore, within the present analysis, we have explored theoretically the Hall and ion slip impacts on an unsteady laminar MHD convective rotating flow of heat generating or absorbing sec-ond grade fluid over a semi-infinite vertical moving permeable surface. The non-dimensional controlling equations are solved to the most excellent possible investigative solution. Bhatti et al. [22] carried out research on the consequences of Hall and ion-slip on non Newtonian fluid flow through the Reynolds number as zero.Srinivasacharya and Shafeeurrahman [23] studied amid two analogous concentric cylinders for the Hall and ion slip effects on MHD mixed convective nanofluid. Jitendra and Srinivasa [24] explored Hall and ion slip consequences on convective flow of revolving fluid through a perpendicular expanding and accelerating surface. Veera Krishna and Chamkha [25] explored the heat radiation and heat absorption, diffusion-thermo and Hall and ion slip effects through MHD natural convection gyrating flow by nano-fluids past a moving porous plate with constant heat source. Sara and Bhatti [26] explored the MHD pumping flow of a non-Newtonian nano-fluid through chemical reaction, Hall and ion slip consequences. Olajuwon and Oahimire [27] explored the unsteady free convective heat and mass transport of MHD micro-polar fluid within the occurrence of thermo-diffusion and heat radiation. Veera Krishna et al. [28] explored that the heat and mass transport impacts on a variable flow of a chemical reactive micropolar fluid past an unlimited perpendicular porous plate into the occurrence of a transverse magnetic field, Hall currents and heat radiation concept brought into description. The heat and mass transport impacts on free convection flow of micro-polar fluid researched past an infinite vertical porous plate with the existence of a transverse magnetic field through a constant suction velocity and captivating Hall impacts addicted to description have been explored by VeeraKrishna et al. [29].VeeraKrishna et al. [30] researched the Hall and ion slip impacts on the unsteady hydromagnetic natural convective gyrating flow through porous medium over an exponential accelerated plate. The united effects of Hall and ion slip for MHD gyrating flow of ciliary propulsion of microscopic organism through porous media are premeditated by Veera Krishna et al. [31]. Veera Krishna and Chamkha [32] investigated the Hall and ion slip effects on the MHD convective flow of elastico-viscous fluid through porous medium between two rigidly rotating parallel plates with time fluctuating sinusoidal pressure gradient. Veera Krishna [33] reported that the Hall and ion slip effects on MHD free convective rotating flow bounded by the semi-infinite vertical porous surface. Veera Krishna [34] discussed the MHD laminar flow of an elastic viscous electrically conducting Walter's fluid through a circular cylinder or a pipe. The Hall and ion slip effects on unsteady MHD convective rotating flow of nanofluids have been discussed by Veera Krishna and Chamkha [35].

2.Mathematical formulation

We consider the heat and mass transport on an unsteady two dimensional MHD convective flow of a viscous laminar heat generating/absorbing second grade fluid over a semi-infinite vertical moving porous plate embedded in a uniform porous medium and applied to a uniform transverse magnetic field taking Hall and ion slip effects into account. The physical model of the investigative problem is as revealed in the Fig.1

The constitutive equation for the fluids of second grade is in the following form

$$T = -pI + \mu A_1 + \alpha_1 A_2 + \alpha_2 A_1^2 \quad (1)$$

where T is the Cauchy stress tensor, I is the identity tensor, p is the static fluid pressure, μ is the dynamic viscosity co-efficient, α_1 and α_2 are the normal stress moduli, i.e., α_1 is the elastic coefficient and α_2 is the transverse viscosity coefficient, and the kinematic tensors A_1 and A_2 are defined through

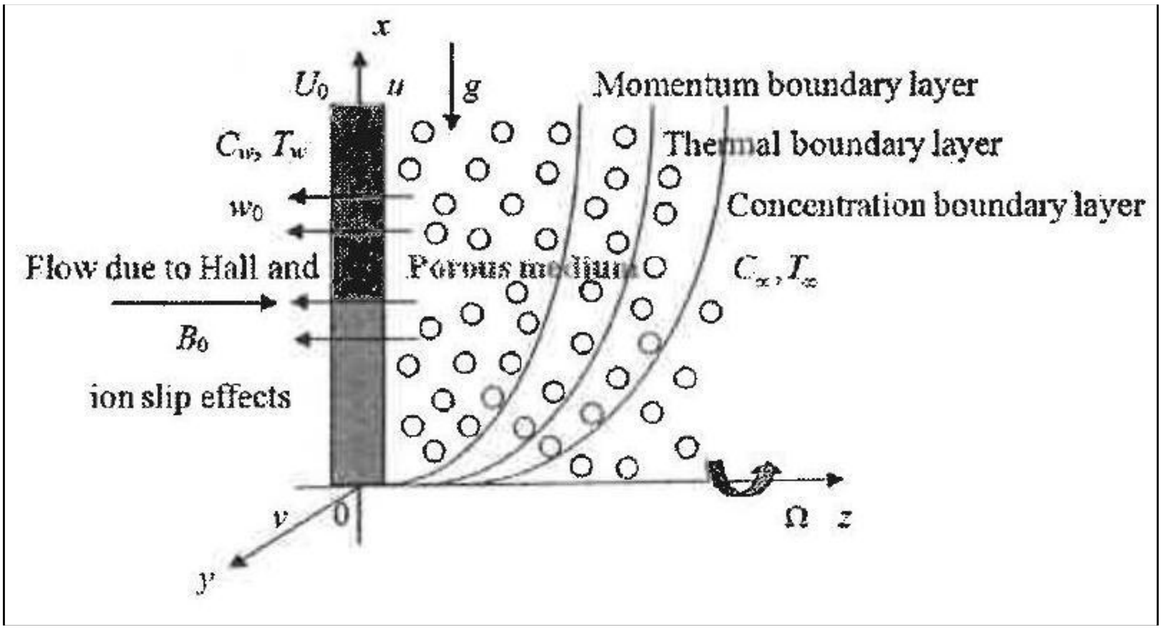

Fig. 1. Physical model.

$A_1 = (grad\ V) + (grad\ V)^T$,

$A_2 = \frac{dA_1}{dt} + A_1(grad\ V) + (grad\ V)^T A_1$ (2)

where$V$ is the velocity vector, grad is the gradient operator and d/dt denotes the material time derivative. Since the fluid is incompressible, it can undergo only isochoric motion and hence, divV$= 0$ and the equation of motion is,

$\rho \frac{dV}{dt} = T + \rho F$ **(3)**

whereρ is the density of the fluid and F is the body force

$\mu \geqslant 0, \alpha_1 \geqslant 0, \alpha_1 + \alpha_2 = 0$ (4)

This, then, was shown to give to the theory a rather well behaved and pleasant stability and boundedness structure. It was also shown that if α_1 was taken negative, the remainder of (4) being preserved, then in quite arbitrary flows instability and unboundedness were unavoidable. However, it is well known that for most non-Newtonian fluids of current rheological interest, conclusions (α) are contradicted by experiments.

$\mu \geqslant 0, \alpha_1 \leqslant 0, \alpha_1 + \alpha_2 \neq 0$ (5)

Which were supposedly obtained by data reduction from experiments for those fluids it is assumed to be constitutively described by as a second grade fluid, and it showed that such values for the material moduli led to anomalous behavior, thus questioning whether the fluid under consideration in the experiments could be described as a second grade fluid.

The unsteady hydro magnetic flow in a rotating system is controlled by the continuity, momentum, energy and concentration equations in the form as,

$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho V) = 0$ (6)

$$\rho\left(\frac{\partial V}{\partial t} + (V \cdot \nabla)V + 2\Omega \times V + \Omega \times (\Omega \times r)\right)$$

$=\nabla \cdot T + J \times B$ **(7)**

where J is the current density, B is the total magnetic field, ∇ is the operator, T is the Cauchy stress tensor for second grade fluid specified in Ω is the angular velocity as well as r is radial co-ordinate specified through $r^2 = x^2 + y^2$.

The equation of energy can be specified in various manners, such as,

$\rho\left(\frac{\partial h}{\partial t} + \nabla(hV)\right) = -\frac{Dp}{Dt} + \nabla \cdot (k_t \nabla T) + \Phi$ (8)

where h is the unambiguous enthalpy this is related to particular internal energy as $h = e + p/\rho$, Tis the total temperature, k_t is the conductivity of thermal energy, and Φ is the dissipation variable portraying the work done versus forces of viscosity, this is irrevocably changed into internal energy. This is specified as

$\Phi = (\tau.\nabla)V = \tau_{ij}\frac{\partial V_i}{\partial x_j}$ (9)

The pressure term on the RHS of Eq. (8) is generally abandoned. It is developed the equation of energy and assumed that, the conductive heat transport is controlled as a result of Fourier's law through the conductivity of thermal energy of the fluid. Also, radiative heat transfer and internal heat generation due to a probable chemical or nuclear reaction is deserted.

The equation of mass transfer with chemical reaction is specified by,

$\frac{\partial C}{\partial t} = D\nabla^2 C - K_c(C - C_\infty)$ (10)

The entire thermo-physical characteristics are assumed to be constant of the momentum equation in linear form; it is estimated in accordance with the Boussinesq approximation. The plate is extending to infinitely hence all the physical variables are function of z and the time t merely. Under these assumptions, the governing equations that portray the physical conditions for the flow with respect to the rotating frame are specified by,

$$\frac{\partial u}{\partial x} + \frac{\partial u}{\partial y} = 0 \quad (11)$$

$$\frac{\partial u}{\partial t} + w\frac{\partial u}{\partial z} - 2\Omega v = -\frac{1}{\rho}\frac{\partial p}{\partial x} + v\frac{\partial^2 u}{\partial z^2} + \frac{\alpha}{\rho}\frac{\partial^3 u}{\partial z^2 \partial t} + \frac{B_0 J_y}{\rho} - \frac{v}{k}u + g\beta(T - T_\infty) + g\beta * (C - C_\infty) \quad (12)$$

$$\frac{\partial v}{\partial t} + w\frac{\partial v}{\partial z} + 2\Omega u = -\frac{1}{\rho}\frac{\partial p}{\partial y} + v\frac{\partial^2 v}{\partial z^2} + \frac{\alpha}{\rho}\frac{\partial^3 v}{\partial z^2 \partial t} - \frac{B_0 J_x}{\rho} - \frac{v}{k}v \quad (13)$$

$$\frac{\partial T}{\partial t} + w\frac{\partial T}{\partial z} = \frac{k_1}{\rho C_p}\frac{\partial^2 T}{\partial z^2} - \frac{Q_0}{\rho C_p}(T_w - T_\infty) \quad (14)$$

$$\frac{\partial C}{\partial t} + w\frac{\partial C}{\partial z} = D\frac{\partial^2 C}{\partial z^2} - K_c(C_w - C_\infty) \quad (15)$$

It is assumed that the permeable surface actuates with a constant velocity in the direction of fluid flow. Also, the temperature and concentrations at the wall and the suction velocity is expeditiously unreliable by means of time.

$$u = U_0, v = 0, T = T_w + \varepsilon(T_{w'} - T_\infty)e^{i\omega t} \;\; C = C_w + \varepsilon(C_{w'} - C_\infty)e^{i\omega t} \; at \; z = 0 \quad (16)$$

$$u \to U_\infty, v \to 0, T \to T_\infty, C \to C_\infty \; as \; z \to \infty \quad (17)$$

From equation (11), the suction velocity at the surface is moreover a steady or a segment of time. Then, the velocity of suction perpendicular to the plate is assumed in the frame be,

$$w = -w_0(1 + \varepsilon A e^{i\omega t}) \quad (18)$$

Ohm's law is modified to include the Hall and ion slip effect

$$J = \sigma(E + V \times B) - \frac{\omega_e \tau_e}{B_0}(J \times B) + \frac{\omega_e \tau_e \beta_i}{B_0^2}((J \times B) \times B)) \quad (19)$$

Additionally, it is assumed that the Hall parameter $\beta_e = \omega_e \tau_e \sim O(1)$ and the ion slip parameter $\beta_i = \omega_i \tau_i << 1$, in Eq. (19), the electron pressure gradient and thermoelectric effects are abandoned, i.e., the electric field $E = 0$ under these assumptions, Eq. (19) condensed to,

$$(1 + \beta_i \beta_e)J_x + \beta_e J_y = \sigma B_0 v \quad (20)$$

$$(1 + \beta_i \beta_e)J_y - \beta_e J_x = -\sigma B_0 u \quad (21)$$

On solving equations (20) and (21), we acquired as,

$$J_s = \sigma B_0(\alpha_2 u + \alpha_1 v) \quad (22)$$

$$J_y = -\sigma B_0(\alpha_2 v - \alpha_1 u) \quad (23)$$

where $\alpha_1 = \frac{1+\beta_e\beta_i}{(1+\beta_e\beta_i)^2 + \beta_e^2}$ and $\alpha_2 = \frac{\beta_e}{(1+\beta_e\beta_i)^2 + \beta_e^2}$

Substituting Eqs. (22) and (23) in (13) and (12) respectively. we acquired,

$$\frac{\partial u}{\partial t} + w\frac{\partial u}{\partial z} - 2\Omega v = -\frac{1}{\rho}\frac{\partial p}{\partial x} + v\frac{\partial^2 u}{\partial z^2} + \frac{\alpha}{\rho}\frac{\partial^3 u}{\partial z^2 \partial t} + \frac{\sigma B_0^2(\alpha_2 v - \alpha_1 u)}{\rho} - \frac{v}{k}u + g\beta(T - T_\infty) + g\beta * (C - C_\infty) \quad (24)$$

$$\frac{\partial v}{\partial t} + w\frac{\partial v}{\partial z} + 2\Omega u = -\frac{1}{\rho}\frac{\partial p}{\partial y} + v\frac{\partial^2 v}{\partial z^2} + \frac{\alpha}{\rho}\frac{\partial^3 v}{\partial z^2 \partial t} - \frac{\sigma B_0^2(\alpha_2 u + \alpha_1 v)}{\rho} - \frac{v}{k}v \quad (25)$$

Combining Eqs. (24) and (25) , let $q = u + iv$ and $\xi = x - iy$, we acquired that,

$$\frac{\partial q}{\partial t} + w\frac{\partial q}{\partial z} + 2i\Omega q = -\frac{1}{\rho}\frac{\partial p}{\partial \xi} + v\frac{\partial^2 q}{\partial z^2} + \frac{x}{\rho}\frac{\partial^3 q}{\partial z^2 \partial t} - \frac{\sigma B_0^2(\alpha_1 + i\alpha_2)}{\rho}q - \frac{v}{k}q + g\beta(T - T_\infty) + g\beta * (C - C_\infty) \quad (26)$$

Outer surface of the boundary layer, Eq. (26) gives,

$$-\frac{1}{\rho}\frac{\partial p}{\partial \xi} = \frac{dU_\infty}{dt} + \left(\frac{\sigma\beta_0^2}{\rho} + \frac{v}{k}\right)U_\infty \quad (27)$$

It is introducing the non-dimensional variables,

$$q* = \frac{q}{w_0}, w* = \frac{w}{w_0}, z* = \frac{w_0 z}{v}, U_0^* = \frac{U_0}{w_0}, U_\infty^* = \frac{U_\infty}{w_0},$$

$$t* = \frac{t w_0^2}{v}, \theta = \frac{T - T_\infty}{T_w - T_\infty}, \phi = \frac{C - C_\infty}{C_w - C_\infty},$$

$$M^2 = \frac{\sigma B_0^2 v}{\rho w_0^2}, K = \frac{k w_0^2}{v^2}, Pr = \frac{v\rho C_p}{k_1} = \frac{v}{\alpha}, R = \frac{\Omega v}{w_0^2},$$

$$Gr = \frac{v\beta g(T_w - T_\infty)}{w_0^3}$$

$$Gm = \frac{v\beta g*(C_w - C_\infty)}{w_0^3}, H = \frac{v Q_0}{\rho C_p w_0^2}, S = \frac{w_0^2 \alpha_1}{\rho v^2},$$

$$Sc = \frac{v}{D}, Kc = \frac{K_c v}{w_0^2}.$$

Making use of the non-dimensional variables, the governing equations are diminished to

$$\frac{\partial q}{\partial t} - (1 + \varepsilon A e^{i\omega t})\frac{\partial q}{\partial z} = \frac{dU_\infty}{dt} + \frac{\partial^2 q}{\partial z^2} + S\frac{\partial^3 q}{\partial z^2 \partial t} - \lambda q + Gr\,\theta + Gm\,\phi \quad (28)$$

$$\frac{\partial \theta}{\partial t} - (1 + \varepsilon A e^{i\omega t})\frac{\partial \theta}{\partial z} = \frac{1}{Pr}\frac{\partial^2 \theta}{\partial z^2} - H\theta \quad (29)$$

$$\frac{\partial\phi}{\partial t}-\left(1+\varepsilon Ae^{i\omega t}\right)\frac{\partial\phi}{\partial z}=\frac{1}{Sc}\frac{\partial^2\phi}{\partial z^2}-Kc\phi \quad (30)$$

The boundary conditions be,

$$q=U_0, 0=1+\varepsilon e^{i\omega t}, \phi=1+\varepsilon e^{i(\rho)}\text{atz}=0 \quad (31)$$

$$q=0, \theta=0, \phi=0\text{asz}\rightarrow\infty \quad (32)$$

By using of perturbation technique ($\varepsilon << 1$), the velocity, temperature and concentration are assumed be,

$$q=q_0(z)+\varepsilon e^{i\omega t}q_1(z)+O(\varepsilon^2) \quad (33)$$

$$\theta=\theta_0(z)+\varepsilon e^{i\omega r}\theta_1(z)+O(\varepsilon^2) \quad (34)$$

$$\phi=\phi_0(z)+\varepsilon e^{i\omega t}\phi_1(z)+O(\varepsilon^2) \quad (35)$$

Substituting Eqs. (33), (34) and (35) in Eqs.(28-30) respectively, we obtained the equations of zeroth and first order be,

$$\frac{d^2q_0}{dz^2}+\frac{dq_o}{dz}-\lambda q_0=-Gr\ \theta_0-Gm\ \phi_0 \quad (36)$$

$$\frac{d^2\theta_0}{dz^2}+Pr\ \frac{d\theta_0}{dz}-HPr\ \theta_0=0 \quad (37)$$

$$\frac{d^2\phi_0}{dz^2}+Sc\ \frac{d\phi_0}{dz}-ScKc\ \phi_0=0 \quad (38)$$

$$(1+Si\omega)\frac{d^2q_1}{dz^2}+\frac{dq_1}{dz}-\lambda q_1=-Gr\ \theta_1-Gm\ \phi_1-A\frac{dq_o}{dz}-i\omega \quad (39)$$

$$\frac{d^2\theta_1}{dz^2}+Pr\ \frac{d\theta_1}{dz}-(i\omega+H)Pr\ \theta_1=-APr\ \frac{d\theta_0}{dz} \quad (40)$$

$$\frac{d^2\phi_1}{dz^2}+Sc\ \frac{d\phi_1}{dz}-(i\omega+Kc)Sc\ \phi_1=-ASc\frac{d\phi_0}{dz} \quad (41)$$

Corresponding boundary conditions are,

$$q_0=U_0, q_1=0, \theta_o=1, \theta_1=1, \phi_o=1, \phi_1=1\ at\ z=0 \quad (42)$$

$$q_0=0, q_1=0, \theta_0=0, \theta_1=0, \phi_o=0, \phi_1=0\ at\ z\rightarrow\infty \quad (43)$$

Solving Eqs. (36) to (41) with respect to the boundary conditions (42) and (43), we obtained as,

$$q=\ a_3e^{-m_5z}-a_4e^{-m_3z}-a_5e^{-m_1z}+\varepsilon e^{i\omega t}\{-(a_6+a_7+b_3+b_4\ +a_8+a_9+a_{10}+a_{11})e^{-m_6z}+a_8e^{-m_5z}+a_6e^{-m_4z}+(a_7+a_9)e^{-m_3z}+b_3e^{-m_2z}+(b_4+a_{10})e^{-m_1z}+a_{11}\} \quad (44)$$

$$\theta=e^{-m_3z}+\varepsilon(a_1e^{-m_4z}+a_2e^{-m_3z})e^{i\omega t} \quad (45)$$

$$\phi=e^{-m_1z}+\varepsilon(b_1e^{-m_2z}+b_2e^{-m_1z})e^{i\omega t} \quad (46)$$

$$q_0=u_0+iv_0\text{and}q_1=u_1+iv_1 \quad (47)$$

At present, this is expedient to inscribe the primary and secondary velocity distributions in expressions of the oscillating components, splitting the real and imaginary parts as of the equation (44) and taking only the real parts as that include the substantial importance. The velocity distribution of the flow can be articulated as into oscillating parts,

$$q(z,t)=\ q_0(z)+\varepsilon q_1(z)e^{i\omega t}\ u+iv=\ u_0+iv_0+\varepsilon u_1cos\ \omega t+i\varepsilon u_1sin\ \omega t+i\varepsilon v_1cos\ \omega t\ -\varepsilon v_1sin\ \omega t$$
(48)

Equating real in addition to imaginary parts,

$$u(z,t)=w_0\big(u_0(z)+\varepsilon(u_1cos\ \omega t-v_1sin\ \omega t)\big)\ v(z;t)=w_0\big(v_0(z)+\varepsilon(u_1sin\ \omega t+v_1cos\ \omega t)\big)$$
(49)

Then the part for the unsteady velocity profiles for $\omega t=\pi/2$ are specified by

$$u\left(z,\frac{\pi}{2\omega}\right)=w_0(u_0(z)-\varepsilon v_1(z)) \quad (50)$$

$$v\left(z,\frac{\pi}{2\omega}\right)=w_0(v_0(z)+\varepsilon u_1(z)) \quad (51)$$

For engineering curiosity, the non-dimensional skin friction, Nusselt and Sherwood number at the surface of the plate $z=0$ are specified by,

$$\tau=\left(\frac{dq}{dz}\right)_{z=0}, Nu=-\left(\frac{d\theta}{dz}\right)_{z=0}\text{and}Sh=-\left(\frac{d\phi}{dz}\right)_{z=0} \quad (52)$$

3.Analysis of the numerical results.

The thermal radiation, Hall and ion-slip impacts on double-diffusive unsteady MHD natural convective rotating flow of micro-polar fluid enclosed past a semi infinite vertical moving porous plate under the influence of uniform transverse magnetic field and convective boundary conditions have been considered. It is looked from the Fig. 1 that, the resultant velocity and micro-rotation heighten with ever growing in the permeability parameter K. When an increasing the values of K, enhances the resultant velocity and micro-rotation, and then conse-quently enlarges the momentum boundary layer thickness. Lesser the permeability causes slighter the fluid speed is observed in the flow region occupied by the liquid. Physically, an increase in the permeability of porous medium lead to a rise in the flow of the fluid through it, since when the holes of the porous medium become large, the resistance of the medium may be neglected.Under the influence of a uniform transverse magnetic field and convective boundary conditions, the effects of thermal radiation, chemical reactions, Hall, and ion-slip is seen in the liquid-occupied flow area. Physically, an increase in a porous medium's permeability results in an increase in the fluid flow through it since the medium's resistance may be disregarded as the holes get bigger. The behavior of the velocity and micro-rotation dispensations with Hall and ion-slip parameters βe and βi was shown in Figs. 2&3. It is patterned that increases the resulting velocity, micro-rotation, and thickness of the momentum boundary layer across the fluid section as a reinforcement in Hall and ion-slip characteristics. The magnetic renitent fierceness decreases when the Hall parameter is included because it reduces the effective conductibility. on double-diffusive unsteady MHD natural convective rotating flow of micro-polar fluid enclosed past a semi-infinite vertical moving porous plate have been examined. Figs. 4&5 depicted the special consequences of thermal as well as concentration buoyancy forces on the resultant velocity and micro-rotation. These velocities are escalating with an increasing in thermal Grashof number Gr or mass Grashof number Gm. Thermal Grashof number defined as the ratio of thermal buoyancy forces to viscous forces, likewise mass Grashof number signifies the ratio of concentration buoyancyforce to viscous force. Hence, thermal Grashof number Gr and mass Grashof number Gc enhance on an increase in the potencies of thermal and solutal buoyancy forces respectively. The enormous quantities of Grashof number develop the buoyancy forces. the induced flow. This is provided to enhance in the induced flow. Hence the outcome of this implies the velocity enlarges. Here the free convection flow is satisfied due to thermal and solutal buoyancy forces; hence thermal and solutal buoyancy forces have a propensity to speed up the resultant velocity and micro-rotation of fluid throughout the boundary layer region. It is discovered that, the fluid resultant velocity and micro-rotation boost up nearby the surface quickly followed by grow mouldy to approaches to zero. Thus momentum boundary layer thickness raises with an enhancement in thermal Grashof number Gr and mass Grashof number Gc.Further more, the consequence of thermal radiation parameter N on the resultant velocity and rotation is established in Fig. 6. Table. 1 depicts the consequences of non-dimensional parameters on coefficients the local skin friction Cf and local couple stress Cw. It is respected that the local skin friction coefficient and local couple stress coefficient enlarges through an increase in Prandtl number Pr, magnetic field parameter M and thermal radiation parameter N, and it declines through heightening in parameters Schmidt number Sc, chemical reaction parameter Kr, permeability parameter K, thermal Grashof number Gr, mass Grashof number Gm, rotation parameter R, dimensionless viscosity ratioδ, material parameterβ, Hall and ion slip parameters βe and βi Although it is originated that the local Nusselt number and local Sherwood number are remains constant with varying all pertinent parameters.

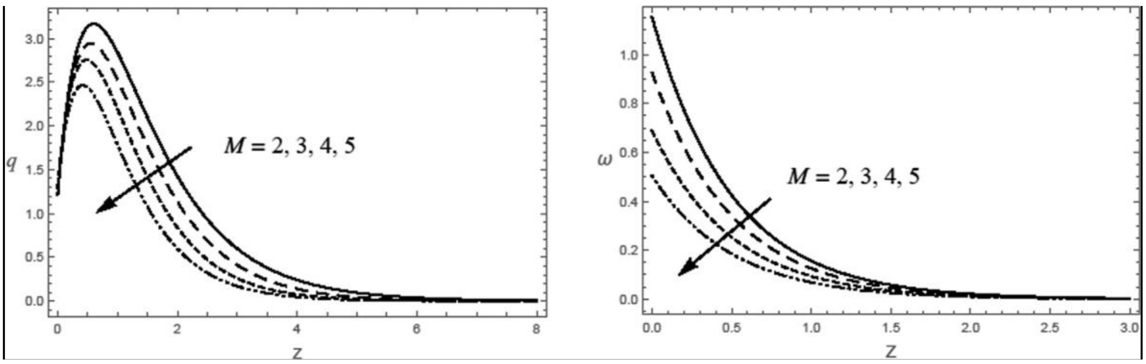

Fig. 1 The velocity and rotation profiles against K

M= 2,R= 1,βe= 1,βi= 0.2, β =2,Gr= 5,Gm= 3,Pr= 0.71,N= 0.5, Sc = 0.22,
Kr = 1, δ= 0.5, n = π/6, t = 0.2.

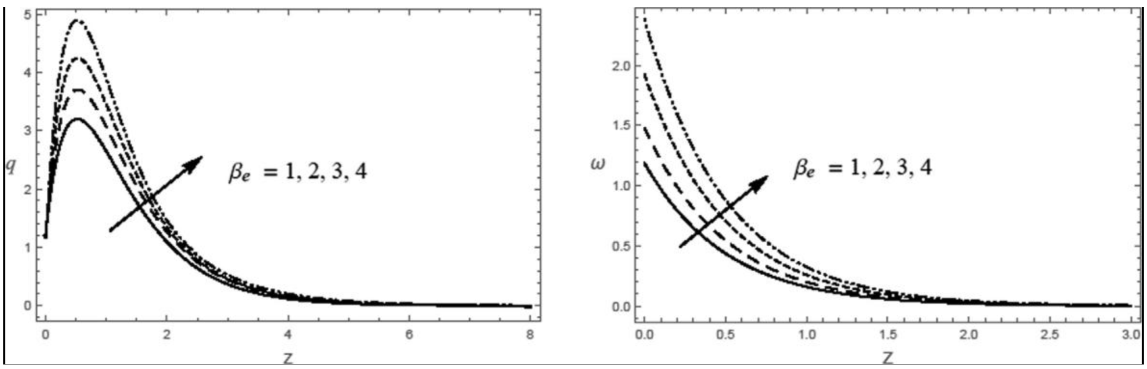

Fig.2 The velocity and rotation profiles against β_e

M= 2,K=0.5,R= 1,βi=0.2, β=2,Gr= 5,Gm= 3,Pr=0.71,N=0.5,Sc=0.22,
Kr=1,δ =0.5,n=π /6,t=0.2.

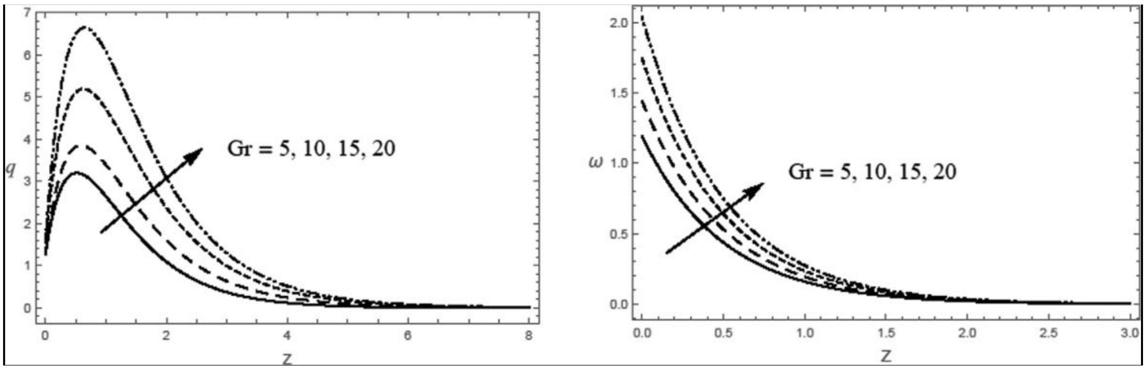

Fig. 3 The velocity and rotation profiles against βi

M= 2,K= 0.5,R= 1, βe= 1, β = 2,Gr= 5,Gm= 3,Pr= 0.71,N= 0.5, Sc = 0.22,
Kr = 1, δ= 0.5,n = π/6, t = 0.2.

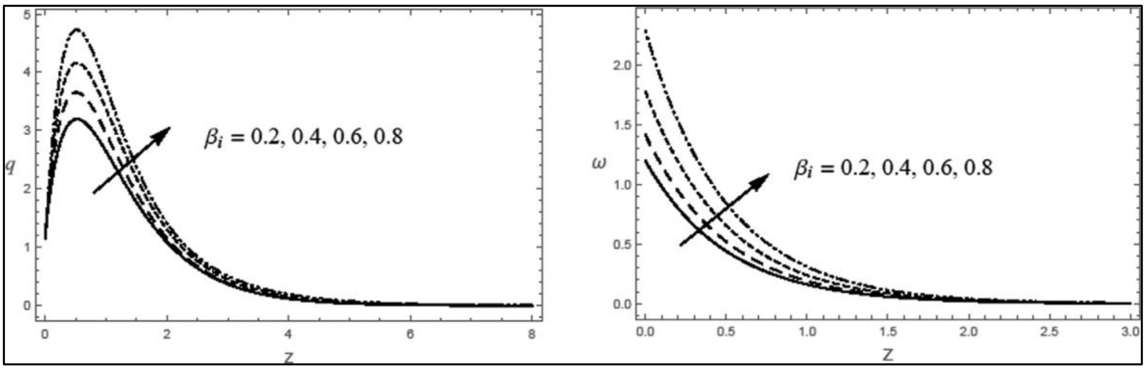

Fig.4 The velocity and rotation profiles against Gr

M= 2,K= 0.5,R= 1,βe= 1, βi= 0.2, β = 2,Gm= 3,Pr= 0.71,N= 0.5, Sc = 0.22,
Kr = 1, δ= 0.5, n = π/6, t = 0.2.

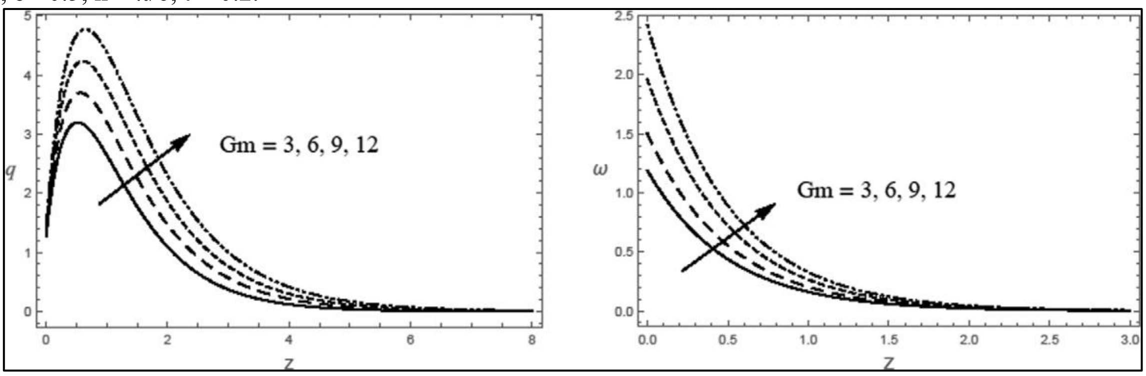

Fig.5 The velocity and rotation profiles against Gm M=2,K=0.5,R=1,βe=1,
βi=0.2, β=2,Gr=5,Pr=0.71, N=0.5, Sc=0.22,Kr=1, δ=0.5, n=π /6, t=0.2.

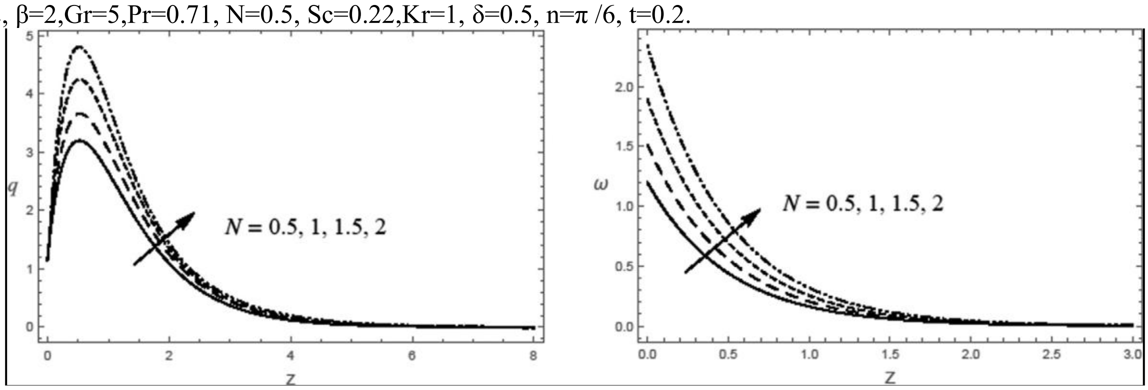

Fig.6 The velocity and rotation profiles against N

M =2, K =0.5, R =1, βe=1, βi=0.2, β=2, Gr =5, Gm = 3, Pr = 0.71,Sc = 0.22, Kr = 1, δ= 0.5,
n = π/6, t = 0.2.

M	K	Gr	Gm	N	R	Pr	β	δ	Sc	Kr	βe	βi	C_f	C_w
0.5	0.5	5	3	0.5	1.0	0.71	0.2	0.5	0.22	1.0	1.0	0.2	1.658485	-0.425389
1.0													2.811749	-0.684309
1.5													3.91889	-0.689592
	1.0												1.508879	-0.582563
	1.5												1.355254	-0.5825753
		10											1.585564	-0.582587
		15											1.457547	-0.582600
			5										1.611871	-0.582612
			7										1.555564	-0.582624
				1.0									2.241548	-0.582637
				1.5									2.819987	-0.582649
					2								1.476654	-0.582661
					3								1.138479	-0.582674
						1.38							2.075547	-0.58268
						7.0							4.255547	-0.582698
							0.4						2.36778	-0.582711
							0.6						4.133014	-0.582723
								0.8					2.138794	-0.582736
								1.0					3.81174	-0.582748
									0.3				1.507785	-0.582760
									0.6				0.265485	-0.582773
										2			1.478478	-0.582785
										3			0.305248	-0.582797
											2		1.438479	-0.582810
											3		1.13847	-0.582822
												0.4	1.588248	-0.582834
												0.6	1.451745	-0.582847

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