Chemical Reaction and Radiation Effects on MHD Free Convection of Micropolar Fluid Saturated in Porous Regime with Slip Condition

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Abstract-The impact of heat and mass exchange on free convective Micropolar fluid flow through a porouse medium with chemical reaction and slip condition has been examined. The overseeing equality of the micropolar flow field are solved finite difference method and the articulations for the velocity, temperature, concentration distribution, skin friction, rate of heat effect as far as Nusselts numeral are acquired. The impacts of Grashof number for heat and mass transfer, radiation parameter, permeability parameter,Schmidt numeral, Prandtl numeral, Eckert numeral on the stream field have been examined and the outcomes are exhibited graphically and talked about quantitatively.

Keywords-Free convection, MHD, Chemical reaction, porous medium, Slip condition,heat and mass transfer, Micropolar fluid.

I. INTRODUCTION

Free convection stream of heat and mass transfer happens much of the time in nature and modern forms. Numerous fields of enthusiasm for which consolidated heat and mass exchange plays out an vital job is in the field of science and building, for example, structuring substance preparing gear, crop harms because of solidifying and ecological contamination. Precedent of free convection is the climatic stream because of temperature distinction etc.Magneto hydrodynamic free convection of a gooey incompressible liquid along a vertical permeable medium channel plates must be contemplated in the event that we are to comprehend the conduct of liquid stream parameters. MHD free convection stream and heat and mass exchange have turned out to be increasingly essential as of late in light of its applications in horticultural building and oil enterprises. As of late, impressive consideration has additionally been centre around new utilizations of MHD and heat and mass exchange, for example, metallurgical preparing Kishore [1].Attia and Kotb[2] contemplated the MHD stream between two parallel permeable plates. Sanyal and Adhikari [3] examined the impacts of radiation on MHD vertical channel stream. Aldoss [4] considered Magneto hydrodynamic blended convection from a vertical plate implanted in a permeable medium. Hoshiyarsingh [5] have consider the impact of warm dissemination under limit condition.FM Abbasi[6] dissected effects of inclined magnetic field and Joule heating in mixed convective peristaltic transport of non-Newtonian fluidschannel.Ali and Sandeep [7] broke down the heat exchange nature of MHD streams. Buddy [8] broke down the impacts of warm radiation and non-uniform heat source/sink on a penetrable extending sheet.Kandasamy and Devi [9] examined the impacts of substance response, heat and mass exchange on non-straight laminar limit layer stream over a wedge with suction or injection. Kandasamy [10] contemplated thermophoresis and variable consistency consequences for MHD blended convective heat and mass exchange past a permeable wedge within the sight of synthetic reaction.

The point of this paper is to consider the impact of heat and mass exchange on free convective Micropolar liquid course through a porous medium with synthetic response and slip condition.

Nomenclature:

y^*horizontalcoordinate	(m)	$k$thermalconductivity	(W/mK)
u^*axialvelocity	(m/s)	q_r^*radiative heat flux iny-direction	(W/m^2)
v^*transverse velocity	(m/s)	D massdiffusioncoefficient	(m^{2}s^{-1})
ω_a^* angular velocity vector normal to the xy–plane	(rad/s)	k_l rate ofchemicalreaction	(s^{-1})
p^* pressure	(Pa)	m_w wallmassflux	(mol/m^{2}s)
T^* temperature of the fluid	(K)	$T_w$walltemperature	(K)
T_∞far field temperature	(K)	V_0suctionvelocity	(m/s)
C^*speciesconcentration	(mol/m^3)	Q heatgenerationcoefficient	(W m^{-3}K^{-1})
C_∞farfieldconcentration	(mol/m^3)	R material parameter	
ϑ kinematic viscosity	(m^2/s)	y dimensionless horizontal coordinate	
ρ density	(kg/m^3)	u dimensionless axial velocity	
κvortexviscosity	(Pa.s)	M magnetic field parameter	
μdynamic coefficientofviscosity	(Pa.s)	PrPrandtlnumber	
g acceleration dueto gravity	(m/s^2)	θdimensionless temperature	
$\beta_T$coefficientofthermalexpansion	(K^{-1})	C dimensionless species concentration	
β_C coefficient of concentration expansion	(m^3/mol)	EcEckert number	
K^*permeability ofporous medium	(H/m)	G_r thermal Grashof number	
σelectricalconductivity	(S/m)	G_c solutalGrashof number	
B_0 magneticfieldcoefficient	(T)	$\omega_a$dimensionless angular velocity	
j microinertiadensity	(m^2)	Sc Schmidt number	
γspingradient viscosity	(kg.m/s)	F radiation parameter	
$c_p$specific heat	(J kg^{-1}K^{-1})	K_c chemical reaction parameter	
		K dimensionless permeability parameter	

Mathematical analysis:

The dommating equality of continuance, sequential momentum, angular momentum, energy and congregation for this stream are:

$$\frac{\partial v^*}{\partial y^*} = 0 \qquad (1)$$

$$\rho v^* \frac{\partial u^*}{\partial y^*} = (\kappa+\mu)\frac{\partial^2 u^*}{\partial y^{*2}} + \rho g \beta_T (T^* - T_\infty) + \rho g \beta_C (C^* - C_\infty) + \kappa \frac{\partial {\omega_a}^*}{\partial y^*} - \frac{\mu}{K^*}u^* - \sigma B_0^2 u^* \qquad (2)$$

$$\rho j \left(v^* \frac{\partial {\omega_a}^*}{\partial y^*}\right) = \gamma \frac{\partial^2 {\omega_a}^*}{\partial y^{*2}} - 2\kappa {\omega_a}^* \qquad (3)$$

$$\rho c_P v^* \frac{\partial T^*}{\partial y^*} = k\frac{\partial^2 T^*}{\partial y^{*2}} + \mu\left(\frac{\partial u^*}{\partial y^*}\right)^2 - \frac{\partial {q_r}^*}{\partial y^*} - \sigma B_0^2 u^* \qquad (4)$$

$$\rho v^* \frac{\partial C^*}{\partial y^*} = D\frac{\partial^2 C^*}{\partial y^{*2}} - k_l (C^* - C_\infty^*) \qquad (5)$$

The periphery modes are

$$y = 0: u^* = U_0 + L_1\frac{\partial u}{\partial y}, \frac{\partial {\omega_a}^*}{\partial y^*} = -\frac{\partial^2 u^*}{\partial y^{*2}}, T^* = T_w, -D\frac{\partial C^*}{\partial y^*} = m_w$$

$$y \to \infty: u^* \to 0, {\omega_a}^* \to 0, T^* \to T_\infty, C^* \to C_\infty \qquad (6)$$

$q_r$is writtern as: $\frac{\partial {q_r}^*}{\partial y^*} = -4\left({T_\infty}^4 - T^4\right)I'$ (7)

Integration of equality (1) originated

$$V = -V_0 \qquad (8)$$

Bring out the correspondent dimensionless quantities:

$$y = \frac{V_0 y^*}{\nu}, u = \frac{u^*}{V_0}, \theta = \frac{T^* - T_\infty}{T_W - T_\infty}, C = \frac{C^* - C_\infty}{C_w - C_\infty} \quad (9)$$

$$E_c = \frac{V_0^2}{C_p(T_W - T_\infty)} \quad (10)$$

Equality(2) to (5)changes to

$$(1+R)\frac{\partial^2 u}{\partial y^2} + \frac{\partial u}{\partial y} - \left(M + \frac{1}{K}\right)u + R\frac{\partial \omega_a}{\partial y} + \theta G_r + CG_c \quad (11)$$

$$\left(1 + \frac{R}{2}\right)\frac{\partial {\omega_a}^2}{\partial^2 y} + \frac{\partial \omega_a}{\partial y} - 2R\omega_a = 0 \quad (12)$$

$$\frac{\partial^2 \theta}{\partial y^2} + P_r\frac{\partial \theta}{\partial y} - FP_r\theta + P_r E_c\left(\frac{\partial u}{\partial y}\right)^2 + P_r E_c M u^2 = 0 \quad (13)$$

$$\frac{\partial^2 C}{\partial y^2} + S_C\frac{\partial C}{\partial y} + S_C K_c C = 0 \quad (14)$$

With correspondent periphery modes as

$$y = 0: u = 1 + h\frac{\partial u}{\partial y}, \frac{\partial \omega_a}{\partial y} = -\frac{\partial^2 u}{\partial y^2}, \theta = 1, \frac{\partial C}{\partial y} = -1$$

$$y \to \infty: u \to 0, w_a \to 0, \theta \to 0, C \to 0, \quad (15)$$

Where,

$$P_r = \frac{\mu c_p}{k} \text{ (Prandtl numeral)}$$

$$G_r = \frac{\nu g\beta(T_w - T_\infty)}{{V_0}^2 U_0} \text{ (Thermal Grashof numeral)}$$

$$G_C = \frac{\nu g\beta(C_w - C_\infty)}{{V_0}^2 U_0} \text{ (Mass Grashof numeral)}$$

$$S_C = \frac{\nu}{D} \text{ (Schmidt numeral)}$$

$$M = \frac{\sigma {\beta_0}^2}{\rho {V_0}^2} \text{ (Magnetic variable)}$$

$$R = \frac{16a^*\sigma^*\nu^2 {T_\infty}^3}{\nu^2 k} \text{ (Radiation variable)}$$

Numerical Solutions by Finite Difference Method:

The given equations (11),(12),(13) and (14) are solved under the appropriate initial and boundary conditions (15) by the implicit finite difference method. The transport equations (11), (12),(13) and (12) at the grid point (*i*, *j*) are expressed in difference form using Taylor's expansion.

$$(1+R)\left(\frac{u_{i+1}^j - 2u_i^j + u_{i-1}^j}{(\Delta y)^2}\right) + \left(\frac{u_i^{j+1} - u_i^j}{\Delta y}\right) - \left(M + \frac{1}{K}\right)u_i^j + R\left(\frac{{\omega_a}_i^{j+1} - {\omega_a}_i^j}{\Delta y}\right) + \theta_i^j G_r + C_i^j G_c = 0$$

$$\left(1 + \frac{R}{2}\right)\left(\frac{{\omega_a}_{i+1}^j - 2{\omega_a}_i^j + {\omega_a}_{i-1}^j}{(\Delta y)^2}\right) + \left(\frac{{\omega_a}_i^{j+1} - {\omega_a}_i^j}{\Delta y}\right) - 2R{\omega_a}_i^j = 0$$

$$\left(\frac{\theta_{i+1}^j - 2\theta_i^j + \theta_{i-1}^j}{(\Delta y)^2}\right) + P_r\frac{\partial \theta}{\partial y}\left(\frac{\theta_i^{j+1} - \theta_i^j}{\Delta y}\right) - FP_r\theta_i^j + P_r E_c\left(\frac{u_i^{j+1} - u_i^j}{\Delta y}\right)^2 + P_r E_c M\left(u_i^j\right)^2 = 0$$

$$\left(\frac{C_{i+1}^j - 2C_i^j + C_{i-1}^j}{(\Delta y)^2}\right) + S_C\frac{\partial C}{\partial y}\left(\frac{C_i^{j+1} - C_i^j}{\Delta y}\right) + S_C K_c C_i^j = 0$$

The finite-difference equations at every internal nodal point on a particular *n*-level constitute a tri-diagonal system of equations. These equations are solved by using the Thomas algorithm. Computations are carried out until the steady-state solution is assumed to have been reached when the absolute difference between the values of velocity as well as temperature at two consecutive time steps are less than 10−6 at all grid points.

For the design of chemical engineering systems and practical engineering applications, the local skin-friction, Nusselt number important physical parameters for this type of boundary layer flow. The Skin-friction at the plate, which in the non-dimensional form is given by

$$Cf = \left(\frac{\tau_w'}{\rho U_0 \nu}\right)_{y'=0} = \left(\frac{\partial u}{\partial y}\right)_{y=0}$$

The rate of heat transfer coefficient, which in the non-dimensional form in terms of the Nusselt number is given by

$$Nu = -x'\frac{\left(\frac{\partial T'}{\partial y'}\right)_{y'=0}}{T_w' - T_\infty'} \Rightarrow NuRe^{-1} = -\left(\frac{\partial \theta}{\partial y}\right)_{y=0}$$

RESULT AND DISCUSSIONS

Figure 1 represents the effect of material parameter *R* on angular velocityω_a . An increase in the material parameter increasesω_a also. Increase in *R* implies that spin gradient viscosity supersedes the vortex viscosity in value, as *R* increase it enhances the micro-rotation hence the spin gradient viscosity is boosted and micro elements rotates faster therefore the angular velocity rises.

Figure 2 presented the effects of the magnetic parameter F on velocity. The velocity decreases with an increase in F.

Physically, the effect of increasing magnetic field strength is to increase the retarding force and hence reduces the velocity.

Figure 3 plotted for *u* and $\omega_a$for different values of permeability parameter K. It is seen here that increasing K increases *u*. An increase in the porosity parameter physically means reduce the drag force and hence causes the flow velocity to increase. An increase in K will reduce the resistance of the porous medium which leads to increase the velocity Also an increase in K leads to decreaseω_a. The maximum micro-rotation occurs for the lowest permeability. As K rises$\omega_a$falls, this implies a reversal in spin. It would appear, therefore, that larger permeability materials can be used to reduce micro-rotational effects in suspension fluids.

Figure 4 is drawn for the temperature of the fluid (Θ) for varying Pr. It is noted here that (Θ) decreases as Pr increase, and observed that the thermal boundary layer thickness becomes shorter for larger values of Pr. This phenomenon occurs because when Pr increases, that implies lower effective thermal diffusivity for a fixed kinematic viscosity and this leads to the decrease of the thermal boundary layer.

Figure 5 shows the effects of radiation parameter F on (Θ). The figure depicts that (Θ) decreases as F increase. Also for the higher values of radiation parameter correspond to an increased dominance of conduction over radiation thereby decreasing buoyancy force, hence reducing the thickness of the thermal boundary layers.

Figures:

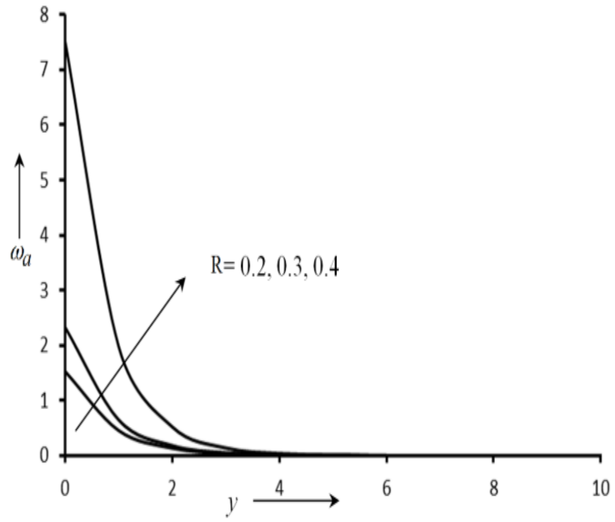

Fig.1: The dimensionless angular velocity verses various values of *R* when *Sc*=0.22, =0.2, Pr=2.0, *F*=3.0, *M*=2.0, *K*=2.0, =1.0, =0.5 and *Ec*=0.01.

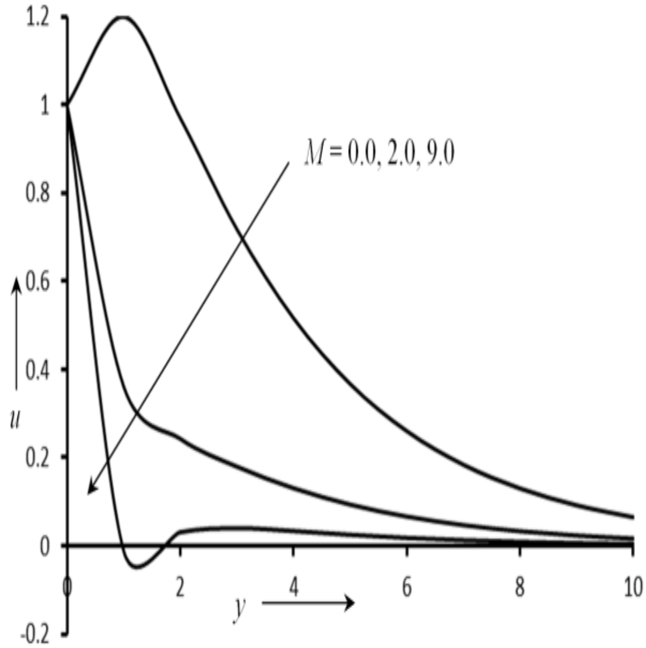

Fig.2: The dimensionless velocity verses various values of *M* when *Sc*=0.22, K_C =0.2, *R*=0.3, Pr=2.0, *F*=3.0, *K*=2.0, G_r =1.0, G_C=0.5and *Ec*=0.01.

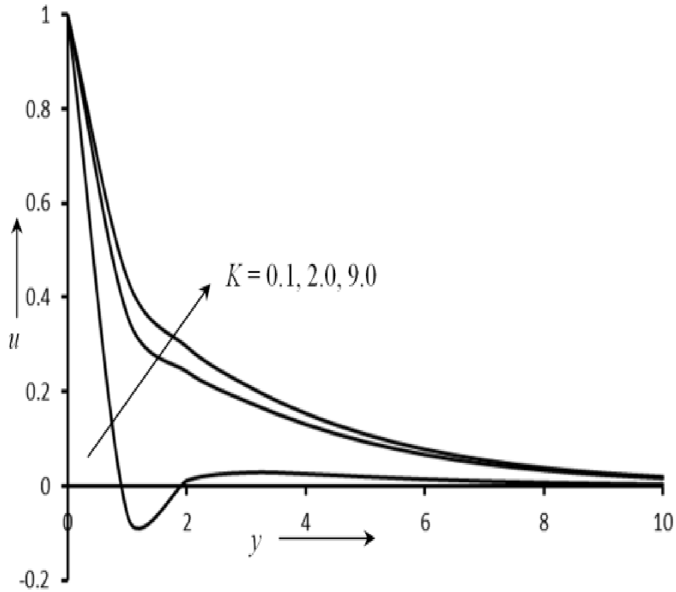

Fig.3: The dimensionless velocity verses various values of *K* when *Sc*=0.22, *Kc* =0.2, *R*=0.3, Pr=2.0, *F*=3.0, *M*=2.0, *Gr* =1.0,*Gc* =0.5 and *Ec*=0.01

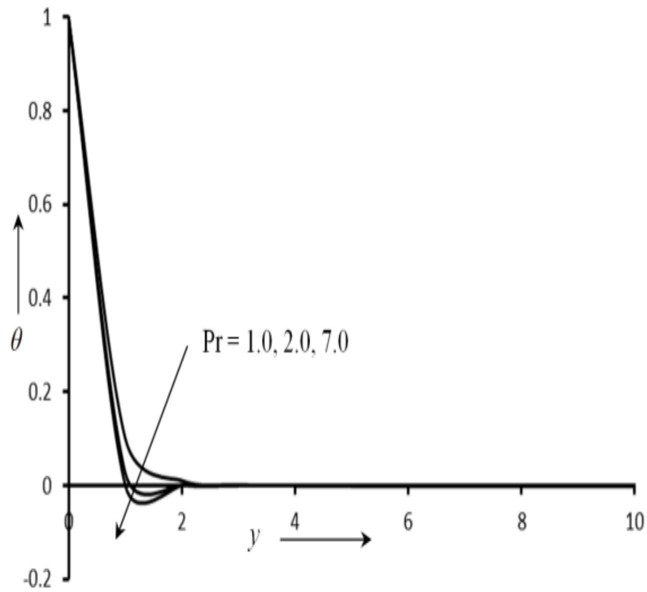

Fig.4 :- The dimensionless temperature verses various values of Pr when *Sc*=0.22, =0.2, *R*=0.3, *F*=3.0, *M*=2.0, *K*=2.0, =1.0, =0.5 and *Ec*=0.01

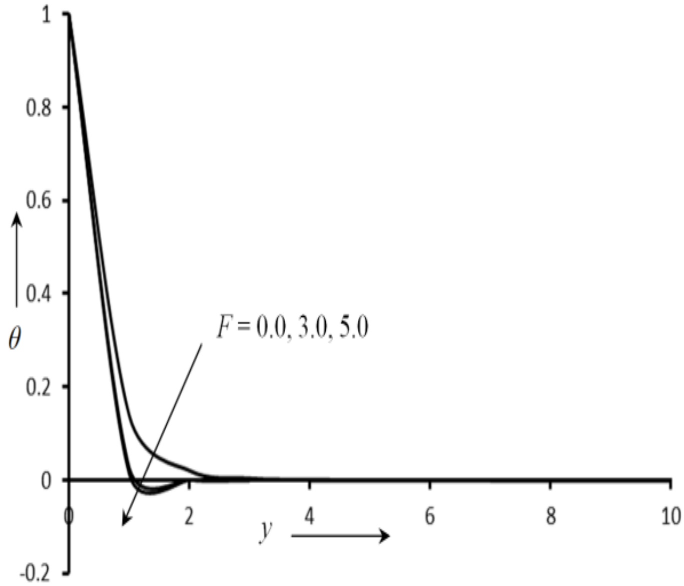

Fig.5: The dimensionless temperature verses various values of *F* when *Sc*=0.22, =0.2, *R*=0.3, Pr=2.0, *M*=2.0, *K*=2.0, =1.0, =0.5 and *Ec*=0.01.

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