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MHD CONVECTIVE FLOW OF SECOND GRADE FLUID THROUGH A POROUS MEDIUM WITH RAMPED WALL TEMPERATURE AND CHEMICAL REACTION

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ABSTRACT
The heat generating and/or absorption as well as thermo-diffusion on the unsteady free convection MHD gyrating flow of radiation and chemical reactive second grade fluid past an unbounded perpendicular plate during absorbent medium have been discussed. Here, it is assumed that, the confining plate has the ramped wall temperature with ramped surface concentration and isothermal temperature with ramped surface concentration. The analytical solutions for the governing equations are found by utilization of Laplace transformation methodology. The velocity, temperature and concentration profiles are analyzed with quite few figures. Nusselt number and Stresses are achieved and characterized numerically with tabular format.
Key Words: Porous medium, vertical plates, Second grade fluid.

I. Introduction
The flow phenomenon is relatively complex rather than that of the pure thermal convection process. Underground spreading of chemical wastes and other pollutants, grain storage, evaporation cooling and solidification are the few other application areas where the combined thermo-solutal natural convection in porous media are observed. Combined heat and mass transfer by free convection under boundary layer approximations has been studied by Bejan and Khair[1], Lai and Kulacki[2]. The free convection Heat and Mass Transfer in a porous enclosure has been studied recently by Angirasa et al[3]. For some industrial applications such as glass production and furnace design in space technology applications ,cosmic flight aerodynamics, rocket propulsion systems, plasma physics which operate at higher temperatures, radiation effects can be significant. In many chemical engineering processes, there does occur the chemical reaction between a foreign mass and the fluid in which the plate is moving. These processes take place in numerous industrial applications viz, polymer production, manufacturing of ceramics or glassware and food processing. Das etc all [4] have studied the effects of Mass Transfer on flow past an impulsively started infinite vertical plate with constant heat flux and chemical reaction. Chamkha et al[5] analysed the effects of radiation on free convection flow past a semi-infinite vertical plate with mass transfer.
Due to growing significances, the application of non-Newtonian liquid is mandatory in the engineering and industry. It is outstanding to those plentiful applications in more than a few regions, they are, the plastic manufacturing, performance of lubricant, food processing, and/or movement of biological liquids. The second graded fluid preserve many fluids these are diluted polymer solution, slurry flow, as well as industrial oil, in addition to a lot of flow problems by a choice of geometry as well as dissimilar mechanical and/or thermal boundary circumstances have been deliberated. Tan and Masuoka [6] found the Stokes first problems for the second graded fluids and Rashidi et al. [7] discussed by the unsteady compressible flows of the second order fluids. Hayat et al. [8] explored by the unsteady stagnation point flow of second grade fluids with changeable free stream.Due to complicated relation between stress and strain in non-Newtonian fluids and their technological application, their study in fluid dynamics is more valuable than Newtonian fluids. Viscous fluids flow has attracted the attention of scientists and engineers because of its important applications notably in the flow of oil through porous rocks, the extraction of energy from geothermal regions, the filtration of solids from liquids and drug penetration through human skin. Second grade fluid is a subclass of non-Newtonian fluid in which velocity field has up to two derivatives in stress strain

tensor relationship where as in Newtonian fluid it has derivatives up to first order. Flow of second grade fluid gains attention of the researchers in many boundary layer flows and have been successfully studied in various kinds of flows. Study of heat transfer in non-Newtonian fluids is much interesting for researchers now-a-days.

The magneto hydrodynamic (MHD) is a subdivision of fluid dynamics and this studied the association of the electrically conducting fluids in the magnetic field. Many of investigative efforts in the MHD has been proceed extensively for the duration of the preceding little decades subsequent to the established work of Hartmann [9] in fluid metalized ducts flow under external magnetic field. There are most applications for the parabolic movement for instance solar cooker, solar concentrator and parabolic through stellar collector. The parabolic concentrator model solar cookers have the wide range of applications for example baking, roast as well as distillations. Solar concentrator model had those applications into growing rates of evaporations in dissipate stream, in food dispensations, for producing consumption water from salt water as well as seawater. Murthy et al. [10] discussed by the evaluations of thermal performances of temperature exchangers units for parabolic solar cookers. Raja et al. [11] explored the designing as well as manufacturing of parabolic during solar collector systems. Muthucumaraswamy and Geetha [12] discussed the impacts of parabolic movement on the isothermal perpendicular plates by the invariable mass flux.

Akbar et al. [13] considered the MHD stagnation point flow of Carreau fluid towards the porous shrinking sheet. Sheikholeslami et al. [14] discussed the magnetic field effects on nanofluids flows as well as temperature transportation. Magnetic field effects on unsteady nanofluids flow as well as temperature transportation utilizing the Buongiornos modeling has been discussed by Sheikholeslami et al. [15]. Sheikholeslami et al. [16] explored the unsteady MHD liberated convective stream in the eccentrics semi-annulus packed by the nanofluids. Sheikholeslami as well as Ellahi [17] explored the 3D meso-scopic simulation

of magnetic field effects on nano liquids. Sheikholeslami et al. [18] defined the solution of forced convective temperature transportation by the changeable magnetic fields. Sheikholeslami and Chamkha [19] studied the free convective temperature transportation of the nanoliquids into the half-annulus enclosures by the sinusoidal walls. Recently, Krishna and Chamkha [20] explored the diffusion-thermo effect, radiating-absorptions, Hall as well as ion slip impacts on the MHD liberated convection gyratory flows of the nanofluids past the

Semi-infinite permeable inspiring plate with the unchanging temperature sources. The impacts of radiating as well as Hall currents on the unsteady MHD liberated central heating flows into the perpendicular channel/duct packed by the absorbent media has been explored by Krishna et al. [21]. The temperature generating/absorption as well as thermo-diffusions on the unsteady complimentary convection MHD flows of radiation as well as the chemical reactive second grade liquid past an unbounded perpendicular plate during the absorbent media aswell as considering the Hall current into accounts had been considered by Krishna and Chamkha [22].Thermal radiation constraint impacts might do the significant rolesin scheming temperature transportation into the polymer processing industries. Numerous investigators similar to, Sheikholeslami et al. [23]the impact of thermal radiating on unsteady MHD nanofluids stream aswell as temperature transport through two phase modelling. Krishnaet al. [24] explored the temperature as well as mass transport on unsteady MHD oscillating flows of second grade liquid during a permeable media between two perpendicular plates under the influences of unpredictable temperature resource and/or sink, as well as chemically reacting. Kataria and Mittal [25] has explored the effects of thermally radiating impacts on nanoliquids flow. Nadeem et [26] investigated the MHD three dimensional Casson fluids movement over the permeable linearly stretching sheet. Kataria and Mittal [27] discussed the velocity, mass as well as temperature transportation analysis of free/forced convective nanofluids flow over on fluctuating perpendicular plate with magnetic field embedded in an absorbent medium. In contrast to the investigative studies associated to temperature generation and/or heat absorption fluids flow are of substantial consequence in quite a lot of physical problems namely viz. Abbasi et al. [28] explored the varied convective flow of Maxwell nanofluids with the temperature generation. Shehzad et al. [29] studied three dimensional MHD Casson fluid flow by the temperature generating during a absorbent medium. And finally, Fetecau et al. [30] dealt with the slip effect on the radiation MHD convective flows over the unbounded upright affecting plate with the temperature source. The various of the plentiful significant applications of temperature and mass transport movement with the chemically reacting might be establish into catalytic chemical reactor, food processes, polymer production, manufacturing of ceramic and glass ware, smelting, undergoing exothermic and/or endothermic chemically reacting. Kataria and Patel [31] explored the radiating along with chemically reacting effects on the MHD Casson fluid flow during an absorbent medium. These impacts are noteworthy if density disparities survive into the flow management.

II. Formulation of the problem

it is assumed that, the bounding plate has the ramped wall temperature by ramped surface concentration and isothermal temperature with ramped surface concentration. The analytical solutions for the governing equations are found by utilizing of Laplace transformation methodology. The velocity, temperature and concentration profiles are analyzed with quite a few z-directions are considered vertical to it. The uniform magnetic field of strength B0 is performing in transverse direction to the flow domain as displayed. Primarily, at the some instant of time t ≤ 0, both the fluid and the plate are at respite to an invariable temperature T∞ and the concentration near the surface are presumed to be C∞ correspondingly. At some instant of time t > 0, the temperature of a plate is either enhanced or demoralized to T∞ + (Tw +T∞)t /t0 if t ≤ t0, and afterwards, for t > t0, is continued near the unvarying temperature Tw and the level of mass transport near the surface of the wall is moreover enhanced or demoralized to C∞ + (Cw +C∞)t /t0 if t ≤ t0 in addition to afterwards, for t > t0 is continued steady surface concentration Cw correspondingly. It is assumed that, the impacts of viscous dissipation, induced magnetic and electric field are insignificant. One of the body force expressions equivalent to MHD flow is the Lorentz forces J× B = σB20 V, here B is the whole magnetic field vector; J is the current density vector, σ is electrical conductivity of the fluid and V is the velocity vector fields. Under above assumptions and considering into relation the Boussinesq approximations, the governing equations are specified as

The equations governing the unsteady flow, heat and mass transfer are

Equation of continuity

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

Equation of linear momentum

$$\rho_e\left(\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}\right)=-\frac{\partial p}{\partial x}+\mu\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right)-\left(\frac{\mu}{k}\right)u \tag{2}$$

$$\rho_e\left(\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}\right)=-\frac{\partial p}{\partial y}+\mu\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right)-\left(\frac{\mu}{k}\right)v \tag{3}$$

Equation of Energy:

$$\rho_e C_p\left(\frac{\partial T}{\partial t}+u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}\right)=\lambda\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}\right)-Q(T-T_e) \tag{4}$$

Equation of diffusion

$$\left(\frac{\partial C}{\partial t}+u\frac{\partial C}{\partial x}+v\frac{\partial C}{\partial y}\right)=D\left(\frac{\partial^2 C}{\partial x^2}+\frac{\partial^2 C}{\partial y^2}\right)-k_1(C-C_e) \tag{5}$$

Equation of state

$$\rho-\rho_e=-\beta\rho_e(T-T_e)-\beta^*\rho_e(C-C_e) \tag{6}$$

where ρ_e is the density of the fluid in the equilibrium state, Te, Ce are the temperature and concentration in the equilibrium state,(u, v)are the velocity components along O(x,y) directions, p is the pressure, T,C are the temperature and Concentration in the flow region,ρis the density of the fluid,μ is the constant coefficient of viscosity ,Cp is the specific heat at constant pressure,λis the coefficient of thermal conductivity ,β is the coefficient of thermal expansion, Q is the strength of the constant internal heat source , β^* is the volumetric coefficient expansion with mass fraction.

The flow is maintained by a constant volume flux for which a characteristic velocity is defined as

$$q = \frac{1}{2L}\int_{-L}^{L} u\, dy. \quad (7)$$

The boundary conditions for the velocity and temperature fields are

$$u = 0,\ v = 0,\ T = T_1,\ C = C_1 \quad \text{on } y = -L$$
$$u = 0,\ v = 0,\ T = T_2 + (T_1 - T_2)\,Sin(mx + nt),\ C = C_2 \quad \text{on } y = L \quad (8)$$

where *Sin* (*mx*+ *nt*) is the imposed traveling thermal wave

In view of the continuity equation we define the stream function ψ as

$$u = -\psi_y,\ v = \psi_x \quad (9)$$

Eliminating pressure p from equations (2) & (3)and using the equations governing the flow in terms of ψ are

$$[(\nabla^2\psi)_t + \psi_x(\nabla^2\psi)_y - \psi_y(\nabla^2\psi)_x] = \nu\nabla^4\psi - \beta g(T - T_e)_y - \\ -\beta^* g(C - C_e)_y - (\frac{\nu}{k})\nabla^2\psi \quad (10)$$

$$\rho_e C_p\left(\frac{\partial T}{\partial t} - \frac{\partial\psi}{\partial y}\frac{\partial T}{\partial x} + \frac{\partial\psi}{\partial x}\frac{\partial T}{\partial y}\right) = \lambda\nabla^2 T - Q(T - T_e) \quad (11$$

$$\left(\frac{\partial C}{\partial t} - \frac{\partial\psi}{\partial y}\frac{\partial C}{\partial x} + \frac{\partial\psi}{\partial x}\frac{\partial C}{\partial y}\right) = D_1\nabla^2 C - K_1(C - C_e) \quad (12)$$

Introducing the non-dimensional variables in (8)& (9) a

$$x' = mx,\ y' = y/L,\ t' = t\nu m^2,\ \Psi' = \Psi/\nu,\ \theta = \frac{T - T_2}{T_1 - T_2},\ \phi = \frac{C - C_2}{C_1 - C_2} \quad (13)$$

the governing equations in the non-dimensional form (after dropping the dashes) are

$$\delta R(\delta(\nabla_1^2\psi)_t + \frac{\partial(\psi,\nabla_1^2\psi)}{\partial(x,y)}) = \nabla_1^4\psi + (\frac{G}{R})(\theta_y + N\phi_y) - D^{-1}\nabla_1^2\psi \quad (14)$$

$$\delta P(\delta\frac{\partial\theta}{\partial t} - \frac{\partial\psi}{\partial y}\frac{\partial\theta}{\partial x} + \frac{\partial\psi}{\partial x}\frac{\partial\theta}{\partial y}) = \nabla_1^2\theta - \alpha\theta \quad (15)$$

$$\delta Sc(\delta\frac{\partial\phi}{\partial t} - \frac{\partial\psi}{\partial y}\frac{\partial\phi}{\partial x} + \frac{\partial\psi}{\partial x}\frac{\partial\phi}{\partial y}) = \nabla_1^2\phi - \gamma_1\phi \quad (16)$$

where

$R = \frac{qL}{\nu}$ (Reynolds number)

$G = \frac{\beta g\Delta T_e L^3}{\nu^2}$ (Grashof number)

$P = \frac{\mu c_p}{k_1}$ (Prandtl number),

$D^{-1} = \dfrac{L^2}{k}$ (Darcy parameter),

$Sc = \dfrac{\nu}{D_1}$ (Schmidt number)

$\alpha = \dfrac{QL^2}{\lambda}$ (Heat source parameter)

$\gamma_1 = \dfrac{K_1 L^2}{D_1}$ (Chemical reaction parameter)

$\delta = m\,L$ (Aspect ratio)

$\gamma = \dfrac{n}{\nu m^2}$ (non-dimensional thermal wave velocity)

$\nabla_1^2 = \delta^2 \dfrac{\partial^2}{\partial x^2} + \dfrac{\partial^2}{\partial y^2}$

The corresponding boundary conditions are

$$\psi(+1) - \psi(-!) = -1$$

$$\frac{\partial \psi}{\partial x} = 0, \quad \frac{\partial \psi}{\partial y} = 0 \quad at\; y = \pm 1 \tag{17}$$

$$\theta(x,y) = 1 \quad , C = 1 \quad on\; y = -1$$

$$\theta(x,y) = Sin(x + \gamma t) \quad , C = 0 \quad on \quad y = +1$$

$$\frac{\partial \theta}{\partial y} = 0, \frac{\partial C}{\partial y} = 0 \quad at \quad y = 0 \tag{18}$$

The value of ψ on the boundary assumes the constant volumetric flow in consistent with the hypothesis (7) .Also the wall temperature varies in the axial direction in accordance with the prescribed arbitrary function t.

III. Nusselt number and Sherwood number

The local rate of heat transfer coefficient (Nusselt number Nu) on the walls has been calculated using the formula

$$Nu = \frac{1}{\theta_m - \theta_w}\left(\frac{\partial \theta}{\partial y}\right)_{y=\pm 1} \qquad \text{where} \quad \theta_m = 0.5\int_{-1}^{1} \theta\, dy$$

and the corresponding expressions are

$$(Nu)_{y=+1} = \frac{(d_9 + \delta d_{11})}{(\theta_m - Sin(x + \gamma t))} \qquad (Nu)_{y=-1} = \frac{(d_8 + \delta d_{10})}{(\theta_m - 1)},$$

where $\theta_m = d_{14} + \delta d_{15}$

The local rate of mass transfer coefficient Sherwood Number (Sh) on the walls has been calculated using the formula

$$Sh = \frac{1}{C_m - C_w}\left(\frac{\partial C}{\partial y}\right)_{y=\pm 1} \qquad \text{where} \quad C_m = 0.5\int_{-1}^{1} C\, dy$$

and the corresponding expressions are

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$$(Sh)_{y=+1} = \frac{(d_4 + \delta d_6)}{(C_m)}$$,

$$(Sh)_{y=-1} = \frac{(d_5 + \delta d_7)}{(C_m - 1)}$$

Where $C_m = d_{12} + \delta d_{13}$ $d_1.d_2,\ldots\ldots\ldots\ldots\ldots\ldots,d_{14}$ are constants.

IV. Results and discussion

In the current investigation, the heat generating and/or absorption as well as thermo-diffusion on the unsteady free convection MHD gyrating flow of radiation and chemical reactive second order fluid past an unbounded perpendicular plate during absorbent medium have been discussed. The analytical solutions for the governing equations are found by utilization of Laplace transformation methodology. The velocity, temperature and concentration profiles are analyzed with some graphical profiles. It is represented the second grade fluid velocity, temperature and concentration distributions for quite a few quantities of permeability parameter K, second grade fluid parameter α, chemical reaction parameter Kr.

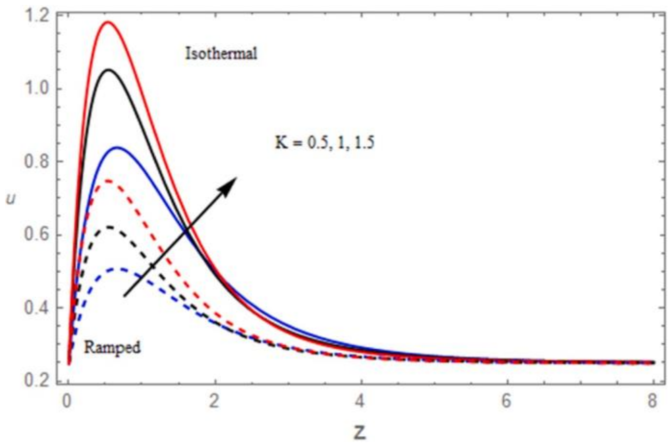

Fig.1. Profiles of u with K

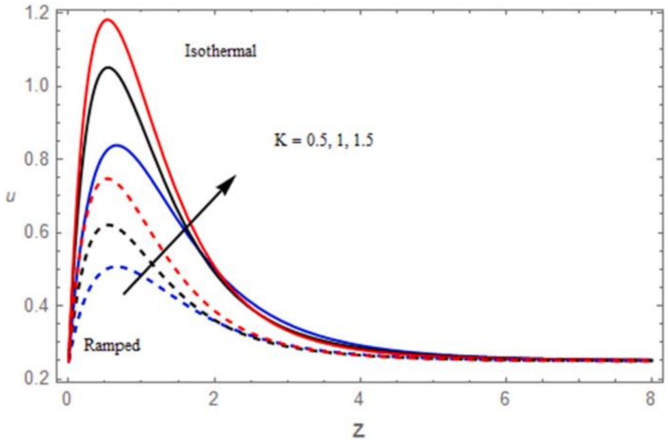

Fig..2 Profiles of v with K

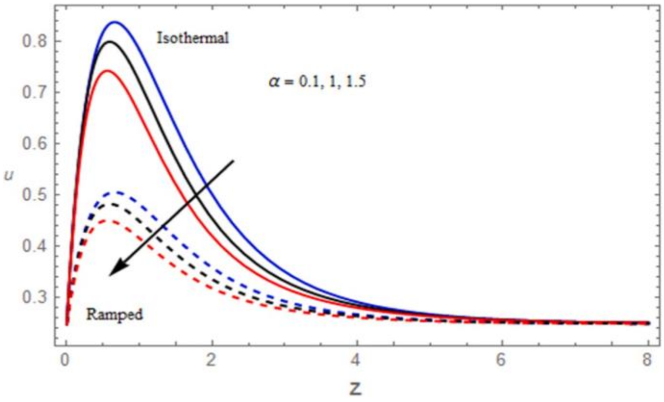

Fig.3. Profiles of u with α

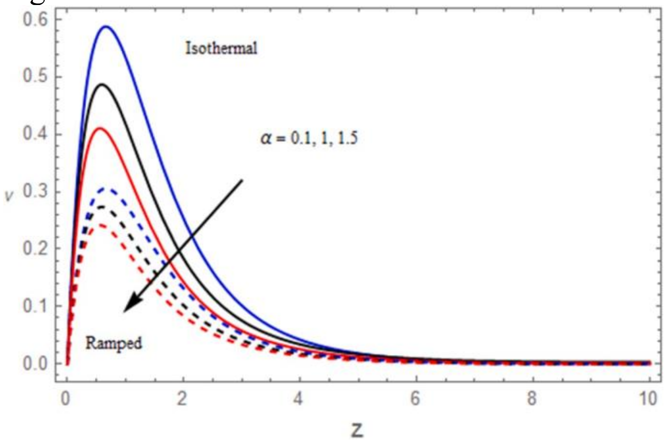

Fig. 4 Profiles of v with α

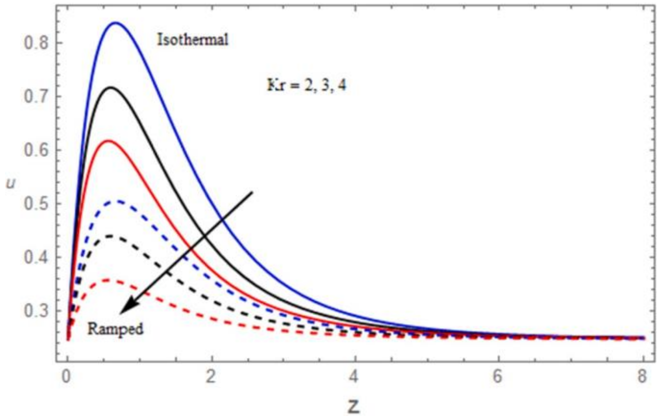

Fig.5 Profiles of u with K_r

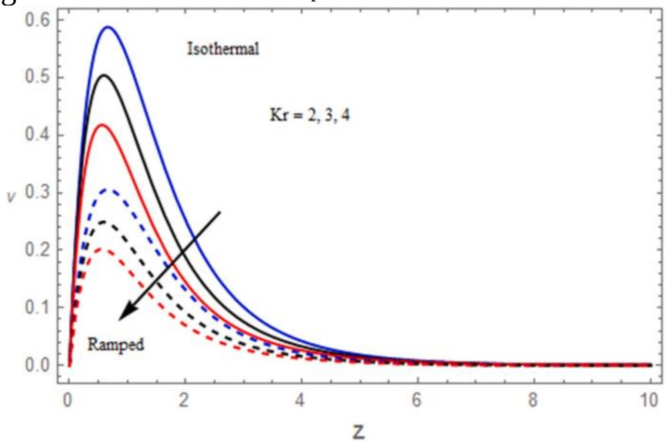

Fig.6 Profiles of v with K_r

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From Figs.1 and 2 components with respected to the permeability parameter K. Mutually the velocity components u and v are enhancing by an escalating into the permeability parameters K. Therefore, an augmentation in the permeability of porous medium lead to mounts throughout the fluid flow region. Inferior the permeability lower the fluid velocity is displayed in entire liquid expanse. These results are also used in petroleum extraction process from crude oil in petroleum engineering. The thicknesses of the boundary layers increase when the permeability parameter increases throughout the fluid region.
Figs. 3 and 4 have been shown that, the effect of second grade parameters on the
velocity components for together thermally vertical plates. It has been seen that, the velocity components are decreasing throughout the flow field by an increasing in the second grade parameter α. This is also notified that, the thicknesses of the boundary layers decrease if the second grade parameter increases. Chemically reacting impacts have the slow down influences on liquid flows velocity for together thermal case as displayed into Fig. 5 as well as 6. It has been shown that, the destructive reactions Kr > 0 led to falls in the velocity field this in turn deteriorates the buoyancy impacts owing into the concentration gradient. Subsequently, the flow field is retarding. These incidences have the higher conformity by the physical reality.
Table.1. The Shear stresses

M	K	α	K_r	S_r	G_r	G_m	H	R	Ramped Temp		Isothermal Temp	
									τx	τy	τx	τy
1	1	0	2	0	5	2	2	2	1.07521	0.07079	1.66479	0.89089
1									0.65606	0.0819	1.37547	0.92055
1									0.31259	0.08858	1.14501	1.02455
	1								0.9778	0.04848	1.48964	0.82497
	2								0.74848	0.0375	1.34479	0.71356
		1							1.64547	0.0819	1.77897	1.02375
		2							2.7789	0.10855	1.92025	1.20159
			3						1.3789	0.07887	2.0188	1.09048
			4						2.01175	0.11075	3.00548	1.49004
				1					0.98275	0.04441	1.11588	0.57195
				1					0.79299	0.03712	0.37086	0.33166
					8				0.97511	0.04804	1.64215	0.85959
					10				0.74652	0.04187	1.62015	0.83385
						5			1.01955	0.05931	1.65227	0.8829
						8			0.91295	0.04445	1.64146	0.85901
							5		0.98267	0.05526	1.6056	0.79375
							5		1.37865	0.08187	1.78985	0.99385
								5	1.14845	0.07829	1.77886	1.09095
								8	1.37748	0.08959	1.86486	1.49047

The variations of the shear stress, and Nusselt numbers are determined in Tables. 1and 2 for different quantities of the governing parameters. This is scrutinized from Table 1 that, it is notified that, for together ramped wall temperature and isothermal plate, the stress components τx as well as τy enhances by an increasing in second graded fluid parameter α, chemical reacting parameter Kr, temperature generations and/or absorptions H and thermal radiation parameter R, as well as it reduces by an increasing in the permeability parameter K, thermal-diffusion (Soret) parameters Sr, thermal Grashof numbers Gr and mass Grashof quantity Gm.

This is also found that by an increasing in the intensity of the magnetic fields then the stress components τx retards and the component τy boosting up for together ramped wall and Isothermal plate.

Table.2. The Nusselt number

P_r	R	H	t	Ramped Temperature	Isothermal Temperature
0.71	2	2	0.2	0.860255	1.490585
3				0.974796	1.788421
7				1.375212	2.090574
	5			0.822214	1.223547
	8			0.785995	0.940544
		-2		0.775895	1.224505
		5		0.974778	1.661362
			0.5	1.002546	1.180585
			0.8	1.086589	1.105758

Table 2 illustrated the consequences of Pr, temperature generating and/or absorbing parameter H and radiating parameter R on Nusselt number. The Nusselt number Nu augment with an enhancing in Prandtl number Pr and temperature generating and/or absorbing parameter H and it retards with an increasing in radiating parameter R for together ramped wall temperature in addition to isothermal plate. Nusselt number is enhancing for ramped wall temperature in addition to it trim downs for an isothermal plate with an increasing in time.

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