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An Unsteady Heat Transfer Flow of Casson Fluid through Porous Medium with Aligned Magnetic Field and Thermal Radiation

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Abstract

The aim of the present artical is to study an unsteady heat transfer flow of Casson fluid through porous medium with aligned magnetic field and thermal radiation. When $t^* > 0$, the velocity $u^* = 0$. At that time, the plate the temperature is raised to T_w^*. The system of Non-dimensional governing partial differential equations are solved analytically by using the Laplace transform technique. The influence of various Non-dimensional parameters on velocity, temperature, Skin friction numbers and Nusselt numbers are discussed and derived through graphs and tables. The velocity decreases with increases the values of Magnetic parameter, Prandtl number, aligned angle and Heat source parameter in case of cooling of the plate and opposite phenomenon is observed in case of heating of the plate and the velocity increases with increases the values of Porosity parameter and thermal radiation in case of cooling of the plate and opposite phenomenon is observed in case of heating of the plate. The temperature increases with an increase the values of thermal radiation and it decreases with an increase the values of Prandtl number and Heat source.

Keywords: Thermal radiation, Casson fluids, Aligned Magnetic field and heat source.

INTRODUCTION

Casson fluids are generally made public as a shear dilution liquid which is assumed to have infinite consistency at a zero rate of shear, a yield stress below that no flows happens and goose egg consistence at academic degree infinite rate of shear. If the shear stress less is a smaller amount than the yield stress applied to the fluid, it behaves sort of a solid, wherever as if a shear stress is larger than the yield stress applied a then the fluid starts to manoeuvre. The Casson Fluid Model was introduced by Casson in 1959, after the flow characteristics of Casson fluids in pipes were first studied by Oka.Few samples of Casson fluids are jelly, pasta sauce, honey, targeted drink and blood etc. Casson model is usually expressed to suit natural philosophy knowledge higher than general elastic model for several materials. Several authors contributed their analysis on Casson fluid with the assistance of mathematical modelling. Thermodynamic design of heat and mass transfer processes and devices was identified by Bejan [1]. MHD flow of a Casson fluid over an exponentially shrinking sheet was investigated by Nadeem *et al*. [2]. Effects of mass transfer on MHD flow of Casson fluid with chemical reaction and suction was studied by Shehzad *et al.* [3]. Mukhopadhyay *et al.* [4] discussed the fluid flow and Casson heat transfer beyond a symmetrical wedge. Mukhopadhyay *et al.* [5] has done the research of Diffusion of chemically reactive species in Casson fluid flow over an unsteady permeable stretching surface. Mukhopadhyay *et al.* [6] identified the Casson fluid flow over an unsteady stretching surface. Casson fluid flow and heat transfer past an exponentially porous stretching surface in presence of thermal radiation by Pramanik [7]. Kataria *et al.* [8] analysed Chemical reaction and thermal Radiation effects on Hydrodynamic Casson fluid flow past an oscillating vertical plate. Reddy, J. V *et al.* [9] found that the behavior of the magnetic field aligned with Casson's fluid flows in a porous medium. Pushpalatha *et al.* [10] discussed Heat transfer and mass transfer in unsteady MHD Casson fluid flow with free convective boundary conditions. Nonlinear radiation effects on squeezing flow of a Casson fluid between parallel disks was analysed by Mohyud-Din *et al.* [11]. Hussanan *et al* [12] studied Unsteady heat transfer flow of a Casson fluid with Newtonian heating and thermal radiation. Heat transfer and mass transfer in an unstable MHD flow of Casson fluid in porous media in the presence of chemical reaction was discussed by Ullah *et al.* [13]. Mohan, S. R *et al*. [14] examined the effects of Soret's magnetic field and aligned to an unstable MHD free convection Casson fluid flow over an exponentially infinite vertical plate through porous medium in the presence of thermal radiation, chemical reaction and heat source or sink. Mohan, S. R *et al.* [15] mentioned Effects of chemical reaction and aligned magnetic field on unsteady MHD Casson fluid flow in a porous medium. Effects of Chemical Reaction, Radiation, and Magnetic Field Aligned on Unstable Casson MHD Fluid Flow Beyond Motion an Infinite Vertical Plate Through Porous Medium in Presence of Heat Absorption by Mohan, S. R *et al.* [16]. Seth *et al* [17] studied Modeling and numerical simulation of hydro magnetic natural convection Casson fluid flow with nth-order chemical reaction and Newtonian heating in porous medium. Shamshuddin *et al*. [18] mentioned chemically reacting radiative Casson fluid over an inclined porous plate. Effect of Heat source on an unsteady MHD convection flow of Casson fluid beyond a vertical oscillating plate in porous medium using finite element analysis was analyzed by Goud *et al.* [19]. Effect of suction/blowing on heat-absorbing unsteady radiative Casson fluid past infinite flat plate with conjugate heating and inclined magnetic field was investigated by Mahato *et* *al.* [20]. Kodi, *et al.* [21] analyzed Unsteady MHD oscillatory Casson fluid flow past an inclined vertical porous plate in the presence of chemical reaction with heat absorption and Soret effects. Baby *et al.* [22] worked on MHD Casson Fluid Flow along Inclined Plate with Hall and Aligned Magnetic Effects. Effects of Aligned Magnetic Field and Radiation Absorption on MHD Cassion Fluid beyond one Vertical Porous Plate in Porous Media was published by Kodi *et al.* [23]. Vijayaragavan *et al.* [24] found the Heat and Mass Transfer Investigation on MHD Casson Fluid Flow past an Inclined Porous Plate in the Effects of Dufour and Chemical Reaction. Effects of aligned magnetic field on heat transfer of water-based carbon nanotubes nanofluid on a stretching sheet with homogeneous–heterogeneous reactions was analyzed by Pal, D *et al.* [25]. Devi, R *et al.* [26] researched the impact of Aligned and Non-aligned MHD Casson Fluid with Inclined outer Velocity Past a Stretching Sheet. Impacts of chemical reaction, thermal diffusion and radiation on unstable natural convective flow beyond an inclined vertical Plate under Aligned Magnetic Field was mentioned by Ramakrishna *et al.* [27]. Ali, B *et al.* [28] investigated Aligned magnetic and bio convection effects on tangent hyperbolic nanofluid flow across faster/slower stretching wedge with activation energy. Qayyum, S. *et al.* [29] was discussed Interpretation of entropy generation in Williamson fluid flow with nonlinear thermal radiation and first-order velocity slip. Khan, M. I. *et al.* [30] was analyzed slip flow of micropolar nanofluid over a porous rotating disk with motile microorganisms, nonlinear thermal radiation and activation energy. Applications of modified Darcy law and nonlinear radiation in bioconvection flow of micropolar nanofluid over an off centered rotating disk was reseached by Ying-Qing, S. *et al.* [31].Ramesh, K. *et al.* [32] has identified Bioconvection assessment in Maxwell nanofluid configured by a Riga surface with nonlinear thermal radiation and activation energy. Waqas, H. *et al.* [33] was mentioned Falkner-Skan time-dependent bioconvrction flow of cross nanofluid with nonlinear thermal radiation, activation energy and melting process. Zero velocity regions near forward and rare points of circular cylinder: A heat and mass transfer study was published by Salahuddin, T. *et al.* [34]. Zhao, T. *et al.* [35] has investigated Entropy generation approach with heat and mass transfer in magnetohydrodynamic stagnation point flow of a tangent hyperbolic nanofluid. Heat transfer analysis on MHD flow over a stretchable Riga wall considering Entropy generation rate: A numerical study was derived by Shah, F.*et al.* [33].Khan, M. I. *et al.* [37] has researched Heat and mass transfer analysis for bioconvective flow of Eyring Powell nanofluid over a Riga surface with nonlinear thermal features. Reliable methods to look for analytical and numerical solutions of a nonlinear differential equation arising in heat transfer with the conformable derivative was published by Hosseini, K. *et al.* [38].

In the study, we tend to analyze the results of thermal radiation, Aligned magnetic field and heat source/sink on the flow of Casson fluid past associate degree infinite inclined plate through porous medium. The set of linear partial differential equations area unit solved analytically by victimization Laplace Transform technique. The result of varied non-dimensional parameters on velocity, temperature, Skin friction coefficient and Nusselt number are completely investigated by graphs and tables.

MATHEMATICAL FORMULATION

In this chapter, we consider an unsteady MHD free convection heat transfer flow of a viscous, incompressible, electrically, conducting, radiating & chemically reacting fluid past a semi-infinite inclined plate at α to the vertically in the presence of aligned magnetic field. Let x^*-axis is taken on the plate and y^*-axis is taken normal to it. Initially, when $t^* \leq 0$, each the fluid and plate are at stationary condition having constant temperature. When $t^*>0$, then the momentum $u^* = 0$. At an equivalent time, the plate temperature is raised to T^*_w. For free convection flow, it's additionally assumed that, the evoked magnetic flux is negligible because the magnetic Reynolds range of the flow is taken to be terribly little. The viscous dissipation isn't taken within the heat equation. The effects of variation in density (ρ) with temperature area thought of solely on the body force term, in accordance with usual Boussinesq approximation. The fluid thought of here is grey, absorbing/emitting radiation however a non-scattering medium. Since the flow of the fluid is assumed to be within the direction of x*-axis, that the physical quantities area unit functions of the area co-ordinate y*and t*only.

The following governing equations are

Momentum equation:

$$\frac{\partial u^*}{\partial t^*} = \nu\left(1+\frac{1}{\beta}\right)\frac{\partial^2 u^*}{\partial y^{*^2}} + g\beta_T(T^* - T^*_\infty)\cos\alpha - \frac{\sigma B_0^2 \sin^2\varphi}{\rho}u^* - \frac{\nu}{K}u^* \tag{1}$$

Energy equation:

$$\frac{\partial T^*}{\partial t^*} = \frac{\kappa}{\rho C_p}\frac{\partial^2 T^*}{\partial y^{*^2}} - \frac{1}{\rho C_p}\frac{\partial q_r}{\partial y^*} - \frac{Q^*}{\rho C_p}(T^* - T^*_\infty) \tag{2}$$

The initial boundary conditions are

$$\begin{aligned} &t^* \leq 0, u^* = 0, T^* = T^*_\infty \ for\, all\ y^*, \\ &t^* > 0,\ u^* = 0, T^* = T^*_w,\ at\ y^* = 0, \\ &\qquad u^* \to 0, T^* \to T^*_\infty\ as\ y \to \infty \end{aligned} \tag{3}$$

The radiative heat flux q_r, under Rosseland approximation of the form

$$q_r = -\frac{4\sigma^*}{3k^*}\frac{\partial T^{*^4}}{\partial y^*} \tag{4}$$

Where σ*-the Stefan-Boltzmann constant,

k^*- The mean absorption coefficient and

The linear temperature operate T^{*^4} is expanded by victimization Taylor series enlargement regarding T_∞^* as

$$T^{*^4} = 4T_\infty^{*^3} T^* - 3T_\infty^{*^4}. \tag{5}$$

From equations (4) and (5), equation (2) reduces to

$$\frac{\partial T^*}{\partial t^*} = \frac{\kappa}{\rho C_p}\frac{\partial^2 T^*}{\partial y^{*2}} - \frac{16\sigma^* T_\infty^{*^3}}{3\rho C_p k^*}\frac{\partial^2 T^*}{\partial y^{*2}} - \frac{Q^*}{\rho C_p}(T^* - T_\infty^*) \tag{6}$$

The following non- dimensional quantities are

$$u = \frac{u^*}{u_0}, y = \frac{u_0}{v}y^*, t = \frac{u_0^2}{v}t^*, K = \frac{k^* u_0^2}{v}, M = \frac{\sigma B_0^2 v \sin^2\varphi}{\rho u_0^2}, \theta = \frac{(T^* - T_\infty^*)}{(T_w^* - T_\infty^*)},$$
$$Gr = \frac{vg\beta_T(T_w^* - T_\infty^*)}{u_0^3}, \Pr = \frac{\rho v C_p}{\kappa}, k = \frac{k^* u_0^2}{v}, Q = \frac{Q^* v}{\rho C_p u_0^2}, R = \frac{16\sigma^* T_\infty^{*^3}}{3k^* k} \tag{7}$$

In view of (7), the equations (1) and (6), reduce the following non-dimensional forms

$$\frac{\partial u}{\partial t} = \left(1 + \frac{1}{\beta}\right)\frac{\partial^2 u}{\partial y^2} - \left(M + \frac{1}{K}\right)u + Gr\,\theta\cos\alpha \tag{8}$$

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

The corresponding boundary conditions reduce to

$$\begin{aligned} &t \le 0,\ u = 0, \theta = 0 \ for\ all\ y, \\ &t > 0, u = 0, \theta = 1\, at\ y = 0, \\ &\quad u \to 0, \theta \to 0\ as\ y \to \infty. \end{aligned} \tag{10}$$

SOLUTION OF THE PROBLEM

The system of equations (8) and (9) with subject to the boundary conditions (10), are solved analytically by using Laplace Transform technique and the expressions for

$$u(y,t) = \frac{b}{c}[I_1 - I_2 - I_3 + I_4] \tag{11}$$

$$\theta(y,t) = I_4 \tag{12}$$

Here

$$I_1 = \frac{e^{ct}}{2}\left[\exp\left(-y\sqrt{H_3(c+H_4)}\right)erfc\left(\frac{y\sqrt{H_3}}{2\sqrt{t}} - \sqrt{(c+H_4)t}\right) + \exp\left(y\sqrt{H_3(c+H_4)}\right)erfc\left(\frac{y\sqrt{H_3}}{2\sqrt{t}} + \sqrt{(c+H_4)t}\right)\right]$$

$$I_2 = \frac{1}{2}\left[\exp\left(-y\sqrt{H_3H_4}\right)erfc\left(\frac{y\sqrt{H_3}}{2\sqrt{t}} - \sqrt{H_4t}\right) + \exp\left(y\sqrt{H_3H_4}\right)erfc\left(\frac{y\sqrt{H_3}}{2\sqrt{t}} + \sqrt{H_4t}\right)\right]$$

$$I_3 = \frac{e^{ct}}{2}\left[\exp\left(-y\sqrt{H_1(c+Q)}\right)erfc\left(\frac{y\sqrt{H_1}}{2\sqrt{t}} - \sqrt{(c+Q)t}\right) + \exp\left(y\sqrt{H_1(c+Q)}\right)erfc\left(\frac{y\sqrt{H_1}}{2\sqrt{t}} + \sqrt{(c+Q)t}\right)\right]$$

$$I_4 = \frac{1}{2}\left[\exp\left(-y\sqrt{H_1Q}\right)erfc\left(\frac{y\sqrt{H_1}}{2\sqrt{t}} - \sqrt{Qt}\right) + \exp\left(y\sqrt{H_1Q}\right)erfc\left(\frac{y\sqrt{H_1}}{2\sqrt{t}} + \sqrt{Qt}\right)\right]$$

Skin friction coefficient:

The proportion of derivative of velocity is assumed by

$$\tau = -\left(1 + \frac{1}{\beta}\right)\left[\frac{\partial u}{\partial y}\right]_{y=0} \tag{13}$$

From equations (11) and (13), we obtain Skin friction coefficient as follows

$$\tau = -\left[1 + \frac{1}{\beta}\right]\frac{b}{c}\left[J_1 - J_2 - J_3 + J_4\right]$$

Nusselt number:

The proportion of derivative of heat transfer is assumed by

$$Nu = -\left[\frac{\partial \theta}{\partial y}\right]_{y=0} \tag{14}$$

From equations (12) and (14), we obtain Nusselt number as follows

$$Nu = \sqrt{H_1Q}\,erf\left(\sqrt{Qt}\right) + \sqrt{\frac{H_1}{\pi t}}e^{-Qt}$$

Here

$$J_1 = e^{ct}\left[\sqrt{H_3(c+H_4)}\,erf\left(\sqrt{(c+H_4)t}\right) + \sqrt{\frac{H_3}{\pi t}}e^{-(c+H_4)t}\right]$$

$$J_2 = \sqrt{H_3H_4}\,erf\left(\sqrt{H_4t}\right) + \sqrt{\frac{H_3}{\pi t}}e^{-H_4t}$$

$$J_3 = e^{ct}\left[\sqrt{H_1(c+Q)}\,erf\left(\sqrt{(c+Q)t}\right) + \sqrt{\frac{H_1}{\pi t}}e^{-(c+Q)t}\right]$$

$$J_4 = \sqrt{H_1Q}\,erf\left(\sqrt{Qt}\right) + \sqrt{\frac{H_1}{\pi t}}e^{-Qt}$$

Where

$$H_1 = \frac{\Pr}{1+R}, H_2 = 1+\frac{1}{\beta}, H_3 = \frac{1}{H_2}, H_4 = M+\frac{1}{K}, b = \frac{H_3 Gr\cos\alpha}{H_1 - H_3}, c = \frac{H_3 H_4 - H_1 Q}{H_1 - H_4}$$

RESULTS AND DISCUSSION:

The systems of linear, non-dimensional equations (8) and (9), with the boundary conditions (10), are solved analytically by using Laplace Transform technique. The obtained solution reveals that the flow, heat transfer of the fluid will be affected by various non-dimensional governing parameters, such as Casson parameter (β), Magnetic parameter (M), Porosity parameter (K), Prandtl number (Pr), Thermal Grashof number (Gr), Aligned angle (φ), inclined angle (α), Thermal Radiation parameter (R), heat source parameter (Q) and unsteady parameter (t). Hence, the distribution of velocity and temperature are studied by the graphs which are obtained by Matlab package. Also, the numerical values of, Nusselt number and skin friction coefficient are presented in tables. Figures (1) to (12) are drawn to discuss the case of cooling (Gr>0 and heating (Gr<0) of the plate. The heating & cooling taken position by putting in location free transfer currents in as much as of mixture and concentration gradient.

The influences of Magnetic parameter (M) and Prandtl number (Pr) on the fluid velocity are shown in figures (1) and (2) respectively, in case of cooling and heating of the plate. It is observed that the fluid velocity decreases as M or Pr increases in case of cooling of the plate and opposite phenomenon is observed in case of heating of the plate. Velocity decreases with increasing Magnetic parameter due to Lorentz force thereby decreasing the magnitude of velocity. Also increase in Pr leads to an enhancement in the viscosity of the fluid or decrease in the thermal diffusivity of the fluid, this will result a gradual reduction in the flow of velocity of the fluid. Figure (3), shows the effect of porosity parameter (K) on velocity in case of cooling and heating of the plate. It is found that the velocity increases as K increases in case of cooling of the plate. But a reverse effect is identified in case of heating of plate.

The effect of thermal radiation (R) on velocity is shown figure (4), in case of cooling and heating of the plate. It is seen that the velocity increase as R increases in case of cooling of the plate and opposite phenomenon is observed in case of heating of the plate. Therefore using radiation we can direct the flow diagnostic and mixture dispersion. Figures (5) depict the effect of heat source parameter (Q) on velocity in cases cooling and heating of the plate. It is seen that the velocity decreases as Q increase in case of cooling of the plate and a reverse effect is noticed in case of heating of the plate. The effect of Casson parameter (β) on velocity is shown figure (6), in case of cooling and heating of the plate. It is observed that the velocity increases initially and slowly reduces as β increases in case of cooling of the plate and it is noticed opposite phenomenon in case of heating of the plate. Figure (7), reveals the behavior of α on velocity in case of cooling and heating of the plate. It is clear that the velocity increases as the Aligned angle ($\boldsymbol{\varphi}$) increases for both cooling and heating of the plate. Figure (8), reveals the behavior of α on velocity in case of cooling and heating of the plate. It is clear that the velocity increases as the inclined angle (α) increases for both cooling and heating of the plate. When $\alpha=\frac{\pi}{2}$ we obtain the velocity flow in vertically.

The effects of Prandtl number (Pr) and the heat source parameter (Q) on the fluid temperature are shown in figures (9) and (10). It is observed that temperature decreases as Pr or Q increases on the fluid f low. Because, Prandtl number (Pr) is the ratio of kinematic viscosity to thermal diffusivity. Also, the positive sign of Q indicates the heat generation (heat source) whereas negative means heat absorption (heat sink). Heat source physically implies generation of heat from the surface (this is due to $T_w > T_\infty$), which increases temperature in the flow field. Therefore, as heat source parameter increased, temperature increases steeply and exponentially from the surface. The influence of heat source parameter $Q > 0$ on temperature distribution is very much significantly related to the heat sink parameter $Q < 0$. These effects are clearly nurtured from the physical moment of appearance. The effect of thermal radiation (R) on temperature is shown in figure (11). It is seen that the temperature increases as R increases on the fluid flow.

From table-1, the effect of Nusselt number increases with the values Pr or Q increases and reduces when R or t increases. From table-2: the effect of skin friction coefficient in case cooling and heating. From this it is clear that the Skin friction coefficient increases with the values of M, Pr, Q, β, φ or α increase and it decreases with the values of R, K or t increases in case of cooling. But it is opposite phenomenon in case of heating.

GRAPHS AND TABLES:

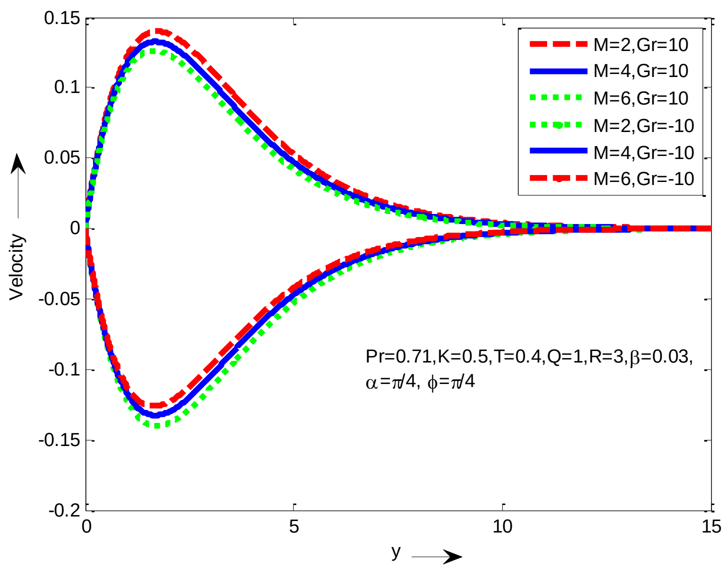

Fig.1. Effect of ***M*** on velocity

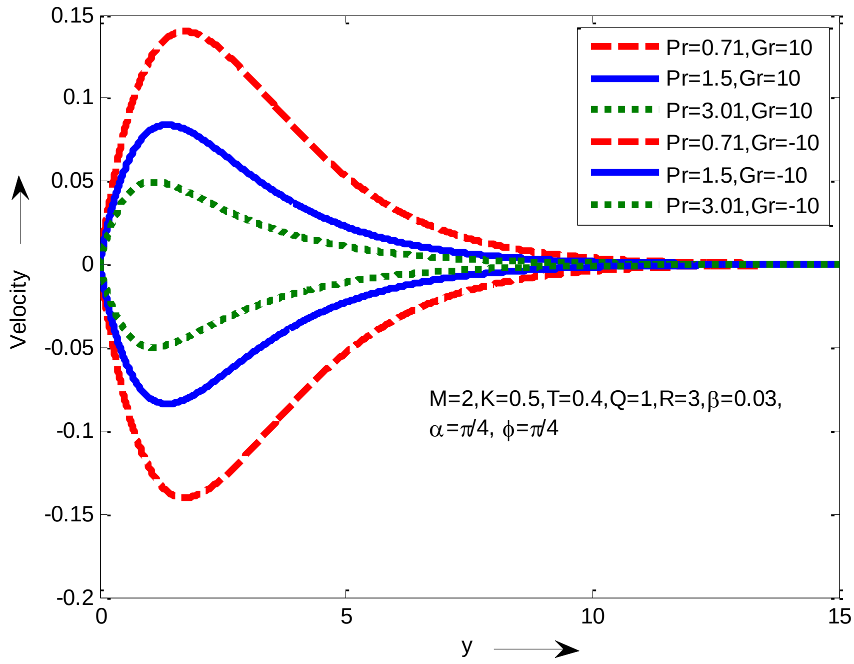

Fig.2. Effect of ***Pr*** on velocity

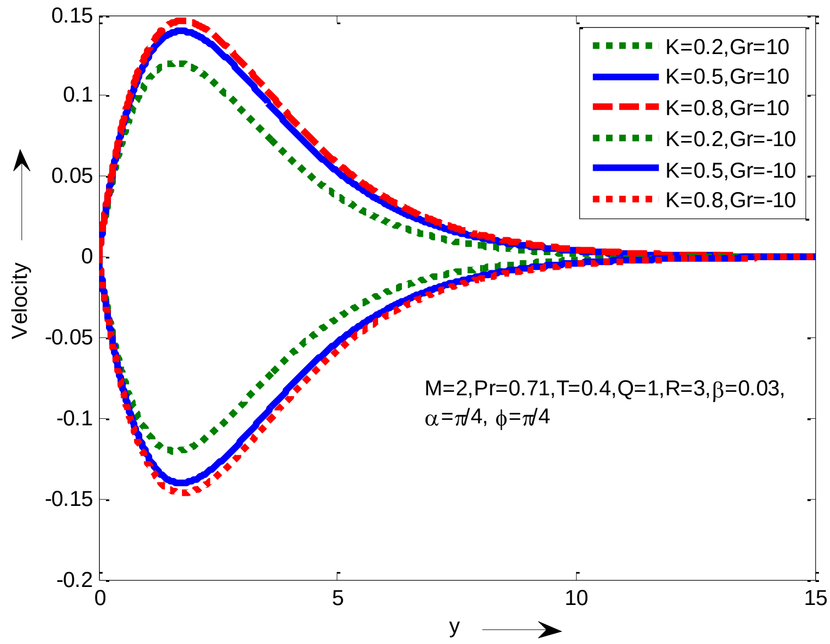

Fig.3. Effect of ***K*** on velocity

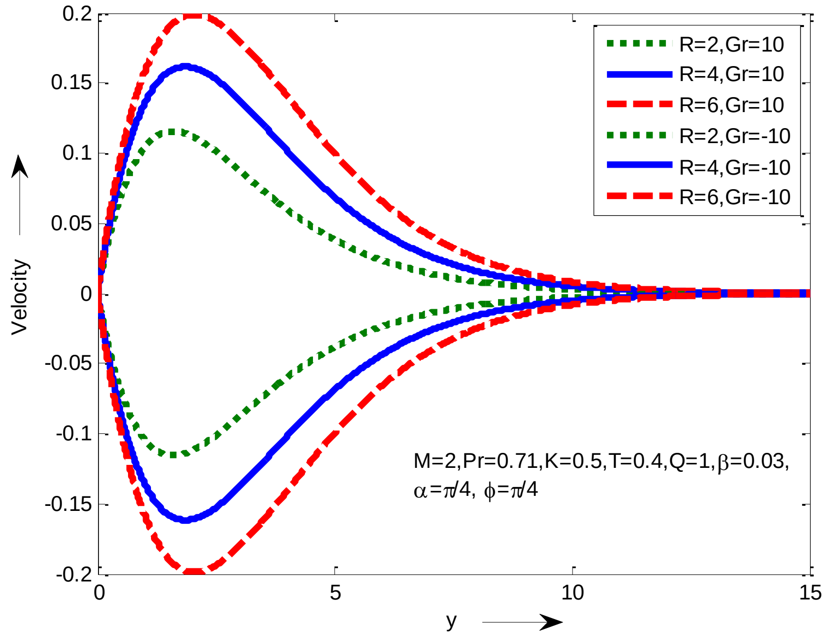

Fig.4. Effect of ***R*** on velocity

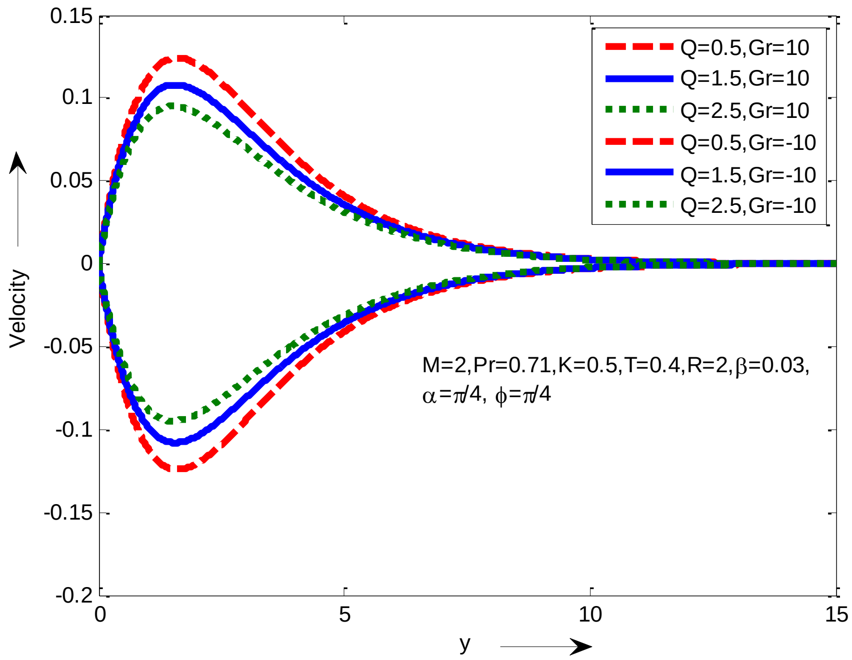

Fig.5. Effect of ***Q*** on velocity

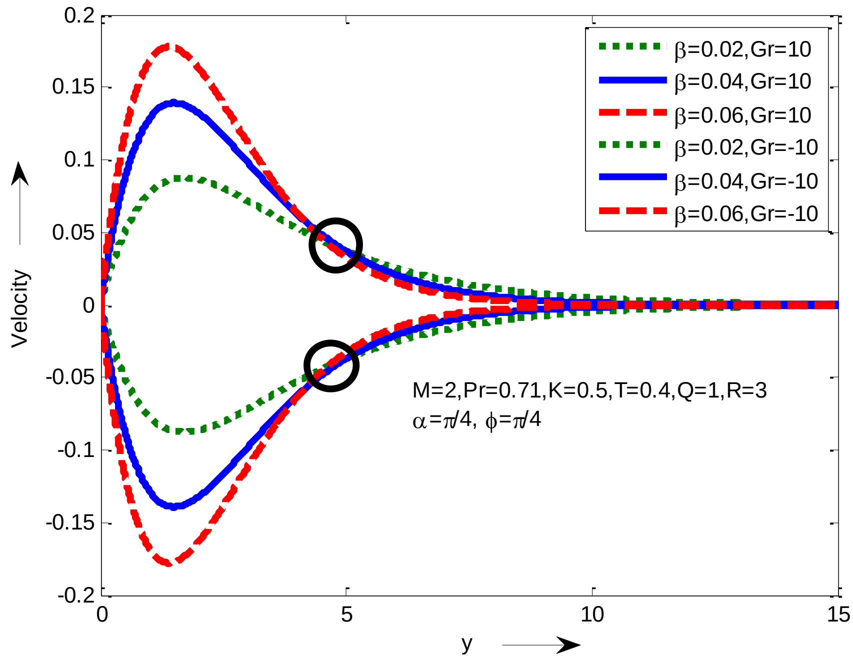

Fig.6. Effect of $\boldsymbol{\beta}$ on velocity

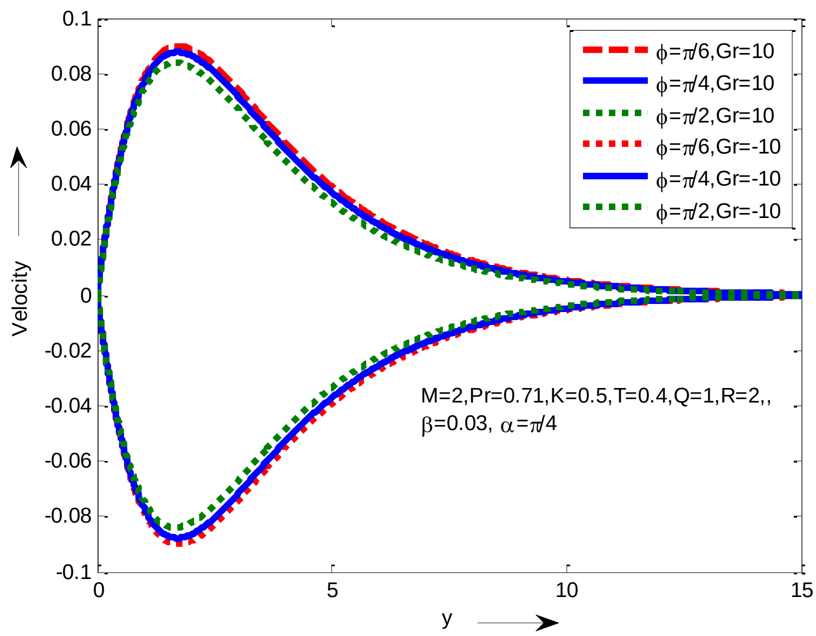

Fig.7. Effect of $\boldsymbol{\varphi}$ on velocity

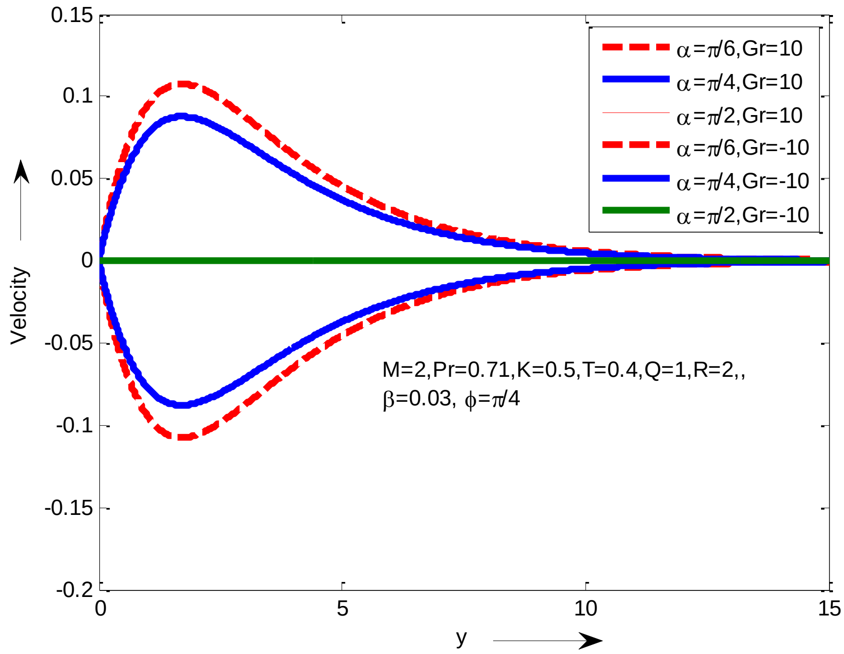

Fig.8. Effect of α on velocity

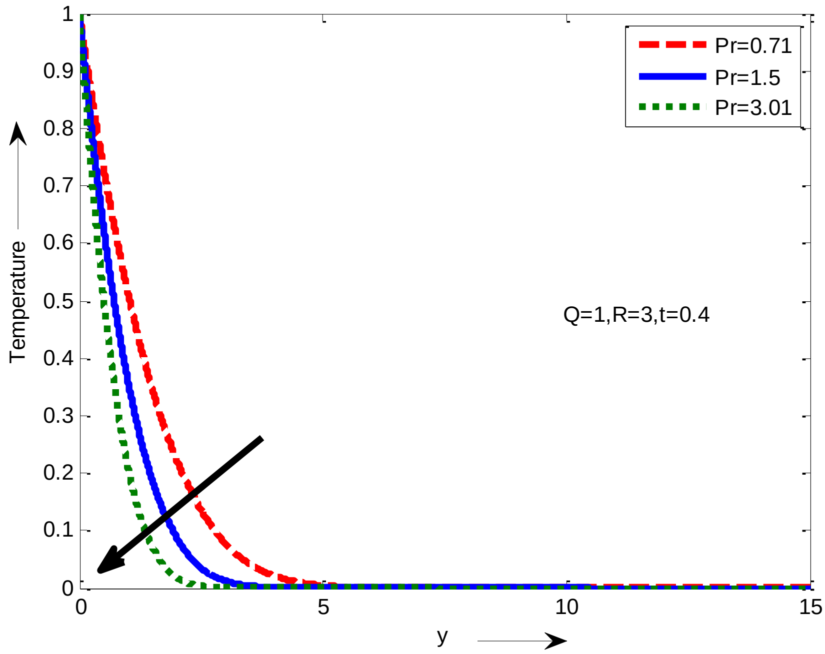

Fig.9. Effect of ***Pr*** on Temperature

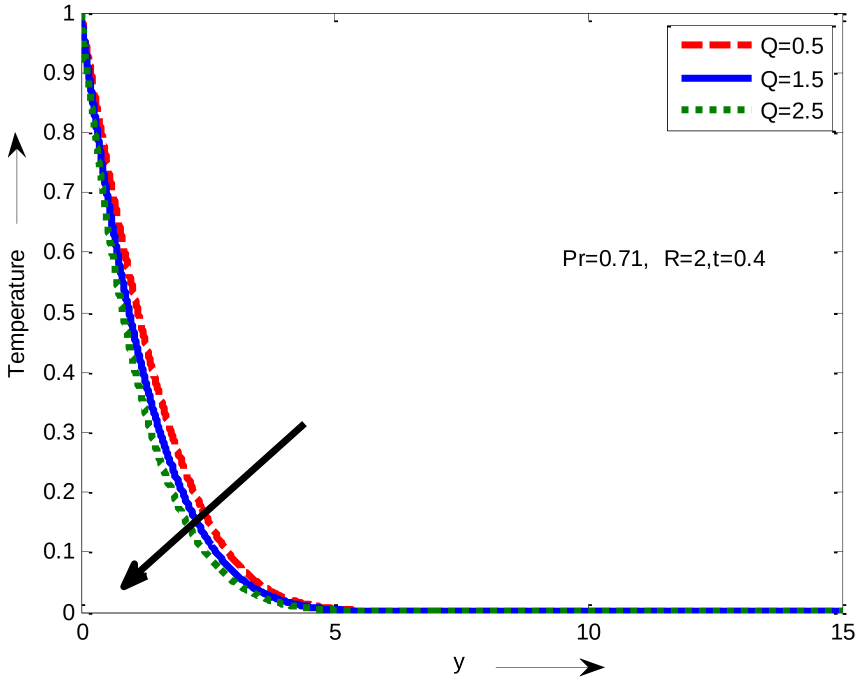

Fig.10. Effect of ***Q*** on Temperature

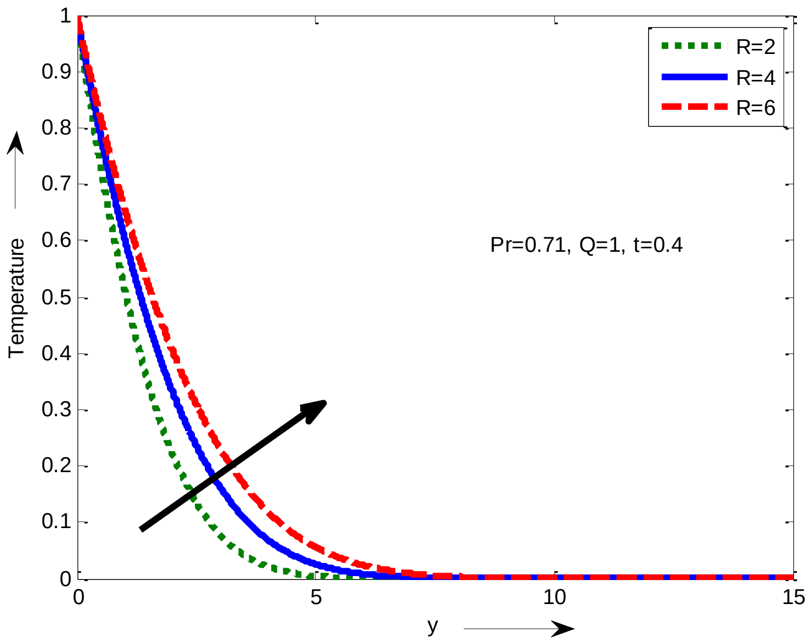

Fig.11. Effect of ***R*** on Temperature.

Table- 1: Nusselt number

Pr	R	Q	t	Nu
0.71	2	1	0.4	0.5969
1.5				0.8675
3.01				1.2789
	3			0.5169
	4			0.4623
		2		0.7413
		3		0.8711
			0.8	0.8465
			1	0.8442

Table 2: Skin-friction coefficient; (for cooling Gr>0 and for heating Gr<0)

M	Pr	K	t	Q	R	β	φ	α	τ (Gr=10,)	τ (Gr= -10)
2	0.71	0.5	0.4	1	3	0.03	π/4	π/4	-6.3900	6.3900
3									-6.3074	6.3074
4									-6.2289	6.2289
	1.5								-4.8529	4.8529
	3.01								-3.6728	3.6728
		0.3							-6.1786	6.1786
		0.4							-6.3074	6.3074
			0.6						-7.2281	7.2281
			0.8						-7.7622	7.7622

M	Pr	K	t	Q	R	β	φ	α	τ (Gr=10,)	τ (Gr= -10)
				2					-5.8825	5.8825
				2.5					-5.6613	5.6613
					4				-7.5832	7.5832
					5				-8.0321	8.0321
						0.04			-6.7156	6.7156
						0.05			-6.4504	6.4504
							π/6		-7.1556	7.1556
							π/2		-6.8529	6.8529
								π/6	-8.6336	8.6336
								π/3	-4.9846	4.9846

CONCLUSIONS:

From the above work the following conclusions are made:

- Velocity increases as K, R or β increases in case of cooling and reverse phenomenon is observed in case of heating. Velocity decreases as M, Pr, Q, φ or α increases in case of cooling and it is noticed opposite behavior in case of heating. But both the cases velocity increases as inclined angle (α) increases.
- Nusselt number increase with the values of Pr or Q increases and it decay as R or t rises.
- Using field of force we are able to management the flow characteristics & heat transfer.
- Radiation has important effects on velocity & temperature.
- Skin friction coefficient increases with the values of M, Pr, Q, β, φ or α increases and it is decreases as R, K or t increases in case of cooling. But the reverse effect is noticed in case of heating.

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