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Influence of Aligned Magneticfield on the Flow through Vertical Surface in Porous Medium with Heat Source

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Abstract
In this paper we analyzed the influence of aligned magneticfiled, radiation and chemical reaction on the flow through vertical surface in porous medium in presence of heat source. The governing partial differential equations are reduced to ordinary differential equations and solved numerically by using Shooting technique with Matlab Package. The effects of non-dimensional governing parameters on the flow, heat and mass transfer are discussed and presented with the help of graphs. Also, coefficient of skin friction, Nusselt and Sherwood numbers are discussed and presented through tables. Comparisons of the results with the existed studies were presented. Present results have an excellent agreement with the existed studies under some special conditions.
Keywords: Radiation, Aligned magneticfiled, Chemical reaction, Heat source, Dissipation.

1. Introduction

In the recent years the problems of radiation effects on MHD flow and heat transfer have been studied due to the wide range of industry applications. The study of chemical reaction and radiation on natural convection MHD flow past a porous medium bounded by a vertical infinite surface in the presence of magnetic field was presented by Rout et al. (2014). The Effects of thermal radiation and heat source on unsteady magneto hydrodynamics free convection flow past an infinite vertical plate in a porous medium in presence of thermal diffusion and diffusion thermo stated by Raju et al. (2013). Vijaya kumar et al (2013) has discussed the Chemical reaction and radiation absorption on unsteady MHD flow of an incompressible, viscous, electrically conducting fluid over an exponentially accelerated vertical moving plate with heat source. Sandeep et al. (2013), Mohan Krishana et al. (2014) analyzed the influence of radiation on unsteady MHD flow of nanofluid over a vertical plate.

Heat and mass transfer of MHD micropolar fluid bounded by a semi finite porous plate in a rotating frame under the action of transverse magnetic field with chemical reaction was presented by Olajuwon et al. (2014). Heat and mass transfer effects on the unsteady flow of a micropolar fluid through a porous medium bounded by a semi-infinite vertical plate in a slip-flow regime are studied by Chaudhary et al. (2008). Effects of radiation absorption and chemical reaction on MHD free convection heat transfer flow over a vertical plate was discussed by Sandeep et al. (2012). Sandeep and Sugunamma (2013) studied effect of inclined magnetic field on MHD dusty fluid flow over infinite flat plates. (Ramana Reddy et al., 2014), Mohan Krishna et al. (2013) discussed the influence of radiation and chemical reaction of magnetohydrodynamic dusty fluid flow by considering different channels. Ibrahim et al. (2008) presented and discussed the influence of chemical reaction and radiation absorption on the unsteady MHD free convection flow of moving plate with heat source. The steady and unsteady MHD micropolar fluid flow and mass transfer with constant heat sources in presence of chemical reaction was illustrated by Bakr (2011).Visco-elastic free convective transient MHD flow over a vertical porous plate through porous media in presence of radiation and chemical reaction was presented by Choudhury et al. (2014). Chemically reacting and radiating viscoelastic fluid through a porous medium with constant injection velocity in the presence of uniform magnetic field was discussed by Khem Chand et al. (2013). MHD flow, heat and mass transfer through porous media was analyzed by Sharma et al. (2014).

Unsteady laminar boundary-layer flow of MHD free convective heat and mass transfer past a semi-infinite vertical permeable moving plate with transverse magnetic field in presence of radiation, chemical reaction, soret effect and thermal diffusion effects was presented by Madhusudhana Rao et al. (2013). Radiation effects on an unsteady magneto hydrodynamic free convective flow past a vertical porous plate in the presence of soret effect was analyzed by Anand Rao et al. (2012). Unsteady boundary layer flow with heat and mass transfer characteristics of viscous fluid through porous media was studied by Husnain et al. (2012). The effects of chemical reaction on mixed convection flow of a micropolar fluid through a porous medium due to the combined effects of thermal and mass diffusion stated by Patil et al. (2012). The unsteady heat and mass transfer of free convective MHD micropolar fluid flow bounded by a semi-infinite porous plate in a rotating frame under the action of transverse magnetic field with chemical reaction in the presence of heat generation was reported by Olajuwon et al. (2014). Recently, the influence of radiation and chemical reaction by considering different types of fluids at different channels was discussed by the researchers (Murshed et al.,2015), Jones et al. (2015), Raju et al. (2015). Effect of MHD and injection through one side of a long vertical channel embedded in porous medium with transpiration cooling was examined by Govardhan et al. (2014).

In this study we analyzed the influence of aligned magneticfiled, radiation and chemical reaction on the flow through vertical surface in porous medium in presence of heat source. The governing partial differential equations are reduced to ordinary differential equations and solved numerically by using Shooting technique with Matlab Package. The effects of non-dimensional governing parameters on the flow, heat and mass transfer are discussed and presented with the help of graphs. Also, coefficient of skin friction, Nusselt and Sherwood numbers are discussed and presented through tables.

2. Mathematical Analysis

Consider a steady, incompressible, viscous dissipative MHD free convective flow embedded in a porous medium in a vertical surface in presence of thermal radiation, chemical reaction, viscous dissipation and heat source. The x^1 axis is taken along the surface in an upward direction and the y^1 axis is normal to it. An aligned magnetic field is also applied in the direction perpendicular to the plate. The induced magnetic field and Hall effect are neglected. Here, there is no applied voltage, which means there is no electric current. The equations describing the above flow are given by

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

$$v^1 \frac{\partial u^1}{\partial y^1} = v \frac{\partial^2 u^1}{\partial y^{1^2}} + g\beta_1 \left(T^1 - T_\infty\right) + g\beta_2 \left(C^1 - C_\infty\right) - \frac{\sigma B_0^2}{\rho} \sin^2 \alpha u^1 - \frac{v}{k_1} u^1, \tag{2}$$

$$v^1 \frac{\partial T^1}{\partial y^1} = \frac{k}{\rho c_P} \frac{\partial^2 T^1}{\partial y^{1^2}} + \frac{v}{c_p} \left(\frac{\partial u^1}{\partial y^1}\right)^2 - \frac{1}{\rho c_P} \frac{\partial q_r}{\partial y^1} - \frac{Q_0}{\rho c_P} (T^1 - T_\infty), \tag{3}$$

$$v^1 \frac{\partial C^1}{\partial y^1} = D \frac{\partial^2 C^1}{\partial y^{1^2}} - k_0 (C^1 - C_\infty), \tag{4}$$

Equation (1) gives

$$v^1 = const = -v_0, \tag{5}$$

where v_0 is positive and v^1 is the study normal velocity of suction on the surface. The boundary conditions are as follows:

$$u^1 = 0, T^1 = T_w, C^1 = C_w, \text{ at } y^1 = 0,$$
$$u^1 \to 0, T^1 \to T_\infty, C^1 \to C_\infty \text{ at } y^1 \to \infty, \tag{6}$$

Introducing the following non-dimensional parameters:

$$u = \frac{u^1}{v_0}, y = \frac{v_0 y^1}{v}, \theta = \frac{T^1 - T_\infty}{T_\omega - T_\infty}, \phi = \frac{C^1 - C_\infty}{C_\omega - C_\infty}, \Pr = \frac{\mu c_p}{k},$$
$$Sc = \frac{v}{D}, Gr = \frac{vg\beta_1 \left(T_w - T_\infty\right)}{v_0^3}, Gc = \frac{vg\beta_2 \left(C_w - C_\infty\right)}{v_0^3}, Ec = \frac{v_0^2}{c_p \left(T_w - T_\infty\right)},$$
$$K = \frac{v_0^2}{v^2} k_1, K_1 = \frac{v}{v_0^2} k_0, R = \frac{16\sigma^* T_\infty^3}{3k_s k}, Q_H = \frac{Q_0}{v_0 \rho Cp}, M = \frac{\sigma B_0^2}{\rho v_0}, \tag{7}$$

By using the Rosseland approximation q_r takes the following value:

$$q_r = -\frac{4\sigma^*}{3k_s} \frac{\partial T^4}{\partial y}, \tag{8}$$

where σ^* and k_s are the Stefan-Boltzman constant and Roseland mean absorption coefficient, respectively. Assuming the temperature difference within the flow is sufficiently small, by Taylor series expansion neglecting order terms we can express T^4 as a linear function of temperature of the following form:

$$T^4 \approx 4T_\infty^3 T - 3T_\infty^3, \tag{9}$$

By using (8) and (9)

$$\frac{\partial q_r}{\partial y} = -\frac{16\sigma^1 T_\infty^3}{3k_s}\frac{\partial^2 T}{\partial y^2}, \tag{10}$$

Using (7) and (10) in the system of equations (1) – (4), the reduced non-dimensional equations are given by

$$u'' + u' + Gr\theta + Gc\phi - \left(\frac{1}{K} + M\sin^2\theta\right)u = 0, \tag{11}$$

$$\theta'' + \frac{\Pr}{1+R}\theta' + \frac{\Pr}{1+R}Ec\left(u'\right)^2 + Q_H\theta = 0, \tag{12}$$

$$\phi'' + Sc\phi' - K_1 Sc\phi = 0, \tag{13}$$

The corresponding boundary conditions are

$$u = 0, \theta = 1, \phi = 1 \text{ at } y = 0,$$

$$u \to 0, \theta \to 0, \phi \to 0 \text{ at } y \to \infty, \tag{14}$$

For engineering interest we calculated skin friction coefficient and reduced Nusselt number.

3. Results and Discussion

The influence of magneticfield parameter on velocity profiles of the flow is shown in Fig.1. It is observed from the figure that an increasing value of magnetic field parameter depreciates the velocity profiles of the flow. It is due to the fact that the increasing magnetic field parameter improves the opposite force to the flow direction, it is called Lorentz force. Due to this force, we observed decreasing phenomena in the momentum boundary layer. The homogeneous results are seen in Fig.2. It displays the effect of aligned magneticfield parameter on velocity profiles. It is evident from the figure that the increasing value of aligned angle reduces the velocity profiles. This may happen due the reason that an increase in aligned angle strengthens the applied magneticfield.

The Figs. 3 and 4 show the effect of porosity parameter on velocity and temperature profiles. It is noticed from the figures that increasing in the porosity parameter enhances the momentum and thermal boundary layer thickness. Normally increasing the porous parameter releases the internal heat to the flow and widens the porous layers causes to develop the momentum boundary layer.

The figures 5 and 6 depict the velocity and temperature profiles for various values of thermal Grashof number (Gr). It is observed from the figures that an increase in thermal Gashof number increases the velocity and temperature profiles of the flow. Similar types of results have seen in figures 7 and 8. It explains the effect of concentration Grashof number (Gc) on velocity and temperature profiles. It notices that increasing values of (Gc) enhances the momentum and thermal boundary layer thickness.

The figures 9 and 10 depict the influence of chemical reaction parameter (K_l) on velocity, and concentration profiles. It is found from the figures that decrease in the momentum and concentration boundary layers of the flow with increase in the chemical reaction parameter. Usually increasing values of chemical reaction parameter enhances the interfacial mass transfer per unit volume. It is also pointed out the similar types of results in figures 11 and 12. It displays the effect of Schmidt number (Sc) on velocity and concentration profiles. We noticed from figures that the higher values of Schmidt number reduce the velocity and concentration boundary layers.

Figs.13-16 shows the influence of radiation parameter and viscous dissipation meter on velocity and temperature profiles of the flow. It is evident from the figures that an increase in radiation parameter and Eckert number enhances the velocity and temperature profiles of the flow. This shows the domination of Rosseland radiation and enhanced conductivity due to increase in viscous dissipation.

Table1 demonstrates the influence of various physical parameters on friction factor, Nusselt number and Sherwood numbers. It is noticed that increasing magnetic field parameter increases the heat transfer rate and decreases the friction factor coefficient. It is interesting to mention that increasing values of R, K, Gr, Gc and Ec reduce the Nusselt number and enhance the skin friction coefficient. It is also interesting to mention that the parameters α, K_l, Sc and $\Pr$ help to enhance the heat transfer rate and reduce the friction factor.

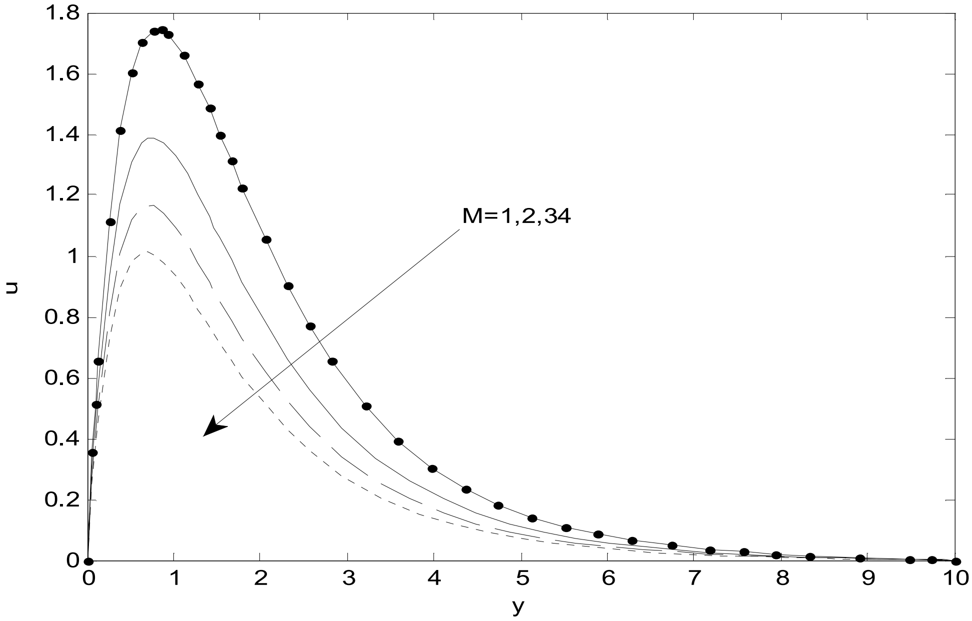

Fig.1 Velocity profiles for different values of M

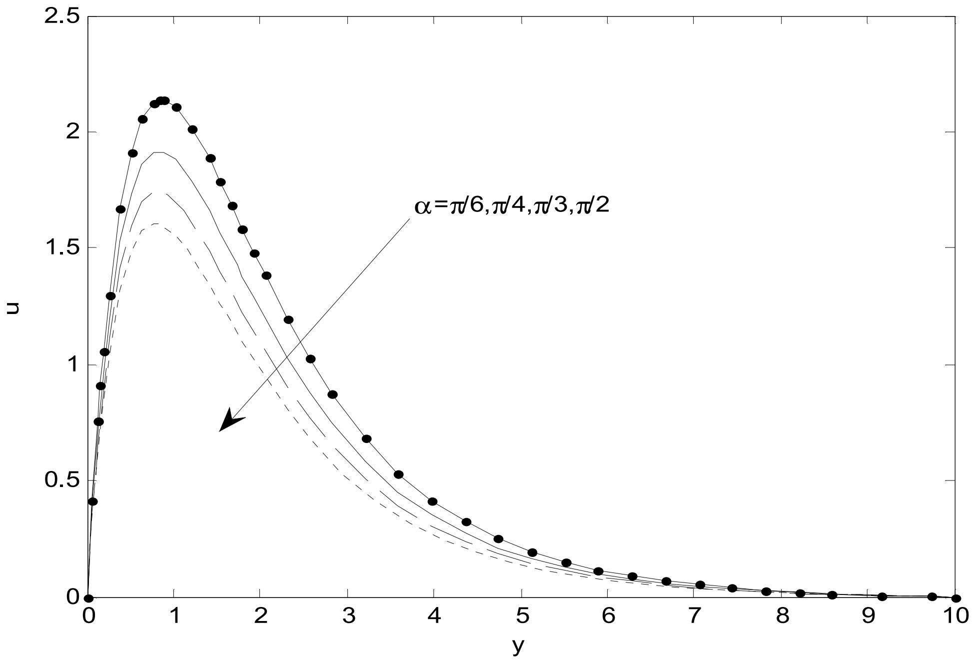

Fig.2 Velocity profiles for different values of α

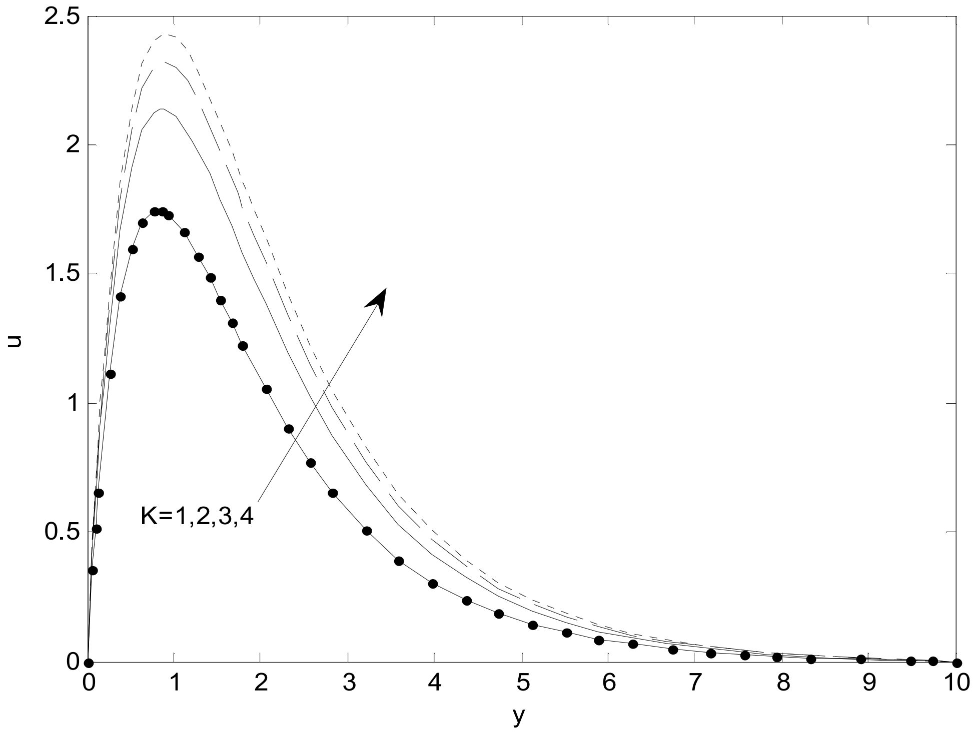

Fig.3 Velocity profiles for different values of K

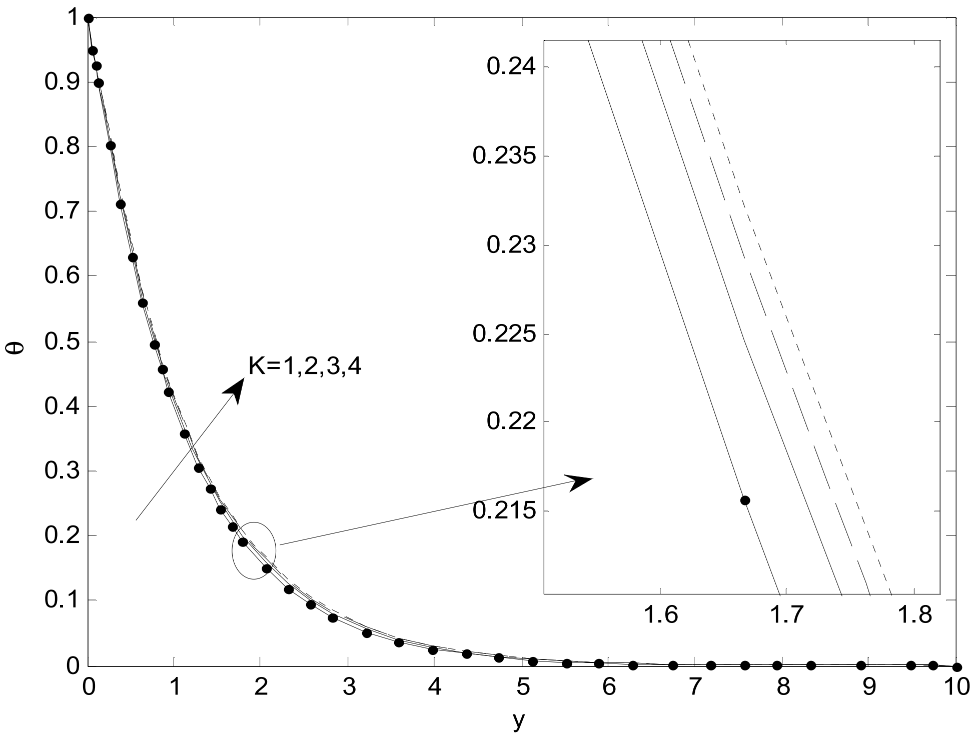

Fig.4 Temperature profiles for different values of K

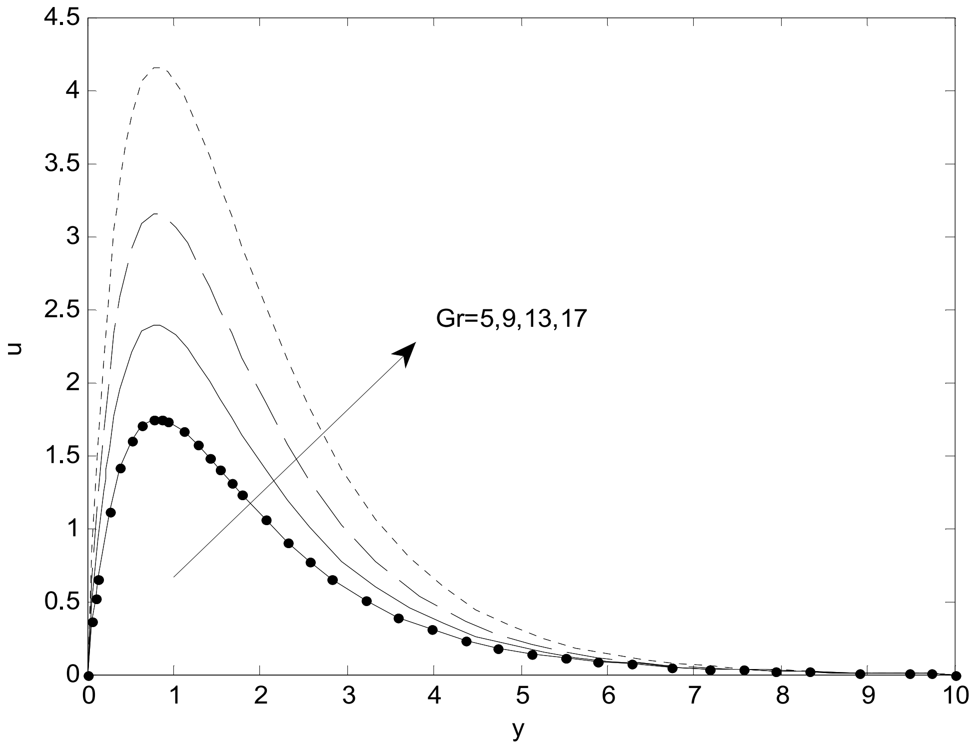

Fig.5 Velocity profiles for different values of Gr

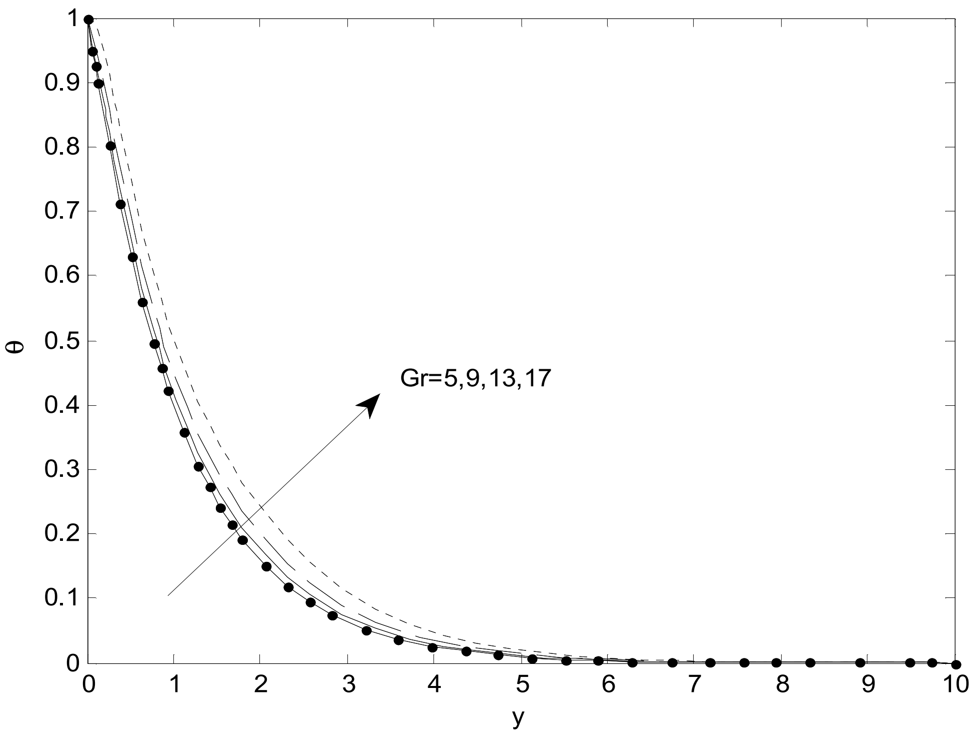

Fig.6 Temperature profiles for different values of Gr

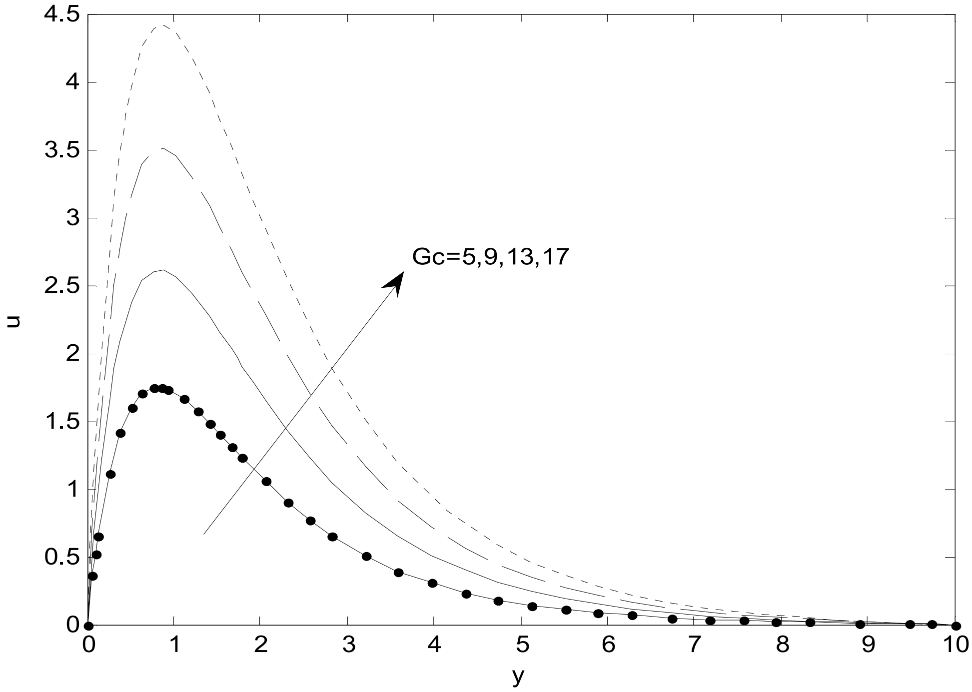

Fig.7 Velocity profiles for different values of Gc

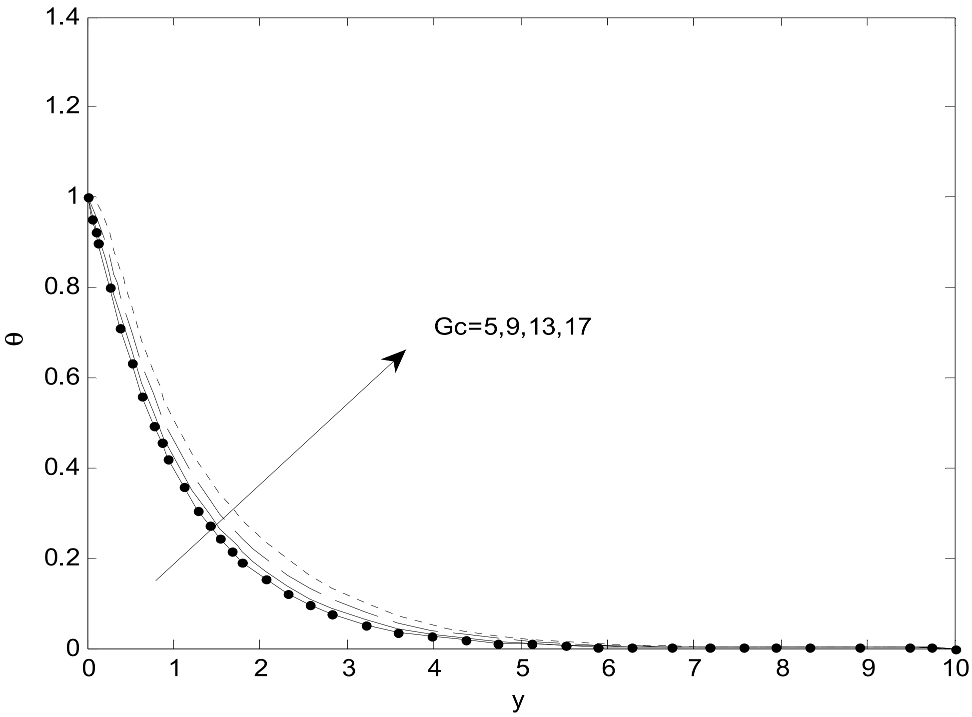

Fig.8 Temperature profiles for different values of Gc

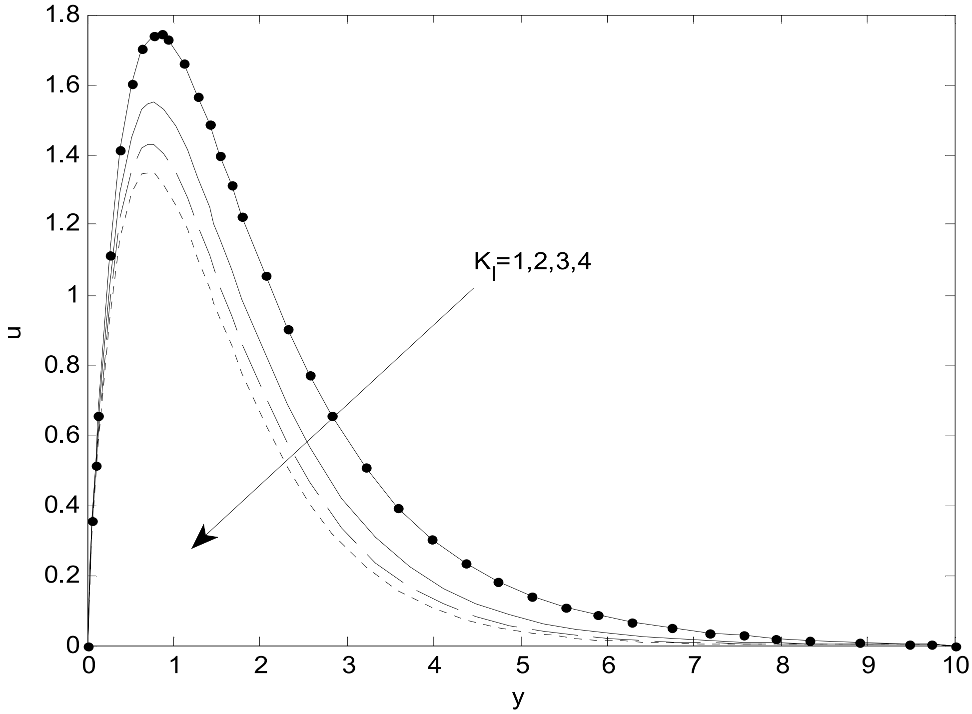

Fig.9 Velocity profiles for different values of K_l

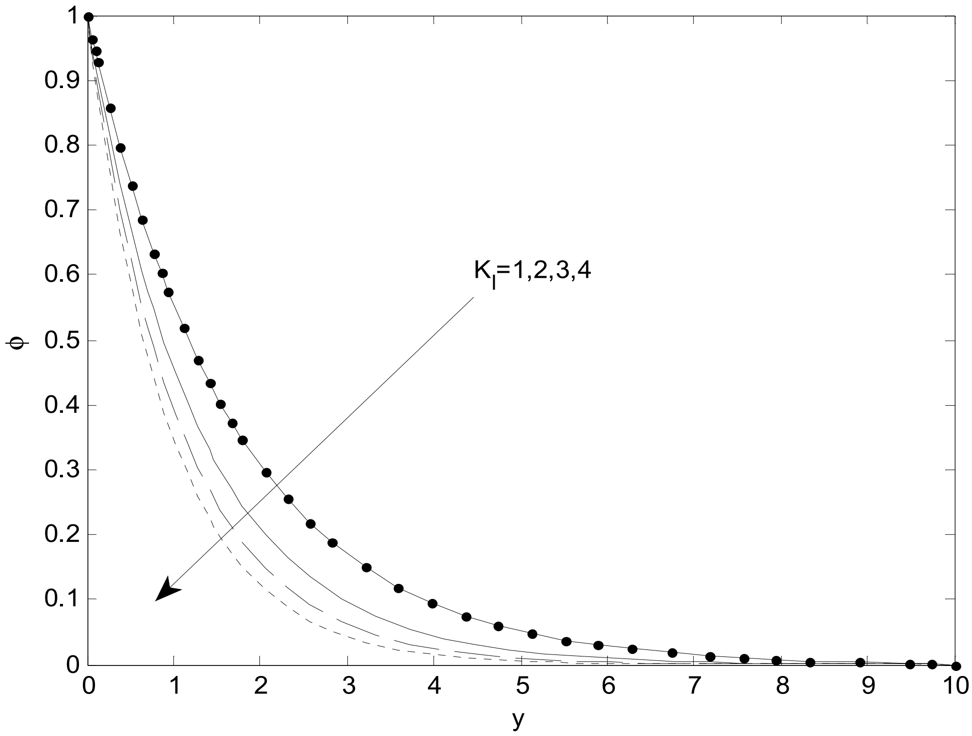

Fig.10 Concentration profiles for different values of K_l

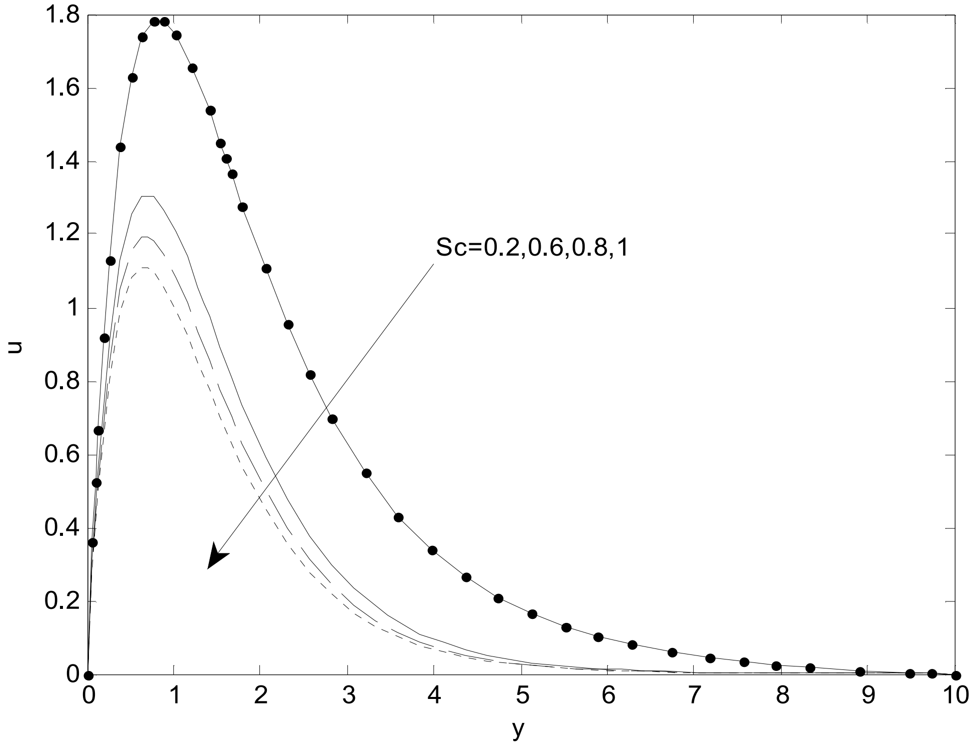

Fig.11 Velocity profiles for different values of Sc

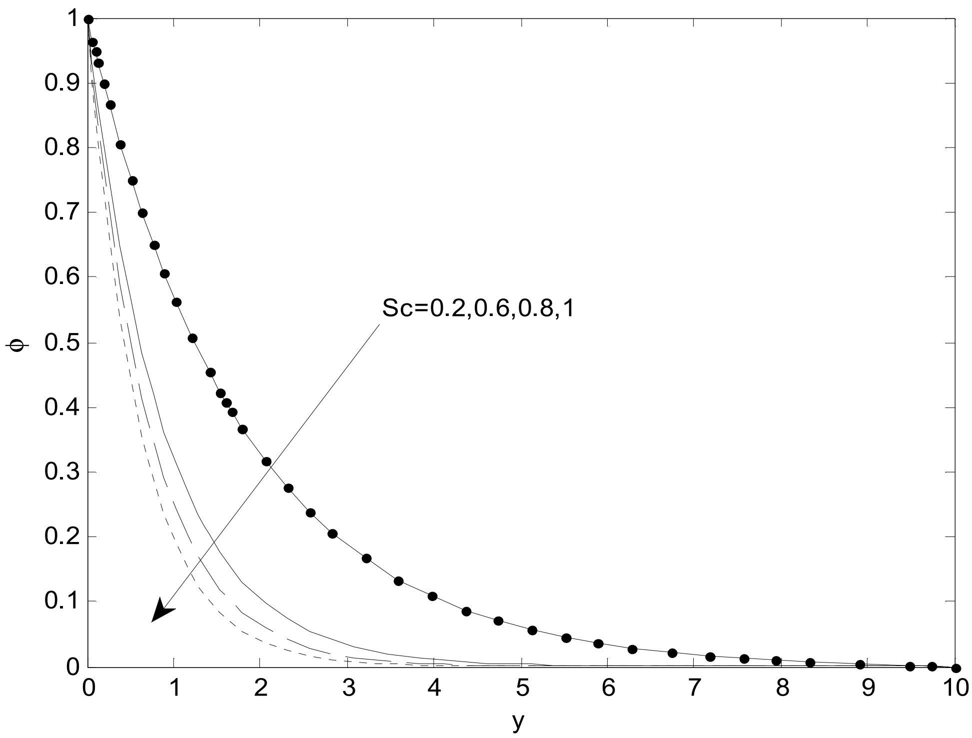

Fig.12 Concentration profiles for different values of Sc

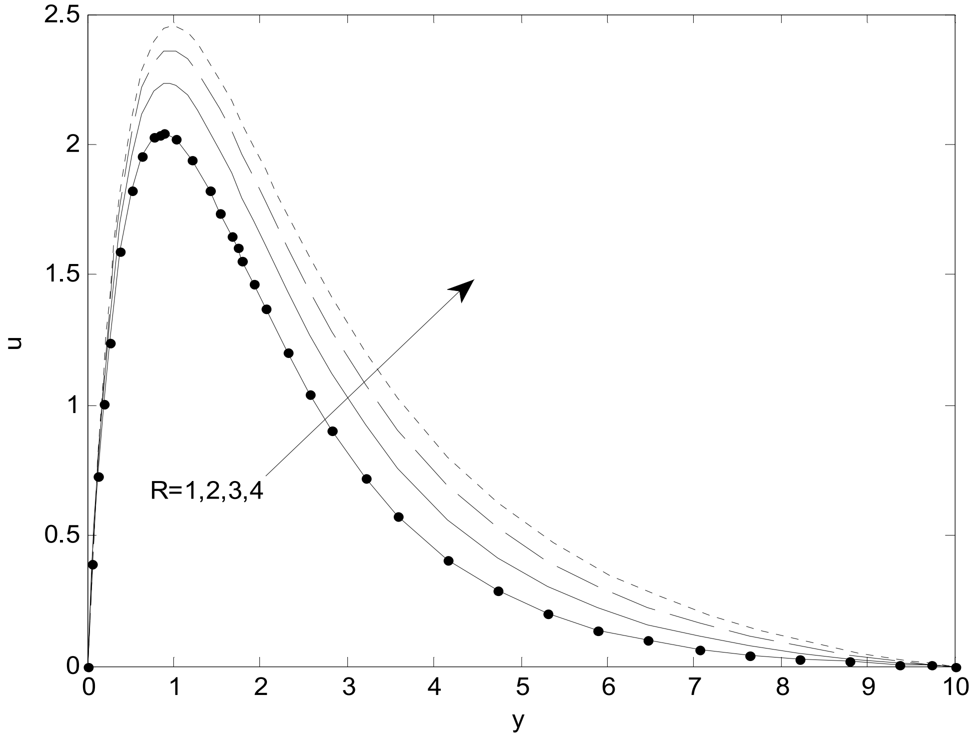

Fig.13 Velocity profiles for different values of R

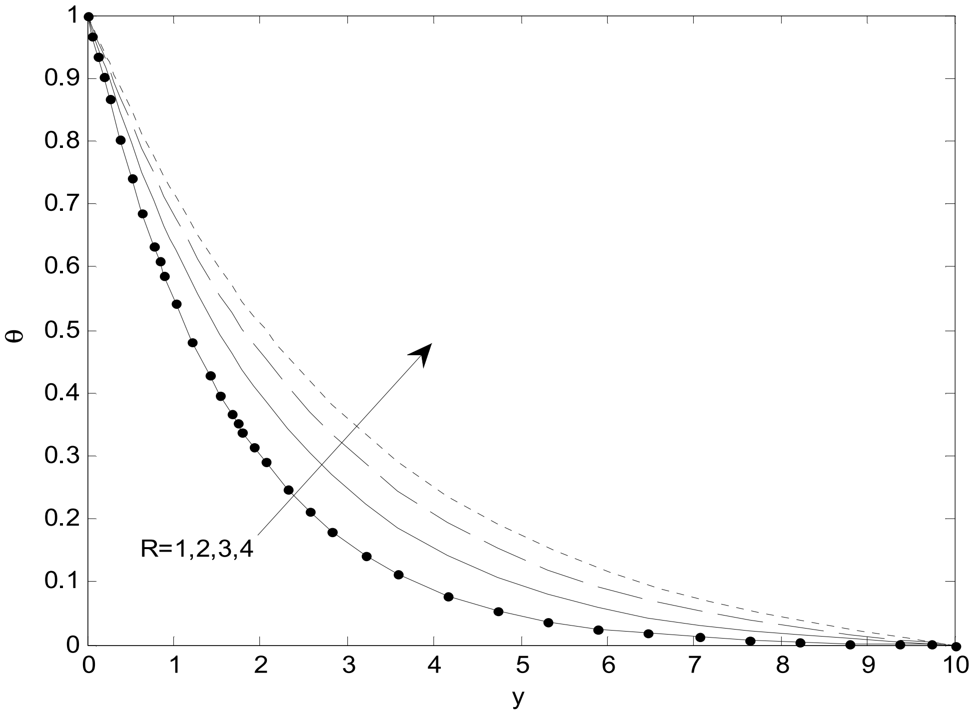

Fig.14 Temperature profiles for different values of R

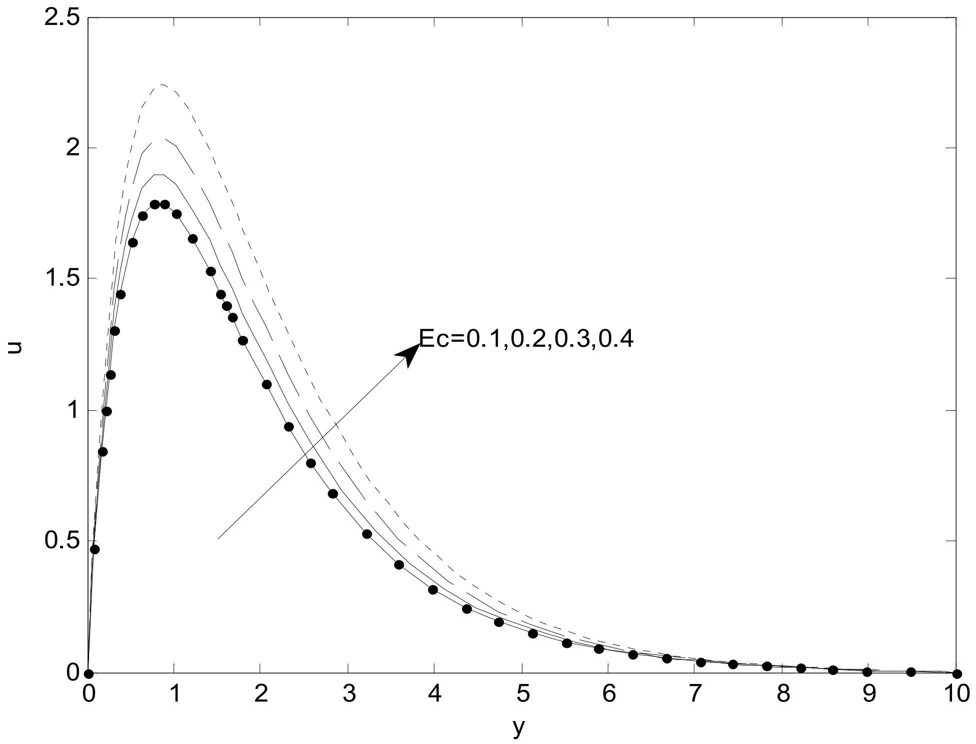

Fig.15 Velocity profiles for different values of Ec

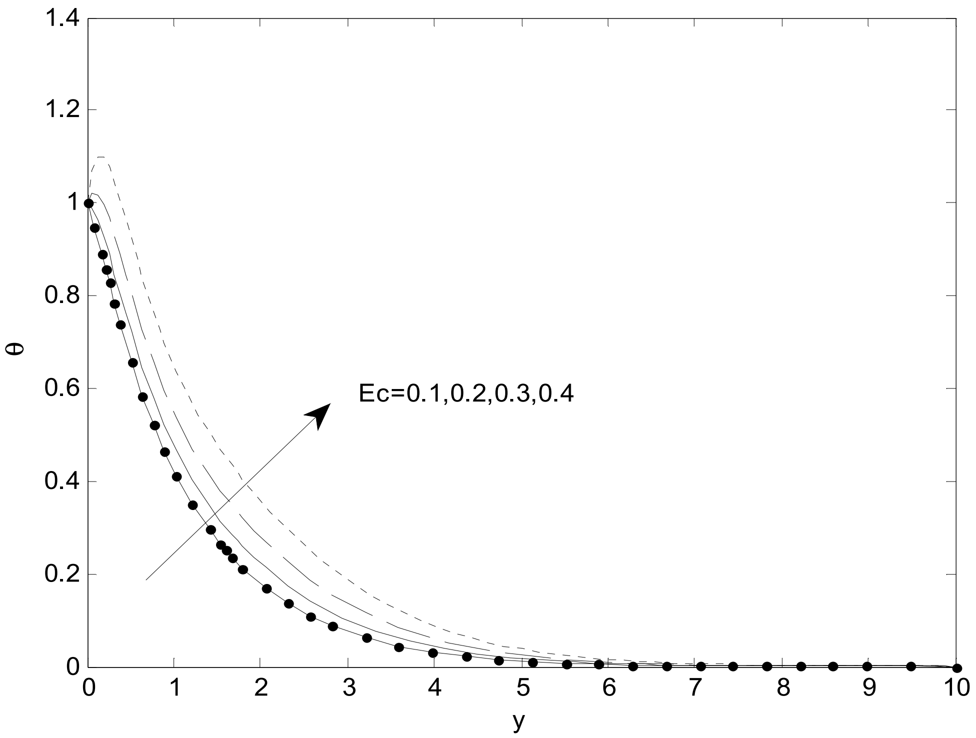

Fig.16 Temperature profiles for different values of Ec

Table 1 Variation in $f''(0)$ and $-\theta'(0)$ for different non-dimensional parameters

M	R	K	Gr	Gc	α	K_l	Ec	Sc	Pr	$f''(0)$	$-\theta'(0)$
1										6.068176	0.774642
2										5.254141	0.837108
3										4.711594	0.871497
4										4.314838	0.893111
	1									6.640145	0.492781
	2									6.977567	0.374064
	3									7.187837	0.312449
	4									7.333495	0.274221
		1								6.068176	0.774642
		2								6.919517	0.694850
		3								7.306732	0.653537
		4								7.529969	0.628272
			5							6.068176	0.774642
			9							8.437280	0.589896
			13							11.097669	0.303731
			17							14.337623	-0.168642
				5						6.068176	0.774642
				9						8.847380	0.538341
				13						11.679587	0.202889
				17						14.568795	-0.238737
					$\pi/6$					6.919517	0.694850
					$\pi/4$					6.448006	0.740901
					$\pi/3$					6.068176	0.774642
					$\pi/2$					5.752918	0.800413
						1				6.068176	0.774642
						2				5.679263	0.806026
						3				5.433659	0.824368
						4				5.254865	0.837004
							0.1			6.181827	0.554842
							0.2			6.448993	0.043967
							0.3			6.794201	-0.606150
							0.4			7.278527	-1.503952
								0.2		6.146865	0.767945
								0.6		5.156499	0.843696
								0.8		4.880799	0.861458
								1		4.668473	0.874120
									0.7	6.082546	0.765907
									1	5.714371	1.026936
									3	4.632089	2.741124
									6	4.132277	5.261838

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