Effect of induced magnetic field and linear / non-linear vertical stretching sheet on mixed convection Jeffrey fluid near a stagnation-point flow through a porous medium with suction or injection

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Abstract.

The present study deals with the effect of induced magnetic field on mixed convective near a stagnation point flow with linear / non-linear vertical stretching sheet of Jeffrey fluid flow through porous medium in the presence of slip flow regime. The set of governing non-linear coupled partial differential equations are transformed into a set of non-linear coupled ordinary differential equations using suitable similarity transformations, which are then solved numerically using Runge-Kutta fourth order in association with shooting technique in MATLAB. The effects of non-dimensional parameters such as Jeffrey parameter, magnetic force number, magnetic Prandtl number, magnetic parameter, suction/injection parameter, slip velocity parameter, linear or non-linearity parameter, permeability parameter, velocity ratio parameter, Prandtl number, thermal radiation parameter and Eckert number on velocity, induced magnetic field and temperature are presented graphically while the skin friction and local Nusselt number are represented numerically.

Key words: Induced magnetic number, Jeffrey parameter, MHD mixed convection, Non-linearly stretching sheet, Porous medium, Slip flow, Thermal radiation, Viscous dissipation.

I. Introduction

The problem of stagnation-point flow and heat transfer on stretching sheet arises an abundance of practical applications in industry and engineering, such as cooling of electronic devices and nuclear reactors, polymer extrusion, drawing of plastic sheets and moreover the MHD flow which has both liquid and magnetic properties and can exhibit particular characteristics in thermal conductivity. Many fluids such as a blood, dyes, ketchup, shampoo, clay cooling, mud, polymer melts certain oils and greases etc., have complex relations between stress and strain. Such fluids don’t obey the Newton’s law of viscosity and are usually called non-Newtonian fluids. The study of non-Newtonian fluids has much interest because of their numerous technological applications, movement of biological fluids, performance of lubricants, including manufacturing of plastic sheets, thermal oil recovery and transpiration cooling. In view of their differences with Newtonian fluids, several models of non-Newtonian fluids have been proposed by various researchers. Among these, the Jeffrey model is a rate type of non-Newtonian fluid which can describe the characteristic of relaxation and retardation times. The induced magnetic field has received extensive interest due to its practice in many scientific and technological phenomena, for example, in MHD energy generator systems and magneto-hydrodynamic boundary layer control technologies. Denno et al. [1] investigated the effects of a non-uniform magnetic field on MHD channel flow between two parallel plates of infinite extent. The influence of magnetic Reynolds number is less than unity but greater than zero is included. The goal is to use the MHD effect to reduce the amount of heat transfer from the fluid to the channel walls. The impacts of magnetic induction and transverse magnetic field on natural convection MHD boundary layer flow over an infinite vertical flat plate were analytically studied by Ghosh et al. [2]. Md. Ali et al. [3] studied the steady magneto hydrodynamic boundary layer flow and heat transfer of a viscous and electrically conducting fluid over a stretching sheet and further investigated on steady MHD stagnation-point flow of an incompressible viscous fluid over a stretching sheet and the effect of an induced magnetic field is taken into account. Anand Kumar and Singh [4] studied the effect of an induced magnetic field on unsteady free convective flow of an
electro-physically conducting fluid past a semi-infinite vertical plate. It is found that the effect of magnetic parameter is to decrease the velocity, temperature and induced magnetic fields while the effect of magnetic Prandtl number is to increase them. The steady viscous incompressible electro-physically conducting fluid near a stagnation point flow over a stretching sheet has been investigated Sinha and Misra [5]. Ibrahim [6] analyzed the effect of convective heating and induced magnetic field on MHD stagnation point flow of a nanofluid over the boundary layer flow and heat transfer on a stretching sheet using Runge-Kutta fourth order with shooting technique. Jayachandra Babu et al. [7] analyzed the effects of non-linear thermal radiation and induced magnetic field on nano ferrofluid particle flows near a stagnation-point flow towards a stretching sheet in the presence of and non-uniform heat source/sink. They considered two types of base fluids namely kerosene and water embedded with magnetite (Fe₃O₄) nano particles and in addition with Ramana Reddy et al. [8] considered another two types of magneto-nano particles namely Copper (Cu) and Alumina (Al₂O₃) with base fluid as water. Pal and Gopinath [9] inveseted the buoyancy-driven hydromagnetic mixed convection stagnation-point flow of nanofluids over a stretching sheet in the presence of induced magnetic field. Three types of nanofluids namely, Cu–water, Al₂O₃–water, TiO₂–water is considered. Hayat and Nadeem [10] analyzed the combined effects of buoyancy force convective heating Brownian, and thermophoresis motion on MHD stagnation point flow and heat transfer of electro-physically conducting nanofluid towards a stretching sheet under the influence of induced magnetic field. Raju et al. [11] and Shit and Roy [12] analyzed the effect of induced magnetic field on non-Newtonian fluid near a stagnation-point flow over a stretching sheet with homogeneous –heterogeneous reactions and non-uniform heat source or sink and they considered the effect of the induced magnetic field is taken into account. A steady two-dimensional hydromagnetic stagnation-point flow of an electrically conducting nanofluid past a stretching surface with induced magnetic field, melting effect and heat generation/absorption has been analyzed numerically by Gireesha et al. [13]. Ibrahim [14] analyzed the effect of induced magnetic and convective heating on MHD boundary layer flow and heat transfer of upper-convected Maxwell fluid near a stagnation point flow of nano-particle over a stretching sheet using Runge-Kutta-Fehlberg method with shooting technique. Animasaun et al. [15] analyzed MHD mixed convection buoyancy-driven stagnation-point flow of dust nanofluid particles embedded over an inclined non-isothermal stretching sheet in the presence of induced magnetic field and non-uniform heat source/sink and suction. Two types of nanofluids namely Cu-water and Al₂O₃–water embedded with conducting dust particles is considered. Iqbal et al. [16] studied the combined effects of induced magnetic field and entropy generation on nanofluid near a stagnation point flow and heat transfer towards a stretching sheet.

Recently Nandkeolyar et al. [17] studied two-dimensional laminar viscous, incompressible boundary layer flow of mixed convective and electrically conducting fluid under the influence of an aligned magnetic field, which is applied along the flow outside the boundary layer. Athira et al. [18] observed the impacts of induced magnetic field and non-linear convection in the flow of viscous fluid over a porous plate under the influence of chemical reaction and heat source/sink. The steady two-dimensional stagnation-point flow of an incompressible electro-physically conducting nanofluid caused by a stretching/shrinking surface is studied Junoh et al. [19]. Aziz and Ahmed [20] analyzed the effect of induced magnetic field on MHD Casson fluid near a stagnation-point flow and heat transfer over a stretching surface. Sumalatha et al. [21] analyzed the effects of thermal radiation and slip parameters on MHD stagnation point flow of a stretching sheet. The bio-magnetic fluid (BMF) flow and heat transfer in the three-dimensional unsteady stretching/shrinking sheet is examined Murtaza et al. [22]. They analyzed that the version of bio-magnetic fluid dynamics (BFD) which is consistent with the principles of ferro hydrodynamics (FHD) be used in bio-medical and bio-engineering applications. In the present paper, we have investigated the effect of induced magnetic field on mixed convection Jeffrey fluid near a stagnation point flow of a linear / non-linear vertical stretching sheet through porous medium in the presence of slip flow regime. The motivation behind this study is to consider the effect of induced magnetic field on MHD slip flow near a stagnation-point on a non-linearly vertical stretching sheet in the presence of thermal radiation and viscous dissipation Shatey and Mabood [23]. The effects of linear or non-linear parameter $m (m=1 \ or \ m=2)$ , suction/injection parameter $f_s$ , mixed convection parameter $\lambda$, induced magnetic constant $M$, magnetic force number $M_f$, magnetic Prandtl number $P_m$ and other above mentioned parameters on velocity $f' (\eta)$, induced magnetic field $H (\eta)$ and temperature $\theta (\eta)$ profiles are discussed through graphs.

2. Mathematical formulation of the problem

Consider a steady two-dimensional linear or non-linearly stretching sheet and suction or injection of mixed convection electro-physically conducting Jeffrey fluid near a stagnation-point towards a vertical plate embedded in a porous medium in the presence of induced magnetic field. Here the prescribed surface heat flux is also considered. The stretching

![Figure 1. Physical Flow](image-url)
sheet is considered along the $x$-axis and $y$-axis is normal to it and the flow is confined in half plane $y>0$. A uniform magnetic field of strength $B(x)$ is applied in the direction of normal to the surface as shown in Fig. 1. The stretching sheet velocity is supposed to be $u_s(x) = cx^m$ and $u_c(x) = ax^m$ as an external velocity, where $c$ and $a$ are positive constants. Meanwhile $m$ is the linearity parameter with $m=1$ for the linear case and $m \neq 1$ for the non-linear case. The fluid velocity vector and induced magnetic field vector are assumed as $\vec{q} = (u, v, 0)$, $\vec{H} = (h_x, h_y, 0)$ where $u$, $v$, $h_x$ and $h_y$ are the components of fluid velocity and induced magnetic field. Under the above assumptions and the boundary-layer and Boussinesq approximation, the governing equations for the current study are given by [23]

\begin{equation}
\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0
\end{equation}

\begin{equation}
\frac{\partial h_x}{\partial x} + \frac{\partial h_y}{\partial y} = 0
\end{equation}

\begin{equation}
\frac{u}{\partial x} + \frac{\partial u}{\partial y} = u_\frac{d u}{d y} + \frac{\nu}{1+\lambda}\frac{\partial^2 u}{\partial y^2} - \frac{\sigma B^2}{\rho}(u_s - u) - \frac{\nu}{K}\frac{u}{\partial y} + g\beta(T - T_s) + \frac{u}{\rho}\frac{\partial h_y}{\partial y}
\end{equation}

\begin{equation}
\frac{u}{\partial x} + \frac{\partial h_x}{\partial y} = h_x \frac{\partial u}{\partial x} + h_y \frac{\partial u}{\partial y} + \frac{a_m^2 h_y}{\partial y^2} + \frac{1}{\rho\beta} \frac{q_T}{\partial y} + \frac{\mu}{\rho\beta} \left(\frac{\partial u}{\partial y}\right)^2
\end{equation}

\begin{equation}
\frac{\partial u}{\partial x} + \frac{\partial T}{\partial y} = \frac{\alpha^2 T}{\partial y^2} - \frac{1}{\rho C_p} \frac{q_T}{\partial y} + \frac{\mu}{\rho C_p} \left(\frac{\partial u}{\partial y}\right)^2
\end{equation}

The corresponding boundary conditions to the current model is given by:

\begin{equation}
\begin{align*}
u &= v_n(x), & \frac{\partial H}{\partial y} &= -H_s(x), & \frac{\partial T}{\partial y} &= -q_s(x) k & \text{at } y = 0 \\
u \rightarrow u_s(x), & h_y \rightarrow 0, & T \rightarrow T_s & \text{as } y \rightarrow \infty
\end{align*}
\end{equation}

By using the Rosseland diffusion approximation, Hossain et al. [26], Raptis [27] among other researchers the radiative heat flux $q_r$ is given by:

\begin{equation}
q_r = -\frac{4\sigma T^4}{3K_s} \frac{\partial T}{\partial y}
\end{equation}

We assume that the temperature differences within the flow are sufficiently small, so that $T^4$ may be expressed as a linear function of temperature $T$.

\begin{equation}
T^4 \approx 4T^3 + 3T^3
\end{equation}

Using eqs (8) and (9) in the fourth term of eq (5) we obtain:

\begin{equation}
\frac{\partial q_r}{\partial y} = \frac{16\sigma T^4}{3K_s} \frac{\partial^2 T}{\partial y^2}
\end{equation}

3. Similarity analysis

we define the following similarity transformations as followed by Shen et al. [25]:

\begin{equation}
\eta = \frac{a}{\sqrt{v}} \frac{m^{-1}}{x^2}, \quad \psi = \frac{m+1}{2} f(\eta), \quad \theta = \frac{a}{\sqrt{v}} \frac{k(T - T_s)}{q_0 x^{2m-1}}, \quad H = \frac{3m^{-1}}{x^2} \frac{H_0 h_x}{\mu}
\end{equation}

Here $\psi$ is the stream function such that $u = \frac{\partial \psi}{\partial y}$, $v = -\frac{\partial \psi}{\partial x}$ and continuity equation is automatically satisfied. By using eq. (11), the velocity components for $u$ and $v$ are given:

\begin{equation}
\begin{align*}
u &= \frac{m+1}{2} f(\eta), & \psi = -\frac{m+1}{2} f(\eta) + \frac{m-1}{2} \eta f'(\eta)
\end{align*}
\end{equation}

where primes denote differentiation with respect to $\eta$. We remark that to obtain similarity solutions $B(x)$, $v_n(x)$ and $q_n(x)$ are taken:

\begin{equation}
\begin{align*}
B(x) &= B_0 x^{m-1}, & v_n(x) &= v_n(x) \frac{m+1}{2} f_n(x), & H_n(x) &= H_0 x^{2m-1}, & q_n(x) &= q_0 x^{5m-1}
\end{align*}
\end{equation}
where $B_0, f_w, H$, and $q_0$ are arbitrary constants. We also have $f_w > 0$ and $f_w < 0$ are the injection and suction cases respectively and substituting the similarity variables in eqs (3-5) we obtain the following system of ODE:

$$
\frac{1}{1 + \lambda} f'' + m \left(1 - f' - \frac{m+1}{2} \right) + \left(1 - f' - \frac{m+1}{2} \right) + \lambda \frac{M}{K} \frac{\partial H}{\partial \eta} = 0
$$

$$
H' + M \left(1 - f' - \frac{m+1}{2} \right) H' = 0
$$

$$
\left(1 + \frac{4}{3 R} \right) \theta' + Pr \left(1 - f' - \frac{m+1}{2} \right) \theta' = 0
$$

the corresponding boundary conditions are:

$$
f'(0) = f_w, \quad f'(0) = \epsilon + \delta f'(0), \quad H'(0) = -1, \quad \theta'(0) = -1
$$

$$
H(x) = 0, \quad \theta(x) = 0
$$

Where $M = \kappa / \rho a$, $\lambda = g \beta q_w (\nu)^{1/2} / k k a$, $M_1 = v H_s x^{n_1} / a^2 \rho$, $M_2 = a^2 v H_s x^{n_2} / \alpha_n$, $Pm = v H_s / \rho \sqrt{a}$, 

$$
Pr = v / a, \quad Ec = a^{1/2} x^{n_1} / \rho c_p, \quad \epsilon = c / a, \quad R = 4 a T' / \rho c_p k, \quad \delta = (2 - \sigma_w) k n w_{\text{Re}} / \sigma_v.
$$

4. Local skin friction and Nusselt Number

The physical parameters interested for the present problem are the local skin friction coefficient $C_f$ and the local Nusselt number $Nu_x$ which are defined as:

$$
C_f = \frac{\tau_w(x)}{\rho(1 + \lambda) u_w}, \quad Nu_x = \frac{x q_w(x)}{k(T_w - T_{\text{in}})}
$$

with the surface shear stress $\tau_w(x) = \epsilon u / \eta$ and $q_w(x)$ is the wall heat flux. We then obtain the following expressions after applying the similarity variables:

$$
Re^\nu_x C_f = \frac{f'(0)}{(1 + \lambda)}, \quad Re^\nu_x Nu_x = \frac{1}{\theta'(0)}
$$

5. Results and discussion

In this paper, the effect of induced magnetic field on mixed convection Jeffrey fluid near a stagnation point flow with a linear / non-linear vertical stretching sheet through porous media in the presence of slip flow regime is analyzed. The boundary value problem containing coupled equations in velocity and temperature is solved numerically by shooting technique with Runge-Kutta fourth order using MATLAB. The effects of linear or non-linear parameter $m$ ($m=1$ or $m=2$), suction/injection parameter $f_w$, mixed convection parameter $\lambda$, induced magnetic constant $M_1$, magnetic force number $M_2$, magnetic Prandtl number $Pm$, Jeffrey parameter $\lambda$, magnetic parameter $M$, porous medium parameter $K$, the velocity slip parameter $\delta$, velocity ratio parameter $\epsilon$, Prandtl number $Pr$, Eckert number $Ec$ and thermal radiation parameter $R$ are depicted through graphs on velocity $f'(\eta)$, induced magnetic field $H(\eta)$ and temperature $\theta(\eta)$ profiles with fixed values of $\lambda = 1$, $M_1 = 0.5$, $M_2 = 0.5$, $M = 2$, $K = 1$, $\delta = 1$, $\epsilon = 0.5$, $Pr = 0.7$, $Ec = 1$, $f_w = 1$, $\lambda = 1$, $m = 1$ or $m = 2$. In order to assure the accuracy of the applied numerical scheme the computed values of Skin friction coefficient $f'(0)/(1 + \lambda)$ and local Nusselt number $-\theta'(0)$ are compared with the available results of Shateyi and Mabood [23] and Wang [24] in Table 1 and have found in excellent agreement. Graphical representations of the numerical results are illustrated in Figs. (2-17). From Figs. (2-5) illustrates that the effects of magnetic force number $M_2$, Jeffrey parameter $\lambda$, the velocity slip parameter $\delta$ and velocity ratio parameter $\epsilon$, on the velocity distribution for both assisting and opposing cases vary with linear ($m=1$) and non-linear ($m=2$) in the presence of with and without $M_1 = M_2 = Pm = 0$ induced magnetic field. It is observed that velocity exponentially grows with an increasing of magnetic force number $M_2$, Jeffrey parameter $\lambda$, slip parameter $\delta$ and velocity ratio parameter $\epsilon$, for all the cases of linearity ($m=1$), non-
linearity \( (m = 2) \) vary with assisting flow \( (\lambda = 1) \) and opposing flow \( (\lambda = -1) \). This is due to the fact that the presence of the non-Newtonian characteristics of Jeffrey fluid flows which decrease the velocity and the boundary layer thickness as well. And it is observed that the velocity attains the maximum value at \( M_f = M_i = Pm = 0 \) i.e. without induced magnetic field. The opposite behavior is observed for the induced magnetic constant \( M_f \), from Fig. 6. Fig. 7 and 8 demonstrates the influence of porous medium parameter \( K \) and magnetic parameter \( M \) on the velocity distribution for both assisting \( (\lambda = 1) \) and opposing \( (\lambda = -1) \) cases in addition with linear \( (m = 1) \) and non-linear \( (m = 2) \) in the presence of with and without \( (M_f = M_i = Pm = 0) \) induced magnetic field. It can be seen that increase of the mixed buoyancy parameter causes the velocity profiles to increase. The velocity decreases with an increasing of porous medium parameter \( K = (0,1,2) \) and magnetic parameter \( M = (1,2,3) \) with non-linearity value \( m = 2 \) and the opposite behavior at \( \lambda = -1 \). This is due to the fact that the presence of transverse magnetic field sets in Lorentz force which results in retarding force on the velocity field. Therefore, as the values of \( M \) increase, so does the retarding force and hence the velocity decreases. The velocity attains the maximum value at \( M_f = M_i = Pm = 0 \) i.e. without induced magnetic field. Fig. 9 and 10 reveals the influence of mixed buoyancy parameter \( \lambda \) and suction/injection parameter \( f_s \) on the velocity distribution for both assisting and opposing cases vary with linear \( m = 1 \) and non-linear \( m = 2 \) in the presence of with and without \( (M_f = M_i = Pm = 0) \) induced magnetic field. It can be seen that increasing the mixed buoyancy parameter causes the velocity profiles to increase. We can also observe that the velocity profiles are significantly influenced by suction/injection parameter \( f_s \). The velocity decreases with an increasing of suction parameter \( f_s \) in the case of \( (\lambda = 1) \) and the opposite behavior is observed for the case of \( (\lambda = -1) \). The velocity attains the maximum value for all the cases at \( M_f = M_i = Pm = 0 \) i.e., without induced magnetic field. Fig. 11, 12 and 13 represent the effects of Prandtl number \( \text{Pr} \), thermal radiation parameter \( R \) and Jeffrey fluid parameter \( \lambda_i \) on the temperature distribution for both assisting \( (\lambda = 1) \) and opposing \( (\lambda = -1) \) cases vary with linear \( m = 1 \) and non-linear \( m = 2 \) in the presence of with and without \( (M_f = M_i = Pm = 0) \) induced magnetic field. The temperature decreases with an increasing of \( \text{Pr} \), \( R \) and \( \lambda_i \) with linear \( m = 1 \) and non-linearity value \( m = 2 \). This is due to the fact that a higher Prandtl number fluid has relatively low thermal conductivity which reduces conduction and there by the thermal boundary layer thickness and as a result temperature decreases. The opposite behavior is observed for the Eckert number \( Ec \) from Fig. 14. The temperature profile attains the minimum value for all the cases at \( M_f = M_i = Pm = 0 \) i.e. without induced magnetic field.

Fig. 15 and 16, depicts the influence of induced magnetic constant \( M \) and magnetic Prandtl number \( Pm \) on induced magnetic field for both assisting \( \lambda = 1 \) and opposing \( \lambda = -1 \) cases vary with linear \( m = 1 \) and non-linear \( m = 2 \). It can be seen that increase in the mixed buoyancy parameter causes the temperature profiles to increase. We can also observe that the induced magnetic field profiles are significantly influenced by \( M \) and \( Pm \). The induced magnetic field increases with an increasing of \( M_i \) and \( Pm \). It is also observed that the induced magnetic field profile attains the maximum value for the values of \( m = 1 \) and \( \lambda = 1 \). The opposite behavior is observed for the magnetic force number \( M_f \), from the Fig. 17.

6. Conclusions

Numerically investigate the effect of induced magnetic field on mixed convective near a stagnation point flow in a linear / non-linear vertical stretching sheet of Jeffrey fluid flow through porous medium in the presence of slip flow regime. The boundary value problem containing coupled equations in velocity temperature and induced magnetic field are solved numerically by shooting technique with Runge-Kutta fourth order using MATLAB. Further numerical results for the skin friction coefficient and Nusselt number at the surface are in good agreement with the results which were obtained by earlier researchers in the absence of Jeffrey parameter \( \lambda_i \), porous medium parameter \( K \) and induced magnetic constant \( M_i \).

- The governing coupled equations are solved numerically by shooting technique with Runge-Kutta fourth order with MATLAB.
We conclude that the velocity decreases with increase of $M$, $K$, $M_i$ as well as the temperature decreases with increasing of $Pr$, $R$, $\delta$. And also the velocity increases with increase of $M_i$, $\lambda$, $\epsilon$, $\lambda$ and $f_w$ as well as the temperature increases with increasing of $Ec$ for different aspects ($\lambda = 1$, $\lambda = -1$ with $m = 1$, $2$).

The skin friction coefficient $f_s(0)$ increases with the increasing values of the Jeffrey fluid parameter $\lambda_i$ and decreasing with the vales of porous medium $K$ and induced magnetic constant $M_i$. Further it is observed that the values of the Nusselt number $-1/\theta'(0)$ at the surface. From this table it is identified that the rate of heat transfer $-1/\theta'(0)$ decreases with increasing of Jeffrey fluid parameter $\lambda_i$, porous medium $K$ and magnetic constant $M_i$.

Table 1. Comparison of $-f_s(0)$ and $-1/\theta'(0)$ for various values of $\lambda_i$, $K$ and $M_i$. For fixed values of $\lambda_i = 1$, $M_i = 0.5$, $\delta = \epsilon = \lambda = M = Pr = f_w = 1$, $\lambda_i = 0$, $K = 0$, $M_i = 0$.

| $\lambda_i$ | $K$ | $M_i$ | Present study | Shateyi and Fazle [23] | Wang [24] |
|------------|-----|------|---------------|----------------------|-----------|
|            | $M = 2$, $\epsilon = 0.5$, $Pr = 0.7$ | $f_s(0)$ | $\theta'(0)$ | $f_s(0)$ | $\theta'(0)$ |
| 1          | 1   | 0.5  | 0.0945       | 1.9685              | 0.0970    |
| 2          | 1   | 0.5  | 0.2368       | 1.5942              | 0.1156   |
| 3          | 1   | 0.5  | 0.3729       | 1.2486              | 0.1421   |
| 1          | 1   | 0.5  | 0.5124       | 2.0174              | 0.0973   |
| 1          | 2   | 0.5  | 0.3591       | 1.5247              | 0.1428   |
| 1          | 3   | 0.5  | 0.2316       | 1.2576              | 0.1804   |
| 1          | 1   | 1    | 0.5124       | 2.0174              | 0.1574   |
| 1          | 1   | 1    | 0.2465       | 1.8745              | 0.1574   |
| 1          | 1   | 1.5  | 0.1156       | 1.4572              | 0.1574   |

After substituting the parameter values as $\lambda_i = 0$, $M_i = 0$, $\delta = \epsilon = \lambda = M = Pr = f_w = 1$ in the present results for skin friction and Nusselt number will be coincide with the results of Stanford Shateyi and Fazle Mabood [23]. In addition to the after substituting the parameter values $\delta = \epsilon = \lambda = M = Pr = f_w = 0$, $m = 1$ in the present work we obtain good agreement is originated with the existing results of Wang [8].

**Figure 2.** Velocity profile for different values of magnetic force number $M_i$.

**Figure 3.** Velocity profile for different values of Jeffrey fluid parameter $\lambda_i$. 
Velocity profile for different values of the slip velocity parameter $\delta$

Velocity profile for different values of the magnetic parameter $M$

Velocity profile for different values of the induced magnetic constant $M_I$

Velocity profile for different values of the velocity ratio parameter $\varepsilon$

Velocity profile for different values of the porous medium parameter $K$

Velocity profile for different values of the mixed convection parameter $\lambda$

Velocity profile for different values of suction parameter $f$

Velocity profile for different values of Prandtl number $Pr$

Figure 4

Figure 5

Figure 6

Figure 7

Figure 8

Figure 9

Figure 10

Figure 11
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