Slip Effects on Unsteady MHD and Heat Transfer Flow over A Stretching Sheet Embedded with Suction in A Porous Medium Filled With A Jeffrey Fluid.

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Abstract: The effects of slip on unsteady MHD flow and heat transfer of a Jeffrey fluid flow over a stretching sheet embedded through porous medium in the presence of suction are examined. The unsteady flow problems is reduced to ordinary differential equations using similarity transformations and are solved numerically using Runge-Kutta fourth order in association with shooting technique in MATLAB. Based on the solution of these equations an extensive analysis is performed to investigate the effects.

The effects of non-dimensional parameters such as suction parameter, Jeffrey parameter, magnetic parameter, permeability parameter, Prandtl number, thermal radiation parameter, heat source or sink parameter and Eckert number on velocity and temperature profiles are presented graphically moreover, the numerical values of the skin friction coefficient and the local Nusselt number are calculated and shown in tabular form. It is found that present result has been good agreement with the existed studies under some special cases.

Keywords: *Heat transfer, Jeffrey parameter, MHD, Slip, Stretching sheet, Unsteady parameter.*

I. INTRODUCTION

Analysis of non-Newtonian fluids has been the focus on several investigations during the past few decades because of its extensive engineering and industrial applications. Especially, flow and heat transfer of non-Newtonian fluids play central role in food engineering, petroleum production, power engineering and in polymer solutions and in polymer melt in the plastic processing industries. The flow regime is called the slip flow regime and its effect cannot be neglected.

The problem of the slip flow regime is very important in this area of modern science, technology and vast ranging industrialization. In many practical applications, the particle adjacent to a solid surface no longer takes the velocity of the surface. The fluid slippage phenomenon at the solid boundaries appear in many applications such as micro channels or Nano channels and in applications where a thin film of light oils is attached to the moving plates or when the surfaces are coated with special coating to minimize the friction between them.

Recently, interest in boundary layer flow and heat transfer over a stretching sheet has gained considerable attention because of its application in industry and manufacturing process. Such applications include polymer extrusion, drawing of copper wires, continuous stretching of plastic films and artificial fibers, hot rolling, wire drawing, glass fiber, metal extrusion and metal spinning. A large number of researchers are engaged with this rich area. Understanding the modeling the flows of non-Newtonian fluids are of both fundamental and practical significance in the industrial and engineering applications. The rheological characteristics of such fluids are important in the flows of nuclear fuel slurries, lubrication with heavy oils and greases, paper coating, plasma and mercury, fossil fuels, polymers etc.

Quinn Brewster [1] studied thermal radiative transfer and properties. Makinde and Mhone [2] investigated the combined effect of a transverse magnetic field and radiative heat transfer to unsteady flow of a conducting optically thin fluid through a channel filled with saturated porous medium and nonuniform walls temperature. Mehmood and Ali [3] extended the work of Makinde and Mhone [2] by considering the fluid slip at the lower wall. An analytical study on MHD flow of a micropolar fluid due to heat and mass transfer through a porous medium bounded by an infinite vertical porous plate in the presence of a transverse magnetic field in slip-flow regime is discussed by Mansour et al. [4]. Chandra and Swati Mukhopadhyay [5] are studied the boundary layer flow and heat transfer towards an exponentially stretching porous sheet embedded in a porous medium with variable surface heat flux.

They found that the skin-friction coefficient increases with increasing the permeability parameter as well as with the suction parameter and momentum and thermal boundary layer thickness decrease with increasing exponential parameter. Swati Mukhopadhyay [6] analysis the boundary layer flow and heat transfer towards a porous exponential stretching sheet in presence of a magnetic field. Velocity slip and thermal slip are considered instead of no-slip conditions at the boundary. Chaudhary et al. [7] studied the effects of different parameters on an unsteady magneto polar free convection flow of an incompressible fluid in the presence of thermal radiation and uniform magnetic field of strength B_0 through a porous medium in slip flow regime. They observe that on decreasing Gr (thermal Grashof number), skin friction drops in air but rises in water.

Also, we notice that the rate of heat transfer rises on decreasing h_2 (jump parameter). Nazibuddin Ahmed and Kishor Kumar Das [8] are studied the effects of thermal radiation and chemical reaction on magneto-hydro-dynamic convective mass transfer flow of an unsteady viscous incompressible eclectically conducting fluid past a semi-infinite vertical permeable plate embedded in a porous medium in slip flow regime. Mahdy [9] analyzed the effect of partial slip boundary condition on diffusion of chemically reactive species of viscous incompressible fluid in a vertical nonlinearity stretching sheet taken into account the suction or injection effect.

Ramachandra Prasad et al. [10] investigated the nonlinear steady state boundary layer flow, heat and mass transfer of an incompressible Jeffery non-Newtonian fluid past a vertical porous plate in a non-Darcy porous medium. The governing equations are solved using Keller-box finite-difference technique. Elbashbesy et al. [11] was discussed effects of thermal radiation and heat transfer over an unsteady stretching surface embedded in a porous medium in the presence of heat source/sink. Sami Haq et al. [12] consideration the combined effect of slippage and ramped temperature at the wall on the unsteady free convection flow of a viscous incompressible fluid near a vertical flat plate. Santosh Chaudhary et al. [13] discussed effects of thermal radiation on hydromagnetic flow over an unsteady stretching sheet embedded in a porous medium in the presence of heat source/sink.

Gaur et al. [14] obtained an analytical solution of free convective heat transfer for the flow of a polar fluid through a porous medium with variable permeability bounded by a semi-infinite vertical plate in a slip flow regime using an exponentially decreasing small perturbation law. The steady two-dimensional MHD mixed convection boundary layer flow and heat transfer of a Jeffrey fluid over an exponentially stretched plate is investigated by Kartini Ahmad et al. [15]. Al-Khafajy [16] studied analytically the influence of heat transfer on MHD oscillatory flow of Jeffrey fluid with variable viscosity model through porous medium by using perturbation technique. Joseph et al. [17] applied the perturbation technique and analyzed the effect of variable suction on unsteady MHD oscillatory flow of Jeffrey fluid in a horizontal channel with heat and mass transfer.

The unsteady magnetohydrodynamic (MHD) free convection flow of Jeffrey fluid embedded in porous medium past an oscillating vertical plate generated by thermal radiation with ramped wall temperature is investigated by Athirah Mohd Zin et al. [18]. They observed that, the permeability parameter tends to retard the fluid velocity for ramped wall temperature but enhance the velocity for an isothermal plate. Besides that, this study shows, the amplitude of velocity and temperature fields for ramped wall temperature are always lower than isothermal plate. Shravani et al. [19] are analyzes the steady MHD boundary-layer flow with permeable stretching sheet using radiative heat transfer in energy equation and slip condition at boundary by using the fourth-order Runge-Kutta method. They indicate that the skin friction coefficient increase and Sherwood number decrease with an increase in velocity slip parameter.

Falade et al. [20] are investigated that the effect on suction/injection on the slip flow of oscillatory hydro-magnetic fluid through a channel filled with saturated porous medium. They observe that skin friction increases on both channel plates as injection increases on the heated plate. Abdul Gaffar et al. [21] considered the composite effects of Joule heating, Hall and ion slip currents, and also viscous frictional heating on two-dimensional natural MHD convection of Eyring–Powell Fluid in a Darcy-Forchheimer porous medium from a vertical plate. Krishna Murthy and Sreenadh [22] examined the effects of suction and thermal radiation on MHD flow of Jeffrey fluid over an unsteady stretching sheet. The governing equations are solved numerically using Runge-Kutta fourth order in association with shooting technique. They are examined their work with the previous work and they have been good agreement with the existed studies under some special cases. Srinivasacharya and Himabindu [23] studied the effect of convective heating and velocity slip on flow generation of an incompressible micropolar fluid through a porous channel. They observed that the convective heating tends to increase the entropy generation within the channel.

Motivated by the above studies, the effects of velocity slip and temperature slip on unsteady MHD flow of Jeffrey fluid over a stretching sheet through porous medium are examined. The effects of physical parameter on the flow quantities are discussed in detail.

2. MATHEMATICAL FORMULATION OF THE PROBLEM

Let us consider an unsteady MHD flow of two-dimensional an incompressible Jeffrey fluid over an exponentially stretching sheet embedded surface with slip regime. The $x-$axis is taken along the continuous stretching surface in the direction of motion with the slot as the origin and y -axis is perpendicular to it and the flow is confined in half plane $y > 0$. A uniform magnetic field of strength B_0 is assumed to be applied normal to the stretching surface as, shown in Fig. 1. The magnetic Reynolds number is taken to be very small so the induced magnetic field is negligible.

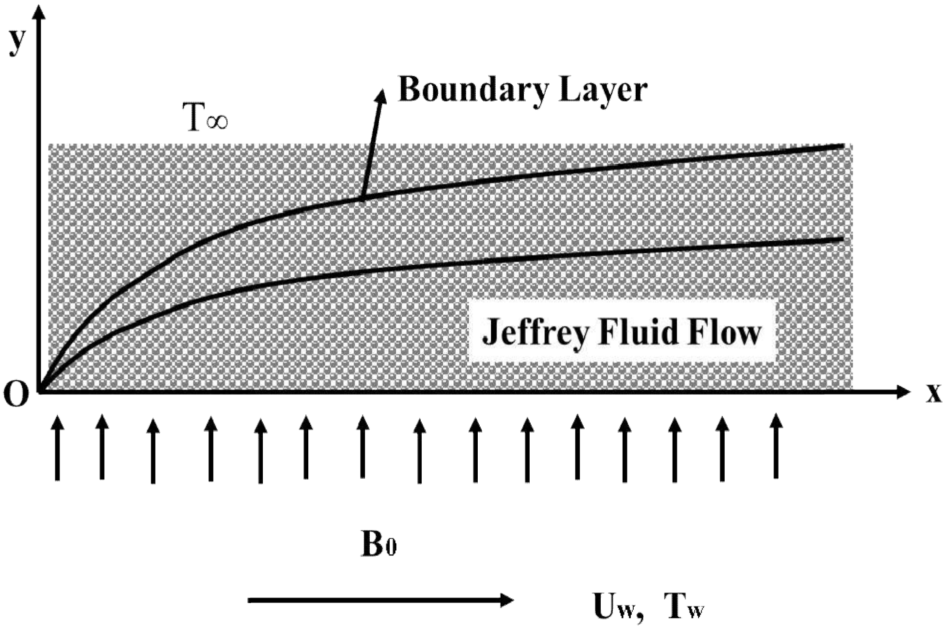

Fig.1 : Physical Model

The surface is assumed to be highly elastic and is stretched in the x -direction with surface velocity $U_w = \frac{bx}{1-\gamma t}$ and surface temperature $T_w = T_\infty + \frac{b}{2\upsilon x^2}(1-\gamma t)^{-3/2}$ where b is the positive constant, x is the coordinate measured along the stretching surface, γ is the rate of stretching constant, t is the time, T_∞ is the free stream temperature and υ is the kinematic viscosity. The governing equations of such type of flow are, in the usual notations

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

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = \frac{\upsilon}{1+\lambda_1}\frac{\partial^2 u}{\partial y^2} - \frac{\upsilon}{(1+\lambda_1)K}u - \frac{\sigma B_0^2}{\rho}u \tag{2}$$

$$\frac{\partial T}{\partial t} + u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} = \frac{k}{\rho\ Cp}\frac{\partial^2 T}{\partial y^2} - \frac{1}{\rho\ Cp}\frac{\partial q_r}{\partial y} + \frac{Q}{\rho\ Cp}(T - T_\infty) + \frac{\upsilon}{(1+\lambda_1)Cp}\left(\frac{\partial u}{\partial y}\right)^2 + \frac{\sigma B_0^2}{\rho\ Cp}u^2 \tag{3}$$

The associated boundary conditions of equations (2), (3) at the wall can be expressed as

$$\left.\begin{aligned} &u = U_w = U_0\, e^{\frac{x+y}{L}} + \alpha_1\frac{\partial u}{\partial y}, \quad v = V_w = \frac{v_0}{\sqrt{1-\gamma t}}, \quad T = T_w = T_\infty + T_0\, e^{A\left(\frac{x+y}{2L}\right)} + \alpha_2\frac{\partial T}{\partial y} \quad \text{at} \quad y = 0 \\ &u \to 0, \quad T \to 0 \quad \text{as} \quad \mathrm{y} \to 0 \end{aligned}\right\} \tag{4}$$

where u and v are the velocity components in the x and y directions respectively. K is permeability parameter, σ is electrical conductivity, ρ is the fluid density, T is the temperature of the fluid, k is thermal conductivity, Cp is the specific heat at constant pressure, q_r is the radiative heat flux, Q is the heat source when $Q > 0$ or heat sink when $Q < 0$, λ_1 is Jeffrey parameter U_w and V_w are the stretching velocities, T_w is the surface temperature, T_0 is the reference temperature, T_∞ is the ambient temperature, U_0 and V_0 are constants, A is the temperature exponents, velocity and temperature slip factors and L is the reference length. V_w is the prescribed suction at the porous stretching surface and is given by $V_w = \frac{v_0}{\sqrt{1-\gamma t}}$, v_0 is a constant with $v_0 < 0$ corresponding to suction parameter. Using Rosseland approximation for radiation (Brewster [1]), the radiative heat flux is simplified as

$$q_r = -\frac{4\sigma^*}{3k^*}\frac{\partial T^4}{\partial y} \tag{5}$$

where σ^* and k^* are the Stefan-Boltzmann constant and the mean absorption coefficients respectively. Assuming that the temperature differences within the flow is such that the term T^4 may be expressed as a linear function of temperature. Hence, expanding T^4 in a Taylor series about T_∞ and neglecting higher-order terms we obtain

$$T^4 \cong 4T_\infty^3 - 3T_\infty^4 \tag{6}$$

Using equation (5) and (6) the equation (3) reduces to

$$\frac{\partial T}{\partial t} + u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} = \frac{k}{\rho\ Cp}\frac{\partial^2 T}{\partial y^2} + \frac{16\sigma^* T_\infty^3}{3k^*\rho\ Cp}\frac{\partial^2 T}{\partial y^2} + \frac{Q}{\rho\ Cp}\left(T - T_\infty\right) + \frac{\upsilon}{\left(1+\lambda_1\right)Cp}\left(\frac{\partial u}{\partial y}\right)^2 + \frac{\sigma B_0^2}{\rho\ Cp}u^2 \tag{7}$$

We now introduce the stream function $\psi(x, y)$ as

$$u = \frac{\partial\psi}{\partial y},\ v = -\frac{\partial\psi}{\partial x} \tag{8}$$

then continuity equation (1) is satisfied automatically. The momentum and energy equations (2) and (7) can be transformed into the corresponding ordinary differential equations by introducing the following similarity transformations (Elbashbeshy and Emam [11]):

$$\psi(x, y) = \sqrt{\frac{vb}{(1-\gamma t)}}\, x\, f(\eta) \tag{9}$$

$$\eta = \sqrt{\frac{b}{v(1-\gamma t)}}\ y \tag{10}$$

$$T_w = T_\infty + \frac{b}{2\,\nu x^2}(1-\gamma t)^{-3/2}\;\theta(\eta) \qquad (11)$$

where $f(\eta)$ is the dimensionless stream function, η is the similarity variable, y is the coordinate measured along normal to the stretching surface and $\theta(\eta)$ is the dimensionless temperature.

Finally, we obtain the self-similar equations as follows:

$$\frac{1}{(1+\lambda_1)} f''' + f f'' - (f')^2 - A\left(\frac{\eta f''}{2} + f'\right) - \left(\frac{\lambda}{1+\lambda_1} + M\right) f' = 0 \qquad (12)$$

$$\left(1+\frac{4}{3}R\right)\theta'' + \Pr\left\{ f\theta' - \frac{B}{2}(\eta\theta' + 3\theta) + 2f'\theta + \delta\theta + \frac{Ec}{1+\lambda_1}(f'')^2 + M\,Ec(f')^2 \right\} = 0 \qquad (13)$$

The transformed boundary conditions can be written as

$$\left.\begin{array}{l} f = S, \quad f' = 1 + \gamma_1 f'', \quad \theta = 1 + \gamma_2 \theta' \quad \text{at} \quad \eta = 0 \\ f' \to 0, \quad \theta' \to 0 \quad \text{as} \quad \eta \to \infty \end{array}\right\} \qquad (14)$$

where primes denote differentiation with respect to η. $A = \frac{\gamma}{b}$ is the unsteadiness parameter, $\lambda = \frac{\nu^2 \mathrm{Re}_x}{K U_w^2}$ is the permeability parameter, $\gamma_1 = \alpha_1 \left(\frac{U_0 e^x}{\nu L}\right)^{1/2}$ is the velocity slip parameter, $\gamma_2 = \alpha_2 \left(\frac{U_0 e^x}{\nu L}\right)^{1/2}$ is the temperature slip parameter, $\mathrm{Re}_x = \frac{U_w x}{\upsilon}$ is the local Reynolds number, $M = \frac{\sigma B_0^2 \upsilon \mathrm{Re}_x}{\rho U_w^2}$ is the magnetic parameter, $R = \frac{k k^*}{4\sigma^* T_\infty^3}$ is the thermal radiation parameter, $\Pr = \frac{\mu\, Cp}{k}$ is the Prandtl number, $\delta = \frac{Q\upsilon^2}{\mu\, Cp}\frac{\mathrm{Re}_x}{U_w^2}$ is the heat source or sink parameter, $Ec = \frac{U_w^2}{Cp(T_w - T_\infty)}$ is the Eckert number, λ_1 is the Jeffrey parameter and $S = -\frac{\upsilon_0}{\sqrt{\nu b}}$ is the suction parameter $S > 0(\upsilon_0 < 0)$

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3. Local Skin Friction and Nusselt Number

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

$$C_f = \frac{\mu}{1+\lambda_1} \frac{\left(\frac{\partial u}{\partial y}\right)_{y=0}}{\frac{\rho U_w^2}{2}} \qquad (15)$$

$$Nu_x = \frac{-x}{T_w - T_\infty}\left(\frac{\partial T}{\partial y}\right)_{y=0} \qquad (16)$$

which are the present case, can be expressed in the following forms

$$C_f = \frac{2}{\sqrt{\mathrm{Re}_x}} \frac{f''(0)}{1+\lambda_1} \tag{17}$$

$$Nu_x = -\sqrt{\mathrm{Re}_x} \quad \theta'(0) \tag{18}$$

Numerical values of the function $f''(0)$ and $\theta'(0)$ which represent the wall shear stress and the heat transfer rate at the surface respectively for various values of the parameter are presented in Tables 1 and 2.

4. RESULTS AND DISCUSSION

In this paper, the effects of suction and thermal radiation on MHD flow of Jeffrey fluid over an unsteady stretching sheet are 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 suction parameter S, Jeffrey parameter λ_1, Magnetic parameter M, permeability parameter λ, the velocity slip parameter γ_1, the temperature slip parameter γ_2, Prandtl number Pr, Eckert number Ec, thermal Radiation parameter R and heat source or sink parameter δ are depicted through graphs on velocity $f'(\eta)$ and temperature $\theta(\eta)$ profiles with fixed values of $S = 0.5$, $\lambda_1 = 0.5$, $M = 0.5$, $\lambda = 0.1$, $\gamma_1 = 0.5$, $\gamma_2 = 0.5$, $\mathrm{Pr} = 0.7$, $R = 0.3$, $Ec = 0.01$.

In order to assure the accuracy of the applied numerical scheme the computed values of Skin friction coefficient $\frac{f''(0)}{1+\lambda_1}$ and local Nusselt number $-\theta'(0)$ are compared with the available results of Krishna Murthy and Sreenadh [22] and Elbashbeshy et *al.* [11] in Table 1, Table 2 and have found in excellent agreement.

The effect of S on the velocity $f'(\eta)$ and temperature $\theta(\eta)$ are shown in Figures 2 & 3. It is observed that the velocity and temperatures enhanced with increasing of the suction parameter. Similar behavior is obtained in the case of no slip at the wall and comparing the cases. We finding they are higher in magnitude where there is no slip at the wall. Figures 4 and 5, depicts the effect of Jeffrey parameter λ_1 on the velocity $f'(\eta)$ and temperature $\theta(\eta)$. The velocity and temperatures curves show that when the Jeffrey parameter rises, then the velocity and temperatures decrease in both the conditions of slip and without slip regime. Figures 6 & 7 exhibits the nature of velocity field for the variation of magnetic parameter M. With increasing M, velocity is found to be decrease (Fig. 6) as well as the temperature also decreases (Fig. 7). The transverse magnetic field opposes the motion of the fluid and the rate of transport is considerably reduced. This is because with the increase in M, Lorentz force increases and it produces more resistance to the flow. As M increases, thermal boundary layer thickness increases. For different values of the permeability parameter λ, the velocity and temperature profiles are plotted in figures 8, 9. It is obvious that, as λ is increasing, the velocity and temperature decreasing. This leads to enhancement of the momentum boundary layer thickness.

In Figs. 10 and 11, are shows the velocity and temperature profiles for different values of velocity slip parameter γ_1 and thermal slip parameter γ_2. The velocity curves show that the rate of transport decreases with the increasing distance (η) of the sheet. In all cases the velocity vanishes at some large distance from the sheet (at η =3). With the increasing γ_1, the horizontal velocity is found to decrease. When slip occurs, the flow velocity near the sheet is no longer equal to the stretching velocity of the sheet.

With the increase in γ_1, such slip velocity increases and consequently fluid velocity decreases because under the slip condition, the pulling of the stretching sheet can be only partly transmitted to the fluid. It is noted that γ_1 has a substantial effect on the solutions. Temperature profiles are presented in Fig.11 for the variation of temperature slip parameter γ_2. It is seen that the temperature decreases with increasing of $\gamma_{2.}$ From figures 12 &13, we analyze that the velocity and the thickness of the boundary layer decreases as well as temperature and the thermal boundary layer thickness for both cases with the increasing values of the unsteady parameter A in both the cases slip and without slip.

The temperature profiles $\theta(\eta)$ are depicted in figures for different values of the Prandtl number $\Pr$ and thermal radiation parameter R. The effect of the Prandtl number $\Pr$ on temperature profile is presented in Fig. 14. It is found that temperature increases as the Prandtl number $\Pr$ decreases. The effect of thermal radiation R on temperature profile is presented in Fig. 15. It is found that temperature increases as the radiation parameter R decreases [Fig. 15]. This is in agreement with the physical fact that the thermal boundary layer thickness increases with increasing R. The temperature profiles $\theta(\eta)$ for different values of the heat source or sink parameter δ and the Eckert number Ec in the presence of slip and without slip are shown in Figures 16-17. It is observed that for both δ and Ec, the temperature is enhancing with increasing of both δ and Ec.

5. CONCLUSIONS

A numerical model is developed to the effects of velocity slip and temperature slip on unsteady MHD flow of Jeffrey fluid over a stretching sheet through porous medium. The governing partial differential equations for the velocity flow and temperature fields are reduced to a system of coupled nonlinear differential equations. Finally, the set of ordinary differential equations are solved using shooting method. Further numerical results for the skin friction coefficient and the rate of heat transfer at the surface are in closed agreement with the results which were obtained by earlier researchers in the absence of suction parameter S, Jeffrey parameter λ_1, Magnetic parameter M, permeability parameter λ and the unsteady parameter A.

- The governing equations are solved numerically by shooting technique with Runge-Kutta fourth order using MATLAB.

- We conclude that the velocity as well as the temperature decreases with increasing values of the unsteady parameter A, the permeability parameter λ, the suction parameter S, the Jeffrey parameter λ_1, the magnetic parameter M, velocity slip γ_1 and temperature slip γ_2. Moreover, the temperature increases with an increase in the value of Eckert number and the heat source or sink parameter δ.

- From Table 1 shows that the skin friction coefficient $f''(0)$ increases with the increasing values of the unsteady parameter A and permeability parameter λ keeping other parameters are constant. Further it is observed that the values of the local skin friction coefficient are always negative for all the values of physical parameters considered.

Table 1: Comparison of $-f''(0)$ for various values of A and λ. For fixed values of $\delta = -0.5$, $\lambda_1 = 0.5$, $\Pr = 10$, $R = 0.3$, $M = 0.5$, $Ec = 0.01$, $\gamma_1 = 0.5$, $\gamma_2 = 0.5$ and $S = 0.5$.

λ	A	Present syudy	Krishna Murthy and Sreenadh [22] $\gamma_1 = \gamma_2 = 0$	Elbashbeshy and Emam [11] $\gamma_1 = \gamma_2 = \lambda_1 = M = S = 0$	Elbashbeshy and Emam [11] Original values
0.2	0.5	0.978076	2.135500	1.251707	1.251707
0.4	0.5	0.993687	2.192047	1.329395	1.329395
0.6	0.5	1.008318	2.246820	1.402809	1.402809
0.8	0.5	1.022080	2.299790	1.472561	1.472561
0.5	**0.2**	0.977348	2.133583	1.283046	1.286210
0.5	**0.4**	0.993381	2.191168	1.339108	1.341593
0.5	**0.6**	1.008670	2.247900	1.393711	1.395593
0.5	**0.8**	1.023234	2.303717	1.446831	1.448212

- Physically, positive sign of skin friction coefficient $f''(0)$ implies that the fluid exerts a drag force on the sheet.

- Table 2 illustrates that the unsteady parameter A, the permeability parameter λ and Prandtl number $\Pr$ on the rate of heat transfer $-\theta'(0)$ at the surface. From this table it is observed that the rate of heat transfer $-\theta'(0)$ increases with increasing values of the unsteady parameter A, the permeability parameter λ and Prandtl number $\Pr$ keeping other parameters as constant. It is also evident that the rate of heat transfer $\theta'(0)$ is negative for all the values of physical parameters considered. This means that there is a heat flow from the wall.

- It is obtained that the present results for Skin friction and Nusselt number reduce to the corresponding ones of Krishna Murthy and Sreenadh [22] & Elbashbeshy and Emam[11] the parameters whereas γ_1, γ_2, λ, M, S are and taken as zero. i.e good agreement is found with the existing results.

Table 2: Comparison of $-\theta'(0)$ for various values of A, λ and Pr. For fixed values of $\delta=-0.5$, $\lambda_1=0.5$, $R=0.3$, $M=0.5$, $Ec=0.01$, $\gamma_1=0.5$, $\gamma_2=0.5$ and $S=0.5$.

A	λ	Pr	Present syudy	Krishna Murthy and Sreenadh [22] $\gamma_1=\gamma_2=0,\ S=0.5$	Elbashbeshy and Emam [11] $\gamma_1=\gamma_2=\lambda_1=M=S=0$	Elbashbeshy and Emam [11] Original values
0.2	0.5	10	1.339028	3.501990	0.073709	0.068188
0.4	0.5	10	1.370083	3.807322	0.709300	0.711781
0.6	0.5	10	1.396727	4.095654	1.234320	1.242366
0.8	0.5	10	1.419860	4.368562	1.681328	1.693325
0.5	**0.2**	10	1.382063	3.943465	0.908460	0.938288
0.5	**0.4**	10	1.383307	3.950250	0.940752	0.972813
0.5	**0.6**	10	1.384461	3.956691	0.969788	1.003977
0.5	**0.8**	10	1.385535	3.962822	0.996134	1.032360
0.5	0.5	**0**	0.22222	0.25	0.25	0.25
0.5	0.5	**0.7**	0.561909	0.672757	0.474997	0.472703
0.5	0.5	**7**	1.260847	2.934146	0.909372	0.911898
0.5	0.5	**10**	1.38522	3.951224	0.982113	0.988775

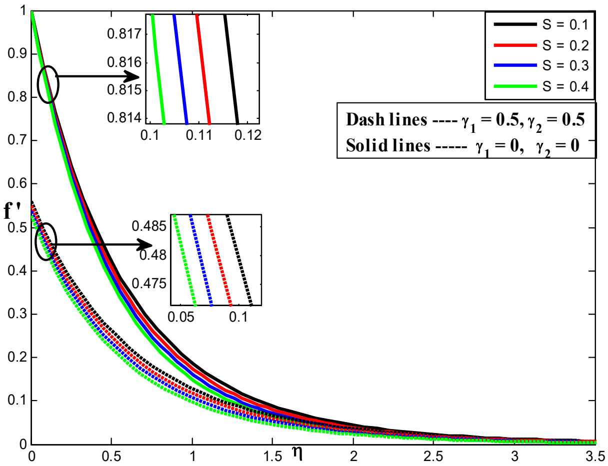

Fig. 2: Velocity profile for different values of suction parameter.

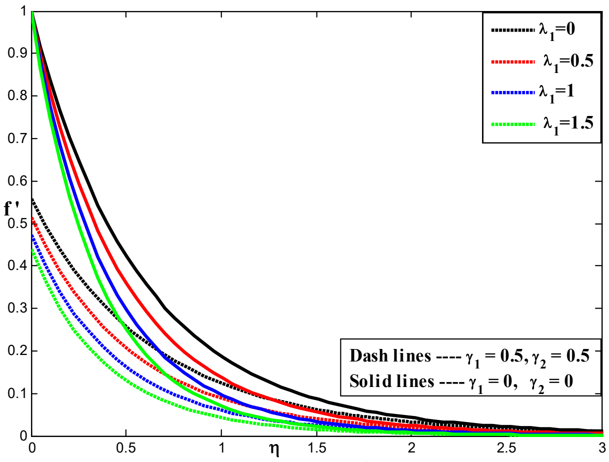

Fig. 4: Velocity profile for different values of Jeffrey parameter λ_1.

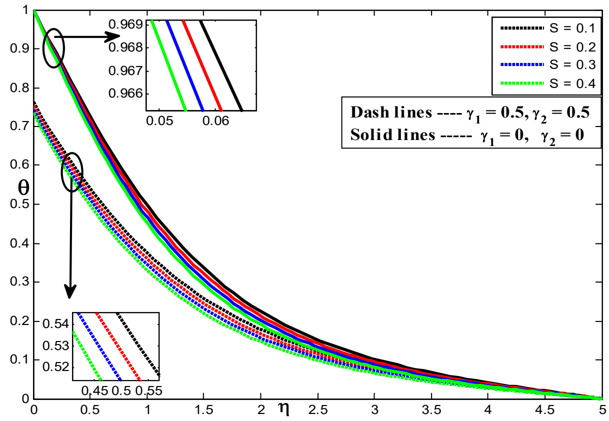

Fig. 3: Temperature profile for different values of suction parameter S.

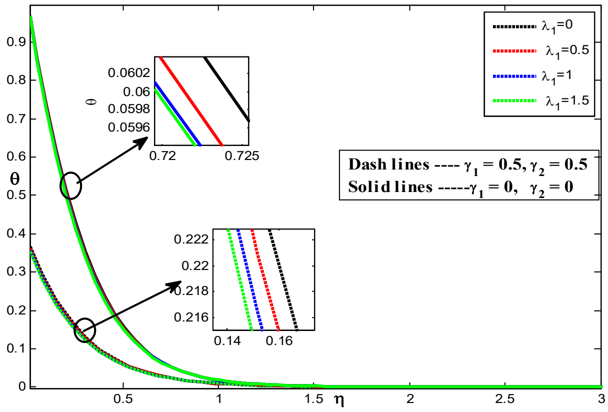

Fig. 5: Temperature profile for different values of Jeffrey parameter λ_1

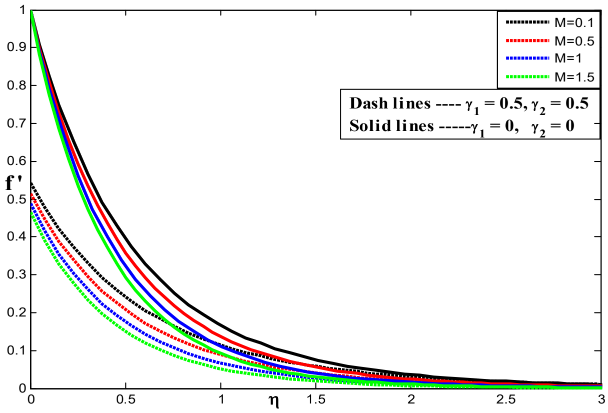

Fig. 6: Velocity profile for different values of Magnetic

parameter M

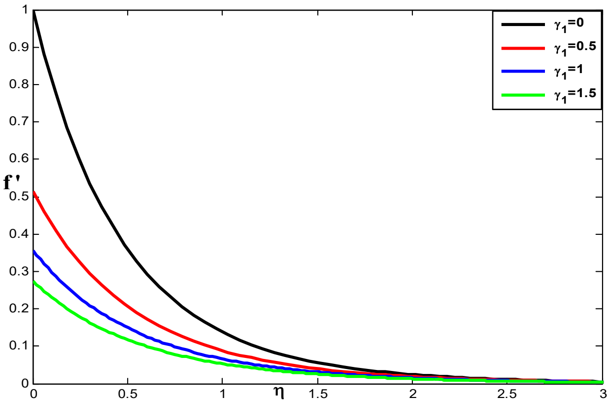

Fig. 10: Velocity profile for different values of the velocity slip parameter γ_1

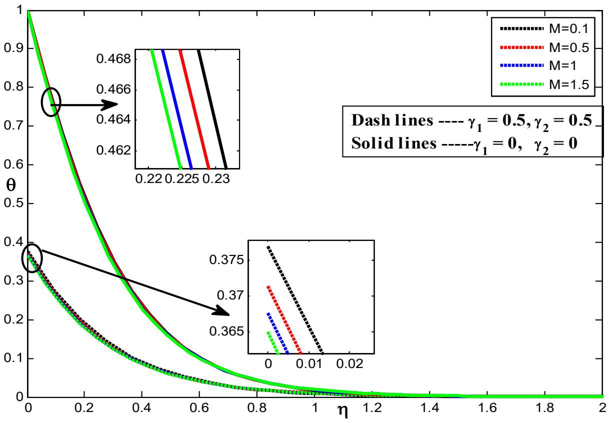

Fig. 7: Temperature profile for different values of

Magnetic parameter M

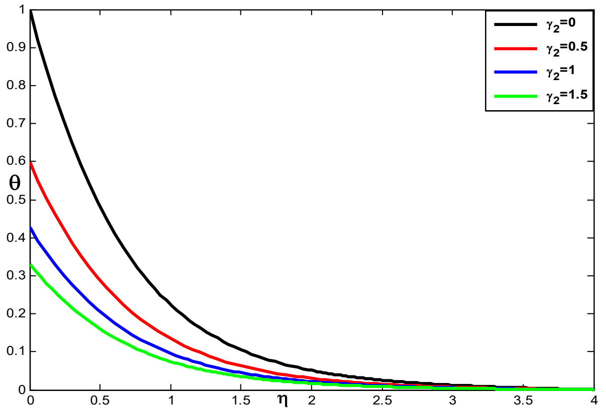

Fig. 11: Temperature profile for different values of the

temperature slip parameter γ_2

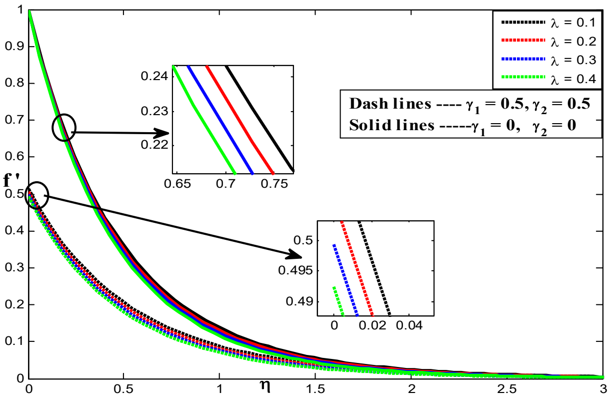

Fig. 8: Velocity profile for different values of permeability parameter λ

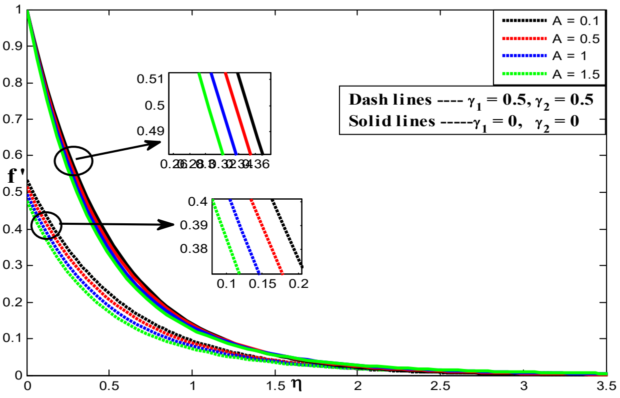

Fig. 12: Velocity profile for different values of the unsteadiness parameter A

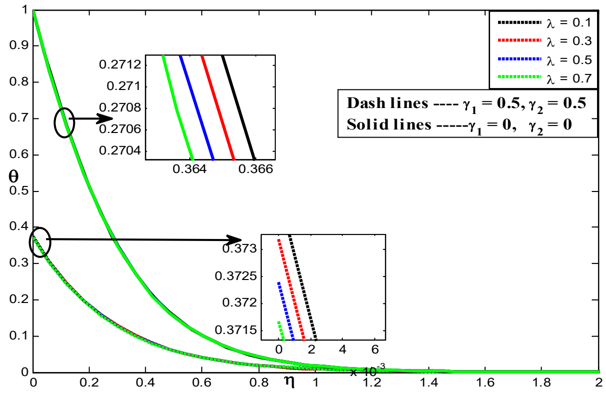

Fig. 9: Temperature profile for different values of permeability parameter λ

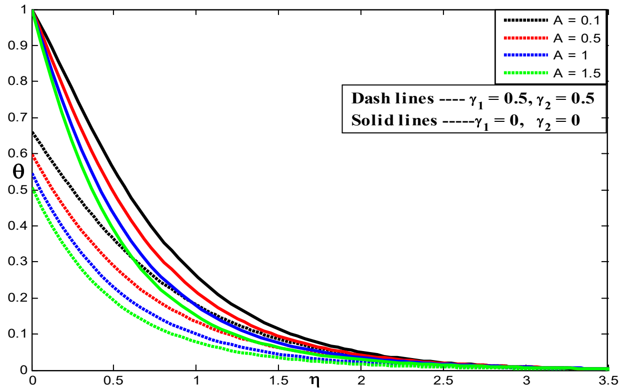

Fig. 13: Temperature profile for different values of the unsteadiness parameter A

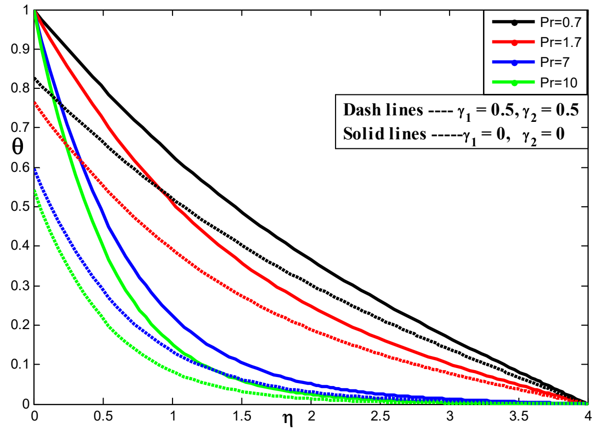

Fig. 14: Temperature profile for different values of the

Prandtl number Pr

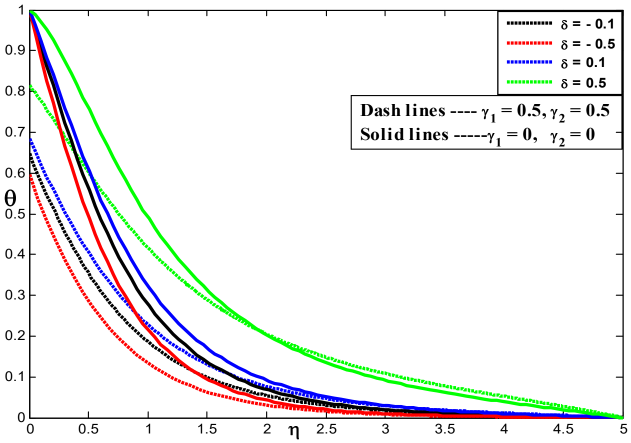

Fig. 16: Temperature profile for different values of thermal Radiation parameter R

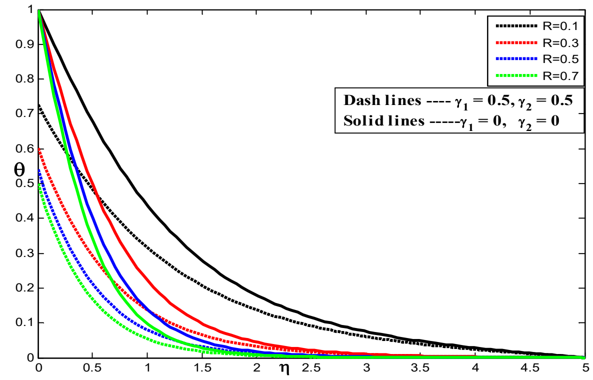

Fig. 15: Temperature profile for different values of thermal Radiation parameter R

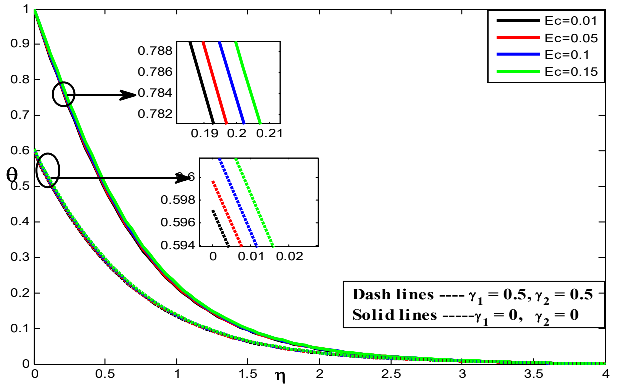

Fig. 17: Temperature profile for different values of Eckert number Ec

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