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EFFECTS OF MASS SUCTION ON MHD BOUNDARY LAYER FLOW AND HEAT TRANSFER OVER A POROUS SHRINKING SHEET WITH HEAT SOURCE/SINK

Shankar Goud B[a], Ratna Kumari Jilugu[b,*], Navya Sravani V[c]
[a] *Department of Mathematics, JNTUH College of Engineering Hyderabad, Kukatpally-85, Telangana state, India*
[b] *02 Electrical Machines, BHEL Ramachandrapuram, Hyderabad-32, Telangana state, India*
[c] *Department of Mechanical Engineering, JNTUH College of Engineering Hyderabad, Kukatpally-85, Telangana state, India*
*Email: bsgoud17@gmail.com, ratna.227@gmail.com, navyasravani@gmail.com

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An examination is made to think about the impacts of the mass suction on the steady two dimensional magnetohydrodynamic (MHD) boundary layer flow and heat transfer past a shrinking sheet with source/sink. In the dynamic framework, a uniform magnetic field acts normal to the plane of flow. The governing non-dimensional partial differential equations are changed into ordinary differential equations using similarity transformations. Then the obtained ordinary differential equations are solved numerically by using the MATLAB in built solver bvp5c. From the investigation it is discovered that the velocity inside the boundary layer increments with increment of wall mass suction and magnetic field and accordingly the thickness of the momentum layer diminishes. The temperature diminishes with increase of Prandtl number. Hartmann number and heat sink parameter and the temperature increments with heat source parameter. Moreover, for strong heat source heat absorption at the sheet happens.

***Keywords*:** Heat transfer, heat source/sink, MHD boundary layer, shrinking sheet, mass suction, bvp5c.

1. Introduction

The analysis of mixed convection boundary layer flow of an incompressible viscous fluid over a shrinking sheet has play an important role in many manufacturing and technological applications, such as metal and polymer processing industries, paper production, wire drawing and many others. Several authors have studies the problem of boundary layer flow of an electrically conducting viscous fluid about the stretching sheet problems, such as Postelnicu [1]investigated the influence of chemical reaction on heat and mass transfer by natural convection from vertical surfaces in porous media considering Soret and Dufour effects. Shankar Goud and Raja Shekar [2] studied effects of thermal radiation and heat source on MHD free convection over a vertical plate with thermal diffusion and diffusion thermo. Chemically reactive solute distribution in MHD boundary layer flow over a permeable stretching sheet with suction or blowing was studied by Bhattacharyya and Layek [3]. Mohamed Ali and Khaled Al-Salem [4] discussed the effect of suction or injection on the boundary layer flows induced by continuous surfaces stretched with prescribed skin friction. Uwanta and Hamza [5] analyzed the effect of suction/injection on unsteady hydromagnetic convective flow of reactive viscous fluid between vertical porous plates with thermal diffusion. Shankar Goud et.al [6] discussed on an implicit finite difference method for MHD flow of a micropolar fluid past a stretching sheet with heat transfer. Effects of chemical reaction, heat and mass transfer along a wedge with heat source and concentration in the presence of suction or injection was discussed by Kandasamy et.al [7]. Kandasamy et.al [8] studied the effects of chemical reaction, heat and mass transfer on boundary layer flow over a porous wedge with heat radiation in the presence of suction or injection. Shankar Goud and Dharmendar Reddy [9] studied on chemical reaction effect on MHD Heat and Mass transfer fluid flow over a moving vertical plate with heat source and convective boundary condition Effects of heat source/ sink on MHD flow and heat transfer over a shrinking sheet with mass suction was analysed by Krishnendu Battacharrya [10] .

Muhaimin et.al [11] examined the effects of heat and mass transfer on nonlinear MHD boundary layer flow over a shrinking sheet in the presence of suction. G. Bal Reddy et.al [12] studied the Keller box solution of magnetohydrodynamic boundary layer flow of nanofluid over an exponentially stretching permeable sheet. B. Shankar Goud [13] analysed the MHD flow past a vertical oscillating plate with radiation and chemical reaction in porous medium-finite difference method. B. Finite element method application of effects on an unsteady MHD convective heat and mass transfer flow in a semi-infinite vertical moving in a porous medium with heat source and suction was studied by Shankar Goud, and MN Rajashekar [14].

In the present analysis, the effects of suction on MHD boundary layer flow and heat transfer over a porous stretching sheet with heat source or sink are investigated. Using the similarity transformation the governing equations are transformed into a set of non-linear ordinary differential equations, which are solved numerically by the using the MATLAB in built solver and results are plotted in figures for different physical parameters involved in the equations are talk over in detail.

1. Mathematical Formulation

Consider the MHD flow of an incompressible viscouss electrically conducting fluid and heat transfer over a permeable shrinking sheet coinside with the plane $y=0$ and the flow is confined to $y>0$ in the presence of heat generation and absorption. The $x-$axis is tken along sheet and $y-$axis is perpendicular to sheet respectively and variable magnetic field B_0 is applied to nomal to the plate. A geometry of the pgysical problem is given in the figure 1. Under the boundary layer conditions the governing equations are given by

Continuity equation: $$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \qquad \ldots(1)$$

Momentum equation: $$u\frac{\partial u}{\partial x}+v\frac{\partial v}{\partial y}=\upsilon\frac{\partial^2 u}{\partial y^2}-\frac{\sigma B_0^2}{\rho}u \qquad \ldots(2)$$

Energy equations: $$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\frac{k}{\rho C_p}\frac{\partial^2 T}{\partial y^2}+\frac{Q_0}{\rho C_p}\left(T-T_\infty\right) \qquad \ldots(3)$$

The appropriate boundary condition are given by

$$\begin{aligned} &u=U_w(x)=-cx,\ v=v_w\ \ T=T_w \quad at\ y\to 0\\ &u\to 0,\ T\to 0 \qquad\qquad as\, y\to\infty \end{aligned} \qquad \ldots(4)$$

Now introducing the stream function ψ, the velocity components u and v can be written as

$$u=\frac{\partial\psi}{\partial y}\ \text{and}\ v=-\frac{\partial\psi}{\partial x} \qquad \ldots(5)$$

Equation (1) satisfied using the eqn.(5) and momentum and temperature equations take the following forms:

$$\frac{\partial\psi}{\partial x}\frac{\partial^2\psi}{\partial x\partial y}-\frac{\partial\psi}{\partial x}\frac{\partial^2\psi}{\partial y^2}=\upsilon\frac{\partial^3\psi}{\partial y^3}-\frac{\sigma B_0^2}{\rho}\frac{\partial\psi}{\partial y} \qquad \ldots(6)$$

$$\frac{\partial\psi}{\partial y}\frac{\partial T}{\partial x}-\frac{\partial\psi}{\partial x}\frac{\partial T}{\partial y}=\frac{k}{\rho C_p}\frac{\partial^2 T}{\partial y^2}+\frac{Q_0}{\rho C_p}\left(T-T_\infty\right) \qquad \ldots(7)$$

Also the boundary conditions becomes to

$$\frac{\partial \psi}{\partial y} = -cx, \frac{\partial \psi}{\partial x} = v_w \quad at\ y \to 0$$
$$\frac{\partial \psi}{\partial y} \to 0,\ \frac{\partial \psi}{\partial x} \to 0 \quad as\ y \to \infty \qquad \ldots (8)$$

Next, we introduce the non-dimensional variables for ψ and T as $\psi = \sqrt{c\upsilon}xf(\eta)$ and $T = T_\infty + (T_w - T_\infty)\theta(\eta)$ where $\eta = y\sqrt{\left(c/\upsilon\right)}$ is a similarity variable. Using the non-dimensional and similarity variables, eqns. (6) and (7) reduces to the following form:

$$f''' + ff'' - f'\left(f' - M^2\right) = 0 \qquad \ldots (9)$$
$$\theta'' + \Pr\left(f\theta' - \lambda\theta\right) = 0 \qquad \ldots (10)$$

Here $\lambda = Q_0/\rho C_\rho$ is a heat source $(\lambda < 0)$ or sink $(\lambda > 0)$ parameter.

The boundary conditions (8) and (4) becomes in the following form:

$$f = S, f' = -1, \theta = 1\ at\ \eta \to 0$$
$$f' \to 0, \theta \to 0, \qquad as \eta \to \infty \qquad \ldots (11)$$

Where $S = v_w/\sqrt{c\upsilon} > 0$ is the mass suction parameter.

2. Numerical procedure for solution

Numerical solutions have been attained for the governing equations (9) and (10) with the assorted boundary condition (11) by using the above mentioned numerical scheme for some of the non-dimensional parameters, namely Magnetic parameter (M), Prandtl number $(\Pr)$, mass suction parameter(S), heat source parameter(λ). The Effects of M, Pr, S and λ on the fluid velocity and temperature flow over shrinking sheet are discussed in detail. The numerical computations are done by using the MATLAB in-built numerical solver bvp5c.

3. Results and Discussion

In order to discuss the results, numerical computations has been carried out using the MATLAB in built solver for various values of non-dimensional parameters. For illustrations of the results, numerical values are plotted in figures 2-5. Also, in table 1 show the comparison between the present study and previous study results of skin friction coefficient $f''(0)$ for different values of mass suction parameter(S) with $M^2 = 2$.

S	Present study	Muhaimin *et.al* [9]	Battacharryya[8]
2	2.414476	2.414214	2.41300
3	3.302816	3.302776	3.30275
4	4.236072	4.236068	4.23609

In this study a focus is laid on the numerical values of physical parameters namely, the mass suction parameter S, the Hartmann number M, the heat source/sink parameter λ and the Prandtl number Pr. In order to enforce a steady flow near the sheet by confining the generated vorticity inside the boundary layer, large values are assigned to S and M indicating a strong magnetic field and wall mass suction. Figures 2-8 depict the flow characteristics and temperature field with varying parameter values. The current results can be assured the accuracy of applied numerical scheme as the results of Muhaimin et al. in table 1 and the computed skin friction coefficients are in perfect agreement. Practically, a lot of importance is given to the impact of Hartmann number M on temperature and velocity profiles. This is studied in Figures 2 and 3, with an increase in M, the value of f' increases indicating the increase in dimensionless velocity. Reasoning to this behaviour is that with a velocity of electrically conducting fluid, there arises a Lorentz force. The thus generated Lorentz force enhances the velocity of fluid in the boundary layer region thereby reducing momentum boundary layer thickness. It can be observed from Figure 3 that temperature value at a point decreases with M. Considering the effects of mass suction parameter S on temperature profile and velocity profile, we understand the following.

From figure 4, it is clear that for a fixed value of η, higher the value of applied suction, higher is the velocity profile leading to a thinner momentum boundary layer. Figure 5 illustrates wall mass suction has an effect on not only on velocity field but also on the dimensionless temperature distribution. Clearly it is evident that for fixed η, the temperature θ decreases on increasing the value of suction. This reduces the thickness of thermal boundary layer as a consequence. Figure 6 depicts the reducing thermal boundary layer thickness and the dimensionless temperature profile with increased values of Prandtl number Pr. Also, it is understood that increased value of Pr means a reduced thermal fluid conductivity. This is the reason for reduced temperature. Also, as momentum equation is the same with or without θ, velocity of fluid field is not affected by Prandtl number Pr. Figure 7 indicates that on increasing heat sink strength, the dimensionless temperature θ decreases while on increasing heat source strength temperature increases. Hence it can be said that increased heat sink parameter reduces the thickness of thermal boundary layer but alternate behaviour can be observed with heat source parameter. Figure 8 depicts the varying temperature gradient at the sheet $\theta'(0)$ for varying values of Pr and λ, which is significant in calculating rate of heat transfer. The sign of $\theta'(0)$ indicates the heat transfer type, absorption is positive value and negative is transfer. On increasing Prandtl number, the rate of heat transfer increases An observation is made that, for small values of Prandtl number, Pr with large values of heat source parameter (λ<0) there is heat absorption at the sheet. However, heat transfer increases with increased heat sink parameter (λ>0).

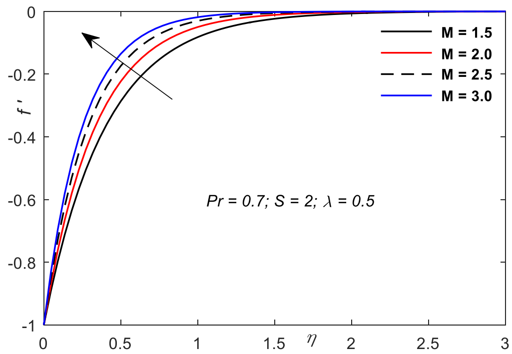

Fig 2: Velocity profile for different values of M

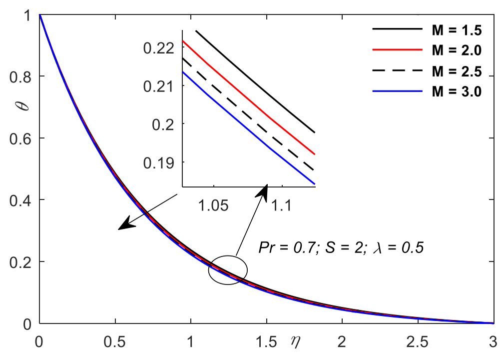

Fig 3: Temperature profile for different values of M

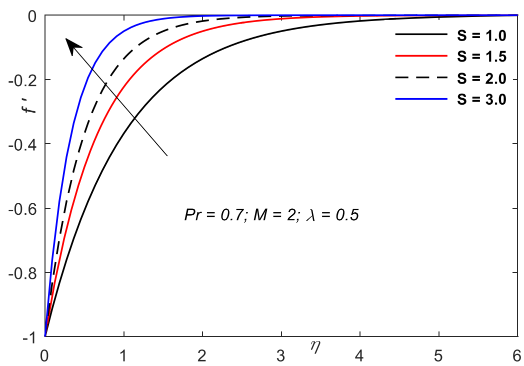

Fig 4: Velocity profile for different values of S

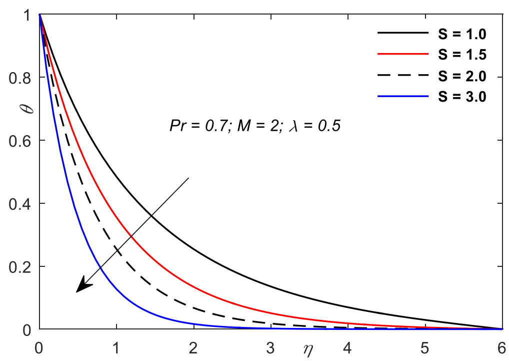

Fig 5: Temperature profile for different values of S

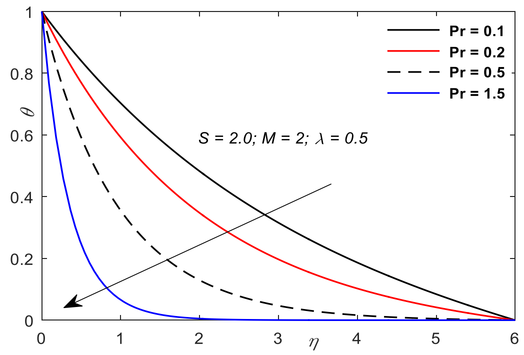

Fig 6: Temperature profile for different values of Pr

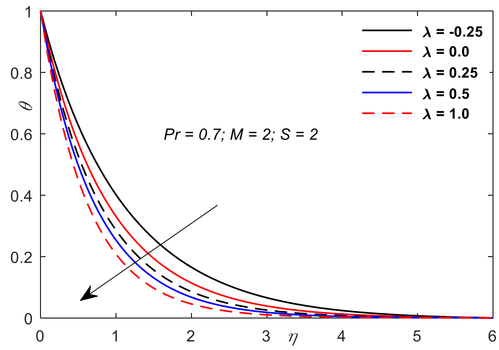

Fig 7: Temperature profile for different values of λ

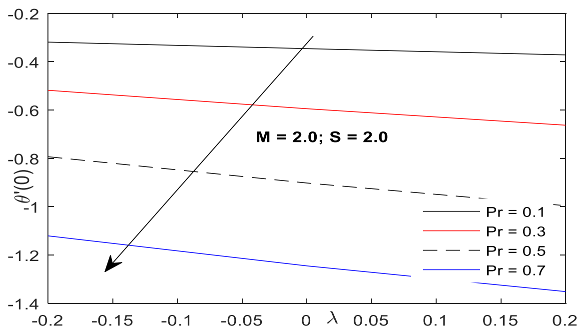

Fig 8: Temperature gradient at the sheet $\theta'(0)$ for different values of λ

4. Conclusions

A study is made on effect of heat source/sink on MHD boundary layer flow and heat transfer over a shrinking sheet subjected to strong suction. Similarity transformations helped obtain the self-similar equations. The obtained equations are solved using MATLAB in built solver bvp5. It can be concluded that temperature at a point and thickness of momentum boundary layer decrease with an increase in Hartnamm number and mass suction parameter. On increasing Prandtl number, the thickness of the thermal boundary layer and temperature decrease.

At the sheet, heat absorption is observed for higher values of heat source parameter. The heat transfer is considerably high for higher values of Prandtl number and heat sink parameter which is a critical aspect of production engineering useful to yield a good quality final product.

Nomenclature

u, v	Velocity components in x & y directions
$\upsilon = \mu/\rho$	Kinematic fluid viscosity
μ	Coefficient of fluid viscocity
ρ	Fluid density
σ	Electrical conductivity of the fluid
B_0	Applied uniform magnetic field
T, T_∞ & T_w	Temperature , Free stream Temperature and Temperature of the sheet
C_p	Specific heat
k	Fluid thermal conductivity
$c > 0$	Shrinking constant
$v_w > 0$	Wall mass suction parameter
$M = \sqrt{\sigma B_0^2 / c\rho}$	Hartmann number
$\Pr = \mu C_p / k$	Prandtl number

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