

Heat and Mass Transfer of an Unsteady MHD Fluid Flow

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A b s t r a c t: Thermal radiation and surface mass transfer over a shrinking sheet have been studied in the present work. All the profiles like velocity, temperature and concentration are presented through graphs. Findings of the present work is explained. Velocity profile is an increasing function for unsteadiness, magnetic, and suction parameters. Temperature profile is an increasing function for unsteadiness and magnetic parameter but decreasing for suction and thermal radiation parameters as well as Eckert and Prandtl numbers. Concentration profile decreases for increasing values of Schmidt number, suction and chemical reaction parameters.

Keywords: Shrinking sheet, Viscous, Joulian and Darcy dissipation.

1. Introduction

In industry, many applications are carried out by considering a shrinking surface in MHD fluid flow related problems such as shrink packing. A best mechanism is used to clarify the purpose is the shrink tunnel [1]. In shrink tunnel, a chamber which is circulating hot air, placed on upper part of conveyer which carries some of its products which can be packed through tunnel. Wang [2] derived the closed form of analytic solution for an unsteady MHD fluid flow in a shrinking film. Heat transfer in a stagnation-point flow towards a stretching sheet was observed by Mahapatra and Gupta [3]. Whereas Mabood et al. [4], found exactly what is studied for the MHD fluid flow over a radiating surface which is stretched exponentially. Mishra et al. [5] did a great job by analysing the effect of heat and mass transfer with on MHD viscoelastic fluid flow. Pattnaik and Biswal [6] derive the analytical solution of MHD flow. Jat and Chaudhary [7] studied the effects of radiation parameter for MHD flow over a stretching sheet. Many researchers [8-14] showed their interest on non-Newtonian fluid over a stretching surface with casson fluid model to discuss the behaviour of different physical parameters. These studies motivate us to work on Mhd fluid flow using casson flow model. The most effective model [15] introduced by Casson to predict the flow behaviour in different situations on MHD flow. Hayat et al. [16] studied the effects of homogeneous and heterogeneous reactions in flow of nanofluids over a nonlinear stretching surface with variable surface thickness. Mahmood et al. [17] investigated hydromagnetic hiemenz flow of micropolar fluid over a nonlinearly stretching/shrinking sheet: dual solutions by using Chebyshev spectral Newton

iterative scheme. Mishra et al. [18] presented the analysis of heat and mass transfer with MHD and chemical reaction effects on viscoelastic fluid over a stretching sheet.

2. Mathematical formulation

We have considered an unsteady 2-D boundary layer MHD flow of an incompressible, electrically conducting viscous fluid generated by a permeable shrinking sheet. Shrinking velocity is considered to be $U_w(x, t)$. The flow region is confined in +ve y-axis. Surface temperature is assumed as $T_w(x, t)$ and concentration distributions is considered as $C_w(x, t)$ which are function 't' and 'x'. We have examined the effects of radiation parameter, viscous heating and chemical reaction. The flow is confined to an variable magnetic field $B = B_0 / \sqrt{1 - ct}$. Considering boundary layer approximation and using Rosseland approximation in the energy equation, we have taken,

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \quad (1)$$

$$\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} = \nu \frac{\partial^2 u}{\partial y^2} - \left(\frac{\sigma B_0^2}{\rho} + \frac{\mu}{\rho C_p k_p} \right) u \quad (2)$$

$$\left(\frac{\partial T}{\partial t} + u \frac{\partial T}{\partial x} + v \frac{\partial T}{\partial y} \right) = \left(\frac{K}{\rho C_p} + \frac{16\sigma^* T_\infty^3}{3\rho C_p k^*} \right) \frac{\partial^2 T}{\partial y^2} + \frac{\mu}{\rho C_p} \left(\frac{\partial u}{\partial y} \right)^2 + \frac{\mu}{\rho C_p k_p} u^2 + \frac{\sigma B_0^2}{\rho C_p} u^2 \quad (3)$$

$$\frac{\partial C}{\partial t} + u \frac{\partial C}{\partial x} + v \frac{\partial C}{\partial y} = D \frac{\partial^2 C}{\partial y^2} - k_c^* (C - C_\infty) \quad (4)$$

with

$$u = U_w(x, t) = \frac{-ax}{(1 - ct)}, \quad v = v_w(x, t), \quad T = T_w, \quad C = C_w \quad \text{at} \quad y = 0 \quad (5)$$

$$u \rightarrow 0, \quad T \rightarrow T_\infty, \quad C \rightarrow C_\infty \quad \text{as} \quad y \rightarrow \infty \quad (6)$$

where 'a' and 'c', positive constants.

We have considered the suction in prescribed form as: $v_w(t) = v_0 / \sqrt{(1 - ct)}$ where $v_0 < 0$, constant measuring. We have considered surface temperature and concentration to proceed our work as,

$$T_w(x, t) = T_\infty + T_{ref} \frac{ax^2}{2\nu(1 - ct)^{3/2}} \quad (7)$$

$$C_w(x, t) = C_\infty + C_{ref} \frac{ax^2}{2\nu(1 - ct)^{3/2}} \quad (8)$$

Using the following transformations we get,

$$u = \frac{\partial \psi}{\partial y} = \frac{ax}{(1-ct)} f'(\eta) \quad (9)$$

$$v = -\frac{\partial \psi}{\partial x} = -\left(\frac{av}{1-ct}\right)^{1/2} f(\eta) \quad (10)$$

$$\psi = -\left(\frac{va}{1-ct}\right)^{1/2} x f(\eta) \quad (11)$$

$$\eta = \left(\frac{a}{v(1-ct)}\right)^{1/2} y \quad (12)$$

$$T_w(x,t) = T_\infty + T_{ref} \frac{ax^2}{2v(1-ct)^{3/2}} \theta(\eta), \quad \theta(\eta) = \frac{T - T_\infty}{T_w - T_\infty} \quad (13)$$

$$C_w(x,t) = C_\infty + C_{ref} \frac{ax^2}{2v(1-ct)^{3/2}} \phi(\eta), \quad \phi(\eta) = \frac{C - C_\infty}{C_w - C_\infty} \quad (14)$$

So, Eqns. (2–6) reduced to,

$$f''' + ff'' - (f')^2 - A\left(f' + \frac{\eta}{2} f''\right) - (M + k_p^{-1}) f' = 0 \quad (15)$$

$$\frac{1}{Pr} \left(1 + \frac{4}{3} Nr\right) \theta'' + f\theta' - 2f'\theta - \frac{A}{2} (3\theta + \eta\theta') + E_c (f'')^2 + E_c (M + k_p^{-1}) (f')^2 = 0 \quad (16)$$

$$\frac{1}{Sc} \phi'' + f\phi' - 2f'\phi - \frac{A}{2} (3\phi + \eta\phi') - K_c \phi = 0 \quad (17)$$

$$f(\eta) = S, \quad f'(\eta) = -1, \quad \theta(\eta) = 1, \quad \phi(\eta) = 1 \quad \text{at } \eta = 0 \quad (18)$$

$$f'(\eta) \rightarrow 0, \quad \theta(\eta) \rightarrow 0, \quad \phi(\eta) \rightarrow 0 \quad \text{as } \eta \rightarrow \infty \quad (19)$$

where k_p , porosity parameter, K_c , chemical reaction parameter and other parameters are defined in [13].

3. Conclusion

- Velocity profile is an increasing function for unsteadiness, magnetic, and suction parameters.
- Temperature profile is an increasing function for unsteadiness and magnetic parameter but decreasing for suction and thermal radiation parameters as well as Eckert and Prandtl numbers.
- Concentration profile decreases for increasing values of Schmidt number, suction and chemical reaction parameters.

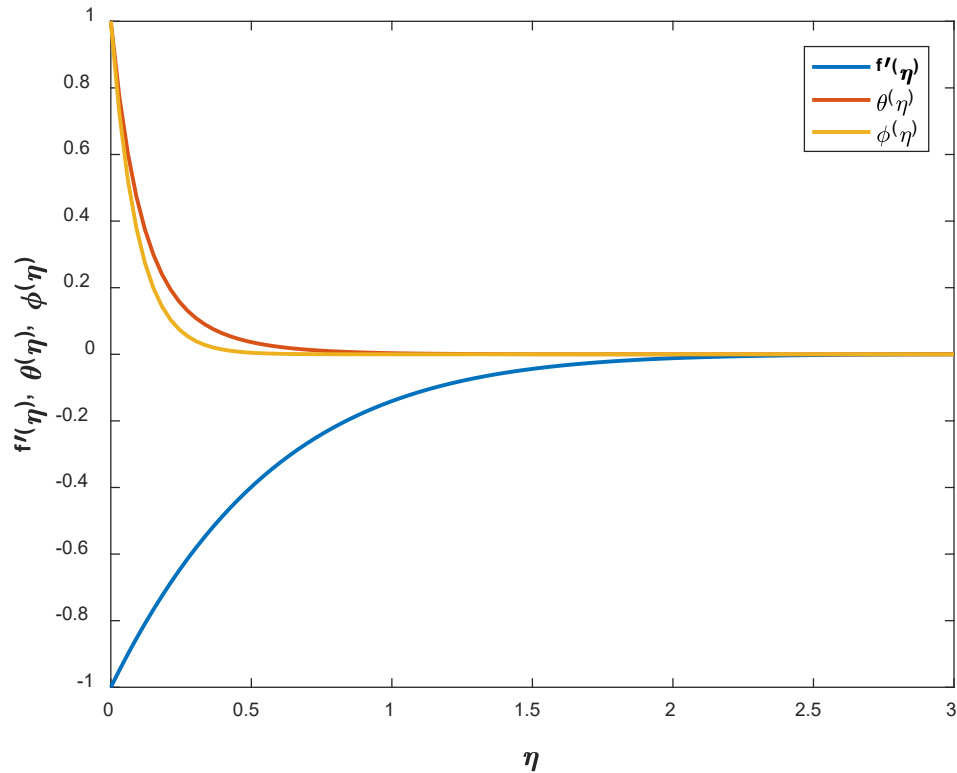


Fig. 1 Validation Check for Velocity, Temperature and Concentration Profile

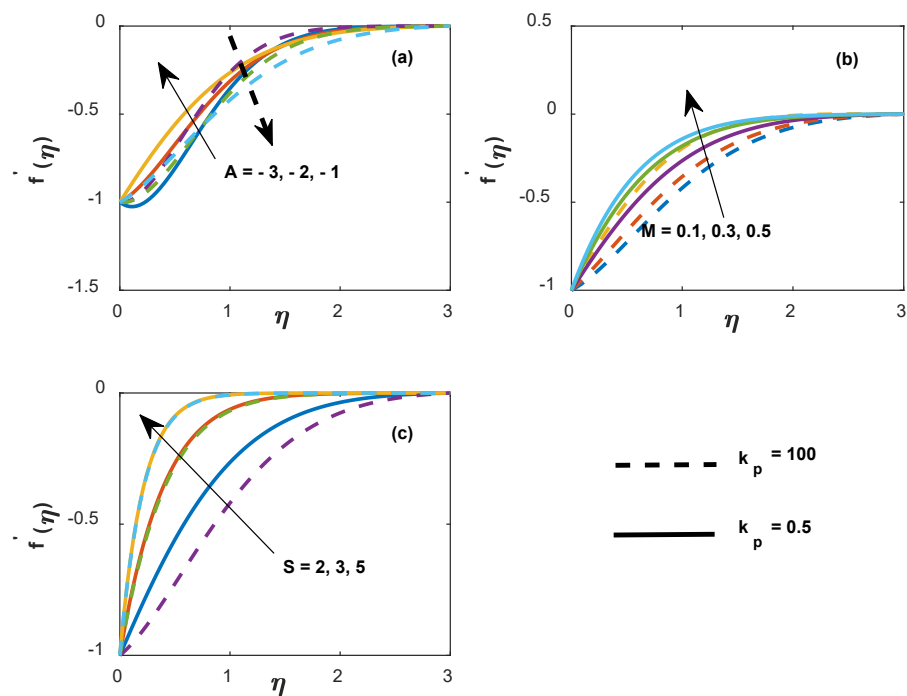


Fig. 2 Variation of Velocity Profile for (a) A (b) M (c) S

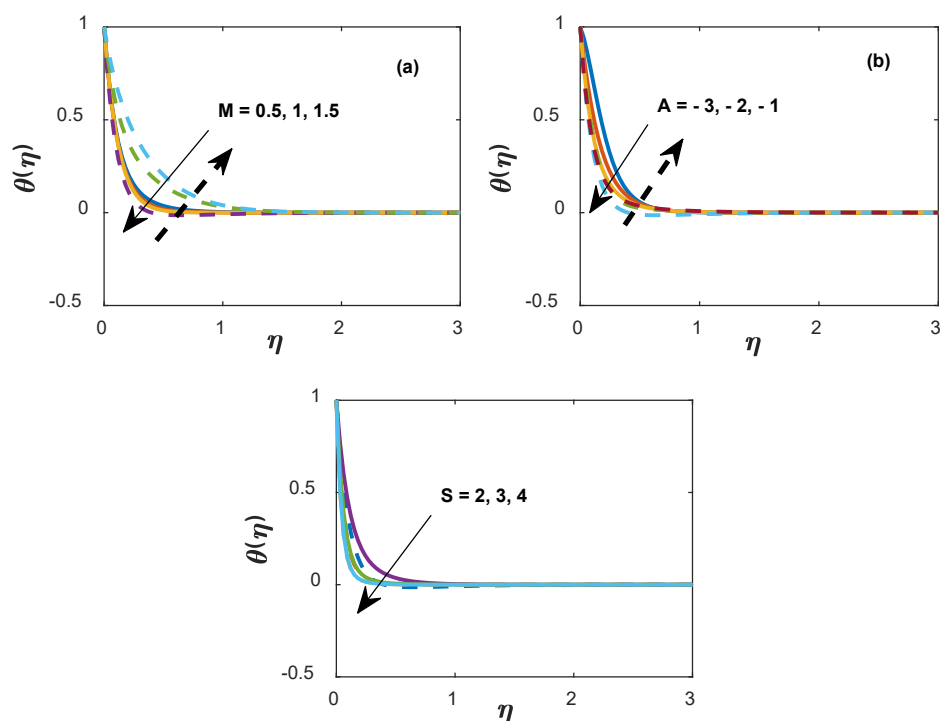


Fig. 3 Variation of Temperature Profile for (a) M (b) A (c) S

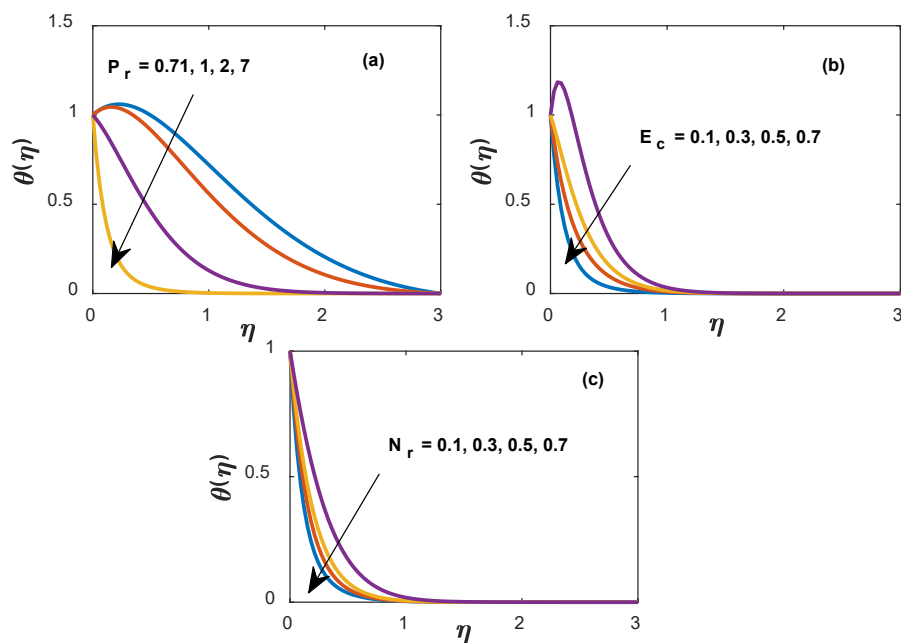


Fig. 4 Variation of Temperature Profile for (a) P_r (b) E_c (c) N_r

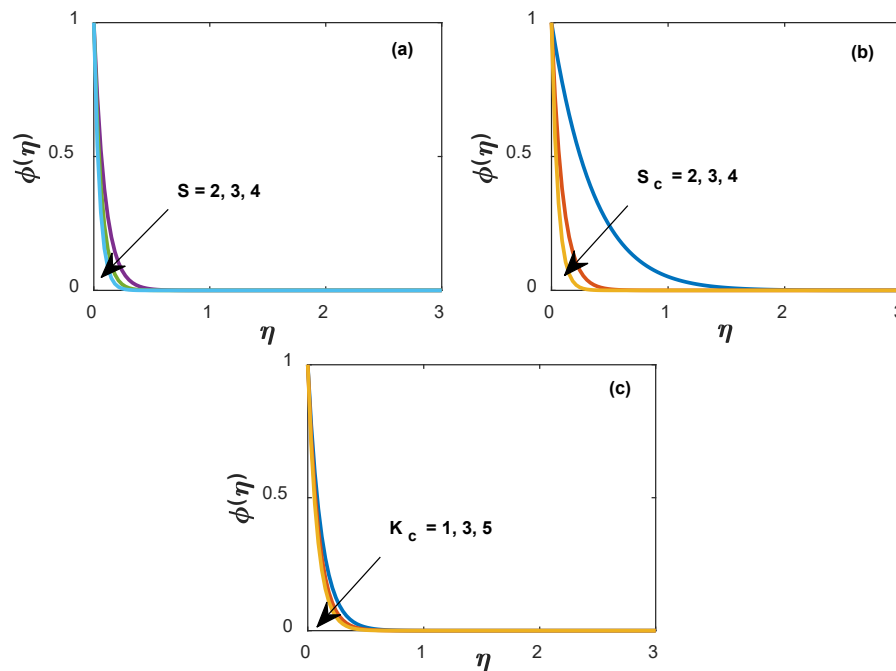


Fig. 5 Variation of Concentration Profile for (a) S (b) S_c (c) K_c

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