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Stagnation Point Flow and Heat Transfer through Porous Medium

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Abstract :- To study the two-dimensional laminar boundary layer flow of viscous incompressible, electrically conducting fluid through porous medium near a stagnation point. It is assumed that the velocity and temperature proportional to the distance from the stagnation point. The numerical solution for the governing non-linear momentum and energy equation has been obtained independently by a perturbation technique for small magnetic parameters. In this problem the effect of porosity of the medium, surface velocity, Hartmann number, Prandtl number and Eckert number for velocity and temperature distribution have been discussed with graphical representation.

Key Words: Stagnation Point Flow, Porous Medium, Heat Transfer, and Finite Difference.

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INTRODUCTION

The 2-D flow and heat transfer of incompressible viscous fluid through porous medium has important application in the polymer industry. The study of heat transfer and flow field is necessary for determining the quality of the final product of such process. Dutta et al (1985) discussed the temperature field in flow over a stretching surface with uniform heat flux. Attia (1999) studied the Transient MHD flow and heat transfer between two parallel plates with temperature dependent viscosity. Garg (1994) gave the Heat Transfer due to stagnation point flow of a Non-Newtonian fluid. Malashetty,

et al (1997) studied the Two-phase magneto hydrodynamic flow and heat transfer in an inclined channel. Ahmed et al (2004) gave the Hall Effect on unsteady MHD Couette flow and heat transfer of a Bingham fluid with suction and injection**.** Ogulu et al (2007) discussed the Heat and mass transfer of an unsteady MHD natural convection flow of a rotating fluid past a vertical porous flat plate in the presence of radiative heat transfer. Pop (2008) Magneto hydrodynamic (MHD) flow and heat transfer due to a stretching cylinder. Prasad et al (2009) studied Heat transfer in the MHD flow of a power law fluid over a non-isothermal stretching sheet. Pop et al (2010) discussed the MHD mixed convection boundary layer flow towards a stretching vertical surface with constant wall temperature.

This paper is concerned with a study, 2-D stagnation flow of an electrically conducting fluid through porous medium. The numerical solution obtained for governing momentum and energy equation.

MATHEMATICAL ANALYSIS

The two-dimensional study flow of viscous incompressible fluid through porous medium with velocity proportional to the distance from the stagnation point in presence of applied normal magnetic field of constant strength H. the surface has uniform temperature T_w^* and a linear velocity u_w^*, while the velocity of the flow of external to the boundary layers is $U^*(x)$. The systems of boundary layer equation are:

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

$$\rho\left(u\frac{\partial u}{\partial x}+v\frac{\partial v}{\partial y}\right)=\rho U^*\frac{dU^*}{dx}+\mu\frac{\partial^2 u}{\partial y^2}+\frac{\mu}{K}\left(U^*-u\right)$$
… (2)

And

$$\rho C_p\left(u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}\right)=\rho U^*\frac{dU^*}{dx}+K\frac{\partial^2 T}{\partial y^2}+\sigma^*\mu^{*2}H^2u^2+q(T-T_\infty)$$
…. (3)

The corresponding boundary conditions are

$$\left. \begin{array}{l} y = 0 : u = u_w^* = cx, \quad v = 0, \quad T = T_w^* \\ y = \infty : u = U^* = dx, \quad T = \infty \end{array} \right\}$$

…. (4)

Where c is constant d is proportional to the free stream velocity far away from the surface, and T_∞ is constant temperature of the fluid far away from sheet, ρ is the density, σ^* is the electrical conductivity, μ^* is the magnetic permeability, c_p is the coefficient of viscosity, q is the volumetric rate of heat generation, K is the thermal conductivity, μ is the coefficient of viscosity.

The continuity equation (1) are identically satisfied by the stream function $\psi(x, y)$ defined as

$$u = \frac{\partial \psi}{\partial y}, \qquad v = -\frac{\partial \psi}{\partial y}$$

…. (4)

The dimensionless variables are defined

$$\psi(x, y) = x\sqrt{c\upsilon}\, f(\eta), \; \eta = y\sqrt{\frac{c}{\upsilon}}, \; \theta = \frac{T - T_\infty}{T_w - T_\infty}$$

…. (5)

Using (5) and the equation (4) become in the form

$$u(x, y) = cxf'(\eta), \qquad v = -\sqrt{c\upsilon}\, f(\eta)$$

…. (6)

Applying (5) and (6) the equations (2) and (3) becomes in the form

$$f'^2 - f''' - ff'' - \delta^2 - m(\delta - f') = 0$$

…. (7)

$$\frac{1}{\Pr}\theta'' + f\theta' + Ha^2 Ecf'^2 + B\Pr\theta = 0$$

…. (8)

The corresponding boundary conditions are

$$\begin{array}{l} \eta = 0, \; f = 0, \; f' = 0, \; \theta = 0 \\ \eta = \infty, \quad f' = \delta, \quad \theta = 0 \end{array}$$

…. (9)

Where

$$\delta = \frac{d}{c}$$ Is the velocity parameter

$$Ha = \mu^* H \sqrt{\frac{\sigma^*}{\rho c}}$$ Is the Hartmann number

$$\Pr = \frac{\mu Cp}{K}$$ Is the prandtl number

$$Ec = \frac{u_w^*}{Cp(T_w - T_\infty)}$$ Is the Eckert number

$$m = \frac{\upsilon}{cK}$$ Is the porosity parameter

$$B = \frac{q}{c\rho Cp}$$ Is the dimensionless heat generator

Numerical solution of the equation (7) and (8) we apply the technique

$$f(\eta) = \sum_{i=0}^{\infty} (Ha^2)^i f_i(\eta)$$

$$\theta(\eta) = \sum_{j=0}^{\infty} (Ha^2)^j f_j(\eta)$$

…. (10)

Substitute the equation (10) in equation (7) and (8), equating the coefficient of like powers of Ha^2, we get

$$f_0'^2 - f_0''' - f_0 f'' - mf_0' = m\delta + \delta^2$$

$$\frac{1}{\Pr}\theta_0'' + f_0\theta_0' = -B\Pr\theta_0$$

…. (11)

$$f_1''' - 2f_0 f_1' + f_0 f_1'' + f_1 f_0'' - mf_1' = 0$$

$$\frac{1}{\Pr}\theta_1'' + f_0\theta_1' + \theta_0' f_1 + Ecf_0'^2 + B\Pr\theta_1 = 0$$

…. (12)

With the boundary conditions are

$$\eta = 0: f_i = 0, f_0' = 1, f_j' = 1, \theta_0 = 1, \theta_j = 0,$$

$$\eta = \infty: f_0' = \delta, \quad f_j' = 0, \quad \theta_i = 0,$$

RESULT AND DISCUSSION:

The velocity profiles against η are plotted for the various value of δ and Ha

Show in figure-1. In this figure we observed that the thickness of the velocity layer decreases $\delta > 1$. It can be seen that the flow has inverted layer stricture when $\delta < 1$ and velocity distribution decreases with increases Ha. $\delta > 1$ The velocity distribution increases with increasing the value of δ and H. The figure-2 represents the temperature distribution for the value δ and Ec i.e. δ =.3 and Ec=.1 the temperature distribution decreases with increases δ and Ec. The fixed value of δ, Pr, and Ec the temperature distribution increases with increasing the value of Ha.

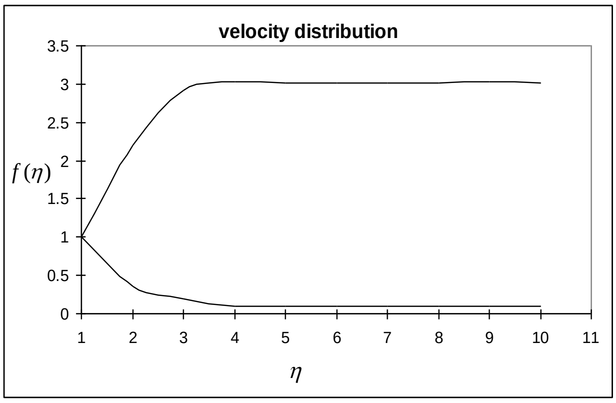
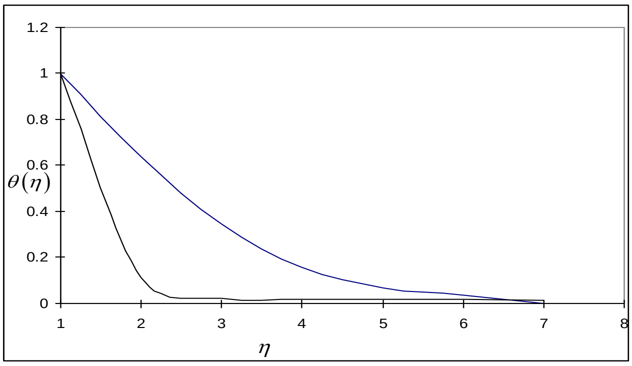


Figure-1 velocity distribution against η



Temperature distribution against η for the various values δ and Ha with Pr=.06 and Ec=0.1.

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