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ANALYTICAL STUDY FOR THE BOUNDARY LAYER FLOW IN THE PRESENCE OF HEAT TRANSFER THROUGH A POROUS MEDIUM

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Abstract

In this paper we study a problem of the boundary layer flow through a porous media in the presence of heat transfer. Here we consider high porosity bounded by a semi-infinite horizontal plate. The main aim of this study is to point out local similarity transformations for the boundary layer flow, through a homogeneous porous medium. Here we applying finite difference schemes to find out the numerical solutions of the problem. The free stream velocity and the temperature far away from the plate are exponential function of variables.

***Keywords**:-Infinite Plate, Porous Medium, Finite Difference Scheme.*

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Introduction:-

The problem of the boundary layer flow through porous medium in the presence of heat transfer with the use of local similarity transformations has been investigated. Patankar [1980] have investigated the effect of fluid flow past an hemisphere with heat transfer. Neild and Bejan [1998] is studied the effect of the convection in porous media. Yang and Chang [2000] have studied the flow and heat transfer in a curved pipe with periodically varying curvature. The free stream velocity is constant and the temperature far away from the plate are exponential function of variable. Acharya and Singh (2000) studied the effect of magnetic field on the force convection and mass transfer flow through porous medium with constant suction and constant heat flux. Ahmed, Sharma et. al (2005) discussed free convective MHD flow and heat transfer through porous medium between two long way walls. Ahmed and Sharma (1997) analysed three dimensional free convective flow of an incompressible viscous fluid through a porous medium with uniform free stream velocity. Ambedkar and Rai (2004) presented a problem on numerical solution of free convection effects of MHD Stoke's problem. Chiiti and Prasad (2006) analysed free convection flow of heat and mass transfer past a vertical porous plate. Ferdows et. al (2005) discussed similarity solution for MHD flow through vertical porous plate with suction. Jaiswal and Soundalgekar (2005) investigated transient forced and free convection flow of dissipative fluid with mass transfer past an infinite vertical plate with constant heat flux. Kumari and Nath (2004) discussed transient MHD rotating flow over a rotating sphere in the vicinity of the equator. Raju et. al (1984) analysed a formulation of combined force and free convection past horizontal and vertical surface. Sattar (1992) studied free and forced convection flow through a porous medium near the leading edge. Sattar (1993) presented a free and forced connection boundary layer flow through a porous medium with large suction. Singh and Dikshit (1988) discussed hydro magnetic flow past a continuously moving semi-infinite plate for large suction. Singh et. al (2008) analysed computational study of hydro magnetic effects on the viscous in compressible dissipative fluid past an infinite vertical plate. Soundalgekar and Thakkar (1977) studied MHD forced and free convectional flow past a semi-infinite plate. Tomar et. al (2009) discussed a numerical study of the three dimensional coquette MHD flow through a porous medium with heat transfer.

The main purpose is to point out local similarity transformations for the boundary layer flow through a porous medium. We assuming that the porosity is bounded by a semi-infinite horizontal plate. Similarly, transformations are the transformation in which n-independent variable of the system of partial differential equations can be converted into a system with n-1 independent variables. The free stream velocity is constant a monomial or a polynomial and the temperature far away from the plate is constant. Here we use finite difference techniques to find out of the numerical solution of the problem.

Governing Equations

We consider an viscous incompressible fluid through a porous medium with high porosity which is bounded by a semi infinite horizontal plate in the presence of heat transfer.

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The flow is governed by the equations

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

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=-\frac{1}{\rho}\frac{\partial p}{\partial x}+\upsilon\frac{\partial^2 u}{\partial y^2}-\upsilon\frac{\gamma}{k}u-C\gamma^2u^2 \qquad (2)$$

$$u\frac{\partial \theta}{\partial x}+v\frac{\partial \theta}{\partial y}=\frac{C_t}{\rho C_p}\frac{\partial^2\theta}{\partial y^2} \qquad (3)$$

Where [$C_t= (1-\gamma)C_s+\gamma C_f$], C_t is the thermal conductivity and C_s is the conductivity of the solid and C_f is the conductivity of the fluid, $\gamma$is the porosity, C Forchheimer ' s inertia coefficient, *k* the permeability of the porous medium, θ is temperature of the fluid.

The boundary conditions of the problem are

$$\left.\begin{matrix} u=0, v=0, \theta=\theta_{C,} \quad at\ y=0 \\ u\to U_f,\ \ \theta\to\theta_\infty, \quad as\ \ y\to\infty \end{matrix}\right\} \qquad (4)$$

Where U_f, is the free stream velocity , θ_C the constant temperature of the horizontal plate, θ_C the constant temperature of the horizontal plate, θ_∞ the temperature of the fluid far away from the plate.

In the free stream velocity equation (2) becomes

$$U_f\frac{dU_f}{dx}=-\frac{1}{\rho}\frac{\partial p}{\partial x}-\upsilon\frac{\gamma}{k}U_f-C_{\gamma^2}U^2{}_f \qquad (5)$$

Now from equation (2) and (5) we get

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=\upsilon\frac{\partial^2 u}{\partial_{y^2}}+\upsilon\frac{\gamma}{k}\left(U_f-u\right)+C_{\gamma^2}\left(U_f^2-u^2\right)+U_f\frac{dU_f}{dx} \qquad (6)$$

Equations are non-dimensional by using

$$\left.\begin{matrix} x^*=\frac{U_0}{\upsilon}x,\ \ y^*=\frac{U_0}{\upsilon}y,\ \ u^*=\frac{u}{U_0} \\ v^*=\frac{v}{U_0},\ \ U_f^*=\frac{U_f}{U_0},\ \ \theta^*=\frac{\theta-\theta_C}{\theta_C} \end{matrix}\right\} \qquad (7)$$

Substituting these variables in in equation (1), (3) and (6) (after dropping the astrics) we get

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \qquad (8)$$

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}=\frac{\partial^2 u}{\partial_{y^2}}+U_f\frac{dU_f}{dx}+\alpha\left(U_f-u\right)+\beta(\left(U_f^2-u^2\right) \qquad (9)$$

$$u\frac{\partial \theta}{\partial x}+v\frac{\partial \theta}{\partial y}=\frac{1}{P_r}\frac{\partial^2\theta}{\partial y^2} \qquad (10)$$

Where, $\alpha=\frac{}{U_0^2k}, \beta=\frac{}{U_0}$

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$$P_r = \frac{}{C_t}$$

The corresponding boundary conditions becomes,

$$\left.\begin{array}{l} u = 0,\ \ v = 0,\ \ \theta(0) = 0,\ \ at\ y = 0 \\ u \rightarrow U_f,\ \ \theta \rightarrow \theta_\infty(x)\ \ \ as\ \ \ \ \ y \rightarrow \infty \end{array}\right\} \quad (11)$$

Now introducing the transformations

$s = ye^{\left(\frac{m}{2}\right)x}, \qquad u = e^{mx} f_1(s)$

$v = e^{\left(\frac{m}{2}\right)x}\ f_2(s), \qquad U_f = ke^{mx}$

$\theta = e^{mx} f_3(s), \qquad \theta_\infty = \lambda e^{mx}$

Here, *m*, *k*, λ are constant

In equations (8)-(10) we get the following local similarity system of ordinary differential equations

$$\left(\frac{m}{2}\right) s f_1' + f_2' + m f_1 = 0 \quad (12)$$

$$f_1'' - m f_1^2 - \left(\frac{m}{2}\right) s f_1' f_2 + \alpha^*(k - f_1) + \beta(k^2 - f_1^2) = 0 \quad (13)$$

$$m f_1 f_3 + s f_1 f_3' \left(\frac{m}{2}\right) + f_2 f_3' = \frac{1}{P_r} f_3'' \quad (14)$$

Here primes denotes differentiation with respect to s and $\alpha^* = \alpha / e^{mx}$.

Now the boundary conditions (11) becomes

$$\left.\begin{array}{c} f_1(0) = 0,\ \ f_2(0) = 0, \qquad f_3(0) = 0 \\ f_1(\infty) = k, f_3(\infty) = \lambda \end{array}\right\} \quad (15)$$

Result and Discussion

Here we observe the local similarity transformations for the boundary layer flow through a homogeneous porous medium ,which is bounded by a semi infinite horizontal plate in the presence of heat transfer. Now we solve the differential equations(12),(13)and (14) using numerical techniques with the boundary conditions and compare results with the solution of the differential equations (8),(9) and (10) using boundary conditions.

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