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Effects of Variable Viscosity on Flow Over A Porous Wedge.

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Abstract

An analysis was carried out to study the variable viscosity effect on flow in a viscous fluid over a porous wedge. The wall of the wedge is embedded in a uniform Darcian porous medium to allow for injection or suction. The governing equations are written into a dimensionless form by a similarity transformation. The transformed ordinary differential equation is solved analytically and the effect of parameters on it is shown graphically.

Keywords: Flow, wedge, viscosity.

1.0 Introduction

Flow transfer through porous wedge has several practical applications such as transpiration, crude oil extraction, the cooling of an infinite metal in a cooling path. The study of such process is useful for improving a number of chemical technologies such as polymer production. In metallurgical process involving the cooling of continuous filaments by drawing them through an electrically conducting fluid subject to a magnetic field, the rate of cooling can be controlled (variable viscosity effect) and final products of desired characteristics can be achieved.

Many researches have been made in this area. Kafousssias and Nanoussa [1] studied the effects of temperature dependent viscosity on free forced convection laminar boundary layer flow past a vertical isothermal flat plate. The effect of heat and mass transfer on a laminar boundary layer flow over a porous wedge was studied by [2], while**[3]** studied MHD flow of a uniformly stretched vertical permeable membrane in the presence of zero order reaction and quadratic heat generation and they concluded that temperature field and velocity field depend heavily on thermal Grashof number, heat generation or absorption, magnetic induction, chemical reaction parameters and reaction order. In this work, we considered a mixed convection flow and the effects of variable viscosity were considered on it over a porous wedge. It is believed that the result will not only provide useful information for application, but also serve as a complement to other previous studies.

Nomenclature

V is the velocity component of fluid
U is the flow velocity of fluid away from the wedge
Y is the transverse coordinate
T is the temperature of the fluid
T_w is the temperature far away from the wall
α is the thermal diffusivity
Pr is the prandtl number.

2.0 Mathematical Formulation

Consider a steady, laminar transfer by a mixed convection flow over a wedge embedded in a porous medium. The fluid is assumed to be Newtonian and its property variation due to temperature is limited to viscosity and density. It is also assumed that the viscous dissipation and joule heating effects are negligible and thermo physical properties are assumed to be

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constant except density. The equations that describe the physical properties are:

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

$$\frac{v\partial T}{\partial y} = \alpha \frac{\partial^2 T}{\partial y^2} + Q(T_\infty - T) \tag{2}$$

The boundary conditions are

$$v(0) = v_0,\ T(0) = T_w,\ T(\infty) = T_\infty \tag{3}$$

The term Q ($T_\infty - T$) is assumed to be the amount of heat generated per unit volume. Q is a constant which can be positive or negative. When the wall temperature T_w exceeds the free stream temperature T_∞, the source term represents the heat source when Q < 0 and sink when Q > 0.

3.0 Method Of Solution

We transform equation (2) to ordinary differential equation using the following dimensionless variables

$$\eta = y\sqrt{\frac{(1+m)x}{2vU}} \tag{4}$$

$$\theta = \frac{T - T_\infty}{T_w - T_\infty} \tag{5}$$

$$pr = \frac{v}{\alpha} \tag{6}$$

$$S = v_o\sqrt{\frac{(1+m)x}{2vU}} \tag{7}$$

$$Y = y_0\left(\frac{v}{v_0}\right) \tag{8}$$

Now, equation (2) becomes:

$$\frac{d^2\theta}{d^2 y} - \frac{pr}{s}\frac{d\theta}{dy} - Q\left(\frac{v_0^2}{\alpha s^2}\right)\theta = 0 \tag{9}$$

solving the equation (9) by seeking its complementary and particular solutions we have

$$\theta(\eta) = 0.5\left\{\frac{pr}{s} \pm \sqrt{\left(\frac{pr}{s}\right)^2 + \left(4\frac{Qv_0}{prs^2}\right)}\right\}\eta \tag{10}$$

The results are shown in the figures 1, 2, 3, 4

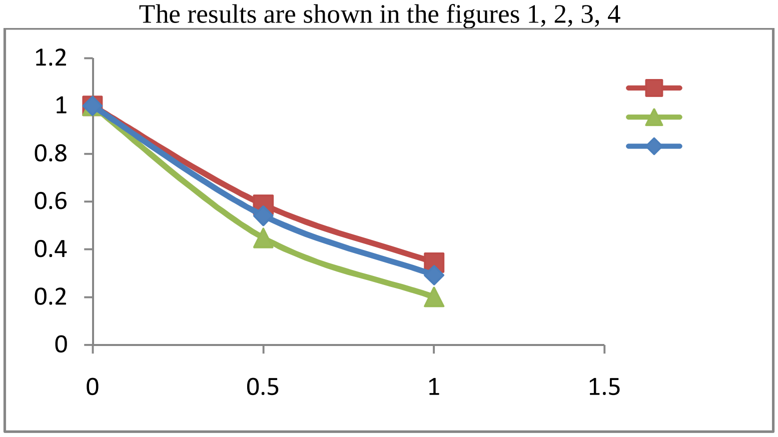

Figure1: Temperature distribution for various values of Pr when Suction is greater than zero. (Hint: a1=Pr=0.9, a3=Pr=0.71, a0=Pr=0.5).

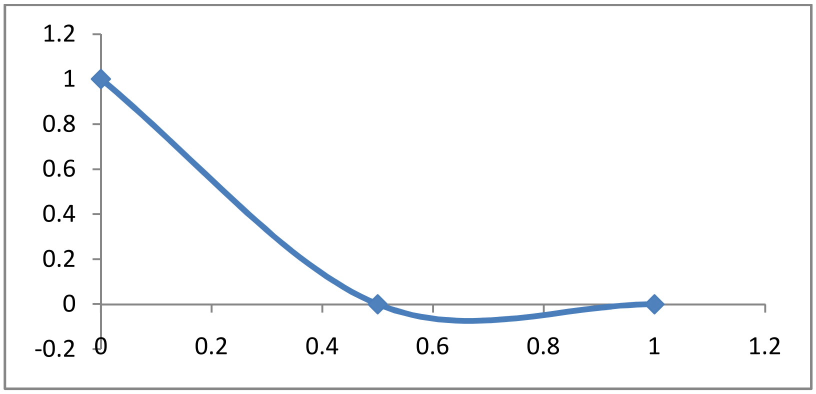

Figure 2: Temperature distribution when suction is greater than zero

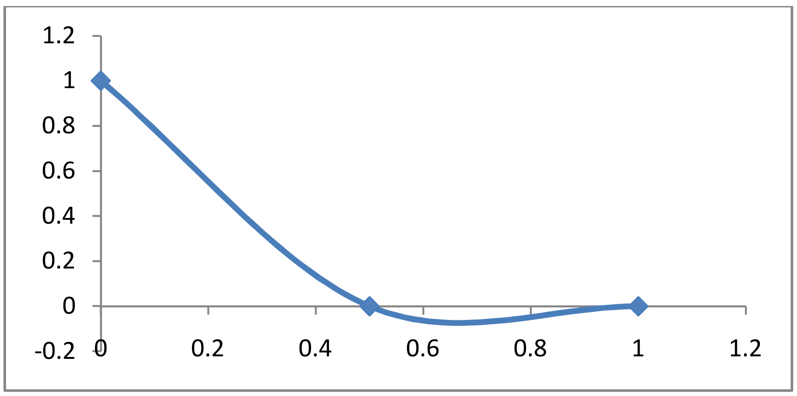

Figure 3: Temperature distribution when suction is less than zero

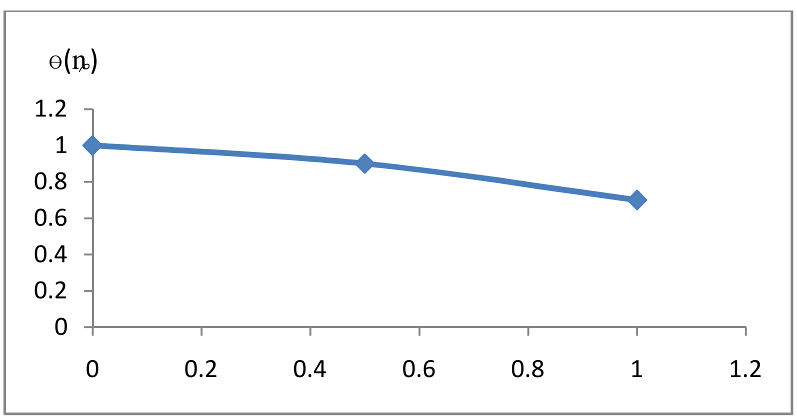

Figure 4: Temperature distribution when suction is equal to zero.

Hint: For figures 1, 2, 3 and 4, x-axis represents the position of graph and y-axis represents temperature profile.

4.0 Discussion Of Results

We have considered in some details the effect of physical parameters S, Pr, V_0, and γ on temperature and viscosity of fluid. **Figure 1** displays the variation of temperature for different values of the Prandtl number. It is observed that the temperature decreases as the Prandtl number increases.

Figure 2 displays the variation of temperature for different values of Suction when the suction is greater than zero for different values of viscosity. We observed that viscosity and temperature depend on each other

Figure 3 depicts the relationship between the two physical parameters when there is no suction and shows that they depend on each other.

Figure 4 depicts the linearity between the two physical parameters. Show that if Suction is equal zero (i.e. no suction); temperature and viscosity depend on each other.

5.0 Conclusion

We have studied the effects of variable viscosity on mixed convection flow over a porous wedge and we are able to show that temperature and viscosity depend on each other when suction is either less or greater than zero and that increases in Prandtl number leads to decrease in temperature.

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