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Variable Thermal Conductivity and Viscosity Flow past a Stretching Porous Surface with Viscous Dissipation through a Porous Medium

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ABSTRACT

In this work, we study variable thermal conductivity and viscosity flow past a porous surface with viscous dissipation through a porous medium. We transformed the governing partial differential equations into ordinary differential equations in terms of a suitable similarity variable. We employed Galerkin weighted residual method to solve the resulting non-linear equations. The results show the effects of variable viscosity parameter, variable thermal conductivity parameters and those of viscous dissipation parameter on the flow system.

Keywords: Weighted residual method; Porous Surface and Viscous Dissipation.

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1.0 INTRODUCTION

Although, the non-Newtonian behavior of many fluids has been recognized for a long time, the science of rheology is still in its infancy in many respects. As such, new phenomena are being discovered on a constant basis with new theories propounded. The study of flow and heat transfer in porous media has received much attention in the last a few decades due to its ever increasing applications in industries and in contemporary technology, particularly in applied geophysics, geology, groundwater flow, food technology, filtration processes, oil reservoir engineering and oil recovery processes. Advancement in computational techniques are making possible much more detailed analyses of complex flow and complicated simulation of the structural and molecular behavior that give rise to non-Newtonian behaviors.

Soundalgekar [1] studied the viscous dissipation effect on unsteady free convective flow past an infinite vertical porous plate with constant suction. Soundalgekar and Desai [2] considered the effects of viscous dissipation effect on unsteady free convective flow of an elastic-viscous fluid past an infinite vertical porous plate with constant suction. Anjali and Ganga [3] studied viscous dissipation effects on non-linear MHD flow in porous medium over a stretching porous surface. The effects of variable viscosity, viscous dissipation and chemical reaction on heat and mass transfer flow of MHD micropolar fluid along a permeable stretching sheet in a non-Darcian porous medium was considered by Salem [4]. Motivated by the work of Singh [5], he considered viscous dissipation and chemical reaction effects on flow past a porous surface in a porous medium. Based on this, we considered variable thermal conductivity and viscosity flow past a porous surface with viscous dissipation through a porous medium.

2. GOVERNING EQUATIONS

The governing equations are continuity, momentum and energy equations.

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \tag{2.1}$$

$$u\frac{\partial u}{\partial x}+v\frac{\partial v}{\partial y}=\frac{1}{\rho}\frac{\partial}{\partial y}\left(\mu(T)\frac{\partial u}{\partial y}\right)-\frac{\mu_{ef}}{\rho K(y)} \tag{2.2}$$

$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\frac{1}{\rho c_p}\frac{\partial}{\partial y}\left(k(T)\frac{\partial u}{\partial y}\right)+\frac{\mu(T)}{\rho c_p}\left(\frac{\partial u}{\partial y}\right)^2 \tag{2.3}$$

$$u\frac{\partial C}{\partial x}+v\frac{\partial C}{\partial y}=D\frac{\partial^2 u}{\partial y^2}-k_1 C \tag{2.4}$$

Together with the boundary conditions

$$\mathrm{u}=\mathrm{ax}^{\mathrm{m}}, v=-v_m, T=T_w(x)=T_0x^m+T_\infty, C=C_w(x)=C_0x^m+C_\infty, at\ \ y=0$$

$$u=0,\ T\to T_\infty, C\to C_\infty, at\ \ y\to\infty \tag{2.5}$$

where k -Thermal conductivity, $\rho - Density$, C_p -Specific heat at constant pressure,

μ -Dynamic viscosity, u, v are the dimensional velocity component in the horizontal and vertical directions, k_0 – The thermal conductivity of the fluid, γ -Thermal expansion exponent, T -Temperature within the boundary layer, $T_1,\ T_2, ...T_\infty$ -Temperature at the plate, θ -Dimensionless temperature, ζ – is the stream function.

Following [6] we introduce the following similarity transformations

$$\varsigma(x,y)=\left[\frac{2vxU(x)}{1+m}\right]^{1/2} f(\eta), \eta=\left[\frac{(1+m)U(x)}{2vx}\right]^{1/2} y, v_w(x)=+\lambda\sqrt{\frac{va(1+m)}{2}}x^{m-\frac{1}{2}} \tag{2.6}$$

where $\lambda > 0$ for suction at the plate, the velocity components are given by

$$u=\frac{\partial\zeta}{\partial y}, v=-\frac{\partial\zeta}{\partial x}, \theta=\frac{T-T_\infty}{T_w-T_\infty}, C=\frac{C-C_\infty}{C_w-C_\infty} \tag{2.7}$$

Substituting (2.7) into (2.1) -(2.4), we obtain

$$f'''e^{-M\theta} + ff'' - \psi^{-1} f' - f'^2 = 0 \quad (2.8)$$

$$e^{-\gamma\theta}\theta'' + \Pr f\theta' - 2\Pr f'\theta + Ec\Pr f''^2 = 0 \quad (2.9)$$

$$\phi + Scf\phi' - Sc\phi f' - \alpha Sc\phi = 0 \quad (2.10)$$

$$f(0)=1,\ f(\infty)=0,\ \theta(0)=1,\theta(\infty)=0,\phi(0)=1,\phi(\infty)=0 \quad (2.11)$$

$$\Pr = \frac{\mu_0 \rho c_P}{v}, Ec = \frac{a^2}{c_P T_0}, Sc = \frac{v}{D}, \psi = \frac{K}{D}, \alpha = \frac{x^2 k_1}{v} \quad (2.12)$$

3. NUMERICAL SOLUTION

We now proceed to solve equations (2.8) and (2.9) subject to (2.10) numerically using Galerkin-Weighted Residual Method as follows:

let $f = \sum_{i=0}^{2} A_i e^{(-i/5)r}, \theta = \sum_{i=0}^{2} B_i e^{\left(-i/4\right)r}, \phi = \sum_{i=0}^{2} C_i e^{\left(-i/4\right)r}$

The results are presented in figures 1-3

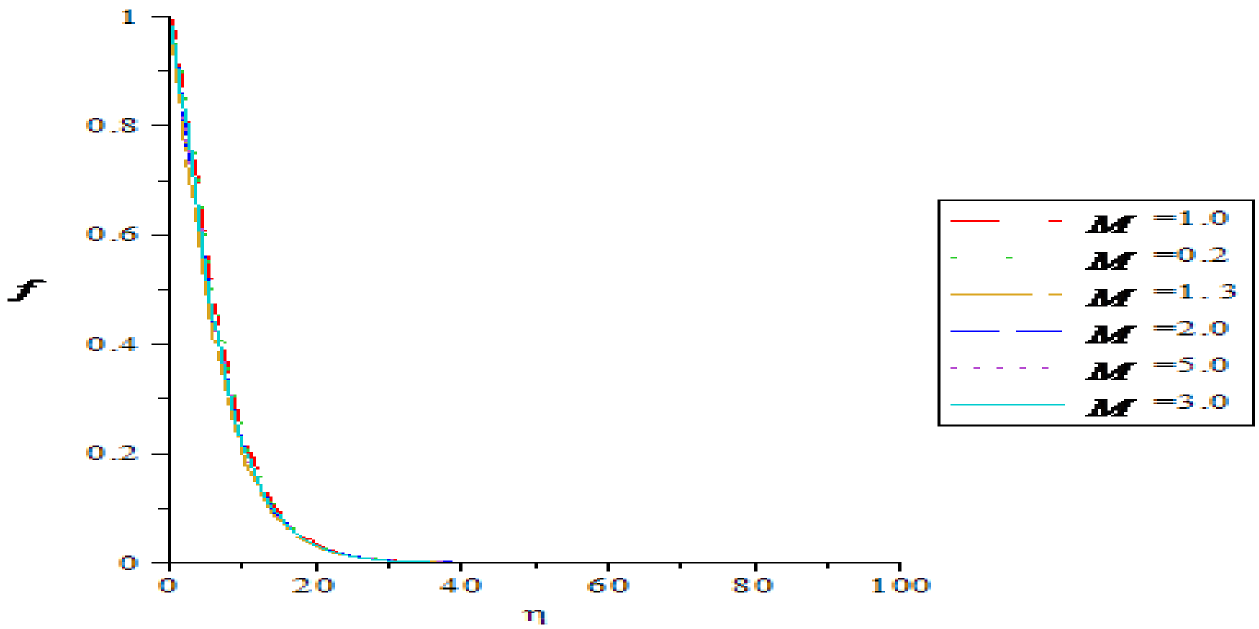

Figure1: Graph of the velocity function f for various values of $M = 0.5, \Pr = k_0 = 1.0, \psi \geq 0.1$

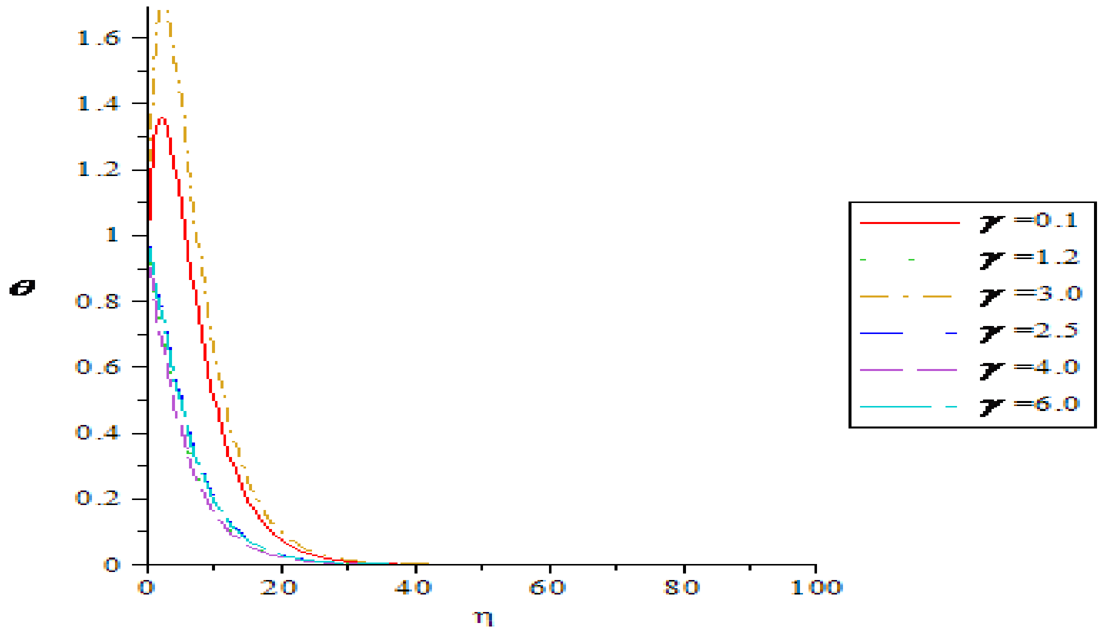

Figure 2: Graph of the temperature function θ **for various values of** $\gamma = 0.5, \Pr = k_0 = 1.0, Ec \geq 0.1$

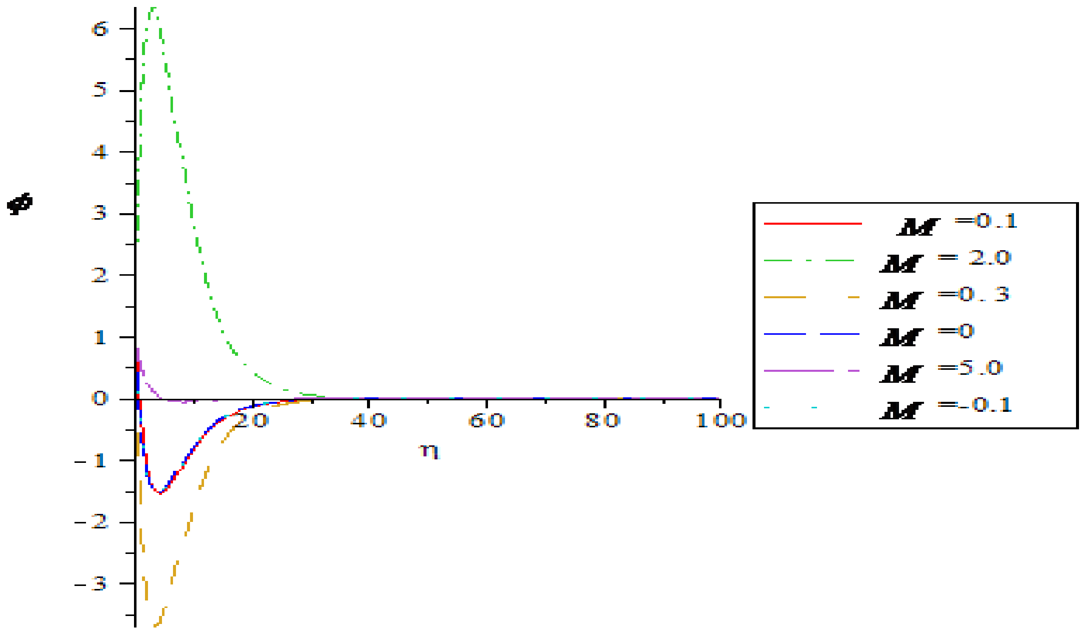

Figure 3: Graph of the concentration function ϕ **for various values of** $M = 0.5, Sc \geq 0, \alpha = k_0 = 1.0, \psi \geq 0.1$

4. Discussion of Results/Conclusion

From Figure 1 the result shows that the velocity profile decreases with increase in variable viscosity parameter M and each of $\Pr = 0.71; \psi$ *and* Sc parameters. From Figure 2 the result shows that the temperature profile decreases with increase in γ variable thermal conductivity parameter and each of $\Pr = 0.71; \psi; Ec$ *and* Sc parameters. From Figure 3 the result shows that the concentration profile decreases with increase in variable viscosity parameter M and each of $\Pr = 0.71; \psi; Ec, \alpha$ *and* Sc parameters.

Conclusion

A comprehensive set of graphical results for velocity profile, temperature and concentration profile are discussed. It is observed that velocity and the temperature profiles decreases as variable thermal conductivity and viscosity parameters increases. It is noted that the concentration profile decreases as variable viscosity and chemical reaction parameters

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increases. For engineering purpose, the results of this problem are of great interest in automobile engine, for the safety of life and proper handling of the materials during processing.

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