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EFFECT OF SUCTION PARAMETER ON VISCOSITY IN BOUNDED MHD BOUNDARY LAYER FLOW OVER A MOVING VERTICAL CYLINDER

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ABSTRACT

We examined a Newtonian flow which gave insight into the theory of magneto-hydrodynamic (MHD). The flow problem considered shown that viscosity behave in three dimension depending on how the suction parameter depends on it.

Keywords: *Newtonian flow, Magnetic-hydrodynamic (MHD), Viscosity, Boundary Layer, Suction parameters*.

INTRODUCTION

Magneto-hydrodynamic is of great important to man since it pervades nearly every scientific and engineering discipline. Most of the processes occurring in nature starting from minute movement on earth to the formation of galaxies are involved, understanding the dynamic of the fluid motion provide changes to utilize and control the fluid motion in various natural and scientific systems for the benefit of the society. Shear stresses are developed between layers of fluid moving with different velocities as a result of viscosity and the interchange of momentum due to turbulence causing particle of fluid to move from one layer to another, but outside boundary layer in a real fluid can be treated as it were an ideal fluid, which is assumed to have no viscosity and in which there are no shear stresses. Meanwhile, if the fluid velocity is high and its velocity low, the boundary layer is comparatively thin, and the assumption that a fluid can be treated as an ideal fluid greatly simplifies the analysis of the flow and still leads to useful results [3]. Meanwhile, the theory of Newton law of viscosity has been in existence for decades. Many scientists have built on the work of Newton. Amongst are **Attia [2]** which studied the effect of variable viscosity on the transient couette flow of dusty fluid with heat transfer between parallel plates. The fluid is acted upon by a constant pressure gradient and an external uniform magnetic field is applied perpendicular to the plates. The parallel plates are assumed to be porous and subjected to a uniform suction from above and injection from below. Also, **Muharram and Ahmed [5]** investigated the pressure gradient flow rate relationship for steady-state non-isothermal pressure driven flow of a non-Newtonian fluid in a channel including the effect of viscous heating. In the work of **Maryem and Adnane [4],** they studied a similarity solution of MHD boundary layer flow over a moving vertical cylinder; where the steady flow of an incompressible electrically conducting fluid over a semi-infinite moving vertical cylinder in presence of a uniform magnetic field.

Mathematical Formulation

For the purpose of this work, following Maryem and Adnane [4] we consider the following governing continuity and momentum equation of the form

$$\frac{\partial(ru)}{\partial x}+\frac{\partial(ru)}{\partial r}=0 \tag{2.1}$$

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial r}=\frac{u}{r}\frac{\partial}{\partial r}\left(r\frac{\partial u}{\partial r}\right)+u_{\rho}\frac{du_{\rho}}{dx}+\frac{\sigma B_0^2}{\rho}(u_{\rho}-u) \tag{2.2}$$

with initial and boundary conditions

$$u(R,x)=u_w x, v(R,x)=-v_w, u(\infty,x)=u_{\rho}(x) \tag{2.3}$$

where u_{ρ} s the external velocity, u is the velocity component in x-direction, v is the velocity component in r-direction, v is the kinematic viscosity, p is the fluid density, σ is the electric conductivity of the fluid, r is the radial coordinate, R is the radius of the cylinder and v_w is the suction/infection parameter

We introduce stream function of the form

$$ru=\frac{\partial\psi}{\partial r} \qquad where \qquad u=\frac{1}{r}\frac{\partial\psi}{\partial r}$$

and

$$rv=\frac{-\partial\psi}{\partial r}$$

into (2.1) to become

$$\frac{1}{r^2}\frac{\partial\psi}{\partial r}\frac{\partial^2\psi}{\partial x\partial r}+\frac{1}{r^3}\frac{\partial\psi}{\partial x}\frac{\partial\psi}{\partial r}-\frac{1}{r^2}\frac{\partial\psi}{\partial x}\frac{\partial^2\psi}{\partial r^2}=\frac{\upsilon}{r^3}\frac{\partial\psi}{\partial r}-\frac{\upsilon}{r^2}\frac{\partial^2\psi}{\partial r^2}+\frac{\upsilon}{r}\frac{\partial^3\psi}{\partial r^2}+$$

$$u_{\rho}\frac{du_{\rho}}{dx}+\frac{\sigma B_0^2}{\rho}\left(u_{\rho}-\frac{1}{r}\frac{\partial\psi}{\partial r}\right) \tag{2.4}$$

$$\frac{\partial\psi}{\partial r}(R,x)=Ru_w x, \frac{\partial\psi}{\partial x}(R,x)=Ru_w \tag{2.5}$$

we seek similarity solutions of the form

$$\psi(r,x)=\sqrt{\frac{vu_{\infty}R}{3}}xf(t) \tag{2.6}$$

where f is dimensionless stream function and

$$t=\sqrt{\frac{u_{\infty}R}{2\upsilon}\left(\frac{r^2-R^2}{R}\right)} \tag{2.7}$$

but

$$k=2\sqrt{\frac{2\upsilon}{u_{\infty}R}} \quad \Rightarrow \frac{2}{k}=\sqrt{\frac{u_{\infty}R}{2\upsilon}} \tag{2.8}$$

using (2.6), (2.7) and (2.8), then (2.4) and (2.5) becomes

$$Kt+2R)f'''+kf''+ff''-f'^2-m(f'-1)+1=0 \tag{2.9}$$

satisfying the boundary condition

$$f(0)=a, f'(0)=b, f''(0)=c \tag{2.10}$$

with

$$a = \frac{\upsilon_w R}{\sqrt{\upsilon u_\infty R}} \quad and \quad b = \frac{u_w}{2u_\infty} \tag{2.11}$$

Method of Solution

System of equation (2.9), (2.10) and (2.11) are transformed into an initial value problem by shooting technique as follows:

Let

$$\begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{pmatrix} = \begin{pmatrix} t \\ f \\ f' \\ f'' \end{pmatrix} \tag{3.1}$$

Differentiating (3.1) to obtain

$$\begin{pmatrix} x_1^1 \\ x_2^1 \\ x_3^1 \\ x_4^1 \end{pmatrix} = \begin{pmatrix} 1 \\ x_3 \\ x_4 \\ \dfrac{-Kx_4 - x_2 x_4 + x_3^2 + M(x_3 - 1) - 1}{kx_1 + 2R} \end{pmatrix} \tag{3.2}$$

Satisfying the initial condition

$$\begin{pmatrix} x_1(0) \\ x_2(0) \\ x_3(0) \\ x_4(0) \end{pmatrix} = \begin{pmatrix} 0 \\ a \\ b \\ c \end{pmatrix} \tag{3.3}$$

where c is the guess value for shooting method

Numerical Solution

A computer program written a Pascal was used to solve the problem (3.2) together with condition (3.3).

The numerical result is presented for

(i) Various values of K, when M=R=1 and $\upsilon_w = 0$

(ii) Various values of K, when M=R=1 and $\upsilon_w < 0$

(iii) Various values of K, when M=R=1 and $\upsilon_w > 0$

where

K is the viscosity, **M** is the magnetic parameter, **R** is the radius of the cylinder and υ_w is the suction parameter

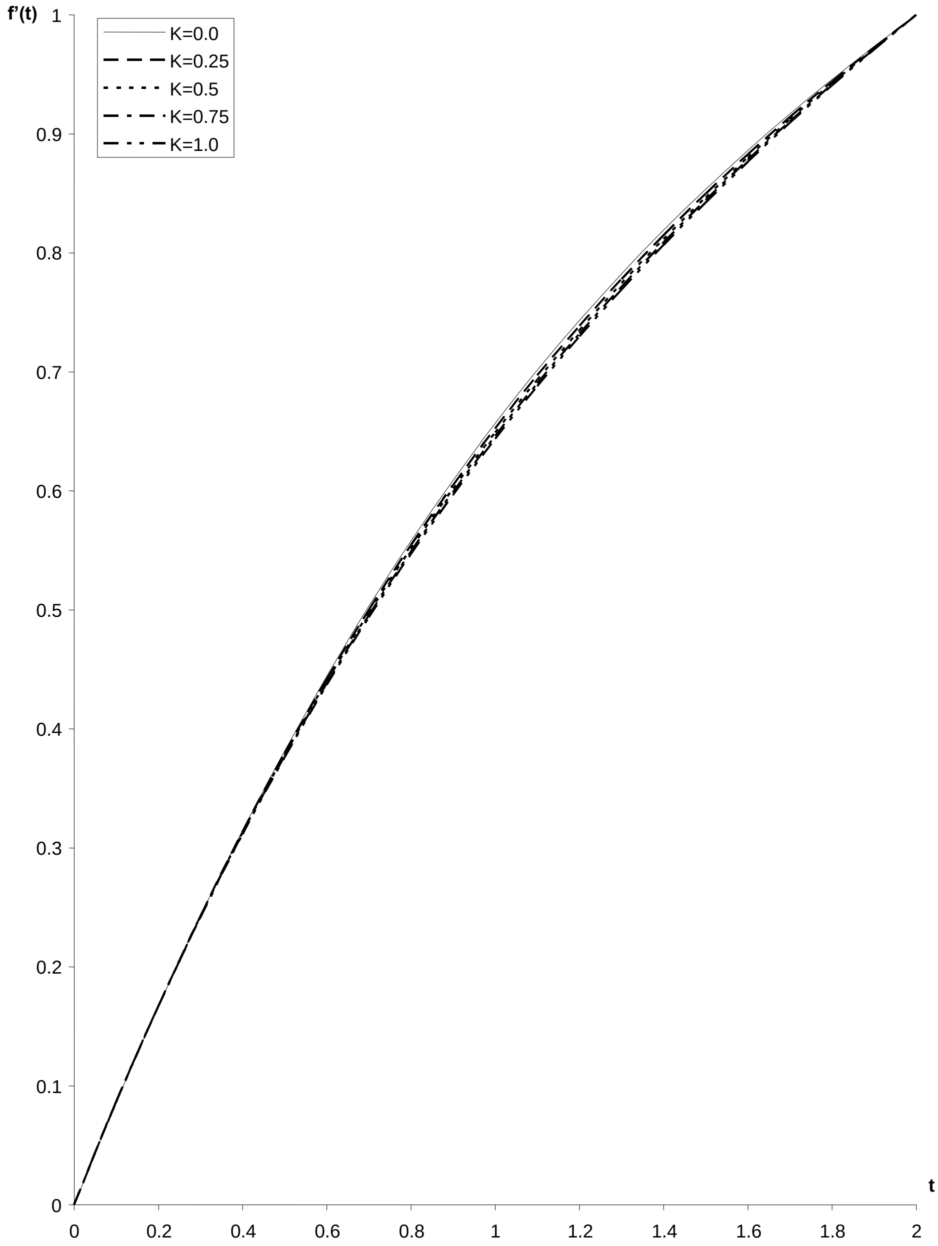

Figure 1: Velocity profile: When v_w=0, M=1, R=1 and at various values of K for equation 2..9

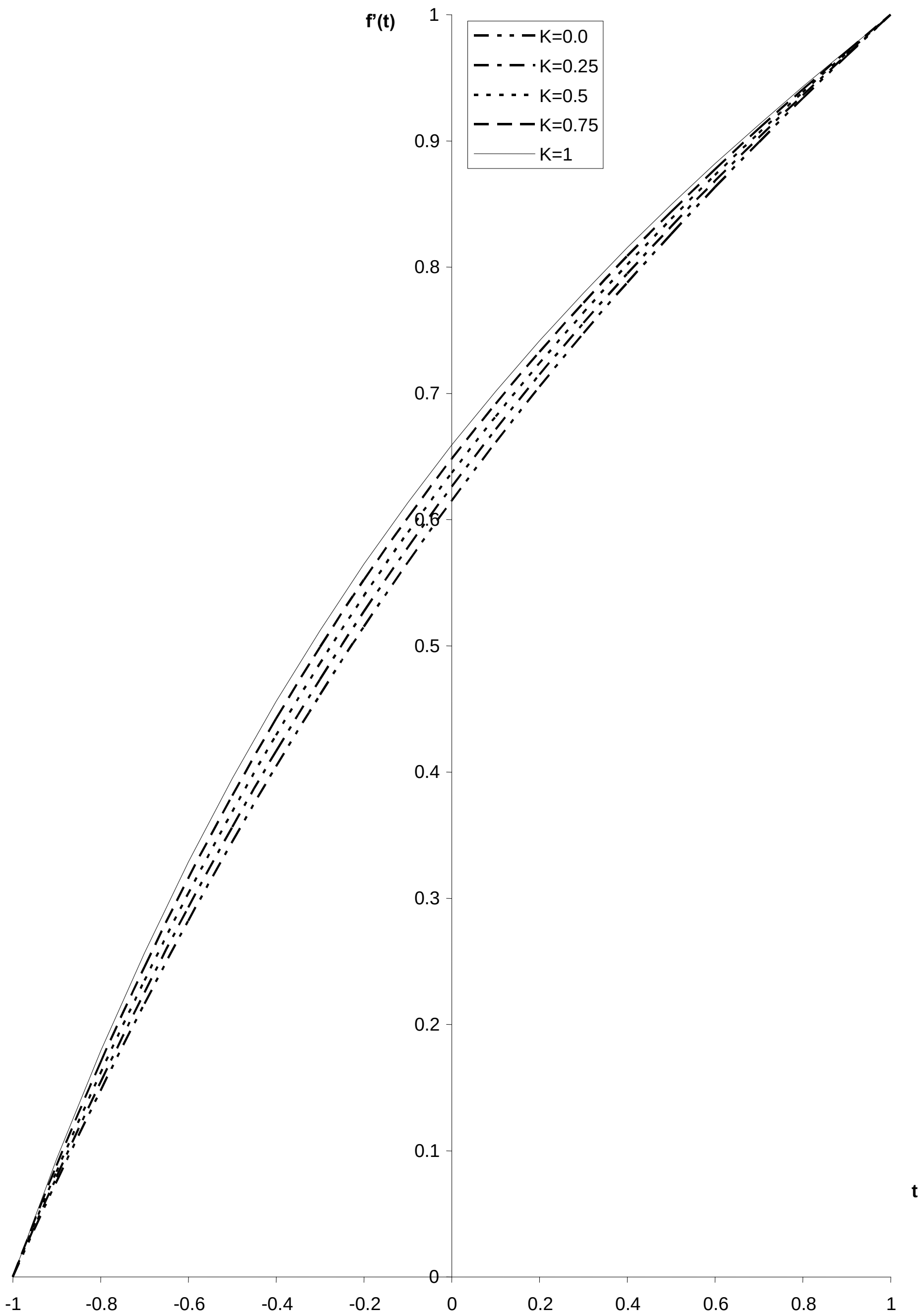

Figure 2: Velocity profile: When v_w<0, M=1, R=1 and at various values of K for equation 2.9

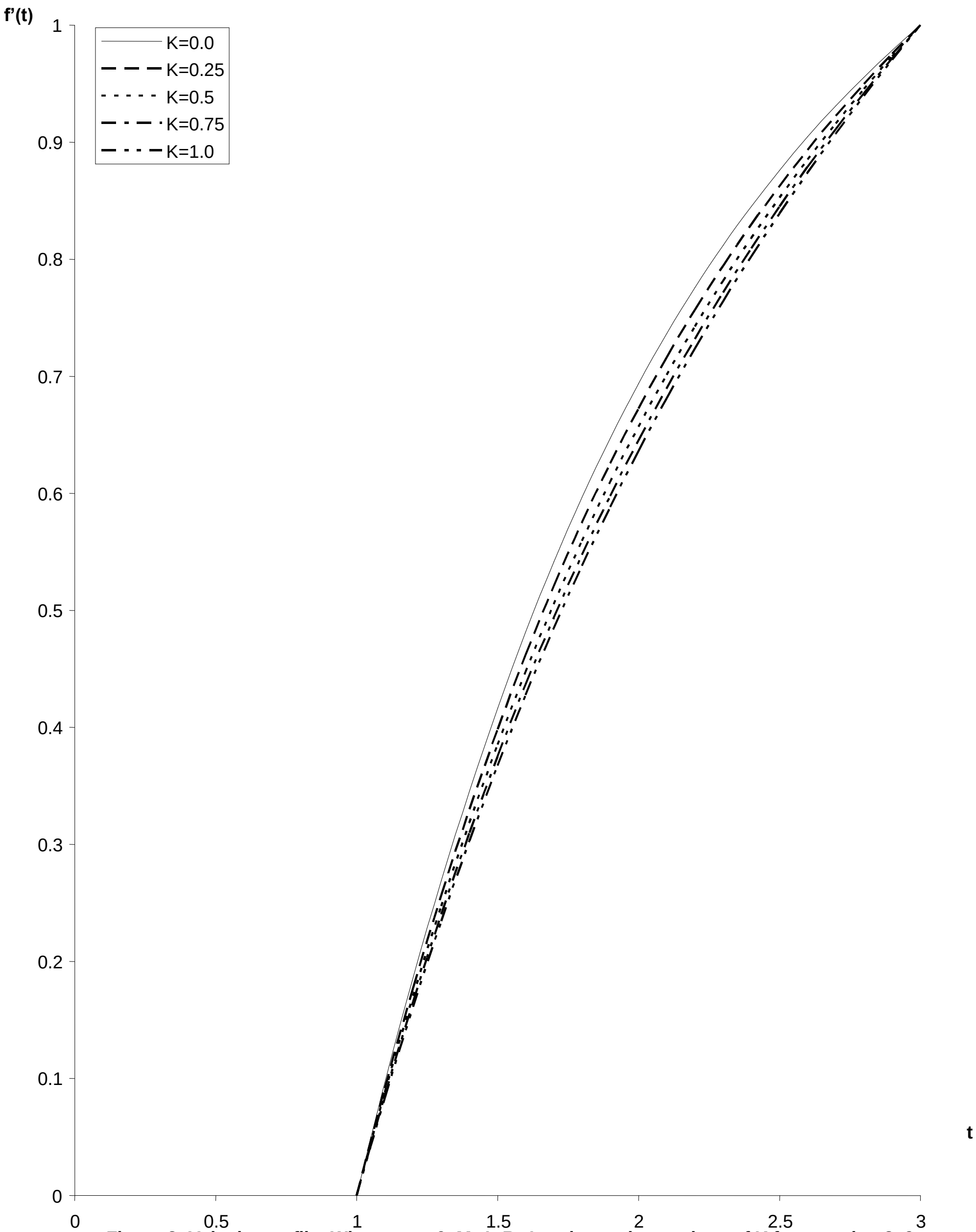

Figure 3: Velocity profile: When v_w>0, M=1, R=1 and at various values of K for equation 2..9

RESULTS AND CONCLUSION

We are able to conclude from the figures above that at fixed value of both magnetic parameter (M) and radius of cylinder (R), when suction parameter υ_w is less than zero (figure 2), velocity increases with increase in viscosity (K). But, when suction parameter υ_w $\geq$0 (figure 1 and figure 3) as viscosity (K) increases, velocity decreases.

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