

# Effects of Variable Viscosity on Mixed Convection Flow over a Porous Wedge in The Presence of Chemical Reaction

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**ABSTRACT:** We investigate the effects of variable viscosity and chemical reaction on mixed convection flow in a viscous fluid over a porous wedge. The governing boundary layer equations are resulted into dimensionless form using similarity transformation. The transformed second order equations are solved analytically. The effects of different parameters on the dimensionless concentration profiles are shown graphically.

**Keywords:** Chemical reaction, steady flow, mixed convection, porous wedge, variable viscosity

## INTRODUCTION

The study of heat and mass transfer with chemical reaction is of great practical importance to engineers and scientists because of its almost universal occurrence in many branches of science and engineering. Possible applications of this type of flow can be found in many industries, especially power industry. **Ahmed Sahin [1]** worked extensively on the study of MHD and chemical reaction effects on unsteady flow. Heat and Mass transfer characteristics in a viscous, incompressible and electrically conducted fluid over a semi-finite vertical porous plate in a slip flowing regime. **Mahdy [2]** studied the effect of chemical reaction and heat generation or absorption on double diffusive convection from a vertical truncated cone in porous media with variable viscosity. **Bakr [3]** studied the effect of chemical reaction on MHD free convection and mass transfer flow of micropolar fluid with oscillatory plate velocity and constant heat source in

a rotating frame of reference. **Chamkha *et al* [4]** studied the unsteady MHD free convection flow past an exponentially accelerated vertical plate with mass transfer, chemical reaction and thermal radiation. **El-Sayed *et al* [5]** studied the effect of chemical reaction, heat and mass on non-Newtonian fluid flow through porous medium in a vertical peristaltic tube. **Gireesh Kumar *et al* [6]** worked extensively on the effects of chemical reaction and mass transfer on radiation and MHD free convection flow of kuvshinski fluid through porous medium. **Kandasamy *et al.* [7, 8]** presented an approximate numerical solution of chemical reaction, heat and mass transfer on MHD flow over a vertical stretching surface with heat source and thermal stratification effects and effects of chemical reaction, heat and mass transfer along a wedge with heat source and concentration in the presence of suction or injection. **Nabil *et al* [9]** studied the effect of chemical reaction heat and mass transfer on peristaltic of power-law fluid in an asymmetric channel with wall properties. **Ravikumar *et al* [10]** presented the combined effects of heat absorption and MHD on convective Rivlin-Erichsen flow past a semi-infinite vertical porous plate with variable temperature and suction. **Sandeep *et al* [11]** worked rigorously on the effect of radiation and chemical reaction on transient MHD free convective flow over a vertical plate through a porous media. Also, **Seddek *et al.* [12]** studied the effect of chemical reaction and variable viscosity on hydro magnetic mixed convection heat and mass transfer for Hiemenz flow through porous media has been studied in the presence of radiation and magnetic field. Also, the effect of variable viscosity, chemical reaction, heat and mass transfer on laminar flow along a semi infinite horizontal plate has been analyzed by **Ghaly and Seddeek [13]. Eldabe *et al.* [14]**, studied the flow in boundary layer includes the temperature which dependent on viscosity with thermal-diffusion and diffusion-thermo effects. Also, **Elbarbary *et al.* [15]** studied the effects of variable viscosity and variable thermal conductivity on heat transfer from moving surfaces in a

micro polar fluid through a porous medium with radiation. The aim of this study to investigate the effect of variable viscosity on mixed convection over a porous wedge in the presence of chemical reaction. The governing boundary layer equations were transformed to ordinary differential equation by similarity transformation and the resulting differential equation was solved analytically.

## MATHEMATICAL FORMULATION

The steady, laminar, mixed convection Newtonian fluid flow over a porous wedge, with variable viscosity and in the presence of chemical reaction has been made. The chemical reactions are taking place in the flow and a suction or injection is imposed on the wedge. All fluid properties are assumed to be constant except fluid viscosity Schmidt number and chemical equation parameter. The boundary layer equations are:

$$\frac{\partial v}{\partial y} = 0 \quad (1)$$

$$\frac{V\partial C}{\partial y} = D \frac{\partial^2 C}{\partial y^2} - k_1 c \quad (2)$$

The boundary conditions

$$V(0) = -V_0, C(0) = C_w, C(\infty) = C_\infty \quad (3)$$

Where,

V is the Transverse Velocity

Y is the transverse coordinate

$k_1$  is the rate of chemical reaction

C is the concentration of the fluid

$C_w$  species concentration along the wall

$C_\infty$  species concentration away from the wall

To transform equation 2 to ordinary differential equation we use the following dimensionless variables

$$\phi = \frac{C - C_\infty}{C_w - C_\infty} \quad (4)$$

$$Sc = \frac{\nu}{D} \quad (5)$$

$$Y = y \left( \frac{\nu_0}{\nu} \right) \quad (6)$$

$$\gamma = \frac{k_1 \nu}{\nu_0^2} \quad (7)$$

$$\frac{\partial C}{\partial y} = \frac{dC}{dY} \cdot \frac{dY}{dy} = (C_w - C_\infty) \frac{d\phi}{dY} \left( \frac{\nu_w}{\nu} \right) = \left( \frac{\nu_0}{\nu} \right) (C_w - C_\infty) \frac{d\phi}{dY} = \frac{\partial \phi}{\partial y} \quad (8)$$

and

$$\frac{\partial^2 C}{\partial y^2} = \left( \frac{\nu_0^2}{\nu^2} \right) (C_w - C_\infty) \frac{d^2 \phi}{dY^2} \quad (9)$$

$$\nu \left( \frac{\nu_0}{\nu} \right) (C_w - C_\infty) \frac{d\phi}{dY} = D \left( \frac{\nu_0^2}{\nu^2} \right) (C_w - C_\infty) \frac{d^2 \phi}{dY^2} - k_1 [(C_w - C_\infty)\phi + C_\infty] \quad (10)$$

$$\nu \left( \frac{\nu_0}{\nu} \right) (C_w - C_\infty) \frac{d\phi}{dY} = D \left( \frac{\nu_0^2}{\nu^2} \right) (C_w - C_\infty) \frac{d^2 \phi}{dY^2} - k_1 [(C_w - C_\infty)\phi + C_\infty] \quad (11)$$

Divide through by  $\frac{\nu^2}{D\nu_0^2} \cdot \frac{1}{C_w - C_\infty}$  we have

$$\nu_0 [C_w - C_\infty] \frac{\nu^2}{D\nu_0^2} \cdot \frac{1}{C_w - C_\infty} \frac{d\phi}{dY} = \frac{d^2 \phi}{dY^2} - \frac{\nu^2}{D\nu_0^2 (C_w - C_\infty)} \cdot k_1 [(C_w - C_\infty)\phi + C_\infty] \quad (12)$$

$$\frac{v^2}{Dv_0} \frac{d\phi}{dY} = \frac{d^2\phi}{dY^2} - \frac{v^2}{Dv_0^2(C_w - C_\infty)} \cdot k_1 [(C_w - C_\infty)\phi + C_\infty] \quad (13)$$

$$\frac{v^2}{Dv_0} \frac{d\phi}{dY} = \frac{d^2\phi}{dY^2} - \frac{k_1 v^2}{v_0^2} \cdot \frac{v}{D} \left[ \left( \frac{C_w - C_\infty}{C_w - C_\infty} \right) \phi + \frac{C_\infty}{C_w - C_\infty} \right] \quad (14)$$

Neglecting  $\frac{C_\infty}{C_w - C_\infty}$  and using the  $v = -v_0$ , we obtain

$$-\frac{v}{D} \frac{d\phi}{dY} = \frac{d^2\phi}{dY^2} - \frac{v}{D} \cdot \frac{k_1 v}{v^2} \phi = 0 \quad (15)$$

From (5) and (7), we have;

$$\frac{d^2\phi}{dY^2} + Sc \frac{d\phi}{dY} - \gamma Sc \phi = 0 \quad (16)$$

we seek the solution  $\phi(Y) = e^{my}$ ,  $\phi' = me^{my}$ ,  $\phi'' = m^2 e^{my}$

we have;

$$m^2 + Scm - \gamma Sc = 0 \quad (17)$$

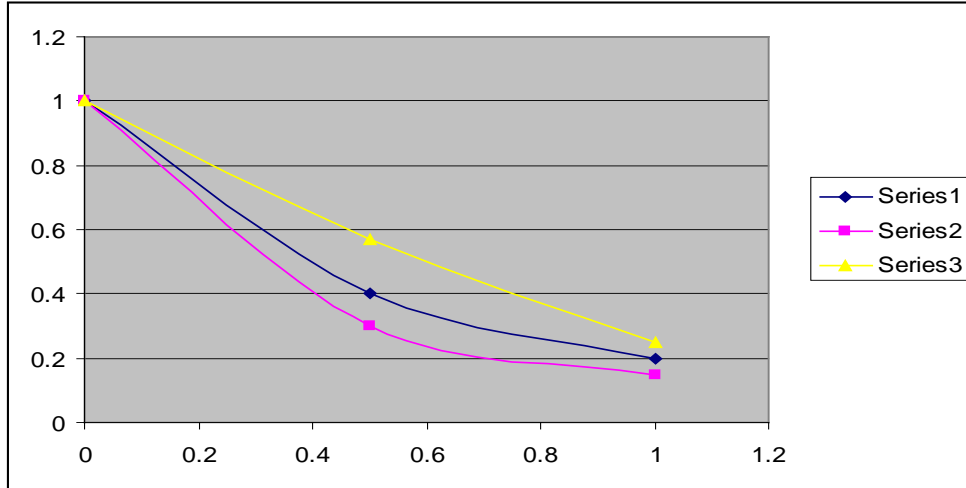
$$\text{and } m = \frac{-Sc \pm \sqrt{Sc^2 + 4\gamma Sc}}{2} \quad (18)$$

using the boundary condition we have

$$\phi(Y) = \exp\left(-0.5(-Sc + \sqrt{Sc^2 + 4\gamma Sc}) Y\right)$$

## RESULTS AND DISCUSSIONS

The computations have been carried out for various values of chemical equation parameter ( $\gamma$ ) and Schmidt number (Sc). The graphical representation of the result is as presented below



$\gamma=1$ , series1  $sc=0.62$ , series 2  $sc=0.5$ , series3  $sc=0.8$

Fig. 1: showing the variation of concentration for different values of Schimdt number and chemical equation parameter=1

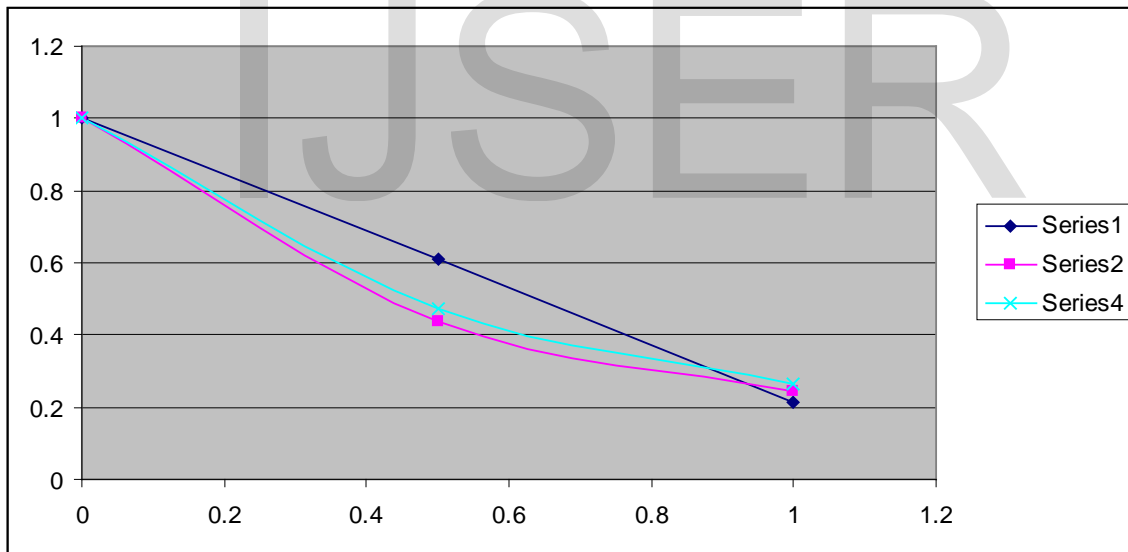


Fig. 2 showing effect of chemical equation parameter at  $\Gamma=1.5$ , series1  $sc=0.62$ , series 2  $sc=0.5$ , series 4  $sc=8$  on concentration distribution.  $\gamma=1$ , series1  $sc=0.62$ , series 2  $sc=0.5$ , series3  $sc=0.8$

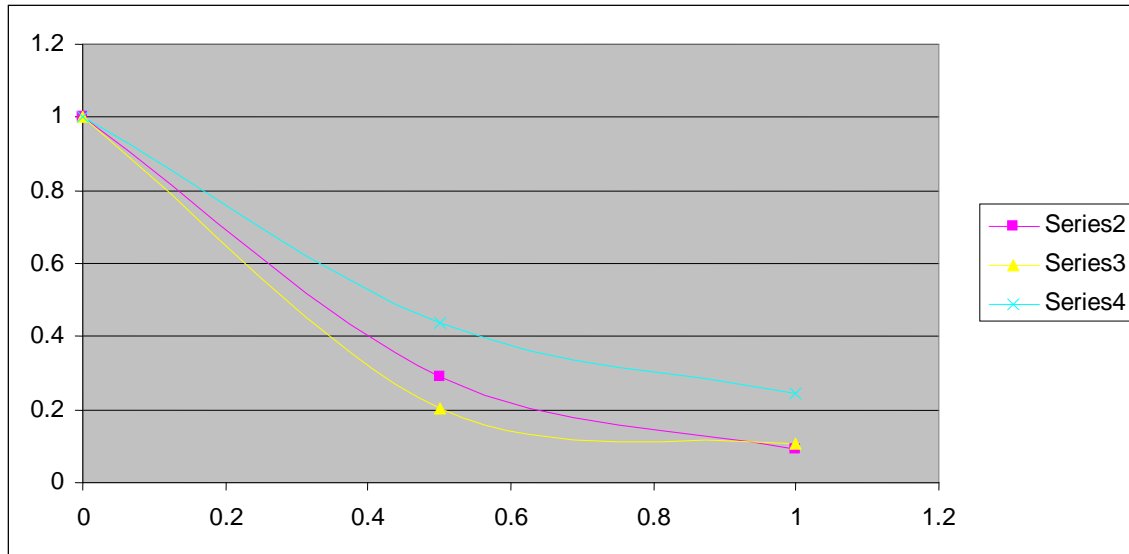


Fig 3 showing effect of chemical equation parameter at  $\Gamma=0.5$  series2  $sc=0.62$ , series3  $sc=0.5$ , series4  $sc=0.8$  on concentration distribution

Figure 1-3 presents the effect of Schmidt number ( $Sc$ ) on concentration and as the chemical equation parameter increases. It shows that magnitude of concentration decreases with increasing values of  $Sc$  and the chemical equation parameter. It is also evident that the concentration of the fluid changes higher value (centre) to lower value at outer boundary, it is hopeful that this work can be used in the mobility of fluid like oil, underground water and be of help to geophysics.

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