Mixed Convection from an Exponentially Stretching Surface in Non-Darcy Porous Medium with Soret and Dufour Effects

Ch. RamReddy

Department of Mathematics, National Institute of Technology, Rourkela-769008, Odisha.

Outline

1. Basic concepts
   - Stretching Surface
   - Porous media
   - Non-Darcy porous media
   - Mixed convection
   - Soret and Dufour effects
2. Mathematical formulation of the proposed problem
3. Results and Discussion

To simplify the analysis the following assumptions are made

1. The flow is in steady state, two-dimensional and laminar.
2. The fluid is incompressible and Viscous.
3. The vertical wall is exponentially stretching.
4. The velocity, temperature and concentrations of the ambient medium are uniform.
5. The porous medium have constant physical properties
6. The flow is moderate, so pressure drop is proportional to the linear combination of fluid velocity and the square of the velocity.
7. Using the Dupuit-Forchheimer relationship and Boussinesq approximations.
8. Employing boundary layer assumptions

In addition, the Soret and Dufour effects are considered.

Governing Equations

The governing equations for the viscous fluid are given by

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

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + \frac{\varepsilon^2 \nu}{K_p}u + \frac{\varepsilon^2 b}{K_p}u^2 = \varepsilon\nu\frac{\partial^2 u}{\partial y^2} + \varepsilon^2 g^* \left(\beta_T(T - T_\infty) + \beta_C(C - C_\infty)\right) \tag{2}$$

$$u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y} = \alpha\frac{\partial^2 T}{\partial y^2} + \frac{DK_T}{C_s C_p}\frac{\partial^2 C}{\partial y^2} \tag{3}$$

$$u\frac{\partial C}{\partial x} + v\frac{\partial C}{\partial y} = D\frac{\partial^2 C}{\partial y^2} + \frac{DK_T}{T_m}\frac{\partial^2 T}{\partial y^2} \tag{4}$$

The boundary conditions are

$$u = u_w(x), \quad v = 0, \quad T = T_w(x), \quad C = C_w(x) \quad at \quad y = 0 \tag{5a}$$

$$u = 0, T = T_\infty, C = C_\infty \quad as \quad y \to \infty \tag{5b}$$

Similarity Transformations

In view of the continuity equation (1), defining the stream function ψ such that

$$u = \frac{\partial \psi}{\partial y} \quad \text{and} \quad v = -\frac{\partial \psi}{\partial x}. \tag{6}$$

Sub.(6) in (2)-(4) and then using the following transformations

$$\left.\begin{aligned}
\eta &= \left(\frac{Re}{2}\right)^{1/2} \frac{y}{L} e^{x/2L}, \\
f(\eta) &= \frac{\psi}{\sqrt{2}\nu} Re^{-1/2} e^{-x/2L}, \\
\theta(\eta) &= \frac{(T(x,y) - T_\infty)}{(T_0 - T_\infty)} e^{-x/2L}, \\
\phi(\eta) &= \frac{(C(x,y) - C_\infty)}{(C_0 - C_\infty)} e^{-x/2L},
\end{aligned}\right\} \tag{7}$$

Reduced Governing Equations

the governing equations become

$$\varepsilon f''' + \left(ff'' - 2f'^2\right) + 2\varepsilon^2 Ri \;\; e^{-3X/2}(\theta + \mathcal{B}\phi) - \frac{2\varepsilon^2}{Da.Re} e^{-X} f' - \frac{2\varepsilon^2 Fs}{Da} f'^2 = 0 \quad (8)$$

$$\frac{1}{Pr}\theta'' + f\theta' - f'\theta + D_f\phi'' = 0 \quad (9)$$

$$\frac{1}{Sc}\phi'' + f\phi' - f'\phi + S_r\theta'' = 0 \quad (10)$$

where $X = \frac{x}{L}$ and remaining parameters have same meaning as in the literature. Boundary conditions (5) in terms of f, θ and ϕ become

$$\eta = 0 : \;\; f(0) = 0, \;\; f'(0) = 1, \;\; \theta(0) = 1, \;\; \phi(0) = 1, \quad (11a)$$

$$\eta \to \infty : \;\; f'(\infty) = 0, \;\; \theta(\infty) = 0, \;\; \phi(\infty) = 0. \quad (11b)$$

Results and Discussions

The system of non-linear ordinary differential equations (8) - (10) together with the boundary conditions (11) are locally similar and solved numerically.

In the present study we have adopted the following default parameter values for the numerical computations: $Pr = 0.71$, $Sc = 0.22$, $Re = 200$, $\varepsilon = 0.6$, $X = 3.0$, $Ri = 1.0$, $Fs = 0.5$, $Da = 0.1$ and $\mathcal{B} = 0.5$ and the maximum value of η at ∞ is 15. These values are used throughout the computations, unless otherwise indicated.

Results and Discussions

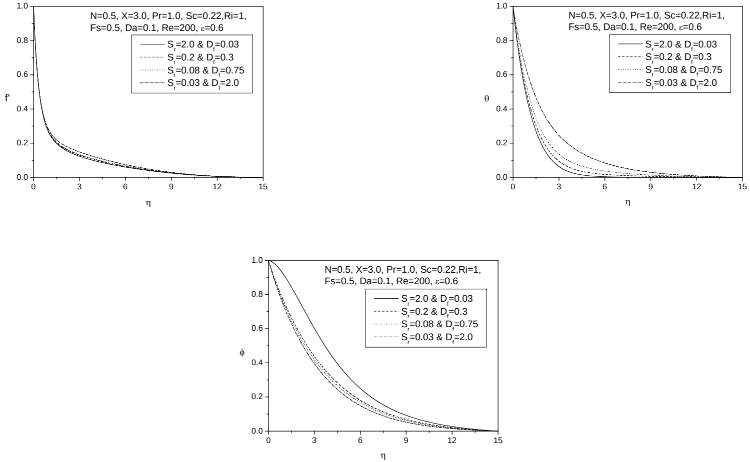

Figure: *(a)Velocity, (b)Temperature and (d)Concentration profiles*

Conclusions

In this paper, we have studied the problem of steady mixed convection from an exponentially stretching surface in a viscous fluid, in the presence of Soret and Dufour effects. Using the local similarity variables, the governing equations are transformed into a set of non-similar parabolic equations and numerical solution for these equations has been presented for different values of parameters. The velocity and temperature profiles increase whereas concentration profile decreases with increase in the value of the Dufour number(or simultaneous decrease in the Soret number).