Thermophoresis and Radiation Effects on MHD Free Convection Flow along a Vertical Plate Immersed in a Porous Medium

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Abstract: Thermophoresis and thermal radiation effects on Magneto-hydrodynamics steady laminar boundary layer flow of a viscous incompressible fluid over a vertical flat plate immersed in a fluid saturated porous medium is studied in this paper. Rosseland approximation for radiative flux is used to model the heat transport phenomena in energy equation. The equations governing the flow concentration and temperature field are reduced to a system of non-linear differential equations. The resultant equations are then solved numerically using fourth-order Runge–Kutta method with shooting technique. The results are obtained and displayed graphically to elucidate the effect of thermophoresis on the various physical flow parameters.

Keywords: Lewis number, Magnentohydrodynamics, Saturated porous media, Temperature gradient, Thermophoresis.

1. Introduction:

Thermophoresis is a phenomenon in which a temperature gradient causes suspended particles to migrate in the direction of decreasing temperature. The study of steady and transient free convection magneto hydrodynamic flows through fluid-saturated porous media is of considerable interest because of its abundant applications in several branches of science and engineering; such as in astrophysical, geo-physical problem, and in developing magnetic generator for obtaining electrical energy at minimum cost, in fibrous materials, in the thermal insulation of buildings, cleaning problems for nuclear reactor safety, clean room and human health topics etc. Thermophoresis plays an important role in the mass transfer mechanism for the chemical vapor deposition process used during the fabrication of optical fibers. Recent books by the authors [1-2] presents a comprehensive account of the available information in the field. Fatemeh Bahadori and Fariborz Rashidi [3] obtained the analytical solution of thermo-diffusion and diffusion-thermo effects on heat and mass transfer in a composite porous media. Joaquın Zueco et al. [4] used Network simulation method to study the effects of thermophoresis particle deposition and of the thermal conductivity in a porous plate with dissipative heat and mass transfer. C. Sulochana and Ramesh H. [5] studied Effect of thermal radiation, thermo-diffusion and radiation absorption on convective heat and mass transfer flow past rotating vertical plate with hall effects. Gurivireddy P et al. [6] applied perturbation method to analyze the Thermal diffusion effect on MHD heat and mass transfer flow past a semi-infinite moving vertical porous plate with heat generation and chemical reaction.

In this paper, simultaneously, we have considered thermophoresis and thermal radiation effect on an unsteady convective heat and mass transfer flow of an incompressible, viscous electrically conducting, heat generating/absorbing fluid along a vertical flat plate embedded in a porous medium with the presence of temperature gradient. In spite of many authors [7] contributed similar works, still there are many important aspects to be concentrated. Hence authors are interested to carry on this investigation.

2. Mathematical Analysis:

Initially, a vertical flat plate, assumed to be at constant temperature T_w and fluid concentration C_w which is embedded in a fluid-saturated porous medium of ambient temperature T_∞ and concentration C_∞, where $T_w > T_\infty$ and $C_w > C_\infty$, respectively in a steady, two dimensional, free convection boundary layer flow. Rosseland approximation is used to describe the radiative heat flux in the energy equation. The effect of thermophoresis is usually prescribed by means of the average velocity, which a particle will acquire when exposed to a temperature gradient. Under these conditions, the physical variables are functions of η and ξ. Then the flow can be shown to be governed by the following equations in non-dimensional form:

$$\theta + N\phi = (M+1)f' \quad (1)$$

$$2\theta'' + f\theta' + \frac{8R}{3}\left[\left(C_p+\theta\right)^3\theta'\right]' = 0 \quad (2)$$

$$\phi'' + \frac{L_e}{2}f\phi' + \frac{kP_rL_e}{C_p+\theta}\left[\theta'\phi' + \phi\theta'' - \frac{\phi}{C_p+\theta}\theta'^2\right] = 0 \quad (3)$$

And the corresponding boundary conditions are

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

$$f' \to 0, \quad \theta \to 0, \quad \phi \to 0 \quad as\ \eta \to 0 \quad (4)$$

Here θ, ϕ are non-dimensional temperature and species concentration respectively. Pr is Prandtl number and Le is the Lewis number for a porous medium, N is the Buoyancy ratio, k is the thermophoretic coefficient, R is the radiation parameter, Cp is the temperature difference. The following special transformations have been used to obtain the above flow governing equations.

$$\theta = \theta(\eta), \phi = \phi(\eta), f(\eta) = \frac{\psi}{\xi^{1/2}}, \eta = \frac{Y}{\xi^{1/2}}, \xi = X$$

3. Numerical computations:

The governing system of equations (1) – (3), subject to boundary conditions (4) has been solved by using Runge-Kutta fourth order method [8] with shooting technique. We have chosen a step size $\Delta\eta = 0.001$ to satisfy the convergence criterion of 10^{-5} in all cases. The value of η_∞, was found in each iteration loop by $\eta_\infty = \eta_\infty + \Delta\eta$ with the maximum value of $\eta_\infty = 10$. The dimensionless velocity profiles, $\phi(\eta)$ wall thermo-diffusion velocity, V_{Dw} is given by

$$V_{Dw} = \frac{kPr}{1+C_p}\theta'(0) \quad (5)$$

4. Results and Discussions:

For the purpose of discussing the results of the flow parameters, numerical calculations are presented in the form of non-dimensional velocity, concentration and wall thermophoretic Particle deposition velocity from Fig.1 to Fig.7. Numerical computations have been carried out for different values of the Magnetic field parameter (M), Lewis number (Le), Buoyancy ratio (N), the thermophoretic coefficient (k), the radiation parameter (R), the temperature difference (Cp) which are displayed along with graphs and Prandtl number, Pr=0.72

Fig.1. displays the effect of Magnetic parameter, Buoyancy ratio and thermophoretic coefficient on the thermophoretic particle deposition velocity. We observe that the particle deposition velocity decreases with the increase of Magnetic Parameter M and Buoyancy Ratio N or thermophoresis coefficient k indicating that increasing magnetic intensity suppresses the fluid velocity.

Fig.2. shows the effects of R, N and C_p on the thermophoretic Particle deposition velocity. It is seen that the particle deposition velocity decreases with the increase of the values of R, N and C_p.

Fig.3. displays the effects of R, M and N on concentration profiles. We observe that the thermo-concentration decreases with the increase of values of M and N.

Fig.4. displays the effects of M and N on concentration profiles. It is observed that dimensionless velocity increases but the concentration decreases uniformly. This indicates that adjacent to the wall there is the large increase in concentration gradient.

Fig.5. displays the effects of Lewis number and radiation parameter on concentration profiles. It is seen that as the values of Le and R increases concentration decreases monotonically indicating the depletion of concentration layer thickness.

Fig.6. displays the effects of M and N on temperature profile. It is observed that with increase of values of N and M the boundary layer thickness reduces.

Fig.7. displays the effects of R, N and M on velocity profile. It is seen that velocity boundary layer thickness increases with decrease of values of R and the velocity of fluid increases with decrease of values of M and N.

5. Conclusions:

In the present study effect of thermophoresis on particle deposition velocity and radiation on steady convective heat and mass transfer flow along a vertical plate immersed in a porous medium is taken into account. The various results have been analyzed numerically. A comparison with previously published work was considered, in obtaining the efficacy of various results. Thermophoretic particle deposition velocity decreases when there is an increase in temperature difference, the magnetic parameter, the radiation parameter and increased as either of thermophoretic coefficient or buoyancy ratio.

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FIGURES:

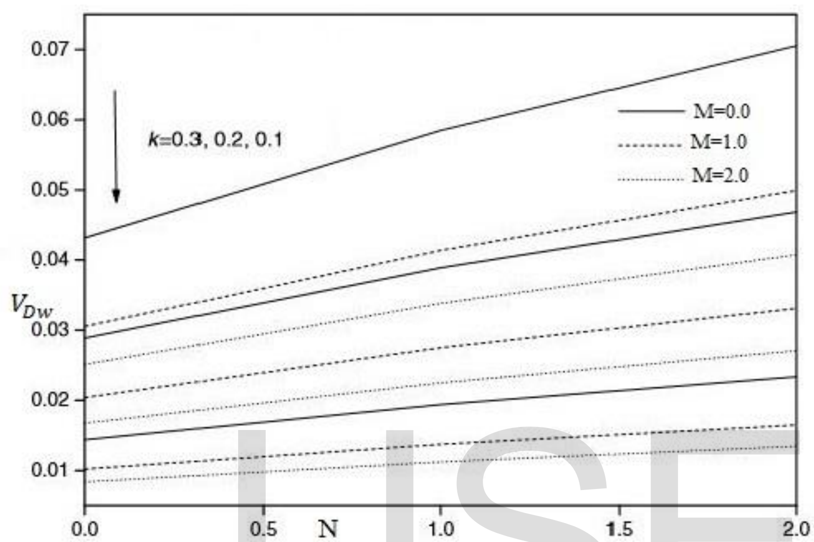

Fig.1.Effects of M, N and k on the V_{Dw} with R=1.0,Le=1.0 and Cp=0.1

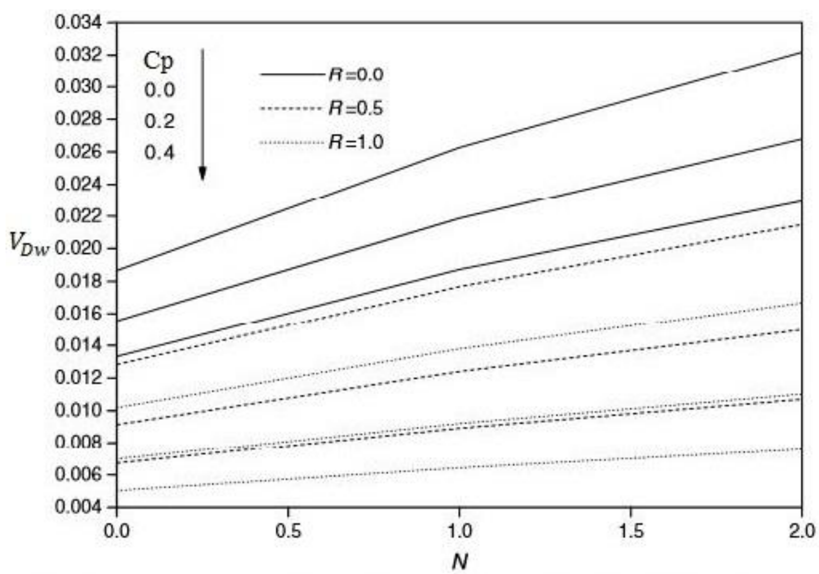

Fig.2.Effects of R, N and C_p on V_{Dw} with Le=1.0,k=0.1 and M=2.0

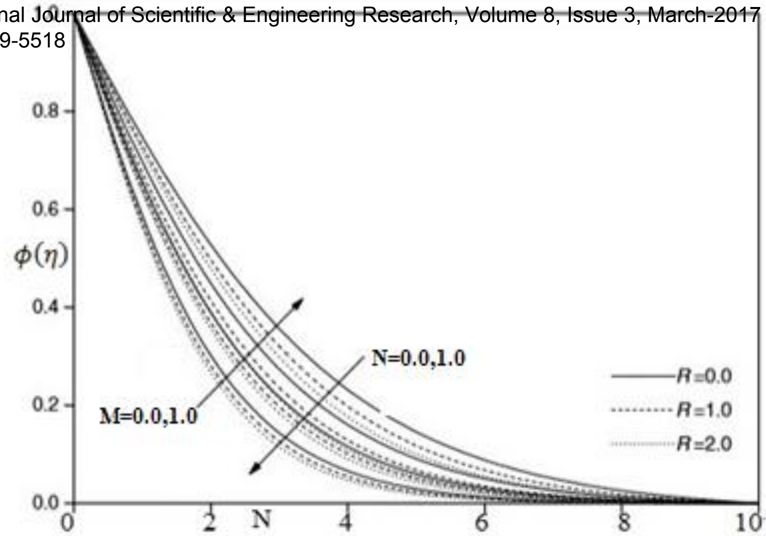

Fig.3.Effects of R, M and N on $\phi(\eta)$ with Le=1.0,Cp=0.0 and k=0.0

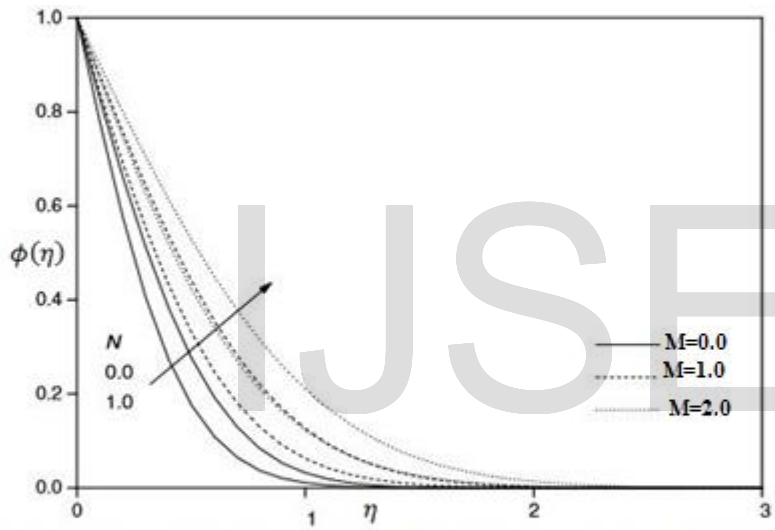

Fig.4. Effect of M and N on $\phi(\eta)$ with R=1.0, Le=10.0,Cp=0.4 and k=0.0

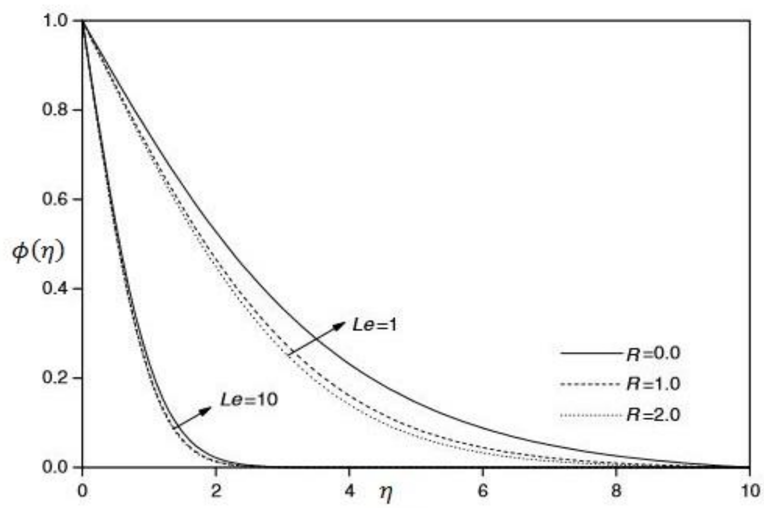

Fig.5.Effects of Le and R on $\phi(\eta)$ with M=2.0,N=0.0,Cp=0.4 and k=0.0

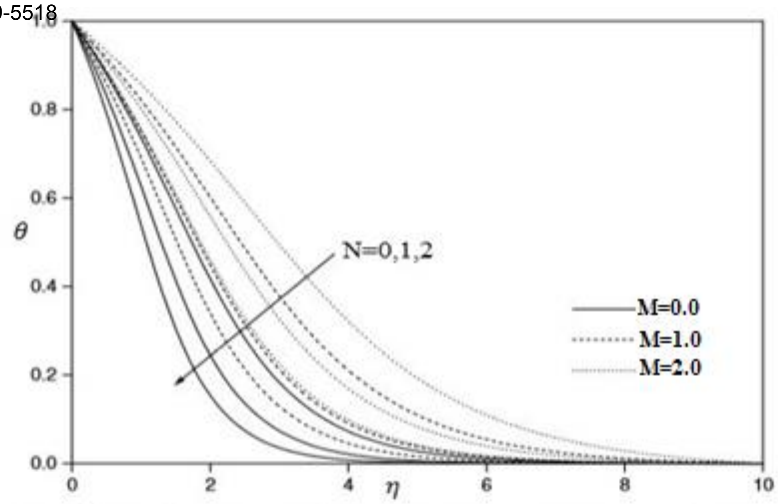

Fig.6.Effects of N and M on θ with Le=1.0. Cp=0.1.R=1.0 and k=0.1

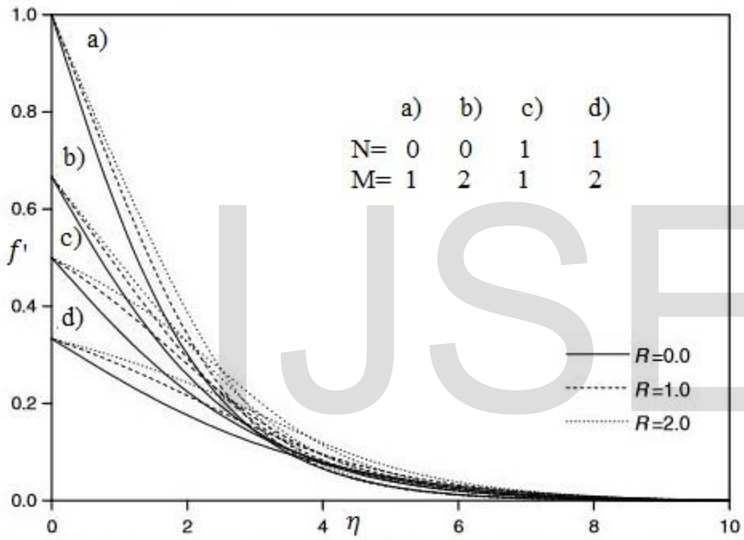

Fig.7.Effects of N,M and R on f with Le=1.0,Cp=0.4 and k=0.0