

Thermal Radiation Effects on MHD Convective Heat and Mass Transfer past a Vertical Porous Plate through Porous Medium, Dufour Effects and Chemical Reaction

Vidyasagar. G ¹, Ramana.B ¹Assistant Professor, Department of BS&H, QIS College of Engineering and Technology, Ongole, A.P., India ¹

ABSTRACT: The objective of this paper is to study the Dufour and radiation effect of Kuvshinski fluid on MHD free convection flow past a vertical porous plate with heat and mass transfer. The velocity, temperature and concentration are obtained by using a Perturbation technique. Skin friction, rate of heat transfer coefficient are also derived. The results have been analyzed graphically and numerically for various values of the flow parameters.

KEYWORDS: Kuvshinski fluid; MHD; Dufour effect; Chemical reaction; Thermal Radiation, Heat and Mass Transfer and Porous medium.

I. INTRODUCTION

The study of hydro magnetic free convection flow finds applications in science and engineering, in areas such as geophysical exploration, solar physics, and astrophysical studies. The convection problem in a porous medium has important applications in geothermal reservoirs and geothermal extractions. The process of heat and mass transfer is encountered in aeronautics, fluid fuel nuclear reactor, chemical process industries and many engineering applications in which the fluid is the working medium. The wide range of technological and industrial applications has stimulated considerable amount of interest in the study of heat and mass transfer in convection flows. In physics and engineering, the radiative effects have important applications. In space technology and high temperature processes, knowledge of radiation heat transfer becomes very important for the design of pertinent equipment. Convective flows with simultaneous heat and mass transfer under the influence of a magnetic field and chemical reaction arise in many transport processes both naturally and artificially in many branches of science and engineering applications. This phenomenon plays an important role in the chemical industry, power and cooling industry for dyeing, chemical vapour deposition on surfaces, cooling of nuclear reactors and petroleum industries. Natural convection flow occurs frequently in nature. Flow and heat transfer of a viscous incompressible fluid over a stretching surface is playing a pivotal role in different realm of technological, engineering and industrial manufacturing processes. Its numerous applications are vital for advancement in the field of metallurgy, chemical engineering and biological system such as paper production, hot rolling, wire drawing, glass fiber, cooling of metal, drawing plastic films, design of various chemical processing equipment and many others. Dulal Pal and Hiranmoy Mondal (2012) was reported influence of chemical reaction and thermal radiation on mixed convection heat and mass transfer over a stretching sheet in Darcian porous medium with Soret and Dufour effects. Dulal Pal and Hiranmoy Mondal (2011) obtained Effects of Soret Dufour, chemical reaction and thermal radiation on MHD non-Darcy unsteady mixed convective heat and mass transfer over a stretching sheet. Srinivasacharya and Swamy Reddy (2016) is studied Chemical reaction and radiation effects on mixed convection heat and mass transfer over a vertical plate in power-law fluid saturated porous medium. Dulal Pal and Hiranmoy Mondal (2011) investigated Effects of Soret Dufour, chemical reaction and thermal radiation on MHD non-Darcy unsteady

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 6, Special Issue 13, July 2017

mixed convective heat and mass transfer over a stretching sheet. Waheed *et al.*(2015) is analyse influence of chemical reaction and thermal radiation on heat and mass transfer for Soret and Dufour's effects on MHD mixed convection hiemenz flow of a micropolar fluid embedded in a porous medium with slip. Lalitha *et al.* (2016) is studied Dufour and thermal radiation effects of kuvshinski fluid on double diffusive and convective MHD heat and mass transfer flow past a porous vertical plate in the presence of radiation absorption, viscous dissipation and chemical reaction. Devasena and LeelaRatnam. (2014) investigated combined influence of chemical reaction, thermo diffusion and thermal radiation on the convective heat and mass transfer flow of a kuvshinski fluid past a vertical plate. Reddy *et al.* (2015) studied unsteady MHD free convection flow of a kuvshinski fluid past a vertical porous plate in the presence of chemical reaction and heat source/sink. Sudershan Reddy *et al.* (2012) investigated chemical and radiation absorption effects on MHD convective heat and mass transfer flow past a semi-infinite vertical moving porous plate with time dependent suction. Gireeshkumar and S. Raman Krishna (2010) analyse effects of chemical reaction and mass transfer on radiation and MHD free convection flow of kuvshinski fluid through a porous medium. Olanrewaju and Gbadeyan (2011) studied effects of Soret, Dufour, chemical reaction, thermal radiation and volumetric heat generation/absorption on mixed convection stagnation point flow on an isothermal vertical plate in porous media. Anand Rao *et al.*[2012] studied the radiation effects on an unsteady MHD free convective flow past a vertical porous plate in the presence of Soret effect. Seethamahalakshmi *et al.* [2011] investigated the unsteady MHD free convection flow and mass transfer near a moving vertical plate in the presence of thermal radiation. Santosh Chaudhary (2015) studied MHD Flow and Heat Generation near Stagnation Point towards a Stretching Sheet in Porous Medium. Kazem *et.al* (2011) analyze improved analytical solutions to a stagnation-point flow past a porous stretching sheet with heat generation. Layek *et.al* (2007) studied heat and mass transfer analysis for boundary layer stagnation-point flow towards a heated porous stretching sheet with heat absorption/generation and suction/blowing. S.Mohammed Ibrahim and K.Suneetha (2014) studied radiation and heat generation effects on steady mhd flow near a stagnation point on a linear stretching sheet in porous medium in presence of variable thermal conductivity and mass transfer, international journal of current research and academic. Babu *et al.* (2014) investigate radiation effect on MHD heat and mass transfer flow over a shrinking sheet with mass suction. Lavanya and Leela Ratnam (2014) analyze the effects of thermal radiation, heat generation, viscous dissipation and chemical reaction on MHD micropolar fluid past a stretching surface in a non-darcian porous medium. Shakhaoath Khan *et al.* (2014) studied MHD boundary layer radiative, heat generating and chemical reacting flow past a wedge moving in a nano fluid. Ziya Uddin *et al.* (2012) investigate influence of thermal radiation and heat generation/absorption on MHD heat transfer flow of a micropolar fluid past a wedge considering hall and ion slip currents. Ramana reddy *et al.* (2015) studied radiation and mass transfer effects on nonlinear MHD boundary layer flow of liquid metal over a porous stretching surface embedded in porous medium with heat generation. Mohammad Ali *et al.* (2014) studied radiation and thermal diffusion effect on a steady MHD free convection heat and mass transfer flow past an inclined stretching sheet with Hall current and heat generation. Subhakar, and Gangadhar (2012) investigate soret and dufour effects on MHD free convection heat and mass transfer flow over a stretching vertical plate with suction and heat source/sink. Mohammed Ibrahim *et al.* (2014) analyze radiation effects on unsteady MHD free convective heat and mass transfer flow of past a vertical porous plate embedded in a porous medium with viscous dissipation.

The objective of this paper is to study the Dufour and radiation effect of Kuvshinshiki fluid on MHD free convection flow past a vertical porous plate with heat and mass transfer. The velocity, temperature and concentration are obtained by using a Perturbation technique. Skin friction, rate of heat transfer coefficient are also derived. The results have been analyzed graphically and numerically for various values of the flow parameters.

Equation of Continuity:

$$\frac{\partial v'}{\partial y'} = 0 \tag{1}$$

Equation of Momentum:

$$(1+\lambda' \frac{\partial}{\partial t'}) \frac{\partial u'}{\partial t'} + v' \frac{\partial v'}{\partial y'} = v' \frac{\partial^2 v'}{\partial y'^2} + g\beta(T' - T'_\infty) + g\beta(C' - C'_\infty) - (1+\lambda' \frac{\partial}{\partial t'}) (\frac{v'}{K'} + \frac{\sigma B_0^2}{\rho}) u' \tag{2}$$

Equation of Energy:

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$$\frac{\partial T'}{\partial t'} + v' \frac{\partial T'}{\partial y'} = \alpha \frac{\partial^2 T'}{\partial y'^2} - \frac{\partial q_r}{\partial y'} + \frac{Q_0}{\rho C_p} (T - T_\infty) + \frac{D_m K_T}{C_s S_p} \frac{\partial^2 C'}{\partial y'^2} \quad (3)$$

Equation of Concentration:

$$\frac{\partial C'}{\partial t'} + v' \frac{\partial C'}{\partial y'} = D \frac{\partial^2 C'}{\partial y'^2} - K_r (C' - C'_\infty) \quad (4)$$

$$\frac{\partial q_r}{\partial y'} = 4\alpha^2 (T' - T'_\infty) \quad (5)$$

The Corresponding boundary conditions are

$$u' = 0, T' = T'_w, C = C'_w \text{ at } y=0$$

$$u' = 0, T' = T'_\infty, C = C'_\infty \text{ at } y \rightarrow \infty \quad (6)$$

We introduce the Non-dimensional Variables

$$u = \frac{u'}{u_0}, t = \frac{t' u_0^2}{\nu}, y = \frac{y' u_0}{\nu}, \theta = \frac{T' - T'_\infty}{T'_w - T'_\infty}, \phi = \frac{C' - C'_\infty}{C'_w - C'_\infty}, K = \frac{K' u_0^2}{\nu^2} \quad (7)$$

$$Pr = \frac{\nu}{\alpha}, Sc = \frac{\nu}{D}, M = \frac{\sigma B_0^2 \nu}{\rho u_0^2}, R = \frac{4\alpha^2 u_0^2}{\nu}, Q = \frac{Q_0 u_0^2}{\nu \rho C_p}$$

$$Gr = \frac{g \beta \nu (T'_w - T'_\infty)}{u_0^3}, N = \frac{\beta' (C'_w - C'_\infty)}{\beta (T'_w - T'_\infty)}, \lambda = \frac{\lambda' u_0^2}{\nu}$$

The governing and reduces to

$$(1 + \lambda \frac{\partial}{\partial t}) \frac{\partial u}{\partial t} - \frac{\partial u}{\partial y} = \frac{\partial^2 u}{\partial y^2} + Gr(\theta + NC) - (1 + \lambda \frac{\partial}{\partial t}) (\frac{1}{K} + M)u \quad (8)$$

$$\frac{\partial \theta}{\partial t} - \frac{\partial \theta}{\partial y} = \frac{1}{Pr} \frac{\partial^2 \theta}{\partial y^2} - R\theta + Q\theta + D_f \frac{\partial^2 C}{\partial y^2} \quad (9)$$

$$\frac{\partial \phi}{\partial t} - \frac{\partial \phi}{\partial y} = \frac{1}{Sc} \frac{\partial^2 \phi}{\partial y^2} - C_h \phi \quad (10)$$

The Corresponding boundary Conditions are

$$u = 0, \theta = 1, \phi = 1 \text{ at } y=0$$

$$u = 0, \theta = 0, \phi = 0 \text{ at } y \rightarrow \infty \quad (11)$$

II. SOLUTION OF THE PROBLEM

We assume the solution of the equations (8), (9) and (10) as

$$u(y, t) = u_0(y) e^{-nt} \quad (12)$$

$$\theta(y, t) = \theta_0(y) e^{-nt} \quad (13)$$

$$\phi(y, t) = \phi_0(y) e^{-nt} \quad (14)$$

Using Equations (12), (13) and (14) in equation (8)–(10) we get

$$u_0'' + u_0' - [(M + \frac{1}{K} - n)(1 - n\lambda)]u_0 = -Gr\theta_0 - GrNC_0 \quad (15)$$

$$\theta_0'' + Pr Df C_0'' + Pr \theta_0' + Pr(n - R + Q)\theta_0 = 0 \quad (16)$$

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$$\phi_0'' + Sc\phi_0' - Sc(Ch - n)\phi_0 = 0 \tag{17}$$

Under the boundary Conditions are

$$u_0 = 0, \theta_0 = 1, \phi_0 = 1, y = 0 \tag{18}$$

$$u_0 = 0, \theta_0 = 0, \phi_0 = 0, y \rightarrow \infty \tag{18}$$

We solve the equations (15)-(17) with the boundary Conditions (18), we get

$$u_0 = A_5 e^{-m_3 y} - A_2 e^{-m_2 y} - (A_3 + A_4) e^{-m_1 y} \tag{19}$$

$$\theta_0 = (1 + A_1) e^{-m_2 y} - A_1 e^{-m_1 y} \tag{20}$$

$$\phi_0 = e^{-m_1 y} \tag{21}$$

Where
$$m_1 = \frac{Sc + \sqrt{Sc^2 + 4Sc(Ch - n)}}{2}, \quad m_2 = \frac{Pr + \sqrt{Pr^2 - 4Pr(n - R + Q)}}{2},$$

$$A_1 = \frac{Pr Df m_1^2}{m_1^2 - Pr m_1 + Pr(n - R + Q)}, \quad A_2 = \frac{Gr(1 + A_1)}{m_2^2 - m_2 - (M + \frac{1}{K} - n)(1 - n\lambda)},$$

$$A_3 = \frac{Gr A_1}{m_1^2 - m_1 - (M + \frac{1}{K} - n)(1 - n\lambda)}, \quad A_4 = \frac{Gr N}{m_1^2 - m_1 - (M + \frac{1}{K} - n)(1 - n\lambda)}, \quad A_5 = 1 + A_2 + A_3 + A_4,$$

$$m_3 = \frac{1 + \sqrt{1 + 4(M + \frac{1}{K} - n)(1 - n\lambda)}}{2}$$

Hence the equations for u, θ and C will be as follows

$$u = [A_5 e^{-m_3 y} - A_2 e^{-m_2 y} - (A_3 + A_4) e^{-m_1 y}] e^{-nt}$$

$$\theta = [(1 + A_1) e^{-m_2 y} - A_1 e^{-m_1 y}] e^{-nt}$$

$$\phi = e^{-m_1 y} e^{-nt}$$

Skin Friction

$$\tau = \left(\frac{\partial u}{\partial y}\right)_{y=0} = [-m_3 A_5 + m_2 A_2 + m_1 (A_3 + A_4)] e^{-nt}$$

III. RESULTS AND DISCUSSION

Numerical computations have been carried out for different values of Hartmann number (M), Grashof Number (Pr), the buoyancy force parameter (N), the radiation parameter (Ra), Chemical Reaction (Ch), Porous medium(K), Schmidt number (Sc), Dufour effect (Df) and Heat generation (Q). With the above mentioned flow parameters, the results are displayed in Figures 1-19 in terms of the velocity profiles, temperature and concentration.

Fig (1) shows that the velocity profile for different values of Pr. We observe that the velocity decreases with the increase of Pr. From fig (2) represents the velocity profile for different values of Df. We notice that the velocity increases with the increase of Df. Fig (3) shows that the velocity profile for different values of M. We observe that the velocity decreases with the increase of M. From fig (4) shows that the velocity profile for different values of Gr. We observe that the velocity increases with the increase of Gr. Fig (5) represents the velocity profile for different values of Ra. We observe that the velocity decreases with the increase of Ra. Fig (6) shows that the velocity profile for different values of N. We observe that the velocity increases with the increase of N. Fig (7) shows that the velocity profile for different values of Sc. We observe that the velocity decreases with the increase of Sc. Fig (8) represents the velocity

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profile for different values of Ch. We observe that the velocity decreases with the increase of Ch with takes the reverse action.

Fig (9) shows that the temperature profile for different values of Ra. We observe that the temperature decreases with the increase of Ra. Fig (10) shows that the temperature profile for different values of Pr. We observe that the temperature decreases with the increase of Pr. Fig (11) shows that the temperature profile for different values of Df. We observe that the temperature increases with the increase of Df. Fig (12) shows that the temperature profile for different values of λ . We observe that the temperature increases with the increase of λ . Fig (13) shows that the temperature profile for different values of Q. We observe that the temperature decreases with the increase of Q. Fig (14) shows that the temperature profile for different values of Ch. We observe that the temperature decreases with the increase of Ch. Fig (15) shows that the temperature profile for different values of Gr. We observe that the temperature increases with the increase of Gr. Fig (16) shows that the temperature profile for different values of K. We observe that the temperature decreases with the increase of K. Fig (17) shows that the temperature profile for different values of M. We observe that the temperature increases with the increase of M. Fig (18) shows that the concentration profile for different values of Sc. We observe that the temperature decreases with the increase of Sc. Fig (19) shows that the concentration profile for different values of Ch. We observe that the temperature decreases with the increase of Ch.

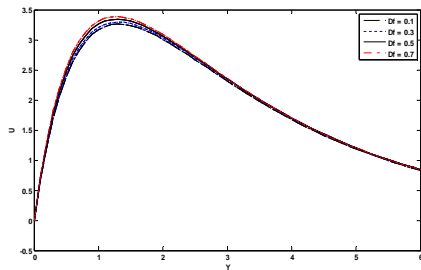


Fig 1: The velocity Profile for different values of Df

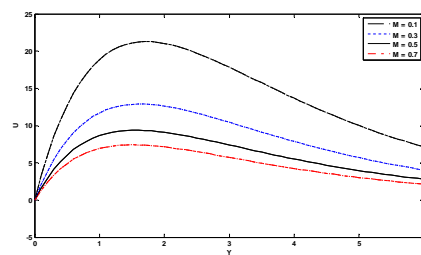


Fig 2: The velocity Profile for different values of M

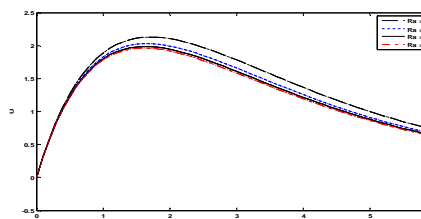


Fig 3: The velocity Profile for different values of Ra

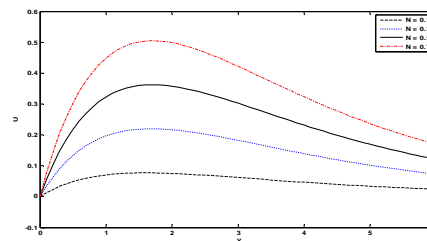


Fig 4: The velocity Profile for different values of N

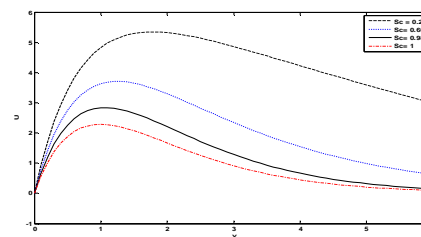


Fig 5: The velocity Profile for different values of Sc

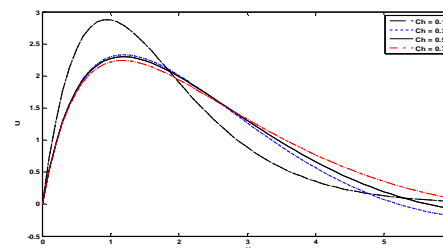


Fig 6: The velocity Profile for different values of Ch

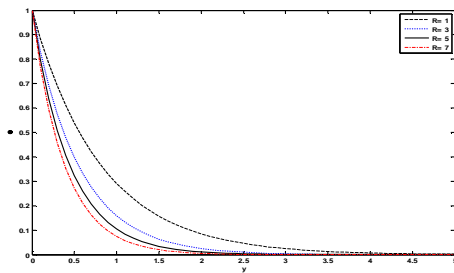


Fig 7: The Temperature Profile for different values of
Ra

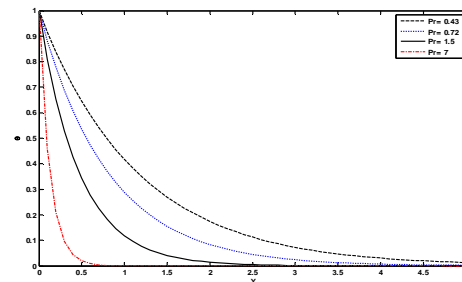


Fig 8: The Temperature Profile for different values of Pr

IV. CONCLUSION

The objective of this paper is to study the Dufour and radiation effect of Kuvshinshiki fluid on MHD free convection flow past a vertical porous plate with heat and mass transfer. The velocity, temperature and concentration are obtained by using a Perturbation technique. Skin friction, rate of heat transfer coefficient are also derived. The results have been analysed graphically and numerically for various values of the flow parameters.

- We observe that the temperature increases with the increase of D_f .
- We observe that the temperature decreases with the increase of Q .
- We observe that the temperature decreases with the increase of Ch .
- We observe that the temperature increases with the increase of λ .
- It is observe that the skin-friction increases with the increase of Ch .
- We notice that the Skin-friction decreases with the increase of k .
- It is observe that the skin-friction increases with the increase of M .
- We observe that the Sherwood number increases with the increase of Ch .
- We observe that the Sherwood number increases with the increase of Ra .
- It is observe that the Sherwood number decreases with the increase of Q .

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