SORET AND DUFOUR EFFECTS ON MHD CONVECTIVE FLOW PAST A VERTICAL PLATE THROUGH POROUS MEDIUM

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Abstract: The objective of the present paper is to investigate the soret and dufour effect of Kuvshinshiki fluid on MHD free convection flow past a vertical porous plate with heat and mass transfer in the presence of chemical reaction. The velocity, temperature and concentration are obtained by using a perturbation technique. The results have been discussed graphically and numerically for various values of the flow parameters by using Matlab.

1. Introduction:

The investigation of hydromagnetic free convection stream discovers applications in science and designing, in territories, for example, geophysical investigation, sun powered material science, and astrophysical examinations. The convection issue in a permeable medium has essential applications in geothermal supplies and geothermal extractions. The procedure of heat and mass move is experienced in aviation, liquid fuel atomic minister, chemical process industries and many other engineering applications in which the fluid is the working medium. The wide scope of mechanical and modern applications has animated significant measure of enthusiasm for the investigation of heat and mass transfer in convection flows. In material science and engineering, the radiative impacts have imperative applications. In space innovation and high temperature forms, learning of radiation heat exchange turns out to be vital for the plan of relevant gear. Convective flows with synchronous heat and mass transfer affected by an attractive field and synthetic response emerge in many transport forms both naturally and artificially in numerous parts of science and engineering applications. This application assumes a vital plays in the chemical industries, power and cooling industry for dying, chemical vapor statement on surfaces, cooling of atomic reactors and oil ventures. Regular convection flows happens every now and again in nature. Flow and heat transfer of viscous incompressible fluid over an extending surface is assuming a critical job in various domain of mechanical, building and modern assembling forms. Its various applications are fundamental for headway in the field of metallurgy, substance building and natural framework, for example, paper creation, hot moving, wire drawing, glass fiber, cooling of metal, drawing plastic movies, structure of different synthetic preparing gear and numerous others. Dulal Pal and Hiranmoy Mondal (2011) acquired 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 examined Chemical reaction and radiation effects on mixed convection heat and mass transfer over a vertical plate in power-law fluid saturated porous medium. Waheed et al. (2015) is examine impact of substance response and thermal radiation on heat and mass transfer for Soret and Dufour's effect for MHD...
mixed convection hiemenz flow of a micropolar fluid implanted in a permeable medium with slip. Lalitha et al. (2016) is considered Dufour and thermal radiation impacts of kuvshinskii fluid on double diffusive and convective MHD heat and mass transfer flow past a permeable vertical plate within the sight of radiation absorption, viscous dissipation and chemical reaction. Devasena and LeelaRatnam. (2014) examined consolidated impact 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) examined unsteady MHD free convection stream of a kuvshinski fluid past a vertical permeable plate within the sight of compound response and heat source/sink. Sudershan Reddy et al. (2012) explored chemical and radiation assimilation consequences for 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) examine impacts of chemical reaction and mass transfer on radiation and MHD free convection flow of kuvshinski fluid through a porous medium. Olanrewaju and Gbadeyan (2011) examined impacts of Soret, Dufour, chemical reaction, thermal radiation and volumetric heat generation on mixed convection stagnation point stream on an isothermal vertical plate in porous media. AnandRao et al. (2012) examined the radiation impacts on unsteady MHD free convective flow past a vertical porous plate within the sight of Soret effect. Seethamahalakshmi et al. (2011) examined the unsteady MHD free convection flow and mass transfer near a moving vertical plate within the sight of thermal radiation. Santosh Chaudhary (2015) considered MHD Flow and Heat Generation near Stagnation Point towards a Stretching Sheet in Porous Medium. Kazem et.al (2011) investigate improved expository solutions for a stagnation-point past a permeable extending sheet with heat generation. Layek et.al (2007) contemplated heat and mass transfer investigation for boundary layer stagnation-point flow towards a heated porous extending sheet with heat generation and suction/blowing. S. Mohammed Ibrahim and K. Suneetha (2014) considered radiation and heat generation impacts on steady mhd flow near to a stagnation point on a linear stretching sheet in porous medium in presence of variable thermal conductivity and mass transfer. Babu et al. (2014) examine radiation impact on MHD heat and mass transfer flow over a contracting sheet with mass suction. Lavanya and LeelaRatnam (2014) dissect the impacts of thermal radiation, heat generation, viscous dissipation and chemical reaction non MHD micropolar fluid past an extending surface in a non-darcian permeable medium. Shakhaoath Khan et al. (2014) considered MHD boundary layer radiative, heat generating and chemical reacting flow past a wedge moving in a nano fluid. Ziya Uddin et al. (2012) examine impact of thermal radiation and heat generation on MHD heat transfer flow of a micropolar fluid past a wedge considering hall and slip currents. Ramanareddy et al. (2015) studied radiation and mass transfer effects on nonlinear MHD boundary layer flow of liquid metal over a permeable extending surface inserted in permeable medium with warmth age. Mohammad Ali et al. (2014) examined radiation and thermal diffusion impact on an steady MHD free convection heat and mass transfer flow past an inclined extending sheet with Hall current and heat generation. Subhakar, and Gangadhar (2012) examine soret and dufour impacts on MHD free convection heat and mass transfer flow over an extending vertical plate with suction and heat source/sink. Mohammed Ibrahim et al. (2014) radiation effects on unsteady MHD free convective heat and mass transfer flow of past a vertical porous plate embedded in a permeable medium with viscous dissipation.

The aim of this paper is to consider the Soret, Dufour and radiation impact of Kuvshinshiki fluid on MHD free convection flow past a vertical permeable plate with heat and mass transfer. The Velocity, temperature and Concentration are acquired by utilizing a Perturbation method. Skin friction, rate of heat transfer coefficient are also determined. The outcomes have been examined graphically and numerically for different values of the flow parameters.

**Equation of Continuity:**

\[
\frac{\partial v}{\partial y} = 0
\]  

(1)
Equation of Momentum:
\[ (1 + \lambda')(\frac{\partial u}{\partial t}) + v \frac{\partial^2 u}{\partial y^2} = \left( \frac{\partial^2 v}{\partial y^2} + g \beta(T - T_0) + g \beta(C - C_0) \right) - \left( (1 + \lambda') \frac{\partial}{\partial t} \left( \frac{v}{K'} \right) + \frac{\sigma B_n^2}{\rho} \right) u' \]  
\[ (2) \]

Equation of Energy:
\[ \frac{\partial T'}{\partial t} + v' \frac{\partial T'}{\partial y} = \alpha \frac{\partial^2 T'}{\partial y^2} - \frac{Q_0}{\rho C_p} (T - T_0) + \frac{D_m K_T}{C_s S_p} \frac{\partial^2 C'}{\partial y^2} \]  
\[ (3) \]

Equation of Concentration:
\[ \frac{\partial C'}{\partial t} + v' \frac{\partial C'}{\partial y} = D \frac{\partial^2 C'}{\partial y^2} - K_s (C - C_0) + \frac{\partial^2 T'}{\partial y^2} \]  
\[ (4) \]

\[ \frac{\partial q'_r}{\partial y} = 4\alpha^2 (T' - T_0) \]  
\[ (5) \]

The Corresponding boundary conditions are
\[ u' = 0, T' = T_0', C = C_0' \text{ at } y = 0 \]  
\[ u' = 0, T' = T_0', C = C_0' \text{ at } y \to \infty \]  
\[ (6) \]

We introduce the Non-dimensional Variables
\[ u = \frac{u'}{u_0}, \quad t = \frac{t u_0^2}{v}, \quad y = \frac{y u_0}{v}, \quad \theta = \frac{T - T_0}{T_0 - T_0'}, \quad \phi = \frac{C - C_0}{C_0 - C_0'}, \quad \lambda = \frac{K u_0}{v}, \quad K = \frac{K u_0}{v} \]  
\[ \text{Pr} = \frac{v}{\alpha}, \quad S_c = \frac{v}{D}, \quad M = \frac{\sigma B_n^2}{\rho u_0}, \quad R = \frac{4\alpha^2 u_0^2}{v}, \quad Q = \frac{Q_0 u_0^2}{\rho C_p}, \quad S_r = \frac{D_m K_T}{C_s S_p}, \quad Gr = \frac{g \beta v_0 (T_0' - T_0)}{u_0^2}, \quad N = \frac{\beta (C_0' - C_0)}{\beta (T_0' - T_0)} \]  
\[ (7) \]

The governing and reduces to
\[ \alpha + \frac{\partial}{\partial t} + \frac{\partial}{\partial y} + \frac{\partial^2 \theta}{\partial y^2} + Gr(\theta + NC) - (1 + \lambda) \frac{\partial}{\partial t} + M \]  
\[ \frac{\partial \theta}{\partial t} + \frac{\partial^2 \theta}{\partial y^2} - R \theta + Q_0 + D \frac{\partial^2 \theta}{\partial y^2} \]  
\[ (8) \]

\[ \frac{\partial \phi}{\partial t} + \frac{\partial \phi}{\partial y} = \frac{\partial^2 \phi}{\partial y^2} - C_s \phi + Sr \frac{\partial^2 \phi}{\partial y^2} \]  
\[ (9) \]

The Corresponding boundary Conditions are
\[ u = 0, \theta = 1, \phi = 1 \text{ at } y = 0 \]  
\[ u = 0, \theta = 0, \phi = 0 \text{ at } y \to \infty \]  
\[ (10) \]

2. Method of Solution:

We Assume the Solution of equations (8),(9),and (10) as
\[ u(y,t) = u_0(y) e^{-at} \]  
\[ (12) \]
\[ \theta(y,t) = \theta_0(y) e^{-at} \]  
\[ (13) \]
\[ \phi(y, t) = \phi_0(y)e^{-mt} \]  \hspace{1cm} (14)

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

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

\[ \theta_0' + PrDfC_0 + Pr\theta_0' + Pr(n - R + Q)\theta_0 = 0 \]  \hspace{1cm} (16)

\[ ScSr\lambda^2\phi_0'' + Sc\phi_0' - Sc(Ch - n)\phi_0 = 0 \]  \hspace{1cm} (17)

Under the boundary Conditions are

\[ u_0 = 0, \theta_0 = 1, \phi_0 = 1, y = 0 \]
\[ u_0 = 0, \theta_0 = 0, \phi_0 = 0, y \rightarrow \infty \]  \hspace{1cm} (18)

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

\[ u_0 = A_y e^{-m_y} - A_y e^{-m_y} - (A_y + A_y)e^{-m_y} \]  \hspace{1cm} (19)

\[ \theta_0 = (1 + A_y)e^{-m_y} - A_y e^{-m_y} \]  \hspace{1cm} (20)

\[ \phi_0 = e^{-m_y} \]  \hspace{1cm} (21)

Hence the equations for \( u, \theta \) and C will be as follows

\[ u(y, t) = [A_y e^{-m_y} - A_y e^{-m_y} - (A_y + A_y)e^{-m_y}]e^{-mt} \]
\[ \theta(y, t) = [(1 + A_y)e^{-m_y} - A_y e^{-m_y}]e^{-mt} \]
\[ \phi(y, t) = e^{-m_y}e^{-mt} \]

3. Result 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 1-16 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. Fig (2) shows that the velocity profile for different values of M. We observe that the velocity decreases with the increase of M. Fig (3) shows the velocity profile for different values of Gr. We observe that the velocity increases with the increase of Gr. Fig (4) represents the velocity profile for different values of R. We observe that the velocity decreases with the increase of R. Fig (5) shows that the velocity profile for different values of N. We observe that the velocity increases with the increase of N. Fig (6) shows that the velocity profile for different values of Sc. We observe that the velocity decreases with the increase of Sc. Fig (7) represents the velocity profile for different values of Ch. We observe that the velocity decreases with the increase of Ch with takes the reverse action.

Fig (8) shows that the temperature profile for different values of Ra. We observe that the temperature decreases with the increase of Ra. Fig (9) shows that the temperature profile for different values of Pr. We observe that the temperature decreases with the increase of Pr. Fig (10)
shows that the temperature profile for different values of $D_f$. We observe that the temperature increases with the increase of $D_f$.

**Graphs and Tables**

**Fig 1:** Velocity Profile for several values of Prandtl number

**Fig 2:** Velocity Profile for several values of $M$
Fig 3: The velocity Profile for different values of Gr

![Graph showing velocity profile for different values of Gr](image)

Fig 4: The velocity Profile for different values of R

![Graph showing velocity profile for different values of R](image)

Fig 5: The velocity Profile for different values of N

![Graph showing velocity profile for different values of N](image)

Fig 6: The velocity Profile for different values of Sc

![Graph showing velocity profile for different values of Sc](image)
Fig 7: The velocity Profile for different values of Ch

Fig 8: The Temperature Profile for different values of R

Fig 9: The Temperature Profile for different values of Pr
Fig 10: The Temperature Profile for different values of Df

TABLE I: NUMERICAL VALUES OF THE SKIN-FRICTION (CF) FOR M, SC, CH, DF, RA, Q, K, SR, PR, GR, GC

| Pr  | M | Ch | Ra | Q | k | Df   | Sr  | Sc  | Gr  | Gc | Skin-Friction(CF) |
|-----|---|----|----|---|---|------|-----|-----|-----|----|-------------------|
| 0.71| 1 | 0.5| 1  | 0.3| 0.1| 0.02 | 0.22| 0.60| 3   | 1  | 2.5161            |
| 0.71| 1 | 0.3| 1  | 0.3| 0.1| 0.02 | 0.22| 0.60| 5   | 1  | 1.6749            |
| 0.71| 1 | 0.5| 3  | 0.3| 0.1| 0.02 | 0.22| 0.60| 5   | 1  | 1.8546            |
| 0.71| 1 | 0.5| 1  | 0.5| 0.1| 0.02 | 0.22| 0.60| 5   | 1  | 1.8181            |
| 0.71| 1 | 0.5| 1  | 0.3| 0.1| 0.02 | 0.22| 0.60| 5   | 1  | 2.1500            |
| 0.71| 1 | 0.5| 1  | 0.3| 0.3| 0.02 | 0.22| 0.60| 5   | 1  | -0.2908           |
| 0.71| 1 | 0.5| 1  | 0.3| 0.1| 0.01 | 0.22| 0.60| 5   | 1  | 1.6931            |
| 0.71| 1 | 0.5| 1  | 0.3| 0.1| 0.02 | 0.63| 0.60| 5   | 1  | 1.7437            |
| 0.71| 1 | 0.5| 1  | 0.3| 0.1| 0.02 | 0.22| 0.98| 5   | 1  | 1.5195            |
| 0.71| 1 | 0.5| 1  | 0.3| 0.1| 0.02 | 0.22| 0.60| 5   | 3  | 1.7458            |
TABLE II.

| M  | Sc  | Ch  | Df | Ra  | Q  | k  | Sr  | Sherwood(Sh) |
|----|-----|-----|----|-----|----|----|-----|--------------|
| 0.2| 0.22| 0.5 | 0.02| 1   | 0.5| 0.1| 0.5 | 0.60         | 0.044887     |
| 0.3| 0.22| 0.5 | 0.02| 1   | 0.5| 0.1| 0.5 | 0.60         | 0.055448     |
| 0.2| 0.22| 0.7 | 0.02| 1   | 0.5| 0.1| 0.5 | 0.60         | 0.070274     |
| 0.2| 0.22| 0.5 | 0.02| 3   | 0.5| 0.1| 0.5 | 0.60         | 0.139379     |
| 0.2| 0.22| 0.5 | 0.03| 1   | 0.5| 0.1| 0.5 | 0.60         | 0.157638     |
| 0.2| 0.63| 0.5 | 0.02| 1   | 0.5| 0.1| 0.5 | 0.60         | 0.186503     |
| 0.2| 0.22| 0.5 | 0.02| 1   | 0.7| 0.1| 0.5 | 0.60         | 0.190479     |
| 0.2| 0.22| 0.5 | 0.02| 1   | 0.5| 0.3| 0.5 | 0.60         | 0.195502     |
| 0.2| 0.22| 0.5 | 0.02| 1   | 0.5| 0.1| 0.3 | 0.60         | 0.195508     |
| 0.2| 0.22| 0.5 | 0.02| 1   | 0.5| 0.1| 0.5 | 0.98         | 0.388293     |

Conclusion:

The objective of this paper is to study the Soret, 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 Df, λ and the temperature decreases with the increase of Q, Ch.
- It is observe that the skin-friction increases with the increase of Ch, M.
- We notice that the Skin-friction decreases with the increase of k.
- We observe that the Sherwood number increases with the increase of Ch, Ra.

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