International Journal of Multidisciplinary Research and Modern Education (IJMRME)
ISSN (Online): 2454 - 6119
(www.rdmodernresearch.com) Volume II, Issue II, 2016

THE CONVECTIVE HEAT AND MASS TRANSFER OF NANO-FLUID PAST A PERMEABLE INCLINED OSCILLATING FLAT PLATE

Dr. G. V. P. N. Srikanth*, Raja Sekhar Gorthi** & Dr. G. Srinivas***

* Assistant Professor, Department of Mathematics, VNR Vignana Jyothi Institute of Engineering & Technology, Hyderabad, Telangana

** Assistant Professor, Department of Electrical and Electronic Engineering, JBIET, Hyderabad, Telangana

*** Professor, Department of Mathematics, Guru Nanak Institute of Technology, Hyderabad, Telangana

Abstract:

The significant research has seen with nano fluid flow and heat transfer. But still there is a wide scope of research in mass transfer with nano fluids due to Brownian motion of particles. A theoretical investigation has attempted in this paper to study the chemical reaction effects during mass transfer. We have studied convective heat and mass transfer of MHD nano fluid flow past inclined, oscillating permeable flat plate with radiation and heat source. It is found that velocity and Diffusion increases for both kind of chemical reactions.

Index Terms: Nano - Fluid, MHD, Inclined Plate, Radiation & R-K 6th Order.

1.Introduction:

The heat and mass transfer has gained great demand due to its applications in many areas like, cooling of electronic devices, reactor cores, high voltage power transformers, energy storages, petroleum industries etc. In the heat and mass transfer all the above areas study can be done with a typical geometry, like a flat plate. The inclined flat plate may consider for various application. If the system is like then the oscillation of the plate shall be considered. In view of this researchers studied the convective heat transfer with this geometry. Among those studies, M.A.A. Hamad [2] studied the convective heat transfer with a vertical permeable, rotating flat plate and reported that heat transfer enhances with nano particles presence. Md.Shakhaoath Khan [3] studied the flow past a wedge moving in a nano fluid and reported that the Brownian motion of nano particle influences the flow and heat transfer significantly. S.P.Anjali Devi [13] also stressed the importance of next generation coolants like nano fluids.

Ch.Ram Reddy [1] reported that the increase in Brownian motion of the particles enhances the momentum and heat transfer. Pravin R.Harde [9] reported that the performance of solar collector increases with increase in inclination of the solar cell and concentration of the nano material. N.F.M.Noor [6] studied the thermos phonetic effect on convective heat transfer over a permeable inclined plate with heat source/sink and suction/injection. Many researchers [8, 12, and 14] studied the significance of nano fluid in convective heat transfer by performing the experiments. Mohammad Mehdi Keshtkar [4] et.al studied the effect of suction/injection on convective boundary layer flow along with some more physical phenomenon. The reported that range of solution for the injection case is smallest for cu-water nano fluid. Few researchers [5, 7, and 11] stressed the importance of the moving flat plate geometry in convective heat transfer with nano fluids. Recently Puneet Rana et.al [10] studied the effect of nano particle diameter on flow and heat transfer along a vertical flat plate.

To the best of available literature, the study of convective heat and mass transfer through the particle size (diameter) and the inter particle spacing in live cases like moving/oscillating plates have not noted. So we made here an attempt to study the effects of size of nano particles and the inter particles spacing in convective heat and mass transfer past a permeable, oscillating, inclined flat plate. We also considered the magnetic field, radiation, heat source, suction and chemical reaction to study.

2. Mathematical Formulation:

Consider the unsteady free convection flow of a nano-fluid past inclined permeable semi-infinite plate in the presence of an applied magnetic field with constant heat source, radiation and suction. We consider Cartesian coordinate system $(\bar{x}, \bar{y}, \bar{z})$, the flow is in the $\bar{x}$ direction, which is taken along the plate, and $\bar{z}$ - axis is normal to the plate. We assume that the plate has an oscillatory movement on time $\bar{t}$ and frequency $\bar{n}$ with the velocity u(0,t),which is given u(0,t) = U_0 (1 + ε cos(nt)), where ε is a small constant parameter ($\varepsilon << 1$) and U_0 is the characteristic velocity. We consider that initially ($t < 0$) the fluid as well as the plate is at rest. A uniform external magnetic field B_0 is taken to be acting along the $\bar{z}$-axis. Also assume that the induced magnetic field is small compared to the external magnetic field B_0. The surface temperature is assumed to have the constant value T_w while the ambient temperature has the constant value T_∞, where $T_w > T_\infty$. The conservation equation of current density $\nabla . J = 0$ gives J_z = constant. Since the plate is electrically non-conducting, this constant is zero. It is assumed that the plate is infinite in extent and hence all physical quantities do not depend on $\bar{x}$ and $\bar{y}$ but depend only on $\bar{z}$ and $\bar{t}$, the Schematic Diagram of this is shown in Fig.1.

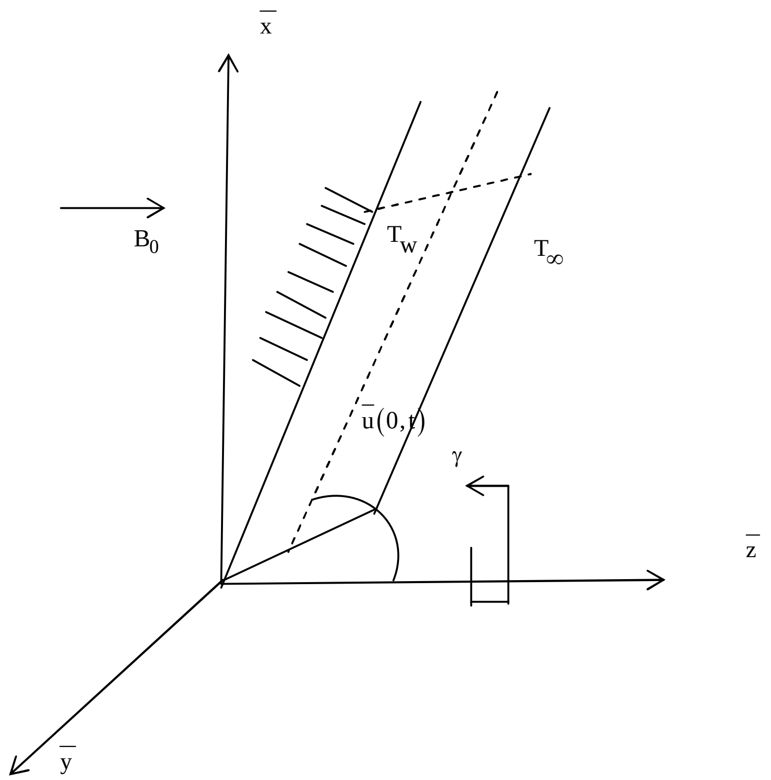


Figure 1: Schematic Diagram

Conservation of Mass is $\bar{\nabla} \bullet \bar{v} = 0$, $\quad \bar{\nabla} = \bar{i}\dfrac{\partial}{\partial x} + \bar{j}\dfrac{\partial}{\partial y} + \bar{k}\dfrac{\partial}{\partial z}$

Absence of x and y gives, $\frac{\partial u}{\partial x} = \frac{\partial v}{\partial y} = 0$

$$\frac{\partial w}{\partial z} = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

It is further assumed that the regular fluid and the suspended nano-particles are in thermal equilibrium and no slip occurs between them. Under Boussinesq and boundary layer approximations, the boundary layer equations governing the flow, temperature and diffusion are:

The Conservation of momentum is

$$\frac{\partial \bar{v}}{\partial t} + \left(\bar{v} \bullet \bar{\nabla}\right)\bar{v} = \frac{1}{\rho_{nf}}\left[\mu_{nf}\,\nabla^2\,\bar{v} + (\rho\,\beta_T)_{nf}\,\bar{g}\,(T - T_\infty)\,\mathrm{Cos}\,\gamma + (\rho\,\beta_c)_{nf}\,\bar{g}\,(c - c_\infty)\,\mathrm{Cos}\,\gamma - \sigma\,B_o^2\,\bar{v}\right]$$

In the direction of z, the above equation is

$$\frac{\partial u}{\partial t} + w\frac{\partial u}{\partial z} = \frac{1}{\rho_{nf}}\left[\mu_{nf}\frac{\partial^2 u}{\partial z^2} + (\rho\beta_T)_{nf}\,g\,(T - T_\infty)\,\mathrm{Cos}\gamma + (\rho\beta_c)_{nf}\,g\,(c - c_\infty)\,\mathrm{Cos}\gamma - \sigma B_o^2 u\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

The Conservation of energy is

$$\frac{\partial T}{\partial t} + \left(\bar{v} \bullet \bar{\nabla}\right) T = \alpha_{nf}\,\nabla^2 T - \frac{Q}{(\rho\ c_p)_{nf}}(T - T_\infty) - \frac{1}{(\rho\ c_p)_{nf}}\frac{\partial q_r}{\partial z}$$

In the direction of z, the above equation is

$$\frac{\partial T}{\partial t} + w\frac{\partial T}{\partial z} = \alpha_{nf}\frac{\partial^2 T}{\partial z^2} - \frac{Q}{(\rho\ c_p)_{nf}}(T - T_\infty) - \frac{1}{(\rho\ c_p)_{nf}}\frac{\partial q_r}{\partial z} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

The Conservation of Diffusion is

$$\frac{\partial c}{\partial t} + \left(\bar{v} \bullet \bar{\nabla}\right) c = D_{nf}\,\nabla^2 c + k_l\,(c - c_\infty)$$

In the direction of z, the above equation is

$$\frac{\partial c}{\partial t} + w\frac{\partial c}{\partial z} = D_{nf}\frac{\partial^2 c}{\partial z^2} + k_l\,(c - c_\infty) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

The appropriate initial and boundary conditions for the problem are given by

$$u(z,t) = 0,\ T = T_\infty, c = c_\infty \quad \text{for } t < 0\ \forall\ z$$

$$\left.\begin{aligned} &u(0,t) = U_0\left[1 + \frac{\varepsilon}{2}(e^{int} + e^{-int})\right], T(0,t) = T_w\,,\ c(0,t) = c_w \\ &u(\infty,t) \to 0, T(\infty,t) \to T_\infty,\ c(\infty,t) \to c_\infty,\ \varepsilon << 1 \end{aligned}\right\} t \geq 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

Thermo-Physical properties are related as follows:

$$\rho_{nf} = (1-\phi)\rho_f + \phi\rho_s\,,\ \alpha_{nf} = \frac{k_{nf}}{(\rho\ c_p)_{nf}}$$

$$(\rho\ c_p)_{nf} = (1-\phi)\,(\rho\ c_p)_f + \phi\,(\rho\ c_p)_s$$

$$(\rho\beta)_{nf} = (1-\phi)\,(\rho\beta)_f + \phi(\rho\beta)_s$$

$$\frac{\mu_{nf}}{\mu_f} = 1 + 2.5\,\phi + 4.5\left[\frac{1}{\frac{h}{d_p}\left(2+\frac{h}{d_p}\right)\left(1+\frac{h}{d_p}\right)^2}\right]$$

$$k_{nf} = k_f\,(1-\phi) + \beta_1 k_p\,\phi + c_1\,\frac{d_f}{d_p}\,k_f\ Re^2_{d_p}\ Pr\ \phi \qquad \ldots\ldots\ldots\ldots\ldots\ (6)$$

We consider the solution of Eq. (1) as $w = -w_0$ ……………… (7)
Where the constant w_0 represents the normal velocity at the plate and is positive for suction ($w_0>0$).Thus, we introduce the following dimensionless variables:

$$z = \left(\frac{\nu_f}{U_0}\right)Z,\ t = \left(\frac{\nu_f}{U_0^{\,2}}\right)t^*,\ n = \left(\frac{U_0^{\,2}}{\nu_f}\right)\eta,\ u = UU_0,\ \theta = \frac{T-T_\infty}{T_w-T_\infty},\ C = \frac{c-c_\infty}{c_w-c_\infty}$$

$$q_r = -\frac{4\sigma_1}{3\delta}\frac{\partial T^4}{\partial y} \qquad \ldots\ldots\ldots\ldots\ldots\ (8)$$

We assume that the temperature differences within the flow are sufficiently small so that the T^4 can be expressed as a linear function after using Taylor series to expand T^4 about the free stream temperature T_∞ and neglecting higher-order terms. This result is the following approximation $T^4 \cong 4T_\infty^{\,3}T - 3T_\infty^{\,4}$

By using above, we obtain $\frac{\partial q_r}{\partial z} = -\frac{16\sigma_1}{3\delta}\frac{\partial^2 T^4\,T^3_\infty}{\partial z^2}$ ……………… (9)

Using equations (5), (6), (7), (8), (9) the Equations (2),(3)&(4) can be written in the following dimensionless form:

$$\left[1-\phi+\phi\left(\frac{\rho_s}{\rho_f}\right)\right]\left(\frac{\partial U}{\partial\tau} - S\frac{\partial U}{\partial Z}\right) = 1+2.5\phi+4.5\left(\frac{1}{\left(\frac{h}{d_p}\right)\left(2+\frac{h}{d_p}\right)\left(1+\frac{h}{d_p}\right)^2}\right)\frac{\partial^2 U}{\partial Z^2} + \left[1-\phi+\phi\frac{(\rho\beta_T)_s}{(\rho\beta_T)_f}\right]\theta\cos\gamma$$

$$+\left[1-\phi+\phi\frac{(\rho\beta_c)_s}{(\rho\beta_c)_f}\right]\frac{Gc}{Gr}\ C\cos\gamma - MU$$

$$\left[1-\phi+\phi\frac{(\rho c_p)_s}{(\rho c_p)_f}\right]\left(\frac{\partial\theta}{\partial\tau} - S\frac{\partial\theta}{\partial Z}\right) = \frac{1}{Pr}\left[\left(1-\phi+0.01\phi\,\frac{k_p}{k_f}+\frac{k_p}{k_f^{\,2}}\,\phi\,\frac{\rho_f^{\,2}c_{pf}}{d_p\mu_f^{\,4}}\,28632.9991\times10^{-52}\right)\frac{\partial^2\theta}{\partial Z^2}\right]$$

$$-\frac{1}{Pr}Q_H\theta + \frac{1}{Pr}\frac{4}{3}\frac{1}{Ra}\frac{\partial^2\theta}{\partial Z^2}$$

$$\left(\frac{\partial C}{\partial \tau} - S\frac{\partial C}{\partial Z}\right) = \frac{1}{Sc}\frac{\partial^2 C}{\partial Z^2} + KC$$

Where the corresponding boundary conditions (5) can be written in the Dimensionless form as:

$$U(z,t) = 0,\ \theta(z,t) = 0,\ c(z,t) = 0 \ \text{ for } t < 0\ \forall\ z$$

$$\left.\begin{aligned} &U(0,t) = U_0\left[1+\frac{\varepsilon}{2}\left(e^{int} + e^{-int}\right)\right],\ \theta(0,t) = 1,\ c(0,t) = 1 \\ &U(\infty,t) \to 0,\ \theta(\infty,t) \to 0,\ c(\infty,t) \to 0 \end{aligned}\right\} \forall\ t \geq 0$$

Here Pr is the Prandtl number, S is the suction (S>0) parameter, M is the Magnetic parameter, Ra is the Radiation parameter and Q_H is the Heat source parameter, Sc is the Schmidt number, K is the chemical Reaction parameter, Gc is the Molecular Grashof number, Gr is the Thermal Grashof number, which are defined as:

$$Pr = \frac{\nu_f}{\alpha_f},\ S = \frac{w_o}{U_0},\ M = \frac{\sigma B_0^{\,2}\nu_f}{\rho_f U_0^{\,2}},\ Ra = \frac{4\alpha\sigma_1 T_\infty^{\,3}}{\delta k_{nf}},\ Q_H = \frac{Q\,\nu_f^{\,2}}{k_f U_0^{\,2}},\ Sc = \frac{\nu_f}{D_{nf}},$$

$$K = \frac{k_l\,\nu_f}{U_0^{\,2}},\ \frac{Gc}{Gr} = \left(\frac{g\,\beta_{cf}\left(c_w - c_\infty\right)\nu_f}{g\,\beta_{Tf}\left(T_w - T_\infty\right)\nu_f}\right)$$

Where the velocity characteristic U_0 is defined as

$$U_0 = \left[g\,\beta_f\,(T_w - T_\infty)\,\nu_f\right]^{1/3}$$

The local Nusselt number Nu in dimension less form:

$$Nu = -\frac{k_{nf}}{k_f}\,\theta'(0)$$

The local Sherwood number Sh in dimension less form:

$$Sh = -\frac{\nu_f}{D_{nf}}\,C'(0)$$

3. Solution of the Problem:

The semi-infinite plate length is limited to 6 for computations because the Diffusion reaches boundary at 6 for variation with 'Sc'. By trail method, we have generalized the semi-infinite plate length as 6 for this reason. R-K 6th order with shooting method is adopted to solve the governing equations numerically. The convergences of the method are guaranteed by satisfaction of the boundary conditions. The Mathematica package has been used to find the solution numerically. The standard values throughout the computations are: $\varphi = 0.02$, $S = 1$, $h = 4$, $d_p= 40$, $Gc = 5$, $Gr = 5$, $M = 5$, $\gamma = \pi/3$, $Q_H = 5$, $Ra = 0.4$, $Sc = 0.6$, $K = 0.5$.

4. Results and Discussions:

The effect of various parameters viz. solid volume fraction (φ), thickness of liquid like layer around the solid particle (h), diameter of the solid particle (d_p), magnetic parameter (M), inclination angle of the plate (γ), heat source parameter (Q_H), Radiation parameter (Ra), Schmidt number (Sc), suction parameter (S) and chemical reaction parameter (K) on velocity (U), temperature (θ) and diffusion (c) are exhibited in graphs from Figures 1 to 32. The other parameters were assumed constant. The Prandtl Number (Pr) kept constant as 7 (for water), $\varepsilon = 0.02$ and $nt = \pi/2$.

The velocity is found maximum near the base of the plate for all parameters and it is found that it drastically decreases as we move along the plate (Fig.1 – Fig. 12). The significance of the nano fluid has clearly observed from Fig. 1. It is evident that the dissolved Cu nano-particles increase the momentum along the plate. The momentum further enhances with the increase in the solid portion of the nano-fluid because the flow enhances for 0% to 5% solid portion in the fluid. The increase in inter particle spacing (h) opposes the momentum and it is found from Fig. 2 that the increase in spacing from 2nm to 10nm reduces the momentum. The momentum increases with size of the particle (Fig. 3). This may be due to the slip along the surface of the particle. Unlike micro particles the nano-particles are dynamic in nature and this nature increase with diameter of the particle (from 20nm to 100nm). The effect of magnetic field reduces the momentum of the nano-fluid (Fig. 4). The magnetization of the Cu nano-particle further opposes the motion of the fluid because the absence of the magnetic field rapidly enhancing the motion of the fluid. The momentum boundary layer is reducing with the increase in the inclination angle (Fig. 5). The nano-fluid flow is more when the plate is tending to be horizontal. The heat source opposes the nano-fluid flow (Fig.6). This is due to various factors like evaporation of liquid, increase in size of nano-particle and Brownian motion of particles etc. The radiation decreases the fluid flow (Fig. 7) but it is found that the variation is low for small variations in Ra. The fluid flow reduces with decrease in the diffusivity (Fig. 8). The destructive chemical reaction (K>0) enhances the momentum and the generative chemical reaction (K<0) reduces the momentum when compared with no chemical reaction (Fig. 9). The increase in suction reduces the momentum (Fig. 10) as the plate is permeable. The increase in molecular Grashof number (Gc) reduces the momentum (Fig.11), whereas the thermal Grashof number (Gr) enhances the momentum (Fig.12).

The temperature profiles (Figs. 13-22) shows that variation of temperature is more with inter particle spacing of nano-particles (h), diameter of the particle (d_p), heat source(Q_H), Radiation(Ra) and suction(S). The temperature is high near the base of the plate and decreases rapidly as we move along the plate. Temperature enhances with the dispersion of Cu particles (Fig. 13). It is observed that the temperature is more for 0% to 5% of particle dispersion in nano-fluid. The inter particle spacing reduces the temperature (Fig. 14). The spacing of 2nm to 10nm are studied, but transfer of temperature distribution is lowered. The variation of temperature for various Cu nano-particle sizes (d_p = 20nm - 100nm) is depicted in Fig. 15. The temperature enhances with size of the particle, which is basic advantage of nano-fluid. The temperature decreases with magnetic field (M) from Fig.16.The variation of temperature for various inclinations (γ) of the plate has shown in Fig. 17. Like momentum the temperature reduces with enhancement in inclination angle. The temperature decreases with increase in the heat source (Q_H) from Fig. 18. The variation of temperature is more for radiation (Ra) is around 0.1 but the variation is less when the radiation is above 0.4 (Fig.19). The temperature decreases with increase in radiation. From Fig. 20 the temperature enhances with diffusivity (Sc) due to Brownian motion of the particles. From Fig. 21 the temperature reduces with increase in chemical reaction (K). The chemical reaction changes the size of the molecule and reduces the dissipation of the temperature. The temperature is more for no suction, and decreases with increase in suction parameter (S) from Fig.22.

The variation of diffusion for various parameters is shown in Figs 23 – 32. The variation of diffusion is found more for solid volume fraction (Φ) diameter of the nano-particle (d_p), Radiation (Ra) and chemical reaction (K) on the other hand variation is less for inclination of the plate (γ), inter particle spacing (h), Magnetic Field (M), Heat source (Q_H), schmidt (Sc) and suction (S). From Fig. 23 the diffusion increases with increase in solid volume fraction (Φ) due to Brownian motion. From Fig. 24 the increase in inter particle spacing (h) decreases the diffusion stressing the importance of the nano-particles. From Fig. 25 the increase in size (d_p) of the particle increases the diffusion due to increase in momentum. From Fig. 26 the increase in magnetic field (M) decreases the diffusion. It happens due to the magnetization of the particles which leads to inertia. Fig. 27 shows that diffusivity is more for horizontal plate than vertical plate. Fig. 28 shows that the reduction of diffusivity with increase in heat source (Q_H). From Fig. 29 Radiation enhances the diffusivity. The diffusion decreases with increase in Sc and diffusion is very less when Sc is around 1.3 (Fig. 30). Diffusion is less for generative chemical reaction and more for destructive chemical reaction (K) and moderate for no reaction (Fig. 31). Diffusion is more for no suction, less for suction, as S is more than or equal to 1 (Fig. 32).

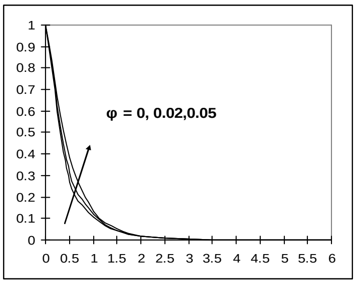


Figure 1: Variation of U with ¤

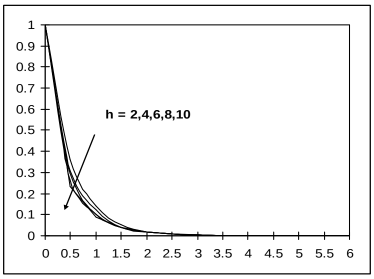


Figure 2: Variation of U with h

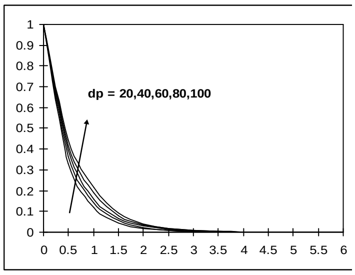


Figure 3: Variation of U with d_p

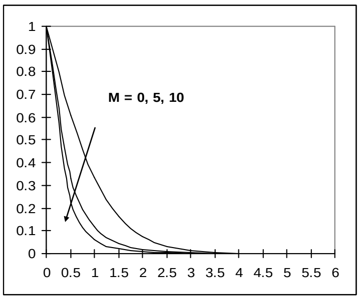


Figure 4: Variation of U with M

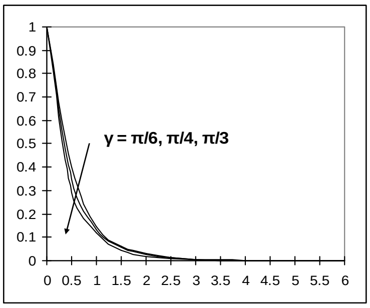


Figure 5: Variation of U with γ

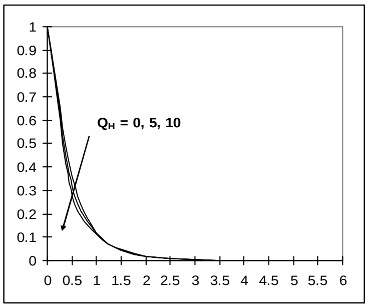
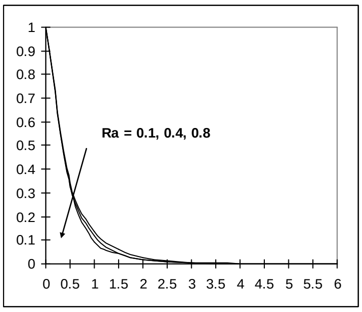
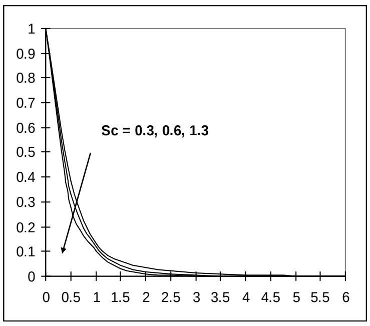


Figure 6: Variation of U with Q_H





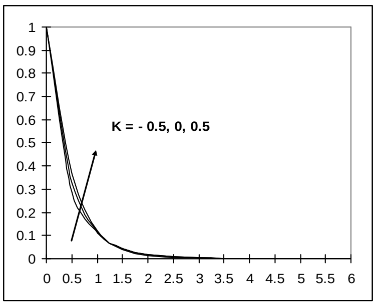


Figure 7: Variation of U with Ra

Figure 8: Variation of U with Sc

Figure 9: Variation of U with K

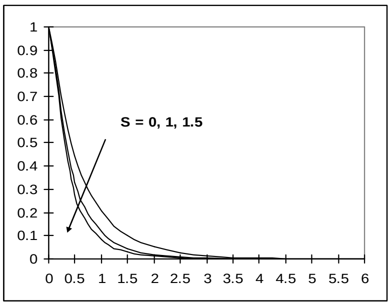


Figure 10: Variation of U with S

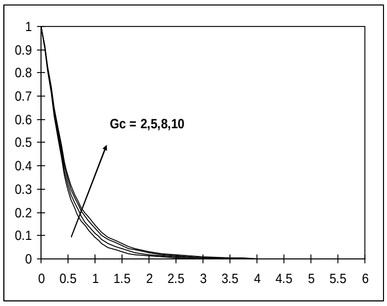


Figure 11: Variation of U with Gc

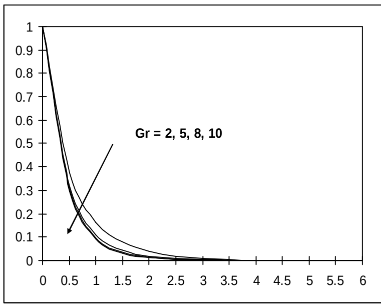


Figure 12: Variation of U with Gr

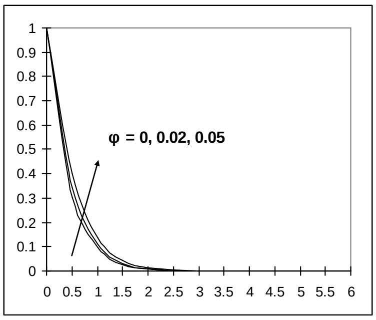


Figure 13: Variation of θ with ¤

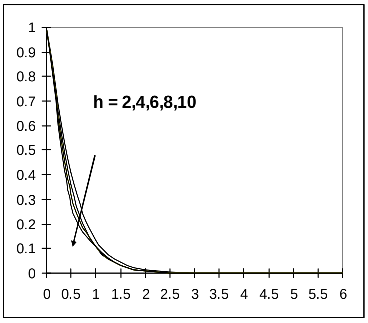


Figure 14: Variation of θ with h

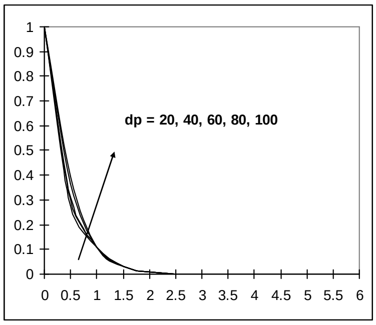


Figure 15: Variation of θ with d_p

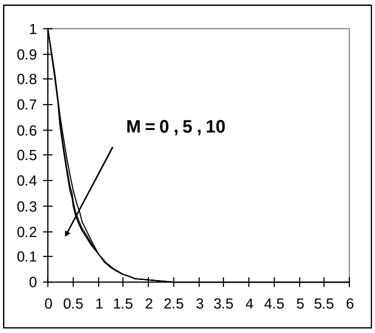


Figure 16: Variation of θ with M

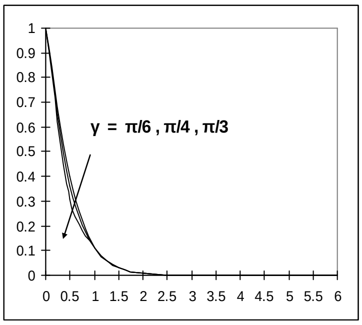


Figure 17: Variation of θ with γ

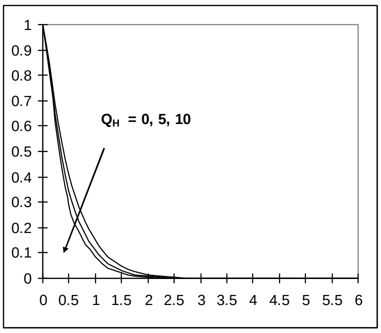


Figure 18: Variation of θ with Q_H

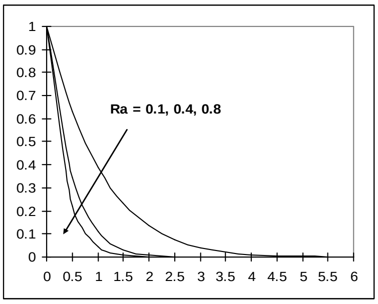


Figure 19: Variation of θ with Ra

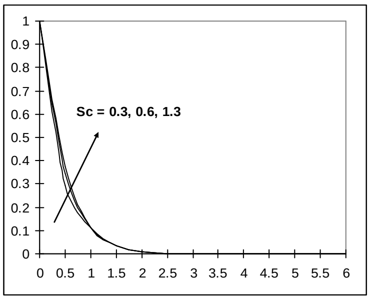


Figure 20: Variation of θ with Sc

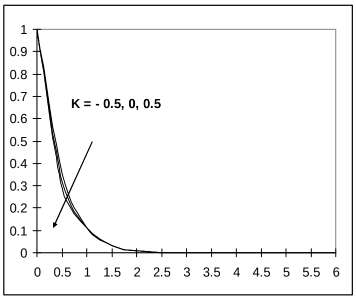


Figure 21: Variation of θ with K

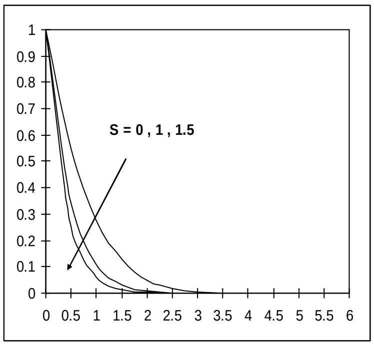


Figure 22: Variation of θ with S

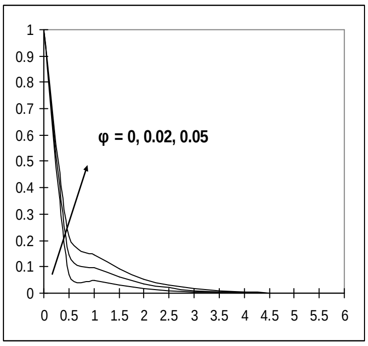


Figure 23: Variation of C with ¤

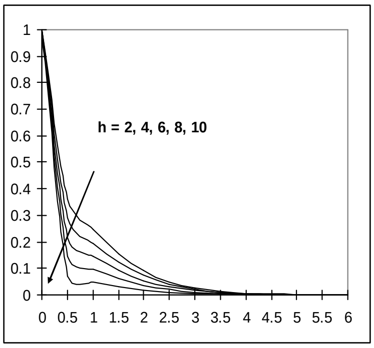


Figure 24: Variation of C with h

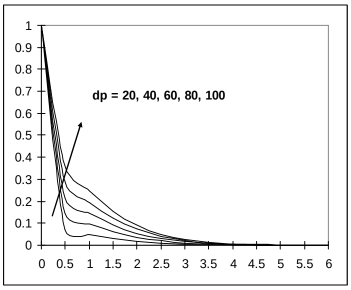


Figure 25: Variation of C with d_p

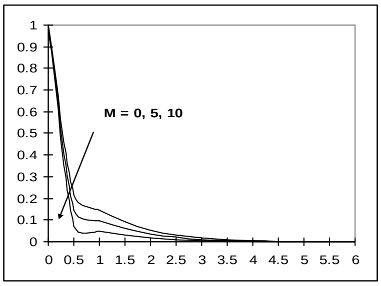


Figure 26: Variation of C with M

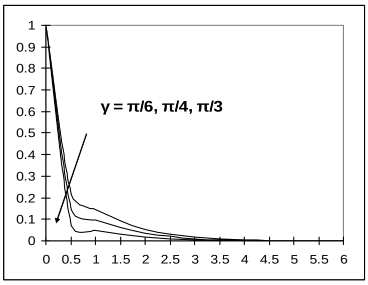


Figure 27: Variation of C with γ

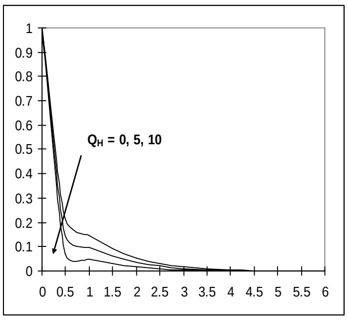


Figure 28: Variation of C with Q_H

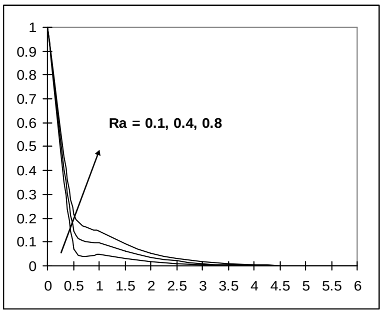


Figure 29: Variation of C with Ra

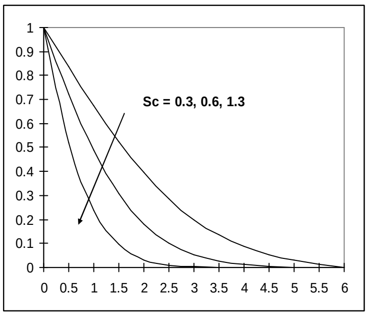


Figure 30: Variation of C with Sc

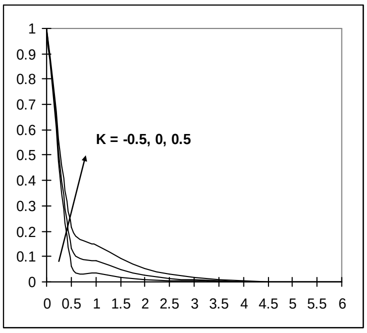


Figure 31: Variation of C with K

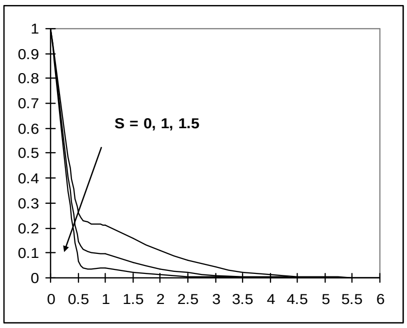


Figure 32: Variation of C with S

ϕ	$d_p = 20$, $Q_H = 5$, $S = 0.5$	$d_p = 60$, $Q_H = 5$, $S = 0.5$	$d_p = 100$, $Q_H = 5$, $S = 0.5$	$d_p = 60$, $Q_H = 10$, $S = 0.5$	$d_p = 60$, $Q_H = 15$, $S = 0.5$	$d_p = 60$, $Q_H = 5$, $S = 0.2$	$d_p = 60$, $Q_H = 5$, $S = 0.8$
0	1.63756	1.63756	1.63756	2.00503	2.31888	1.34674	1.96656
0.05	1.99986	1.99986	1.99984	2.45632	2.84571	1.65636	2.38769
0.1	2.33370	2.33414	2.33417	2.87548	3.33668	1.94552	2.77173

Table 1: Nusselt Number

Table-1 depicts the rate of heat transfer for various parameters ϕ, d_p, Q_H and S. Each column of the table signifies the importance of metal particles for heat transfer. Altogether 4-5% of heat transfer enhancement is noticed for every 1% enhancement of the cu particles in water. The heat transfer rate is more significant about average size of the particle (60 nm), for large size (>60 nm) the heat transfer rate slightly increases. The natural increase in heat transfer is observed for enhancement of heat source. The suction enhances the heat transfer rate due to the quick movement of the cu particles.

K	$Sc = 0.3$, $S = 0.5$	$Sc = 0.6$, $S = 0.5$	$Sc = 0.3$, $S = 0.2$	$Sc = 0.3$, $S = 0.8$
-0.5	0.531874	0.803074	0.482721	0.584537
0	0.389905	0.603457	0.340053	0.443849
0.5	0.222247	0.367911	0.171449	0.27792

Table 2: Sherwood Number

Table-2 depicts the Sherwood number (Mass Transfer coefficient) for variation of K, Sc and S. The rate of mass transfer is significantly high for generative (K<0) chemical reaction on the other hand the rate of mass transfer is significantly low for destructive (K>0) chemical reaction when both the cases are compared with no chemical reaction. Naturally the rate of mass transfer is more for more diffusivity (Sc) for all kinds of chemical reactions. The increase in suction (S) shows a gradual enhancement of the diffusivity during all kinds of chemical reaction.

References:

1. Ch.Ram Reddy, P.V.S.N. Murthy, A.J.Chamka and A.M.Rashad, Influence of viscous Dissipation on free convection in a Non-Darcy porous Medium Saturated with Nano fluid in the Presence of Magnetic Field, The Open Transport Phenomena Journal, 2013,5, 20-29.
2. M. A. A. Hamad and I. Pop, Unsteady MHD free convection flow past a Vertical permeable flat plate In a rotating frame of reference with Constant heat source in a nano-fluid, Heat Mass Transfer (2011)[47:1517–1524].
3. Md Shakhaoath Khan, Ifsana Karim, MdSirajul Islam and Mohammad Wahiduzzaman, MHD boundary layer radiative, heat generating and chemical reacting flow past a wedge moving in a nano fluid, Nano convergence 2014, 1:20.
4. Mohammad Mehdi Keshtkar, Neda Esmaili and Mohammad Reza Ghazanfari, Effect of heat source/sink on MHD Mixed convection Boundary layer flow on a vertical surface in a porous medium saturated by a nanofluid with suction or injection, Int. J. of Engineering And Science Vol.4, Issue 5 (May 2014), PP 01-11.
5. Md. Jashim Uddin, I. Pop& A.I. Md. Ismail, Free Convection Boundary Layer Flow of a Nanofluid from a Convectively Heated Vertical Plate with Linear Momentum Slip Boundary Condition, Sains Malaysiana 41(11)(2012): 1475–1482.

6. N.F.M.Noor, S. Abbasabandy and I.Hashim, Heat and Mass Transfer of thermophoretic MHD flow over an Inclined radiate Isothermal Permeable Surface in the Presence of Heat Source/ Sink, Int. J. of Heat and Mass Transfer, July12, 2013.
7. Olanrewaju, P.O., Olanrewaju, M.A. and Adesanya, A.O., Boundary layer flow of nanofluids over a moving surface in a flowing fluid in the presence of radiation, International Journal of Applied Science and Technology Vol. 2 No. 1; January 2012.
8. Pratik Tiwari and Vinayak Malhotra, Natural Convection over a Flat Plate from side to side Enclosures, IJAIEM, Volume 3, Issue 2, February 2014.
9. Pravin R.Harde, Ashok. T. Pise and Sandesh S Chugule, Thermal Performance of Thermosyphon Heat Pipe Solar Collector with Cuo/ Water Nanofluid, International Journal of Applied Engineering Research, Volume 9, Number 6 (2014) pp. 623-628.
10. Puneet Rana and R. Bhargava, Flow and Heat Transfer Analysis of a Nanofluid along a Vertical Flat Plate with Non-Uniform Heating Using Fem: Effect of Nanoparticle Diameter, International Journal of Applied Physics and Mathematics, Vol. 1, No. 3, November 2011.
11. R.K.Dhal, Unsteady MHD free convection flow in a nanofluid through porous medium with suction and heat source, International Journal of Science Innovations and Discoveries, 2014, 4 (1), 45-55.
12. R.Senthilkumar, S. Vaidyanathan and B. Sivaraman, Effect of copper nanofluid concentration on thermal performance of heat pipes, Frontiers in Heat Pipes (FHP), 4, 013004 (2013).
13. S.P. Anjali Devi and Julie Andrews, Laminar boundary flow of nano fluid over a flat plate, Int. J. of Appl. Math and Mech. 7(6): 52-71, 2011.
14. Thierry Mare, Salma Halelfadl, Ousmane Sow and Patrice Estelle, Comparison of the thermal performances of two nanofluids at low temperature in a plate Heat Exchanger, pp.1-25.