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TRANSIENT MHD FREE CONVECTIVE CHEMICALLY REACTING FLOW OVER A MOVING HOT VERTICAL POROUS PLATE WITH HEAT GENERATION/ABSORPTION, THERMAL RADIATION, VISCOUS DISSIPATION, AND OSCILLATING SUCTION AND FREE STREAM VELOCITY EFFECTS

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Abstract: In this paper, the transient MHD free convective chemically reacting flow over a moving hot vertical porous plate with heat generation/absorption, thermal radiation, viscous dissipation, oscillating suction and free stream effects is investigated. The governing non-linear and coupled partial differential equations are solved using the oscillating time-dependent perturbation series solutions. Expressions for the dependent flow variables are obtained and presented graphically. The results show, amidst others, that increase in the heat generation/absorption parameter increases the temperature, velocity, Nusselt number and skin friction; increase in the chemical reaction rate parameter increases the temperature, velocity, Nusselt, Sherwood numbers and skin friction but decreases the concentration; increase in the frequency of oscillation parameter increases the temperature and velocity but decreases the Nusselt, Sherwood numbers and skin friction. Furthermore, it is seen that Hartmann number increases the temperature, velocity, Nusselt number and skin friction; Schmidt number decreases the temperature, concentration, velocity, Nusselt number and skin friction but increases the Sherwood number; Raleigh number increases the temperature, velocity, Nusselt number and skin friction.

Keywords: heat generation; natural convection; oscillating suction; thermal radiation; viscous dissipation.

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1. INTRODUCTION

Magneto-hydrodynamic natural convective fluid flow over vertical plates have significances in geophysics, ionospheric and stellar physics, power generating systems, chemical engineering and the likes.

Different levels of interactions exist in different fluid flow systems. Some are highly interactive such that Dufour and Soret effects are relevant, some are moderate or less, and others are non-interactive. Considering the non-highly interactive fluid flow over vertical plates, there exist a number of research reports. In some, the roles of MHD are neglected while in others they are considered. Neglecting the effects of magnetic field, the unsteady convective flow over a vertical porous plate with suction effects has been studied by [1]-[5].

Chemically reacting fluids are electrolytic; so they exist as charges. The motion of the charges in a magnetic field produces electric current. In turn, the magnetic field in presence of electric current gives a mechanical force (Lorentz force) which modifies the motion of the fluids. In some systems the Lorentz force increases the flow velocity while in others decreases it. In view of this, the unsteady hydro-magnetic convective flow through porous vertical plates with suction effects has been investigated by [6]-[15]. Specifically, [15] studied numerically the effects of chemical reaction in an unsteady MHD natural convective heat and mass transfer flow over an infinite vertical porous plate whose temperature oscillates with the same frequency as the variable suction, and noticed that increase in: the magnetic field decreases the velocity and skin friction; Schmidt number decreases the velocity, concentration, skin friction and Sherwood number; chemical reaction rate parameter decreases the velocity, concentration, skin friction and Sherwood number. More so, the transient MHD convective flow past a moving vertical porous plate in the presence of suction and thermal radiation has been examined by [16]-[24]. Importantly, [18] investigated the influence of viscous dissipation and radiation on the transient MHD natural convective flow over an infinite vertical porous plate using the method of oscillating time-dependent perturbation series expansion method, and observed that increase in Eckert number increases the velocity and temperature; increase in the magnetic field, radiation and Darcy parameters decrease the temperature and velocity profiles; [22] investigated the thermal radiation effects on an unsteady MHD flow past a vertical porous plate with variable suction using finite element method, and noticed that the velocity function is increased by the increase in the radiation and porosity parameters but is decreased by the increase in Hartmann and Schmidt numbers; the temperature function increases with the increase in the radiation parameter and Hartmann number; concentration is increased by the rise in Schmidt number. [23] considered the transient MHD mixed convective flow over a moving infinite vertical porous plate with suction in the presence of radiation and heat absorption/generation, and observed that the velocity decreases through the increase in the magnetic field parameters; the increase in the heat source/sink parameter enhances the temperature field; the skin friction, Nusselt number and Sherwood number increase as the suction parameter increases; the concentration decreases as the Schmidt number increases.

[18] examined the transient MHD free convective flow over an accelerating infinite heated porous vertical plate but neglected the effects of chemical reaction rate, heat generation/absorption and frequency of oscillation. Therefore, this work is an improvement on it, considering the roles of the afore-mentioned parameters on the flow.

The paper is presented in the following format: section 2 is the physics of problem and mathematical formulation; section 3 is the methodology; section 4 the holds the results and discussion, while section 5 gives he conclusion.

2. PRELIMINARIES

We consider a one-dimensional transient hydro-magnetic natural convective flow of a viscous, incompressible, radiating and chemically reacting fluid over an accelerating hot vertical plate in the presence of heat generation/absorption, oscillating suction and free stream velocity. If y'-axis is along the vertical plate which is moving in the upward direction; $y'=0$ is the edge of the plate and also the origin, the x'-axis is normal to the plate; the pressure does not varies along the x'-axis and is equal to the hydro-static pressure (i.e. $\partial p'(x')/\partial x'=0$); the plate is porous and coated with some chemical substances; the fluid is chemically reactive, optically transparent and magnetically influenced; a constant magnetic field which is either due to the Earth or applied magnetic field is maintained in the x'- direction; the transverse applied magnetic field and the magnetic Reynolds number are very small such that the induced magnetic field and Hall effects are insignificant; the flow system is not highly interactive and such that Dufour and Soret effects are negligible. Upon the transient one-dimensional assumption, the independent variables in the problem are functions of y' and t' only. More so, taking u' as the axial velocity of the fluid; v' as the normal velocity of the fluid and is the velocity at which the fluid is sucked at the wall of the plate; T' and C' are the fluid temperature and concentration, respectively; T_∞ and C_∞ are the fluid temperature and concentration at equilibrium; T_w and C_w are the temperature and concentration at which the plate is maintained, and are high enough to enhance radiative heat transfer. Then, by the Boussineq approximation, the governing mass balance, momentum, energy and diffusion equations are as follows:

$$\frac{dv'}{dy'} = 0 \tag{1}$$

$$\frac{\partial(u'-U)}{\partial t'} + v\frac{\partial u'}{\partial y'} = \frac{\mu}{\rho}\frac{\partial^2 u'}{\partial y'^2} - + g\beta_t\left(T'-T_\infty\right) + g\beta_c\left(C'-C_\infty\right) - \left(\frac{\sigma_e H_o{}^2}{\mu\mu_m} + \frac{\mu}{\kappa}\right)\left(u'-U'\right) \tag{2}$$

$$\frac{\partial T'}{\partial t'} + v'\frac{\partial T'}{\partial y'} = \frac{k_o}{\rho C_p}\frac{\partial^2 T'}{\partial y'^2} - \frac{Q}{\rho C_p}\left(T'-T_\infty\right) + \frac{\mu}{\rho C_p}\left(\frac{\partial u'}{\partial y'}\right)^2 - \frac{1}{\rho C_p}\frac{\partial q_y'}{\partial y'} \tag{3}$$

$$\frac{\partial C'}{\partial t'} + v'\frac{\partial C'}{\partial y'} = D\frac{\partial^2 C'}{\partial y'^2} - k_r{}^2\left(C'-C_\infty\right) \tag{4}$$

$$\frac{\partial^2 q_y'}{\partial y'^2} - 3\alpha^2 q_y' - 16\alpha^2\sigma T_\infty{}^3\frac{\partial T'}{\partial y'} = 0 \tag{5}$$

with the boundary condition

$$u' = u_p = 0, T' = T_w, C' = C_w \ at \ \ y' = 0 \tag{6}$$

$$u' = U'(t') = U_o(1 + \varepsilon e^{i\omega' t'}),\ T' \to T_\infty, C' \to C_\infty \ \ at \ \ y' \to \infty \tag{7}$$

where U' is the free stream velocity; U_o is the uniform free stream velocity; u_p is the plate velocity; β_t and β_c are the volumetric expansion coefficients for temperature and concentration, respectively; ρ is the fluid density; μ is the viscosity of the fluid; g the gravitational field vector acting in the reverse direction of the flow; Q is the heat generation/absorption term, κ is the permittivity of the porous medium; B_o^2 is the uniform magnetic field strength, σ_e is the electrical conductivity of the fluid; k_o is the thermal conductivity of the fluid; C_p is the specific heat capacity at constant pressure; D is the diffusion coefficient; k_r^2 is the chemical reaction term of the fluid; q_y' is the radiative heat flux; t' is the time, ω is the frequency of oscillation; α is the optical depth of penetration of the radiant heat; σ is the Stefan-Botzman constant.

In high temperature regime, radiant heat transfer is seen to be important and is equivalent to the heat transfer by convection. By the optically thin assumption, the radiative heat flux given by equation (5) is approximated in the spirit of [25], and as seen in [18] is prescribed as

$$\frac{\partial q_y'}{\partial y'} = 4\alpha^2 (T' - T_\infty) \tag{8}$$

where $\alpha^2 = \int \delta_1 \lambda \frac{\partial B}{\partial T'}$, α<<1, λ is the frequency of radiation, δ_1 is the radiation absorption coefficient, B is the Planck’s function. By equation (2.8), equation (2.3) becomes

$$\frac{\partial T'}{\partial t'} + v'\frac{\partial T'}{\partial y'} = \frac{k_o}{\rho C_p}\frac{\partial^2 T'}{\partial y'^2} + \frac{Q}{\rho C_p}\left(T' - T_\infty\right) + \frac{\mu}{\rho C_p}\left(\frac{\partial u}{\partial y'}\right)^2 - \frac{4\alpha^2\left(T' - T_\infty\right)}{\rho C_p} \tag{9}$$

More so, being oscillating, the suction/injection is prescribed as

$$v' = v_o(1 + \varepsilon A e^{i\omega' t'}) \tag{10}$$

where v_o is the uniform suction/injection at the wall of the plate, $\varepsilon < 1$ is a small perturbation parameter, A<1 is a positive constant such that $\varepsilon A << 1$. And, by equation (1), the suction/injection is a function of t' and not of y'.

Introducing the following dimensionless quantities:

$$u = \frac{u'}{v_o}, v = \frac{v'}{v_o}, y = \frac{y' v_o}{\upsilon}, t = \frac{t' v_o^2}{4\upsilon}, U = \frac{U'}{U_o}, \qquad \omega = \frac{4\upsilon\omega'}{v_o^{\ 2}}, \theta = \frac{T' - T_\infty}{T_w - T_\infty}, \phi = \frac{C' - C_\infty}{C_w - C_\infty},$$

$$M^2 = \frac{\sigma_e B_o^2 \upsilon}{\rho v_o^{\ 2}}, \chi^2 = \frac{\upsilon^2}{\kappa v_o^2}, P_r = \frac{\upsilon}{k,} \quad , \quad Sc = \frac{\upsilon}{D}, \quad \mathrm{Gr} = \frac{\upsilon g \beta_t \left(T_w - T_\infty\right)}{U_o v_o^3}, \quad Gc = \frac{\upsilon g \beta_c \left(C_w - C_\infty\right)}{U_o v_o^3},$$

$$Ra^2 = \frac{4\alpha^2\left(T_w - T_\infty\right)}{\rho C_p v_o^2 k}, \ N^2 = \frac{Q}{k_o}, \delta^2 = \frac{k_r^2}{D}, \ Ec = \frac{U_o^2}{C_p(T_w - T_\infty)} \tag{11}$$

where u is the velocity in the x-axis; v is the normal velocity; which also stands for the suction; ω is the frequency of oscillation; θ is the fluid temperature; ϕ is the fluid concentration; χ^2 is Darcy permeability parameter, M^2 is the Hartmann number; Pr is the Prandtl number; Sc is the Schmidt number; Gr is the Grashof number due to temperature gradient; Gc is the Grashof number due concentration gradient; Ra^2 is the Raleigh number; υ is the kinematic viscosity; δ^2 is the chemical reaction rate parameter; N^2 is the heat generation/absorption parameter into equations. (1), (2), (4), (6), (7), (9) and (10), we have

$$\frac{\partial v}{\partial y}=0 \tag{12}$$

$$\frac{1}{4}\frac{\partial u}{\partial t}+v\frac{\partial u}{\partial y}=\frac{\partial^2 u}{\partial y^2}+\frac{1}{4}\frac{\partial U}{\partial t}-\left(M^2+\chi^2\right)(u-U)+Gr\theta+Gr\,\phi \tag{13}$$

$$\frac{\Pr}{4}\;\frac{\partial \theta}{\partial t}+\Pr v\frac{\partial \theta}{\partial y}=\frac{\partial^2 \theta}{\partial y^2}-\left(N^2+Ra^2\right)\theta\;+\Pr Ec\left(\frac{\partial u}{\partial y}\right)^2 \tag{14}$$

$$\frac{Sc}{4}\;\frac{\partial \phi}{\partial t}+Scv\frac{\partial \phi}{\partial y}=\frac{\partial^2 \phi}{\partial y^2}-\delta^2\phi \tag{15}$$

with the boundary conditions:

$$u=0,\theta=1,\;\phi=1\quad at\;\;y=0 \tag{16}$$

$$u=1+\varepsilon e^{i\omega t},\;\;\theta=0,\;\phi\;=0\;\;at\;\;y\to\infty \tag{17}$$

and

$$v=1+\varepsilon Ae^{i\omega t} \tag{18}$$

Furthermore, by equation (18), equations (13) - (15) become

$$\frac{1}{4}\frac{\partial u}{\partial t}+\left(1+\varepsilon Ae^{i\omega t}\right)\frac{\partial u}{\partial y}=\frac{\partial^2 u}{\partial y^2}+\frac{1}{4}\frac{\partial U}{\partial t}-M_1^2(u-U)+Gr\theta+Gr\,\phi \tag{19}$$

$$\frac{\Pr}{4}\;\frac{\partial \theta}{\partial t}+\Pr\left(1+\varepsilon Ae^{i\omega t}\right)\frac{\partial \theta}{\partial y}=\frac{\partial^2 \theta}{\partial y^2}-\gamma^2\theta+\Pr Ec\left(\frac{\partial u}{\partial y}\right)^2 \tag{20}$$

$$\frac{Sc}{4}\;\frac{\partial \phi}{\partial t}+Sc\left(1+\varepsilon Ae^{i\omega t}\right)\frac{\partial \phi}{\partial y}=\frac{\partial^2 \phi}{\partial y^2}-\delta^2\phi \tag{21}$$

where $M_1^2=M^2+\chi^2$, $\gamma^2=N^2+Ra^2$ and the boundary conditions, equations (2.16) and (2.17) still hold.

Furthermore, an examination of equations (19) - (21) shows that they are non-linear and coupled. To linearize and make them tractable, we seek for the oscillating time-dependent perturbation series expansion solutions of the form:

$$\left.\begin{aligned} u(y,t)&=u_o(y)+\varepsilon u_1(y)e^{i\omega t}+\dots\\ \theta(y,t)&=\theta_o(y)+\varepsilon\theta_1(y)e^{i\omega t}+\dots\\ \phi(y,t)&=\phi_o(y)+\varepsilon\,\phi_1(y)e^{i\omega t}+\dots\end{aligned}\right\} \tag{22}$$

Substituting equation (22) appropriately into equations (19) – (21), we have

$$\frac{\partial^2 u_o}{\partial y^2} - \frac{\partial u_o}{\partial y} - M_1^2 u_o = -M_1^2 - Gr\theta_o - Gr\,\phi_o \tag{23}$$

$$\frac{\partial^2 \theta_o}{\partial y^2} + \frac{\partial \theta_o}{\partial y} - \gamma^2 \theta_o = -\Pr Ec\left(\frac{\partial u_o}{\partial y}\right)^2 \tag{24}$$

$$\frac{\partial^2 \phi_o}{\partial y^2} + \frac{\partial \phi_o}{\partial y} - \delta^2\, \phi_o = 0 \tag{25}$$

for the zeroth order with the boundary conditions:

$$u_o = 0, \theta_o = 1,\ \phi_o = 1 \quad at\ \ y \ = \ 0 \tag{26}$$

$$u_o = 1,\ \theta_o = 0,\ \ \phi_o = 0 \ \ at\ \ y \to \infty \tag{27}$$

and

$$\frac{\partial u_1}{\partial y^2} + \frac{\partial u_1}{\partial y} - \xi^2 u_1 = -A\frac{\partial u_o}{\partial y} - Gr\theta_1 - Gc\phi_1 \,(3.7)\ \ \frac{\partial^2 \theta_1}{\partial y^2} - \Pr\frac{\partial \theta_1}{\partial y} - \eta^2 \theta_1 = -A\frac{\partial \theta_o}{\partial y} \tag{28}$$

$$\frac{\partial^2 \phi_1}{\partial y^2} - Sc\frac{\partial \phi_1}{\partial y} - \psi^2\, \phi_1 = -A\frac{\partial \phi_o}{\partial y} \tag{29}$$

for the first order where $\xi^2 = M_1^2 + \frac{i\omega}{4}$, $\eta^2 = \gamma^2 + \frac{i\omega}{4}$, $\psi^2 = \delta^2 + \frac{i\omega}{4}$

with the boundary conditions.

$$u_1 = 0,\ \theta_1 = 0,\ \phi_1 = 0 \ \ at \ \ y = 0 \tag{30}$$

$$u_1 = 1,\ \theta_1 = 0,\ \phi_1 = 0 \ \ at \ \ y \to \infty \tag{31}$$

Furthermore, we present the heat transfer rate (Nu), mass transfer rate (Sh) and the skin friction as

$$Nu = k_o \frac{2q_w\sqrt{\upsilon t}}{(T_w - T_\infty)} = -\theta'\big|_{y=0}\ , \tag{32}$$

$$Sh = D\frac{2s_w\sqrt{\upsilon t}}{(C_w - C_\infty)} = -\phi'\big|_{y=0}\ , \tag{33}$$

$$C_f = \mu\frac{\partial u}{\partial y}\Big|_{y=0} \tag{34}$$

where $\quad q_w = -k_o\frac{\partial T}{\partial y}\Big|_{y=0},\ s_w = -D\frac{\partial C}{\partial y}\Big|_{y=0}$ and prime implies differentiation.

Equations (23)-(34) are solved and the graphs below are plotted for varied values of some chosen parameters using *MATHEMATICA 11* computational software.

3. Main results

The roles of heat generation/absorption parameter, chemical reaction rate, frequency of oscillation parameter, magnetic field, and Schmidt number on the problem are investigated, and the results shown graphically in Fig. 2-Fig. 27. For physically realistic constant values of Ra^2=0.3, ε=0.1, χ^2=0.1, and varying values of N^2=0.2, 0.4, 0.6, 0.8, 1.0, 1.2, δ^2=0.2, 0.4, 0.6, 0.8, 1.0, 1.2, ω=0.2, 0.4, 0.6, 0.8, 1.0, 1.2, M^2=0.2, 0.4, 0.6, 0.8, 1.0, 1.2, Sc=0.2, 0.4, 0.6, 0.8, 1.0, 1.2. the profiles shown below are obtained.

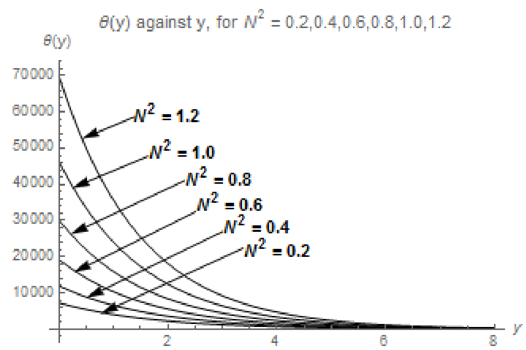

Fig.1 Temperature-Heat Generation/Absorption Parameter Profiles

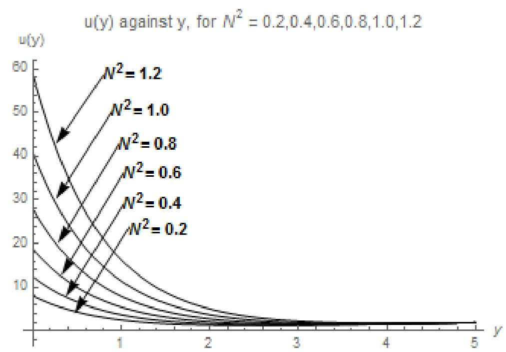

Fig. 2 Velocity-Heat Generation/Absorption Parameter Profiles

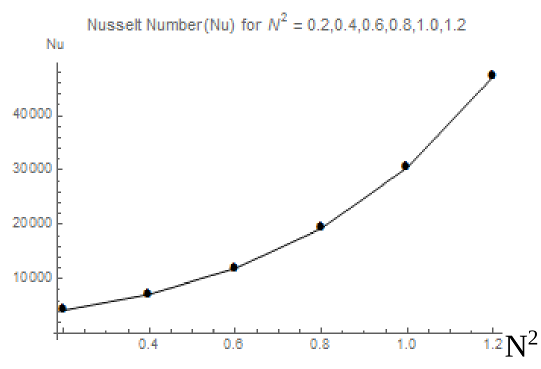

Fig. 3 Nusselt number-Heat Generation/Absorption Pararameter Profile

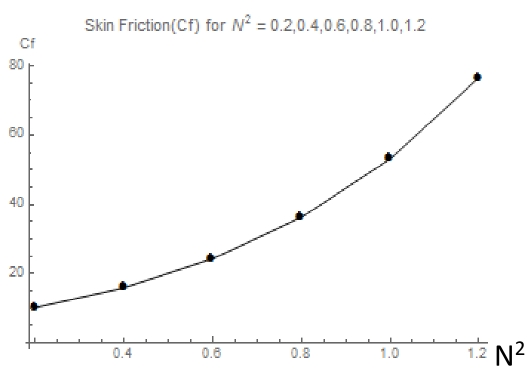

Fig. 4 Skin Friction-Heat Generation/ Absorption Parameter Profile

The influences of heat generation/absorption on the flow are seen in Fig. 1 - Fig. 4. They depict that increase in the heat generation/absorption parameter increases the temperature, velocity, rate of heat transfer from the plate to the fluid and skin friction/force exerted on the plate by the fluid.

Fig. 1 shows that increase in the heat generation/absorption parameter increases the fluid temperature. Fig. 2 depicts that increase in the heat generation/absorption parameter increases the velocity profiles. Fig. 3 and Fig. 4 show that increase in the heat generation/absorption parameter increases the rate of heat transfer from the plate to the fluid, and the force exerted by the fluid on the plate, respectively.

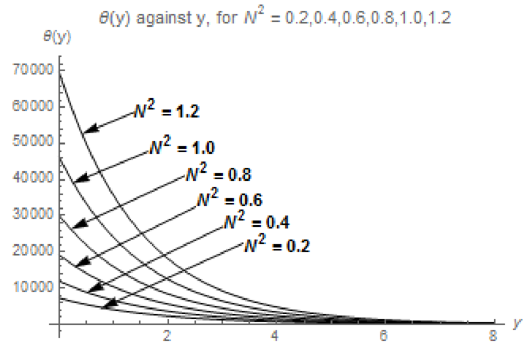

Fig.1 Temperature-Heat Generation/Absorption Parameter Profiles

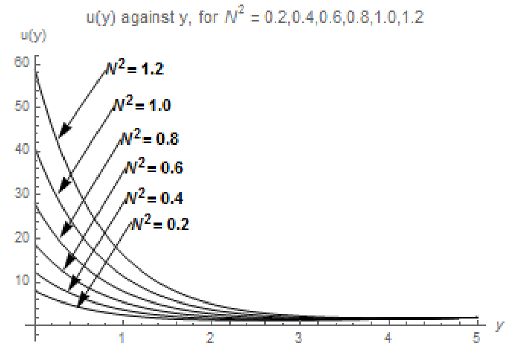

Fig. 2 Velocity-Heat Generation/Absorption Parameter Profiles

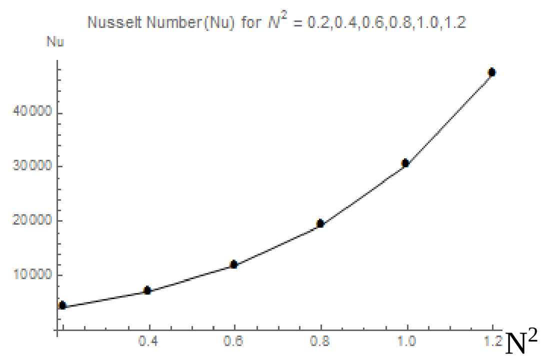

Fig. 3 Nusselt number-Heat Generation/Absorption Pararameter Profile

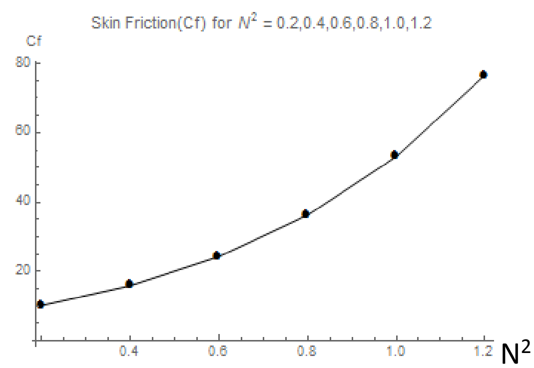

Fig. 4 Skin Friction-Heat Generation/ Absorption Parameter Profile

The influences of heat generation/absorption on the flow are seen in Fig. 1 - Fig. 4. They depict that increase in the heat generation/absorption parameter increases the temperature, velocity, rate of heat transfer from the plate to the fluid and skin friction/force exerted on the plate by the fluid. Fig. 1 shows that increase in the heat generation/absorption parameter increases the fluid temperature. Fig. 2 depicts that increase in the heat generation/absorption parameter increases the velocity profiles. Fig. 3 and Fig. 4 show that increase in the heat generation/absorption parameter increases the rate of heat transfer from the plate to the fluid, and the force exerted by the fluid on the plate, respectively.

On a similar note, it is seen that increase in Raleigh number increases the fluid temperature, velocity, the rate of heat transfer to the fluid and the force exerted on the plate by the fluid. These results agree with [16, 22].

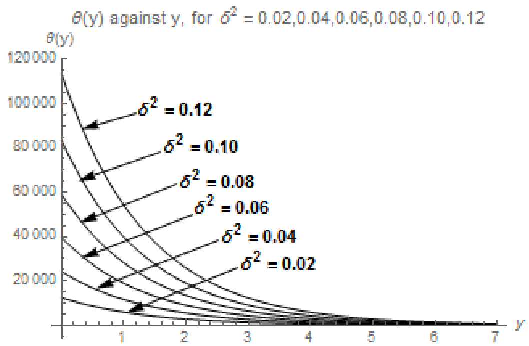

Fig. 5 Temperature-Chemical reaction rate Parameter Profiles

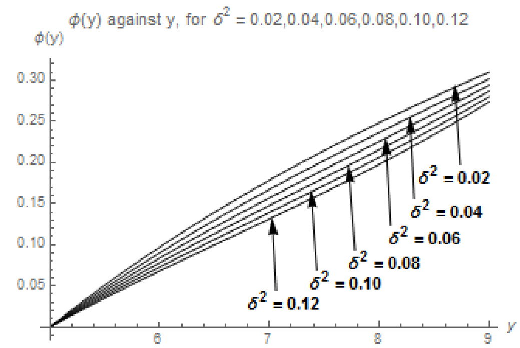

Fig. 6 Concentration-Chemical reaction rate Parameter Profiles

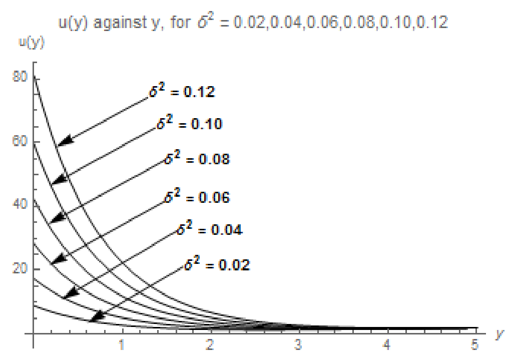

Fig. 7 Velocity-Chemical reaction rate Parameter Profiles

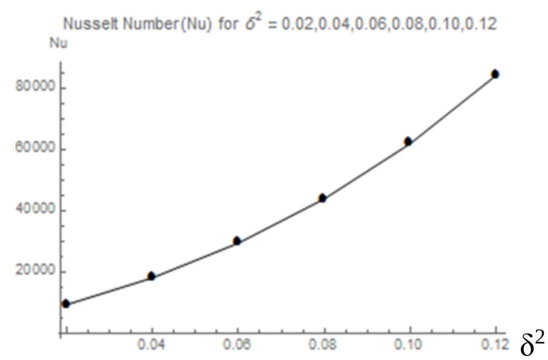

Fig. 8 Nusselt number-Chemical reaction rate Parameter Profile

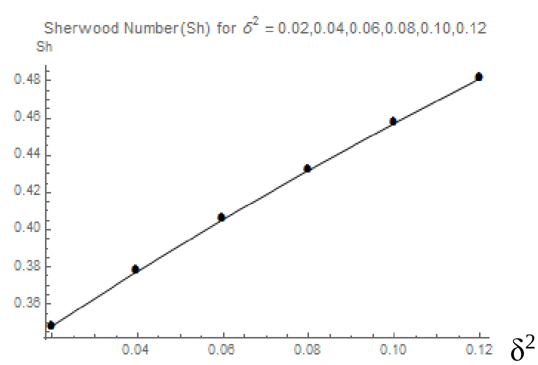

Fig. 9 Sherwood number-Chemical reaction rate Parameter Profile

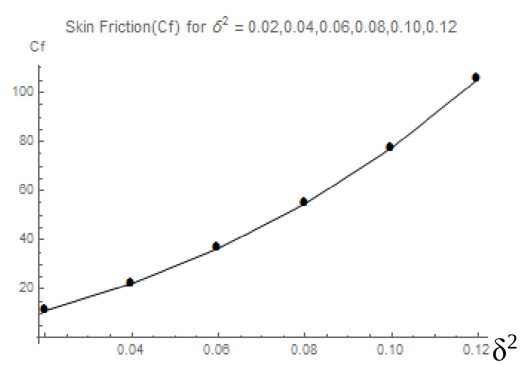

Fig. 10 Skin Friction-Chemical reaction rate Parameter Profile

The roles of chemical reaction rate parameter are seen in Fig. 5-Fig. 10. The results shows that increase in the chemical reaction rate parameter increases the temperature, velocity, Nusselt and Sherwood numbers and skin friction but decreases the concentration function. Chemical reaction rate depends on the nature and order of the reactants, concentration and temperature. In this problem, the effective chemical reaction rate seems to be in the range of $0.01 < \delta^2 < 0.12$. For $0.1 < \delta^2 < 1.2$, no variations are seen in the profiles. Fig. 5 shows that increase in the chemical reaction rate parameter increases the temperature of the fluid. Fig. 6 depicts that increases in the chemical reaction rate parameter decrease the concentration. This is in alignment with [15]. Fig. 7 shows that increase in the chemical reaction rate parameter increases the flow velocity; Fig. 8 depicts that increase in the chemical reaction rate parameter increases the rate at which heat is transferred from the plate to the fluid. Fig. 9 shows that increase in the chemical reaction rate parameter increases the rate of material/mass transfer of from the plate to the fluid; Fig. 10 depicts that increase in the chemical reaction rate parameter increases the force the fluid exerts on the plate.

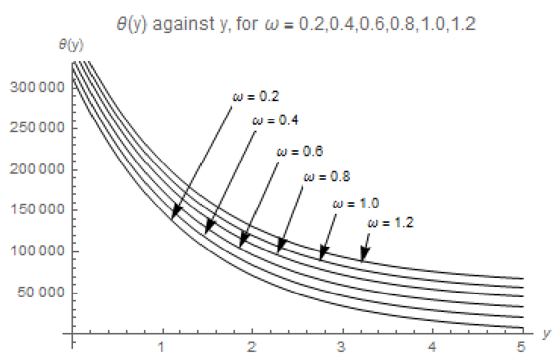

Fig. 11 Temperature-Frequency of oscillation Profiles

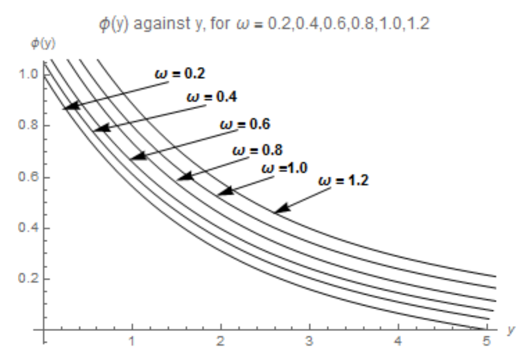

Fig. 12 Concentration-Frequency of oscillation Profiles

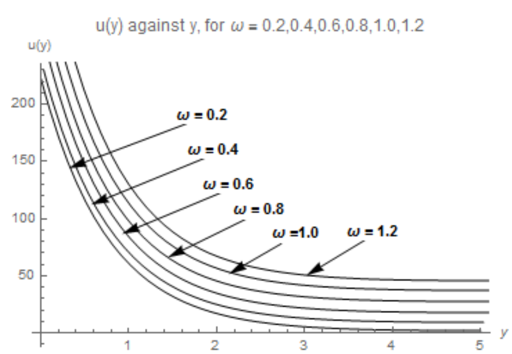

Fig. 13 Velocity-Frequency of oscillation Profiles

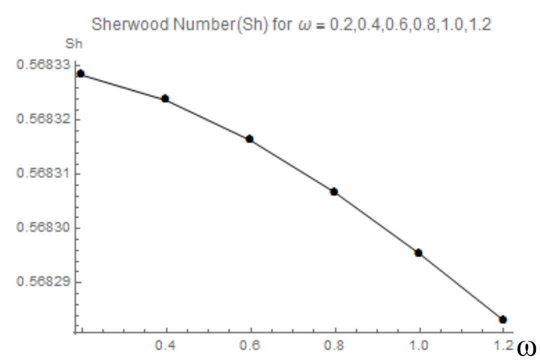

Fig. 14 Nusselt number-Frequency of oscillation Profile

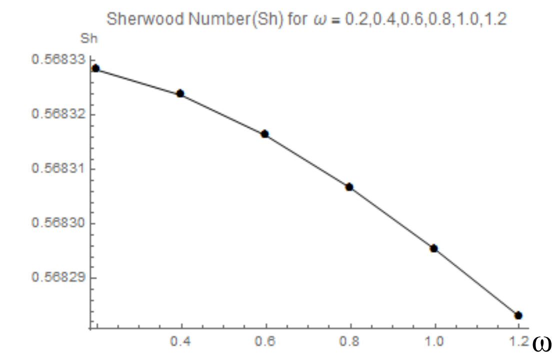

Fig. 15 Sherwood number-Frequency of oscillation Profile

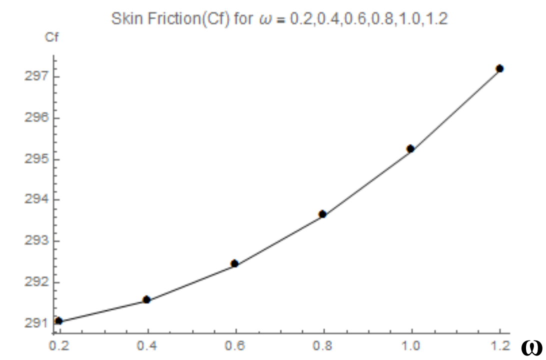

Fig. 16 Skin Friction-Frequency of oscillation Profile

The influences of the frequency of oscillation parameter on the flow problem are shown in Fig. 11-Fig. 16. They show that increase in the frequency of oscillation parameter increases the temperature, concentration, velocity and skin friction but decreases the Nusselt and Sherwood numbers. Increase in the frequency of oscillation parameter: increases the fluid temperature, as seen in Fig. 11; increases the fluid concentration, as seen in Fig. 12; increases the flow velocity, as seen in Fig. 13; decreases the Nusselt number, as seen in Fig. 14; decreases the Sherwood number, as seen in Fig. 15; increases the skin friction, as seen in Fig. 16.

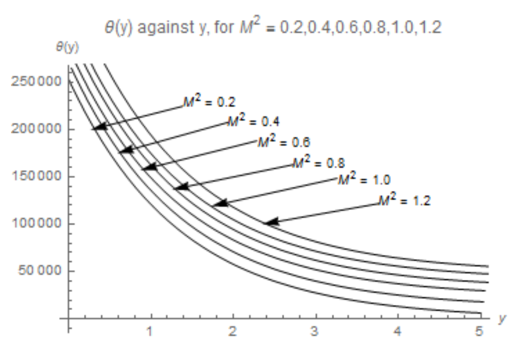

Fig. 17 Temperature-Hartmann number Profiles

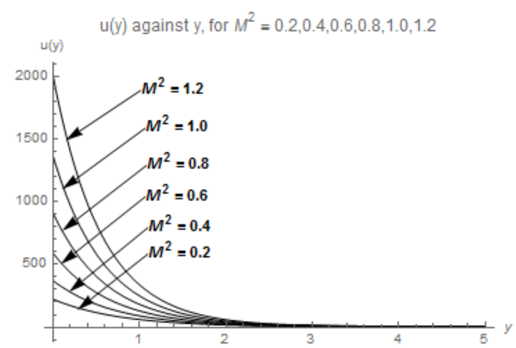

Fig. 18 Velocity-Hartmann number Profiles

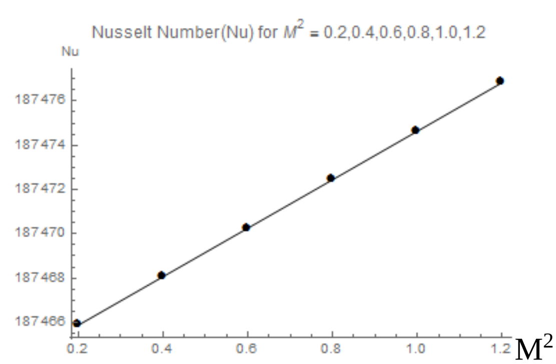

Fig. 19 Nusselt number-Hartmann number Profiles

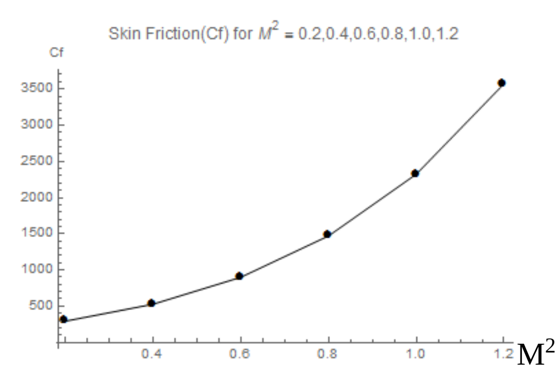

Fig. 20 Skin Friction-Hartmann number Profile

The importances of Hartmann number on the flow are shown in Fig. 17 - Fig. 20. They show that as Hartmann number increases the temperature, velocity, the rate of heat transfer and force on the wall of the plate increase. Fig. 17 shows that as Hartmann number increases the fluid temperature increases. This is in consonance with [23]. Fig. 18 depicts that as Hartmann number increases the flow velocity increases. Fig. 19 and Fig. 20 depict that as Hartmann number increases the rate of heat transfer from the plate/wall to the fluid and the force the fluid exerted on the plate increase, respectively.

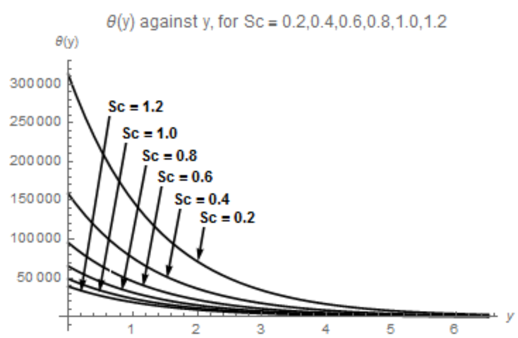

Fig. 21 Temperature-Schmidt number Profiles

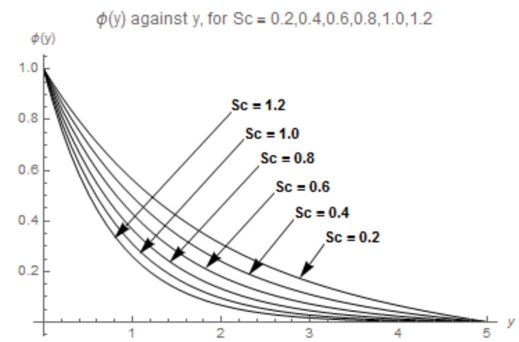

Fig. 22 Concentration-Schmidt number Profiles

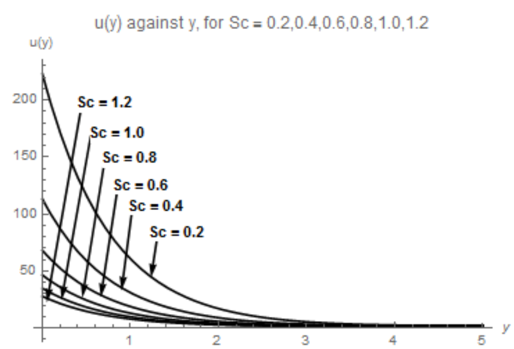

Fig. 23 Velocity-Schmidt number Profiles

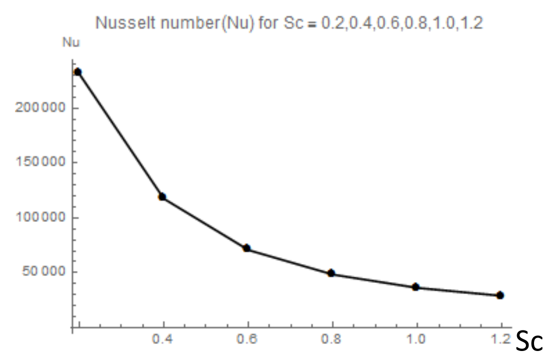

Fig. 24 Nusselt number- Schmidt number Profile

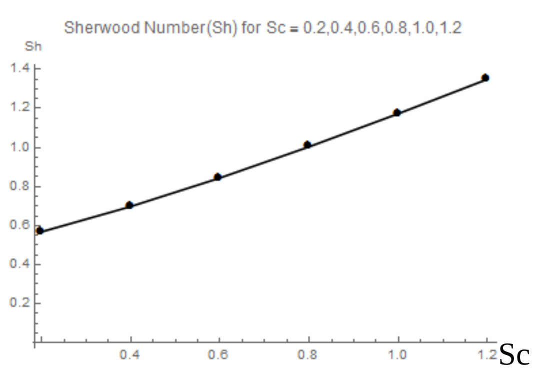

Fig. 25 Sherwood number-Schmidt number Profile

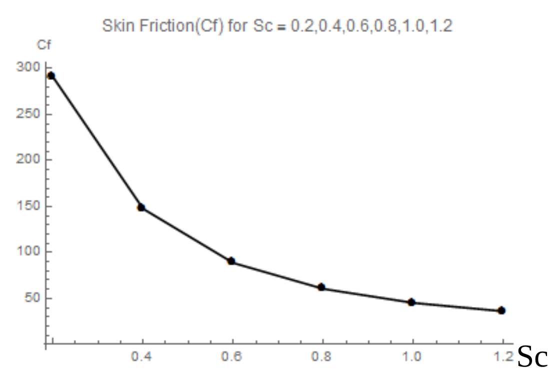

Fig. 26 Skin Friction-Schmidt number Profile

The relevancies of Schmidt number on the flow are seen in Fig. 21–Fig. 26.The results show that increase in Schmidt number decreases the temperature, concentration, velocity, Nusselt number and skin friction but increases the Sherwood number. Fig. 21 shows that increase in Schmidt number decreases the temperature. Fig. 22 depicts that increase in Schmidt number decreases the concentration of the fluid. This agrees with [23]. More so, increase in Schmidt number: decreases the flow velocity, as seen in Fig. 23; decreases the rates of heat transfer from the plate to the fluid and the force exerted by the fluid on the plate, as shown in Fig. 24 and Fig. 26, respectively; increases the rate of material transfer from the plate to the fluid, as seen in Fig. 25. All the results obtained here agree with [15].

Transient hydro-magnetic natural convective chemically reacting flow over an accelerating hot vertical porous plate with heat generation/absorption, thermal radiation, viscous dissipation, and oscillating suction and free stream velocity effects is investigated using the time-dependent oscillating perturbation series solutions approach. The results show that increase in:

- the heat generation/absorption parameter increases the temperature, velocity, Nusselt number and skin friction,
- Raleigh number increases the temperature, velocity, Nusselt number and skin friction,
- the chemical reaction rate parameter increases the temperature, velocity, Nusselt and Sherwood umbers and skin friction but decreases the concentration,
- the oscillating frequency parameter increases the temperature, concentration, velocity and skin friction but decreases the Nusselt and Sherwood numbers,
- Hartmann number increases the temperature, velocity, Nusselt number and skin friction,
- Schmidt number decreases the temperature, concentration, velocity, Nusselt number and skin friction but increases the Sherwood number.

Conflict of Interests

The author(s) declare that there is no conflict of interests.

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