International Journal of Engineering & Technology, 7 (4.10) (2018) 956-962

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

A Numerical Investigation on MHD Couple Heat and Mass Transfer Past a Rotating Vertical Cone Embedded in a Porous Medium

S. Veera Reddy[1], G S S Raju[2] and A.G. Vijaya Kumar[3,*]

[1] *Department of Mathematics, Rayalaseema University, Kurnool, AP, INDIA.*
[2]*Department of Mathematics, JNT University, Kadapa (YSR dist.), AP, INDIA*
[3]*Department of Mathematics, SAS, VIT, Vellore-632 014, TN, INDIA*
**Corresponding Author E-mail: vijayakumarag@vit.ac.in*

Abstract

This collaborative effort highlights the effects of combined energy and species transmission through the both mechanism of convections of a fluid flow witch obeys Newton's law of viscosity, over a rotatory upward directed geometrized cone from conic section surrounded with a medium possessing porosity along with applied magnetic field and chemical reaction effects with Dufour effect. The fundamental laws such as mass conservative, linear momentum conservative, heat energy and molecular diffusion conservative field are transmuted using suitable analogous variables witch do not change anyway the modelling and then shooting method that is implemented along with Runge-Kutta method to obtain the solutions. The results obtained are in excellent agreement with previous works in the same discipline. Graphical representation of with distinct numeral magnitudes for fluid transport, temperatures, species levels, besides that local polar tangential and azimuth (the angle between projected and reference vectors) coefficient of friction drag, local energy and mass transmission rates near the wall surface is displayed as one scrolls down and discussions for mixed values of some physical quantities independent of S.I units to gather much attention upon the results on the solutions are also made. Its applications include making equipment coolant, reactors with bedding, in a system of porous wafers absorbed by solar rays and in the preparation of some fusion materials. Other disciplinarians are aircrafts wings, space research, asteroid and geophysical matters, in concern of energy-species-density dependence.

Keywords: *Dufour effect; Heat and mass transfer; MHD; Newtonian fluid; Rotating cone*

1. Introduction

Chamkha and Rashad [3] have furnished information on flow and heat transfer through rotating systems and then researched combined convective mechanism on MHD heat mass transmissions flow unsteadiness over a gyrating straight up cone. Also cared enough to induce chemical reaction alongside Soret and Dufour effects solved numerically by deploying an implicit finite difference method. Their carried research paper also enfolds skin-friction onlocal radial and azimuthal profiles, energy transmission and species transferal rates. Chamkha [4] analyzed Non-Darcy hydro-magnetic free convection by a cone and a wedge under the presence of a porous media. Chamkha et al. [1] in the year 2002 also gave results energy transference along with mass diffusion surrounded by magnetism across the surface of the cone entrenched in a non-Darcian porosity by considering the impact of energy source or energy sink. In 2005, he discussed varying compressible peripheral flow over a circular cone close to a symmetrical plane. Continuing to amaze us with his work in the field of heat transfer in 2012 he scrutinized both convective radiative effect on nanoscale-particles across surface of geometrically shaped cone in a porous regime.
Chamkha and Rashad in collaboration presented nano-scaled particle suspension in regular liquids through the phenomena of convective mechanism over upright permeable conic sectional cone drenched medium of pores for undeviating nano-sized particles volume ratio metallurgy. Prakash et al. [19] generated results on magnetized convective flow across upward straight up cone with fluctuating Heat and mass rates flowing through cross-sectional area. Ching-Yang Cheng [9] examined heat transmission which occurs due to the convective mechanism around upright cone embedded in a tri-disperse spongy regime. In the year 2010 he also described impact of Soret and Dufour trends on convective mode of energy transmissions on a perpendicular curtailed cone in a fluid-drenched pores zone with varying cone surface hotness and the amount of species levels. Effects of chemical reaction and heat generation/absorption on unsteady chemically reacted energy source, magnetic convective flow over a straight up cone with fluctuating species of mass was investigated by Ravindran et al. [22]. Patil and Pop [18] tested the effects species of mass analogy on non-uniform free and forced convection flow on upward directed cone alongside by chemical reactions. Seddeek et al. [26] performed an analytical study that considers the consequences of due to by chemical reactivity and species of mass on liberal convective mode of flow through an erect isothermal conical surface. Himasekhar and Sarma [11] gained important observations on the effect of suction on heat transfer rates of a cone under gyration. Lin [13] displayed laminar free convection from the same type of cone that had uniform surface heat flux through it. Bapuji et al. [20] probed by implementing a technique of finite difference to gain numerous results on a fluid flow which causes by convective mode past an erect cone which was under non-isothermal milieu. Roy and Anilkumar [23] studied unsteady mixed convection of a

rotating cone where the fluid in it was also revolving owing to the combined outcomes of thermal and mass diffusion. Singh and Roy [28] explored Unsteady mixed convection flow around a vertical cone because of impulsive motion. Roy et al. [24] generated facts regarding varying MHD flow where the cone and fluid, both are in rotation.

Nadeem and Saleem [16] gave information on Unsteady mixed convective flow of Nano fluid within a circling cone to which a magnetic field was applied. Hering and Grosh [10] gave out Laminar Combined Convection from a Rotating Cone. Himasekhar et al. [19] looked into laminar mixed convection on a vertical rotating cone. Tien [28] took a turning cone and investigated the heat and mass transfer in it within laminar flow constraints. Saleh and Al-Harbi [25] also considered the same gyrating cone and presented facts related to analogous solution of transmitting heat and mass matter for fluctuating mixed convection flow entrenched in a porous medium that was soaked within a rotating fluid. Rashad et al. [21] studied thermophoresis effect on heat and mass transfer from a cone under rotation with thermal radiation under a porous medium. Bandaru et al. (2016) also performed similar investigations as Rashad et al. but took into account non-linear convection on heat and mass transfer on a cone that was gyrating with a porous fluid medium. Mahdy [14] gave away effects of energy generating absorbing chemical reacted fluid flow on di-diffusivity proceed by the convection from a perpendicular cut conical sectional cone under porosity zone with changing kinematic viscosity. Srinivasa and Eswara [27] studied unsteady free convection flow and heat transfer from an isothermal truncated cone with variable viscosity. Ching-Yang Cheng [8] studied free convection a kind of non-Newtonianity nanosized-fluid particles across a straight up truncated cone in regime of pores based zone.

The aspiration of current study to fulfill partial incompleteness that has been observed in the survey so as to that to convey some more results through this paper, how the fluid flow influenced by radiative thermophoresis on energy and species transmission due to the notable convective mechanism across the surface of revolving origin based straight up cone which was embedding in saturated porous regime. The mathematical modelling of the flow configuration, obviously partial differential equations, are modified into a comparable form without loss of any generality, thereafter tackled with a popular numerical scheme known as Runge-Kutta method with the necessity of Newton-Raphson technique to trace out initial guesses. Hence, plotted curves with the source of these numerical approximations such as friction drags of radial and polar tangential, azimuth components, cone surface thermophoresis transport, local Nusselt number and Sherwood numbers with respect to significant impact of quantities entering in this model, to understand their physical behavior in more detail way.

2. Mathematical analysis

A steady state of viscous, magnified incompressible, electrolyzed conducting at a low Reynold numbered, 2-D boundary layer, the fluid motion caused by the coupled convection mechanism induced by a revolving upward directed conical cone with a rotational velocity Ω in a regime of varying porosity and due to its practical importance, this investigation is undertaken in an environment of magnetic field is considered. To generate magnetic intensity, a small of amount of magnetic force uniformly has been applied in z-direction against to the conical cone surface region. The cone exterior is uphold a variable temperature T_w and various amount of species mass C_w, they are absolutely superior to ambient degrees of hotness T_∞ and species levels C_∞ moving away from solid cone boundary respectively. It is made an assumption that, properties of the liquids are to be isotropic and the buoyancy effect is only external force supporting the fluid motion while opposed by Lorentz force. Further, take on porous medium and that the fluid attains an equilibrium state, for better results, it has been taken a cone which is made up metallic material without electrification. The magnetic field induces in this process is ignored due to very slight magnetic Reynolds number presented. Aside from, a chemical reaction is influencing the fluid matter at a constant rate by diffusion of species. Based on this analysis under various assumptions, the mass continuity, the momentum transport, energy transport and species transport equations, by incorporating Boussinesq's approximation in Eq.(2), which have been simplified and presented, assigning numbers namely eq.(1), Eq.(2), Eq.(3), Eq.(4) and Eq.(5) as follows.

$$\frac{\partial u}{\partial x}+\frac{\partial w}{\partial z}+\frac{u}{x}=0 \tag{1}$$

$$\varepsilon^{-2}\rho\left(u\frac{\partial u}{\partial x}+w\frac{\partial u}{\partial z}-\frac{v^2}{x}\right)=\varepsilon^{-1}\mu\frac{\partial^2 u}{\partial z^2}-\sigma B_0^{\,2}u-\frac{\mu}{K}u$$
$$-C_b u^2+\rho g\beta_T\left(T-T_\infty\right)\cos\alpha+\rho g\beta_c\left(T-T_\infty\right)\cos\alpha \tag{2}$$

$$\varepsilon^{-2}\rho\left(u\frac{\partial v}{\partial x}+w\frac{\partial v}{\partial z}+\frac{uv}{x}\right)=\varepsilon^{-1}\mu\frac{\partial^2 v}{\partial z^2}-\sigma B_0^{\,2}v-\frac{\mu}{K}v-C_b v^2 \tag{3}$$

$$u\frac{\partial T}{\partial x}+w\frac{\partial T}{\partial z}=\frac{\kappa}{\rho C_p}\frac{\partial^2 T}{\partial z^2}-\frac{1}{\rho C_p}\frac{\partial q_r}{\partial z}+\frac{\phi'}{\rho C_p}\left(T_\infty-T\right)$$
$$+\frac{D_K T}{C_s C_p}\frac{\partial^2 C}{\partial z^2} \tag{4}$$

$$u\frac{\partial C}{\partial x}+w\frac{\partial C}{\partial z}=D\frac{\partial^2 C}{\partial z^2}-\frac{D_K T}{T_m}\frac{\partial^2 T}{\partial z^2}-k_r\left(C-C_\infty\right) \tag{5}$$

The resultant conditions defined at boundaries are

$$u=0,\quad v=r\Omega,\quad w=0,\quad T=T_w(x),\quad C=C_w(x)$$
$$u=0,\quad v=0,\quad T=T_\infty,\quad C=C_\infty \tag{6}$$

For mathematical convenience, some dimensionless expressions are derived from Buckingham's π theorem, listed as follows, and introduced in above set of equations, so that one can read them those are independent of dimensions (S.I. Units)

$$\eta=\left(\frac{\Omega\sin\alpha}{v}\right)^{1/2}z,\ u=x\Omega\sin\alpha T(\eta),\ r=x\sin\alpha$$

$$v=x\Omega\sin\alpha G(\eta),\ w=\left(v\Omega\sin\alpha\right)^{1/2}H(\eta),\ Sc=\frac{v}{D}$$

$$\theta(\eta)=\frac{T-T_\infty}{T_w(x)-T_\infty},\ \phi(\eta)=\frac{C-C_\infty}{C_w(x)-C_\infty},\ \gamma=\frac{Kr}{\Omega\sin\alpha}$$

$$T_w(x)-T_\infty=\frac{\left(T_L-T_\infty\right)x}{L},\ C_w(x)-C_\infty=\frac{\left(C_L-C_\infty\right)x}{L},$$

$$Da^{-1}=\frac{v}{K\Omega\sin\alpha},\ M^2=\frac{Ha^2}{\mathrm{Re}_L},\ Ha^2=\frac{\sigma B_0^{\,2}L^2}{\mu},\ \Pr=\frac{k_e}{\mu C_p}$$

$$\mathrm{Re}_L=\frac{\Omega L^2\sin\alpha}{v},\ gs=\frac{GrL}{\mathrm{Re}^2_L},\ N=\frac{\beta_c\left(C_w-C_\infty\right)}{\beta_T\left(T_w-T_\infty\right)}$$

$$GrL=\frac{g\beta_T\cos\alpha\left(T_w-T_\infty\right)L^3}{v^2} \tag{7}$$

In above quantities, L is taken to be cone be the cone slanting height and T_L denotes hotness of cone shallow while C_L is species concentration on cone shallow is based at ($X=L$)

In accordance of an approximation introduced by famous astro-physicist Svein Rosseland, the heat flux of the radiation q_r taken to be for an boundary layer which are optically thick as;

$$q_r = -\frac{4\sigma^*}{3k^*}\nabla T^4 \tag{8}$$

The variations in temperatures within the fluid region is supposed to be very slight, hence with the help of Taylors series T^4 about the point T_∞, when expanding and ignoring the terms from second degree onwards, it takes the form as:

$$T^4 \cong 4T_\infty^3 T - 3T_\infty^4 \tag{9}$$

Using eqns. (8) and (9), eqn. (4) reduces to

$$\left(u\frac{\partial T}{\partial x} + w\frac{\partial T}{\partial z}\right) = \frac{k_e}{\rho c_p}\frac{\partial^2 T}{\partial z^2} + \frac{1}{\rho c_p}\frac{16\sigma^* T_\infty^3}{3k^*}\frac{\partial^2 T}{\partial z^2} + \frac{\phi(T_\infty - T)}{\gamma C_p} + \frac{D_{kT}}{C_s C_p}\frac{\partial^2 C}{\partial z^2} \tag{10}$$

By substituting (7) in equations (1-5), we get

$$F = \frac{-H'}{2} \tag{11}$$

$$-\varepsilon^{-1}H''' + \varepsilon^{-2}HH'' + \left(M^2 + Da^{-1}\right)H' - \left(\rho x + \frac{\varepsilon^{-2}}{2}\right)H'^2 + 2\varepsilon^{-2}G^2 + 2g_s\left(\theta + N\phi\right) = 0 \tag{12}$$

$$-\varepsilon^{-1}G'' - \left(M^2 + Da^{-1}\right)G - \rho x G^2 - \varepsilon^{-2}\left(HG' - H'G\right) = 0 \tag{13}$$

$$\theta'' = \frac{1}{(AB - N)}\left[\begin{array}{l}\frac{1}{2}\left(\Pr H'\theta - AScH'\phi\right) - \Pr H\theta' + \\ AScH\phi' - S\Pr\theta + A\gamma Sc\phi\end{array}\right] \tag{14}$$

$$\phi'' = \frac{1}{(N - AB)}\left[\begin{array}{l}\frac{1}{2}\left(B\Pr H'\theta - NScH'\phi\right) - B\Pr H\theta' + \\ NScH\phi' - BS\Pr\theta + N\gamma Sc\phi\end{array}\right] \tag{15}$$

The associated boundary conditions are

$$H' = 0, G = 1, \theta = 1, \phi = 1 \text{ at } \eta = 0 \tag{16}$$

$$H' = 0, G = 0, \theta = 0, \phi = 0 \text{ at } \eta \to \infty$$

where primes refer derivatives about η while H', G, H are respectively velocity measurements. θ, C can be read as hotness of the fluid and species mass; Da^{-1} is inversion of Darcy, GrL stands for Grashof quantity with reference length scale L whereas Reynold number is refereed as $R_e L$ further gs symbolizes Buoyancy factor, Ha^2 designates Hartmann quantity, N stand for quotient of Buoyancy effect, which classifies either the flow is opposing are aiding, in mathematical way we speak these cases respectively ($N < 0$ & $N > 0$);s μ signifies viscosity factor: γ is noted for chemical reactivity.

The aspiration of current study to fulfill partial incompleteness that has been observed in the survey so as to that to convey some more results through this paper, how the fluid flow influenced by radiative thermophoresis on energy and species transmission due to the notable convective mechanism across the surface of revolving origin based straight up cone which was embedding in saturated porous regime.

$$C_{fx}\,\mathrm{Re}^{\frac{1}{2}} = -H''(0) \text{ (Skin-friction in along } x\text{)} \tag{17}$$

$$2^{-1}\,\mathrm{Re}^{\frac{1}{2}}\,C_{fy} = -G'(0) \text{ (Skin-friction in along } y\text{)} \tag{18}$$

$$\mathrm{Re}^{-\frac{1}{2}}\,N_{ux} = -\theta'(0) \text{ (Local heat transfer rate)} \tag{19}$$

$$\mathrm{Re}^{-\frac{1}{2}}\,S_{hx} = -\phi'(0) \text{ (Local mass transfer rate)} \tag{20}$$

3. Method of solution

The set of equations (11-15) with the boundary conditions (16) are solved by using shooting method that uses Runge-Kutta method with Newton's scheme. In these equations (11-15) are converted into a system of first order differential equations, by assuming

$$\begin{bmatrix} H' \\ H'' \\ H''' \\ G' \\ G'' \\ \theta' \\ \theta'' \\ \phi' \\ \phi'' \end{bmatrix} = \begin{bmatrix} \xi(2) \\ \xi(3) \\ \varepsilon^{-1}\xi(1)\xi(3) + \varepsilon(M^2 + Da^{-1})\xi(2) - \varepsilon\left(\rho x + \frac{\varepsilon^{-2}}{2}\right)\left(\xi(2)\right)^2 + \\ 2\varepsilon^{-1}\left(\xi(4)\right)^2 + 2\varepsilon g_s\left(\xi(6) + N\xi(8)\right) \\ \xi(5) \\ \varepsilon(M^2 + Da^{-1})\xi(4) + \varepsilon\rho x\left(\xi(4)\right)^2 \\ +\varepsilon^{-1}\left(\xi(1)\xi(5) - \xi(2)\xi(4)\right) \\ \xi(7) \\ \frac{1}{(AB - N)}\left[\begin{array}{l}\frac{1}{2}\left(\Pr\xi(2)\xi(6) - ASc\xi(2)\xi(8)\right) - \Pr\xi(1)\xi(7) \\ +ASc\xi(1)\xi(9) - S\Pr\xi(6) + A\gamma Sc\xi(8)\end{array}\right] \\ \xi(9) \\ \frac{1}{(N - AB)}\left[\begin{array}{l}\frac{1}{2}\left(B\Pr\xi(2)\xi(6) - NSc\xi(2)\xi(8)\right) - B\Pr\xi(1)\xi(7) \\ +NSc\xi(1)\xi(9) - BS\Pr\xi(6) + N\gamma Sc\xi(8)\end{array}\right] \end{bmatrix}$$

4. Results and discussions

For more physical interest, by computing numerical values it has been provided geometrical interpretations through plotting curves for velocity in all notable directions, besides that the fluid curves and species curves also revealed in figures, and more importantly the local friction drags are mapped in the tangential and azimuthal directions, the rate at which energy transmitting and species transmitting are narrated by obtained curves pattern. The findings are supported by geometrically via displaying the impact of distinguished magnitudes of parameters, viz. Darcy number (Da^{-1}), Prandtl number (Pr), mixed convection parameter (gs) and chemical reaction parameter γ. Figs.1-3 illustrate the variation of tangential, circumferential and normal velocity profiles for different values of inverse Darcy parameter (Da^{-1}) respectively. Rise in inverse Darcy parameter causes an enhancement in viscosity effect in boundary layer zone.

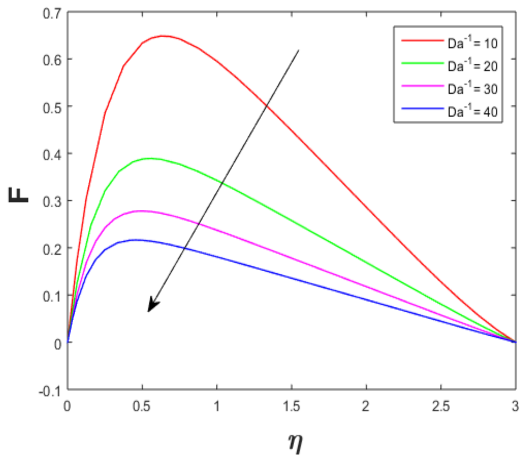


Fig. 1: Fluid flow curves (F) for different values of Da^{-1}

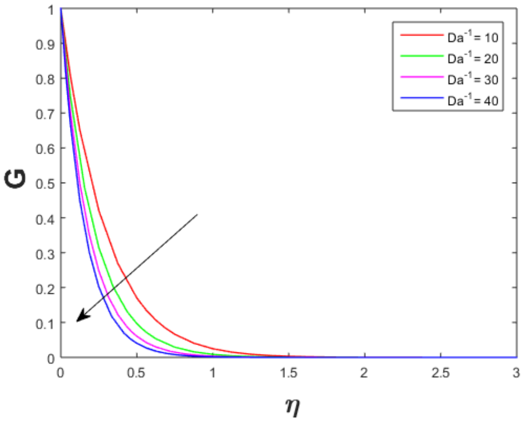


Fig. 2: Circumferential flow pattern (G) for distinctive Da^{-1}

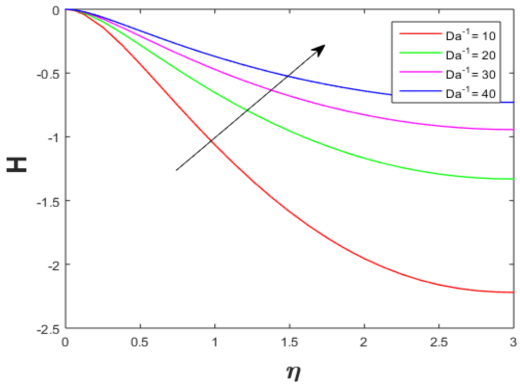


Fig. 3: Normal velocity curves (H) for distinctive Da^{-1}

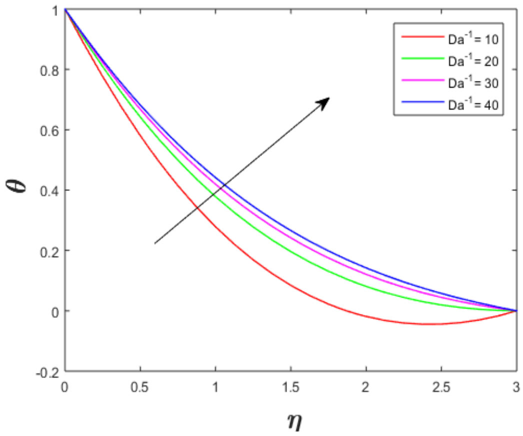


Fig. 4: Temperature profile θ for distinctive Da^{-1}

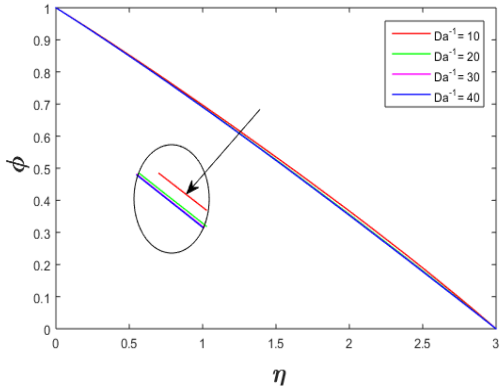


Fig. 5: Concentration for distinctive Da^{-1}

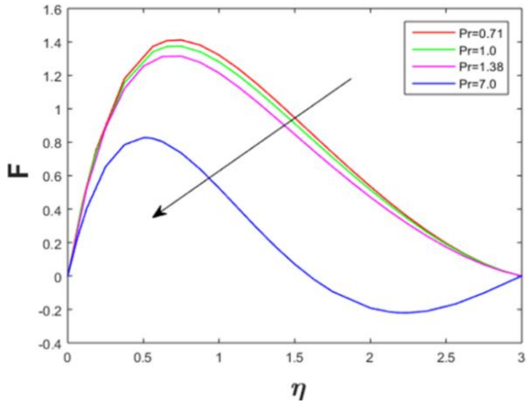


Fig. 6: Velocity curves (F) for distinctive $\Pr$

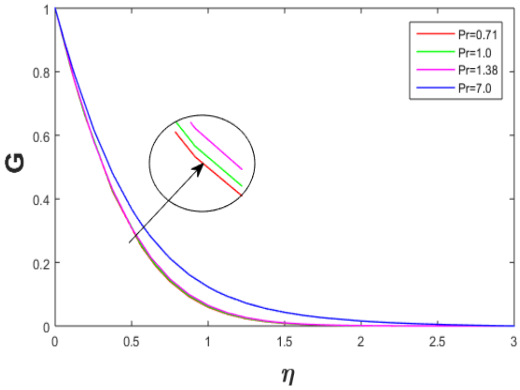


Fig. 7: Circumferential flow pattern (G) for distinctive $\Pr$

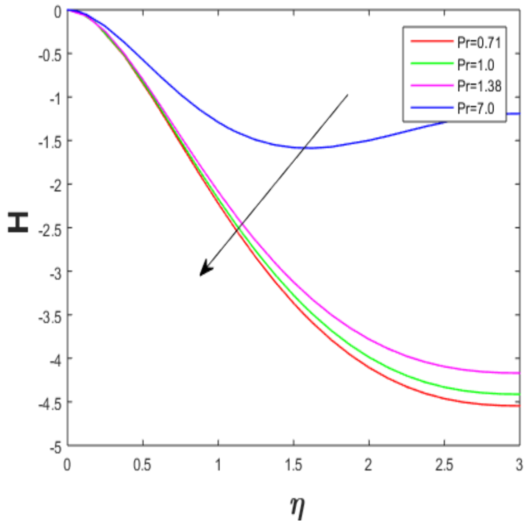


Fig. 8: Normal velocity (H) for distinctive $\Pr$

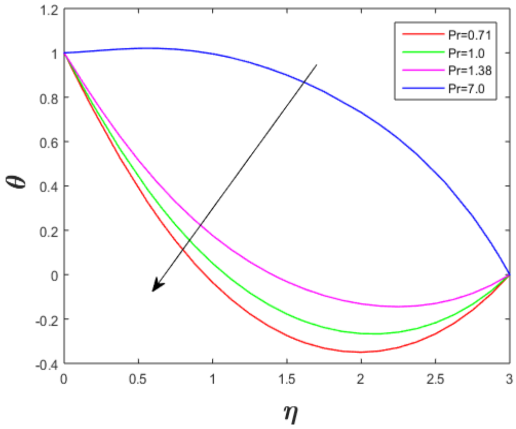


Fig. 9: curves pattern of Temperature for various $\Pr$

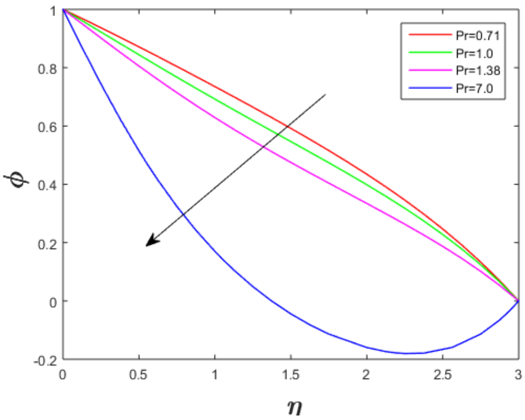


Fig. 10: Concentration ϕ for distinctive $\Pr$

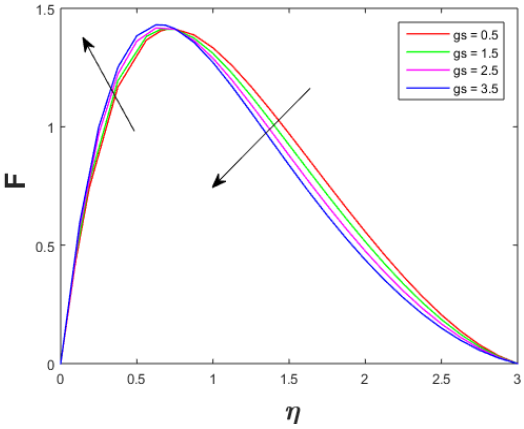
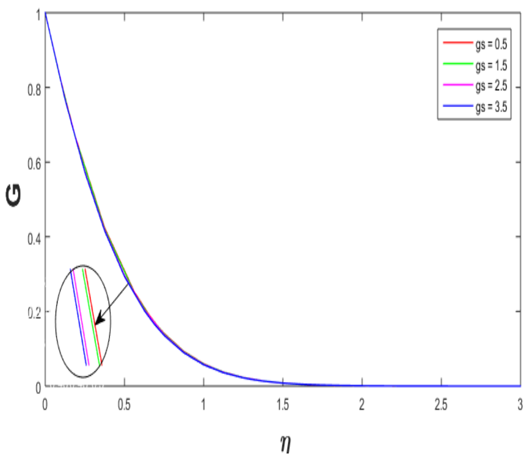


Fig. 11: Fluid flow curves (F) for distinctive gs



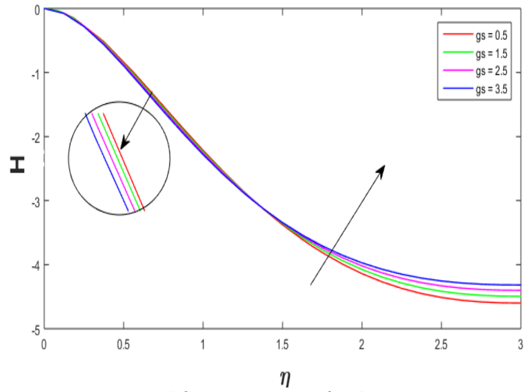


Fig. 13: Normal flow pattern (H) for distinctive gs

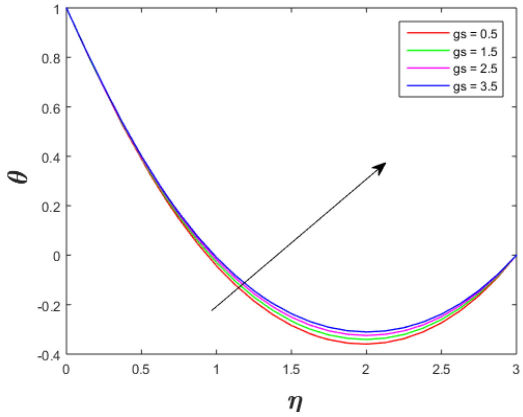


Fig. 14: curves pattern on temperature for distinctive gs

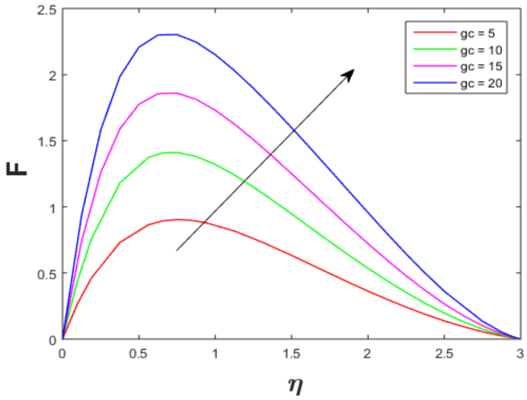


Fig. 15: Fluid flow curves (F) for distinctive gc

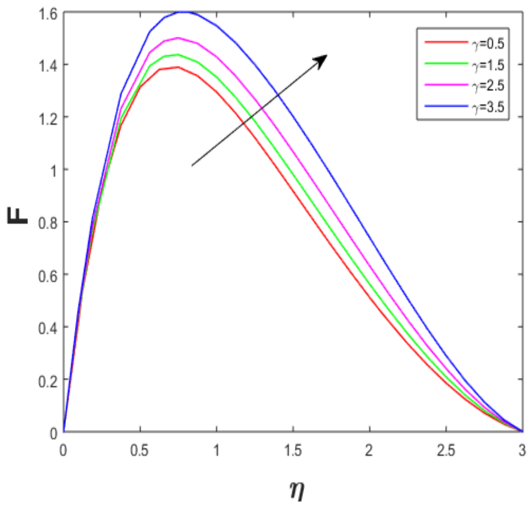


Fig. 16: Fluid flow curves (F) for distinctive γ

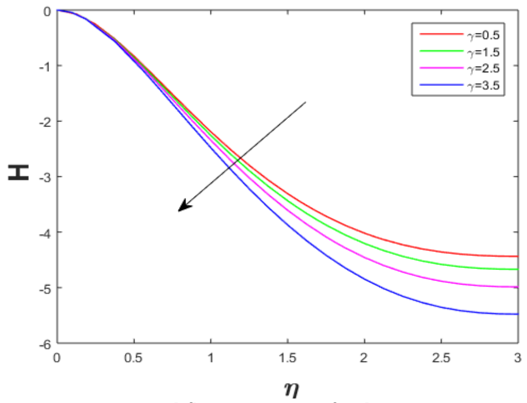


Fig. 17: Normal flow pattern (H) for distinctive γ

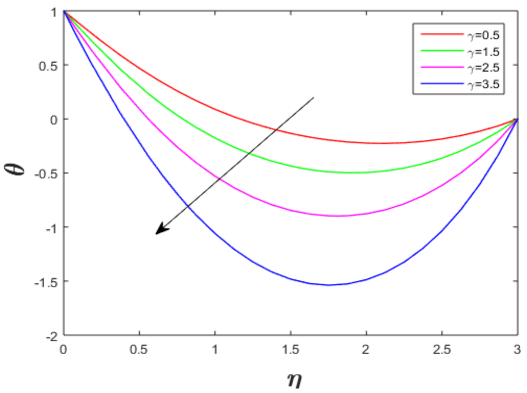


Fig. 18: Fluid flow curves (F) for distinctive γ

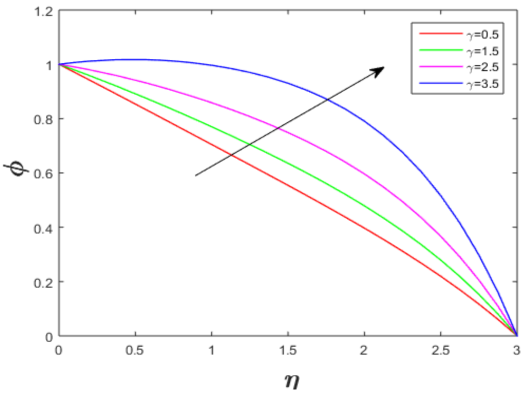


Fig. 19: Concentration for distinctive γ

This leads a reduction in the fluid flow rate over the boundary layer regime. Hence tangential velocity profile retards considerably, make smaller in thickness of velocity boundary layer for significant values of inverse Darcy parameter as revealed in Fig.1. We notice depreciation in circumferential velocity profile with rise in inverse Darcy number as given in Fig. 2. Conversely, normal velocity profiles reported opposite results as increase in inverse Darcy number (Fig. 3). Figs.4 and 5 show the variation of temperature and concentration distributions for different values of inverse Darcy number (Da^{-1}). As observed in Fig. 4, volume flow rate of the fluid is increased in boundary layer regime, transfer of heat is increased. Temperature distribution therefore boosted, i.e. increasing thermal boundary thickness for larger values of inverse Darcy number. Concentration distribution reported similar results in Fig (5), i.e. increase in solutal boundary layer thickness.

Figs.6-8 illustrate the variation of tangential, circumferential and normal velocity curves at various magnitudes of Prandtl number (Pr) respectively. Increase in Prandtl number parameter causes an enhancement in viscosity effect in boundary layer regime. This leads to reduce the fluid flow rate over the boundary layer. Hence tangential velocity profile retards considerably, decrease velocity boundary layer thickness for larger values of Prandtl number parameter as shown in Fig.6. We notice depreciation in circumferential velocity profile with rise in Prandtl number as given in Fig. 7. Conversely, normal velocity profiles reported opposite results as increase in Prandtl number (Fig. 8). Figs.9 and 10 show the variation of temperature and concentration distributions for different values of Prandtl number (Pr). As observed in Fig. 9, volume flow rate of the fluid is increased in boundary layer regime, transfer of heat is increased. Thus amount of energy levels therefore boosted, i.e. an improving thermal boundary thickness for larger values of Prandtl number. Fig 10 shows that species diffusion is decelerates when Prandtl number parameter become stronger. Figs.11-13 illustrate the variation of tangential, circumferential and normal velocity curves for different values of thermal Grashof number respectively. Increase in thermal Grashof number causes an enhancement in viscosity effect in boundary layer regime. This leads to increase velocity nearer to the plate and then decreases in tangential velocity profile Fig. 11. We notice depreciation in circumferential motion with rise in thermal Grashof number as given in Fig. 12. Normal velocity profiles reported the velocity is decreases and then increases as increasing thermal Grashof number (Fig. 13).

Figs.14 shows the variation of temperature for different values of gs. As observed in Fig. 14, volume flow rate of the fluid is increased in boundary layer regime, transfer of heat is increased. Temperature distribution therefore boosted, i.e. increasing thermal boundary thickness for larger values of Grashof number. Figs.15 demonstrates the variation of tangential velocity profiles for different values of gc. Increase thermal Grashof number causes an enhancement in viscosity effect in boundary layer regime. Figs.16-19 demonstrate the impact of γ upon tangential, circumferential and normal velocity curves. Chemical reaction parameter increases the velocity is increases for tangential and circumferential velocity profiles Figs. 16-18. The velocity is decreases for normal velocity (Fig. 17). It is also an evidence that the temperature raises and concentration falls for an upturn in chemical reaction parameter.

5. Conclusions

The describing flow phenomena is well modelled and then numerically attempted after incorporating the suitable similarities without effecting the obtained mathematical model in any way by implementing shooting method for noticing initial guesses followed by R-K method besides Newton-Raphson scheme. The influence of the various relevant physical quantities, so called the permeability parameter, magnetic field quantity, impact of γ the momentums evaluated in both *x&y* directions on the outlet of the cone, curves of fluid temperature and species mass besides that, the local friction drags in the geometrical directions, local heat flow rate and mass flow rate are exhibited by plotting them hence reviewed the results. Through the current study is conveyed some interesting facts on the problem, for instance, as Darcy number enlightens in magnitudes the tangential friction drag near the surface, heat mass flow rates locally however this effect is inverted notably with the azimuthal friction drat at the surface. And one of the findings, reveals the fact that mass flow rate is appreciable when the fluid is interacting with chemical reaction.

References

[1] Chamkha AJ & Quadri MMA (2002) Combined heat and mass transfer by hydro magnetic natural convection over a cone embedded in a non-Darcian porous medium with heat generation/absorption effects, Heat and Mass Transfer 38(6), 487 – 495.

[2] Chamkha AJ & Rashad AM (2012) Natural convection from a vertical permeable cone in a nanofluid saturated porous media for uniform heat and nanoparticles volume fraction fluxes, International

Journal of Numerical Methods for Heat & Fluid Flow. 22(8), 1073-1085.
[3] Chamkha AJ & Rashad AM (2013) Unsteady heat and mass transfer by MHD mixed convection flow from a rotating vertical cone with chemical reaction and Soret and Dufour effects, The Canadian Journal of Chemical Engineering 92(4), 758-767.
[4] Chamkha AJ (1996) Non-Darcy hydro magnetic free convection from a cone and a wedge in porous media, International Communications in Heat and Mass Transfer 23(6), 875- 887.
[5] Chamkha AJ, Abbasbandy S, Rashad AM & Vajravelu K (2012) Radiation effects on mixed convection about a cone embedded in a porous medium filled with a nanofluid, Journal Article in Meccanica 48(2), 275 – 285.
[6] Chamkha AJ, Takhar HS & Nath G (2005) Unsteady compressible boundary layer flow over a circular cone near a plane of symmetry, Heat and Mass Transfer 41(7), 632- 647.
[7] Ching-Yang Cheng (2010) Soret and Dufour effects on heat and mass transfer by natural convection from a vertical truncated cone in a fluid-saturated porous medium with variable wall temperature and concentration, International Communications in Heat and Mass Transfer 37 (8), 1031-1035.
[8] Ching-Yang Cheng (2012) Free convection of non-Newtonian nanofluids about a vertical truncated cone in a porous medium, International Communications in Heat and Mass Transfer 39(9), 1348 – 1353.
[9] Ching-Yang Cheng (2015) Natural convection heat transfer about a vertical cone embedded in a Tridisperse porous medium, Transport in Porous Media 107 (3), 765 -779.
[10] Hering RG & Grosh RJ (1963) Laminar combined convection from a rotating cone, Journal of Heat Transfer 85(1), 29.
[11] Himasekhar K & Sarma PK (1986) Effect of suction on heat transfer rates from a rotating cone, International Journal of Heat and Mass Transfer 29(1), 164 -167.
[12] Himasekhar K, Sarma PK & Janardhan K (1989) Laminar mixed convection from a vertical rotating cone, International Communications in Heat and Mass Transfer 16 (1), 99- 106.
[13] Lin FN (1976) Laminar free convection from a vertical cone with uniform surface heat flux, Letters in Heat and Mass Transfer 3(1), 49 – 58.
[14] Mahdy A (2010) Effect of chemical reaction and heat generation or absorption on double-diffusive convection from a vertical truncated cone in porous media with variable viscosity, International Communications in Heat and Mass Transfer 37 (5), 548 – 554.
[15] Mallikarjuna B, Rashidi M, & Hariprasad Raju (2016) Influence of nonlinear convection and thermophoresis on heat and mass transfer from a rotating cone to fluid flow in porous medium, Journal Article in Thermal Science (00) 4 – 4.
[16] Nadeem S & Saleem S (2013) Unsteady mixed convection flow of nanofluid on a rotating cone with magnetic field, Journal of Applied Nanoscience 4(4), 405 -414.
[17] Param Jeet Singh & Roy S (2007) Unsteady mixed convection flow over a vertical cone due to impulsive motion, International Journal of Heat and Mass Transfer. 50(5-6), 949-959.
[18] Patil PM & Pop I (2011) Effects of surface mass transfer on unsteady mixed convection flow over a vertical cone with chemical reaction, Heat and Mass Transfer 47(11), 1453 – 1464.
[19] Prakash J, Gouse Mohiddin S & Vijaya Kumar Varma S (2013) Free convective MHD flow past a vertical cone with variable heat and mass flux, Journal of Fluids 2013, 1- 8.
[20] Pullepu Bapuji K. Ekambavanan & Pop I (2007) Finite difference analysis of laminar free convection flow past a non isothermal vertical cone, Heat and Mass Transfer 44(5), 517-526.
[21] Rashad AM, Mallikarjuna B, Chamkha AJ & Hariprasad Raju S (2016) Thermophoresis effect on heat and mass transfer from a rotating cone in a porous medium with thermal radiation, Journal Article in Afrika Matematika.
[22] Ravindran R, Ganapathirao M & Pop I (2014) Effects of chemical reaction and heat generation/absorption on unsteady mixed convection MHD flow over a vertical cone with non-uniform slot mass transfer, International Journal of Heat and Mass Transfer 73, 743-751.
[23] Roy S & Anilkumar D (2004) Unsteady mixed convection from a rotating cone in a rotating fluid due to the combined effects of thermal and mass diffusion, International Journal of Heat and Mass Transfer 47 (8-9), 1673 -1684.
[24] Roy S, Takhar HS & Nath G (2004) Unsteady MHD flow on a rotating cone in a rotating fluid, Meccanica 39(3), 271- 283
[25] Saleh M. Al-Harbi (2011) Self-Similar solution of heat and mass transfer of unsteady mixed convection flow on a rotating cone embedded in a porous medium saturated with a rotating fluid, Applied Mathematics 02(10), 1196 – 1203.
[26] Seddeek MA, Odda S N & Abdelmeguid MS (2016) Analytical study for the effects of chemical reaction and mass transfer on free convective flow past a vertical isothermal cone surface, Journal of Aerospace Engineering 29(2), 04015045.
[27] Srinivasa AH & Eswara AT (2013) Unsteady free convection flow and heat transfer from an isothermal truncated cone with variable viscosity, International Journal of Heat and Mass Transfer 57(1), 411 – 420.
[28] Tien CL (1961) Mass transfer in laminar flow about a rotating cone, Journal of Heat Transfer 83(4), 514.