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UNSTEADY HYDROMAGNETIC FLOW OF VISCO-ELASTIC FLUIDS IN A POROUS MEDIUM WITH HEAT AND MASS TRANSFER

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ABSTRACT

In this paper, we have discussed the radiative heat and mass transfer on the unsteady hydromagnetic convective flow of a conducting visco-elastic fluid over an inclined plate embedded in a porous medium. The impulsively started plate with variable temperature and mass diffusion is considered .The analytical expressions for the velocity, temperature and species concentration fields have been obtained. The corresponding expressions for the non-dimensional rates of heat transfer and mass transfer have been obtained. The velocity profile and the shearing stress have been illustrated graphically, for various values of flow parameters involved in the solution to observe the effect of visco-elastic parameter.

1. INTRODUCTION

The study of convective flow with heat and mass transfer under the influence of magnetic field and chemical reactions with radiation has practical applications in many areas of science and engineering. This phenomenon plays an important role in chemical industry, petroleum industry, cooling of nuclear reactors and packed bed catalytic reactors. Natural convection flows frequently in nature due to temperature differences, concentration differences and also due to combined effects. The radiation heat transfer effects on different flows are important in space technology and high temperature processes. Thermal radiation effects may play an important role in controlling heat transfer in polymer processing industry where the quality of the final product depends on the heat controlling factors to some extent. High temperature plasmas, cooling of nuclear reactors, power generation systems are some important applications of radiatons heat transfer from a wall to conductive gray fluids. Das *et al*.(1) heat and mass transfer effects on unsteady MHD free convection flow near a moving vertical plate in porous medium. Das *et al.* (2) mass transfer effects on mhdflow and heat transfer past a vertical porous plate through a porous medium under oscillatory suction and heat source. Again, Das *et al.* (3) natural convection unsteady magneto-hydrodynamic mass transfer flow past an infinite vertical porous plate in presence of suction and heat sink. Das *et al.* (4) unsteady hydromagnetic convective flow past an infinite vertical porous flat plate in aporous medium. Hussanan *et al.* (5) an exact analysis of heat and mass transfer past a vertical plate with newtonian heating. Toki *et al.* (6) exact solutions for the unsteady free convection flows on a porous plate with time-dependent heating. Khan *et al.* (7) free convection flow past an oscillating plate embedded in a porous medium. Turkyilmazoglu *et al.* (8) soret and heat source effects on the unsteady radiative mhd free convection flow from an impulsively started infinite vertical plate. Ahmad (9) soret and radiation effects on transient mhd free convection from an impulsively started infinite vertical plate. Khan *et al.* (10) free convection flow past an oscillating plate embedded in a porous medium. Pal *et al.* (11) MHD non-Darcian mixed convection heat and mass transfer over a non-linear stretching sheet with soret-dufour effects and chemical reaction. Turkyilmazoglu (12) analytic heat and transfer of the mixed hydrodynamic/thermal slip mhd viscous flow over a stretching sheet. Seth *et al.* (13) mhd natural convection flow with radiative heat transfer past an impulsively moving plate with ramped wall temperature. Mishra *et al.* (14) mass and heat transfer effect on mhd flow of a visco-elastic fluid through porous medium with oscillatory suction and heat source. Jingchun *et al.* (15) coupled heat and mass transfer during moisture exchange across a membrane. Khan *et al.* (16) effects of hall current and mass transfer on the unsteady magnetohydrodynamic flow in a porous channel. Chandrakala(17) radiation effects on flow past an impulsively started vertical oscillating plate with uniform heat flux. Rajesh (18) chemical reaction and radiation effects on the transient mhd free convection flow of dissipative fluid past an infinite vertical porous plate with ramped wall temperature. Prasad *et al.* (19) thermal radiation effects on magnetohydrodynamic free convection heat and mass transfer from a sphere in a variable porosity regime. Chandrakala (20) radiation effects on flow past an impulsively started vertical oscillating plate with uniform heat flux.

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Narahari *et al*. (21) free convection flow past an impulsively started infinite vertical plate with newtonian heating in the presence of thermal radiation and mass diffusion. Seethamahalakshmi *et al.* (22). unsteady mhd free convection flow and mass transfer near a moving vertical plate in the presence of thermal radiation. Ziyauddin *et al.* (23) radiation effect on unsteady mhd heat and mass transfer flow on a moving inclined porous heated plate in the presence of chemical reaction. Magyari *et al*. (24) note on the effect of thermal radiation in the linearized rosseland approximation on the heat transfer characteristics of various boundary layer flows. Reddy *et al.* (25) radiation and mass transfer effects on nonlinear mhd boundary layer flow of liquid metal over a porous stretching surface embedded in porous medium with heat generation. Venkateswarlu *et al.* (26) thermal diffusion and radiation effects on unsteady mhd free convection heat and mass transfer flow past a linearly accelerated vertical porous plate with variable temperature and mass diffusion. Venkateswarlu *et al.* (27) radiation and chemical reaction effects on MHD flow past an oscillating vertical porous plate with constant heat flux. Kumar *et al.* (28) radiation and chemical reaction effects on mhd flow fluid over an infinite vertical oscillating porous plate. Reddy *et al.* (29) Soret Effect on MHD Mixed Convection Oscillatory Flow over a Vertical Surface in a Porous Medium with Chemical Reaction and Thermal Radiation. Lakshmi *et al.* (30) chemical reaction and radiation effect on the unsteady hd free convection flow past a semi infinite vertical permeable moving plate with heat source and suction. Ali *et al.* (31) unsteady magnetohydrodynamic oscillatory flow of visco-elastic fluids in a porous channel with heat and mass transfer. Osman *et al.* (32) analytical solution of thermal radiation and chemical reaction effects on unsteady MHD convection through porous media with heat source/sink. Sami-ul-haq *et al.* (33) radiation and porosity effects on the magnetohydrodynamic flow past an oscillating vertical plate with uniform heat flux. Makinde (34) chemically reacting hydromagnetic unsteady flow of a radiating fluid past a vertical plate with constant heat flux. Makinde *et al.* (35) unsteady mixed convection with soret and dufour effects past a porous plate moving through a binary mixture of chemically reacting fluid. Senapati *et al.* (36) effects of chemical reaction on free convection mhd flow through porous medium bounded by vertical surface with slip flow region. Narahari *et al.* (37) Radiation Effects on Free Convection Flow Near a Moving Vertical Plate with Newtonian Heating.

Jhansi Rani *et al.* [40] have studied combined effects of radiation and chemical reaction on the magnetohydrodynamic free convection flow of an electrically conducting incompressible viscous fluid over an inclined plate embedded in a porous medium In this study, an attempt has been made to extend the problem studied by Jhansi Rani *et al.* [40] to the case of visco-elastic fluid characterized by second-order fluid.

The constitutive equation for the incompressible Second-order fluid is of the form

$$\sigma = -pI + \mu_1 A_1 + \mu_2 A_2 + \mu_3 (A_1)^3 \tag{1}$$

Where σ is the stress tensor, $A_n\left(n=1,2,3\right)$ are the kinematic Rivlin-Ericksen tensors; μ_1, μ_2, μ_3 are the material coefficients describing the viscosity, elasticity and cross-viscosity respectively. The material coefficients μ_1, μ_2, μ_3 are taken constants with μ_1 and μ_3 as positive and μ_2 as negative [Coleman and Markovitz (1964)] [38]. The equation (1) was derived by Coleman and Noll [39] from that of simple fluids by assuming that the stress is more sensitive to the recent deformation than to the deformation that occurred in the distant past.

2. FORMULATION OF THE PROBLEM

we consider the unsteady flow of an incompressible viscous fluid past an infinite inclined plate with variable heat and mass transfer. The *x*′-axis is taken along the plate with the angle of inclination α to the vertical and the *y*′-axis is taken normal to the plate. The viscous fluid is taken to be electrically conducting and fills the porous half space *y*′ > 0. A uniform magnetic field of strength B0 is applied in the *y*′-direction transversely to the plate. The applied magnetic field is assumed to be strong enough so that the induced magnetic field due to the fluid motion is weak and can be neglected. This assumption is physically justified for partially ionized fluids and metallic liquids because of their small magnetic Reynolds number. Since there is no applied or polarization voltage imposed on the flow field, the electric field due to polarization of charges is zero. Initially, both the fluid and the plate are at rest with constant temperature T∞′ and constant concentration C∞′. At time *t*′ > 0, the plate is given a sudden jerk, and the motion is induced in the direction of flow against the gravity with uniform velocity U0. The temperature and concentration of the plate are raised linearly with respect to time. Also, it is considered that the viscous dissipation is negligible and the fluid is thick gray absorbing-emitting radiation but non-scattering medium. Since the plate is infinite in the (x′, z′) plane, all physical variables are functions of *y*′ and *t*′ only. In view of the above assumptions, as well as of the usual Boussinesq's approximation, the unsteady flow is governed by the following equations:

$$\frac{\partial u'}{\partial t'} = v_1 \frac{\partial^2 u'}{\partial y'^2} + v_2 \left(\frac{\partial^2 u'}{\partial y' \partial t'} \right) + g\beta(T' - T'_\infty) + g\beta'(C' - C'_\infty)\cos\alpha - \frac{\sigma B_0^2 u'}{\rho} - \frac{v u'}{K^*} \tag{1}$$

$$\frac{\partial T'}{\partial t'} = \frac{k}{\rho C_p} \frac{\partial^2 T'}{\partial y'^2} - \frac{1}{\rho C_p} \frac{\partial q_c}{\partial y'} \tag{3}$$

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

The initial and boundary conditions for the velocity, temperature and concentration fields are:

$$t' \le 0 : u' = 0, T' = T'_\infty,\ C' = C'_\infty \quad for\ all \quad y' > 0$$

$$t' > 0 : \begin{cases} u' = U_0, T' = T'_\infty + (T'_w - T'_\infty)At',\ \ C' = C'_\infty + (C'_W - C'_\infty)At' \ \ at\ \ y' = 0 \\ u' = 0, T' = T'_\infty,\ \ C' = C'_\infty \qquad\qquad as \quad y' \to \infty \end{cases} \tag{5}$$

Where $A = \frac{U_0^2}{\nu_1}$, u′ is the axial velocity, T′ is the temperature of the fluid, C′ is the species concentration, qr is the radiation heat flux, x′ and y′ are the dimensional distances along and perpendicular to the plate, t′ is the time, σ is the electrical conductivity, $\nu_i = \frac{\mu_i}{\rho}, (i = 1, 2)$

K^* is the permeability of the porous medium, g is the acceleration due to gravity, β is the coefficient of thermal expansion, β* is the coefficient of concentration expansion, Cp is the specific heat at constant pressure, k is the thermal diffusivity, D is the mass diffusivity and K_r^* is the chemical reaction constant.

We adopt the Rosseland approximation for radiative heat flux q_r, namely

$$q_r = -\frac{4\sigma_0}{3k^*}\frac{\partial T^{*4}}{\partial y^*} \tag{6}$$

where σ_0 is the Stefan-Boltzmann constant and k^* the mean absorption coefficient.

Assuming the temperature differences within the flow tube sufficiently small, we can expand T'^4 in a Taylor series about T_∞ and neglecting higher order terms we have,

$$T'^4 \cong 4T_\infty'^3 T' - 3T_\infty^4 \tag{7}$$

From equation (6) and (7), equation (3) reduces to

$$\rho C\rho \frac{\partial T'}{\partial y'} = \kappa \frac{\partial^2 T'}{\partial y'^2} + \frac{16\sigma_0 T_\infty'^3}{3k^*}\frac{\partial^2 T'}{\partial y'^2} \tag{8}$$

We introduce the following non-dimensional quantities

$$u = \frac{u'}{U_0}, t = \frac{t' U_0^2}{v_1}, y = \frac{y' U_0}{v_1}, \theta = \frac{T' - T'_\infty}{T'_w - T'_\infty}, \varphi = \frac{C' - C'_\infty}{C'_w - C'_\infty} \tag{9}$$

The following governing equations which are dimensionless

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial y^2} + D_0 \frac{\partial^2 u}{\partial y \partial t} + Gr\theta\cos\alpha + Gm\varphi\cos\alpha - \left(M + \frac{1}{k}\right) \tag{10}$$

$$\frac{\partial \theta}{\partial t} = \left(\frac{1+N}{\Pr}\right)\frac{\partial^2 \theta}{\partial y^2} \tag{11}$$

$$\frac{\partial \varphi}{\partial t} = \frac{1}{Sc}\frac{\partial^2 \varphi}{\partial y^2} - \gamma\varphi \tag{12}$$

The initial and boundary conditions in dimensionless form are as follows:

$$t \le 0 : u = 0, \theta = 0, \varphi = 0 \quad for\ all \quad y > 0$$

$$t > 0, \begin{cases} u = 1,\ \theta = t,\ \varphi = t\ \ at\ \ y = 0 \\ u \to 0,\ \theta \to 0,\ \varphi \to 0 \quad as\ \ y \to \infty \end{cases} \tag{13}$$

Where

$\Pr = \frac{\mu_1 C_P}{k}$, $\Pr andtl\ \ number$

$$M = \frac{\sigma B_0^2 v_1}{\rho U_0^2}, Magnetic\ \ parameter$$

$$K = \frac{U_0^2 K^*}{v_1^2},\ permeability\ \ parameter$$

$$Gr = \frac{g\beta v_1 (T'_w - T'_\infty)}{U_0^3},\ \ thermal\ \ Grashof\ \ number$$

$$Gm = \frac{g\beta^* v_1 (C'_w - C'_\infty)}{U_0^3},\ mass\, Grashof\ \ number$$

$$Sc = \frac{v_1}{D},\ Schmidt\ number$$

$$N = \frac{16\sigma T'^3_\infty}{3kk^*}, Radiation\ \ parameter$$

$$\gamma = \frac{K'_r v_1}{U_0^2},\ chemicalreaction\ \ parameter$$

$$D_0 = \frac{v_2 U_0}{v_1}, visco-elastic\ \ parameter$$

3. METHOD OF SOLUTION

In order to reduce the above system of partial differential equations to a system of ordinary equations in dimensionless form, we may represent the velocity, temperature and concentration as:

$$u(y,t) = u_0(y)e^{\omega t} \tag{14}$$

$$\theta(y,t) = \theta_0(y)e^{\omega t} \tag{15}$$

$$\varphi(y,t) = \varphi_0(y)e^{\omega t} \tag{16}$$

Using (14)-(16) in the equations (10)-(12), we obtain

$$D_0 \frac{\partial^2 u_0}{\partial y \partial t} + \frac{\partial^2 u_0}{\partial y^2} - \left(M + \omega + \frac{1}{k} \right) u_0 + Gr\theta_0 \cos\alpha + Gm\varphi_0 \cos\alpha = 0 \tag{17}$$

$$\frac{\partial^2 \theta_0}{\partial y^2} = \frac{\omega \Pr}{1+N}(\theta_0) \tag{18}$$

$$\frac{1}{Sc}\frac{\partial^2 \varphi_0}{\partial y^2} = (\gamma + \omega)\varphi_0 \tag{19}$$

We choose $u_0 = u_{00} + D_0 u_{11}$ then from the equation (17), we have

The purpose of this study is to bring out the effects of visco-elastic parameter on hydro-magnetic, heat and mass transfer characteristics as the effects of other parameter have been discussed by Das *et al.* [17]. The non-Newtonian effect is exhibited through the parameter α. The corresponding results for Newtonian fluid is obtained by setting α=0 and it is worth mentioning that these results show conformity with earlier results.

In order to understand the physics of the problem, analytical results are discussed with the help of graphical illustrations. The parameters S=.05, n=.7, k=1.5, A=.3, α=-.03, ε=.02 are kept fixed throughout the discussions.

Figure 1 illustrates the effect of velocity profile for different values of visco-elastic parameter α. It is observed that the velocity decreases with an increasing absolute values of the visco-elastic parameter α.

Figure 2 reveals the effects of Magnetic parameter (M) on velocity profile. It is observed from the figure that the velocity decreases with the increase of the magnetic parameter (M). Physically, it is justified because the application of transverse magnetic field always results in a resistive type of force called Lorentz force and tends to resist the fluid motion, finally reducing the velocity.

Figure 3, shows that the effect of velocity profile for different values of thermal Grashof number (Gr). It is observed that an increasing in thermal Grashof number(Gr) leads to an increase in the velocity due to the enhancement in buoyancy forces. Actually, the thermal Grashof number signifies the relative importance of buoyancy force to the viscous hydrodynamic force. Increase of Grashof number (Gr) indicates small viscous effects in the momentum equation and consequently causes increase in the velocity profiles.

Figure 4, shows the variation of velocity distribution with different values of Grashof number for mass transfer (Gm). It is observed from the figure that the velocity increases with an increasing the Grashof number for mass transfer.

Figure 5, illustrate the effect of velocity profile for different values of Prandtl number (Pr). It is observed that the velocity decreases with an increasing the Prandtl number (Pr).

Figure 6, shows the variation of velocity distribution with different values of Schmid number (Sc). It is observed that the velocity decreases with an increasing the Schmid number (Sc).

Figure 7 reveals the effect of permeability parameter (k) on velocity profile. It is evident that from the figure that the velocity increases with the increasing of porosity parameter.

Figure 8, shows the variation of velocity distribution with different values of thermal radiation parameter (N). It is observed that the velocity increases with an increasing the thermal radiation parameter.

Figure 9, shows the variation of velocity distribution with different values of chemical reaction parameter (γ). It is observed that the velocity decreases with an increasing the thermal radiation parameter.

The study of skin friction experienced by the governing fluid flow gives the significance of the concerned problem. So, knowing the velocity field, the shearing stress at the plate is obtained for various values of visco- elastic parameter. Figures 10-13 portray the nature of viscous drag formed during the motion of Newtonian and non-Newtonian fluids.

Figures10,11 and 12 depict that the magnitude of skin-friction improved along with the amplified values of Prandtl number (Pr) and Grashof number for heat and mass transfer (Gr and Gm) for Newtonian and non-Newtonian cases.

But a complete reverse trend is observed in Figure 13. Figure 13 represent the viscous drag against various values of magnetic parameter (M). It is observed that skin-friction profile follow a diminishing trend with the increasing values of magnetic parameter (M)

8. CONCLUSION

The influence of visco-elastic effects on Unsteady MHD free convection and mass transfer for boundary layer flow along with radiation and transpiration is studied analytically. Computed results are presented to exhibit their dependence on the important physical parameters. Some of the important conclusions this paper are as follows:

i) The velocity profile shows an enhancement trnd in the neighbourhood of the plate and then follow a decreasing path.
ii) The fluid is decelerated with increasing absolute values of visco-elastic parameter.
iii) The skin-friction increases with increase in Prandtl number (Pr), Grashof number for heat transfer (Gr) and Grashof number number for mass transfer (Gm).
iv) The skin-friction decreases with increasein magnetic parameter (M).
v) The rate of heat and mass transfer are not significantly affected by visco-elastic parameters.

REFERENCES

1. Das, K., Jana, S. :Heat and Mass Transfer Effects on Unsteady MHD Free Convection Flow Near a Moving Vertical Plate in Porous Medium: Bull. Soc. Math. Banja Luka, 17(2010),15-32
2. Das,S. S., Satapathy, A. Satapathy: J. K. Das and J. P. Panda: Mass Transfer Effects on MHD Flow and Heat Transfer Past a Vertical Porous Plate Through a Porous Medium Under Oscillatory Suction and Heat Source, Int. J. Heat Mass Transfer, 52(2009) 5962-5969.
3. Das,S. S., Parija, S.,Padhy, R. K. and Sahu,M.: Natural Convection Unsteady Magneto-Hydrodynamic Mass Transfer Flow Past an Infinite Vertical Porous Plate in Presence of Suction and Heat Sink, Int. J. Energy Environ., 3(2012), 209-222.
4. Das,S. S.,Maity, M. and Das,J. K.: Unsteady Hydromagnetic Convective Flow Past an Infinite Vertical Porous Flat Plate in a Porous Medium, Int. J. Energy Environ., 3(2012),109-118.
5. Hussanan,A., Khan, I. and Sharidan, S.: An Exact Analysis of Heat and Mass Transfer Past a Vertical Plate with Newtonian Heating, J. Appl. Math. Article ID 434571 http://dx.doi.org/10.1155/2013/434571 (2013).
6. Toki,C. J.,Tokis, J. N.: Exact Solutions for the Unsteady Free Convection Flows on a Porous Plate with Time-Dependent Heating, ZAMM Z. Angew. Math. Mech., 87(2007), 4-13.

7. Khan,I.,Fakhar, K., and Sharidan, S.: Magnetohydrodynamic: Free Convection Flow Past an Oscillating Plate Embedded in a Porous Medium, J. Phys. Soc. Jpn, 80(2011), 104401.
8. Turkyilmazoglu, M., Pop,I.: Soret and Heat Source Effects on the Unsteady Radiative MHD Free Convection Flow from an Impulsively Started Infinite Vertical Plate, Int. J. Heat Mass Transf, 55(2012) 7635-7644 .
9. Ahmad, N.: Soret and Radiation Effects on Transient MHD Free Convection from an Impulsively Started Infinite Vertical Plate: J. Heat Transf, 134(2012) 062701.
10. Khan,I., Fakhar K. and Shafie,S. Magnetohydrodynamic Free Convection Flow Past an Oscillating Plate Embedded in a Porous Medium: J. Phys. Soc. Jpn, 80, 104401 (2011).
11. Pal,D. and Mondal, H.: MHD Non-Darcian Mixed Convection Heat and Mass Transfer Over a Non-Linear Stretching Sheet with Soret-Dufour Effects and Chemical Reaction: Int. J. Commun. Heat Mass Transf., 38(2011), 463-467.
12. Turkyilmazoglu, M.: Analytic Heat and Transfer of the Mixed Hydrodynamic/Thermal Slip MHD Viscous Flow over a Stretching Sheet: Int. J. Mech. Sci., 53(2011), 886-896.
13. Seth,G. S., Ansari, M. S. and Nandkeolyar, R.: MHD Natural Convection Flow with Radiative Heat Transfer Past an Impulsively Moving Plate with Ramped Wall Temperature: Heat Mass Transf., 47(2011), 551-561.
14. Mishra, S. R. Dash, G. C and Acharya, M.: Mass and Heat Transfer Effect on MHD Flow of a Visco-Elastic Fluid Through Porous Medium with Oscillatory Suction and Heat Source, Int. J. Heat Mass Transf., 57(2013), 433-438.
15. Jingchun, M., Lining,W.: Coupled Heat and Mass Transfer during Moisture Exchange Across a Membrane, J. Membrane Sci., 430(2010), 150-157.
16. Khan,I., Ali, F., Sharidan ,S. and Norzieha,M.: Effects of Hall Current and Mass Transfer on the Unsteady Magnetohydrodynamic Flow in a Porous Channel, J. Phys.Soc. Jpn, 80(2011), 064401.
17. Chandrakala,P.: Radiation Effects on Flow Past an Impulsively Started Vertical Oscillating Plate with Uniform Heat Flux:Int. J. Dyn. Fluids, 7(2011), 1-8.
18. Rajesh, V.:Chemical Reaction and Radiation Effects on the Transient MHD Free Convection Flow of Dissipative Fluid Past an Infinite Vertical Porous Plate with Ramped Wall Temperature, Chem. Ind. Chem. Eng., 17(2011), 189-198.
19. Prasad,V. R., Vasu, B., Beg, O. A. and Parshad, R. D.: Thermal Radiation Effects on Magnetohydrodynamic Free Convection Heat and Mass Transfer from a Sphere in a Variable Porosity Regime, Commun Nonlinear Sci. Numer. Simul, 17(2012), 654-671.
20. P. Chandrakala, Radiation Effects on Flow Past an Impulsively Started Vertical Oscillating Plate with Uniform Heat Flux, Int. J. Dyn. Fluids, 6(2010) 209-218.
21. Narahari, M. and Yunus, M. N.: Free Convection Flow Past an Impulsively Started Infinite Vertical Plate with Newtonian Heating in the Presence of Thermal Radiation and Mass Diffusion, Turkish J. Eng. Environ. Sci., 35(2011), 187-198.
22. Seethamahalakshmi, Ramana Reddy ,G. V. and Prasad, B. D. C. N.: Unsteady MHD free Convection Flow and Mass Transfer Near a Moving Vertical Plate in the Presence of Thermal Radiation, Adv. Appl. Sci. Res., 2(2011), 261-269.
23. Ziyauddin and Kumar, M.: Radiation Effect on Unsteady MHD Heat and Mass Transfer Flow on a Moving Inclined Porous Heated Plate in the Presence of Chemical Reaction, Int. J. Math. Modell. Simul. Appl., 3(2010), 155-163.
24. Magyari, E. and Pantokratoras, A.: Note on the Effect of Thermal Radiation in the Linearized Rosseland Approximation on the Heat Transfer Characteristics of Various Boundary Layer Flows, Int. Commun. Heat Mass Transf., 38(2011), 554-556.
25. Reddy, G. V. R., Reddy K. J. and Lakshmi, R.: Radiation and Mass Transfer Effects on Nonlinear MHD Boundary Layer Flow of Liquid Metal over a Porous Stretching Surface Embedded in Porous Medium with Heat Generation, WSEAS Trans. Fluid Mechanics, 10(2015), 1-12.
26. Venkateswarlu, M., Reddy G. V. R. and Lakshmi, D. V.: Thermal Diffusion and Radiation Effects on Unsteady MHD Free Convection Heat and Mass Transfer Flow Past a Linearly Accelerated Vertical Porous Plate with Variable Temperature and Mass Diffusion, J. KSIAM, 18(3)(2014), 257-268.
27. M. Venkateswarlu, Reddy, G. V. R. and Lakshmi, D. V.: Radiation And Chemical Reaction Effects On Mhd Flow Past An Oscillating Vertical Porous Plate With Constant Heat Flux, International Conference On Mathematical Sciences, ISBN –978-93-5107-261-4.
28. Kumar, G. C., Reddy, G. V. R.: Radiation and Chemical Reaction Effects on MHD Flow Fluid Over an Infinite Vertical Oscillating Porous Plate, Int. J. Mathemat. Archive, 5(6) (2014), 247-258.
29. Reddy,G. V. R.,. Subrahmanyam S. V. and Kumar, D. Satish :Soret Effect on MHD Mixed Convection Oscillatory Flow over a Vertical Surface in a Porous Medium with Chemical Reaction and Thermal Radiation, Int. J. Phys. Sci., B 26(1)(2014), 49-60 .
30. Lakshmi,R., Ramana Reddy, G. V. and Jayarami K. :Reddy, Chemical Reaction and Radiation Effect on the Unsteady HD Free Convection Flow Past a Semi Infinite Vertical Permeable Moving Plate with Heat Source and Suction, J. Comp. Math. Sci., 5(1) (2014), 23-34.
31. Ali,F., Khan, I., Samiulhaq, Mustapha, N. and Shafie, S. : Unsteady Magnetohydrodynamic Oscillatory Flow of Viscoelastic Fluids in a Porous Channel with Heat and Mass Transfer, J. Phys. Soc. Jpn, 81(2012)., 064402.

32. Osman, A. N. A., Abo-Dahab S. M. and Mohamed, R. A.: Analytical Solution of Thermal Radiation and Chemical Reaction Effects on Unsteady MHD Convection Through Porous Media with Heat Source/Sink, Math. Probl. Engg., 2011, 1-18.
33. Sami-ul-haq, Fetecau, C., Khan, I., Ali, F. and Shafie, S.: Radiation and Porosity Effects on the Magnetohydrodynamic Flow Past an Oscillating Vertical Plate with Uniform Heat Flux, Z. Naturforsch., 67a (2012), 572-580.
34. Makinde, O. D.: Chemically Reacting Hydromagnetic Unsteady Flow of a Radiating Fluid Past a Vertical Plate with Constant Heat Flux, Z. Naturforsch., 67a(2012)., 239-247
35. Makinde, O. D., Olanrewaju,P. O.: Unsteady Mixed Convection with Soret and Dufour Effects Past a Porous Plate Moving Through a Binary Mixture of Chemically Reacting Fluid, Chem. Engg. Commun., 7(2011), 920-938.
36. Senapati, N., Dhal, R. K. and Das, T. K.: Effects of Chemical Reaction on Free Convection MHD Flow Through Porous Medium Bounded by Vertical Surface with Slip Flow Region, Am. J. Comput. Appl. Math., 2(2012), 124-135.
37. Narahari M. and Ishaq, A.: Radiation Effects on Free Convection Flow Near a Moving Vertical Plate with Newtonian Heating, J. Appl. Sci., 11(2011), 1096-1104.
38. Coleman, B. D. and Markovitz, H.: Incompressible second order fluid. Adv. Appl. Mech. 8(1964), 69.
39. Coleman, B.D. and Noll, W.: An approximation theorem for functional with applications in continuum mechanics, Archs ration, MechAnalysis. 6(1960). 355.
40. Jhansi Rani .K, Ramana Reddy.G.V., Ramana Murthy.Ch.V., and Ramana Murthy.M.V., Heat and Mass Transfer Effects on MHD Free Convection flow Over an Inclined plate Embedded in a Porous Medium.

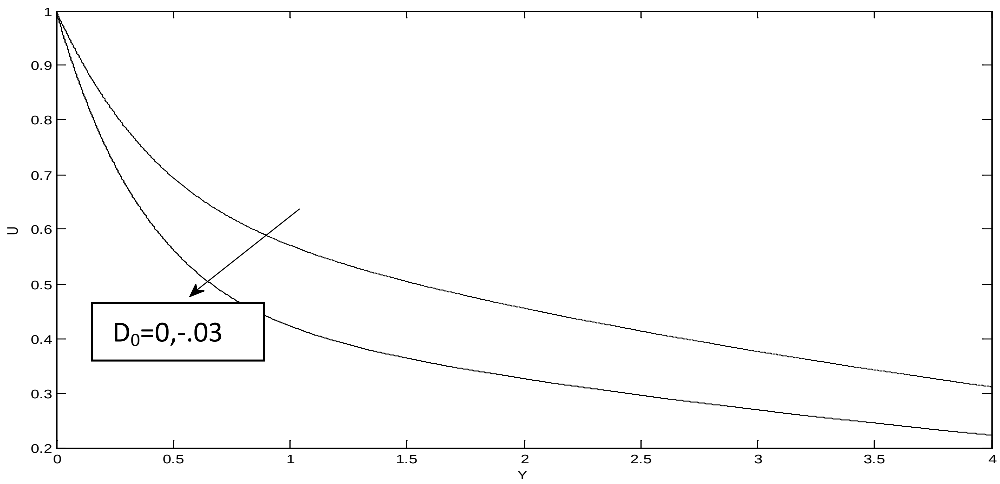

Figure-1: The velocity profile u against the displacement variable y for
M=5, Pr=.71, Gr=5, Gm=2, Sc=.3, Kr=.5, Nr=.5, S=.05, n=.7, k=1.5, A=.3, α=-.03, ε=.02

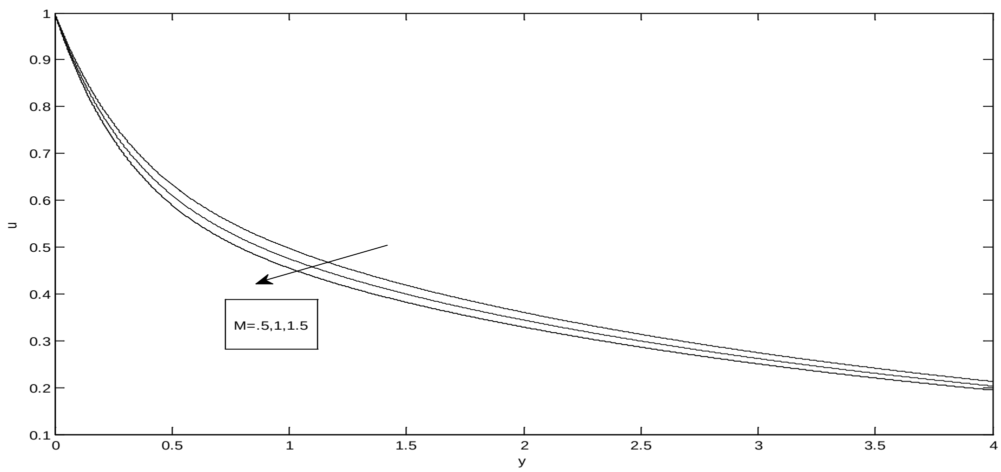

Figure-2: The velocity profile u against the displacement variable y for
M=5, 0Pr=.71, Gr=5, Gm=2, Sc=.3, Kr=.5, Nr=.5, S=.05, n=.7, k=1.5, A=.3, α=-.03, ε=.02

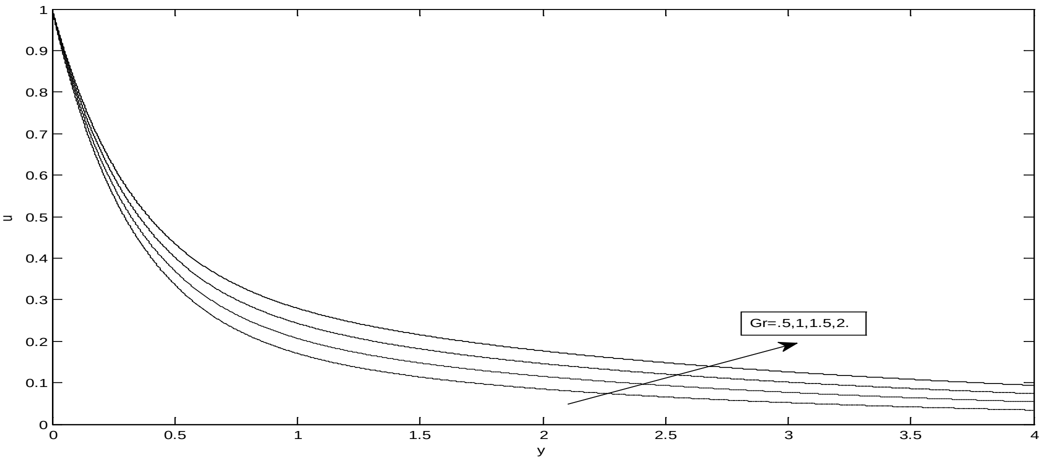

Figure-3: The velocity profile u against the displacement variable y for
M=5, Pr=.71, Gr=5, Gm=2, Sc=.3, Kr=.5, Nr=.5, S=.05, n=.7, k=1.5, A=.3, α=-.03, ε=.02

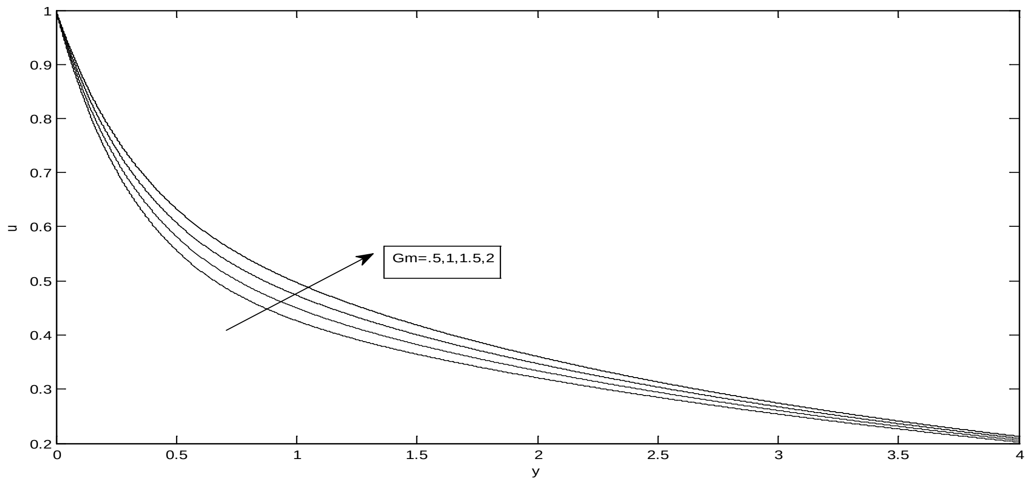

Figure-4: The velocity profile u against the displacement variable y for
M=5, Pr=.71, Gr=5, Gm=2, Sc=.3, Kr=.5, Nr=.5, S=.05, n=.7, k=1.5, A=.3, α=-.03, ε=.02

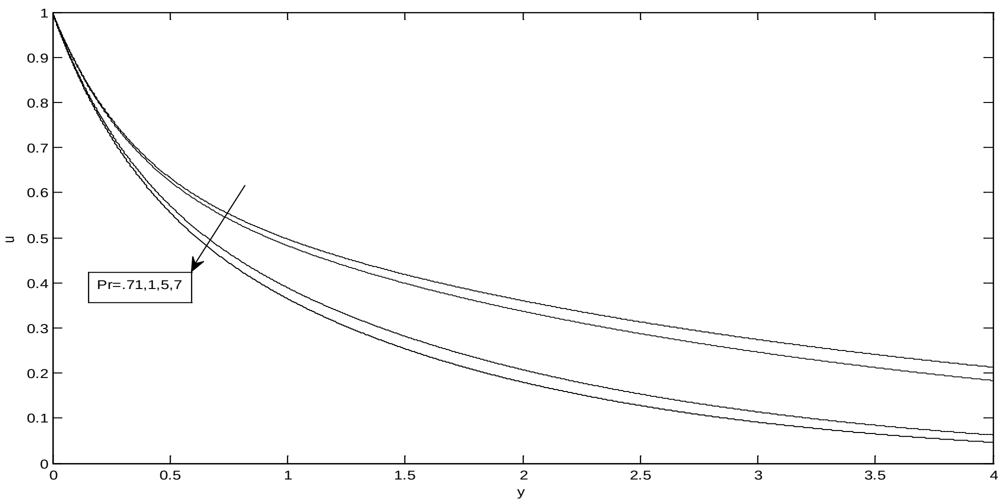

Figure-5: The velocity profile u against the displacement variable y for
M=5, Pr=.71, Gr=5, Gm=2, Sc=.3, Kr=.5, Nr=.5, S=.05, n=.7, k=1.5, A=.3, α=-.03, ε=.02

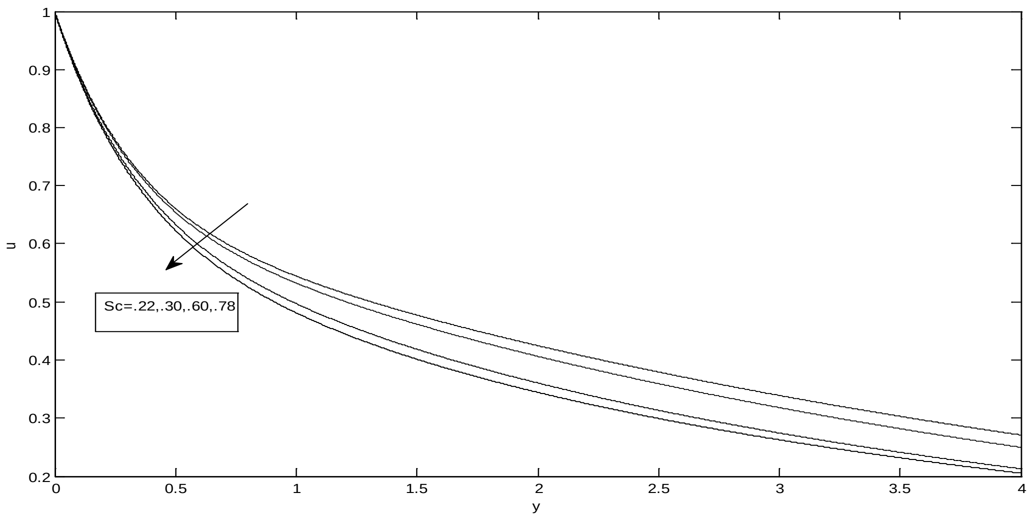

Figure-6: The velocity profile u against the displacement variable y for
M=5, Pr=.71, Gr=5, Gm=2, Sc=.3, Kr=.5, Nr=.5, S=.05, n=.7, k=1.5, A=.3, α=-.03, ε=.02

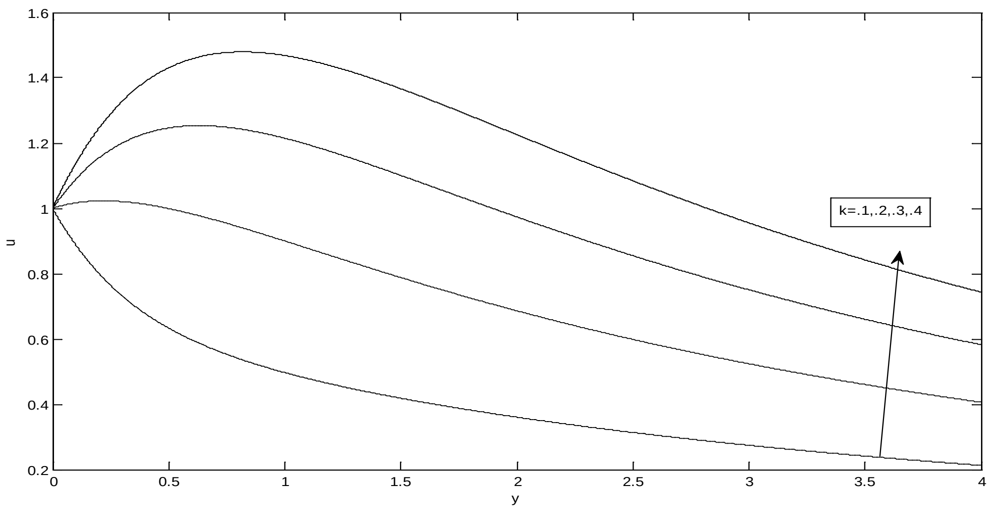

Figure-7: The velocity profile u against the displacement variable y for
M=5, Pr=.71, Gr=5, Gm=2, Sc=.3, Kr=.5, Nr=.5, S=.05, n=.7, k=1.5, A=.3, α=-.03, ε=.02

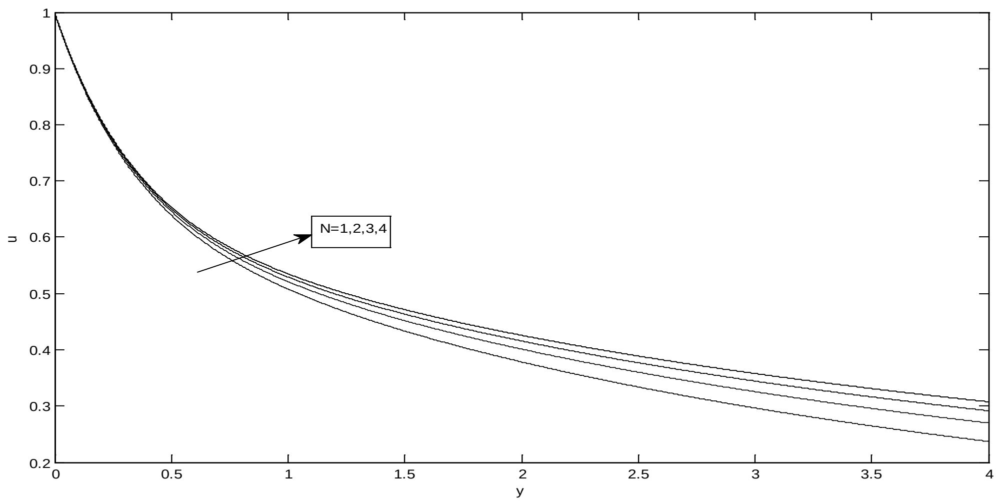

Figure-8: The velocity profile u against the displacement variable y for
M=5, Pr=.71, Gr=5, Gm=2, Sc=.3, Kr=.5, Nr=.5, S=.05, n=.7, k=1.5, A=.3, α=-.03, ε=.02

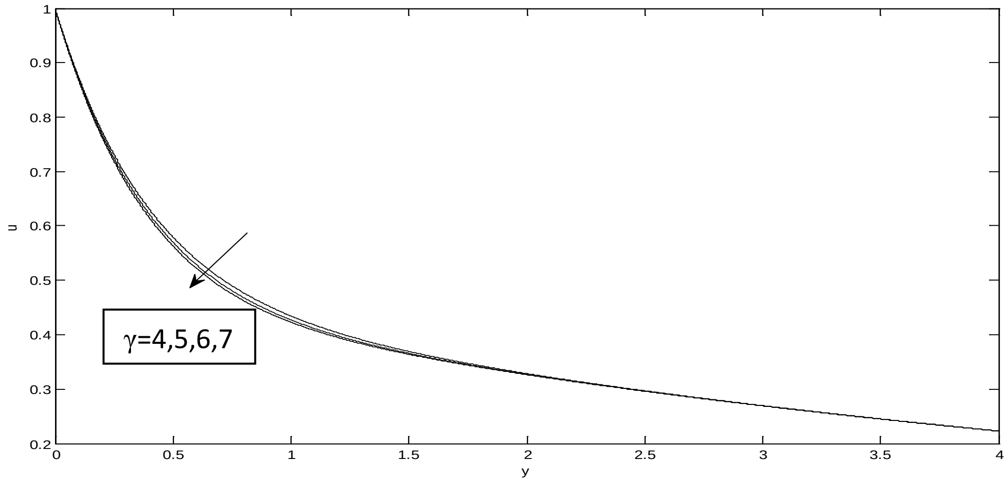

Figure-9: The velocity profile u against the displacement variable y for
M=5, Pr=.71, Gr=5, Gm=2, Sc=.3, Kr=.5, Nr=.5, S=.05, n=.7, k=1.5, A=.3, α=-.03, ε=.02

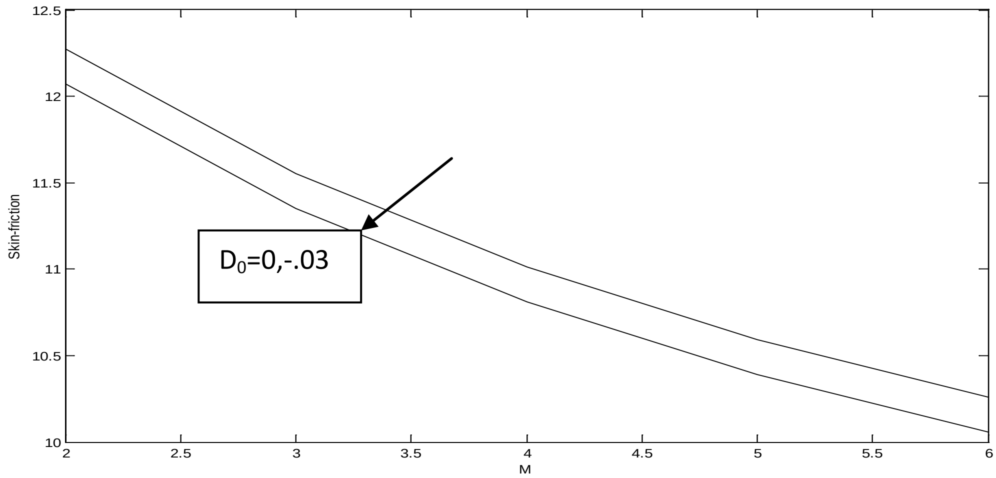

Figure-10: Variation of shearing stress (C_f) against M for
Pr=.71, Gr=5, Gm=2, Sc=.3, Kr=.5, Nr=.5, S=.05, n=.7, k=1.5, A=.3, α=-.03, ε=.02

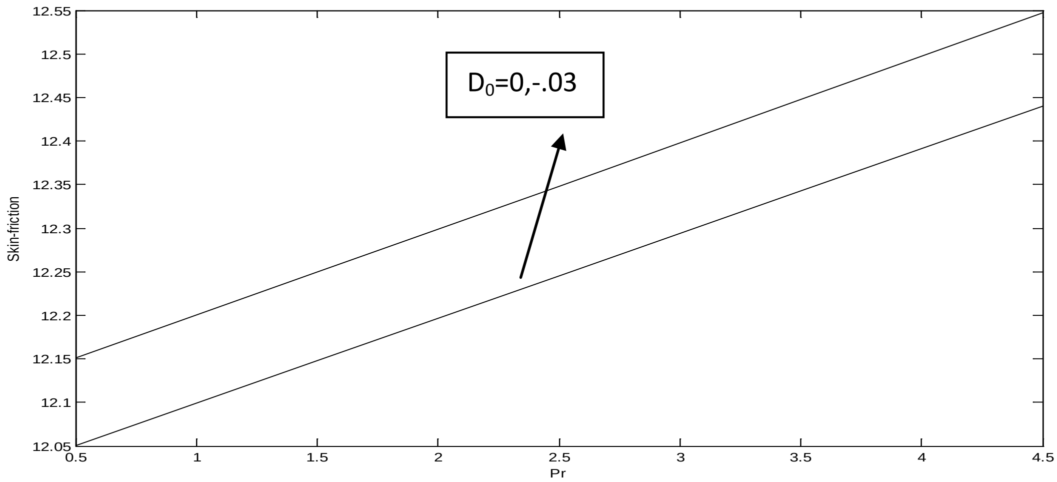

Figure-11: Variation of shearing stress (C_f) against Pr for
M=5, Gr=5, Gm=2, Sc=.3, Kr=.5, Nr=.5, S=.05, n=.7, k=1.5, A=.3, α=-.03, ε=.02

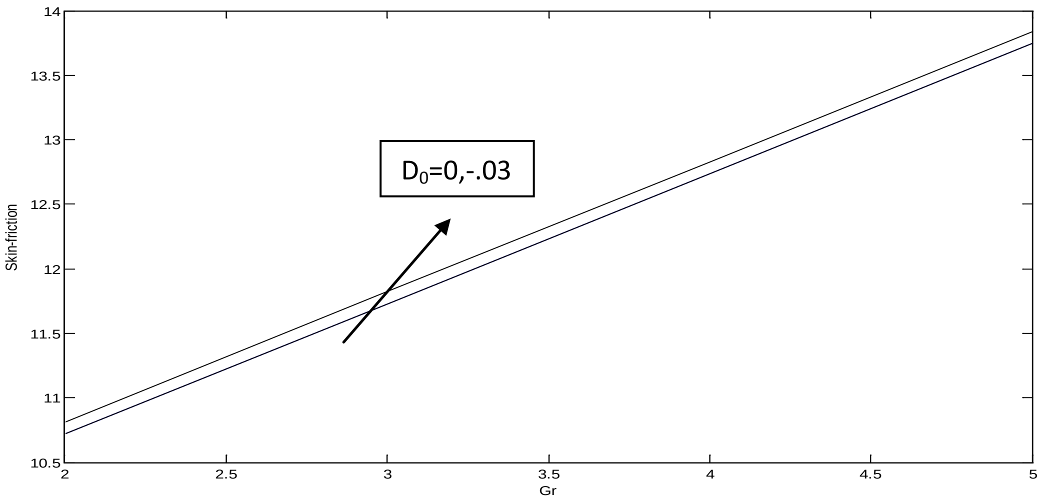

Figure-12: Variation of shearing stress (C_f) against Gr for
M=5, Pr=.71, Gm=2, Sc=.3, Kr=.5, Nr=.5, S=.05, n=.7, k=1.5, A=.3, α=-.03, ε=.02

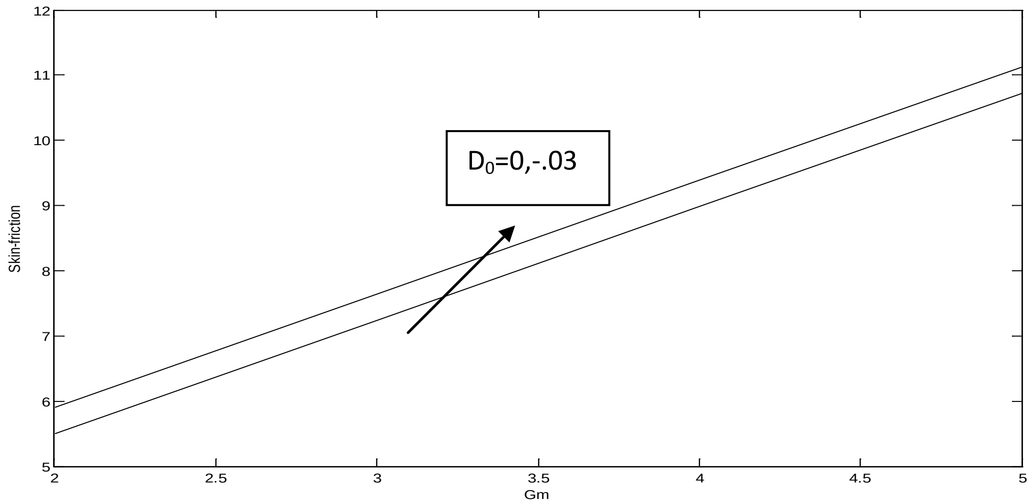

Figure-13: Variation of shearing stress (C_f) against Gm for
M=5, Pr=.71, Gr=5, Sc=.3, Kr=.5, Nr=.5, S=.05, n=.7, k=1.5, A=.3, α=-.03, ε=.02

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