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Boundary Layer Flow and Heat Transfer of a Dusty Fluid over an Exponentially Stretching Sheet

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Abstract

The aim of this paper is to analyze the effect of magnetic field on a boundary layer flow and heat transfer of a dusty fluid over an exponentially stretching surface with an exponential temperature distribution. The governing boundary layer equations are reduced into system of coupled non-linear ordinary differential equations with the help of similarity transformation. The transformed equations are then solved numerically using RKF-45 method. The effects of various physical parameters such as local fluid-particle interaction parameter, Prandtl Number, Eckert Number and Magnetic parameter on velocity and temperature profiles are discussed in detail.

Keywords: Boundary layer flow, heat transfer, exponentially stretching sheet, dusty fluid, numerical solution.

2010 Mathematics Subject Classification: 76T15; 80A20

1 Introduction

The interest in boundary layer flow and heat transfer over a stretching sheet has gained considerable attention because of its wide range of application in industry and manufacturing processes. Such applications include polymer extrusion, drawing of copper wires, continuous stretching of plastic films and artificial fibers, hot rolling, wire drawing, glass fiber and in metallurgy for the metal processing like metal extrusion and metal spinning. Few examples of such technological processes are the cooling of an infinite metallic plate in a cooling bath, the boundary layer along material handling conveyers, the boundary layer along a liquid film in condensation processes. So the study of two-dimensional boundary layer flow and heat transfer of a dusty fluid over a stretching sheet has gained much interest. A large number of researchers are engaged with this rich area. There are few attempts in which nonstandard stretching is used, known as exponential stretching.

Starting from the work of Sakiadis (Sakiadis, 1961a; Sakiadis, 1961b) who studied the stretching flow problem, encourages many authors to investigate the various aspects of this problem. Magyari

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et al (Magyari and Keller, 1999) was the first to consider the boundary layers on an exponentially stretching continuous surface with an exponential temperature distribution and are examined both analytically and numerically. Partha et al (2005) studied the effect of viscous dissipation on the mixed convection heat transfer from an exponentially stretching surface. Khan and Sanjayanand (2005) also discussed the viscoelastic boundary layer flow and heat transfer over an exponential stretching sheet. The numerical analysis was investigated by Al-odat et al (2006) for the effect of magnetic field in the thermal boundary layer on an exponentially stretching continuous surface with an exponential temperature distribution. After them the effect of a transverse magnetic field on the flow and heat transfer characteristics over a stretching surface was given by Devi and Thiyagarajan (2006) by assuming that the magnetic strength is non-linear.

The extension of this problem was recently investigated by Sajid and Hayat (2008) for the radiation effects on the flow over an exponentially stretching sheet and this problem was solved analytically using the homotopy analysis method. On the other hand, the numerical solution for the same problem was given by Bidin and Nazar (2009). Aziz (2009) discussed the similarity solution for laminar thermal boundary layer over a flat plate with a convective surface boundary condition. Pal (2010) studied on the mixed convection heat transfer in the boundary layers on an exponentially stretching continuous surface with magnetic field and verified the results those obtained by Magyari and Keller (1999) and Al-Odat et al (2006). Ishak (2011) investigated the MHD boundary layer flow due to an exponentially stretching sheet with radiation effect. Soret and Dufour Effects on Mixed Convection from an Exponentially Stretching Surface is studied by Srinivasacharya and RamReddy (2011) recently. They solved for numerical solution by using kellar-box method. Very recently Singh and Agarwal (2012) have been studied the heat transfer in a second grade fluid over an exponentially stretching sheet through porous medium with thermal radiation and elastic deformation under the effect of magnetic field for both PEST and PEHF cases.

These investigations deals with the flow and heat transfer only for fluids induced by stretching sheet. Important applications of dust particles in a boundary layer include wide range of real world applications. The study of heat transfer in the boundary layer induced by continuous stretching surface with a given temperature distribution in a conducting dusty fluid is important in several manufacturing process in industries like extrusion of plastic sheets, glass fibre and paper production, metal spinning and the cooling of metallic plate in a cooling bath. Initially Saffman (1962) worked on the stability of laminar flow of a dusty gas which describes the fluid-particle system and derived the motion of a gas equations carrying the dust particles. Datta and Mishra (1982) have discussed the dusty fluid in boundary layer flow over a semi-infinite flat plate.

Vajravelu and Nayfeh (1992) analyzed the hydromagnetic flow of a dusty fluid over a stretching sheet on the effects of fluid-particle interaction, particle loading and suction on the flow characteristics and compared their analytical solution with numerical ones. Recently, Gireesha et al (2011a; 2011b) have studied on the unsteady hydromagnetics boundary layer flow and heat transfer of dusty fluid over a stretching sheet with variable wall temperature (VWT) and variable heat flux (VHF). In these papers the effect of magnetic field on an unsteady boundary layer flow and heat transfer of a dusty fluid over an unsteady stretching surface in the presence of non uniform heat source/sink are discussed. Further Gireesha et al (2011c) have discussed the steady boundary layer flow and heat transfer of a dusty fluid flow over a stretching sheet with non-uniform heat source/sink. Here they have considered two types of heating processes namely (i) prescribed surface temperature and (ii) prescribed surface heat flux.

In all the above works on dusty fluid, the authors considered linearly stretching sheet, so only on basis of these we have considered an exponentially stretching sheet. The objective of the present investigation is to study the effect of magnetic field on flow and heat transfer of a dusty fluid over an exponentially stretching sheet. The governing boundary layer equations have been simplified using suitable similarity transformations and then have been solved numerically using Runge-Kutta-Fehlberg-45 method with the help of Maple. The convergence of the solutions have been discussed by plotting graphs.

2 Mathematical Formulation And Solution of The Problem

Consider a steady two-dimensional laminar boundary layer flow and heat transfer of an incompressible viscous dusty fluid near an impermeable plane wall stretching with velocity U_w and a given temperature distribution T_w. It is assumed that the impermeable surface is stretched with exponential velocity $U_w = U_0 e^{x/L}$ in quiescent fluid and the surface is maintained at a temperature $T_w = T_\infty + (T_0 - T_\infty)e^{x/2L}$. The x-axis is chosen along the sheet and y-axis normal to it. Two equal and opposite forces are applied along the sheet so that the wall is stretched exponentially. A uniform magnetic field B is assumed to be applied in the y-direction.

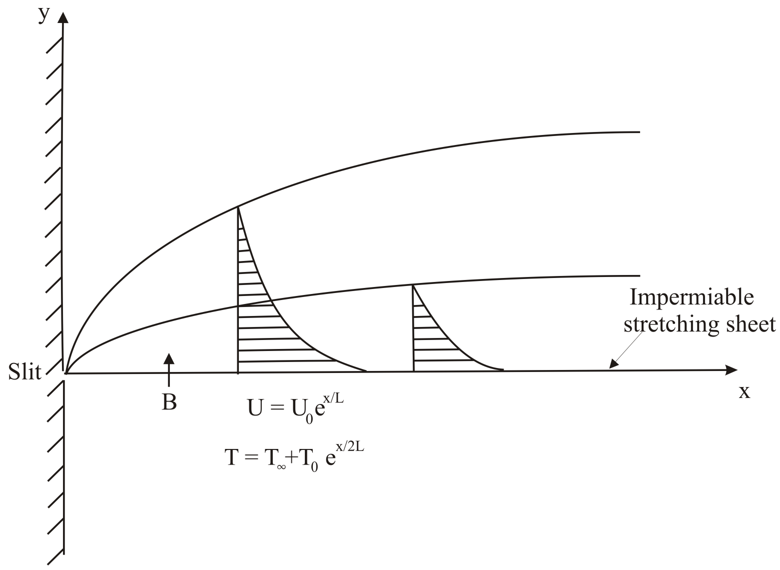

Figure 1: Schematic representation of boundary layer flow.

Under these assumptions, the two dimensional boundary layer equations can be written as,

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0, \tag{2.1}$$

$$u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} = \nu\frac{\partial^2 u}{\partial y^2} + \frac{KN}{\rho}(u_p - u) - \frac{\sigma B^2 u}{\rho}, \tag{2.2}$$

$$\frac{\partial u_p}{\partial x} + \frac{\partial v_p}{\partial y} = 0, \tag{2.3}$$

$$u_p\frac{\partial u_p}{\partial x} + v_p\frac{\partial u_p}{\partial y} = \frac{K}{m}(u - u_p), \tag{2.4}$$

where x and y represents coordinate axes along the continuous surface in the direction of motion and perpendicular to it, respectively. (u, v) and (u_p, v_p) denotes the velocity components of the fluid and particle phase along the x and y directions respectively, ν is the coefficient of viscosity of fluid, ρ is the density of the fluid phase, K is the Stoke's resistance, N is the number density of dust particles, m is the mass concentration of dust particles, $\tau_v = m/K$ is the relaxation time of particle phase and σ is the electrical conductivity.
In order to solve the governing boundary layer equations consider the following appropriate boundary conditions on velocity:

$$\begin{aligned} &u = U_w(x), \quad v = 0 \quad \text{at} \;\; y = 0, \\ &u \longrightarrow 0, \quad u_p \longrightarrow 0, \quad v_p \longrightarrow v, \quad \text{as} \;\; y \longrightarrow \infty, \end{aligned} \tag{2.5}$$

where $U_w(x) = U_0\ e^{\frac{x}{L}}$ is the sheet velocity, U_0 is reference velocity and L is the reference length. Equations (2.1) to (2.4) are subjected to boundary condition (2.5), admits self-similar solutions in terms of the similarity function f and the similarity variable η as

$$\begin{aligned} u &= U_0\ e^{\frac{x}{L}} f'(\eta), \qquad v = -\sqrt{\frac{U_0\nu}{2L}}\ e^{\frac{x}{2L}}[f(\eta)+\eta f'(\eta)], \\ u_p &= U_0\ e^{\frac{x}{L}} F'(\eta), \qquad v_p = -\sqrt{\frac{U_0\nu}{2L}}\ e^{\frac{x}{2L}}[F(\eta)+\eta F'(\eta)], \\ \eta &= \sqrt{\frac{U_0}{2\nu L}} e^{\frac{x}{2L}} y, \qquad B = B_0\ e^{\frac{x}{2L}}, \end{aligned} \tag{2.6}$$

where B_0 is the magnetic field flux density.
These equations identically satisfies the governing equation (2.1) and (2.3). Substitute (2.6) into (2.2) and (2.4), then one can get

$$f'''(\eta) + f(\eta)f''(\eta) - 2f'(\eta)^2 + 2l\beta\left[F'(\eta) - f'(\eta)\right] - Mf'(\eta) = 0, \tag{2.7}$$

$$F(\eta)F''(\eta) - 2F'(\eta)^2 + 2\beta\left[f'(\eta) - F'(\eta)\right] = 0, \tag{2.8}$$

where a prime denotes the differentiation with respect to η and $l = \frac{mN}{\rho}$ is the mass concentration, $\beta = \frac{L}{\tau_v U_0} e^{\frac{-x}{L}}$ is the local fluid-particle interaction parameter, $M = \frac{2\sigma B_0^2 L}{\rho U_0}$ is the magnetic parameter. Similarity boundary conditions (2.5) will become,

$$\begin{aligned} f'(\eta) &= 1, \quad f(\eta) = 0 \quad \text{at} \quad \eta = 0, \\ f'(\eta) &= 0, \quad F'(\eta) = 0, \quad F(\eta) = f(\eta) + \eta f'(\eta) - \eta F'(\eta) \quad \text{as} \quad \eta \longrightarrow \infty. \end{aligned} \tag{2.9}$$

2.1 Heat Transfer Analysis

The governing steady, dusty boundary layer heat transport equations are given by

$$\rho c_p\left[u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y}\right] = k\frac{\partial^2 T}{\partial y^2} + \frac{Nc_p}{\tau_T}(T_p - T) + \frac{N}{\tau_v}(u_p - u)^2, \tag{2.10}$$

$$Nc_m\left[u_p\frac{\partial T_p}{\partial x} + v_p\frac{\partial T_p}{\partial y}\right] = -\frac{Nc_p}{\tau_T}(T_p - T), \tag{2.11}$$

where T and T_p are the temperatures of the fluid and dust particle inside the boundary layer, c_p and c_m are the specific heat of fluid and dust particles, τ_T is the thermal equilibrium time i.e., it is time required by a dust cloud to adjust its temperature to the fluid, k is the thermal conductivity and τ_v is the relaxation time of the of dust particle i.e., the time required by a dust particle to adjust its velocity relative to the fluid.
To solve the temperature equations (2.10) and (2.11), we employ the following temperature boundary conditions:

$$\begin{aligned} &T = T_w(x) \quad \text{at} \quad y = 0, \\ &T \longrightarrow T_\infty, \quad T_p \longrightarrow T_\infty \quad \text{as} \quad y \longrightarrow \infty. \end{aligned} \tag{2.12}$$

where $T_w = T_\infty + T_0\ e^{\frac{x}{2L}}$ is the temperature distribution in the stretching surface, T_0 is a reference temperature.
Introduce the dimensionless variables for the temperatures $\theta(\eta)$ and $\theta_p(\eta)$ as follows:

$$\theta(\eta) = \frac{T - T_\infty}{T_w - T_\infty}, \qquad \theta_p(\eta) = \frac{T_p - T_\infty}{T_w - T_\infty}, \tag{2.13}$$

where $T - T_\infty = T_0 \ e^{\frac{x}{2L}}\theta(\eta)$.
Using the similarity variable η and (2.13) into (2.10) to (2.11), one can arrive the following system of equations:

$$\begin{aligned} \theta''(\eta) + Pr\left[f(\eta)\theta'(\eta) - f'(\eta)\theta(\eta)\right] + 2a_1 NPr\left[\theta_p(\eta) - \theta(\eta)\right] & \\ +2a_2 NPrEc\left[F'(\eta) - f'(\eta)\right]^2 &= 0, \quad (2.14) \\ F'(\eta)\theta_p(\eta) - F(\eta)\theta_p'(\eta) + 2b_1\left[\theta_p(\eta) - \theta(\eta)\right] &= 0, \quad (2.15) \end{aligned}$$

where $Pr = \frac{\mu C_p}{k}$ Prandtl number, $Ec = \frac{U_0^2}{C_p T_0}$ Eckert number, $a_1 = \frac{L}{\tau_T \rho U_0} e^{\frac{-x}{L}}$ and $b_1 = \frac{C_p L}{\tau_T C_m U_0} e^{\frac{-x}{L}}$ are local fluid particle interaction parameter for heat transfer and $a_2 = \frac{L}{\tau_v \rho U_0} e^{\frac{x}{2L}}$ is the local fluid particle interaction parameter for velocity.
Corresponding thermal boundary conditions becomes,

$$\begin{aligned} &\theta(\eta) = 1 \quad \text{at} \quad \eta = 0, \\ &\theta(\eta) \longrightarrow 0, \quad \theta_p(\eta) \longrightarrow 0 \quad \text{as} \quad \eta \longrightarrow \infty, \end{aligned} \quad (2.16)$$

2.2 Numerical Solution

Consider two-dimensional, boundary layer flow and heat transfer of a dusty fluid over an exponential stretching sheet. The exact solutions do not seem feasible for a complete set of the equations (2.1) to (2.4) and (2.10) to (2.11) because of the nonlinearity and couplings between the momentum and thermal boundary layer equations. Therefore, the solutions are obtained numerically. The system of nonlinear equations (2.1) to (2.4), (2.10) to (2.11) subject to the boundary conditions (2.5) and (2.12) are converted into a system of non-linear ordinary differential equations using similarity transformations. These non-linear ordinary differential equations are then solved numerically using Runge-Kutta-Fehlberg 45 scheme with the help of Maple software. In this method, we choose suitable finite values of $\eta \longrightarrow \infty$ say η = 5. Comparison of our results of $-\theta'(0)$ with those obtained by Magyari and Keller (1999), El-Aziz (2007), Pal (2010) and Srinivasacharya and RamReddy (2011) in absence of fluid-interaction parameter, Number of dust particles and magnetic field. From the Table 1, one can notice that there is a close agreement with these approaches and thus verifies the accuracy of the method used.

Table 1: Comparison of the results for the dimensionless temperature gradient $-\theta'(0)$ for various values of Pr with $\beta = N = M = 0$.

Pr	Magyari - Keller	El-Aziz	Pal	Srinivasacharya - RamReddy	Present Study
0.5	-0.59434	-	-0.59434	-0.59438	-0.59447
1.0	-0.95478	-0.95478	-0.95478	-0.95478	-0.95481
3.0	-1.86908	-1.86907	-1.86907	-1.86908	-1.86907
5.0	-2.50014	-2.50013	-2.50013	-2.50015	-2.49992
8.0	-3.24213	-	-3.00587	-3.24218	-3.24177
10.0	-3.66038	-3.66037	-3.66037	-3.66043	-3.66037

Further, we study the effect of magnetic field on velocity and temperature profiles and are depicted graphically for different values of local fluid-particle interaction parameter (β), Magnetic parameter (M), Prandtl number (Pr) and Eckert number (Ec).

3 Results and Discussion

A steady dusty boundary layer problem for momentum and heat transfer over an exponentially stretching continuous surface with an exponential temperature distribution in presence of magnetic field effect is examined. The boundary layer equations are then solved numerically. The velocity and temperature profiles are depicted graphically for different physical flow parameters such as fluid particle interaction parameter β, Prandtl number Pr, Eckert number Ec, and Magnetic parameter M (from figure 2 to figure 7). A comparison between wall-temperature gradient values computed by the present method for $M = 0$, $\beta = 0$ and $N = 0$ are made with that of Magyari and Keller (1999), El-Aziz (2007), Pal (2010) and Srinivasacharya and RamReddy (2011) as in Table 1.

From figure 2, the observation shows that increase of local fluid-particle interaction parameter β decreases the fluid velocity $f'(\eta)$ and increases the particle velocity $F'(\eta)$ for $Pr = 1$, $M = 2$ and $Ec = 2$. From this one can noticed that at a certain point as β increases velocity of both fluid and dust will be same. Figure 3 depicts the temperature profiles $\theta(\eta)$ and $\theta_p(\eta)$ versus η for different values of fluid particle interaction parameter β with $Pr = 1$, $M = 2$ and $Ec = 2$. We infer from this figure that temperature decreases with increases in fluid particle interaction parameter β and also it indicates that both the fluid and dust particle temperature are parallel to each other.

The velocity profiles $f'(\eta)$ and $F'(\eta)$ versus η for different values of the magnetic parameter M by taking $\beta = 0.5$, $Ec = 2$ and $Pr = 1$ presented in figure 4. It shows that the rate of transport is considerably reduced with the increase of M. Further it clearly indicates that the transverse magnetic field opposes the transport phenomena. This is because the variation of M leads to the variation of the Lorentz force due to the magnetic field and the Lorentz force produces more resistance to the transport phenomena. The figure 5 shows the temperature distributions $\theta(\eta)$ and $\theta_p(\eta)$ versus η for different values of magnetic parameter M when $Pr = 1$, $Ec = 2$ and $\beta = 0.5$. We infer from this figure that temperature increases with increases in M.

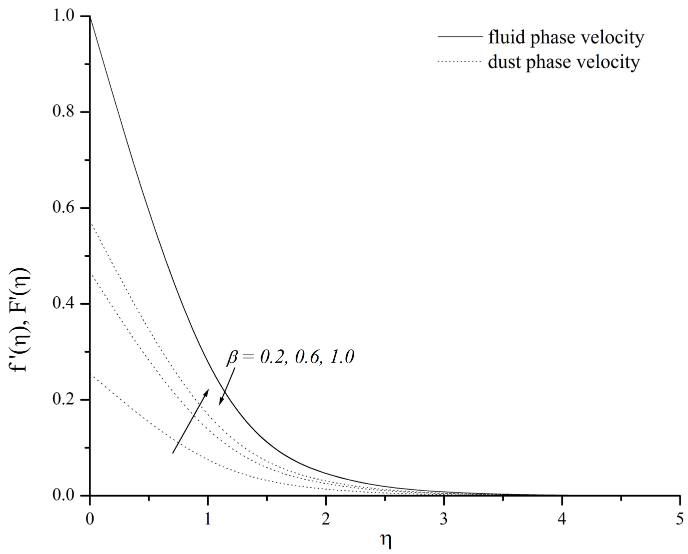

Figure 2: Effect of local fluid-particle interaction parameter β on velocity profiles.

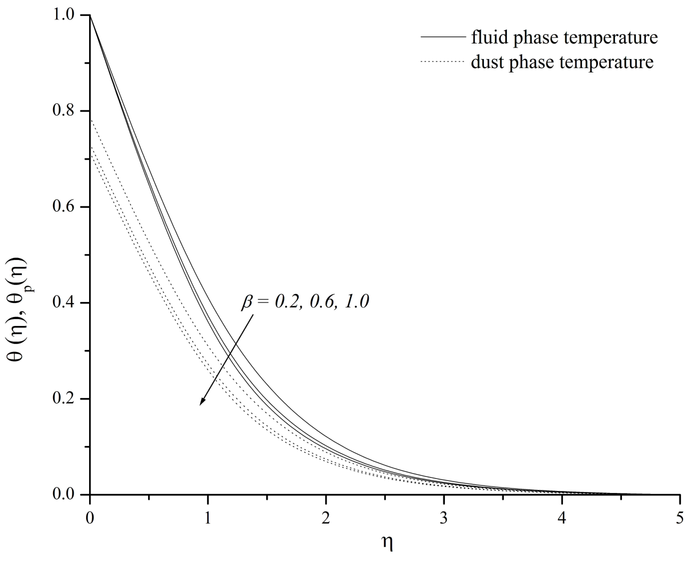

Figure 3: Effect of local fluid-particle interaction parameter β on temperature profiles.

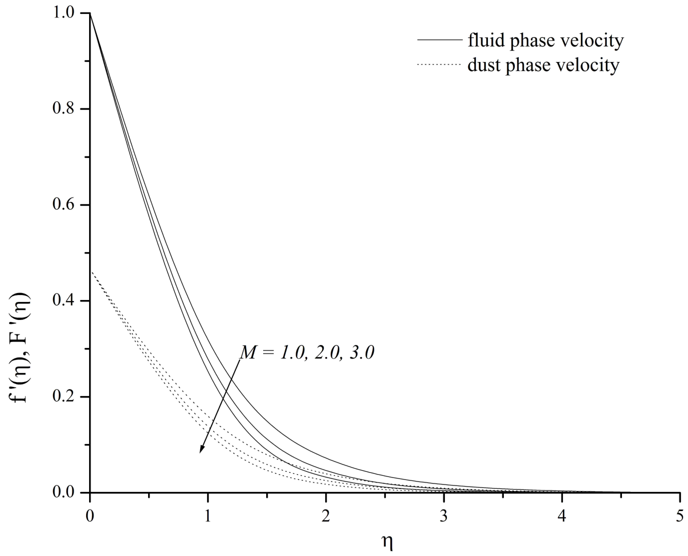

Figure 4: Effect of magnetic parameter M on velocity profiles.

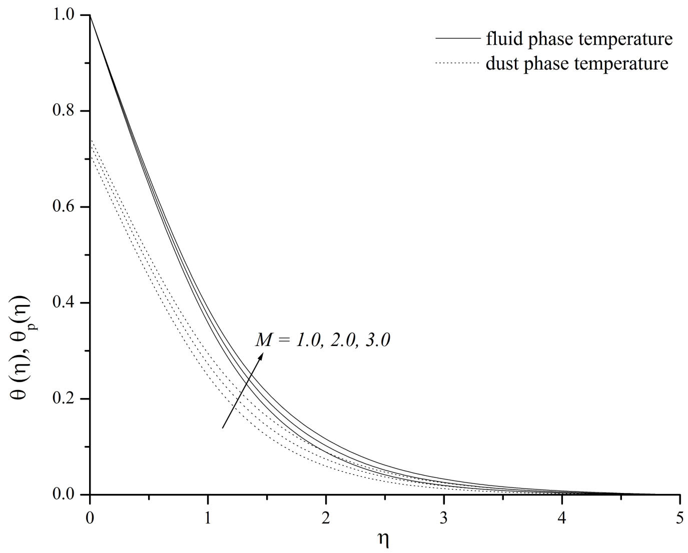

Figure 5: Effect of magnetic parameter M on temperature profiles.

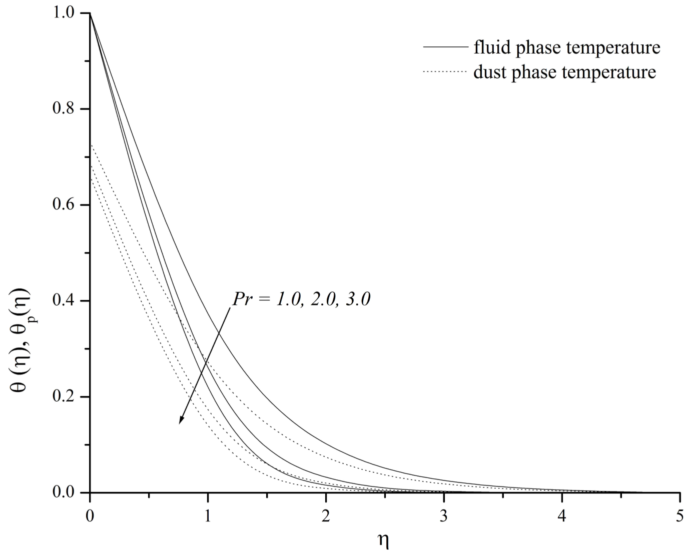

Figure 6: Effect of Prandtl number Pr on temperature profiles.

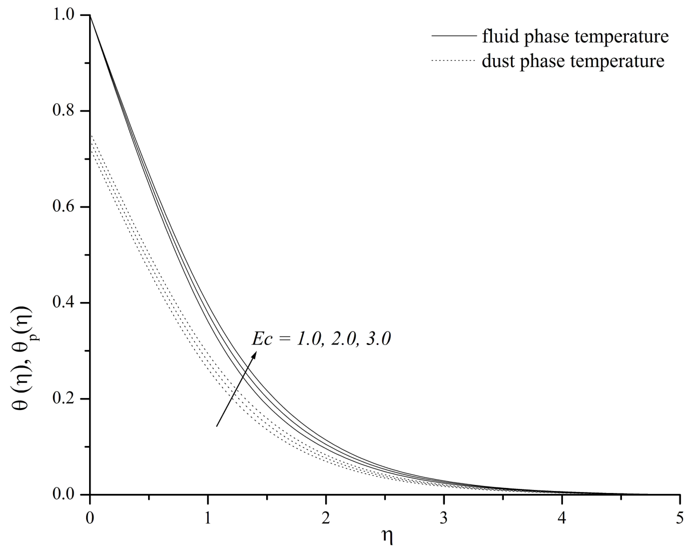

Figure 7: Effect of Eckert number Ec on temperature profiles.

Figure 6 illustrates the effect of Prandtl number Pr on velocity profiles with η for $Ec = 2$, $\beta = 0.5$ and $M = 1$. It is actually the ratio of velocity boundary layer to thermal boundary layer. When Pr=1, the boundary layers coincide and Pr is small, it means that heat diffuses very quickly compared to the velocity. This means the thickness of the thermal boundary layer is much bigger than the velocity boundary layer for fluid (liquid metals). From this figure, it reveals that the temperature decreases with increase in the value of Pr. Figure 7 explains the effect of Eckert number Ec on temperature profiles with η for $Pr = 1$, $\beta = 0.5$ and $M = 1$. From this one can see that the temperature increases with increase in the value of Ec. This is due to the heat energy is stored in the liquid due to the frictional heating. We have used throughout our thermal analysis the values of $a_1 = a_2 = 2$, $b_1 = 1$, $N = 1$, and $l = 0.1$.

4 CONCLUSIONS

The two-dimensional boundary layer flow and heat transfer of a steady dusty fluid over an exponential stretching sheet with magnetic field is considered. The governing partial differential equations are reduced into set of non-linear ordinary differential equations using the suitable similarity transformations. The obtained coupled non-linear ordinary differential equations are solved numerically by applying RKF-45 order method using the software Maple. The velocity and temperature profiles are obtained for various values of physical parameters like fluid particle interaction parameter β, Magnetic parameter M, Prandtl number Pr and Eckert number Ec. The present numerical solutions have been compared with previously reported results from Magyari and Keller (1999), El-Aziz (2007), Pal (2010) and Srinivasacharya and RamReddy (2011) and found them in good agreement. The major findings from the present study can be summarized as follows:

a The fluid particle interaction parameter decreases the velocity components in the fluid phase and increases in the dust phase.

b As fluid particle interaction parameter increases, temperature distribution decreases both in the fluid and dust phase.

c Velocity distribution decreases as magnetic parameter increases in both the fluid and dust phase.

d The effect of increasing the value of magnetic parameter is to increase the temperature distribution.

e The prandtl number decreases the temperature profile where as Eckert number increases the temperature profile.

f If $\beta \longrightarrow 0, M \longrightarrow 0, N \longrightarrow 0$ then our results coincide with the results of Magyari and Keller (1999), El-Aziz (2007), Pal (2010) and Srinivasacharya and RamReddy (2011) for different values of Prandtl number.

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References

A. Aziz. (2009). A similarity solution for laminar thermal boundary layer over a flat plate with a convective surface boundary condition. Com. Non. Sci. Num. Simul., 14, 1064-1068.

Al-Odat, M.Q. Damseh, R.A., Al-Azab, T.A. (2006). Thermal boundary layer on an exponentially stretching continous surface in the presence of magnetic field effect. Int. J. of Appl. Mech. Eng., 11(2), 289-299.

Devi, A.S.P., Thiyagarajan, M. (2006). Steady nonlinear hydromagnetic flow and heat transfer over a stretching surface of variable temperature. Heat Mass Transfer, 42, 671-677.

Ishak, A. (2011). MHD Boundary Layer Flow Due to an Exponentially Stretching Sheet with Radiation Effect. Sains Malaysiana, 40(4), 391-395.

Bidin, B., Nazar, R., (2009). Numerical Solution of the Boundary Layer Flow Over an Exponentially Stretching Sheet with Thermal Radiation. Eur. J. Sci. Res., 33(4), 710-717.

Datta, N., Mishra, S.K. (1982). Boundary layer flow of a dusty fluid over a semi-infinite flat plate. Acta. Mech., 42, 71-83.

Pal, D. (2010). Mixed convection heat transfer in the boundary layers on an exponentially stretching surface with magnetic field. Appl. Math. Comput., 217, 2356-2369.

El-Aziz, M.A. (2007). Viscous dissipation effect on mixed convection flow of a micropolar fluid over an exponentially stretching sheet. Can. J. Phys., 87, 359-368.

Gireesha, B.J. Ramesh, G.K. Abel, S.M., Bagewadi, C.S. (2011a). Boundary layer flow and heat transfer of a dusty fluid flow over a stretching sheet with non-uniform heat source/sink. Int. J. of Multiphase Flow, 37(8), 977-982.

Gireesha, B.J., Manjunatha, S., Bagewadi, C.S. (2011b). Unsteady hydromagnetics boundary layer flow and heat transfer of dusty fluid over a stretching sheet. Afrika Matematika, 22, (Article in Press).

Gireesha, B.J., Roopa, G.S., Bagewadi, C.S. (2011c). Boundary layer flow of an unsteady dusty fluid and heat transfer over a stretching sheet with non uniform heat source/sink. Engineering, 3, 726-735.

Magyari, E., Keller, B. (1999). Heat and mass transfer in the boundary layers on an exponentially stretching continuous surface. J. Phys. D: Appl. Phys., 32, 577-585.

Partha, M.K., Murthy, P.V.S.N., Rajasekhar, G.P. (2005). Effect of viscous dissipation on the mixed convection heat transfer from an exponentially stretching surface. Heat Mass Transfer, 41, 360-366.

Saffman, P.G. (1962). On the stability of laminar flow of a dusty gas. J. Fluid Mechanics., 13, 120-128.

Sajid, M, Hayat, T. (2008). Influence of thermal radiation on the boundary layer flow due to an exponentially stretching sheet. Int. Comm. Heat and Mass Trans., 35(3), 347-356.

Sakiadis, B.C. (1961a). Boundary-layer behavior on continuous solid surfaces: I. Boundary-layer equations for two-dimensional and axisymmetric flow. AIChE J., 7(1), 26-28.

Sakiadis, B.C. (1961b). Boundary-layer behavior on continuous solid surfaces: II. The boundary layer on a continuous flat surface. AIChE J., 7(2), 221-225.

Singh, V., Agarwal, S. (2012). Heat transfer in a second grade fluid over an exponentially stretching sheet through porous medium with thermal radiation and elastic deformation under the effect of magnetic field. Int. J. of Appl. Math and Mech., 8(4), 41-63.

Khan, S.K., Sanjayanand, E. (2005). Viscoelastic boundary layer flow and heat transfer over an exponential stretching sheet. Int. J. Heat and Mass Trans., 48(8), 1534-1542.

Vajravelu, K., Nayfeh, J. (1992). Hydromagnetic flow of a dusty fluid over a stretching sheet. Int. J. Non-linear Mech., 27(6), 937-945.

Srinivasacharya, D., RamReddy, Ch. (2011). Soret and Dufour Effects on Mixed Convection from an Exponentially Stretching Surface. Int. J. Non-linear Scie., 12, 60-68.

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