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Magnetic Field and Chemical Reaction Effects on Convective Flow of Dusty Viscous Fluid

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ABSTRACT: In this paper we analyses the laminar convective flow of a dusty viscous fluid of non conducting walls in the presence of transverse magnetic field with volume fraction and the first order chemical reaction is taken into consideration. An exact analytic solution is obtained for the temperature and concentration fields by using perturbative technique from these temperature and concentration fields, we obtain numerical solution for the velocity field and we analyze the effects of velocity, temperature and concentration of the fluid at the various parameters as t (time), M (Magnetic parameter), Pr(Prandtl number) ,Gr (Grashof number), K_1(Chemical reaction parameter).From these we observed that increase in transverse magnetic field causes the decrease of velocity of the fluid and fluid temperature decreases by increase in prandtl number and Concentration profile increases by increase in chemical reaction parameter.

Key Words: Convective flow, MHD, Dusty fluid, Concentration, Chemical Reaction.

1. Introduction

The concept of heat transfer of a dusty fluid has a wide range of applications in air conditioning ,refrigeration, pumps, accelerators, nuclear reactors space heating, power generation, chemical processing,filtration and geothermal systems etc. The good example of heat transfer is the radiator in a car, in which the hot radiator fluid is cooled by the flow of air over the radiator surface. The experimental and theoretical works on MHD flow with chemical reaction have been done extensively in various areas i.e. sustain plasma confinement for controlled thermo nuclear fusion, liquid metal cooling of nuclear reactions and electromagnetic casting of metals. Keeping above facts many authors attracted in this field of study of heat and mass transfer through dusty fluids. Seddeek et al [1] examined the effect of chemical reaction and variable viscosity on hydromagnetic mixed convection heat and mass transfer for Hiemenz flow through porous media he has been analysed in the presence of radiation and magnetic field. Chambre and Yang [2] have worked on thermal diffusion of a chemically reactive species in a laminar boundary layer flow. Muthucumaraswamy R and P. Ganesan [3] studied the chemical reaction on the flow past an impulsively started vertical plate with uniform heat and mass flux. The same type of problem with inclusion of constant wall suction was studied by Makinde.O.D. and P. Sibanda [4] . Soundalgekar et al [5] discussed MHD effects on impulsively started vertical infinite plate with variable temperature in the presence of transverse magnetic field. Ghosh [6] studied the hydromagnetic flow of a dusty viscoelastic Maxwell fluid through a rectangular channel for an arbitrary pressure gradient. Unsteady hydromagnetic flow and heat transfer from a non isothermal stretching sheet immersed in a porous medium was discussed by Chamkha [7].Viscous heating of high Prandtl number fluids with temperature dependent viscosity. Eckert et al. [8] studied the effect of radiation on temperature and velocity in electrodynamics froth flow process. They concluded that the velocity and temperature increases as the radiation parameter increases. Attia [9] has investigated an unsteady MHD Couette flow and heat transfer of dusty fluid with variable physical properties. Mishra et al. [10] have studied the transient conduction and radiation heat transfer with temperature dependent thermal conductivity on two dimensional flows. Chakraborty [11] studied MHD flow and heat transfer of a dusty viscoelastic stratified fluid down an inclined channel in porous medium under variable viscosity.

Nag and Jana [12] have discussed unsteady couette flow of a dusty gas between two infinite parallel plates, when one plate is kept fixed and the other plate moves in its own plane by using Laplace Transform technique. Here they found that the dust velocity in the case of accelerated start of the plate is less than the fluid velocity. They carried out a similar calculation for the simpler case of a homogeneous flow without porous medium. The convective magnetohydrodynamic two phase flow and heat transfer of a fluid in an inclined channel was investigated by Malashetty et al. [13]. Attia [14] has investigated an unsteady MHD Couette flow and heat transfer of dusty fluid with variable physical properties.

Keeping above facts and applications, in the present paper we discuss the laminar convective flow of a dusty viscous fluid of non-conducting walls in the presence of transverse magnetic field with volume fraction and chemical reaction. Here we analyze the effect of velocity, velocity of the particle phase, temperature of the dusty fluid and concentration at the transverse magnetic field along with various physical parameters.

2. Mathematical Formulation

In Cartesian co-ordinate system, we consider unsteady laminar flow of a dusty, incompressible, Newtonian, electrically conducting, viscous fluid of uniform cross section h, when one wall of the channel is fixed and the other is oscillating with time about a constant non-zero mean. Initially at $t \leq 0$, the channel wall as well as the fluid is assumed to be at the same temperature T_0 and concentration C_0. When $t>0$, the temperature of the channel wall is instantaneously raised to T_w and concentration raised to C_w which oscillate with time and is thereafter maintained constant. Let x-axis be along the fluid flow at the fixed wall and y-axis perpendicular to it. The transverse magnetic field is applied to the flow along y direction with the first order chemical reaction.

2.1 Assumptions:

The governing equations are written based on the following assumptions:

The dust particles are solid, spherical, non-conducting, and equal in size and uniformly distributed in the flow region.

(i) The density of dust particles is constant and the temperature between the particles is uniform throughout the motion.

(ii) The interaction between the particles, chemical reaction between the particles and liquid has been considered.

(iii) The volume occupied by the particles per unit volume of the mixture, (i.e., volume fraction of dust particles) and mass concentration have been taken into consideration.

2.2 Governing equations of the flow

The fluid flow is governed by the momentum and energy equations under the above assumptions are

$$(1-\emptyset)\frac{\partial u}{\partial t} = (1-\emptyset)\left[-\frac{1}{\rho}\frac{\partial p}{\partial x} + \nu\frac{\partial^2 u}{\partial y^2} + g\beta(T-T_0) + g\beta^*(C-C_0)\right]$$

$$+\frac{KN_0}{\rho}(v-u) - \frac{KN_0\sigma\mu_c^2 H_0}{\rho}u \quad (1)$$

$$N_0 m\frac{\partial v}{\partial t} = \emptyset\left[-\frac{\partial p}{\partial x} + \mu\frac{\partial^2 u}{\partial y^2} + \rho g\beta(T-T_0) + \rho g\beta^*(C-C_0)\right] + KN_0(u-v) \quad (2)$$

$$\frac{\partial T}{\partial t} = \frac{k}{\rho C_p}\frac{\partial^2 T}{\partial y^2} \quad (3)$$

$$\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial y^2} + K_l(C-C_0) \quad (4)$$

The boundary conditions to the problem are:

$$t \le 0;\, u(y,t) = v(y,t) = 0, \quad T(y,t) = C(y,t) = 0 \text{ for } 0 \le y \le 1$$

$$t > 0;\, u(y,t) = v(y,t) = 0, \quad T(y,t) = C(y,t) = 0 \text{ at } y = 0$$

(5)

$$u(y,t) = v(y,t) = 1 + \varepsilon e^{int}, \quad T(y,t) = C(y,t) = 1 + \varepsilon e^{int} \text{ at } y = 1$$

Where $u(y,t)$ is the velocity of the fluid and $v(y,t)$ is velocity of the dust particles, m is the mass of each dust particle, N_0 is the number density of the dust particle, T is the temperature, T_0 is the initial temperature, T_w is the raised temperature, C is the concentration, C_0 is the initial concentration, C_w is the raised concentration, $\emptyset$ is the volume fraction of the dust particle, f is mass concentration of dust particle, β volumetric coefficient of the thermal expansion, K is the Stoke's resistance coefficient, σ is the electrical conductivity of the fluid, μ_c is the magnetic permeability, H_0 is the magnetic field induction, C_p is the specific heat at constant pressure, k is the thermal conductivity, K_l is chemical reaction parameter, K_1 is dimensionless chemical reaction parameter.

The problem is simplified by writing the equations in the following non dimensional. Here the characteristic length is taken to be h and the characteristic velocity is υ.

$$x^* = \frac{x}{h}, y^* = \frac{y}{h}, p^* = \frac{h^2 p}{\rho \nu^2}, t^* = \frac{\nu t}{h^2}, u^* = \frac{uh}{\nu}, T^* = \frac{T - T_0}{T_w - T_0}, C^* = \frac{C - C_0}{C_w - C_0}, v^* = \frac{vh}{\nu} \quad (6)$$

Substituting the above non-dimensional parameters equation (6) in the governing equations (1-4) (after removing asterisks), we get

$$\frac{\partial u}{\partial t} = -\frac{\partial p}{\partial x} + \frac{\partial^2 u}{\partial x^2} + G_r T + G_c C + \varepsilon_1 (v - u) - \varepsilon_2 M$$
(7)

$$f \frac{\partial v}{\partial t} = \emptyset \left[-\frac{\partial p}{\partial x} + \frac{\partial^2 u}{\partial y^2} + G_r T + G_c C \right] + \beta (u - v) \quad (8)$$

$$\frac{\partial T}{\partial t} = \frac{1}{P_r} \frac{\partial^2 T}{\partial y^2}$$
(9)

$$\frac{\partial C}{\partial t} = \frac{1}{S_c} \frac{\partial^2 C}{\partial y^2} + K_1 C \quad (10)$$

Where

$G_r = \frac{g\beta(T_w - T_0)h^3}{\nu^2}$ (Thermal Grashof number), $G_c = \frac{g\beta^*(C_w - C_0)h^3}{\nu^2}$ (mass Grashof number), $\varepsilon_1 = \frac{f}{\sigma_1(1-\emptyset)}$, $\sigma_1 = \frac{m\nu}{Kh^2}$, $\varepsilon_2 = \frac{1}{1-\emptyset}$, $M = \mu_c^2 h^2 H_0^2 \frac{\sigma}{\mu}$ (Magnetic parameter), $f = \frac{mN_0}{\rho}$ (mass concentration of dust particles), $\beta = \frac{f}{\sigma_1}$ (concentration resistance ratio) and $P_r = \frac{\mu C_p}{k}$ (Prandtl number), $S_c = \frac{\nu}{D}$ (Schmidt number), $K_1 = \frac{K_l h^2}{\nu}$ (Chemical Reaction parameter).

The corresponding non-dimensional boundary conditions are:

$$t \le 0; u(y,t) = v(y,t) = 0, \quad T(y,t) = C(y,t) = 0 \text{ for } 0 \le y \le 1$$

$$t > 0; u(y,t) = v(y,t) = 0, \quad T(y,t) = C(y,t) = 0 \text{ at } y = 0$$

(11)

$$u(y,t) = v(y,t) = 1 + \varepsilon e^{int}, \quad T(y,t) = C(y,t) = 1 + \varepsilon e^{int} \text{ at } y = 1$$

3. Solution of the Problem:

To solve the equations (7-10) we use the below equations introduced by Soundalgekar and Bhat equations.

$$u(y,t) = u_0(y) + \varepsilon u_1(y) e^{int}$$

$$v(y,t) = v_0(y) + \varepsilon v_1(y) e^{int} \tag{12}$$

$$T(y,t) = T_0(y) + \varepsilon T_1(y) e^{int}$$

$$C(y,t) = C_0(y) + \varepsilon C_1(y) e^{int}$$

After substituting equation (10) in equations (6 - 8), we can write

$$u_0''(y) - (\varepsilon_1 + \varepsilon_2 M) u_0(y) + \varepsilon_1 v_0(y) = P - G_r T_0(y) - G_c C_0(y) \tag{13}$$

$$\beta v_0(y) = \beta u_0(y) + \emptyset[u_0''(y) - P + G_r T_0(y) + G_c C_0(y)] \tag{14}$$

$$T_0''(y) = 0 \tag{15}$$

$$C_0''(y) + K_1 S_c C_0(y) = 0 \quad (16)$$

$$u_1''(y) - (\varepsilon_1 + \varepsilon_2 M + in)u_1(y) + \varepsilon_1 v_1(y) = -G_r T_1(y) - G_c C_0(y) \quad (17)$$

$$(\beta + inf)v_1(y) = \beta u_1(y) + \emptyset[u_1''(y) + G_r T_0(y) + G_c C_0(y)]$$
(18)

$$T_1''(y) - inP_r T_1(y) = 0 \quad (19)$$

$$C_1''(y) + [K_1 - in]S_c C_1(y) = 0$$
(20)

The corresponding boundary conditions becomes

$$u_0(y) = u_1(y) = v_0(y) = v_1(y) = 0, T_0(y) = T_1(y) = C_0(y) = C_1(y) = 0 \text{ at } y = 0$$

$$u_0(y) = u_1(y) = v_0(y) = v_1(y) = 1, T_0(y) = T_1(y) = C_0(y) = C_1(y) = 1 \text{ at } y = 1 \quad (21)$$

On solving equation (15) and (16) with the help of boundary conditions (21), we get

$$T_0(y) = y \quad (22)$$

$$C_0(y) = \frac{sinL_1 y}{sinL_1} \quad (23)$$

Substituting equations (22) and (23) in equations (13) and (14)

$$u_0''(y) - (\varepsilon_1 + \varepsilon_2 M)u_0(y) + \varepsilon v_0(y) = P - G_r y - G_c \frac{sinL_1 y}{sinL_1} \quad (24)$$

$$\beta v_0(y) = \beta u_0(y) + \emptyset \left[u_0''(y) - P + G_r \text{y} + G_c \frac{sinL_1 y}{sinL_1}\right] \quad (25)$$

Substituting equation (25) in equation (24), we obtain

$$u_0''(y) - A^2 u_0(y) = P - G_r y - G_c \frac{sinL_1 y}{sinL_1} \quad (26)$$

Where $A^2 = \frac{\beta \varepsilon_2 M}{\beta + \varepsilon_1 \emptyset}$

By solving equation (26) with the boundary conditions (21), we get

$$u_0(y) = \frac{P}{A^2}(coshAy - 1) + \left[1 - \frac{P(coshA-1)+G_r}{A^2} - \frac{G_c}{L_1^2+A^2}\right]\frac{sinhAy}{sinhA} + \frac{G_r}{A^2}y + \frac{G_c}{L_1^2+A^2}\frac{sinL_1y}{sinL_1}$$

(27)

The first and second order partial derivatives of $u_0(y)$ are

$$u_0'(y) = \frac{P}{A}sinhAy + \left[1 - \frac{P(coshA-1)+G_r}{A^2} - \frac{G_c}{L_1^2+A^2}\right]A\frac{coshAy}{sinhA} + \frac{G_r}{A^2} + \frac{G_cL_1}{L_1^2+A^2}\frac{cosL_1y}{sinL_1} \quad (28)$$

$$u_0''(y) = P\,coshAy + \left[1 - \frac{P(coshA-1)+G_r}{A^2} - \frac{G_c}{L_1^2+A^2}\right]A^2\frac{sinhAy}{sinhA} - \frac{G_cL_1^2}{L_1^2+A^2}\frac{sinL_1y}{sinL_1} \quad (29)$$

Substituting equations (27) and (29) in equation (14), we obtain

$$v_0(y) = \frac{A_1P}{A^2}(coshAy - 1) + A_1\left[1 - \frac{P(coshA-1)+G_r}{A^2} - \frac{G_c}{L_1^2+A^2}\right]\frac{sinhAy}{sinhA} + \frac{A_1G_ry}{A^2} + \frac{A_1G_c}{L_1^2+A^2}\frac{sinL_1y}{sinL_1} \quad (30)$$

Where $A_1 = 1 + \frac{\emptyset}{\beta}A^2$

By solving equations (19) and (20) with the boundary conditions (21), we get

$$T_1(y) = \frac{sinhL_0y}{sinhL_0} \quad (31)$$

$$C_1(y) = \frac{sinhL_2y}{sinhL_2}$$

(32)

Substituting equations (31) and (32) in equations (17) and (18), we obtain

$$u_1''(y) - (\varepsilon_1 + \varepsilon_2M + in)u_1(y) + \varepsilon_1v_1(y) = -G_r\frac{sinhL_0y}{sinhL_0} - G_c\frac{sinh\,L_2y}{sinhL_2} \quad (33)$$

$$(\beta + inf)v_1(y) = \beta u_1(y) + \emptyset\left[u_1''(y) + G_r\frac{sinhL_0y}{sinhL_0} + G_c\frac{SinhL_2y}{SinhL_2}\right] \quad (34)$$

Substituting equation (34) in equation (33) we obtain

$$u_1''(y) - B^2u_1(y) = -G_r\frac{sinhL_0y}{sinhL_0} - G_c\frac{sinhL_2y}{sinhL_2}$$

(35)

On solving equation (35), with the boundary conditions (21), we get

$$u_1(y) = \left(1 + \frac{G_r}{L_0^2 - B^2} + \frac{G_c}{L_2^2 - B^2}\right)\frac{sinhBy}{sinhB} - \frac{G_r}{L_0^2 - B^2}\frac{sinhL_0y}{sinhL_0} - \frac{G_c}{L_2^2 - B^2}\frac{sinhL_2y}{sinhL_2} \quad (36)$$

The first and second order partial derivatives $u_1(y)$ are given by

$$u_1'(y) = \left(1 + \frac{G_r}{L_0^2 - B^2} + \frac{G_c}{L_2^2 - B^2}\right)\frac{B\,coshBy}{sinhB} - \frac{G_r}{L_0^2 - B^2}\frac{L_0\,coshL_0y}{sinhL_0} - \frac{G_c}{L_2^2 - B^2}\frac{L_2\,coshL_2y}{sinhL_2} \quad (37)$$

$$u_1''(y) = \left(1 + \frac{G_r}{L_0^2 - B^2} + \frac{G_c}{L_2^2 - B^2}\right)\frac{B^2\,sinhBy}{sinhB} - \frac{G_r}{L_0^2 - B^2}\frac{L_0^2\,sinh\,L_0y}{sinhL_0} - \frac{G_c}{L_2^2 - B^2}\frac{L_2^2\,sinhL_2y}{sinhL_2} \quad (38)$$

Substituting equations (37) and (38) in equation (34), we obtain

$$v_1(y) = A_2B_0\left[\left(1 + \frac{G_r}{L_0^2 - B^2} + \frac{G_c}{L_2^2 - B^2}\right)\frac{sinhBy}{sinhB} - \frac{G_r}{L_0^2 - B^2}\frac{sinhL_0y}{sinhL_0} - \frac{G_c}{L_2^2 - B^2}\frac{sinhL_2y}{sinhL_2}\right] \quad (39)$$

$A_0 = 1 + \frac{\emptyset}{\beta}B^2$ and $B_0 = \frac{\beta(\beta - nif)}{\beta^2 + n^2f^2}$

Substituting the equations (27) and (36) in the equation (12), we obtain

$$u(y,t) = \frac{P}{A^2}(coshAy - 1) + \left[1 - \frac{P(coshA - 1) + G_r}{A^2} - \frac{G_c}{L_1^2 + A^2}\right]\frac{sinhAy}{sinhA} + \frac{G_r}{A^2}y + \frac{G_c}{L_1^2 + A^2}\frac{sinL_1y}{sinL_1}$$

$$+\varepsilon\left[\left(1 + \frac{G_r}{L_0^2 - B^2} + \frac{G_c}{L_2^2 - B^2}\right)\frac{sinhBy}{sinhB} - \frac{G_r}{L_0^2 - B^2}\frac{sinhL_0y}{sinhL_0} - \frac{G_c}{L_2^2 - B^2}\frac{sinhL_2y}{sinhL_2}\right]e^{int} \quad (40)$$

Substituting the equations (30) and (39) in the equation (12), we obtain

$$v(y,t) = \frac{A_1P}{A^2}(coshAy - 1) + A_1\left[1 - \frac{P(coshA - 1) + G_r}{A^2} - \frac{G_c}{L_1^2 + A^2}\right]\frac{sinhAy}{sinhA} + \frac{A_1G_ry}{A^2} + \frac{A_1G_c}{L_1^2 + A^2}\frac{sinL_1y}{sinL_1}$$

$$+\varepsilon A_2B_0\left[\left(1 + \frac{G_r}{L_0^2 - B^2} + \frac{G_c}{L_2^2 - B^2}\right)\frac{sinhBy}{sinhB} - \frac{G_r}{L_0^2 - B^2}\frac{sinhL_0y}{sinhL_0} - \frac{G_c}{L_2^2 - B^2}\frac{sinhL_2y}{sinhL_2}\right]e^{int} \quad (41)$$

Substituting equations (22) and (31) in equation (12), we obtain

$$T(y,t) = y + \varepsilon\frac{sinhL_0y}{sinhL_0}e^{int} \quad (42)$$

Substituting equations (23) and (32) in equation (12), we obtain

$$C(y,t) = \frac{sinL_1y}{sinL_1} + \varepsilon\frac{sinhL_2y}{sinhL_2}e^{int} \quad (43)$$

Hence the equations (40)-(43) represents velocity of the fluid, velocity of the dust particle, temperature and concentration respectively.

4. Results and Discussion:

In order to study the behavior of fluid velocity (u), dusty velocity (v), temperature (T) and concentration (C) fields, a comprehensive numerical computation is carried out for various values of the parameters that describe the flow characteristics, and the results are reported in terms of graphs as shown in Figures (1) – (15).

The variation of fluid velocity for different values of M is shown in Figure 1. It is observed that the velocity decreases with increases of magnetic parameter (M).The effect of fluid velocity for different Prandtl number (P_r) are shown in Figure 2. In this case, the velocity decreases with increases of P_r .Figure 3 shows the variation of fluid velocity for different thermal Grashof number(G_r). It is clear that the velocity increases with increase of thermal Grashof number. Figure 4 represent the effect of fluid velocity for different values of Schmidt number(S_c). It is clear that the velocity increases with increases of Schmidt number. The effect of fluid velocity for different time is shown in Figure 5. We observe that, the velocity decreases with the increases of time. The effects of dusty velocity for different values of M are shown in Figure 6. We observe that, the velocity increases gradually with respect to magnetic parameter (M). Figure 7 shows the dusty velocity for different Prandtl number(P_r), we observe that the decreases of velocity with increases of P_r. Figure 8 shows the variation of dusty velocity for different thermal Grashof number(G_r). It is clear that the velocity increases gradually with respect to thermal Grashof number. Figure 9 represent the effect of dusty velocity for different values of Schmidt number(S_c). It is clear that the velocity increases with increases of Schmidt number.

The effect of dusty velocity at different time intervals is shown in Figure 10. We observe that, the velocity decreases with the increases of time

The variations of concentration for different values of the chemical reaction parameter are shown in Figure 11. It is observed that the concentration increases gradually with respect to chemical reaction parameter. Figure 12 represents the effect of concentration for different values of Schmidt number (S_c). We observed that the concentration increases gradually with respect to Schmidt number. Figure 13 represents the effect of concentration for different values of time, it is observed that the concentration decreases with increases of time.

Figure 14 represents the effect of Temperature for different values of Prandtl number (P_r), it is observed that the Temperature decreases with increases of P_r.Figure 15 represents the effect of Temperature for different values of time, it is observed that the Temperature decreases with increases of time.

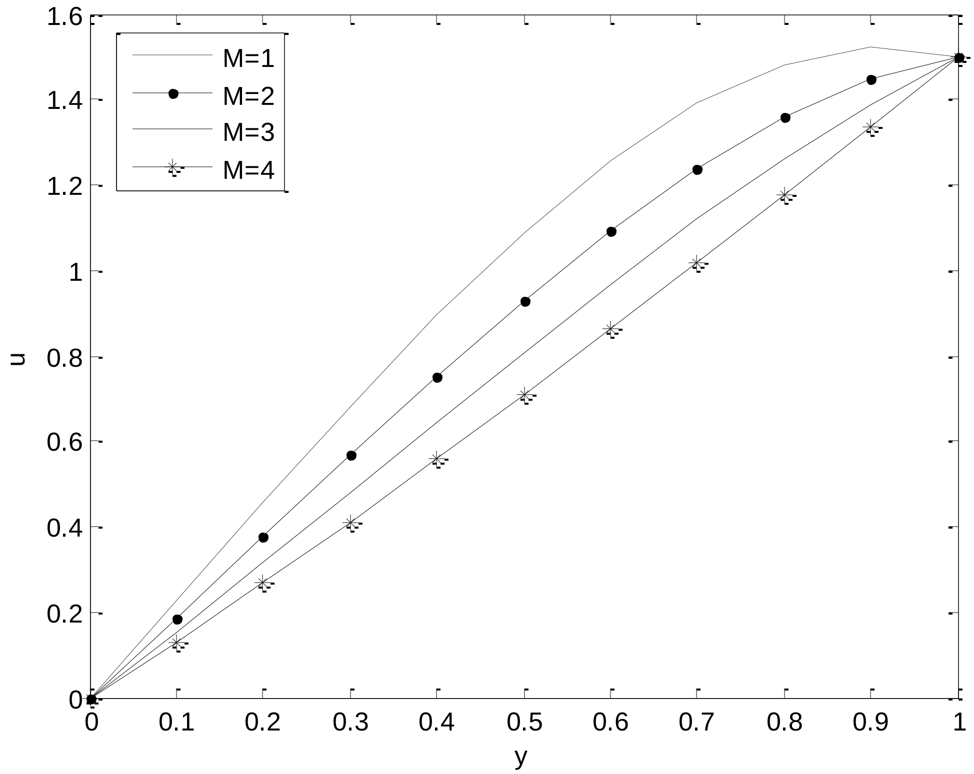

Fig.1: Variation of Fluid velocity for different values of M

When K_1=2, P_r=0.71, S_c=0.6, t=0.02, f=0.2, G_c=2, G_r=5.

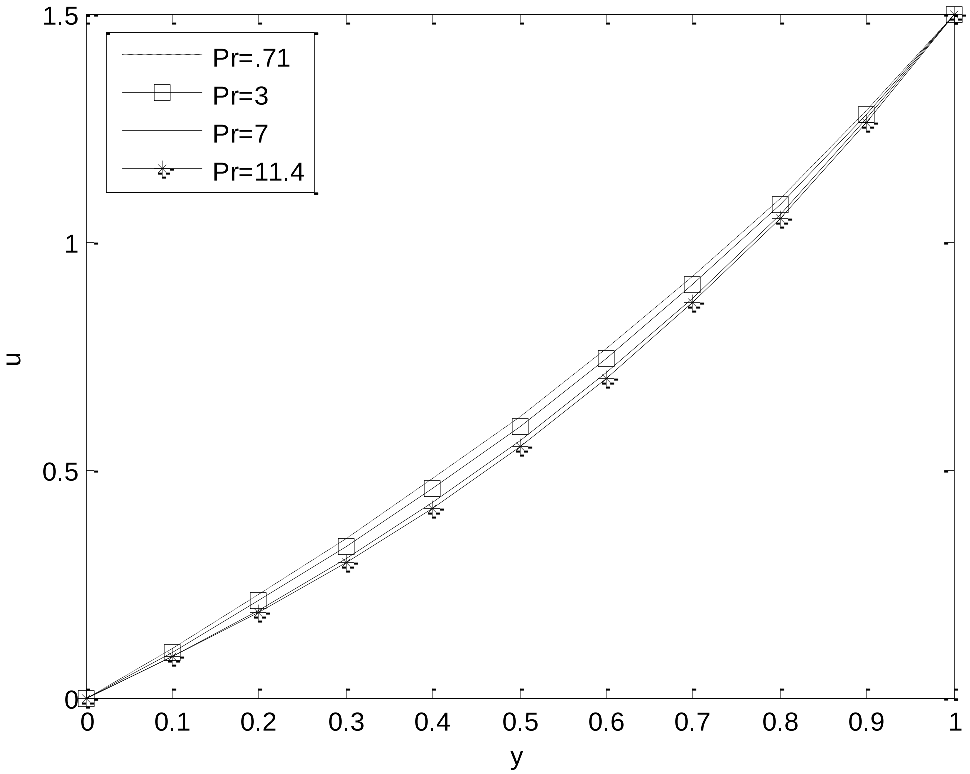

Fig.2: Variation of Fluid velocity for different values of Pr

When K_1=2, M=5, S_c=0.6, t=0.02, f=0.2, G_c=2, G_r=5.

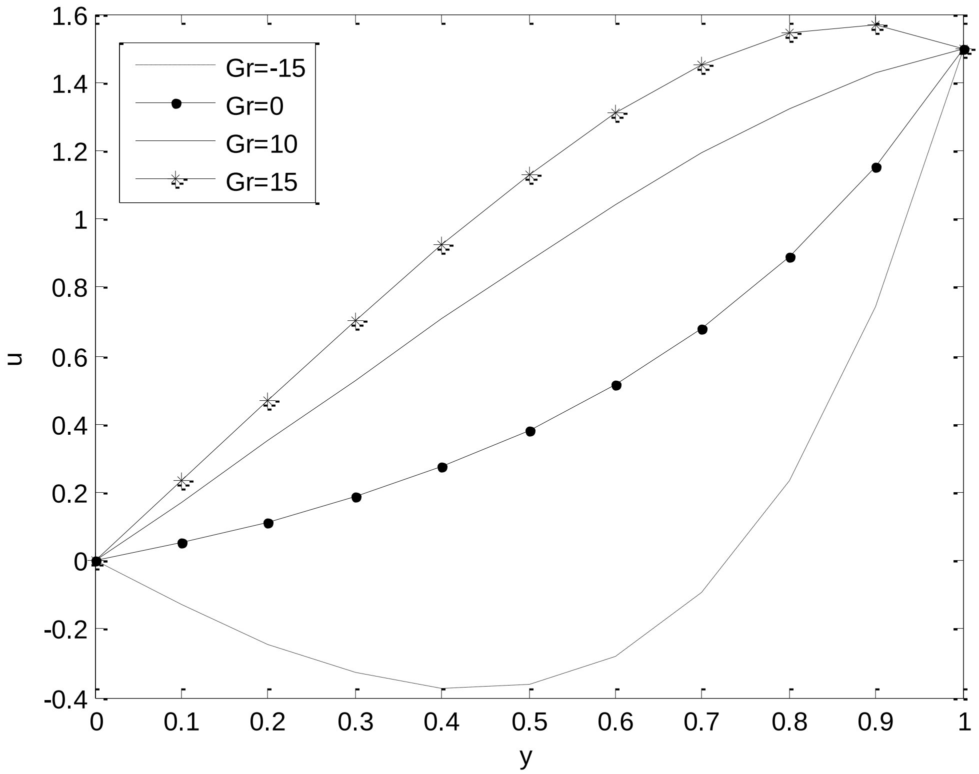

Fig.3: Variation of Fluid velocity for different values of Gr

When K_1=2, P_r=0.71, S_c=0.6, t=0.02, f=0.2, G_c=2, M=5.

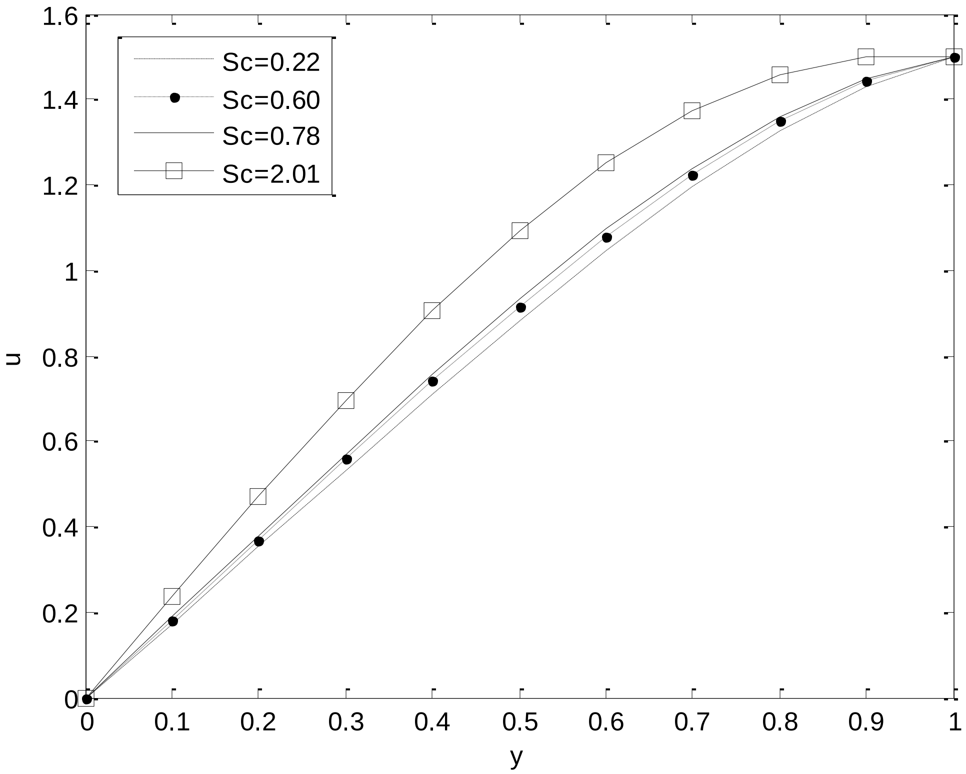

Fig.4: Variation of Fluid velocity for different values of Sc

When K_1=2, P_r=0.71, M=5, t=0.02, f=0.2, G_c=2, G_r=5.

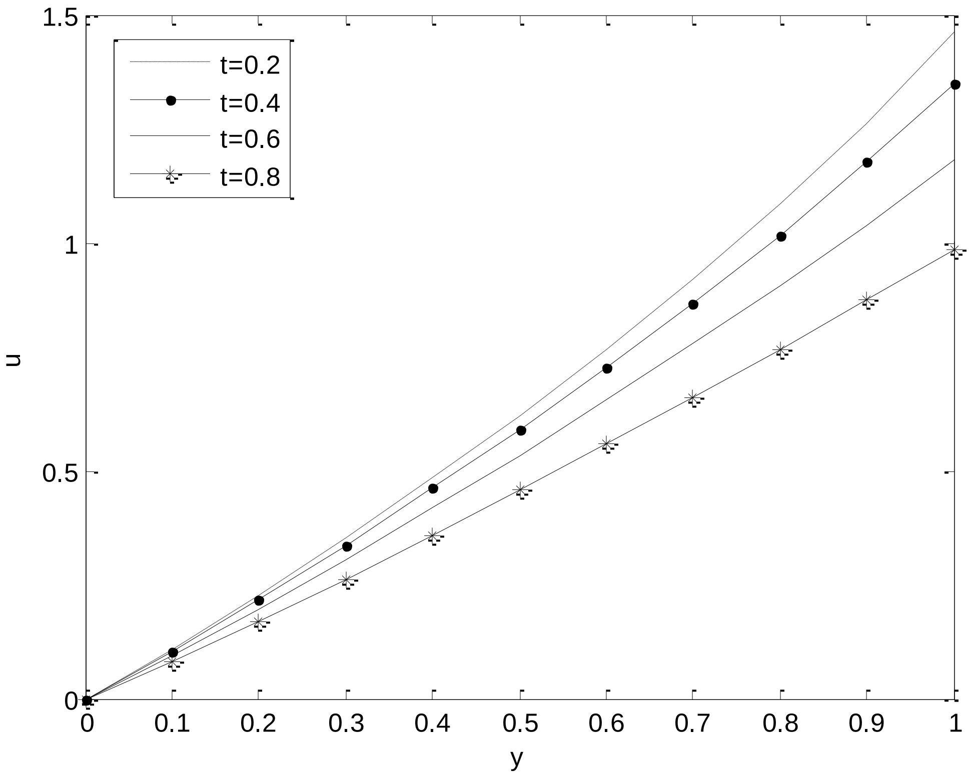

Fig.5: Variation of Fluid velocity for different values of t When K_1=2, P_r=0.71, S_c=0.6, M=5, f=0.2, G_c=2, G_r=5.

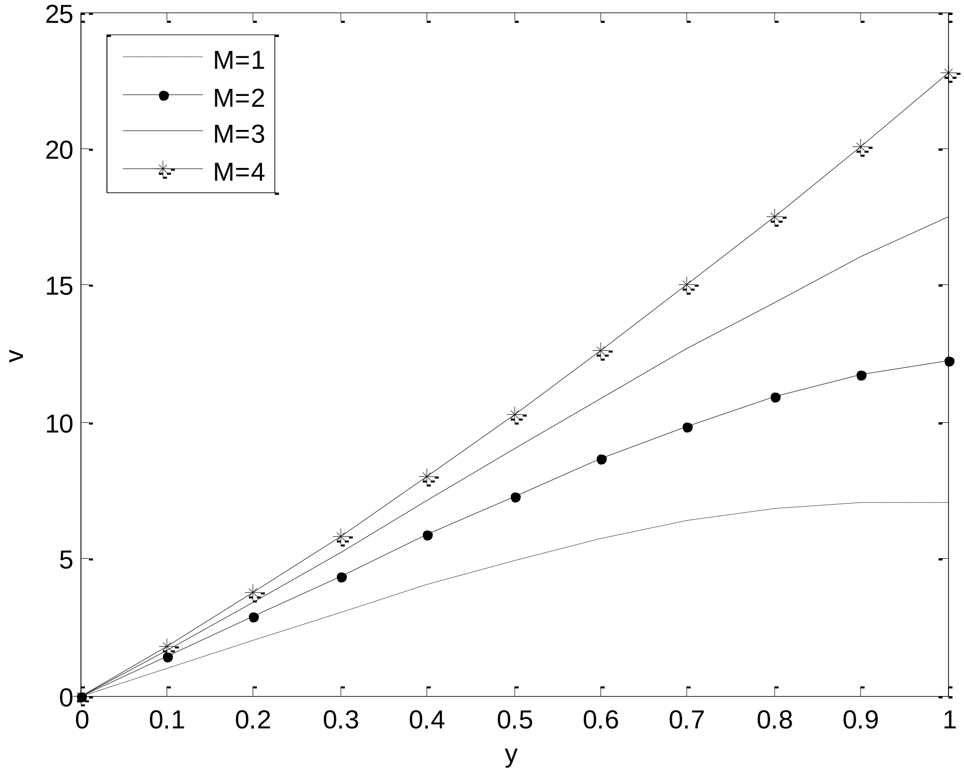

Fig.6: Variation of dusty velocity for different values of M

When K_1=2, P_r=0.71, S_c=0.6, t=0.02, f=0.2, G_c=2, G_r=5.

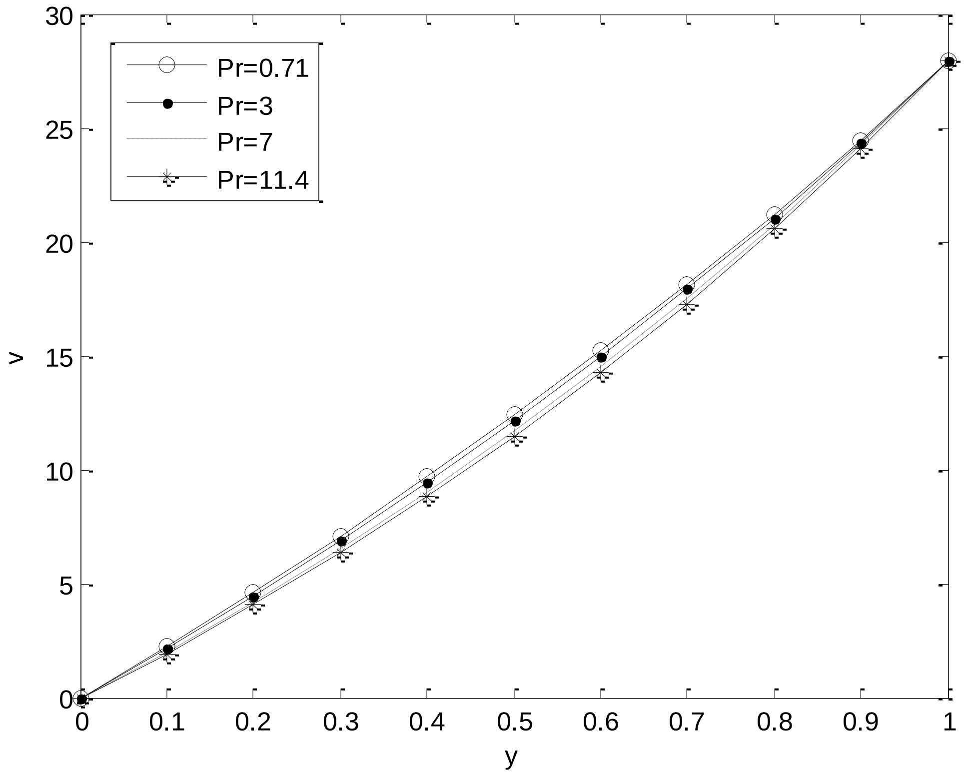

Fig.7: Variation of dusty velocity for different values of Pr When K_1=2, M=5, S_c=0.6, t=0.02, f=0.2, G_c=2, G_r=5.

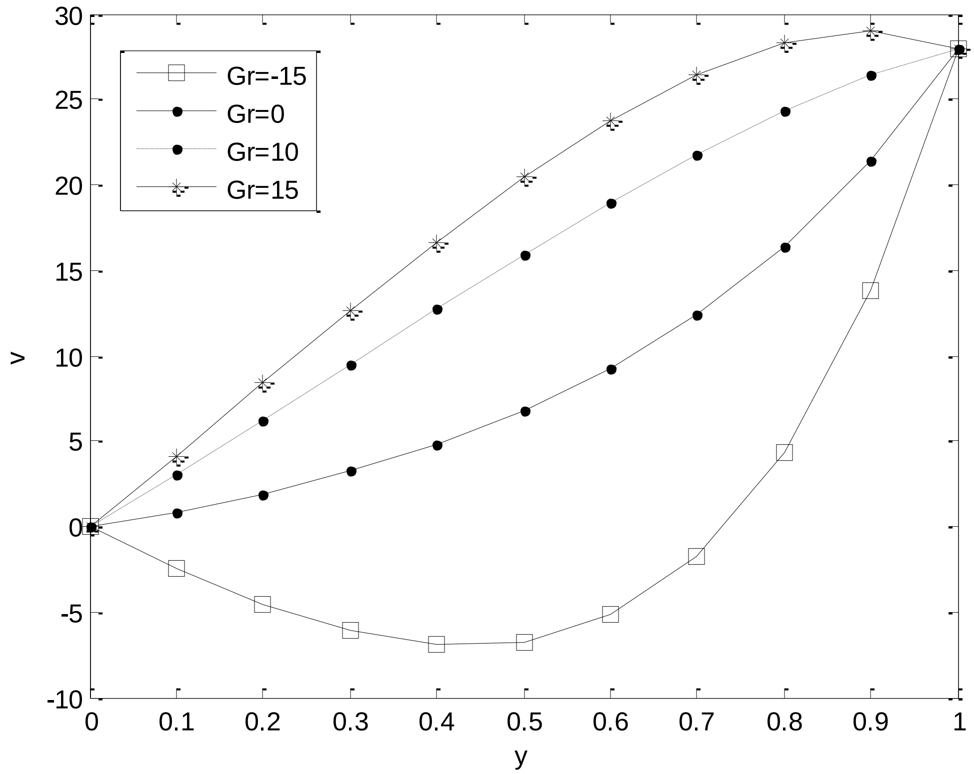

Fig.8: Variation of dusty velocity for different values of Gr

When K_1=2, P_r=0.71, S_c=0.6, t=0.02, f=0.2, G_c=2, M=5.

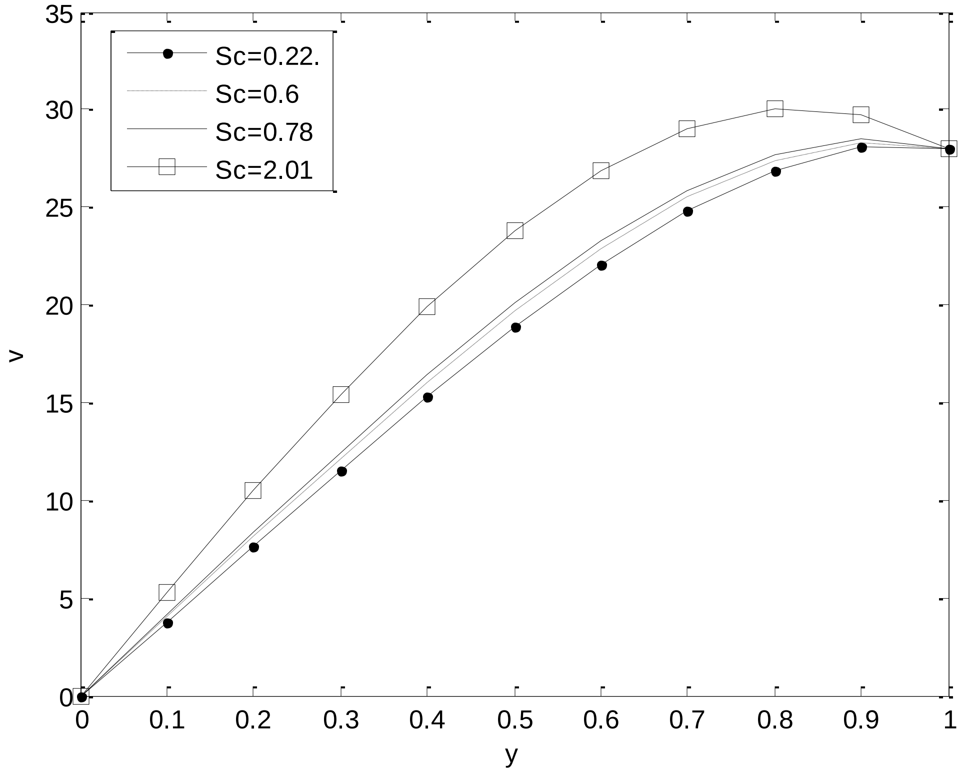

Fig.9: Variation of dusty velocity for different values of Sc

When K_1=2, P_r=0.71, M=5, t=0.02, f=0.2, G_c=2, G_r=5.

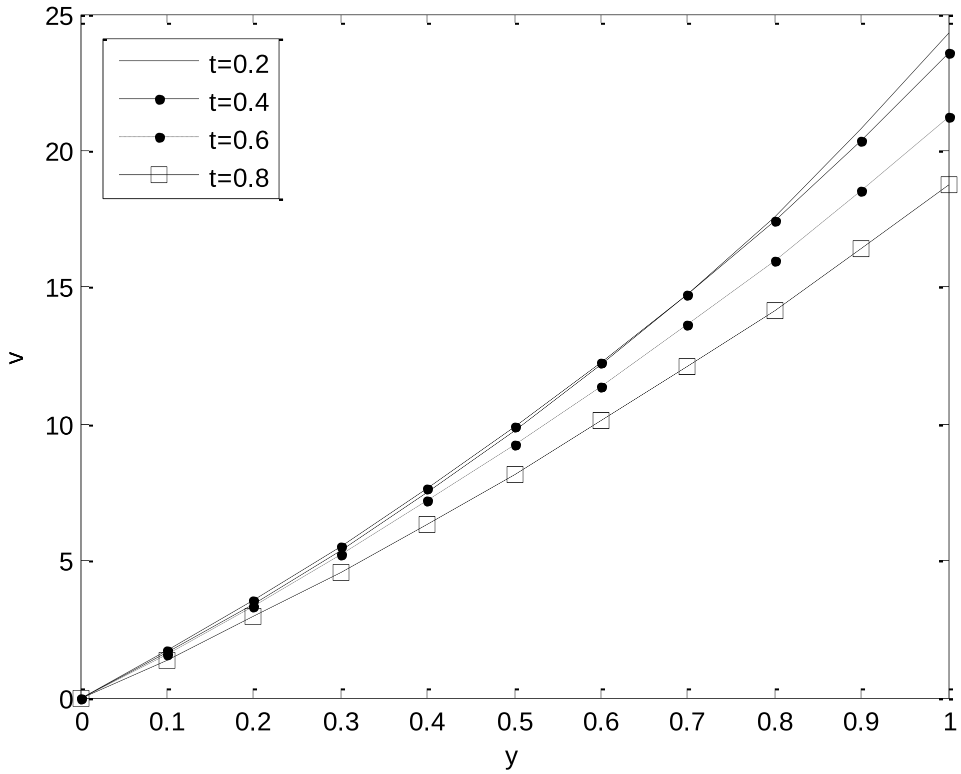

Fig.10: Variation of dusty velocity for different values of t

When K_1=2, P_r=0.71, S_c=0.6, M=5, f=0.2, G_c=2, G_r=5.

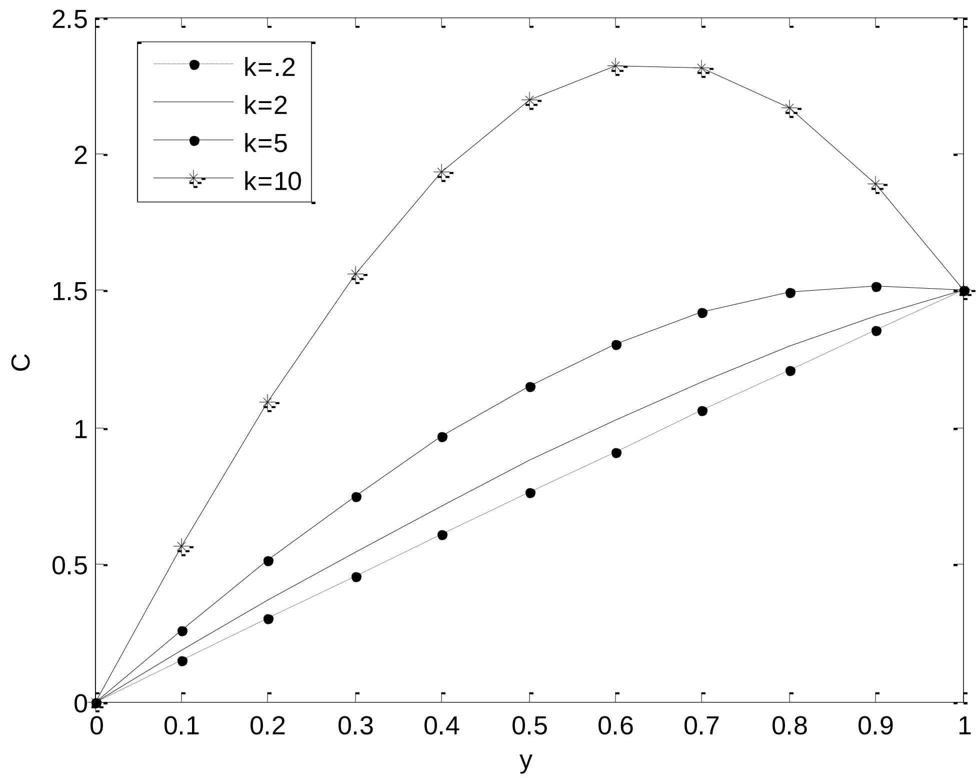

Fig.11: Variation of Concentration for different values of K_1
When M=5, P_r=0.71, S_c=0.6, t=0.02, f=0.2, G_c=2, G_r=5.

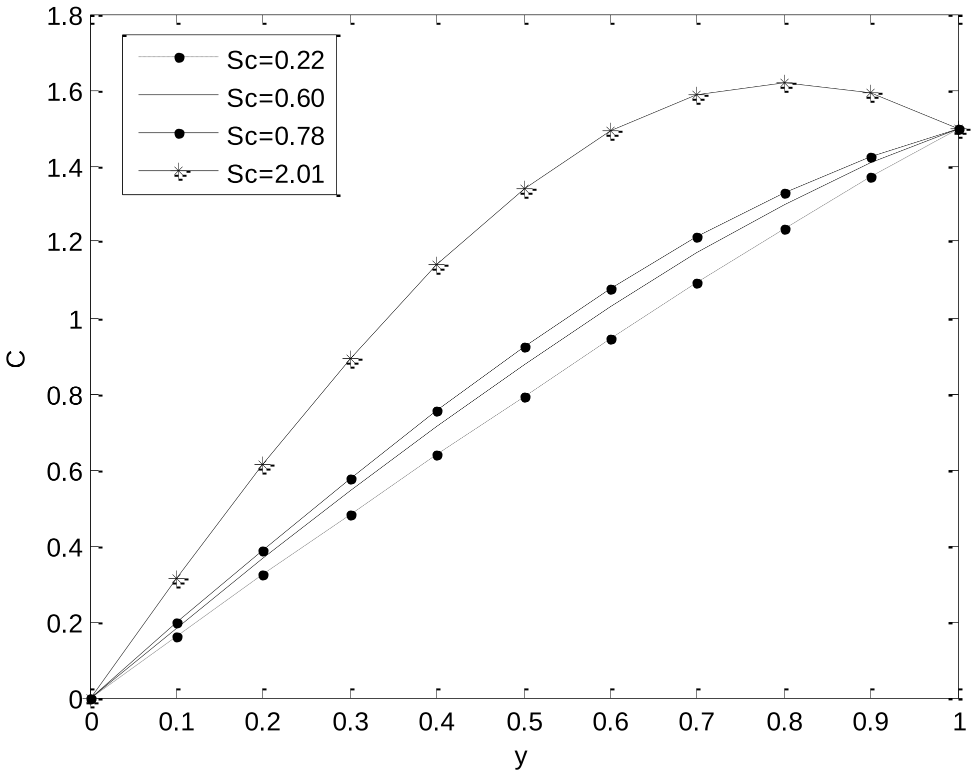

Fig.12: Variation of Concentration for different values of Sc

When K_1=2, P_r=0.71, M=5, t=0.02, f=0.2, G_c=2, G_r=5.

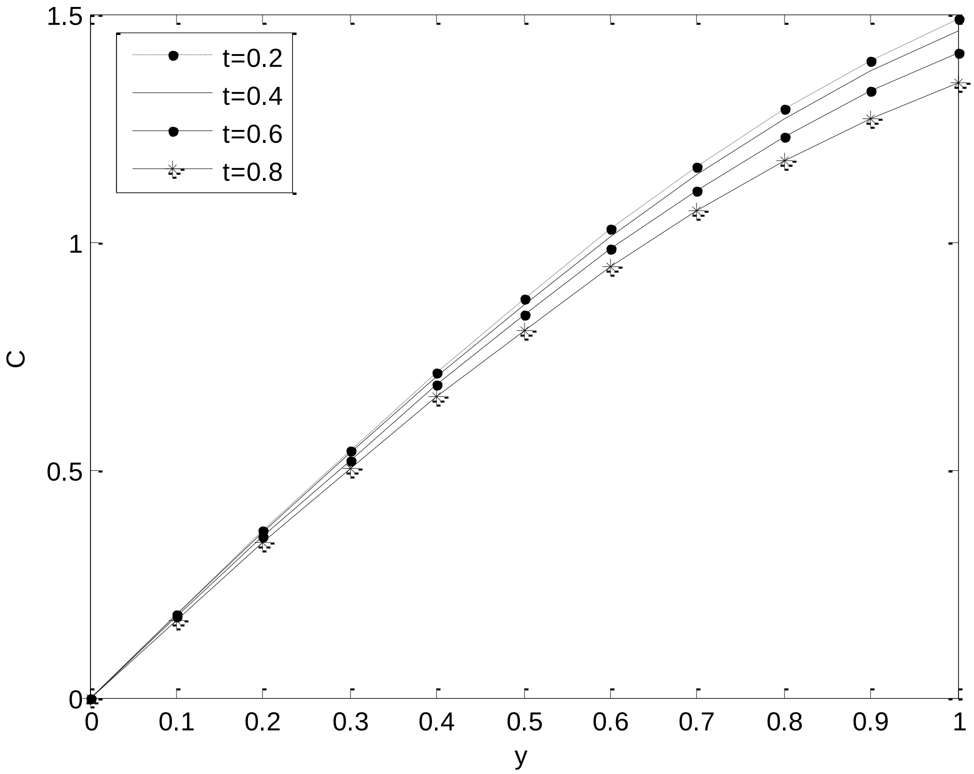

Fig.13: Variation of Concentration for different values of t

When K_1=2, P_r=0.71, S_c=0.6, M=5, f=0.2, G_c=2, G_r=5.

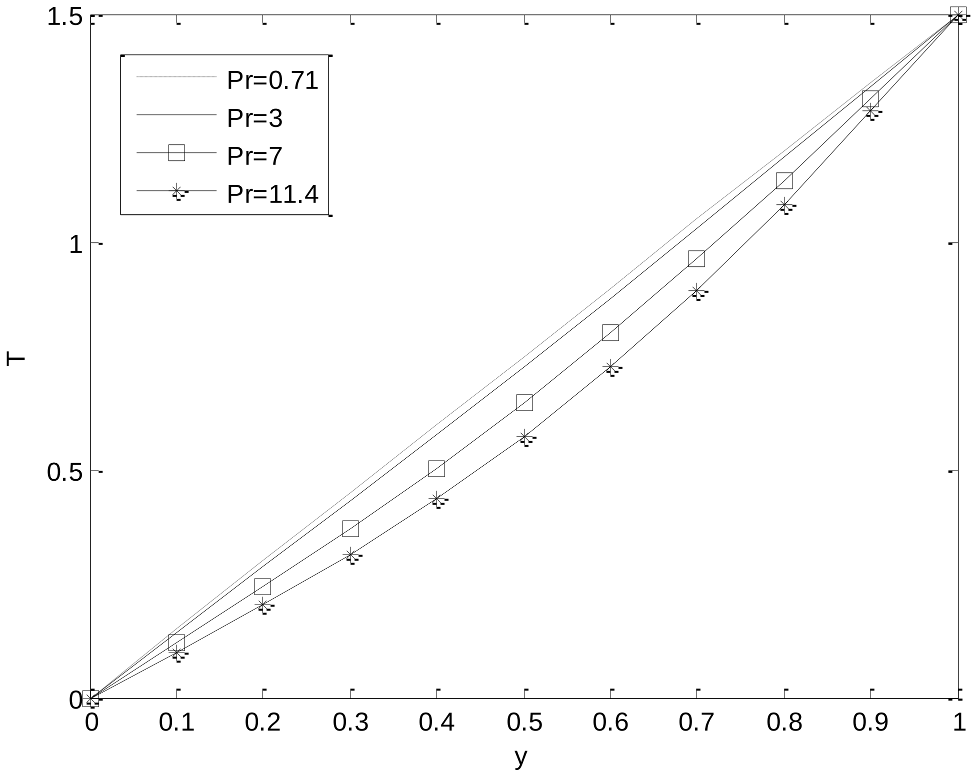

Fig.14: Variation of Temperature for different values of Pr

When K_1=2, M=5, S_c=0.6, t=0.02, f=0.2, G_c=2, G_r=5.

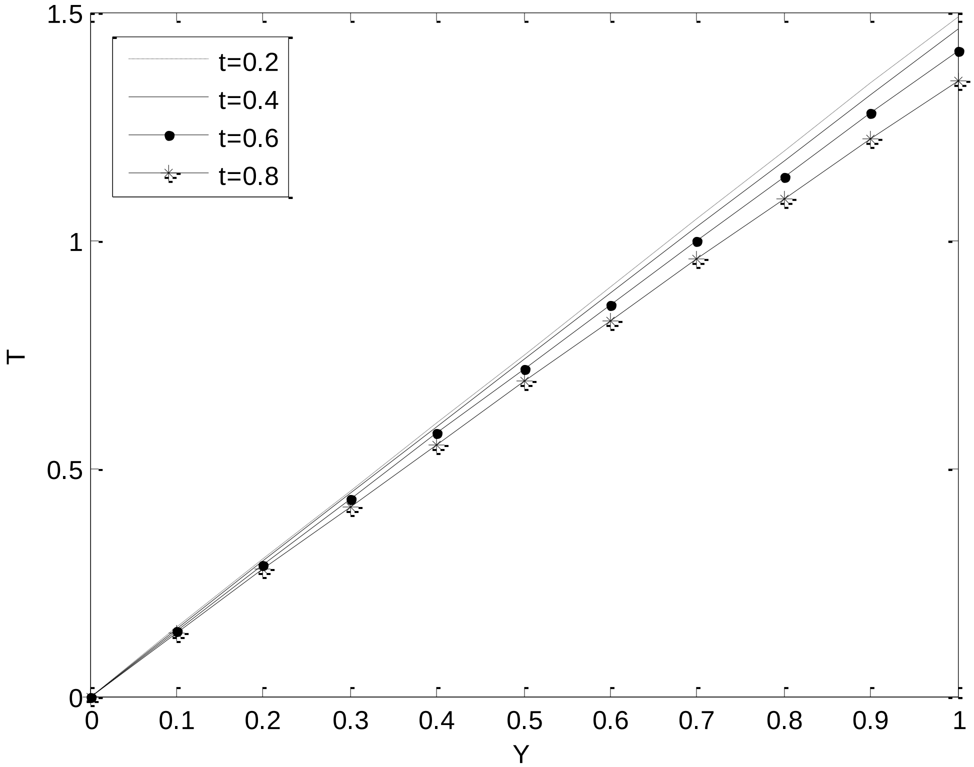

Fig.15: Variation of Temperature for different values of t When K_1=2, P_r=0.71, S_c=0.6, M=5, f=0.2, G_c=2, G_r=5.

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