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Free Convective Couette Flow of a Dusty Fluid through a Porous Medium with Periodic Permeability in the Absence of Electrically Magneto Hydro Dynamic Model

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Abstract

The purpose of this investigation stands to discuss the effects of periodic permeability on the free convective flow of a dusty viscous incompressible fluid through a highly porous channel. The porous medium is confined by an infinite perpendicular porous plate supercilious the free stream velocity to be uniform. Analytical solutions are gained for the dusty flow field, the temperature field, the skin friction and the rate of heat transfer. when there is an increase in mass concentration of dust particles, it is found that the velocity profile of fluid and dust particles reduces.

Keywords - Couette flow; free convective; Porous medium; Periodic Permeability; Dust Parameters; Heat transfer

1. Introduction

Free convection flow in enclosures has become increasingly significant in engineering applications in recent years outstanding to fact growth of technology, effecting cooling of electronic equations range from individual transistors to mainframe computers.The study of flow through porous medium finds application in geophysics, agricultural engineering and technology to study the underground water resources.The flow of viscous fluids through porous medium is very much prevalent in nature: therefore, such studies have been attracting the considerable attention of engineers and scientist all over the world. Convection in porous media finds applications in oil extraction, thermal energy storage and flow through filtering devices. Govindarajan etal [3] discussed 3D Couette flow of dusty fluid with transpiration cooling. Vidhya etal [4] studied Laminar convection through porous medium between two vertical parallel plates with heat source. Reddy etal [5] analyzed about Heat transfer in hydro magnetic rotating flow of viscous fluid through non-homogeneous porous medium with constant heat source/sink. Raju etal [6] described Unsteady MHD free convection and chemically reactive flow past an infinite vertical porous plate. Umamaheswar etal [7] deliberated that unsteady MHD free convective visco-elastic fluid flow bounded by an infinite inclined porous plate in the presence of heat source, viscous dissipation and ohmic heating. Ravikumar et al [8] analyzed same method for Heat and mass transfer. Raju etal [9] investigated Analytical study of MHD free convective, dissipative boundary layer flow past a porous vertical surface in the presence of thermal radiation, chemical reaction and constant suction. Seshaiah etal [10] studied about the effects of chemical reaction and radiation on unsteady MHD free convective fluid flow embedded in a porous medium with time-dependent suction with temperature gradient heat source. Gurivireddy etal [11] analyzed Thermal diffusion effect on MHD heat and mass transfer flow rections.Reddy etal [12] undertaken research on Unsteady MHD Free Convection Flow Characteristics of a Viscoelastic Fluid Past a Vertical Porous Plate. Raju etal [13] investigated Unsteady free convection flow past a periodically accelerated vertical plate with Newtonian heating. Umamaheswar etal [14] spotted that Combined Radiation in fluid flow. Mamatha etal [15] reported Thermal diffusion in MHD. Rao etal [16] conveyed about MHD transient free convection and chemically reactive flow past a porous vertical plate with radiation and temperature gradient dependent heat source in slip flow regime. Reddy etal [17] confirmed that Magneto convective flow with non-Newtonian fluid porous with variable suction. Raju etal [18] established the Radiation absorption effect on MHD free convection chemically reacting visco-elastic fluid past an oscillatory vertical porous plate in slip regime. Raju etal [19] studied about Unsteady MHD thermal diffusive, radiative and free convective flow past a vertical porous plate through non-homogeneous porous medium., Raju etal [20] investigated on Heat transfer effects magnetic field. M.Vidhya etal [21] discussed that Free convective and oscillatory flow of a dusty fluid through a porous medium. Sharma etal [22] reported Rotational impact on micro polar fluid past a semi-infinite vertical porous plate with suction. Mohan etal [24] states that Thermal Radiation and Chemical Reaction Effects on Unsteady MHD Free Convection Flow of a Viscous Dissipative Casson Fluid Past an Exponentially Infinite Vertical Plate Through Porous Medium with TGHS. Kumar etal [25] undertaken research on Unsteady MHD free convective flow of a radiating fluid past an inclined permeable plate in the presence of heat source. Swapna etal [26] analyzed chemical reaction and thermal vertical porous plates. Chitra etal [27] states that Heat and Mass transfer on unsteady MHD flow past an infinite vertical plate through a porous medium with time varying pressure gradient. Lalitha etal [28] deliberated Effects of chemical reaction and heat generation on MHD free convective oscillatory couette flow through a variable porous medium. Swarnalathamma etal [29] described about Combined Effects on Unsteady MHD Convective flow of Rotating Viscous Fluid through a Porous Medium over a Moving Vertical Plate. Mohan etal [30] found that Thermal Diffusion and TGHS Effect on MHD Viscous Dissipative Kuvshinski´ S Fluid Past an Inclined Plate Through Porous Medium with Thermal Radiation and Chemical Reaction. Veeresh etal [31] presented about Thermal Diffusion Effects on Unsteady Magnetohydrodynamic Boundary Layer Slip Flow past a Vertical Permeable Plate. Varma etal [32] investigated MHD rotating heat and mass transfer free convective flow in mass diffusion. Raju etal [33] described about Thermal diffusion and rotational effects on magneto hydrodynamic mixed convection flow of heat absorbing/generating visco-elastic fluid through a porous channel. Frontiers in Heat and Mass Transfer. Sivaiah etal [34] investigated the Numerical study of mhd boundary layer flow of a viscoelastic and dissipative fluid past a porous plate in the presence of thermal radiation.

The purpose of this present paper is to study the effect of transverse periodic variation of the permeability on the heat transfer and the free convective flow of a dusty viscous incompressible fluid. The purpose of this is to study the effect of permeability parameter, Grashof number and dust parameters on the velocity field, temperature field, skin friction and nusselt number. Analytical solutions remain given through graph.

2. MATHEMATICAL MODELLING:

We consider the flow of a viscous incompressible dusty fluid through a highly porous medium bounded by an infinite vertical porous plate with constant suction. The plate lying vertically on x* - z* plane with x* axis occupied along the plate in upward direction. The y*-axis is taken normal to the plane of the plate and directed into the dusty fluid flowing laminarly with a uniform free stream velocity U. The permeability of the porous medium is assumed to be of the form,

$$K^*(z^*) = \frac{K_o^*}{\left(1+\varepsilon \cos\left(\frac{\pi z^*}{l}\right)\right)} \tag{1}$$

The problem becomes 3-Dimensional due to such a permeability variation. All the fluid assets are supposed constant except that the influence of the density variation with temperature being measured only in the body energy term.

Thus denoting the velocity components by u*, v*, w* in x*, y*, z* - directions for the fluid and u_p*, v_p*, w_p* to be the components in x*, y*, z* direction for the dust particles, the flow through a highly porous medium is governed by the following equations:

Equation of Continuity in Fluid Phase:

$$\frac{\partial v^*}{\partial y^*}+\frac{\partial w^*}{\partial z^*}=0 \tag{2}$$

Equation of Motion in x direction in Fluid phase

$$v^*\frac{\partial u^*}{\partial y^*}+w^*\frac{\partial u^*}{\partial z^*}=g\beta(T^*-T_\infty^*)+\upsilon\left(\frac{\partial^2 u^*}{\partial y^{*2}}+\frac{\partial^2 u^*}{\partial z^{*2}}\right)-\frac{\upsilon}{K^*}(u^*-U)+\frac{KN_0}{\rho}(u_p^*-u^*) \tag{3}$$

Equation of Motion in y direction in Fluid phase

$$v^*\frac{\partial v^*}{\partial y^*}+w^*\frac{\partial v^*}{\partial z^*}=\frac{-1}{\rho}\frac{\partial p^*}{\partial y^*}+\upsilon\left(\frac{\partial^2 v^*}{\partial y^{*2}}+\frac{\partial^2 v^*}{\partial z^{*2}}\right)-\frac{v^*\upsilon}{K^*}+\frac{KN_0}{\rho}(v_p^*-v^*) \tag{4}$$

Equation of Motion in z-direction in Fluid phase

$$v^*\frac{\partial w^*}{\partial y^*}+w^*\frac{\partial w^*}{\partial z^*}=\frac{-1}{\rho}\frac{\partial p^*}{\partial z^*}+\upsilon\left(\frac{\partial^2 w^*}{\partial y^{*2}}+\frac{\partial^2 w^*}{\partial z^{*2}}\right)-\frac{\upsilon w^*}{K^*}+\frac{KN_0}{\rho}(w_p^*-w^*) \tag{5}$$

Energy Equation is

$$v^*\frac{\partial T^*}{\partial y^*}+w^*\frac{\partial T^*}{\partial z^*}=\frac{k}{\rho C_p}\left(\frac{\partial^2 T^*}{\partial y^{*2}}+\frac{\partial^2 T^*}{\partial z^{*2}}\right)+\frac{N_0 m C_s}{\rho C_p \tau_T}(T_p^*-T^*) \tag{6}$$

Equations of Continuity in Particles Phase:

$$\frac{\partial v_p^*}{\partial y^*}+\frac{\partial w_p^*}{\partial z^*}=0 \tag{7}$$

Equation of Motion in x direction in Particle phase

$$v_p^*\frac{\partial u_p^*}{\partial y^*}+w_p^*\frac{\partial u_p^*}{\partial z^*}=\frac{K}{m}(u^*-u_p^*) \tag{8}$$

Equation of Motion in y direction in Particle phase

$$v_p^*\frac{\partial v_p^*}{\partial y^*}+w_p^*\frac{\partial v_p^*}{\partial z^*}=\frac{K}{m}(v^*-v_p^*) \tag{9}$$

Equation of Motion in z direction in Particle phase

$$v_p^*\frac{\partial w_p^*}{\partial y^*}+w_p^*\frac{\partial w_p^*}{\partial z^*}=\frac{K}{m}(w^*-w_p^*) \tag{10}$$

Energy Equation in Particle phase

$$\left(v_p^*\frac{\partial T_p^*}{\partial y^*}+w_p^*\frac{\partial T_p^*}{\partial z^*}\right)=-\left(\frac{T_p^*-T_p^*}{\tau_T}\right) \tag{11}$$

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The boundary conditions for fluid phase:

$$y^* = 0: \quad u^* = 0, \quad v^* = -V, \quad w^* = 0, \quad T^* = T_W^*, \quad y^* \to \infty: \quad u^* = U, \quad w^* = 0, \quad p^* = p_\infty^*, \quad T^* = T_\infty^*. \tag{12}$$

The boundary conditions for particle phase:

$$y^* = 0: u_p^* = 0, v_p^* = +V, w_p^* = 0, T_p^* = T_W^*, y^* \to \infty : u_p^* = U, w_p^* = 0, T_p^* = T_\infty^*. \tag{13}$$

We introduce the following Non dimensional Variables for fluid phase:

$$y = \frac{y^*}{l}, \quad z = \frac{z^*}{l}, \quad u = \frac{u^*}{U}, \quad v = \frac{v^*}{V}, \quad w = \frac{w^*}{V}, \quad \theta = \frac{T^* - T_\infty^*}{T_W^* - T_\infty^*}, \ f = \frac{N_0 m}{\rho}, \ \Lambda = \frac{\tau_p V}{l}, \ \gamma = \frac{C_s}{C_p}$$
$$p = \frac{p^*}{\rho V^2},$$

For Particle phase:

$$u_p = \frac{u_p^*}{U}, \quad v_p = \frac{v_p^*}{V}, \quad w_p = \frac{w_p^*}{V},$$

$$\theta_p = \frac{T_p^* - T_\infty^*}{T_W^* - T_\infty^*}$$

Equations (2) to (11) take the following forms

After introducing the Non-Dimensional quantities, the equation of motion for Fluid Phase is obtaining as

$$\frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0 \tag{14}$$

$$v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} = \frac{1}{\mathrm{Re}}\left(\frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}\right) + G\,\mathrm{Re}\,\theta - \frac{(u-1)[1+\varepsilon \cos\pi z]}{\mathrm{Re}\,K_0} + \frac{f}{\Lambda}(u_p - u) \tag{15}$$

$$v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z} = -\frac{\partial p}{\partial y} + \frac{1}{\mathrm{Re}}\left(\frac{\partial^2 v}{\partial y^2} + \frac{\partial^2 v}{\partial z^2}\right) - \frac{[1+\varepsilon \cos\pi z]v}{\mathrm{Re}\,K_0} + \frac{f}{\Lambda}(v_p - v) \tag{16}$$

$$v\frac{\partial w}{\partial y} + w\frac{\partial w}{\partial z} = -\frac{\partial p}{\partial z} + \frac{1}{\mathrm{Re}}\left(\frac{\partial^2 w}{\partial y^2} + \frac{\partial^2 w}{\partial z^2}\right) - \frac{[1+\varepsilon \cos\pi z]w}{\mathrm{Re}\,K_0} + \frac{f}{\Lambda}(w_p - w) \tag{17}$$

$$v\frac{\partial \theta}{\partial y} + w\frac{\partial \theta}{\partial z} = \frac{1}{\mathrm{Re}\,\mathrm{Pr}}\left(\frac{\partial^2 \theta}{\partial y^2} + \frac{\partial^2 \theta}{\partial z^2}\right) + \frac{2f}{3\Lambda\,\mathrm{Pr}}(\theta_p - \theta) \tag{18}$$

After introducing the Non-Dimensional quantities, the equation of motion for Particle Phase is obtaining as

$$\frac{\partial v_p}{\partial y} + \frac{\partial w_p}{\partial z} = 0 \tag{19}$$

$$v_p\frac{\partial u_p}{\partial y} + w_p\frac{\partial u_p}{\partial z} = -\frac{1}{\Lambda}(u_p - u) \tag{20}$$

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$$v_p \frac{\partial v_p}{\partial y} + w_p \frac{\partial v_p}{\partial z} = -\frac{1}{\Lambda}(v_p - v) \tag{21}$$

$$v_p \frac{\partial w_p}{\partial y} + w_p \frac{\partial w_p}{\partial z} = -\frac{1}{\Lambda}(w_p - w) \tag{22}$$

$$v_p \frac{\partial \theta_p}{\partial y} + w_p \frac{\partial \theta_p}{\partial z} = a\,(\theta_p - \theta) \tag{23}$$

where $G = \upsilon g \frac{\beta\ (T_W * - T_\infty *)}{UV^2}$, $\mathrm{Re} = \frac{Vl}{\upsilon}$, $\mathrm{Pr} = \frac{\mu\ C_p}{k}$, $k_0 = \frac{K_0 *}{l^2}$

The corresponding boundary conditions become

$y = 0$: $u = 0$, $v = -1$, $w = 0$, $\theta = 1$, $u_p = 0$, $v_p = 1$, $w_p = 0$, $\theta_p = 1$, (24)

$y \to \infty$: $u = 1$, $w = 0$, $p = p_\infty$, $\theta = 0$, $u_p = 1$, $w_p = 0$, $\theta_p = 0$ (25)

In order to obtain the solution of problem we expand the velocity components, pressure and temperature fields in powers of the amplitude.

$h(y\ z) = h_0(y) + \varepsilon h_1(y,z) + \varepsilon^2 h_2(y,z)$ (26)

Where h positions for u, u_p, v, v_p, w, w_p, θ, θ_p, p

when $\varepsilon = 0$, the problem reduces to the two-dimensional free convective dusty flow through a porous medium with constant permeability which is governed by the equations and the matching boundary conditions.The solution of this 2- dimensional problem is

$v_0 = -1$, $v_{p_0} = 1$, $p_0 = p_\infty$, $w_0 = 0$, $w_{p0} = 0$, (27)

$$\theta_0 = e^{-my} \tag{28}$$

$$\theta_{P_0} = \frac{ae^{-my} - me^{-ay}}{a - m} \tag{29}$$

$$u_0 = 1 - G\lambda_0 e^{-my} + (G\lambda_0 - 1)e^{-Ry} \tag{30}$$

$$u_{p0} = (a_1 + a_2 - 1)e^{-\frac{y}{\Lambda}} + a_2 e^{-Ry} - a_1 e^{-my} + 1 \tag{31}$$

when $\varepsilon \neq 0$, substituting (25) and the non-dimensional eqn.

$$K(z) = \frac{k_0}{1 + \varepsilon\ \cos \pi z} \tag{32}$$

For periodic permeability mad about the equations (14) to (23) and comparation the coefficients of identical powers of ε, neglecting those of ε^2, ε^3 etc., we get the first orde requations and the corresponding boundary conditions with help of (26). These equations are the partial differential equations which describe free convective 3-Dimensional dusty flow. For solution we shall first consider

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equations are the temperature field and independent of the main dusty flow. We assume v_1, v_{p1}, w_1, w_{p1}, p_1 of the form:

$$v_1(y,z) = -v_{11}(y) \cos \pi z \quad (33)$$

$$w_1(y,z) = \frac{1}{\pi} v'_{11}(y) \sin \pi z \quad (34)$$

$$p_1(y,z) = p_{11}(y) \cos \pi z \quad (35)$$

$$v_{P1}(y,z) = -v_{P11}(y) \cos \pi z \quad (36)$$

$$w_{P1}(y,z) = \frac{1}{\pi} v'_{P11}(y) \sin \pi z \quad (37)$$

wherever the prime in $v'_{11}(y)$ enotes the differentiation with respect to 'y' Expressions for $v_1(y,z)$, $w_1(y,z)$ and $v_{p1}(y,z)$, $w_{p1}(y,z)$ have been chosen so that the equations of continuity are satisfied. Substituting the expressions (32) to (36) into continuity equations and explaining under the corresponding altered boundary conditions as we get solutions of v1, v_{p1}, w_1, w_{p1}, p_1 as:

$$v_1(y,z) = \frac{-(\pi e^{-\lambda y} - \lambda e^{-\pi y} - \pi + \lambda)}{(\pi^2 k_0 + 1)(\pi - \lambda)} \cos \pi z$$

(38)

$$w_1(y,z) = \frac{\lambda}{(\pi^2 k_0 + 1)(\pi - \lambda)} (e^{-\pi y} - e^{-\lambda y}) \sin \pi z \quad (39)$$

$$p_1(yz) = \frac{-\lambda e^{-\pi y} \cos \pi z}{(\lambda - \pi)(\pi^2 k_0 + 1) M} \quad (40)$$

$$v_{p_1} = \frac{1}{a_7} (a_3 e^{-\frac{y}{\Lambda}} + a_4 e^{-\pi y} + a_5 e^{-\lambda y} + a_6) \cos \pi z \quad (41)$$

$$w_{p_1} = \frac{-1}{a_7} (a_8 e^{-\frac{y}{\Lambda}} - \pi a_4 e^{-\pi y} - \lambda a_5 e^{-\lambda y}) \frac{\sin \pi z}{\pi} \quad (42)$$

for the main flow and temperature field solution we assume u_1, u_{p1}, θ_1, θ_{P1} as per

$$u_1(y,z) = u_{11}(y) \cos \pi z \quad (43)$$

$$\theta_1(y,z) = \theta_{11}(y) \cos \pi z \quad (44)$$

$$u_{p1}(y,z) = u_{p11}(y) \cos \pi z \quad (45)$$

$$\theta_{P1}(y,z) = \theta_{P11}(y) \cos \pi z \quad (46)$$

Substitution of (42), (43), (44) & (45) into the partial differential equations and reduce them to the ordinary

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differential equations.

$$\theta''_{11} + Re\,Pr\,\theta'_{11} - \left(\pi^2 + \frac{2f}{3\Lambda}Re\right)\theta_{11} + \frac{2f}{3\Lambda}Re\,\theta_{P11} = -Re\,Pr\,V_{11}\theta_0^1 \tag{47}$$

$$(D+a)\theta_{p11} = a\theta_{11} - v_{p11}\theta'_{po} \tag{48}$$

with corresponding boundary conditions

$y = 0 : u_{11} = 0, \theta_{11} = 0, u_{p11} = 0, \theta_{p11} = 0,$

$y \to \infty : u_{p11} = 0, u_{11} = 0, \theta_{11} = 0, \theta_{p11} = 0$ (49)

$$\theta_1 = [c_1e^{-\beta y} + A_2e^{-(\lambda+m)y} + A_3e^{-my} + A_4e^{-(\pi+a)y} + A_5e^{-(\frac{1}{\Lambda}+a)y} + A_6e^{-(\lambda+a)y} + A_7e^{-ay} + A_8e^{-(\frac{1}{\Lambda}+m)y}]\cos\pi z \tag{50}$$

$$u_1 = [c_2e^{-\lambda y} + T_1e^{-my} + T_2e^{-Ry} + T_3e^{-(\lambda+m)y} + T_4e^{-(m+\pi)y} + T_5e^{-(R+\pi)y} + T_6e^{-\beta y} + T_7e^{-(\pi+a)y} + T_8e^{-(\frac{1}{\Lambda}+a)y} + T_9e^{-(\lambda+a)y} + T_{10}e^{-ay} + T_{11}e^{-(\frac{1}{\Lambda}+m)y} + T_{12}e^{-(\frac{1}{\Lambda}+\pi)y} + T_{13}e^{-(\frac{1}{\Lambda}+\lambda)y} + T_{14}e^{-\frac{2y}{\Lambda}} + T_{15}e^{-\frac{y}{\Lambda}} + T_{16}e^{-(\lambda+R)y} + T_{17}e^{-(\frac{1}{\Lambda}+R)y}]\cos\pi z \tag{51}$$

$$\theta_{p11} = \begin{bmatrix} (A_1 - yA_2)e^{\frac{-2f}{3\Lambda}y} + A_3e^{(\lambda-r)y} - A_4e^{-(\pi+r)y} + A_5e^{\left(\lambda-\frac{2f}{3\Lambda}\right)y} - \\ A_6e^{-(\pi+\frac{2f}{3\Lambda})y} + A_7e^{-ry} + A_8e^{-my} + A_9e^{-\lambda y} + A_{10}e^{-(\lambda+m)y} \end{bmatrix}\cos\pi z \tag{52}$$

$$u_{p11} = \begin{bmatrix} A_{19}e^{(\lambda-m)y} + A_{20}e^{-(m+\pi)y} - A_{21}e^{-m_1y} + A_{22}e^{(\lambda-Re\,Pr)y} + A_{23}e^{-(\pi+Re\,Pr)y} - \\ A_{24}e^{-Re\,Pr\,y} - A_{25}e^{\lambda y} - A_{26}e^{(\lambda-r)y} - A_{27}e^{(\lambda-m)y} + A_{28}e^{-(m+r)y} \\ +A_{29}e^{-(m+\pi)y} + A_{30}e^{-ry} + A_{31}e^{-my} + A_{32}e^{-\beta y} - A_{33}e^{(\lambda-\frac{2f}{3\Lambda})y} + \\ A_{34}e^{-(\pi+\frac{2f}{3\Lambda})y} + A_{35}e^{-\frac{2f}{3\Lambda}y} \end{bmatrix}\cos\pi z \tag{53}$$

Where A_1 to A_{35} are known constants and not presented here for the sake of brevity

3. RESULTS AND DISCUSSION

(a) VELOCITY PROFILES FOR THE FLUID PHASE:

We make the following conclusions from fig (1and 2)

The velocity profiles of both the fluid and the dust decrease with either an increase in the mass concentration of the dust particles (or) increase in the Grashof number (or) increase in the permeability of the porous medium (or) increase in the Reynolds number. All the profiles obtain their maximum value very near the lower plate as it maintain an increasing trend near the lower plate and thereafter they become constant and reach the value 1 at the other plate. This graph is drawn for (Gr>0) which corresponds to cooling of the plate. While (Gr < 0) corresponds to heating of the plate for which the profiles maintain a reversing trend in its behaviour. That is

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the reason for not drawing a separate graph for (G<0).

Both the dust particles and the fluid perform in the equal manner. But the profiles of the dust are at a lower height as compared with the fluid. The entire curve coincides very near the upper plate for both fluid and dust.

(b) SKIN FRICTION:

From table 1 it is clear that the coefficient of skin friction T_x increases with an increase in mass concentration of the dust particles (or) an increase in Prandtl number while it decreases with an increase in Grashof number (or) increase in the permeability of the porous medium (or) increase in Reynolds number.

For clean fluid (f = 0) the skin friction coefficient decreases with decreasing permeability k_0 of the porous medium it also decreases with increase of Grashof number. The values of T_x are less in air (Pr == 0.7) and more in water (Pr = 7.0). An increase in the Reynolds number leads to decrease in T_x.

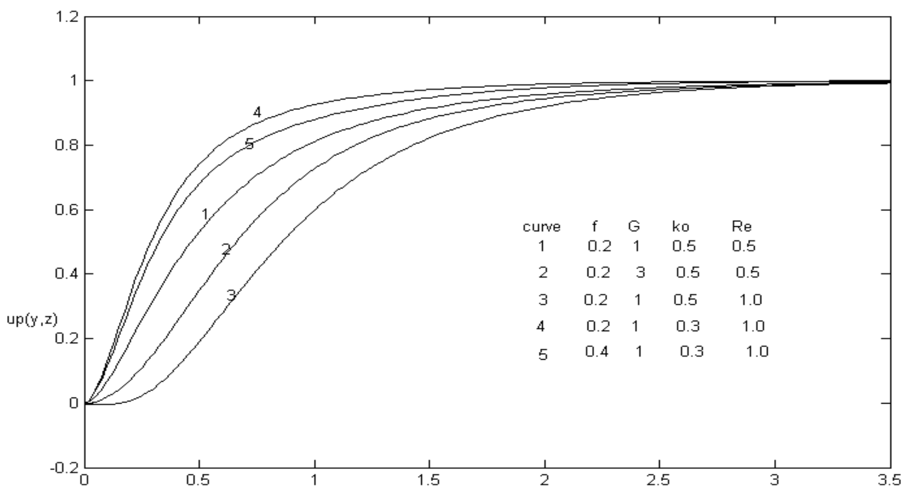
(c) NUSSELT NUMBER:

From table 2 it clear that the coefficient of Nusselt number Nu in the case of water (Pr = 7.0) increases with an increase in mass concentration of the dust particles (or) an increase in Reynolds number. While it decreases with an increase in the permeability of the porous medium

From table 3 it is clear that the coefficient of Nusselt number Nu in the case of air (Pr = 0.7) increase in the permeability of porous medium (or) increase in the Reynolds number (or)decreases with an increase in mass concentration of the dust particles. Nu is positive in the case of water and negative in the case of air. Nu for air is less when compared with Nu for water.

For clean fluid (f = 0) an increasing in the permeability of the porous medium leads to a decrease Nu. The values of Nu are much less in the case of water (Pr=7.0) than in the case of air (Pr=0.7). Nu decreases with increasing Reynolds number.

$\Pr = 0.7,\ \Lambda = 0.2,\ \varepsilon = 0.2$



<------------y--------------> FIG-2 VELOCITY PROFILES OF THE DUST up(y,z) FOR (G > 0)

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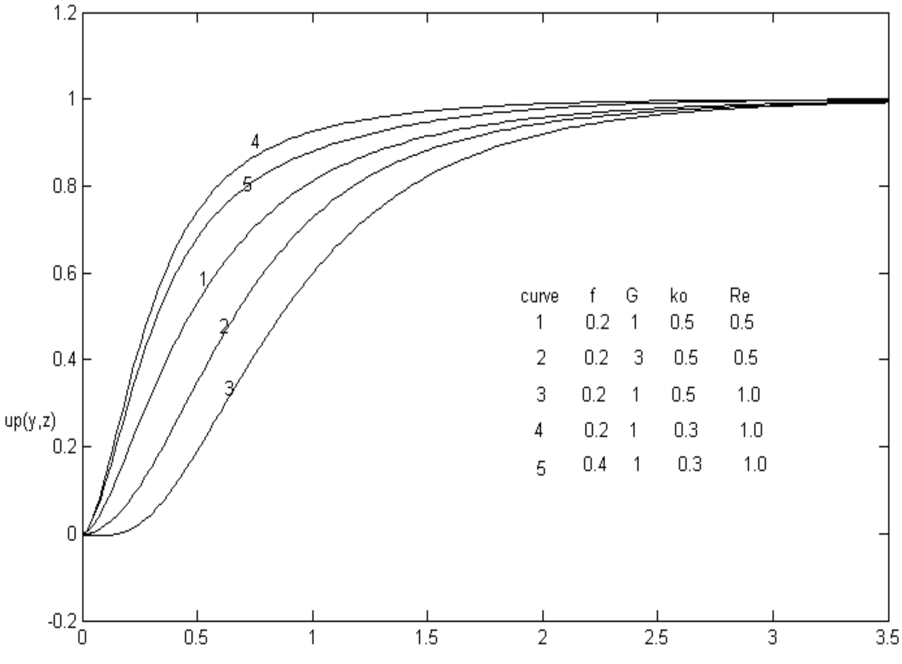

FIG-2 VELOCITY PROFILES OF THE DUST up(y,z) FOR (G > 0)

Pr = 0.7, Λ = 0.2, ε = 0.2

Table – 1 Values of Skin friction coefficient at the plate when ε = 0.2, z = 0, Λ = 0.2

T_x	f	G	k0	Pr	Re		
					0.5	**1**	**1.5**
T_{X1}	0.2	1	0.5	0.7	3.7680	3.0076	2.2522
T_{X2}	0.2	3	0.5	0.7	0.6118	-1.0163	-2.8819
T_{X3}	0.4	1	0.5	0.7	3.4020	3.2015	3.1029
T_{X4}	0.4	1	0.6	0.7	3.2479	3.1642	3.1228
T_{X5}	0.4	1	0.6	7.0	3.3395	3.2610	3.1894

Table – 2 Values of Nusselt Number at the plate when ε = 0.2, z = 0, Λ = 0.2, Pr = 7.0

Nu	f	k_0	Re		
			0.5	**1**	**1.5**
Nu_1	0.2	0.5	2.0843	4.0392	6.4689
Nu_2	0.4	0.5	2.1811	4.1182	6.5534
Nu_3	0.4	0.6	1.2234	2.7440	4.7101

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Table – 3 Values of Nusselt Number at the plate when $\varepsilon = 0.2$, $z = 0$, $\Lambda = 0.2$, $Pr = 0.7$

Nu	f	k_0	Re		
			0.5	1	1.5
Nu_1	0.2	0.5	-0.2431	-0.9030	-1.3434
Nu_2	0.4	0.5	-2.2646	-2.5484	-2.7220
Nu_3	0.4	0.6	-2.6507	-2.8996	-3.0537

6. Conclusion

Velocity profile for both fluid and dust decreases after there is an increase in mass concentration of the dust particles Grashof number., Permeability and Reynolds number. As a result the profile of the dust are at lower height as compared with the fluid $\mathbf{T_x}$ decreases with decreasing $\mathbf{k_0}$ and increasing Gr for clean fluid (f=0). For increasing $\mathbf{k_0}$ leads to decrease in Nu for clean (f=0). The values of T are less in air (Pr=0.7) and more in water (Pr=7.0) whereas the values in Nu is more in air (Pr=0.7) and less in water (Pr=7.0).

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