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FEM Simulations in Convective Viscous Fluid Flow through Porous Vertical Channel

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Abstract

An attempt of Finite Element Method is made on the viscous fluid of free convection nature in a vertical porous channel. The porous medium in which the flow is assumed is bouneded by impermeable parallel walls. A specific direction of axis of channel is considered. The vicous porous flow in the medium in the present investigation is an assumption with certain boundery conditions. Brinkman Model is implemented in the commutation of equations for heat and momentum concepts in developing conservation equations. The viscous and Darcy dissipation have been modeled in the energy equation for the heat flow phenomenon. In the simulation of the finite element method, the fluid and the porous matrix have been imagined to be in local thermal equilibrium and the flow is consider to be one direction of the buoyancy. The non-linear equations which govern the phinominon of the flow, heat and mass transfer are clearly demonstrated in the simulation. Velocity profile and heat dissipation with respect to temperature, Sherwood number, concentration, Nusselt number are analyzed and their profile is studied in the paper.

Keywords: ***Nusselt number, Fluid Flow Sherwood Number, viscous fluid, Galerkin, Finite element method.***

1. Introduction

The Numerical simulation on various models convey the solutions to industrial systems where the heat and temperature effects involved[1]. It is observed that a chance of exponential increase of failure in the performance of a system with the increase in heat rate. The numerical attempt made in the paper lead to the solutions of enhancing the expected levels of performance of the working systems with the techniques of thermal managements through various techniques developed in simulation attempts. The efficiency in the performance can lead to reliability. The various cooling techniques is template.

2. Formulation and methodology

The model has been framed so as to trace the mathematical information and conclusion. The problem relating to convective phonominon of Porouschannel filled medium matrix that are bounded walls of impermeable nature has been carefully modeled and fluid matrix is assumed to be with the direction of axis of flow channel. It has to be carefully seen to keep constant temperature at the surface parts of walls. The concept of Brinkman model is implemented in writing the equations of momentum conservation for analyzing flow. The fluid and the porous matrix are in local thermal equilibrium and the flow is unidirectional along the direction of the buoyancy. The possibility of dissipations due to various causes are considered and assumed as Darcy dissipation which needs to involve in the energy driving equations to describe the heat flow.

A reference frame of mathematical situation 0 (x, y, z) is considered in which the x-axis will be assumed to along normal direction against buoyancy. And it is to see that the vertical walls must be along (y ,z) plane y = $\pm$ b. Let (u, 0, 0) be the one indicating profile of velocity field only in one direction of flow and T the temperature can be an ambient temperature. The equations that govern the concepts of the flow and heat transfer will be as follows

$$\frac{\partial u}{\partial x} = 0 \qquad (2.1)$$

$$\mu\left(\frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2} - \frac{u}{k}\right) + g\beta(T - T_0) + g\beta^*(C - C_o) = -v_0 \frac{\partial u}{\partial y} \qquad (2.2)$$

$$\frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial z^2} + \frac{\rho_0 \nu}{k_1}\left[\left(\frac{\partial u}{\partial y}\right)^2 + \left(\frac{\partial u}{\partial z}\right)^2\right] + \frac{\rho_0 \nu}{k k_1} u^2 - \frac{\partial}{\partial y}(r q_{\partial r}) = \rho_0 C_p \frac{v_0}{k_1}\frac{\partial T}{\partial y} \qquad (2.3)$$

$$D_1\left(\frac{\partial^2 C}{\partial y^2} + \frac{\partial^2 C}{\partial z^2}\right) + K_{11}\left(\frac{\partial^2 \theta}{\partial y^2} + \frac{\partial^2 \theta}{\partial z^2}\right) = 0 \qquad (2.4)$$

$$\rho = \rho_0(1 - \beta(T - T_0) - \beta^*(C - C_0)) \qquad (2.5)$$

where ρ_0 is the density at the ambient temperature T_o and concentration C_o and β , k, ν are the coefficients of Kinematic viscosity, thermal conductivity and thermal expansion of the fluid respectively, β^* is the volumetric coefficient of expansion with mass fraction concentration, k is the permeability of the porous medium and C_p is the specific heat at constant pressure, this the molecular diffusivity and $k_{11}$is the cross diffusivity..

In view of the continuity equations, we take u = u (y, z)

The boundary conditions are

u = 0 on z = ± b

T = ± T_1 , C = ± C_1 (2.6)

$$\frac{\partial u}{\partial z} = 0 \ , \ \frac{\partial T}{\partial z} = 0 \ \text{and} \ \frac{\partial C}{\partial z} = 0$$ on Z = 0 in view of the symmetry.

We introduce the following non-dimensional variables as follows.

$$z^* = \frac{z}{b} \ ; \ y^* = \frac{y}{b} \ ; \ \theta^* = \frac{T - T_0}{T_1 - T_0},$$

$$C^* = \frac{C - C_o}{C_1 - C_o},$$

$$u^* = \frac{\nu u}{\beta g b^2 (T_1 - T_0)}$$

Substituting these in the governing equations the corresponding dimensionless equations under Boussinesq approximations (on dropping the asteriks) are

$$\frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2} - D^{-1}u + (\theta + NC) = -S\frac{\partial u}{\partial y} \qquad (2.7)$$

$$\frac{\partial^2 \theta}{\partial y^2} + N_2\frac{\partial^2 \theta}{\partial z^2} + GP_1 Ec\left[\left(\frac{\partial u}{\partial y}\right)^2 + \left(\frac{\partial u}{\partial z}\right)^2\right) + D^{-1}u^2\right] = -P_1 S\frac{\partial \theta}{\partial y} \qquad (2.8)$$

$$\left(\frac{\partial^2 C}{\partial y^2} + \frac{\partial^2 C}{\partial z^2}\right) + \frac{S_0 Sc}{N}\left(\frac{\partial^2 \theta}{\partial y^2} + \frac{\partial^2 \theta}{\partial z^2}\right) = 0$$

Where

$D = \frac{k}{b^2}$ is the Darcy parameter

$P = \frac{\mu C_p}{k_1}$ is the Prandtl number

$Ec = \frac{\beta g b}{C_p}$ is the Eckert number

$G = \frac{\beta g b^3 (T_1 - T_0)}{\nu^2}$ is the Grash of number

$S = \frac{v_0 b}{\nu}$ is the suction Reynolds number

$N = \frac{\beta^*(C_1 - C_0)}{\beta(T_1 - T_0)}$ is the buoyancy ratio

$S_c = \frac{\nu}{D_1}$ is the Schmidt number

$S_o = \frac{\beta^* K_{11}}{\beta \nu}$ is the Soret number

$N_1 = \frac{\infty \beta_R K_1}{4\sigma T_e^3}$ is the radiation parameter

$N_2 = \frac{3N_1}{3N_1 + 4}$ $\quad P_1 = PN_2 \quad \alpha_1 = \alpha N_2$

The corresponding boundary conditions in the non-dimensional form are

u = 0 , θ = 1, C = 1 on z = ± 1

$$\frac{\partial u}{\partial z}=0 \quad , \quad \frac{\partial \theta}{\partial z}=0 \quad \text{and} \quad \frac{\partial C}{\partial z}=0 \quad \text{On} \quad Z=0 \qquad (2.10)$$

The observation of symmetrical mathematical flow in the present study is in view of mid plane of the fluid flow medium. It is investigated to observe the fluid floe pattern with respect to one half of the domain which was bounded by the walls of properties of impermeability. The finite element simulation is executed with functions having quadratic approximation as designed by eight nodded rectangular elements in the normal cross sectional plane (y - z) that is completely bounded by the planes of z = 0 and 1.

3. FINITE ELEMENT ANALYSIS OF THE PROBLEM

If u^i and θ^i are the approximations of u and θ we define the errors (residual) E_1^i and E_2^i as

$$E_1^i=\frac{\partial^2 u^i}{\partial y^2}+\frac{\partial^2 u^i}{\partial z^2}-D^{-1}u^i+(\theta^i+NC^i)+S\frac{\partial u^i}{\partial y} \qquad (3.1)$$

$$E_2^i=\frac{\partial^2\theta^i}{\partial y^2}+N_2\frac{\partial^2\theta^i}{\partial z^2}+GP_1Ec[(\frac{\partial u^i}{\partial y})^2+(\frac{\partial u^i}{\partial z})^2)+D^{-1}(u^i)^2]+P_1S\frac{\partial\theta^i}{\partial y} \qquad (3.2)$$

$$E_3^i=(\frac{\partial^2 C^i}{\partial y^2}+\frac{\partial^2 C^i}{\partial z^2})+\frac{S_0Sc}{N}(\frac{\partial^2\theta^i}{\partial y^2}+\frac{\partial^2\theta^i}{\partial z^2}) \qquad (3.3)$$

where

$$u^i=\sum_{k=1}^{8}u_k^i N_k^i \qquad (3.4)$$

$$\theta^i=\sum_{k=1}^{8}\theta_k^i N_k^i \qquad (3.5)$$

$$C^i=\sum_{k=1}^{8}C_k^i N_k^i \qquad (3.6)$$

These errors are orthogonal to the weight function over the domain of e^i. Under Galerkin we choose the approximation functions as the weight function. Multiply both sides of the equations (3.1) - (3.3) by the weight function i.e., each of the approximation function N_j^i and integrate over the surface Ω_i, we obtain

$$\int_{\Omega_i}E_1^i N_j^i d\Omega_i=0 \qquad (j=1,2,\ldots\ldots\ldots,8) \qquad (3.7)$$

$$\int_{\Omega_i}E_2^i N_j^i d\Omega_i=0 \qquad (j=1,2,\ldots\ldots\ldots,8) \qquad (3.8)$$

$$\int_{\Omega_i}E_3^i N_j^i d\Omega_i=0 \qquad (j = 1.2\ldots\ldots\ldots,8) \qquad (3.9)$$

$$\int_{\Omega_i}[\frac{\partial^2 u^i}{\partial y^2}+\frac{\partial^2 u^i}{\partial z^2}-D^{-1}u^i+(\theta^i+NC^i)+S\frac{\partial u^i}{\partial y}]N_j^i d\Omega_i=0 \qquad (3.10)$$

$$\int_{\Omega_i}[\frac{\partial^2\theta^i}{\partial y^2}+N_2\frac{\partial^2\theta^i}{\partial z^2}+GP_1Ec[(\frac{\partial u^i}{\partial y})^2+(\frac{\partial u^i}{\partial z})^2)+D^{-1}(u^i)^2]+P_1S\frac{\partial\theta^i}{\partial y}]N_j^i d\Omega_i=0 \qquad (3.11)$$

$$\int_{\Omega_i}[(\frac{\partial^2 C^i}{\partial y^2}+\frac{\partial^2 C^i}{\partial z^2})+\frac{S_0Sc}{N}(\frac{\partial^2\theta^i}{\partial y^2}+\frac{\partial^2\theta^i}{\partial z^2})]N_j^i d\Omega_i=0 \qquad (3.12)$$

$$\int_{\Omega_i}[\frac{\partial N_j^i}{\partial y}\frac{\partial u^i}{\partial y}+\frac{\partial N_j^i}{\partial z}\frac{\partial u^i}{\partial z}-D^{-1}u^iN_j^i+(\theta^i+NC^i)N_j^i+SN_j^i\frac{\partial u^i}{\partial y}]d\Omega_i$$

$$=\int_{\Gamma}[N_j^i\frac{\partial u^i}{\partial y}n_y+N_j^i\frac{\partial u^i}{\partial z}n_z]d\Gamma_i \qquad (3.13)$$

$$\int_{\Omega_i}[\frac{\partial N_j^i}{\partial y}\frac{\partial\theta^i}{\partial y}+N_2\frac{\partial N_j^i}{\partial z}\frac{\partial\theta^i}{\partial z}+GP_1EcN_j^i[(\frac{\partial u^i}{\partial y})^2+(\frac{\partial u^i}{\partial z})^2+D^{-1}(u^i)^2]+P_1SN_j^i\frac{\partial\theta^i}{\partial y}]d\Omega_i$$

$$=\oint_{\Gamma}[N_j^i\frac{\partial\theta^i}{\partial y}n_y+N_j^i\frac{\partial\theta^i}{\partial z}n_z]d\Gamma_i \qquad (3.14)$$

$$\int_{\Omega_i}[N\frac{\partial N_j^i}{\partial y}(N\frac{\partial C^i}{\partial y}+S_cS_o\frac{\partial\theta^i}{\partial y})+\frac{\partial N_j^i}{\partial z}(N\frac{\partial C^i}{\partial z})]d\Omega_i$$

$$=\oint_{\Gamma}N_j^i(N\frac{\partial C^i}{\partial y}+S_cS_o\frac{\partial\theta^i}{\partial y})n_y+N_j^i(N\frac{\partial C^i}{\partial z}+S_cS_o\frac{\partial\theta^i}{\partial z})n_z d\Gamma_i \qquad (3.15)$$

where Ω_i is the serendipity element bounded by Γ_i , n_y , n_z are the direction cosines normal to Γ_i .Substituting (3.4) , (3.5) & (3.6) in L.H.S of (3.13) , (3.14) & (3.15) we get

$$\int_{\Omega_i} \sum_{k=1}^{8} u_k^i [\frac{\partial N_j^i}{\partial y}\frac{\partial N_k^i}{\partial y} + \frac{\partial N_j^i}{\partial z}\frac{\partial N_k^i}{\partial z} - D^{-1} N_k^i N_j^i + SN_j^i \frac{\partial N_k^i}{\partial y}] d\Omega_i + \int_{\Omega_i} \sum_{k=1}^{8} (\theta_k^i + NC_k^i) N_j^i N_k^i d\Omega_i = Q_j^i$$

(3.16)

$$\int_{\Omega_i} \sum_{k=1}^{8} \theta_k^i [\frac{\partial N_j^i}{\partial y}\frac{\partial N_k^i}{\partial y} + N_2 \frac{\partial N_j^i}{\partial z}\frac{\partial N_k^i}{\partial z} + P_1 SN_j^i \frac{\partial N_k^i}{\partial y}] d\Omega_i + \int_{\Omega_i} \sum_{k=1}^{8} u_k^i GP_1 Ec[(\frac{\partial N_k^i}{\partial y})^2 + (\frac{\partial N_k^i}{\partial z})^2 + D^{-1}(N_k^i)^2] d\Omega_i = (Q^T)_j^i$$

(3.17)

$$\int_{\Omega_i} [\sum_{k=1}^{8} C_k^i \{\frac{\partial N_k^i}{\partial y}\frac{\partial N_j^i}{\partial y} + \frac{\partial N_k^i}{\partial z}\frac{\partial N_j^i}{\partial z}\} d\Omega_i - \int_{\Omega_i} N_2 Sc \sum_{k=1}^{8} u_k^i (N_j^i N_k^i) d\Omega_i$$

$$- ScS_o \int_{\Omega_i} \sum_{k=1}^{8} \theta_k^i \{\frac{\partial N_k^i}{\partial y}\frac{\partial N_j^i}{\partial y} + \frac{\partial N_k^i}{\partial z}\frac{\partial N_j^i}{\partial z}\} d\Omega_i = (Q^C)_j^i$$

(3.18) where

$$Q_j^i = \oint_{\Gamma_i} (N_j^i)(\frac{\partial u^i}{\partial y}) n_y + N_j^i \frac{\partial u^i}{\partial z} n_z) d\Gamma_i$$

$$(Q^T)_j^i = \oint_{\Gamma_i} (N_j^i)(\frac{\partial T^i}{\partial y}) n_y + N_j^i \frac{\partial T^i}{\partial z} n_z) d\Gamma_i$$

(j = 1 , 2, ……,8)

$$(Q^C)_j^i = \oint_{\Gamma_i} [N_j^i \{N \frac{\partial C^i}{\partial y} + S_0 Sc \frac{\partial \theta^i}{\partial y}\} n_y + N_j^i \{N \frac{\partial C^i}{\partial z} + S_0 Sc \frac{\partial \theta^i}{\partial z}\} n_z] d\Gamma_i \quad j = 1,2,\ldots\ldots\ldots,8.$$

Choosing different N_k^i's corresponding to each element e_i (3.11) results in sixteen equations for two sets of unknown (u_k^i) *and* (θ_k^i) viz

$$(a_{kj}^i)(u_k^i) = Q_j^i \quad (3.19)$$

$$(b_{kj}^i)(\theta_k^i) + (c_{kj}^i) u_k^i = (Q^T)_j^i \quad (j = 1, 2, \ldots\ldots,8) \quad (3.20)$$

$$(m_{kj}^i)(C_k^i) + (l_{kj}^i)(u_k^i) = (n_{kj}^i)(\theta_k^i) + (Q_j^C)^i \quad (j,k = 1,2,\ldots\ldots\ldots\ldots,8) \quad (3.21)$$

where (a_{kj}^i), (b_{kj}^i) ,c_{kj}^i),(m_{kj}^i) ,(n_{kj}^i) *and* (l_{kj}^i) are 8 × 8 stiffness matrices and Q_j^i, $(Q^T)_j^i$ and $(Q_j^C)^i$ are 8 × 1 dimenional matrices. The process of simulation at each point of element mn has been periodically made with the consideration of boundery conditions and then an integration of elements in the matrix was done. The unknown parameters of u, θ and C in the process of computation is attempted with respect to global nodes which ultimately determine them on solving the matrix equation and it may lead to solution of matrix solution.

In order to compute, It is to consider a serendipity element having the vertices of (0,0), (0,1) (1,0) and (1,1). The eight nodes of the selected and computed element are clearly given in Fig.(a) and the operations of functions for the quadratic interpolation at these nodes have been as under

$$N_1 = -2\ (y-1)(z-1)(z+y-\frac{1}{2}) \quad ; \quad N_2 = -4z(z-1)(y-1)$$

$$N_3 = -2\ z\ (y-1)\ (z-y+\frac{1}{2}) \quad ; \quad N_4 = -\ 4\ y\ z\ (y-1)$$

$$N_5 = 2\ y\ z\ (z+y\ -\frac{3}{2}) \quad ; \quad N_6 = -\ 4\ y\ z(z-1)$$

$$N_7 = 2\ y\ (z-1)(z-y+\frac{1}{2}) \quad ; \quad N_6 = -\ 4\ y\ (z-1)(y-1)$$

Substituting these shape functions in (3.19) and integrating over the element domain the matrix for the global nodes of u viz. u_i (i =1,2,……) reduces to a 8 × 8 matrix equations.

This 8× 8 matrix equations can be partitioned in the form

$$\begin{bmatrix} A^{11} & A^{12} \\ A^{21} & A^{22} \end{bmatrix} \begin{bmatrix} \Delta_U^1 \\ \Delta_U^2 \end{bmatrix} = \begin{bmatrix} F_U^1 \\ F_U^2 \end{bmatrix}$$

(3.22)

Where $\Delta_U^1, \Delta_U^2, F_U^1, F_U^2$ are column matrices given by

$$\Delta_U^1 = \begin{bmatrix} U_1 \\ U_2 \\ U_3 \\ U_4 \end{bmatrix} \quad , \quad \Delta_U^2 = \begin{bmatrix} U_5 \\ U_6 \\ U_7 \\ U_8 \end{bmatrix}$$

Equation (3.20) yields the following two equations in terms of the partitioned matrices.

$$\left[S^{11}\right] \left[\Delta_U^1\right] + \left[S^{12}\right] \left[\Delta_U^2\right] = \left[F_U^1\right]$$

$$\left[S^{21}\right] \left[\Delta_U^1\right] + \left[S^{22}\right] \left[\Delta_U^2\right] = \left[F_U^2\right]$$

(3.23)

Similarly the 8 × 8 matrix equations for θ_j, C_j (j = 1,2,.....,8) in the partitioned form are

$$\begin{bmatrix} B^{11} & B^{12} \\ B^{21} & B^{22} \end{bmatrix} \begin{bmatrix} \Delta_\theta^1 \\ \Delta_\theta^2 \end{bmatrix} = \begin{bmatrix} F_\theta^1 \\ F_\theta^2 \end{bmatrix}$$

(3.24)

$$\begin{bmatrix} L^{11} & L^{12} \\ L^{21} & L^{22} \end{bmatrix} \begin{bmatrix} \Delta_C^1 \\ \Delta_C^2 \end{bmatrix} = \begin{bmatrix} F_C^1 \\ F_C^2 \end{bmatrix}$$

(3.25)

Where Δ_θ^1, Δ_θ^2, F_θ^1, F_θ^2, Δ_C^1, Δ_C^2, F_C^1, F_C^2 are column matrices given by

$$\Delta_\theta^1 = \begin{bmatrix} \theta_1 \\ \theta_2 \\ \theta_3 \\ \theta_4 \end{bmatrix} \quad ; \quad \Delta_\theta^2 = \begin{bmatrix} \theta_5 \\ \theta_6 \\ \theta_7 \\ \theta_8 \end{bmatrix} \quad ;$$

$$\Delta_C^1 = \begin{bmatrix} C_1 \\ C_2 \\ C_3 \\ C_4 \end{bmatrix} \quad ; \quad \Delta_C^2 = \begin{bmatrix} C_5 \\ C_6 \\ C_7 \\ C_8 \end{bmatrix}$$

The boundary conditions (essential) on the primary variables are

$u_3 = u_4 = u_5 = 0$;

$\theta_3 = \theta_4 = \theta_5 = 1$ and

$C_3 = C_4 = C_5 = 1$ on y =1 (3.26)

In view of the symmetry conditions we obtain

$Q_1 = Q_2 = Q_6 = Q_7 = Q_8 = 0$

$$Q_1^T = Q_2^T = Q_6^T = Q_7^T = Q_8^T = 0$$

(3.27)

$$Q_1^C = Q_2^C = Q_3^C = Q_4^C = Q_8^C = 0$$

Solving the ultimate 8 × 8 matrices we determine the unknown global nodal values of u_i, θ_i

(i =1 ,2,……..,8).

The solution for u, θ may now be represented as

$$u = \sum_{k=1}^{8} u_i N_i \ , \ \theta = \sum_{j=1}^{8} \theta_j N_j \text{ and } C = \sum_{i=1}^{8} C_i N_i$$

4. DISCUSSION OF NUMERICAL RESULTS

It is observed in the results of simulations that the behaviour of fluid flow in the direction of planes y=0&1 and Z=0 & Z=1/2 can be acompanied with movement in the direction from y=0 to 1 in vertical manner. A higher value is observed to at at y=0.4 while at Z=1/2 level it can be maximum at the position of y=1. It is clearly noticed that the velocity is decreases with increase in D^{-1}. Permeability of the porous medium smaller and therefore the velocity in the fluid region can also be very low. The variation of u along the normal planes y= 0 & 1 shows that u decreases with D^{-1} (Figs 1, 2). This situation in the stud gives the fact that lesser the permeability of the porous medium smaller the magnitude of u. The values of u at y=0 are higher than those at y=1 level for all variations in parameters. Figures 3 and 4 show the variation of non-dimensional temperature at the horizontal levels y=0 & ½ with respect to α, and N_1. A marginal depreciation in θ is observed to be with increase in the heat source parameter α. The variation of θ with radiation parameter N_1 reveals that the enhancement in N_1 may cause an increase in the actual temperature at y=0&1 levels. The variation of θ with α, and N, at the vertical levels Z=0&1/2 is shown in figures. From figures 7&8 it can concluded that the actual temperature experiences depreciation with increase in the heat source parameter α. This indicates that the presence of the heat generating source in the fluid region leads to a reduction in the actual temperature at both the vertical levels.

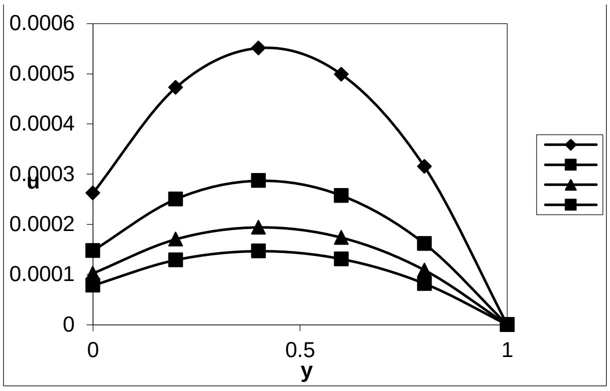
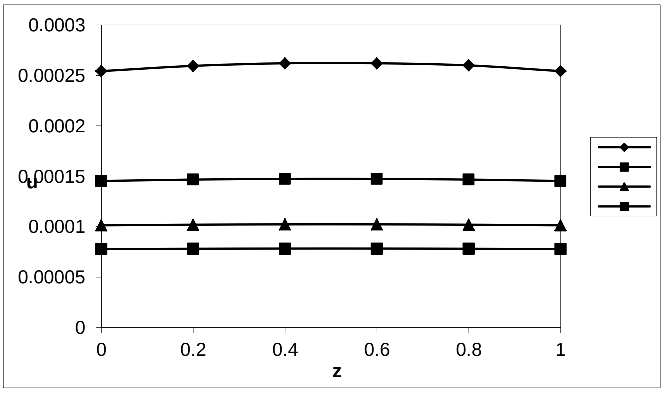


Fig. 1

Variation of u with D^{-1} at y=0.5 level

M=5; G=200; N_1=0.5; S=0.8; k=0.5; P=0.71; D^{-1}=2000; z=0.5

	I	II	III	IV
D^{-1}	$2x10^3$	$4x10^3$	$6x10^3$	$8x10^3$



(1)

Fig. 2

Variation of u with D^{-1} at z=0 level

M=5; G=200; N_1=0.5; S=0.8; k=0.5;P=0.71; β=2; D^{-1}=2000; z=0.5

	I	II	III	IV
D^{-1}	$2x10^3$	$4x10^3$	$6x10^3$	$8x10^3$

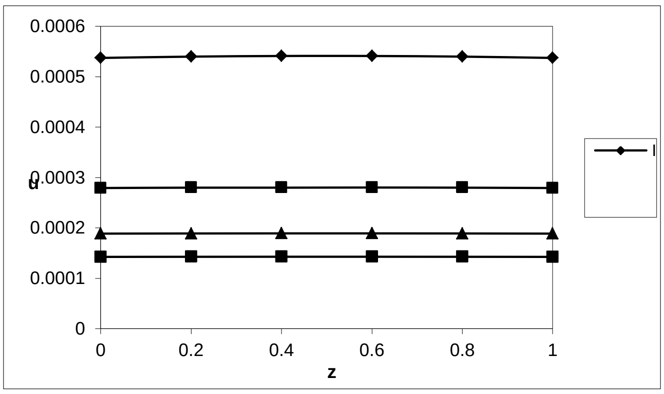


Fig. 3

Variation of u with D^{-1} at z=0.5 level

M=5; G=200; cn=0.5; S=0.8; k=0.5; P=0.71; D^{-1}=2000; z=0.5

	I	II	III	IV
D^{-1}	$2x10^3$	$4x10^3$	$6x10^3$	$8x10^3$

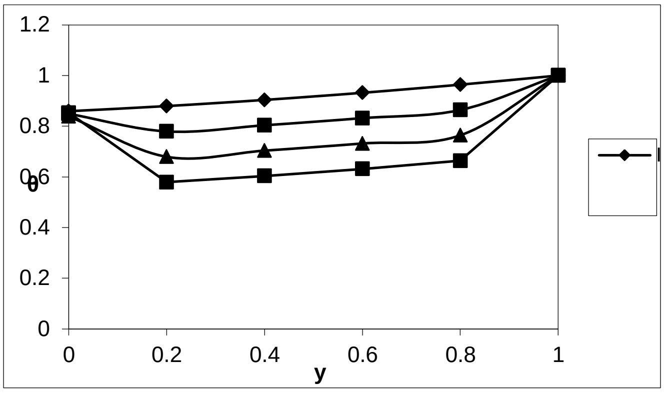


Fig. 4

Variation of θ with α at y=0 level

M=5; G=200; N_1=0.5; S=0.8; k=0.5; P=0.71; β=2; D^{-1}=2000; z=0.5

	I	II	III	IV
α	0	2	4	10

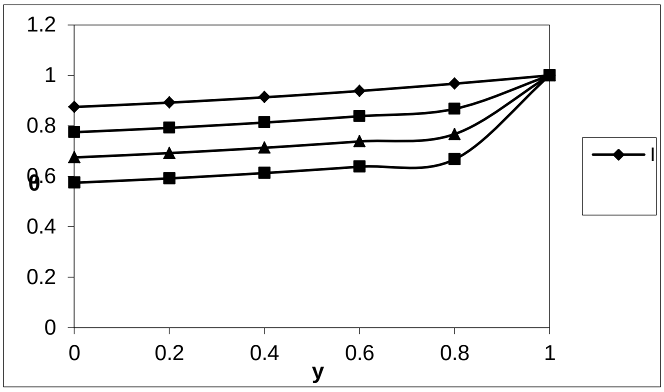


Fig. 5

Variation of θ with α at y=0.5 level

M=5; G=200; N_1=0.5; S=0.8; k=0.5; P=0.71; D^{-1}=2000; z=0.5

	I	II	III	IV
α	0	2	4	10

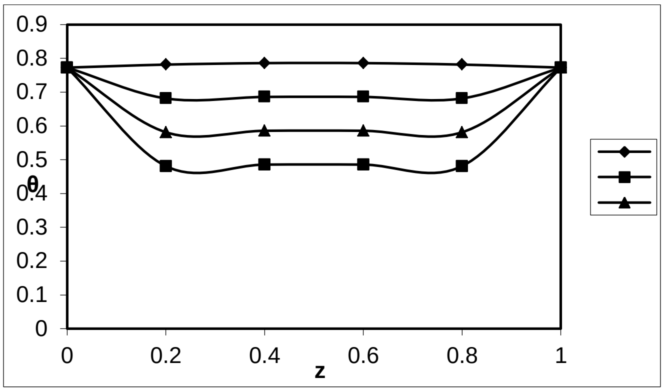


Fig. 6

Variation of θ with α at z=0 level

M=5; G=200; N_1=0.5; S=0.8; k=0.5; P=0.71; β=2; D^{-1}=2000; z=0.5

	I	II	III	IV
α	0	2	4	10

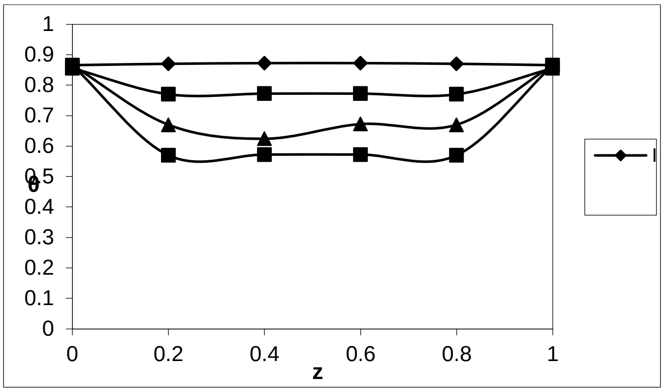


Fig. 7

Variation of θ with α at z=0.5 level

M=5; G=200; N_1=0.5; S=0.8; k=0.5; P=0.71; D^{-1}=2000; z=0.5

	I	II	III	IV
α	0	2	4	10

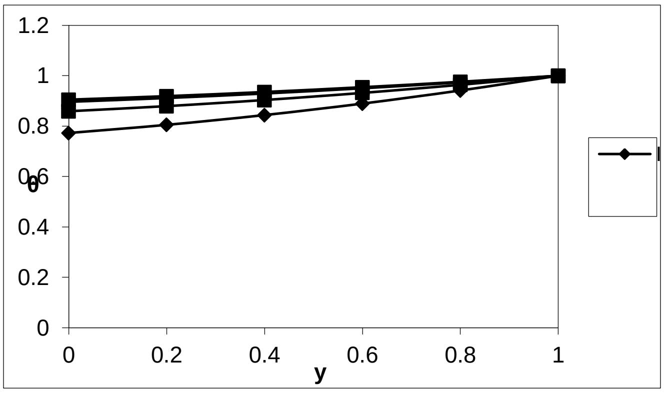


Fig. 8

Variation of θ with N1 at y=0 level

M=5; G=200; S=0.8; k=0.5; P=0.71; β=2; D^{-1}=2000; z=0.5

	I	II	III	IV
N_1	0.5	1.5	5	10

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