Research Inventy: International Journal Of Engineering And Science
Vol.2, Issue 12 (May2013), Pp 01-05
Issn(e): 2278-4721, Issn(p):2319-6483, Www.Researchinventy.Com

Non-Darcian Convective Heat and Mass Transfer through a Porous Medium in a Vertical Channel through Radiation and Thermo-Diffusion Effect

[1] Dr.V.Nagaradhika,
[1,]Associate Professor, Moula ali college of Engg & Technology, gutkur(vill&Post),Bellary road, Anantapur-515711.AP,India

Abstract: *In this analysis we discuss the effect of radiation and thermo-diffusion on convective heat and mass transfer flow of viscous incompressible fluid through a porous medium in a vertical channel with Non-Darcian approach. The governing coupled non-linear equations are linear zed with perturbation technique and solved. Many results obtained were represented graphically to illustrate the influence of the radiation and soret parameter on velocity, temperature, concentration profiles, Nusselt number and Sherwood number.*

Keywords: *Thermal diffusion, Radiation, Non-Darcy, Heat transfer, Mass transfer, Porous medium, Nusselt number, Soret parameter, Sherwood number.*

I. INTRODUCTION

Combined heat and mass transfer exists simultaneously due to the buoyancy difference in temperature and concentration difference and is of particle importance in many engineering and geophysical applications such as thermal insulation of buildings and energy recovery of petroleum resources, chemical reactors , nuclear waste disposals, migration of moisture through the air contained in fibrous insulators, grain storage of installation and dispersion of chemical contaminants through water saturated soils. The state of art concerning the combined heat and mass transfer through a porous medium has been summarized in excellent monographs by Nield and Bejan [1] and Bejan and Khair[2] studied the heat and mass through a porous medium with constant temperature and constant concentration but Sigh and Queeny[3] were analyzed the free convection transfer with a geometry vertical surface embedded in porous medium using an integral method. Lai and Kulacki[4] considered the case of wall with constant heat flux and constant mass flux including the effect of wall injection. The dispersion and opposing buoyancy effects were analyzed by Telles[5], Trevison and Bejan[6,7].

Radiation plays a vital role when convection is relatively small and this cannot be neglected. Raptis[8] explained the effect of radiation in free convection flow, Irfan et.al.[9] analyzed the heat transfer by radiation in annulus. Thermophoresis is a phenomenon which causes small particles to be driven away from hot surface and towards a cold one. Small particles suspended in a gas with temperature gradient experiences a force in a direction opposite to the temperature gradient. It has an application in removing small particles from gas streams in determining the exhaust gas particle trajectories from combustion devices. It also been shown that thermal-diffusion is dominant in mass transfer mechanism in the

modified chemical vapor deposition process used in the fabrication of optical fibour. Garg[10] studied the thermophoresis of aerosol particle over inclined plates, Chamka[11] explained the effect of heat generation and absorption on thermophoresis free convection flow from a vertical plate embedded in a porous medium. Darcy model which assumes the proportionality both velocity and pressure gradient, this model is valid only for slow flows through a porous media with low permeability see Nakayamma[12]. At higher flow rates or highly porous medium there is a departure from the linear flow and inertial effects important. The flow in the porous medium Riley and Rees[13] studied non-darcy natural convection in a inclined surface. Due to the wide application we make an attempt to study the radiation and thermo-diffusion effect on non-Darcian mixed convective heat and mass transfer through a porous medium in a vertical channel. Nomenclatures: N,D,D^{-1},K_{11},T_e,F, G, g,N_1,Nu,p_r,q_r,Sc,k. Greek symbols: λ, μ,ρ,α,ν,β,σ, Λ

II. FORMULATION OF THE PROBLEM

We consider the flow of viscous fluid in a parallel plate vertical channel through a porous medium. The coordinate system O(X, Y) is considered X-axis vertically along axial direction and Y-axis is normal to the plates. The plates are maintained at constant temperature and constant concentration. The effect of temperature

on the concentration is taken in the diffusion equation represents the soret effect and the radiation energy is taken in the energy equation. In order to consider the boundary and inertial effects we approaching in non-Darcian model.
By the above assumptions the governing equations of the flow are given by:

$$-\frac{\partial P}{\partial x}+\frac{\mu}{\delta}(\frac{\partial^2 u}{\partial y^2})-\frac{\mu}{k}u-\frac{\rho\delta F}{\sqrt{k}}u^2-\rho g=0 \quad (1)$$

$$\rho_o C_P u\frac{\partial T}{\partial y}=\lambda\frac{\partial^2 T}{\partial y^2}+Q(T_o-T)-\frac{\partial(q_r)}{\partial y} \quad (2)$$

$$u\frac{\partial C}{\partial y}=D\frac{\partial^2 C}{\partial y^2}+K_{11}\frac{\partial^2 T}{\partial y^2} \quad (3)$$

$$\rho-\rho_o=-\beta\rho_o(T-T_o)-\beta^*\rho_o(C-C_o) \quad (4)$$

Corresponding boundary conditions are:

$u=0$ On $y=\pm L$, $T=T_1, C=C_1$ On $y=-L$, (4a)

$T=T_2, C=C_2$ On $y=+L$. (4b)

Invoking Roseland approximation (Brevet) the radiative heat flux q_r is

$$q_r=\frac{-4\sigma_s}{3K_e}\frac{\partial T^{1^4}}{\partial y} \quad (5)$$

Linearized by expanding T^{1^4} into Taylor series about T_e^1 which after neglecting higher order terms and takes the form $T^{1^4}\cong 4T_e^{1^3}T^1-3T_e^{1^4}$ (6)

The non-dimensional variables are used

$$u^1=u/(\frac{\rho\nu}{L})\ (x^1,y^1)=\frac{(x,y)}{L},\quad u^1=u/(\frac{\rho\nu}{L}),\ \theta=\frac{T-T_2}{T_1-T_2}, \quad (7)$$

Equations (1), (2), (3), (4a), (4b) are non-dimensionalised by using above variables.

$$-\frac{\partial P}{\partial x}=\frac{\partial^2 u}{\partial y^2}-D^{-1}\delta u-\delta^2\Lambda u^2+\delta G(\theta+NC) \quad (8)$$

$$\frac{\partial^2\theta}{\partial y^2}-\alpha_1\theta=(P_1N_T)u \quad (9)$$

$$\frac{\partial^2 C}{\partial y^2}+(\frac{S_cS_o}{N})\frac{\partial^2\theta}{\partial y^2}-(S_cN_c)u=0 \quad (10)$$

$$u=0\ \ on\ y=\pm1,\ \ \theta=C=1\ \ on\ y=-1,\ \ \theta=C=0\ \ on\ y=+1 \quad (10a)$$

III. ANALYSIS OF THE FLOW

The governing equation of the flow of heat and mass transfer are coupled and non-linear equations. Using Perturbation method assuming the porosity δ to be small, we write the solution of the above problem as

$$u=u_0+\delta u_1+\delta^2u_2+......., \quad (11a)$$

$$\theta=\theta_0+\delta\theta_1+\delta^2\theta_2+....... \quad (11b)$$

$$C=C_0+\delta C_1+\delta^2C_2+....... \quad (11c)$$

Substituting the equations (11.a, 11.b, 11.c) in (8, 9, 10, 10.a) and equating like powers of δ , we obtain equations to the zero order, first and second order equations. Solving these equations we get expressions for velocity temperature and concentrations.
The stresses were calculated by using the expression at both the wall using

$$\tau = \mu(\frac{du}{dy})_{y=\pm L}$$

The rate of heat transfer (Nusselt number) at both the walls are calculated with the expression

$$Nu = -\frac{qL}{(T_1 - T_2)k} = (\frac{d\theta}{dy})_{y=\pm 1} \qquad \text{Where } q = -k(\frac{dT}{dy})_{y=\pm L}$$

The rate of mass transfer (Sherwood number) at the both the walls are calculated using the formula

$$Sh = -\frac{JL}{(C_1 - C_2)D} = (\frac{dC}{dy})_{y=\pm 1} \qquad \text{Where } J = -D(\frac{dC}{dy})_{y=\pm L}$$

IV. RESULTS AND DISCUSSIONS

1)Figures (1) represent the variation of velocity, temperature and concentration with radiation parameter N_1, keeping the parameter values are fixed. The influence of radiation parameter N_1 on u , shows that |u| experiences an enhancement with increase in the radiation parameter N_1.

2) The variation of θ with radiation parameter N_1 reveals that the actual temperature experiences depreciation with increase in radiation parameter N_1. The behavior of C with radiation parameter N_1 reveals that an increase in the tendency of the radiation effect on the actual concentration.

3)The Figure (2) represents the variation of velocity, temperature and concentration with radiation parameter N_1, An increase in the soret parameter So >0 depreciates |u|, while it enhances with increase in |So| <0. An increase in the soret parameter So>0 depreciates the actual temperature and it enhances with increase in |So|<0. An increase in the soret parameter So, the concentration enhances with increase in So>0 and depreciates with |So|<0.

4)Table.1 represents variation of the rate of heat transfer (Nusselt number) with radiation parameter N_1 at the right plate y=1 and left plate y=-1. The variation of │Nu│ with radiation parameter N_1 reveals that the rate of heat transfer depreciates at y=1 and enhances at y=-1. In general the rate of heat transfer at the right wall y=1 is lesser than at y=-1.

5) Table. 2 represents variation of Sherwood number with radiation parameter at the right wall y=1 and left wall y=-1. An increase in the radiation parameter N_1 enhances the magnitude of the rate of mass transfer at both the walls in heating and cooling case.

6)Table.3 shows the variation of the rate of heat transfer (Nusselt number) with soret parameter S_o at the right plate y=1 and left plate y=-1. The variation of Nusselt number with soret parameter at the right plate y=1 shows that an increase in So (>0) │Nu│ enhances in cooling case and decreases in heating case. Increase in So │So│ (<0) decreases in cooling case and enhances in the heating case it decreases. At the plate y=-1 variation of Nu with So shows that an increase in So (>0) │Nu│ decreases in cooling case and increases in heating case. Increase in So │So│ (<0) increases in cooling case and decreases in the heating case.
7) Table. 4 variation of the rate of mass transfer with the Soret parameter S_o at the right wall y=1 and left wall y=-1. The variation of Sh with soret parameter shown in the table 4 reveals that an increase in So(<0) enhances │Sh│ at y=1 for G<0 and reduces it for G>0. Whereas at y=-1│Sh│ enhances for all values of G. While for increase in │So│ (<0) enhances Sh at y=1for G>0 and reduces it for G<0, while at y=-1│Sh│ reduces with │So│.

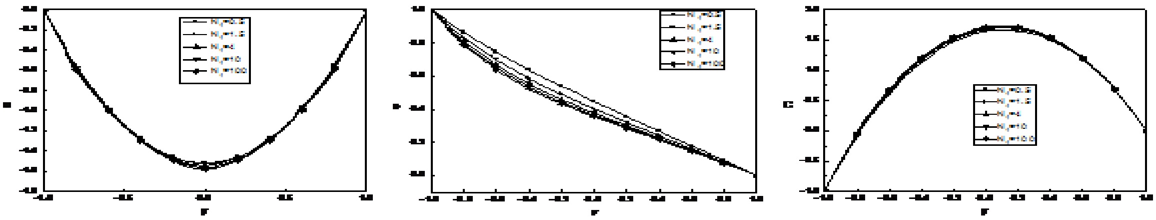
V. CONCLUSIONS

The effect of radiation and thermo-diffusion effect on non-Darcian mixed convective heat and mass transfer flow through a porous medium in the geometry vertical channel and we find that, at the hot surface Nusselt number (Nu) increases with radiation parameter where as at the cold surface the values of Nu is negative and the magnitude of the rate of heat transfer decreases. At hot and cold surface the variation of Nu with Soret parameter (S_o) for positive S_o, Nu decreases in cooling case and increases in heating case, but for negative values of S_o reversal effect is observed. At both the surfaces the Sherwood values are negative. The mass transfer rate enhances by increasing the radiation effect. For positive values of S_o the rate of mass transfer enhances and the mass transfer rate decreases for negative values of S_o.

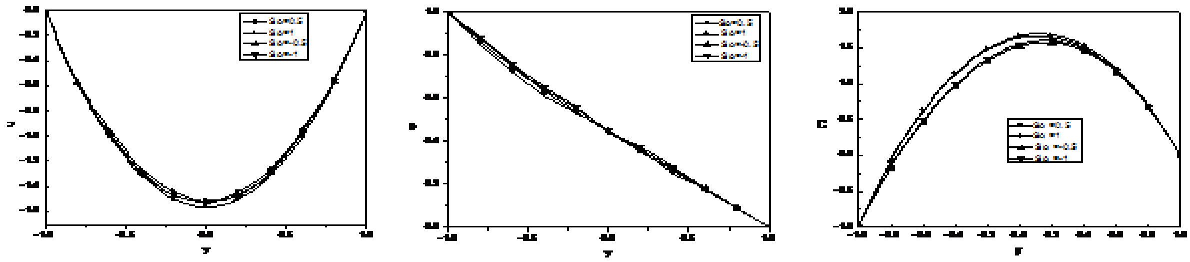
REFERENCES

[1] D.A. Nield, A. Bejan, Convection in Porous Media, second ed., Springer, New York, 1998.
[2] A. Bejan, K.R. Khair, Heat and mass transfer by natural convection in a porous medium, Int. J. Heat Mass Transfer 28 (1985) 909-918.
[3] P. Singh, Queeny, Free convection heat and mass transfer along a vertical surface in a porous medium, Acta Mech. 123 (1997) 69-73.
[4] F.C. Lai, C.Y. Choi, F.A. Kulacki, Coupled heat and mass transfer by natural convection from slender bodies of revolution in porous media, Int. Commun. Heat Mass Transfer 17 (1990) 609-620.
[5] R.S. Telles, O.V. Trevisan, Dispersion in heat and mass transfer natural convection along vertical boundaries in porous media, Int. J. Heat Mass Transfer 36 (1993) 1357- 1365.
[6] O.V. Trevisan, A. Bejan, Natural convection with combined heat and mass transfer buoyancy effects in a porous medium, Int. J. Heat Mass Transfer 28 (1985) 1597-1611.
[7] O.V. Trevisan, A. Bejan, Mass and heat transfer by natural convection in a vertical slot filled with porous medium, Int. J. Heat Mass Transfer 29 (1986) 403-415.
[8] Raptis, Raidation and free convection flow through a porous medium , Int.Commun. Heat and Mass Transfer, 25 (1998) 289-295.
[9] Irfan Anjum Badruddin, Z.A.Zainal, P.A. Aswatha Narayana, K.N. Seetharamu, Heat transfer by radiation and natural convection through a vertical annulus embedded in porous medium, Int. Commun. Heat and Mass Transfer 33 (2006) 500-507.
[10] V.K. Garg, S.Jayaraj, Thermophoresis aerosol particles in laminar flow over inclined plates, Int. J. Heat and Mass transfer 31 (1988) 875-890.
[11] Ali J.Chamka, Ali F.Al-Mudhaf, Ioan Pop, Effects of heat generation or absorption on thermophoretic free convection boundary layer from a vertical flat plate embedded in a porous medium, Int.Comm. Heat and Mass transfer 33 (2006) 1096-1102.
[12] A.Nakayamma, T.Kokudai, H.Koyamma, Non-Darcian boundary layer flow and forced convection heat transfer over a flat plate ihn a fluid saturated porous medium, ASME J.Heat transfer 112 (1990) 157-162.
[13] D.S.Riley and D.A.S. Rees, Non-darcy natural convection from arbitrary inclined heat surface in saturated porous media, Q.J.Mech.Appl.Math 38 (1985) 277-295.

FIGURES & TABLES



Fig(1) Variation of of u, θ ,C with Radiation parameter N_1



Fig(2) Variation of of u, θ ,C with Soret parameter S_o

(Table.1)Variaton of Nusselt number (Nu) with Radiation parameter (N_1) at the right plate y=1					
G/Nu	I	II	III	IV	V
-2x10^3	-0.436162	-0.40496	-0.387861	-0.380653	-0.376196
-1x10^3	-0.437599	-0.405305	-0.387822	-0.380463	-0.375912
0	-0.43903	-0.40564	-0.38777	-0.380261	-0.375615
1x10^3	-0.440455	-0.405965	-0.387708	-0.380047	-0.375306
2x10^3	-0.441875	-0.406281	-0.387634	-0.37982	-0.374984
N_1	N1=0.5,N=2,Sc=1.3,So=0.5	1.5	4	10	100
Variaton of Nusselt number (Nu) with Radiation parameter (N_1) at the left plate y=-1					
G/Nu	I	II	III	IV	VI
-2x10^3	0.739376	0.925346	1.06836	1.14828	1.20874
-1x10^3	0.737936	0.924997	1.06839	1.14846	1.20902
0	0.736503	0.92466	1.06844	1.14866	1.20931
1x10^3	0.735078	0.924333	1.0685	1.14887	1.20961
2x10^3	0.733661	0.924017	1.06857	1.14909	1.20993
N_1	N1=0.5,N=2,Sc=1.3,So=0.5	1.5	4	10	100

(Table.2)Variaton of Sherwood number (Sh) with Radiation parameter (N_1) at the right plate y=1					
G/Sh	I	II	III	IV	V
$-2x10^3$	-3.97085	-3.9892	-3.99973	-4.00421	-4.00699
$-1x10^3$	-3.96746	-3.98748	-3.99855	-4.00323	-4.00613
0	-3.96404	-3.98574	-3.99736	-4.00224	-4.00526
$1x10^3$	-3.96059	-3.98398	-3.996l5	-4.00123	-4.00438
$2x10^3$	-3.95711	-3.98218	-3.99491	-4.00021	-4.00348
N1=0.5,N=2,Sc=1.3,So=0.5	N1=0.5	1.5	4	10	100
Variaton of Sherwood number (Sh) with Radiation parameter (N_1) at the left plate y=-1					
G/Sh	I	II	III	IV	VI
$-2x10^3$	-5.08533	-5.20425	-5.29658	-5.34829	-5.38744
$-1x10^3$	-5.08176	-5.20236	-5.29525	-5.34717	-5.38646
0	-5.07814	-5.20044	-5.2939	-5.34604	-5.38546
$1x10^3$	-5.07447	-5.19849	-5.29252	-3.34489	-5.38445
$2x10^3$	-5.07076	-5.1965	-5.29113	-3.34372	-5.38343
N=2,Sc=1.3,So=0.5	N_1=0.5	1.5	4	10	100

(Table.3)Variation of the Nusselt number with soret parameter S_o at the right plate y=1				
G/Nu	I	II	III	IV
$-2x10^3$	-0.436162	-0.436262	-0.436166	-0.436159
$-1x10^3$	-0.437599	-0.437601	-0.437595	-0.437593
0	-0.43903	-0.4393	-0.43903	-0.43903
$1x10^3$	-0.440455	-0.440448	-0.44047	-0.437769
$2x10^3$	-0.441875	-0.441817	-0.441916	-0.436501
N1=0.5,N=2,Sc=1.3,	So=0.5	1	-0.5	-1
Variation of the Nusselt number with soret parameter S_o at the left plate y=-1				
G/Nu	I	II	III	IV
$-2x10^3$	0.739376	0.739365	0.739393	0.739399
$-1x10^3$	0.737936	0.73793	0.737945	0.73795
0	0.736503	0.736503	0.736503	0.736503
$1x10^3$	0.735078	0.735084	0.735065	0.735059
$2x10^3$	0.733661	0.733672	0.733633	0.733618
N1=0.5,N=2,Sc=1.3,	So=0.5	1	-0.5	-1

(Table.4)Variation of the Sherwood number with soret parameter S_o at the right plate y=1				
G/Sh	I	II	III	IV
$-2x10^3$	-3.97085	-4.01463	-3.88162	-3.83617
$-1x10^3$	-3.96746	-4.00918	-3.88318	-3.84061
0	-3.96404	-4.00367	-3.88478	-3.84515
$1x10^3$	-3.96059	-3.99811	-3.88642	-3.84978
$2x10^3$	-3.95711	-3.99249	-3.88811	-3.85451
N1=0.5,N=2,Sc=1.3,	S_o=0.5	1	-0.5	-1
Variation of the Sherwood number with soret parameter S_o at the left plate y=-1				
G/Sh	I	II	III	IV
$-2x10^3$	-5.08533	-5.24252	-4.76962	-4.61111
$-1x10^3$	-5.08176	-5.23721	-4.77017	-4.61404
0	-5.07814	-5.23186	-4.77068	-4.61696
$1x10^3$	-5.07447	-5.22647	-4.77116	-4.61985
$2x10^3$	-5.07076	-5.22103	-4.7716	-4.62273
N1=0.5,N=2,Sc=1.3,	S_o=0.5	1	-0.5	-1