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"Effect of Chemical Reaction, Thermal Radiation and Radiation Absorption on Convective Heat and Mass Transfer Flow of a Jeffrey Fluid in a Concentric Cylindrical Annulus with Non – Linear Density Temperature Relation in the Presence of Constant Heat Source"

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Effect of Chemical Reaction, Thermal Radiation and Radiation Absorption on Convective Heat and Mass Transfer Flow of a Jeffrey Fluid in a Concentric Cylindrical Annulus with Non – Linear Density Temperature Relation in the Presence of Constant Heat Source

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Abstract : *The effect of non-linear density temperature variation on mixed convective heat and mass transfer flow of a Jeffrey's fluid through a porous medium in a circular annulus in the presence of constant heat sources is considered. The equations governing the flow, heat and mass transfer have been solved by employing Gauss-Seidel iteration procedure. The effect of various governing parameters on the flow characteristics have been discussed graphically. The rate of heat and mass transfer are evaluated numerically for different variations.*

Keywords : **Jeffrey fluid Circular annulus, nonlinear density variation, chemical reaction, thermal radiation, Radiation absorption.**

1. INTRODUCTION

A large class of real fluids does not exhibit the linear relationship between stress and the rate of strain. Because of the non-linear dependence, the analysis of the behavior of the fluid motion of the non-Newtonian fluids tends to be much more complicated and subtle in comparison with that of the Newtonian fluids. In the literature, the mechanics of non-linear fluids presents special challenges to engineers, physicists and mathematicians since the non-linearity can manifest itself in a variety of ways. It is well known that the rheological properties of many fluids are not well modeled by the Navier–Stokes equations. It is not possible to obtain a single equation exhibiting all properties of all non-Newtonian fluids from available literature. That is why several models of non-Newtonian fluids are proposed. Jeffery- six constant fluid is one of these models.

Free convection flow and heat transfer in hydromagnetic case is important in nuclear and space technology [Ganapathi[5], Nanda[9], Neeraja [11], Osterle [10], Roots [13], Singh [16], Yu et al[21]]. Chen and Yuh [3] have investigated the heat and mass transfer characteristics of natural convection flow along a vertical cylinder under the combined buoyancy effects of thermal and species diffusion. Antonio [1] has investigated the laminar flow, heat transfer in a vertical cylindrical duct by taking in to account both viscous dissipation and the effect of buoyancy. Philip [12] has obtained analytical solution for the annular porous media valid for low modified Reynolds number

In all the above investigations, the variation of density is taken in the linear form

$$\Delta\rho = -\rho\beta(\Delta T) \ldots \qquad .(A)$$

Where β is the co-efficient of thermal expansion and is 2.07 x 10^4 $(OC)^{-1+}$. This is valid for temperature variation near 20^0c. But this analysis is not applicable to the study of the flow of water at 4^0c, the density of water is maximum at atmosphere pressure and the above relations (A) does not hold good. The modified form of (A) is applicable to water at 4^0c is given by

$$\Delta\rho = -\rho\gamma(\Delta T)^2 \ldots \qquad ..(B)$$

where $\gamma = 8 \times 10^{-6}$ $(OC)^{-2}$. Taking this fact into account, Govindarajulu [7] showed that a similarity solution exists for the free convection flow of water at 4°c from vertical and horizontal plates in the presence of suction and injection. Soundalgekar [17] obtained an approximate solution of the same problem using Kraman – Pohlhausen integral method. Datta [4] has investigated the free convection of water at 4^0c from a horizontal plate when wall temperature varies as a power of distance along the plate. An approximate solution for velocity and temperature has been obtained by using Karman – Pohlhausen method together with the method of finding similarity solution. Using the relation (B) Gupta, Dubey and Sharma [8] have discussed the laminar free convection flow through coaxial circular cylinders with and without heat sources. Taking non-linear density temperature variation Sarojamma [14] has analysed the hydromagnetic free convection flow in a cylindrical geometry. Sastri and Vajravelu [15] have solved the problem of free convection between vertical walls by taking the non-linear density temperature variation, viz.,

$$\Delta\rho = -\rho\beta g\,(T - T_e) - \rho\beta_1 (T - T_e)^2 \qquad \ldots\ldots \qquad (C)$$

where β_0 and β_1 are constants. This relation includes both the relationships (A) and (B). Gilpin [6] has used a density temperature relation which is similar to relation (C) and has shown the existence of Quasi – steady modes of convection for some temperature below 4^0c. Bhargawa and Agarwal [2] have investigated the fully developed laminar free convection flow in the presence of constant heat source in a circular pipe taking the same density temperature relationship (C). It is found that the flow and heat transfer both depends up on a new parameter $\gamma = \left(\dfrac{\beta_1}{\beta_0}\right)\Delta T$ in addition to the heat source parameter and free convection parameter k.

The effect of heat transfer on MHD oscillatory flow of a Jeffrey fluid in a channel with slip effect at lower wall. The effects of various emerging parameters on the velocity and temperature are discussed through graphs in detail. Vasudev et al [20] have discussed the effect of Heat Transfer on the peristaltic flow of a Jeffery Fluid through a Porous medium in a vertical Annulus. Sreenath et.al [18] has investigated the effect of quadratic density temperature variation on convection heat transfer flow of a Jeffrey fluid in a tube and circular annulus.

In this paper we discuss the effect of non-linear density temperature variation on mixed convective heat and mass transfer flow of a Jeffrey's fluid through a porous medium in a circular annulus in the presence of constant heat sources. The equations governing the flow, heat and mass transfer have been solved by employing Gauss-Seidel iteration procedure. The effect of various governing parameters on the flow characteristics have been discussed graphically. The rate of heat and mass transfer are evaluated numerically for different variations.

2. FORMULATION OF THE PROBLEM

We analyze the fully developed steady laminar free convective flow of a viscous, electrically conducting Jeffrey fluid through a porous medium confined in an annular region between two vertical co-axial porous circular pipes in the presence of heat generating sources. We choose the cylindrical polar coordinates system O (r , θ , z) with the inner and outer cylinders at r =a and r = b respectively. The fluid is subjected to the influence of a radial magnetic field (H_0 / r). Pipes being sufficiently long, all the physical quantities are independent of the axial coordinate z. The fluid is chosen to be of small conductivity so that the Magnetic Reynolds number is much smaller than unity and hence the induced magnetic field is negligible compared to the applied radial field. Also the motion being rotationally symmetric the azimuthal velocity V is zero.

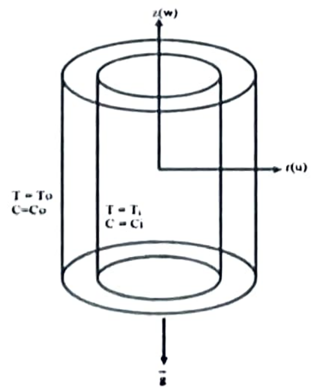

Fig.1:CONFIGURATION OF THE PROBLEM

The equations governing free convective heat and mass transfer flow under no pressure gradient are

$$\left.\begin{aligned} & w_{rr} + (1 - a\,u_a/\nu)\,w_r/r + ((\beta_0 g/\nu)(T - T_e) + (\beta_1 g/\nu)(T - T_e)^2 + \\ & + (\beta^\bullet g/\upsilon)(C - C_e)^\cdot\;(\sigma\mu_e^2 H_0^2 a^2/\nu(1+\lambda_1))(w/r^2) \\ & \qquad -(\nu/k(1+\lambda_1))\,w = 0 \end{aligned}\right\} \qquad (1)$$

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$$T_{rr} + (1 - au_a/\nu)T_r/r + (Q/k_f) + \frac{Q_1'}{k}(C - C_e) = 0 \quad (2)$$

$$C_{rr} + (1 - au_a/\nu)C_r/r - k_1C + k_{11}(T_{rr} + T_r/r) = 0 \quad (3)$$

Under the following non-dimensional variables (r', w', θ')

$r' = r/a$, $w' = w(a/\nu)$,

$$\theta = \frac{T - T_e}{T_i - T_e}, C' = \frac{C - C_e}{C_i - C_e} \quad (4)$$

the equations (1) –(3) reduce to

$$w_{rr} + (1-\lambda)(1/r)w_r - (D^{-1} + (M^2/(1+\lambda_1))r^2))$$
$$w = -(G/(1+\lambda_1))(\theta + \gamma_1\theta^2 + NC) \quad (5)$$

$$\theta_{rr} + (1 - \lambda P)\theta_r/r + \alpha + Q_1C = 0 \quad (6)$$

$$C_{rr} + (1 - \lambda Sc)C_r/r - (krSc)C = 0 \quad (7)$$

where

$M = (\sigma\mu_e^2 H_0^2 a^2/\rho\nu)^{1/2}$ (Hartmann number)

$G = (\beta g a^3(T_1 - T_e)^2/\nu^2)$ (Grashoff number)

$\lambda = a u_a/\nu$ (Suction parameter)

$D^{-1} = (a^2/k)$ (Darcy parameter)

$P = (\mu C_p/k_f)$ (Prandtl number)

$\alpha = \frac{QL^2}{\Delta T k_f}$ (Heat Source parameter)

$\gamma_1 = \frac{\beta_1\Delta T}{\beta_0}$ (non-linear density temperature ratio)

$Q_1 = \frac{Q_1'a^2\Delta c}{k_f\Delta T}$ (Radiation absorption parameter)

$\gamma = \frac{k_1a^2}{D_1}$ (Chemical reaction parameter)

$N = \frac{\beta^*\Delta C}{\beta\Delta T}$ (Density ratio)

$s = \frac{b}{a}$ (width of annular region)

The corresponding boundary conditions are

$w = 0, \theta = 1, C = 1$ on $r = 1$

$w = 0, \theta = 0, C = 0$ on $r = s$ (10)

The differential equations (7) - (9) have been discussed numerically by reducing the differential equations in difference equations which are solved using Gauss-Seidel Iteration method.

3. SHEAR STRESS, NUSSELT NUMBER AND SHERWOOD NUMBER

The shear stress on the pipe is given by $\tau' = \mu(\frac{\partial w}{\partial r})_{r=a,b}$

which in the non-dimensional form reduces to $\tau = \tau'/(\mu^2/a^2) = (w_r)_{r=1,s}$

The heat transfer through the pipe to the flow per unit area of the pipe surface is given by

$$q = k_1(\frac{\partial T}{\partial r})_{r=a}$$

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which in the non-dimensional form is $Nu = (\frac{qa}{k_1(T_1 - T_e)}) = (\frac{\partial \theta}{\partial r})_{r=1,s}$

The mass transfer through the pipe to the flow per unit area of the pipe surface in the non-dimensional form is $Sh = (\frac{q_1 a}{D_1(C_1 - C_e)}) = (\frac{\partial C}{\partial r})_{r=1,s}$

4. PARTICULAR CASE

In the absence of radiation absorption(Q1) the results are in good agreement with that of Suresh Babu et. al [19].

5. RESULTS AND DISCUSSION:

The equations governing the flow, heat and mass transfer have been solved by numerical technique. The velocity, temperature and concentration distributions have been discussed graphically for different parametric variations. The non-dimensional temperature convection is positive or negative according as the actual temperature (T) is greater / lesser than equilibrium temperature (Te). The non-dimensional concentration is positive or negative according as the actual concentration is greater/ lesser than the equilibrium concentration (C_∞).

Figures 2 – 10 represents the axial velocity w, the non-dimensional temperature distribution (θ), the non-dimensional concentration (C) for different values of N, α, Rd, γ, λ, Q1, λ_1, Sc and γ1.

Fig.2a represents w with buoyancy ratio(N). It can be seen from the velocity profiles that when the molecular buoyancy force dominates over the thermal buoyancy force the magnitude of the axial velocity enhances in the entire flow region and the region of reversal flow grows in size. Fig.2b shows the variation of θ with buoyancy ratio(N).It can be seen from the profiles that the actual temperature reduces in the region(1,1.5)and enhances in the region(1.5,2.0) irrespective of the directions of the buoyancy forces.

Fig.3a shows the variation of w with heat source parameter(α).We notice from the graphs that the magnitude of w enhances with increase in the strength of the heat source and reduces in the presence of sink. This is due to the fact that energy is created in the presence of source and absorbed in the presence of heat sink. Fig (3b) represents θ with heat source parameter (α). The actual temperature enhances with increase in α>0 and reduces with |α| (α<0) in the region (1,1.5) while in the region(1.5,2.0) it reduces with α>0 ,enhances with α<0. The region of reversal flow reduces with increased in α>0 and enhances with α<0.

The effect of thermal radiation (Rd) on w can be seen from (fig.4a). We find that higher the thermal heat flux larger the velocity in the annular region and the region of reversal flow reduces with increase in Rd. Higher the Thermal Radiation (Rd) larger the temperature (θ) in the flow region. (fig.4b).

The effect of chemical reaction (γ) on w can be seen from (fig.5a).The magnitude of w enhances in the degenerating chemical reaction case and reduces in the generating case in the region(1,1.5) a reversed effect is noticed in w in the region(1.5,2.0)..The region of reversal flow reduces in the region (1,1.5) and grows in the region(1.5,2). The effect of chemical reaction γ on θ can be seen from Fig (5b). It can be seen from the profiles that the actual temperature reduces in the degenerating chemical reaction case and enhances in the generating chemical reaction case in the region(1,1.5) while a reversed effect is noticed in the region(1.5,2). Fig (5c) represents the concentration with chemical reaction parameter γ. It can be seen from the profile that the actual concentration reduces ion the region(1,1.4) and enhances in(1.5,2.0) in the degenerating chemical reaction case while a reversed effect is observed in the actual concentration in the generating chemical reaction case and reduces in the generating chemical reaction case.

From fig.6a, we find that an increase in the suction parameter(λ).We observe that higher the suction parameter λ larger |w| in the flow region. The region of reversal flow grows in size with increase in λ. The effect of porosity of the boundary λ can be observed from Fig (6b). It is found that higher the suction parameter at the boundary larger the actual temperature in the flow region(1,1.5) and smaller in the region(1.5,2.0). The effect of suction parameter (λ) on C can be seen from (fig.6c).

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It can seen from the profiles that the actual concentration reduces in the region(1,1.4) and enhances in the region(1.5,2.0)with increase in suction parameter.

The effect of radiation absorption (Q1) on w can be seen from fig,7a. We find that higher the radiation absorption effects larger the magnitude of w in the flow region and region of reversal flow increases with increase in Q1. Higher the radiation absorption parameter (Q1) larger the actual temperature in the entire flow region (1.0, 2.0) (Fig.7b).

The effect of Jeffrey parameter (λ_1) on w can be seen from Fig (8a). It is found that |w| experiences a depreciation in the region(1,1,5)and enhancement in the region(1.5,2) and the region of reversal flow increases with λ1 in the entire flow region. Fig (8b) represents θ with Jeffrey parameter λ_1. It is found that the actual temperature enhances with increase in λ_1 in the region(1,1.5) and reduces in the region(1.5,2). Fig (8c) represents C with Jeffrey parameter λ_1. An increase in λ_1 leads to an enhancement in the region(1,1.4) and depreciates in the region(1.5,2.0) in the actual concentration.

Fig (9a) represents the effect of non-linear density temperature variation (γ1). It is found that the non-linearity in the density – temperature variation results in a depreciation in |w| in the flow region (1.5) and enhances in(1.5,2.0) and the region of reversal flow grows with increase in γ1. Fig (9b) represents θ with density ratio γ1. It is found that a non-linearity in the density temperature relation results in an enhancement in the region(1,1.,5) and depreciates in the region(1.5,2) in the actual temperature. The effect of non-linear density temperature variation (γ1) on C is shown in Fig (9c). We observe that the actual concentration enhances in the region(1,1.4) and reduces in (1.5,2.0) with increase in the density ratio γ1 in the entire flow region.

The actual concentration (C) enhances in the region(1,1.4) and reduces in the region(1.5,2.0) with increase in Sc (Fig 10).

The shear stress, Nusselt number and Sherwood number at the inner and outer cylinder r=1 & r=2 are shown in tables 1-2 for different parametric variations.

|τ| enhances with increase in the strength of the heat source and reduces with |α|at the inner cylinder r=1 while at the outer cylinder r=2,it reduces with $\alpha>0$ and enhances with $\alpha<0$.

The molecular buoyancy force (N) dominates over the thermal buoyancy force the stress (τ) enhances at r=1&2 when the buoyancy forces are in the same direction and for the forces acting in opposite directions, it reduces at both the cylinders. When the molecular Buoyancy force (N) dominates over the thermal Buoyancy force the rate of heat transfer (Nu) reduces at r=1 and enhances at r=2 when the buoyancy forces are in same direction and for the forces acting in opposite directions, it enhances at r=1 and reduces at r=2.

Higher the thermal radiation(Rd) larger the stress (τ) at r=1 and smaller at r=2. Higher the thermal radiation(Rd) smaller Nu at r=1 and larger at r=2.

An increase in radiation absorption(Q1) enhances the stress at both the cylinders. Nu experiences an enhancement with increase in radiation absorption(Q1).

The stress reduces at r=1 and reduces at r=2 also |τ| reduces with increase in suction parameter λ. An increase in λ reduces |Nu| at r=1 and enhances at r=2. An increase in λ depreciates |Sh| at r=1 and enhances it at r=2.

The stress enhances at r=1 and reduces at r=2 with increase in the Jeffrey parameter λ_1. An increase in λ_1 reduces |Nu| at r=1 and enhances at r=2. An increase in λ_1 depreciates |Sh| at r=1 and enhances it at r=2.

An increase in the density ratio γ1 results in a depreciation in |τ| at r= 1 and reduction at r= 2. An increase in the density ratio γ1 reduces |Nu| at both the cylinders. An increased γ1 enhances |Sh| at both the cylinder.

|τ| with chemical reaction parameter γ. It is found that the stress enhances at r=1 and reduces at r=2 in the degenerating chemical reaction case while it reduces at r=1 and enhances at r=2 in the generating chemical reaction case.

The variation of Nu with chemical reaction parameter γ shows that the rate of heat transfer reduces at r=1 and enhances at r=2 in the degenerating chemical reaction case while in the generating chemical reaction case it enhances at r=1 and reduces at r=2. The rate of mass transfer (Sh) enhances at r=1 & 2 in the degenerating chemical reaction (γ) case and reduces in the generating chemical reaction case at both the cylinders.

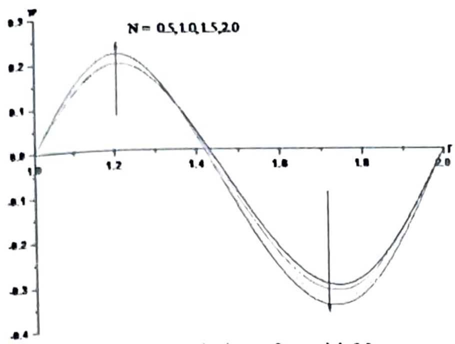

Fig. 2a: Variation of w with N

Q1=0.5, γ=0.5, α=2, λ=0.1, λ1=0.1, γ1=0.1, Rd=0.5

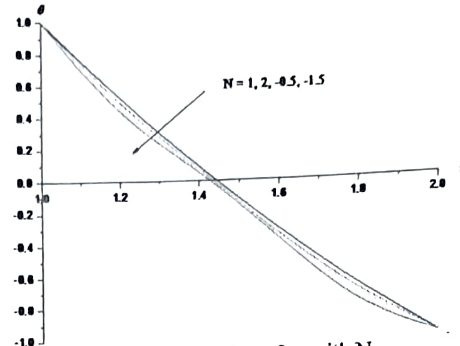

Fig. 2b: Variation of w with N

Q1=0.5, γ=0.5, α=2, λ=0.1, λ1=0.1, γ1=0.1, Rd=0.5

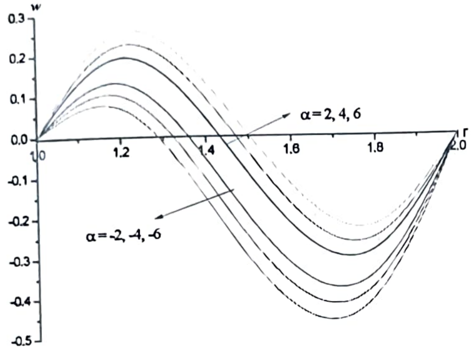

Fig. 3a : Variation of w with α

Q1=0.5, N=1, γ=0.5, λ1=0.1, λ=0.1, γ1=0.1, Rd=0.5

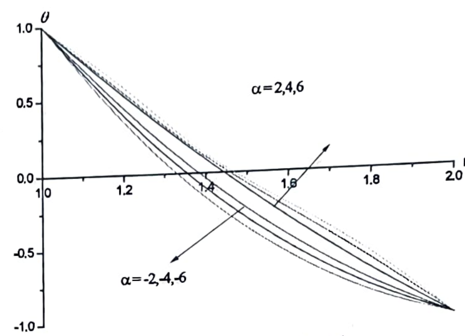

Fig. 3b : Variation of θ with α

Q1=0.5, γ=0.5, λ1=0.1, γ1=0.1, Rd=0.5

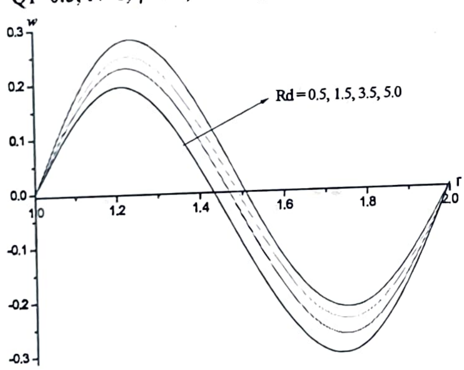

Fig. 4a : Variation of w with Rd

Q1=0.5, N=1, γ=0.5, λ1=0.1, λ=0.1, γ1=0.1

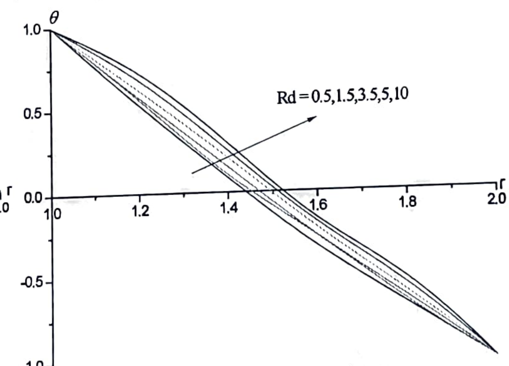

Fig.4b : Variation of θ with Rd

Q1=0.5, γ=0.5,λ1=0.1, γ1=0.1

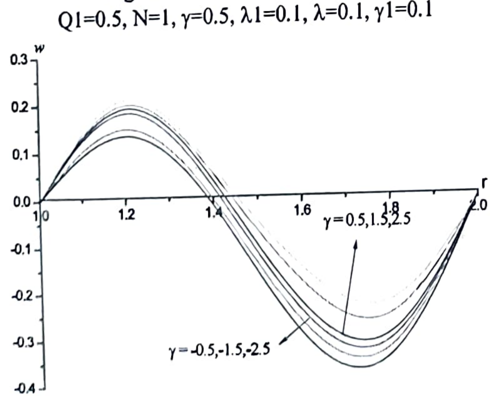

Fig. 5a : Variation of w with γ

Q1=0.5, N=1, α=2, λ1=0.1, λ=0.1, γ1=0.1, Rd=0.5

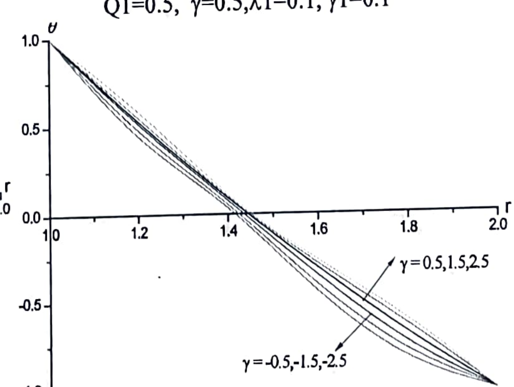

Fig. 5b : Variation of θ with γ

Q1=0.5, α=2, λ1=0.1, γ1=0.1, Rd=0.5

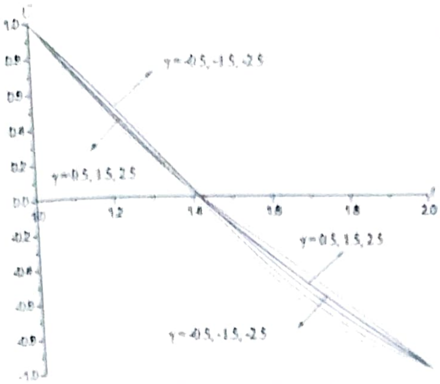

Fig. 5c : Variation of C with γ
Sc=1.3, λ1=0.1

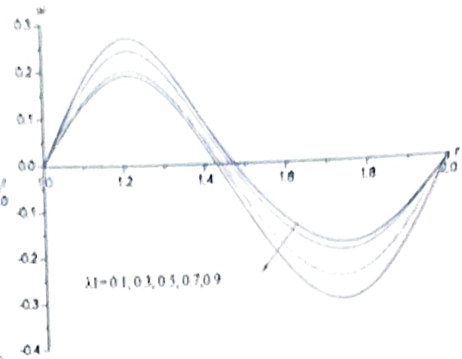

Fig.6a : Variation of w with λ
Q1=0.5, N=1, γ=0.5, α=2, λ1=0.1, γ1=0.1, Rd=0.5

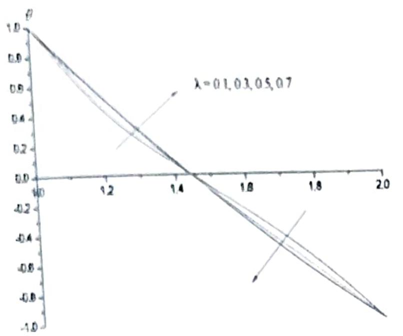

Fig. 6b : Variation of θ with λ
Q1=0.5, Sc=1.3 γ=0.5, α=2, λ1=0.1, γ1=0.1, Rd=0.5

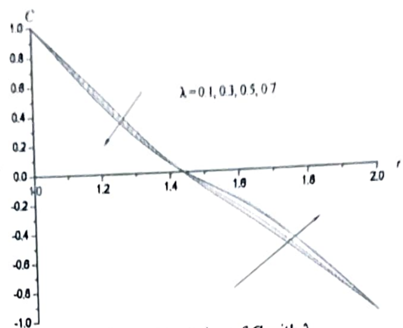

Fig. 6c : Variation of C with λ
Sc=1.3, λ1=0.1, γ=0.5

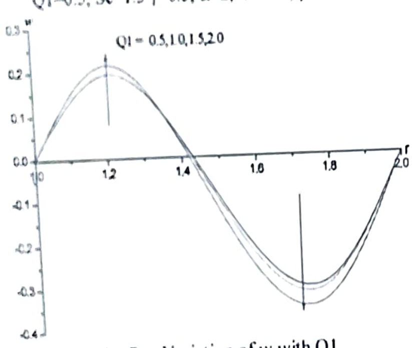

Fig. 7a : Variation of w with Q1
G=2, M=0.5, D^{-1}=0.2, N=1, γ=0.5,
Sc=1.3, α=2, λ1=0.1, λ=0.1, γ1=0.1, Rd=0.5

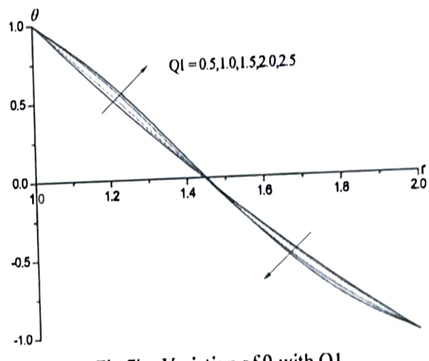

Fig.7b : Variation of θ with Q1
γ=0.5, α=2, λ1=0.1, γ1=0.1, Rd=0.5

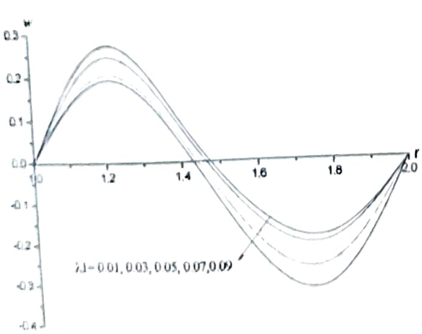

Fig. 8a : Variation of w with λ1
G=2, M=0.5, D^{-1}=0.2, Q1=0.5, N=1,
γ=0.5, Sc=1.3, α=2, λ=0.1, γ1=0.1, Rd=0.5

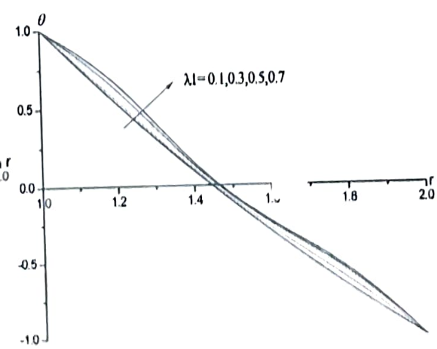

Fig. 8b : Variation of θ with λ1
Q1=0.5, γ=0.5, α=2, γ1=0.1, Rd=0.5

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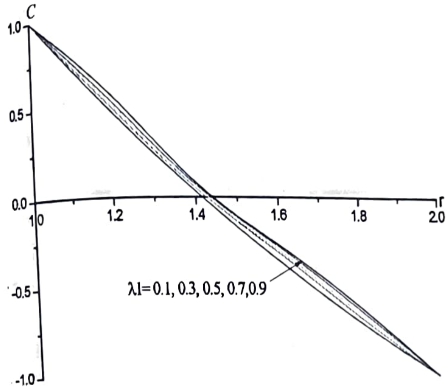

Fig. 8c : Variation of C with $\lambda 1$
$\gamma=0.5$, $Sc=1.3$

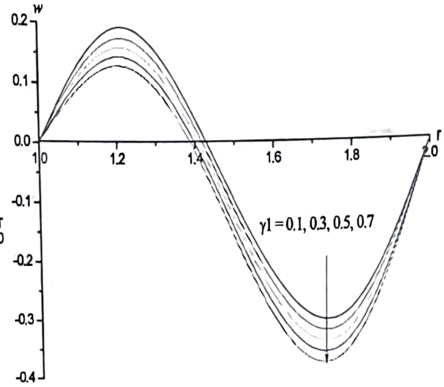

Fig. 9a : Variation of w with $\gamma 1$
$G=2$, $M=0.5$, $D^{-1}=0.2$, $Q1=0.5$, $N=1$,
$\gamma=0.5$, $Sc=1.3$, $\alpha=2$, $\lambda 1=0.1$, $\lambda=0.1$, $Rd=0.5$

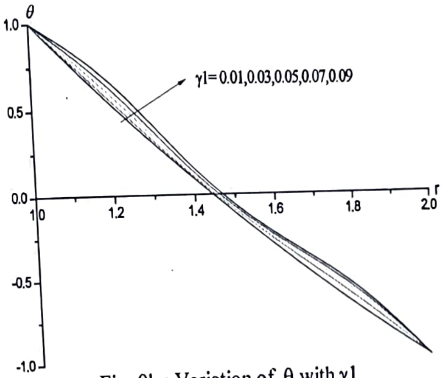

Fig. 9b : Variation of θ with $\gamma 1$
$Q1=0.5$, $\gamma=0.5$, $\alpha=2$, $\lambda 1=0.1$, $Rd=0.5$

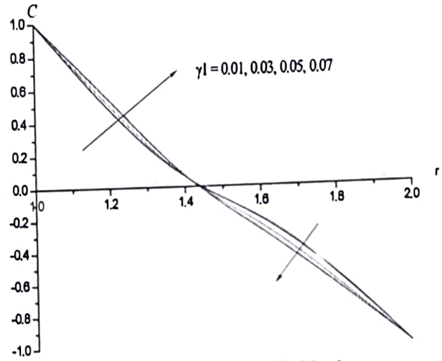

Fig. 9c : Variation of C with $\gamma 1$
$\gamma=0.5$, $Sc=1.3$

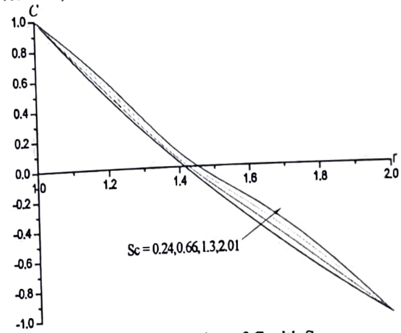

Fig. 10 : Variation of C with Sc
$\gamma=0.5$, $\lambda 1=0.1$

Table 1 : Shear stress (τ) at r = 1 & 2

Parameter		$\tau(1)$	$\tau(2)$	Parameter		$\tau(1)$	$\tau(2)$
N	**1.0**	2.91766	3.11779	γ	**0.5**	2.91766	3.11779
	2.0	4.28710	4.73808		**1.5**	5.93869	6.02293
	-0.5	0.86869	0.67679		**2.5**	2.96014	2.97127
	-1.5	0.44305	0.20108		**-0.5**	2.88197	-3.20945
					-1.5	2.83202	3.31845
					-2.5	2.76099	3.45197
α	**2.0**	2.91766	3.11779	λ	**0.1**	2.91766	3.11779
	4.0	3.10024	2.93088		**0.2**	2.84851	3.19290
	6.0	3.28258	2.74397		**0.3**	2.77976	3.26778
	-2.0	2.55423	3.48995		**0.5**	2.61101	3.34266
	-4.0	2.37297	3.67554				
	-6.0	2.19228	3.86061				

Parameter		τ(1)	τ(2)	Parameter		τ(1)	τ(2)
Rd	0.5	2.91766	3.11779	$\gamma 1$	0.01	2.91766	3.11779
	1.5	3.09967	2.97714		0.02	2.94851	3.09290
	3.5	3.23782	2.79126		0.03	2.97976	3.06778
	5.0	3.28444	2.74381		0.05	3.01101	3.04266
Q1	0.5	2.91766	3.11779	$\lambda 1$	0.1	2.91766	3.11779
	1.0	2.92183	3.16855		0.3	3.40782	3.627343
	1.5	2.92622	3.21908		0.5	3.88654	4.12175
	2.0	2.92876	3.24566		0.7	4.35453	4.60165

Table 2 : Nusselt number (Nu) and Sherwood number (Sh) at r = 1 & 2

Parameter		Nu(1)	Nu(2)	Sh(1)	Sh(2)
α	2	-2.48328	-1.20126	-------------	-------------
	4	-2.18269	-1.45121		
	-2	-3.08276	-0.70260		
	-4	-3.38203	-0.45367		
N	1.0	-2.48328	-1.20126	---------------	--------------
	2.0	-2.45599	-1.22173		
	-0.5	-2.50424	-1.18629		
	-1.5	-2.50558	-1.18556		
Rd	0.5	-2.48328	-1.20126	-------------	----------------
	1.5	-2.17792	-1.45028		
	3.5	-1.94434	-1.63810		
	5.0	-1.86529	-1.70110		
Q1	0.5	-2.48328	-1.20126	--------------	----------------
	1.0	-2.35539	-1.03650		
	1.5	-2.22713	-0.87198		
	2.0	-2.09929	-0.70721		
γ	0.5	-2.48328	-1.20126	-2.90203	-1.12071
	1.5	-2.48148	-1.20487	-2.97629	-1.31488
	2.5	-2.48020	-1.20799	-3.05714	-1.49484
	-0.5	-2.48581	-1.19704	-2.83854	-0.90856
	-1.5	-2.48933	-1.19199	-2.79097	-0.67371
λ	0.1	-2.48328	-1.20126	-2.90203	-1.12071
	0.3	-2.49148	-1.18487	-2.87629	-1.14488
	0.5	-2.51020	-1.16799	-2.77714	-1.16484
	0.7	-2.53581	-1.14704	-2.63854	-1.18856
$\gamma 1$	0.01	-2.48328	-1.20126	-2.90203	-1.12071
	0.03	-2.48304	-1.20116	-2.92629	-1.10488
	0.05	-2.48279	-1.20106	-2.97714	-1.08484
	0.07	-2.48255	-1.20096	-3.03854	-1.06856
$\lambda 1$	0.1	-2.48328	-1.20126	-2.90203	-1.12071
	0.3	-2.47533	-1.20671	-2.97629	-1.11488
	0.5	-2.46621	-1.21268	-3.08714	-1.10484
	0.7	-2.45693	-1.21912	-3.12854	-1.09856

6. CONCLUSIONS

- An increase in suction parameter(λ) enhances the velocity and temperature
- The axial velocity (w) and the temperature depreciates, the concentration reduces in the degenerating chemical reaction case and enhances in the generating chemical reaction case.
- Higher the radiation absorption parameter(Q1) $|w|$ and θ in the flow region. An increase in Q1enhances $|\tau|$ and reduces Nu at both the cylinders.

- |w| and θ experiences an enhancement with increasing Jeffrey parameter λ_1 whereas it leads to a depreciation in the actual concentration.
- Higher the suction parameter λ smaller |w| and large the temperature in the flow region.
- An increase in the density ratio γ1 results in an enhancement | at r= 1 & 2 where as it reduces |Nu|. |Sh| reduces at r=1 and enhances at r=2.
- An increase in λ1 enhances |τ| and reduces , |Nu| and |Sh| at r=1 while they enhance at r=2.
- Higher the radiation (Rd) larger |τ| ,smaller Nu at r=1and smaller |τ| and larger Nu at r=2.

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