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INFLUENCE OF MAGNETIC FIELD ON DISPERSION OF A SOLUTE IN PERISTALTIC FLOW OF A JEFFREY FLUID

G. Ravi Kiran and G. Radhakrishnamacharya
Department of Mathematics, National Institute of Technology, Warangal, India
E-Mail: grk.nitw@yahoo.com

ABSTRACT

In this paper, the dispersion of a solute in the peristaltic flow of a Jeffrey fluid in the presence of magnetic field with both homogeneous and heterogeneous chemical reactions has been discussed. The average effective dispersion co-efficient has been found using Taylor's limiting condition under long wavelength approximation. It is observed that the average dispersion co-efficient decreases with Jeffrey parameter λ_1 and magnetic parameter M in the cases of both homogeneous and combined homogeneous and heterogeneous chemical reactions. But, it increases with amplitude ratio which implies that dispersion is more in the presence of peristalsis. Further, dispersion decreases with homogeneous reaction rate parameter α and heterogeneous chemical reaction rate parameter β .

Keywords: Jeffrey fluid, dispersion, peristalsis, magnetic field, chemical reaction.

1. INTRODUCTION

The study of peristaltic transport has received considerable attention in the last few decades because of its significance in both physiological and mechanical situations. From fluid mechanical point of view, peristaltic motion is defined as the flow generated by a wave traveling along the walls of an elastic tube. In physiology, it may be described as a progressive wave of contraction seen in tubes or channels provided with transverse and muscular fibers. It consists in narrowing and transverse shortening of a portion of the tube, which then relaxes while the lower portion becomes shortened and narrowed. Peristalsis is known to be the main mechanism for fluid transport in many physiological situations such as transport of urine through ureter, food mixing and chyme movement in the intestines, blood flow in cardiac chambers etc. Also, roller and finger pumps use peristalsis for pumping blood and corrosive materials so as to prevent direct contact of the fluid with the pump's internal surfaces. Peristaltic pumping is used in biomedical devices like heart lung machine to pump blood. Hence, several authors have studied peristalsis in both physiological and mechanical situations (Fung and Yih [1], Shapiro *et al*., [2], Sankad and Radhakrishnamacharya [3]).

Most of bio-fluids such as blood exhibit the behavior of non-Newtonian fluids. Hence, the study of peristaltic transport of non-Newtonian fluids may help to get better understanding of the working of biological systems. Radhakrishnamacharya [4] studied long wavelength approximation to peristaltic motion of a power law fluid. Medhavi [5], Narahari and Sreenadh [6] studied peristaltic transport of non-Newtonian fluids under different conditions. Another non-Newtonian fluid that received considerable attention of researchers is Jeffrey fluid, which can be used to represent a physiological fluid. This model is a relatively simpler linear model which uses time derivatives instead of convective derivatives. It represents a rheology different from that of Newtonian fluid. Further, Jeffrey fluid model is significant because Newtonian fluid model can be deduced from this as a special case by taking $\lambda_1 = 0$. Some researchers have studied peristaltic motion of Jeffrey fluid under different conditions. Hayat *et al*., [7] analyzed three-dimensional flow of Jeffrey fluid. Vajravelu *et al*., [8] investigated the influence of heat transfer on peristaltic transport of a Jeffrey fluid. Pandey and Tripathi [9], Kothandapani and Srinivas [10] and Krishna Kumari *et al*., [11] have considered the peristaltic motion of a Jeffrey fluid.

It is well known that many physiological fluids and fluids in engineering systems possess electrically conducting properties. Magneto hydrodynamics (MHD) is the science which deals with the motion of a conducting fluid in the presence of a magnetic field. The motion of the conducting fluid across the magnetic field generates electric currents which change the magnetic field, and the action of the magnetic field on these currents gives rise to mechanical forces which modify the flow of the fluid. The effect of magnetic field on fluid flows finds applications in devices such as magneto hydrodynamic (MHD) power generators, MHD pumps, aerodynamics heating, purification of crude oil etc. It is also realized that the principles of magneto hydrodynamics find extensive applications in bioengineering and medical sciences. They include the development of magnetic devices for cell separation, targeted transport of drugs using magnetic particles as drug carriers, reduction of bleeding during surgeries and development of magnetic tracers. Hence, Sud *et al*., [12], Mekheimer [13], Ramana Kumari and Radhakrishnamacharya [14] have studied the effect of magnetic field on peristaltic transport under different conditions.

The dispersion of a soluble matter in fluids has many biological applications especially in the study of blood circulation. Several authors have studied various characteristics of dispersion in fluid dynamical situations which can be applied to biological systems. Dispersion of a solute in a viscous fluid flowing in a circular pipe under laminar conditions was studied by Taylor [15-17] and Aris [18]. In all these investigations, it is assumed that the

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solute does not chemically react in the liquid in which it is dispersed. However, in a wide variety of problems of chemical engineering, diffusion of a solute takes place with simultaneous chemical reaction in situations such as hydrolysis, gas absorption in an agitated tank, esterification (Padma and Ramana Rao [19]). Hence, Gupta and Gupta [20] and Padma and Ramana Rao [19], Ramana Rao and Padma [21, 22], Gupta and Chatterjee [23] dealt with the effect of chemical reaction on dispersion in Newtonian fluids. Dutta *et al*. [24], Chandra and Agarwal [25] studied dispersion in non-Newtonian fluids by considering only homogeneous first order chemical reaction in the bulk of the fluid. Philip and Chandra [26] also investigated the effects of heterogeneous and homogeneous reactions on the dispersion of a solute in simple micro fluid. Recently, Alemayehu and Radhakrishnamacharya [27, 28] studied the effect of dispersion on peristaltic flow of micropolar and couple stress fluids under different conditions.

Peristalsis and diffusion are very important aspects in biological systems. The effect of dispersion of a solute in peristaltic motion of a Jeffrey fluid in the presence of magnetic field has not received any attention. It is realized that magnetic field and peristalsis may have significant effect on the dispersion of a solute in the flow of conducting fluid and this may lead to better understanding of the flow situation in physiological systems. Hence in this paper the effect of dispersion of a solute in peristaltic flow of a Jeffrey fluid in the presence of magnetic field with simultaneous chemical reaction is studied. Using long wavelength approximation and Taylor's approach, closed form solution has been obtained for the dispersion co-efficient for both the cases of homogeneous first-order irreversible chemical reaction and combined first-order homogeneous and heterogeneous chemical reactions. The effects of various relevant parameters on the average effective dispersion co-efficient are studied.

2. MATHEMATICAL FORMULATION

Consider the dispersion of a solute in peristaltic flow of an electrically conducting Jeffrey fluid in a two dimensional channel of width 2d and with flexible walls on which are imposed traveling sinusoidal waves of long wavelength. Cartesian co-ordinate system (x,y) is chosen with x-axis aligned with the centre line of the channel. The traveling waves are represented by (Figure-1).

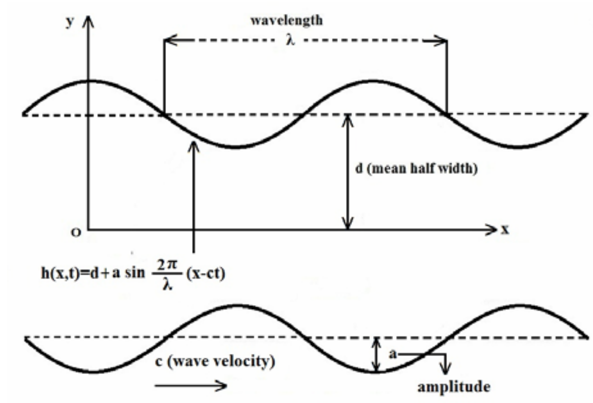

Figure-1. Geometry of the problem.

$$y = \pm h = \pm\left[d + a\sin\frac{2\pi}{\lambda}\left(x - ct\right)\right] \tag{1}$$

where a is the amplitude, c is the speed and λ is the wavelength of the peristaltic wave.

The constitutive equations for an incompressible Jeffrey fluid [7 - 11] are

$$\overline{T} = -\overline{P}\overline{I} + \overline{S} \tag{2}$$

$$\overline{S} = \frac{\mu}{1+\lambda_1}\left(\dot{\gamma} + \lambda_2\ddot{\gamma}\right) \tag{3}$$

where $\overline{T}, \overline{S}$ are Cauchy stress tensor and extra stress tensor respectively, $\overline{P}$ is the pressure, $\overline{I}$ is the identity tensor, λ_1 is the ratio of relaxation to retardation times, λ_2 is the retardation time, μ is the dynamic viscosity, $\dot{\gamma}$ is the shear rate and dots over the quantities indicate differentiation with respect to time.

The equations governing two-dimensional motion of an incompressible, MHD Jeffrey fluid are reduced to

$$\rho\left[\frac{\partial}{\partial t} + u\frac{\partial}{\partial x} + v\frac{\partial}{\partial y}\right]u = -\frac{\partial p}{\partial x} + \frac{\partial S_{xx}}{\partial x} + \frac{\partial S_{xy}}{\partial y} - \sigma B_0^2 u \tag{4}$$

$$\rho\left[\frac{\partial}{\partial t} + u\frac{\partial}{\partial x} + v\frac{\partial}{\partial y}\right]v = -\frac{\partial p}{\partial y} + \frac{\partial S_{yy}}{\partial y} + \frac{\partial S_{yx}}{\partial x} \tag{5}$$

and

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \tag{6}$$

where u,v are the velocity components in the x and y directions respectively, p is the pressure, ρ is the density and S_{xx}, S_{xy}, S_{yx}, S_{yy} are extra stress components.

Under long wavelength approximation, the governing equations for the present problem reduces to,

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$$\frac{\partial p}{\partial x}=\frac{\mu}{1+\lambda_1}\frac{\partial^2 u}{\partial y^2}-\sigma B_0^2 u \tag{7}$$

$$\frac{\partial p}{\partial y}=0 \tag{8}$$

and

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0 \tag{9}$$

We assume that the walls are inextensible so that only lateral motion takes place and the horizontal displacement of the wall is zero.

Thus the no-slip boundary condition for the velocity is given by,

$$u=0 \text{ at } y=\pm h \tag{10}$$

Solving (7) and (8) under the boundary conditions (10), we get

$$u(y)=\frac{1}{\sigma B_0^2}\frac{\partial p}{\partial x}\left[\frac{\cosh(\delta y)}{\cosh(\delta h)}-1\right] \tag{11}$$

$$\text{where } \delta=\sqrt{\frac{\sigma(1+\lambda_1)}{\mu}}B_0 \tag{12}$$

Further, the mean velocity is defined as

$$\bar{u}=\frac{1}{2h}\int_{-h}^{h}u(y)dy \tag{13}$$

Substituting (11) in (13), we get

$$\bar{u}=\frac{1}{h}\frac{1}{\sigma B_0^2}\frac{\partial p}{\partial x}\left[\frac{1}{\delta}\tanh(\delta h)-h\right] \tag{14}$$

If we now consider convection across a plane moving with the mean speed of the flow, then relative to this plane, the fluid velocity is given by

$$u_x=u-\bar{u} \tag{15}$$

Substituting (11) and (14) in (15), we get

$$u_x=\frac{1}{\delta h\sigma B_0^2}\frac{\partial p}{\partial x}\left[\frac{1}{\cosh(\delta h)}\left(\delta h\cosh(\delta y)-\sinh(\delta h)\right)\right] \tag{16}$$

2.1. Diffusion with a homogeneous first order chemical reaction

It is assumed that a solute diffuses and simultaneously undergoes a first order irreversible chemical reaction in peristaltic transport of Jeffrey fluid in a channel under isothermal conditions. Using Taylor's approximation, i.e., $\frac{\partial^2 C}{\partial x^2}<<\frac{\partial^2 C}{\partial y^2}$, the equation for the concentration C of the solute for the present problem is given by

$$\frac{\partial C}{\partial t}+u\frac{\partial C}{\partial x}=D\frac{\partial^2 C}{\partial y^2}-k_1 C \tag{17}$$

where D is the molecular diffusion co-efficient and k_1 is the first order reaction rate constant.

For typical values of relevant parameters of this problem, it is realized that $\bar{u}=c$. Using this condition and making use of the following dimensionless quantities,

$$\theta=\frac{t}{\bar{t}},\ \bar{t}=\frac{\lambda}{\bar{u}},\ \eta=\frac{y}{d},\ \xi=\frac{(x-\bar{u}t)}{\lambda},\ H=\frac{h}{d} \tag{18}$$

equations (16) and (17) reduce to

$$\begin{aligned}u_x=&\frac{d^2}{\mu\sqrt{1+\lambda_1}}\frac{1}{M^3}\frac{\partial p}{\partial x}\frac{1}{\cosh(HM\sqrt{1+\lambda_1})}\\&\left[M\sqrt{1+\lambda_1}\cosh(M\sqrt{1+\lambda_1}\eta)-\frac{1}{H}\sinh(HM\sqrt{1+\lambda_1})\right]\end{aligned} \tag{19}$$

$$\frac{\partial^2 C}{\partial \eta^2}-\frac{k_1 d^2}{D}C=\frac{d^2}{\lambda D}u_x\frac{\partial C}{\partial \xi} \tag{20}$$

where $\delta d=M\sqrt{1+\lambda_1}$ and $M=\sqrt{\frac{\sigma}{\mu}}B_0 d$ is the Hartmann number. (21)

Assuming that there is no absorption at the walls, the boundary conditions for the concentration C are,

$$\frac{\partial C}{\partial \eta}=0 \text{ for } \eta=\pm H=\pm[1+\varepsilon\sin(2\pi\xi)] \tag{22}$$

where $\varepsilon=\frac{a}{d}$ is the amplitude ratio.

Assuming that $\frac{\partial C}{\partial \xi}$ is independent of η at any cross section and solving (20) under the boundary conditions (22), the solution for the concentration of the solute C is given as

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$$C(\eta)=\left[-\frac{d^4}{\lambda\mu D}\frac{\partial C}{\partial \xi}\frac{\partial p}{\partial x}\right]\left[l_1\cosh(\alpha\eta)+l_2\cosh(M\sqrt{1+\lambda_1}\eta)+l_3\right] \quad (23)$$

where

$$l_1=\frac{\sqrt{1+\lambda_1}}{M}\frac{1}{M^2(1+\lambda_1)-\alpha^2}\frac{\tanh(HM\sqrt{1+\lambda_1})}{\alpha\sinh(\alpha H)} \quad (24)$$

$$l_2=\frac{-1}{M^2}\frac{1}{M^2(1+\lambda_1)-\alpha^2}\frac{1}{\cosh\left(HM\sqrt{1+\lambda_1}\right)} \quad (25)$$

$$l_3=\frac{-1}{\alpha^2 H}\frac{1}{M^3\sqrt{1+\lambda_1}}\tanh(HM\sqrt{1+\lambda_1}) \quad (26)$$

$$\text{and } \alpha=\left(\frac{k_1 d^2}{D}\right)^{\frac{1}{2}} \quad (27)$$

The volumetric rate Q at which the solute is transported across a section of the channel of unit breadth is defined by

$$Q=\int_{-H}^{H} C u_x\, d\eta \quad (28)$$

Substituting (19) and (23) in (28), we get the volumetric rate Q as

$$Q=-2\frac{d^6}{\lambda\mu^2 D}\frac{\partial C}{\partial \xi}\left(\frac{\partial p}{\partial x}\right)^2 F(\xi,\alpha,\varepsilon,\lambda_1,M) \quad (29)$$

where

$$\begin{aligned}F(\xi,\alpha,\varepsilon,\lambda_1,M)&=m_1\Big[M\sqrt{1+\lambda_1}\cosh(\alpha H)\\&\sinh(HM\sqrt{1+\lambda_1})-\alpha\cosh(HM\sqrt{1+\lambda_1})\sinh(\alpha H)\Big]\\&-m_2\left[\frac{\sinh(\alpha H)}{\alpha}\right]+m_3\left[\frac{H}{2}+\frac{\sinh(2HM\sqrt{1+\lambda_1})}{2M\sqrt{1+\lambda_1}}\right]\\&+(m_5-m_4)\left[\sinh\left(HM\sqrt{1+\lambda_1}\right)\right]-m_6.\end{aligned} \quad (30)$$

where

$$m_1=\frac{\sqrt{1+\lambda_1}}{\alpha M^3}\frac{\tanh(HM\sqrt{1+\lambda_1})\operatorname{sec}h(HM\sqrt{1+\lambda_1})}{\left[M^2(1+\lambda_1)-\alpha^2\right]^2\sinh(\alpha H)}$$

$$m_2=\frac{1}{HM^4}\frac{1}{M^2(1+\lambda_1)-\alpha^2}\frac{\left[\tanh(HM\sqrt{1+\lambda_1})\right]^2}{\alpha\sinh(\alpha H)}$$

$$m_3=\frac{-1}{M^4}\frac{1}{M^2(1+\lambda_1)-\alpha^2}\left[\operatorname{sec}h(HM\sqrt{1+\lambda_1})\right]^2$$

$$m_4=\frac{-1}{M^6}\frac{\tanh(HM\sqrt{1+\lambda_1})\operatorname{sec}h(HM\sqrt{1+\lambda_1})}{H(1+\lambda_1)\left[M^2(1+\lambda_1)-\alpha^2\right]}$$

$$m_5=\frac{-1}{M^6}\frac{\tanh(HM\sqrt{1+\lambda_1})\operatorname{sec}h(HM\sqrt{1+\lambda_1})}{\alpha^2 H(1+\lambda_1)}$$

$$m_6=\frac{-1}{M^6}\frac{\left[\tanh(HM\sqrt{1+\lambda_1})\right]^2}{\alpha^2 H(1+\lambda_1)}$$

Comparing (29) with Fick's first law of diffusion, we find that the solute is dispersed relative to a plane moving with the mean speed of the flow with an effective dispersion co-efficient D^* given by

$$D^*=2\frac{d^6}{\mu^2 D}\left(\frac{\partial p}{\partial x}\right)^2 F(\xi,\alpha,\varepsilon,\lambda_1,M) \quad (31)$$

Let the average of F be $\overline{F}$, and is defined by

$$\overline{F}=\int_0^1 F(\xi,\alpha,\varepsilon,\lambda_1,M)\,d\xi \quad (32)$$

2.2. Diffusion with combined homogeneous and heterogeneous chemical reactions

We now discuss the problem of diffusion with a first-order irreversible chemical reaction taking place both in the bulk of medium (homogeneous) as well as at the walls (heterogeneous) of the channel which are assumed to be catalytic to chemical reaction. The simplified diffusion equation is same as (17).

The differential material balance at the walls as in Philip and Chandra [26] gives the boundary conditions as

$$\frac{\partial C}{\partial y}+fC=0 \text{ at } y=h=\left[d+a\sin\frac{2\pi}{\lambda}(x-\bar{u}t)\right] \quad (33)$$

$$\frac{\partial C}{\partial y}-fC=0 \text{ at } y=-h=-\left[d+a\sin\frac{2\pi}{\lambda}(x-\bar{u}t)\right] \quad (34)$$

where fC gives the surface reaction rate parameter.

If we introduce the dimensionless variables (18), the diffusion equation remains as (21) and the boundary conditions become

$$\frac{\partial C}{\partial \eta} + \beta C = 0 \text{ at } \eta = H = [1 + \varepsilon \sin(2\pi\xi)] \tag{35}$$

$$\frac{\partial C}{\partial \eta} - \beta C = 0 \text{ at } \eta = -H = -[1 + \varepsilon \sin(2\pi\xi)] \tag{36}$$

where $\beta = fD$ is the heterogeneous reaction rate parameter corresponding to catalytic reaction at the walls.

The solution of (20) under the boundary conditions (35) and (36) is,

$$C(\eta) = \left[\frac{d^4}{\lambda\mu D}\frac{\partial C}{\partial \xi}\frac{\partial p}{\partial x}\right]\left[\frac{-A}{L}\cosh(\alpha\eta) + \frac{1}{M^2}\frac{1}{M^2(1+\lambda_1)-\alpha^2}\frac{\cosh(M\sqrt{1+\lambda_1}\eta)}{\cosh(HM\sqrt{1+\lambda_1})} + \frac{1}{M^3}\frac{1}{\alpha^2 H\sqrt{1+\lambda_1}}\tanh(HM\sqrt{1+\lambda_1})\right] \tag{37}$$

where

$$A = \left[\frac{1}{M}\frac{\sqrt{1+\lambda_1}}{M^2(1+\lambda_1)-\alpha^2}\tanh(HM\sqrt{1+\lambda_1})\right] + \beta\left[\frac{1}{M^2}\frac{1}{M^2(1+\lambda_1)-\alpha^2} + \frac{1}{M^3}\frac{1}{H\alpha^2\sqrt{1+\lambda_1}}\tanh(HM\sqrt{1+\lambda_1})\right] \tag{38}$$

and $L = \alpha\sinh(\alpha H) + \beta\cosh(\alpha H)$ (39)

The volumetric rate Q at which the solute is transported across a section of the channel of unit breadth is defined by

$$Q = \int_{-H}^{H} C u_x \, d\eta \tag{40}$$

Substituting (19) and (37) in (40), we get the volumetric rate Q as

$$Q = -2\frac{d^6}{\lambda\mu^2 D}\frac{\partial C}{\partial \xi}\left(\frac{\partial p}{\partial x}\right)^2 G(\xi,\alpha,\beta,\varepsilon,\lambda_1,M) \tag{41}$$

where

$$\begin{aligned} G(\xi,\alpha,\beta,\varepsilon,\lambda_1,M) = {} & \left[\frac{A}{LM^2}\frac{1}{M^2(1+\lambda_1)-\alpha^2}\right]\left[M\sqrt{1+\lambda_1}\cosh(\alpha H)\tanh(HM\sqrt{1+\lambda_1}) - \alpha\sinh(\alpha H)\right] \\ & - \left[\frac{A}{LHM^3\sqrt{1+\lambda_1}}\frac{\sinh(\alpha H)}{\alpha}\tanh(HM\sqrt{1+\lambda_1})\right] \\ & - \left[\frac{1}{M^4}\frac{1}{M^2(1+\lambda_1)-\alpha^2}\left(\operatorname{sec}h(HM\sqrt{1+\lambda_1})\right)^2 \left[\frac{H}{2} + \frac{\sinh(2HM\sqrt{1+\lambda_1})}{4M\sqrt{1+\lambda_1}}\right] + \left[\frac{1}{HM^6(1+\lambda_1)}\right.\right. \\ & \left.\left. \frac{1}{M^2(1+\lambda_1)-\alpha^2}\left(\tanh(HM\sqrt{1+\lambda_1})\right)^2\right]\right] \end{aligned} \tag{42}$$

Comparing (41) with Fick's first law of diffusion, we find that the solute is dispersed relative to a plane moving with the mean speed of the flow with an effective dispersion co-efficient D^* given by

$$D^* = 2\frac{d^6}{\mu^2 D}\left(\frac{\partial p}{\partial x}\right)^2 G(\xi,\alpha,\beta,\varepsilon,\lambda_1,M) \tag{43}$$

Let the average of G be $\overline{G}$, and is defined by

$$\overline{G} = \int_0^1 G(\xi,\alpha,\beta,\varepsilon,\lambda_1,M)\,d\xi \tag{44}$$

3. RESULTS AND DISCUSSIONS

The effects of various parameters on the average effective dispersion coefficient can be observed through the functions $\overline{F}$ and $\overline{G}$ given by equations (32) and (44), respectively. The expressions for $\overline{F}$ and $\overline{G}$ have been obtained by numerical integration using MATHEMATICA software for different values of relevant parameters and presented graphically. The important parameters involved in the expressions are: the amplitude ratio ε, the homogeneous reaction rate parameter α, the heterogeneous reaction rate parameter β, the Jeffrey parameter λ_1 and the Hartmann number M.

3.1. Homogeneous chemical reaction

Figures 2-8 show the effects of various parameters on dispersion in the presence of homogeneous chemical reaction in the bulk of the medium. It can be noticed that the average effective dispersion co-efficient $\overline{F}$ increases with amplitude ratio ε (Figures 2-3). This may mean that peristalsis enhances dispersion.

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It can be observed that the average effective coefficient of dispersion decreases with homogeneous chemical reaction rate parameter α (Figures 3-8). This result agrees with that of Gupta and Gupta [20], Dutta *et al*., [24], Ramana Rao and Padma [21, 22], Padma and Ramana Rao [19]. This result is expected since increase in α leads to increasing number of moles of solute undergoing chemical reaction and this result in the decrease of dispersion.

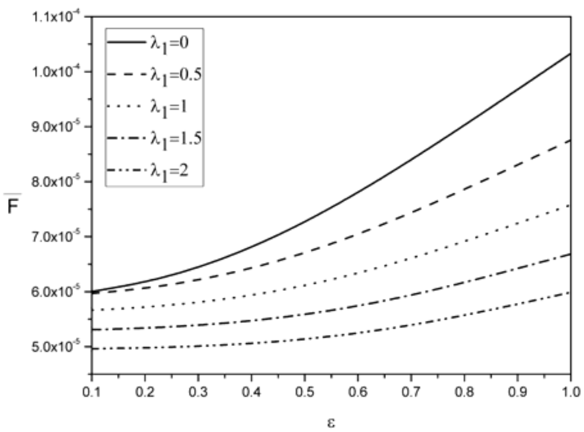

Figure-2. Effect of λ_1 on $\overline{F}$ (M=3, α =1).

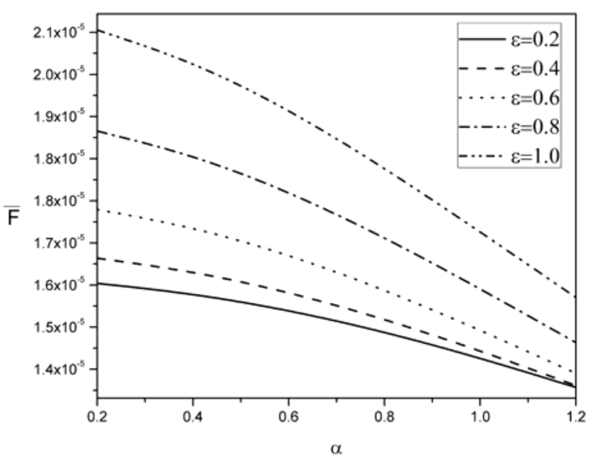

Figure-3. Effect of ε on $\overline{F}$ (λ_1=1, M=4).

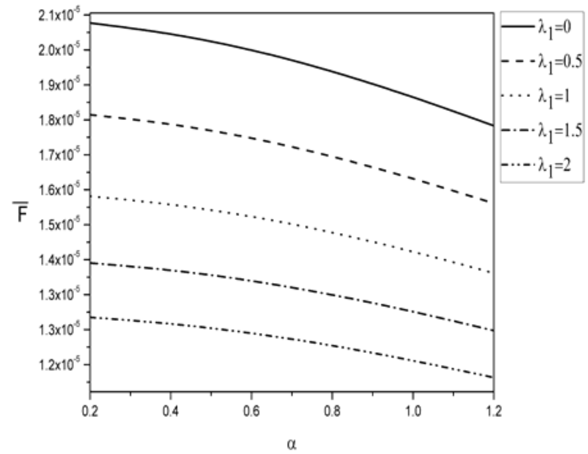

Figure-4. Effect of λ_1 on $\overline{F}$ (M=4, ε=0.2).

The effective dispersion co-efficient decreases with Jeffrey parameter λ_1 (Figures 2, 4 and 5) and Hartmann number M (Figures 6-8). This result is expected since the velocity profile becomes flatter with the increase of Hartmann number M, when compared to the profiles of non-magnetic case and for a fixed pressure gradient the flow rate decreases with increase in M. The result that dispersion decreases with Hartmann number M agrees with the results obtained by Ramana Rao and Padma [21, 22], Gupta and Chatterjee [23], Alemayehu and Radhakrishnamacharya [27, 28].

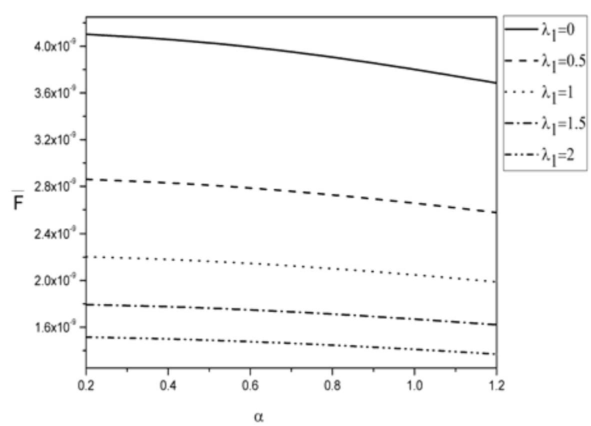

Figure-5. Effect of λ_1 on $\overline{F}$ (M=20, ε=0.2).

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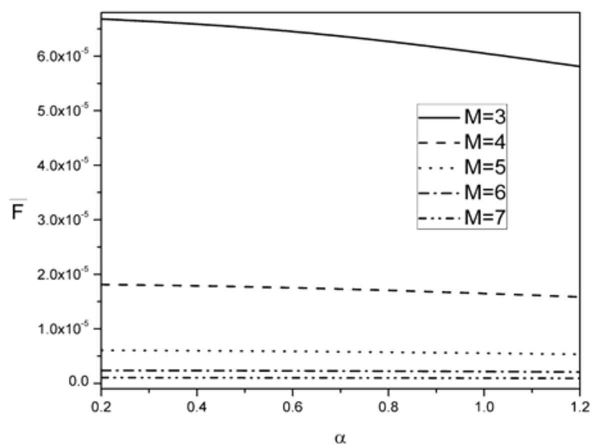

Figure-6. Effect of M on $\overline{F}$ (λ_1=0.5, ε=0.2).

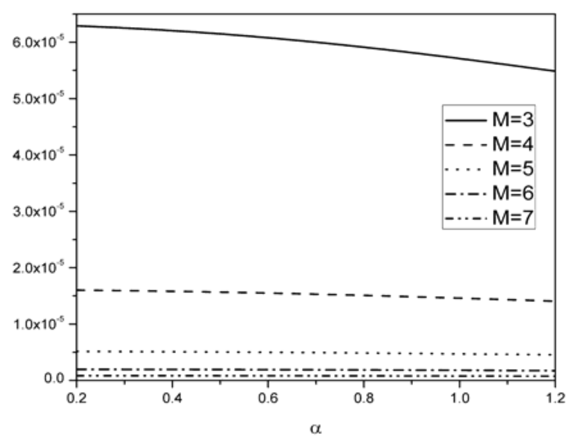

Figure-7. Effect of M on $\overline{F}$ (λ_1=1, ε=0.2).

3.2. Combined homogeneous and heterogeneous chemical reactions

Figures 9-13 display the effects of various parameters on the average effective dispersion co-efficient $\overline{G}$ for the case of combined first order chemical reaction both in the bulk and at the walls. It can be seen that the average effective dispersion co-efficient $\overline{G}$ increases with amplitude ratio ε (Figures 9-10). This implies that peristalsis enhances dispersion of a solute in fluid flow. This result is same as that obtained in the case of homogeneous reaction.

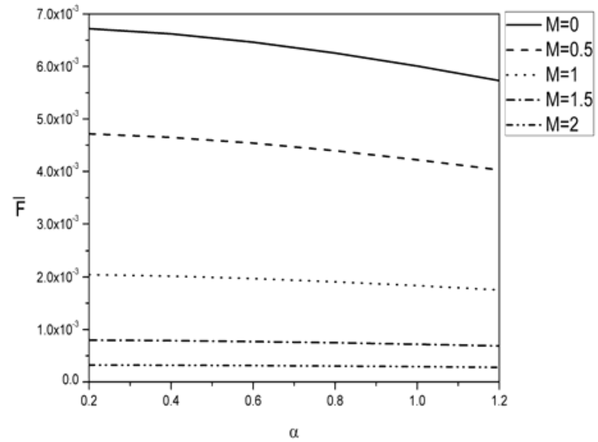

Figure-8. Effect of M on $\overline{F}$ (λ_1=0.5, ε=0.2).

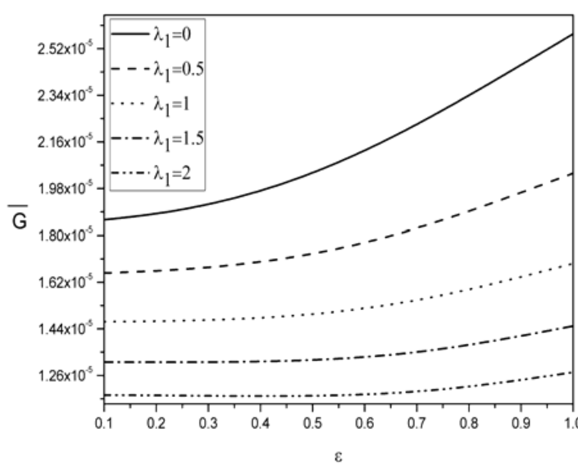

Figure-9. Effect of λ_1 on $\overline{G}$ (β =5, α=0.5, M=4).

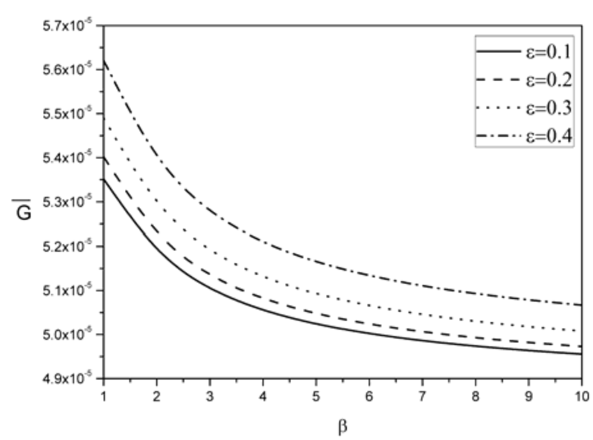

Figure-10. Effect of ε on $\overline{G}$ (λ_1=0.5, α=0.5, M=4).

The average effective dispersion co-efficient $\overline{G}$ decreases with Jeffrey parameter λ_1 (Figures 9, 11 and 14) and Hartmann number M (Figures 12 and 13). These results are same as that obtained in the case of homogeneous reaction. It is also observed that the average effective dispersion co-efficient decreases with homogeneous chemical reaction rate parameter α (Figure-14) and heterogeneous reaction rate parameter β (Figures 10-13).

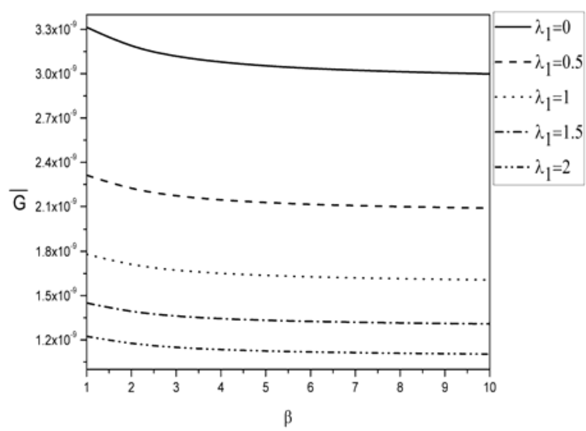

Figure-11. Effect of λ_1 on $\overline{G}$ (ε=0.2, α=1, M=20).

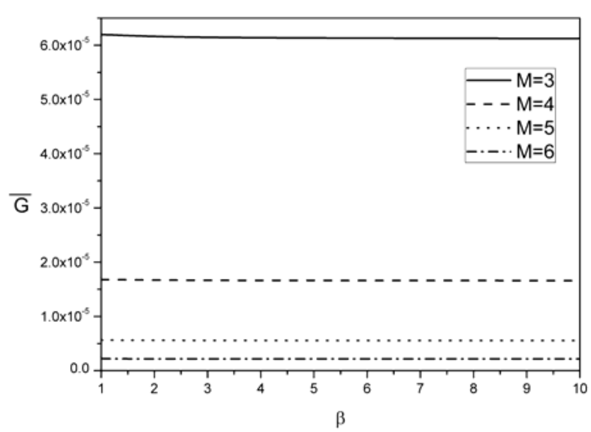

Figure-12. Effect of M on $\overline{G}$ (ε=0.2, α=0.5, λ_1=0.5).

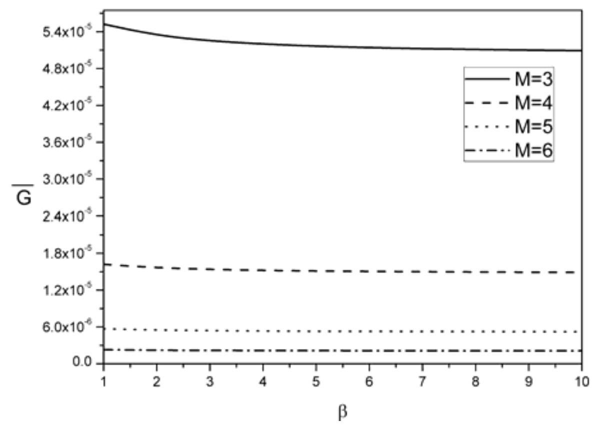

Figure-13. Effect of M on $\overline{G}$ (ε=0.2, α=1, λ1=0.1).

4. CONCLUSIONS

The dispersion of a solute in peristaltic motion of a Jeffrey fluid in the presence of magnetic field with both homogeneous and heterogeneous chemical reactions has been studied under long wavelength approximation and Taylor's limiting condition. It is observed that peristaltic motion enhances dispersion and dispersion decreases with Jeffrey parameter λ_1 and Hartmann number M in the cases of both homogeneous and combined homogeneous and heterogeneous chemical reactions. Further, average dispersion co-efficient decreases with homogeneous reaction rate parameter α and heterogeneous reaction rate parameter β .

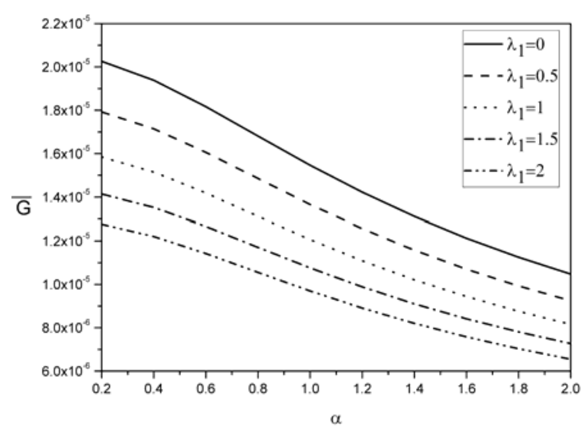

Figure-14. Effect of λ_1 on $\overline{G}$ (ε=0.2, β =5, M = 4).

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