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EFFECT OF COMPLAINT WALLS ON MAGNETO-HYDRODYNAMIC PERISTALTIC PUMPING OF AN INCOMPRESSIBLE VISCOUS FLUID WITH CHEMICAL REACTIONS

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ABSTRACT

In the present study, an analytical investigation on the effect of complaint walls and chemical reactions on the magneto-hydrodynamic peristaltic pumping of an incompressible viscous fluid is carried out as a model of transport phenomena occurring in the small intestine of human being during digestion process. The mean effective coefficient of dispersion on simultaneous homogeneous and heterogeneous chemical reactions has been deliberated through long wavelength hypothesis and condition of Taylor's limit. The impacts of penetrating parameters on the mean effective dispersion coefficient have been inspected through the graphs. It is noticed that wall parameters (rigidity, stiffness, damping force), and amplitude ratio favor the dispersion, while magnetic parameter resist the dispersion.

Keywords: chemical reaction, dispersion, Newtonian fluid, peristaltic motion, wall properties.

1. INTRODUCTION

The dispersion of a solute in a solvent flowing in a channel has applications in physiological fluid dynamics, biomedical and chemical engineering. Dispersion plays a crucial task in chyme transport in small intestine, other applications like environmental pollutant transportation, chromatographic separation, the mixing and transport of drugs or toxic substances in physiological structures (Ng, 2006). The basic theory on dispersion was first proposed by Taylor (1953), who investigated theoretically and experimentally that the distribution of a solute is mixed with a liquid flowing throughout a channel. Aris (1956), Padma and Rao (1975), Gupta and Gupta (1972), Sobh (2013) have been reported the distribution of a substance in viscous fluid, under different limitations. Furthermore, Dutta et al. (1974), Agarwal and Chandra (1983), Chandra and Philip (1993), Alemayehu and Radhakrishnamacharya (2010), Hayat *et al.* (2014), Ravikiran and Radhakrishnamacharya (2015a, 2015b), Hayat *et al.* (2015, 2016), extended this analysis to non Newtonian fluids.

Peristalsis is the most important method of transporting many physiological liquids. It is utilized by several systems in the living body to push or to mix up the substances of a hose. The chemical reactions take place at every stage of digestive process. The digestive process commences in the mouth, after being chewed and swallowed, the food enters the oesophagus, stomach. It is ousted from the stomach into the duodenum and moves through small intestine. The peristaltic flows in the small intestine and chemical reaction are important factors in composite physiological procedures (Taghipoor *et al.* (2012); Robert (2005); Tharakan *et al.* (2010)). This mechanism is used in some biomedical devices: hose pumps, finger and roller pumps that is used to force blood, slurries, and other fluids. Peristaltic action is also involved in eggs movement in the female fallopian tube and advancement of bile in the bile funnel. In the view of its importance, some workers (Fung and Yih (1968), Jaffrin *et al.* (1969), El Naby *et al.* (2006) and Takagi and Balmforth (2011)) have explored the peristaltic transport of different liquids under various circumstances. Mittra and Prasad (1973) examined the effects of wall on Poiseuille flow with peristalsis. In addition, Ellahi et al. (2016), Hina et al. (2015), Muttu *et al.* (2003), Riaz *et al.* (2014), and Sankad and Radhakrishnamacharya (2009) have reported the wall effects on non-Newtonian fluids in peristaltic pumping.

Magnetohydrodynamic (MHD) peristaltic flow nature of liquid is especially imperative in mechanical and physiological procedures. In the existence of magnetic field, many fluids posses an electrically conducting nature, which is an important aspect of the physical circumstances in the flow issues of magnetohydrodynamics. It is useful for tumor treatment, MRI glancing, blood pumping, lessen the flow of blood during surgeries, targeted transportation of drugs, and so on. Magneto-therapy is an essential application to human body. This heals the diseases like ulceration, inflammations and diseases of uterus. Some researchers have explored the magneto hydrodynamic character of incompressible viscous liquids through different conditions (Mekheimer *et al.* (2008), Sobh (2009)). They discussed the effects of magnetic field, permeability, and wall parameters.

Diffusion, peristalsis are more essential characteristics in bio-medical and chemical processes. The liquids present in the ducts of living being can be classified as Newtonian and non-Newtonian fluids based on their behavior. Motivated from the reported literature, a mathematical model of transport phenomena occurring in the small intestine of human being during digestion process is prepared. The present study examines the effect of complaint walls and chemical responses on the magneto-hydrodynamic peristaltic stream of an incompressible viscous liquid. The applications to this issue are transport of water, nutrients to various branches of tree and moment of nutrients in blood veins which have peristalsis on its walls (Lightfoot, 1974). The analytical expression for mean effective scattering coefficient has been obtained. The effects of different values of penetrating parameters are discussed in detail through graphs.

2. MATHEMATICAL MODEL

Figure-1 shows the geometry of the magneto-hydrodynamic peristaltic stream of an incompressible viscous fluid in a two dimensional channel with compliant walls and Cartesian coordinates.

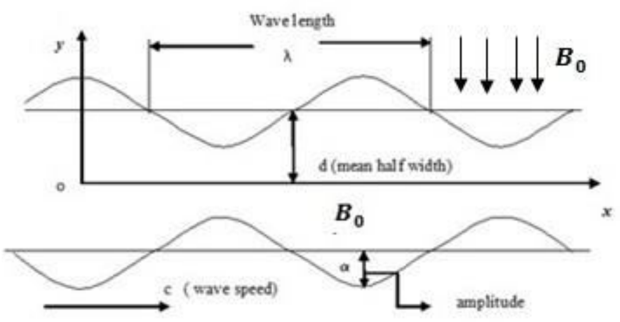

Figure-1. Geometry of an idealized chyme movement in digestive process.

The travelling sinusoidal creeping flow in 2-dimensional conduit is given as:

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

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

The corresponding flow equations of the present issue are as follows:

$$\frac{\partial\mathcal{U}}{\partial x} + \frac{\partial\mathcal{V}}{\partial y} = 0\,, \qquad (2)$$

$$\rho\left[\frac{\partial}{\partial t} + \mathcal{U}\frac{\partial}{\partial x} + \mathcal{V}\frac{\partial}{\partial y}\right]\mathcal{U} = -\frac{\partial p}{\partial x} + \mu\left[\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}\right]\mathcal{U} - \sigma B_0^2\mathcal{U}\,, \qquad (3)$$

$$\rho\left[\frac{\partial}{\partial t} + \mathcal{U}\frac{\partial}{\partial x} + \mathcal{V}\frac{\partial}{\partial y}\right]\mathcal{V} = -\frac{\partial p}{\partial y} + \mu\left[\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}\right]\mathcal{V}\,, \qquad (4)$$

where ρ - the density, p -the pressure, μ - the viscosity coefficient, $\mathcal{U},\mathcal{V}$ - velocity component in the x, y direction.

The equation of the bendable wall movement (Mittra-Prasad, 1973) is given as:

$$L(\hbar) = p - p_0\,, \qquad (5)$$

where L - the movement of an expanded membrane by the damping forces and is given as:

$$L = -T\frac{\partial^2}{\partial x^2} + m\frac{\partial^2}{\partial t^2} + C\frac{\partial}{\partial t}\,. \qquad (6)$$

Here, m - mass/unit area, T - the tension in the membrane, and C - the viscous damping force coefficient.

3. METHOD OF SOLUTION

After solving the equations (2) to (4) under long - wavelength hypothesis, the flow equations reduce as:

$$\frac{\partial\mathcal{U}}{\partial x} + \frac{\partial\mathcal{V}}{\partial y} = 0\,, \qquad (7)$$

$$-\frac{\partial p}{\partial x} + \mu\frac{\partial^2\mathcal{U}}{\partial y^2} - \sigma B_0^2\mathcal{U} = 0\,, \qquad (8)$$

$$-\frac{\partial p}{\partial y} = 0\,. \qquad (9)$$

The associated periphery conditions are

$$\mathcal{U} = 0 \quad at \quad y = \pm\hbar\,. \qquad (10)$$

It is presumed that $p_0 = 0$ and the channel walls are inextensible; therefore, the straight displacement of the wall is nil and lateral movement takes place.
From Equation (5) and (8), we get

$$\frac{\partial}{\partial x}L(\hbar) = \mu\frac{\partial^2\mathcal{U}}{\partial y^2} - \sigma B_0^2\mathcal{U} \quad at \quad y = \pm\hbar\,, \qquad (11)$$

where

$$\frac{\partial}{\partial x}L(\hbar) = \frac{\partial p}{\partial x} = P' = -T\frac{\partial^3\hbar}{\partial x^3} + m\frac{\partial^3\hbar}{\partial x\,\partial t^2} + C\frac{\partial^2\hbar}{\partial x\,\partial t}\,. \qquad (12)$$

After solving Equations (8) and (9) with the help of conditions (10) and (11), we attain

$$\mathcal{U}(y) = \frac{1}{\mu\,m_1{}^2}\frac{\partial p}{\partial x}\left[\frac{cosh(m_1 y)}{cosh(m_1\hbar)} - 1\right]. \qquad (13)$$

The mean velocity is given as

$$\overline{\mathcal{U}} = \frac{1}{2\hbar}\int_{-\hbar}^{\hbar}\mathcal{U}(y)dy\,. \qquad (14)$$

From equation (13) and (14), we obtain

$$\overline{\mathcal{U}} = \frac{1}{\mu m_1{}^2}\frac{\partial p}{\partial x}\left[\frac{sinh(m_1\hbar)}{m_1\hbar\,cosh(m_1\hbar)} - 1\right]. \qquad (15)$$

Utilizing Alemayehu and Radhakrishnamacharya (2010) the fluid velocity is given by the equation:

$$\mathcal{U}_x = \mathcal{U} - \overline{\mathcal{U}}. \qquad (16)$$

From Equations (13), (15) and (16), we obtain

$$\mathcal{U}_x = \frac{1}{\mu m_1{}^2}\frac{\partial p}{\partial x}\left[\frac{m_1\hbar\,cosh(m_1 y) - sinh(m_1\hbar)}{m_1\hbar\,cosh(m_1\hbar)}\right], \qquad (17)$$

where

$$\frac{\partial p}{\partial x} = m\frac{\partial^3\hbar}{\partial x\,\partial t^2} + C\frac{\partial^2\hbar}{\partial x\,\partial t} - T\frac{\partial^3\hbar}{\partial x^3}\,,$$

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$$m_1 = \sqrt{\frac{\sigma B_0^2}{\mu}} \, .$$

3.1 Combined homogeneous and heterogeneous chemical reactions with diffusion

Referring Gupta-Gupta (1972), the dispersion equation for the concentration $\mathbb{C}$ of the substance for the present issue under isothermal conditions:

$$\frac{\partial \mathbb{C}}{\partial t} + \mathcal{U}\,\frac{\partial \mathbb{C}}{\partial x} = D\left[\frac{\partial^2 \mathbb{C}}{\partial x^2} + \frac{\partial^2 \mathbb{C}}{\partial y^2}\right] - k_1\,\mathbb{C}\,. \quad (18)$$

Using Taylor's approximation $\frac{\partial^2 \mathbb{C}}{\partial x^2} \le \frac{\partial^2 \mathbb{C}}{\partial y^2}$, the equation (18) is expressed as:

$$\frac{\partial \mathbb{C}}{\partial t} + \mathcal{U}\,\frac{\partial \mathbb{C}}{\partial x} = D\,\frac{\partial^2 \mathbb{C}}{\partial y^2} - k_1\,\mathbb{C}\,. \quad (19)$$

In the above equations, $\mathbb{C}$ - concentration of the fluid, D - the diffusion coefficient for chemical reactions, and k_1- the rate constant of chemical reaction.

For the common standards of physiologically important parameters of this issue, it is expected that $\overline{\mathcal{U}} \approx \mathbb{C}$ (Alemayehu-Radhakrishnamacharya, 2010).

Applying the clause $\overline{\mathcal{U}} \approx \mathbb{C}$, and subsequent dimensionless quantities,

$$\theta = \frac{t}{\bar{t}},\ \ \bar{t} = \frac{\lambda}{\overline{\mathcal{U}}},\ \ \eta = \frac{y}{d},\ \ \xi = \frac{(x - \overline{\mathcal{U}}\,t)}{\lambda},$$
$$\text{н} = \frac{\hbar}{d}\ ,P = \frac{d^2}{\mu C}P',\ \ M = \sqrt{\frac{\sigma}{\mu}}B_0 d\,. \quad (20)$$

Equations (17) and (19) reduce to

$$\mathcal{U}_x = \frac{d^2}{\mu \mathrm{m}^2}\frac{\partial p}{\partial x}\left[A_1 \cosh(m\eta) - A_2\right], \quad (21)$$
$$\frac{\partial^2 \mathbb{C}}{\partial \eta^2} - \frac{k_1 d^2\,\mathbb{C}}{D} = \frac{d^2}{\lambda D}\,\mathcal{U}_x\,\frac{\partial \mathbb{C}}{\partial \xi}, \quad (22)$$

and further, equation (12) reduces to

$$\mathrm{P} = -\epsilon\left[(2\pi)^3 (\mathrm{E}_1 + \mathrm{E}_2)\cos(2\pi\xi) - (2\pi)^2\ \mathrm{E}_3 \sin(2\pi\xi)\right], \quad (23)$$

where,

$E_1\left(= -\frac{Td^3}{\lambda^3 \mu C}\right)$ is the rigidity, $E_2\left(= \frac{mcd^3}{\lambda^3 \mu}\right)$ is the stiffness, $E_3\left(= \frac{Cd^3}{\mu\lambda^2}\right)$ is the damping characteristic of the wall and $\epsilon\left(= \frac{a}{d}\right)$ is an amplitude ratio.

The diffusion with first-order irreversible chemical reaction taking place in the mass of the fluid medium and at the walls of the channel is discussed and treated that the walls are catalytic to chemical reaction.

Hence, the periphery conditions at the walls (Chandra-Philip, 1993) are given by the following equations:

$$\frac{\partial \mathbb{C}}{\partial y} + f\mathbb{C} = 0 \ \text{ at } y = \hbar = \left[\mathrm{d} + \mathrm{a}\sin\frac{2\pi}{\lambda}\left(\mathrm{x} - \overline{\mathcal{U}}\mathrm{t}\right)\right], \quad (24)$$

$$\frac{\partial \mathbb{C}}{\partial y} - f\mathbb{C} = 0 \ \text{ at } y = -\hbar = -\left[\mathrm{d} + \mathrm{a}\sin\frac{2\pi}{\lambda}\left(\mathrm{x} - \overline{\mathcal{U}}\mathrm{t}\right)\right]. \quad (25)$$

From equations (20), (24) and (25) we get

$$\frac{\partial \mathbb{C}}{\partial \eta} + \beta\mathbb{C} = 0 \ \ at\ \eta = \text{н} = [\,1 + \epsilon\ \sin(\,2\pi\xi\,)], \quad (26)$$

$$\frac{\partial \mathbb{C}}{\partial \eta} - \beta\mathbb{C} = 0 \ \ at\ \eta = -\text{н} = -[\,1 + \epsilon\,\sin(2\pi\xi\,)]. \quad (27)$$

where $\beta = fd$ - the heterogeneous response rate corresponding to the catalytic response at the walls.

From the equations (26) and (27), the primitive of equation (22) as follows:

$$\mathbb{C}(\eta) = \frac{d^4}{\mu D\lambda m^2}\frac{\partial p}{\partial x}\frac{\partial C}{\partial \xi}[\,A_4 \cosh(m\eta) - A_5 \cosh(\alpha\eta) + A_6 - A_7 \cosh(\alpha\eta)\,]. \quad (28)$$

The volumetric rate Q is defined as the rate in which the solute is pumping across a section of channel per unit breadth.

$$Q = \int_{-\text{н}}^{\text{н}} C\,\mathcal{U}_x\,d\eta\,. \quad (29)$$

Using equations (21) and (28) in equation (29), we get

$$Q = -2\frac{d^6}{\lambda D\mu^2}\left(\frac{\partial C}{\partial \xi}\right) G(\xi, \alpha, \beta, \epsilon, E_1, E_2, E_3, M)\,, \quad (30)$$

where

$$G = \left[-\frac{P}{m^4}\left(\frac{A_1 A_4}{2}B_1 - (A_1 A_5 + A_1 A_7)B_2 + (A_1 A_6 - A_2 A_4)B_3 + (A_2 A_5 + A_2 A_7)B_4 - A_2 A_6\,\text{н}\right)\right], \quad (31)$$

and

$$A_1 = \frac{1}{\cosh m\text{н}},\ \ A_2 = \frac{\sinh m\text{н}}{m\text{н}\cosh m\text{н}},$$
$$A_3 = \frac{\sinh m\text{н}}{\alpha \sinh \alpha\text{н}},\ A_4 = \frac{1}{(m^2 - \alpha^2)\cosh m\text{н}},$$
$$A_5 = \frac{(m \sinh m\text{н} + \beta \cosh m\text{н})}{(m^2 - \alpha^2)\cosh m\text{н}\ (\alpha \sinh \alpha\text{н} + \beta \cosh \alpha\text{н})},$$
$$A_6 = \frac{\sinh m\text{н}}{m\text{н}\,\boldsymbol{\alpha}^2 \cosh m\text{н}},$$
$$A_7 = \frac{\beta \sinh m\text{н}}{m\text{н}\,\boldsymbol{\alpha}^2 \cosh m\text{н}\,(\alpha \sinh \alpha\text{н} + \beta \cosh \alpha\text{н})},$$
$$B_1 = \frac{2m\text{н} + \sinh 2m\text{н}}{2m},$$
$$B_2 = \frac{(m \sinh m\text{н} \cosh \alpha\text{н} - \alpha \cosh m\text{н} \sinh \alpha\text{н})}{(m^2 - \alpha^2)},$$
$$B_3 = \frac{\sinh m\text{н}}{m},\ \ B_4 = \frac{\sinh \alpha\text{н}}{\alpha},$$
$$\alpha = \sqrt{\frac{k_1}{D}}\,d,\ \ m = m_1 d = M.$$

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Looking at equation (31) with Fick's law of diffusion, the diffusion coefficient D^* was intended such that the solute diffuses comparative to the plane moving with the average speed of the flow and is given as:

$$D^* = 2\frac{d^6}{D\mu^2} G(\xi, \alpha, \beta, \epsilon, E_1, E_2, E_3, M)\,. \tag{32}$$

Let $\overline{G}$ be the average of G, and is obtained by the following equation:

$$\overline{G} = \int_0^1 G(\xi, \alpha, \beta, \epsilon, E_1, E_2, E_3, M)\, d\xi\,. \tag{33}$$

4. RESULTS AND DISCUSSIONS

The expression for $\overline{G}$ has been obtained by numerical integration using the software *MATHEMATICA* and end results are presented through graphs. The pertinent parameters present in this argument are magnetic field parameter M, an amplitude ratio ε, the homogeneous response rate α, the heterogeneous response rate β, the rigidity E_1, the stiffness E_2, and the viscous damping force E_3. We may ensure that E_1, E_2 and E_3 cannot be zero all together.

The effects of the rigidity parameter (E_1), stiffness (E_2) and viscous damping force (E_3) on the dispersion coefficient ($\overline{G}$) are depicted in figures 2-10. It is observed that $\overline{G}$ ascends monotonically with an increase in E_1, E_2 and E_3. This understanding might be derived to the truths that increment in the flexibility of the channel walls help the stream moment which causes to enhance the scattering. This result is in agreement with the results of Hayat *et al.* (2014, 2015) and Ravikiran-Radhakrisnamacharya (2015b).

In figures 11 -13, it is observed that $\overline{G}$ descends with an increase in magnetic field parameter M. Increase in magnetic field parameter leads to drop in the fluid velocity and as a result scattering may reduce. This finding agrees with the conclusion of Sobh (2013), Ravikiran-Radhakrisnamacharya (2015b). Furthermore, $\overline{G}$ ascends with an increment in the amplitude ratio ε (Figures 4, 7, 10, and 13). As already known, increment in the amplitude ratio is the expansion in the amplitude of the wave across the channel and this cause to increase the fluid velocity within the channel and consequently dispersion may enhance. This outcome concurs with that of Sobh (2013), Ravikiran-Radhakrisnamacharya (2015).

Dispersion reduces with homogeneous compound response rate α (Figures 3, 6, and 9) and heterogeneous substance response rate β (Figures 2, 5, and 8); where as dispersion diminishing with β is less significant. This outcome is normal since expansion in α prompts an expansion in number of moles of solute experiences chemical response. This result is consistent with the arguments of Padma-Rao (1975), Gupta-Gupta (1972), Hayat *et al.* (2014), and Ravikiran-Radhakrisnamacharya (2015).

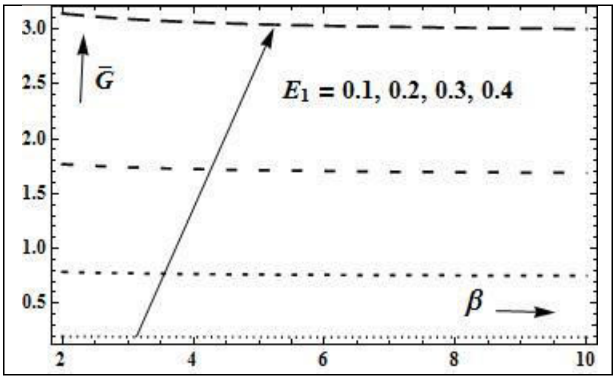

Figure-2. Plot of $\overline{G}$ for E_1 with $\varepsilon = 0.2$, $\alpha = 1.0$, $M = 4.0$, $E_2 = 0.0$, $E_3 = 0.0$.

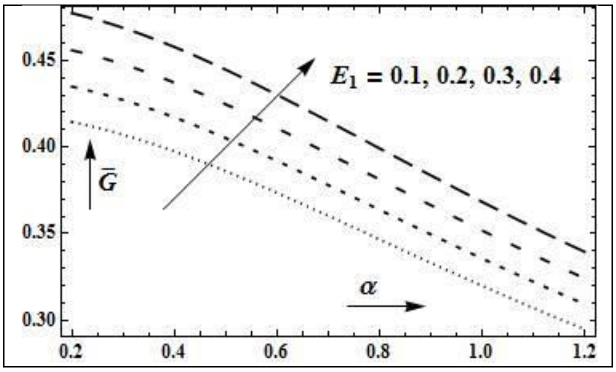

Figure-3. Plot of $\overline{G}$ for E_1 with $\varepsilon = 0.2$, $\beta = 5.0$, $M = 4.0$, $E_2 = 4.0$, $E_3 = 0.06$.

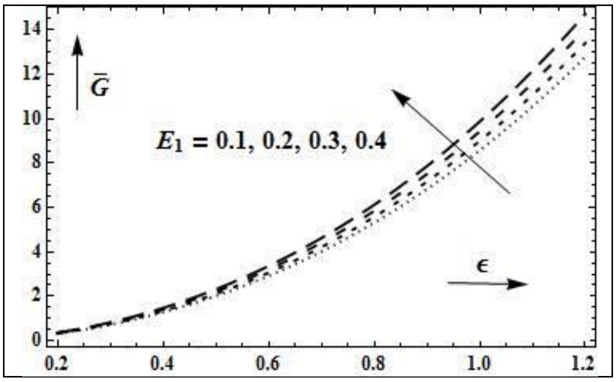

Figure-4. Plot of $\overline{G}$ for E_1 *with* $\beta = 5$, $\alpha = 1.0$, $M = 4.0$, $E_2 = 4.0$, $E_3 = 0.06$.

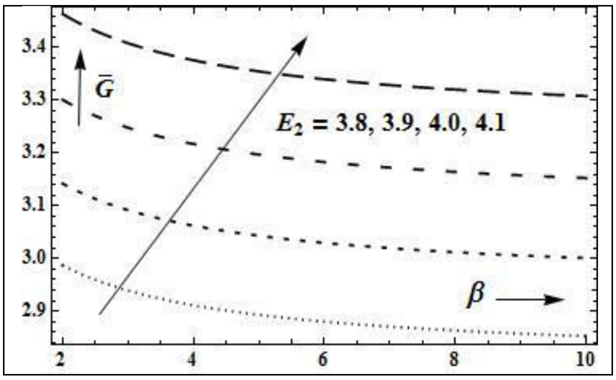

Figure-5. Plot of $\overline{G}$ for E_2 with $\varepsilon = 0.2$, $\alpha = 1.0$, $M = 4.0$, $E_1 = 0.1$, $E_3 = 0.06$.

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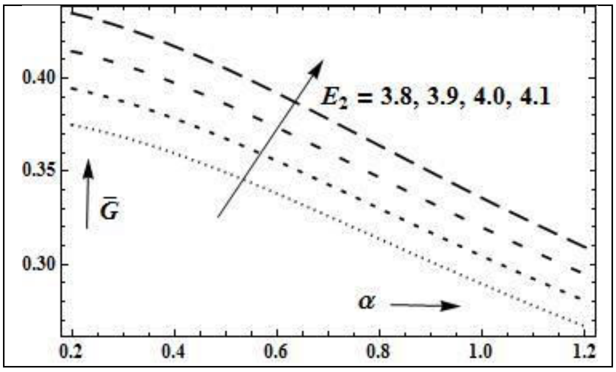

Figure-6. Plot of $\overline{\boldsymbol{G}}$ for E_2 with $\varepsilon = 0.2$, $\beta = 5.0$, $M = 4.0$, $E1 = 0.1$, $E_3 = 0.06$.

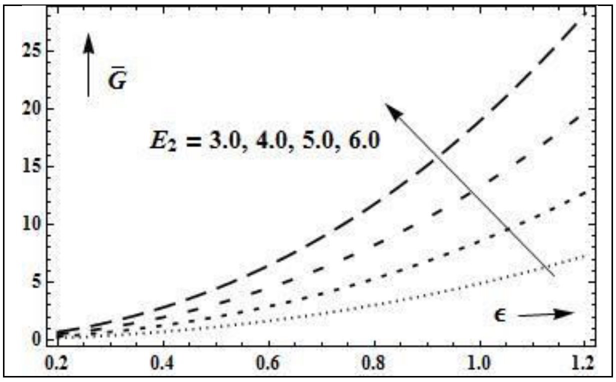

Figure-7. Plot of $\overline{\boldsymbol{G}}$ for E_2 *with* $\beta = 5$, $\alpha = 1.0$, $M = 4.0$, $E_1 = 0.1$, $E_3 = 0.00$.

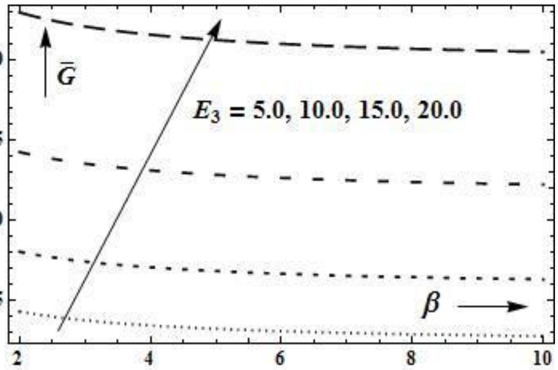

Figure-8. Plot of $\overline{\boldsymbol{G}}$ for E_3 with $\varepsilon = 0.2$, $\alpha = 1.0$, $M= 4.0$, $E_1 = 0.1$, $E_2 = 4.0$.

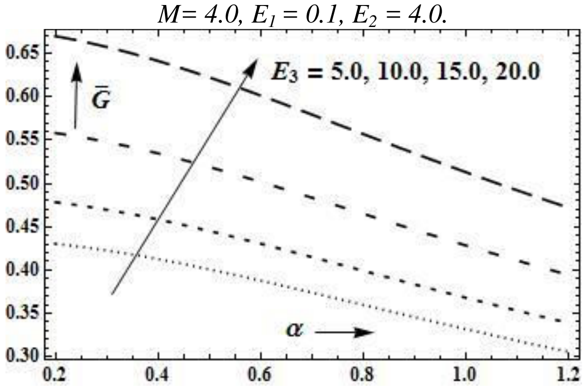

Figure-9. Plot of $\overline{\boldsymbol{G}}$ for E_3 with $\varepsilon = 0.2$, $\beta = 5.0$, $M = 4.0$, $E_1 = 0.1$, $E_2= 4.0$.

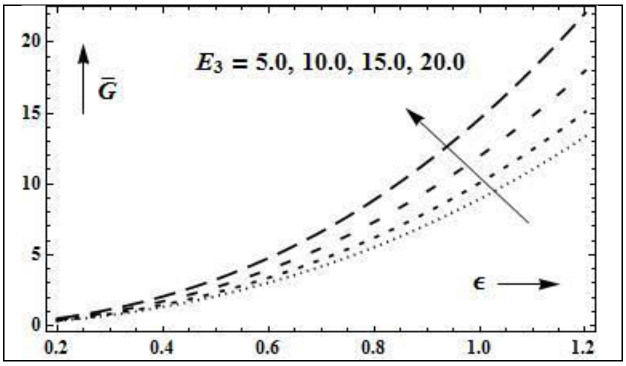

Figure-10. Plot of $\overline{\boldsymbol{G}}$ for E_3 *with* $\beta = 5$, $\alpha = 1.0$, $M = 4.0$, $E_1 = 0.1$, $E_2 = 4.0$.

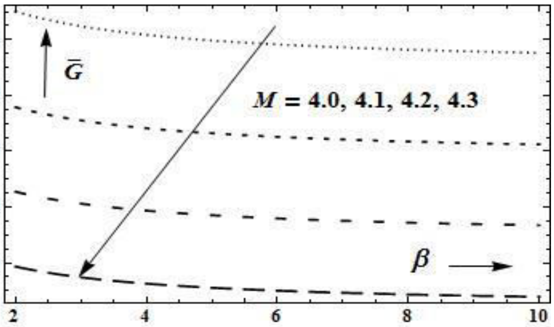

Figure-11. Plot of $\overline{\boldsymbol{G}}$ for M with $\varepsilon = 0.2$, $\alpha = 1.0$, $E_1 = 0.1$, $E_2 = 4.0$, $E_3=0.06$.

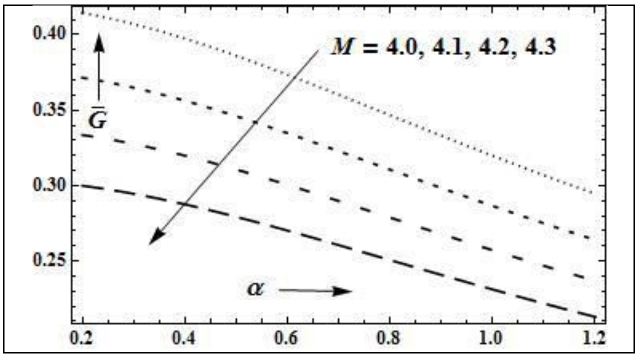

Figure-12. Plot of $\overline{\boldsymbol{G}}$ for M with $\varepsilon = 0.2$, $\beta = 5.0$, $E_1 = 0.1$, $E_2 = 4.0$, $E_3=0.06$.

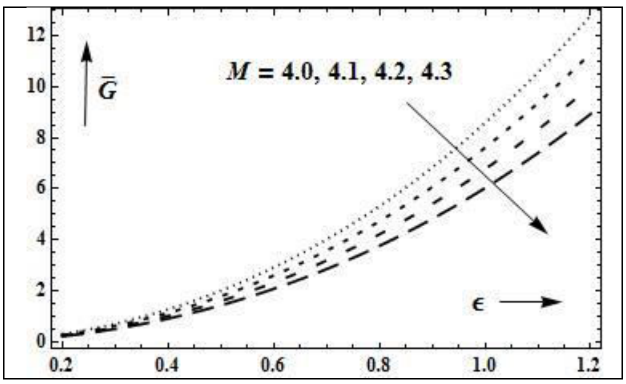

Figure-13. Plot of $\overline{\boldsymbol{G}}$ for M *with* $\beta = 5$, $\alpha = 1.0$, $E_1 = 0.1$, $E_2 = 4.0$, $E_3=0.0$.

5. CONCLUDING REMARKS

In the present study, the effects of magnetic parameter (M), couple stress parameter (γ), amplitude ratio (ϵ), homogeneous response rate (α), heterogeneous response rate (β), rigidity (E_1), stiffness (E_2), damping characteristic of the wall (E_3) on dispersion coefficient $(\overline{G})$ have been inspected for the magneto-hydrodynamic peristaltic pumping of an incompressible viscous fluid in uniform channel. It is observed that the concentration profile $\overline{G}$ ascends with an increase in wall parameters E_1, E_2, E_3, and ϵ. Furthermore, opposite behaviors of homogeneous response rate parameter α and heterogeneous response rate parameter β are observed on $\overline{G}$. Finally, It concludes that wall parameters and amplitude ratio favor the dispersion, while magnetic parameters resist the dispersion in the digestive frame work. This confirms that creeping sinusoidal stream assists the absorption of active components in small intestine. This model may help in understanding the transport phenomena occurring in the small intestine leading to absorption of nutrients and drugs.

Nomenclature

a amplitude	Q volumetric rate
c velocity of the peristaltic wave	t time
C viscous damping force coefficient	T tension in the membrane
$\mathbb{C}$ concentration of substance	$\mathcal{U}, \mathcal{V}$ velocity component in x, y direction
d half width of the channel	$\overline{\mathcal{U}}$ mean velocity
D diffusion coefficient of chemical reaction	(x, y) Cartesian coordinates
D^* equivalent dispersion coefficient	
E_1 rigidity of wall	**Greek symbols**
E_2 stiffness of wall	α homogeneous reaction parameter
E_3 damping force of elastic wall	β heterogeneous reaction parameter
$\overline{G}$ effective dispersion coefficient or concentration profile	λ wavelength of the peristaltic wave
k_1 rate of chemical reaction	μ viscosity coefficient
M mass per unit length	ρ density of fluid
M Magnetic field parameter	
L motion of stretched membrane	
p pressure	

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