MHD Effects on Peristaltic Flow of a Couple Stress Fluid in a Channel with Permeable Walls

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Abstract

Some biomedical instruments, for example, blood pumps in dialysis and the heart lung machine utilize this guideline. Peristaltic transport of a dangerous fluid is utilized as a part of atomic industry to maintain a strategic distance from tainting of the outside environment. The mechanical utilization of this pumping component in roller/finger pumps to pump slurries and destructive liquids is notable. The goal of this paper is to concentrate the MHD impacts on peristaltic stream of a couple stretch liquids in a channel with porous dividers. Utilizing long wavelength and low Reynolds number approximations.

Keywords

Peristaltic flow, non-Newtonian fluids, high polymer additive, electro-rheological fluids.

I. INTRODUCTION

Peristalsis is a characteristic instrument of transport for some physiological liquids. This is accomplished by the entry of dynamic rushes of zone compression or extension along the limit of a liquid filled distensible tube. Diverse physiological wonders, for example, the stream of pee from kidney to the bladder through ureters, transport of nourishment material through the stomach related tract, development of spermatozoa in the pipe's efferent's of the male regenerative tract and cervical channel and the vehicle of ovum in the fallopian tube, occur by the instrument of peristalsis. Some biomedical instruments, for example, blood pumps in dialysis and the heart lung machine utilize this rule. Peristaltic transport of a poisonous fluid is utilized as a part of atomic industry to maintain a strategic distance from tainting of the outside environment. The modern utilization of this pumping system in roller/finger pumps to pump slurries and destructive liquids is outstanding. A few reviews have been made on peristalsis with reference to mechanical and physiological circumstances. (Misra and Pandey [11], [10], Mishra and Rao [9]).

Magnetohydrodynamics (MHD) is the science which manages the movement of leading liquids within the sight of an attractive field. The movement of the directing liquid over the attractive field creates electric streams which change the attractive field and the activity of the attractive field on these ebbs and flows offers ascend to mechanical strengths which alter the stream of the liquid (Mekheimer [7]). MHD stream of a liquid in a channel with flexible, musically contracting dividers (peristaltic stream) is of enthusiasm for association with specific issues of the development of conductive physiological liquids (illustration: the blood and blood pump machines) (Hayat et al. [8]). At present, contemplates on peristaltic movement in MHD streams of electrically directing physiological liquids have turned into a subject of developing enthusiasm for scientists. This is because of the way that such reviews are helpful especially to get an appropriate comprehension of the working of various machines utilized by clinicians for pumping blood. Misra et al. [4] called attention to that hypothetical looks into with a mean to investigate the impact of an attractive field on the stream of blood in atherosclerotic vessels likewise discover application in a blood pump utilized via heart specialists amid the surgical methodology.

It is outstanding that most physiological liquids including blood carry on as non-Newtonian liquids. Subsequently, the investigation of peristaltic transport of non-Newtonian liquids may show signs of improvement comprehension of the organic frameworks. A few re-searchers considered peristaltic transport of non-Newtonian liquids. [8].

Couple stretch liquids are liquids comprising of unbending, arbitrarily arranged particles suspended in a thick medium. Couple push liquid is known to be a superior model for bio-liquids, for example, blood, greases containing little measure of high polymer added substance, electro-rheological liquids and manufactured liquids. The principle highlight of couple stress liquids is that the anxiety tensor is against symmetric and their exact stream conduct can't be anticipated by the established Newtonian hypothesis. Stirs summed up the established model to incorporate the impact of the nearness of the couple stresses and this model has been generally utilized on account of its relative numerical straightforwardness (M. Hussain, Mehwish Ashraf, [3]). For couple stretch liquids, there have been various reviews did because of its far reaching modern and logical applications, for example, the works of Mekheimer and Abd elmaboud [5] and Sobh [6]. Ramesh [2] investigate the peristaltic transport of couple stress fluid in an asymmetric channel. The channel asymmetry is produced by choosing the peristaltic wave train on the walls to have different wave amplitudes and phase differences, and M.G.Reddy [1] discussed under the long wavelength and low Reynolds number approximation. The resultant dimensionless nonlinear governing equations have been tackled numerically.The goal of this paper is to concentrate the MHD impacts on peristaltic stream of a couple push liquid in a channel with penetrable dividers. Utilizing long wavelength and low Reynolds number approximations. The impacts of different important parameters on the time found the middle value of stream rate and weight distinction have been talked about through charts.

II. P II FORMULATION OF THE PROBLEM

Consider the MHD consequences for peristaltic stream of a couple push liquid in a channel with porous dividers under long wavelength and low Reynolds number suspicions in a channel of half – width "an" and longitudinal prepare of dynamic sinusoidal waves happens on the upper and lower dividers of the channel. We accept that a uniform attractive field quality 'B0'is connected along the bearing of the Y-pivot and the instigated attractive field is thought to be irrelevant. For effortlessness we confine our discourse to the half width of the direct channel as appeared in the Figure 1.

The divider twisting is given by

$$H(X,t) = a+b \sin \frac{2\pi}{\lambda} (X-ct) \tag{4.3.1}$$

Under the presumptions that the channel length is an essential different of the wavelength λ and the weight contrast over the closures of the channel is a consistent, the stream turns out to be relentless in the wave outline (x, y) moving with speed c far from the fixed(laboratory) outline (X,Y). The change between these casings is given by

x = X – ct, y = Y, u(x, y) = U(X-ct, Y) and v(x, y) = V(X-ct, Y) where U and V are speed segments in the research facility casing and u and v are speed segments in the wave outline. In the numerous physiological circumstances it is demonstrated tentatively that the Reynolds number of the stream is little. In this way, we expect that the wavelength is vast. So the stream is of Poiseuille sort at every neighborhood cross - segment.

Under these suppositions the administering conditions of the stream are

$$\mu\frac{\partial}{\partial y}(a^2\frac{\partial^3 u}{\partial y^3}-\frac{\partial u}{\partial y})-\sigma B_0^2(u+c)=\frac{\partial p}{\partial x} \tag{4.3.2}$$

$$\frac{\partial p}{\partial y}=0 \tag{4.3.3}$$

The boundary conditions are

$$\frac{\partial u}{\partial y}=0 \quad \text{at } y=0 \tag{4.3.4}$$

$$u=\psi_y=[-c-a\frac{\sqrt{Da}}{\alpha}\frac{\partial u}{\partial y}] \quad \text{at } y=H \tag{4.3.5}$$

$$\frac{\partial^2 u}{\partial y^2}=0 \quad \text{at } y=H \tag{4.3.6}$$

We introduce the stream function ψ such that $u=\frac{\partial\psi}{\partial y}, v=-\frac{\partial\psi}{\partial x}$ and the following non – dimensional quantities are

$$\bar{x}=\frac{x}{\lambda},\bar{y}=\frac{y}{a},\bar{u}=\frac{u}{c},\bar{p}=\frac{a^2 p}{\mu c\lambda},\bar{t}=\frac{ct}{\lambda},h=\frac{H}{a},\phi=\frac{b}{a},\bar{\psi}=\frac{\psi}{ac},\tau_0=\frac{a\tau_0}{\mu c}.$$

Substituting the above non- dimensional quantities in equations (4.3.2) and (4.3.3), then the governing dimensionless equations of the flow (dropping the bars) are

$$\frac{\partial^4 u}{\partial y^4}-\frac{\partial^2 u}{\partial y^2}-M^2(u+1)=\frac{\partial p}{\partial x} \quad (4.3.7)$$

$$\frac{\partial p}{\partial y}=0 \quad (4.3.8)$$

Where $M^2=\frac{\sigma B_0^2 a^2}{\mu}$.

The non- dimensional boundary conditions are

$$\frac{\partial u}{\partial y}=0 \quad \text{at y=0} \quad (4.3.9)$$

$$u=\psi_y=-1-\frac{\sqrt{Da}}{\alpha}\frac{\partial u}{\partial y} \quad \text{at y=h} \quad (4.3.10)$$

$$\frac{\partial^2 u}{\partial y^2}=0 \quad \text{at y=h} \quad (4.3.11)$$

After dropping bars, the non dimensional wall deformation of equation (4.3.1) is

$$h=1+\phi Sin 2\pi x \quad (4.3.12)$$

III. SOLUTION OF THE PROBLEM

Obviously the dimensionless governing equation (4.3.7) is a linear differential equation. The analytical procedure to solve the linear differential equation has two important features. Firstly, investigating the part of complimentary function (C.F), secondly, finding out the part of particular integral (P.I). Finally, the sum of (C.F) and (P.I) gives the required general arrangement of the direct differential condition.. We now make use of the general procedure method of linear differential equations to solve the equation (4.3.7) subject to the limit conditions (4.3.9), (4.3.10) and (4.3.11) we obtain the velocity as

$$u=\psi_y=2C_1 Cosh\alpha y+2C_3 Cosh\beta y-\frac{P}{M^2}$$

(OR)

$$u=\psi_y=2C_2 Cosh\alpha y+2C_4 Cosh\beta y-\frac{P}{M^2} \quad (4.4.1)$$

Where

$$C_1=C_2=(\frac{s_3}{k})(1-\frac{P}{M^2}),$$

$$C_3=C_4=(\frac{s_4}{k})(1-\frac{P}{M^2}),$$

$$k=[2s_1\beta^2 Cosh\beta h-2s_2\alpha^2 Cosh\alpha h],$$

$$s_1=[Cosh\alpha h+\alpha\frac{\sqrt{Da}}{\alpha}Sinh\alpha h],$$

$$s_2=[Cosh\beta h+\beta\frac{\sqrt{Da}}{\alpha}Sinh\beta h],$$

$$s_3=[-\beta^2 Cosh\beta h],$$

$$s_4=[\alpha^2 Cosh\alpha h],$$

$$P=(\frac{\partial p}{\partial x}+M^2).$$

The volume flux q through each cross- section on the wave frame is given by

$$q = \int_0^h u dy$$

$$q = \frac{P}{M^2}[(\frac{2s_3}{k})(\frac{Sinh\alpha h}{\alpha}) + (\frac{2s_4}{k})(\frac{Sinh\beta h}{\beta}) + h] \quad (4.4.2)$$

The instantaneous volume flow rate Q (X, t) in the laboratory frame between the centre line and the permeable wall is

$$Q(X,t) = \int_0^H U(X,Y,t)dY = \int_0^h (u+1)dy = q + h \quad (4.4.3)$$

The average volume flow rate $\overline{Q}$ over one wave period $\left(T = \frac{\lambda}{c}\right)$ of the peristaltic wave is defined as

$$\overline{Q} = \frac{1}{T}\int_0^T Q dt = q + 1$$

From equation (4.4.2) we have

$$\frac{\partial p}{\partial x} = [\frac{M^2(f-q)}{(f+h)} - M^2] \quad (4.4.4)$$

where

$$f = [(\frac{2s_3}{k})(\frac{Sinh\alpha h}{\alpha}) + (\frac{2s_4}{k})(\frac{Sinh\beta h}{\beta})].$$

The pumping characteristics :

Integrating the equation (4.4.4) with respect to x over one wave length, we get the pressure rise (drop) over one cycle of the wave as

$$\Delta p = \int_0^1 \{\frac{M^2[f-(Q-1)]}{(f+h)} - M^2\}dx \quad (4.4.5)$$

The time average flux at zero pressure rise is denoted by $\overline{Q_0}$ and the pressure rise required to produce zero average flow rate is denoted by Δp_0 so we have

$$\Delta p_0 = \int_0^1 \{\frac{M^2(f+1)}{(f+h)} - M^2\}dx \quad (4.4.6)$$

The dimensionless friction force F at the wall across one wave length in the channel is given by

$$F = \int_0^1 h(-\frac{dp}{dx})dx$$

$$F = -\int_0^1 h\{\frac{M^2[f-q]}{(f+h)} - M^2\}dx \quad (4.4.7)$$

IV. DISCUSSION OF THE PROBLEM

From Figures 2, 3 we have ascertained for various estimations of Ø and α. In figure 2, we have ascertained the weight contrast as an element of Q¯for various estimations of abundancy proportion Ø with α = 0.2; Da =0.01; M =1.25. It is watched that for picked parameters the pumping bends converge at a guide conclusion toward Q¯≈ 0.575. For Q¯< 0.575 we watched that the weight rise increments with the adequacy proportion Ø. The conduct is generally when Q¯ > 0.575. For nothing pumping the Q¯diminishes with the expanding Ø.

In figure 3, we have computed the weight distinction as a component of Q¯for various estimations of slip parameter (α) with Da =0.01; M =1.25; Ø= 0.5. It is watched that the pumping bends meet at a point between Q¯

=0.2 and $\bar{Q}$ = 0.4 this esteem evaluated as $\bar{Q}$ = 0.375. At the point when $\bar{Q}$ < 0.375 weight rise increments with expanding slip parameter (α). The inverse conduct is seen for $\bar{Q}$ > 0.375.

From Figures 4, 5 we have ascertained for various estimations of Da and M .We have computed the weight contrast with time found the middle value of stream rate $\bar{Q}$ for various estimations of Darcy number Da , with α = 0.2; M =1.25; ∅= 0.5 and is appeared in Figure 4. It is watched that the pumping bends meet at a point between $\bar{Q}$ =0.2 and $\bar{Q}$ = 0.4 this esteem evaluated as $\bar{Q}$ = 0.395. At the point when $\bar{Q}$ < 0.395 weight rise diminishes with expanding Da. The inverse conduct is seen for $\bar{Q}$ > 0.395.

In figure 5, we have ascertained the weight contrast as a component of $\bar{Q}$ for various estimations of Magnetic parameter M with α = 0.2; Da =0.01; ∅= 0.5. It is watched that for picked parameters the pumping bends are expanding.

We have computed the Frictional compel F as a component of $\bar{Q}$ for various plentifulness proportion (∅), slip parameter (α), Darcy number (Da), Hartmann number (M) and it is watched that the frictional drive F has the inverse conduct contrasted with weight rise (Δp) and is portrayed in figures (6 – 9).

III.TABLE I

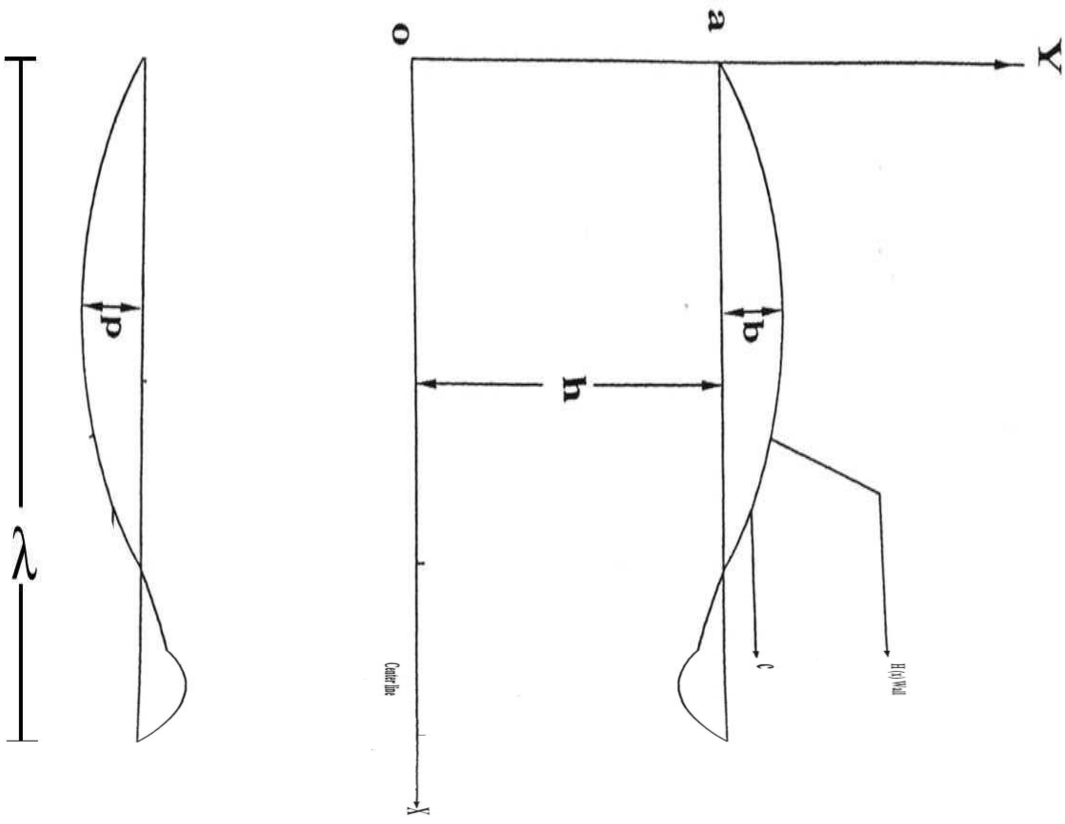

Fig: 1: Physical model for Couple stress fluid.

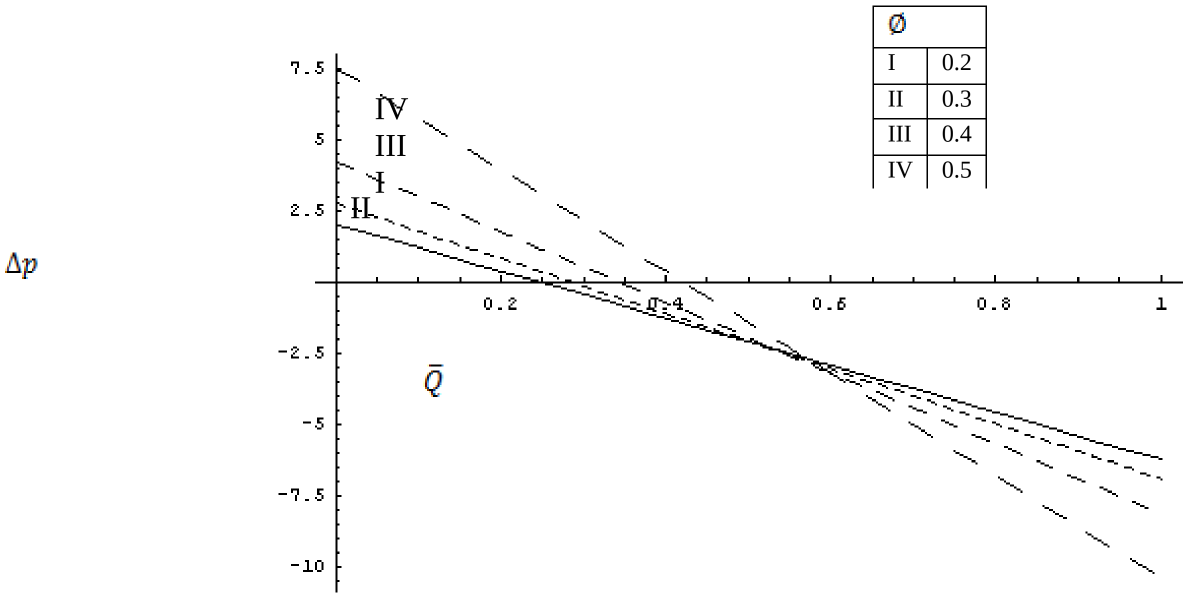

Fig: 2. The variation of Δp with $\bar{Q}$ for different values of $\emptyset$ for fixed
α = 0.2 ; Da =0.01 ; M =1.25;

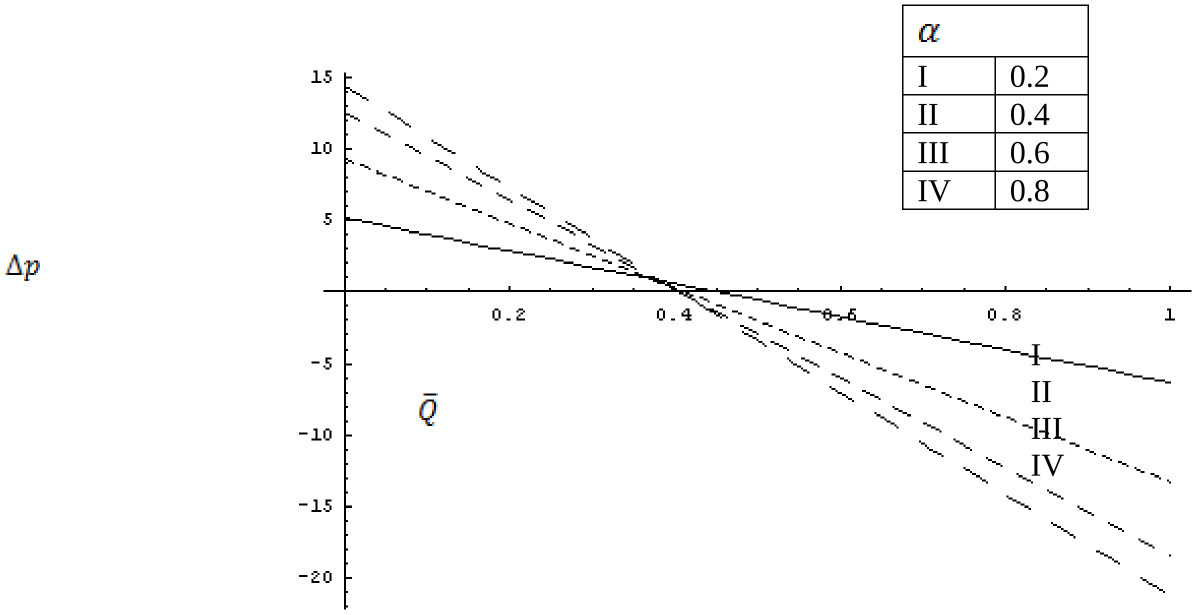

Fig: 3. The variation of Δp with $\bar{Q}$ for different values of α for fixed

Da =0.01; M =1.25; $\emptyset =$ 0.5;

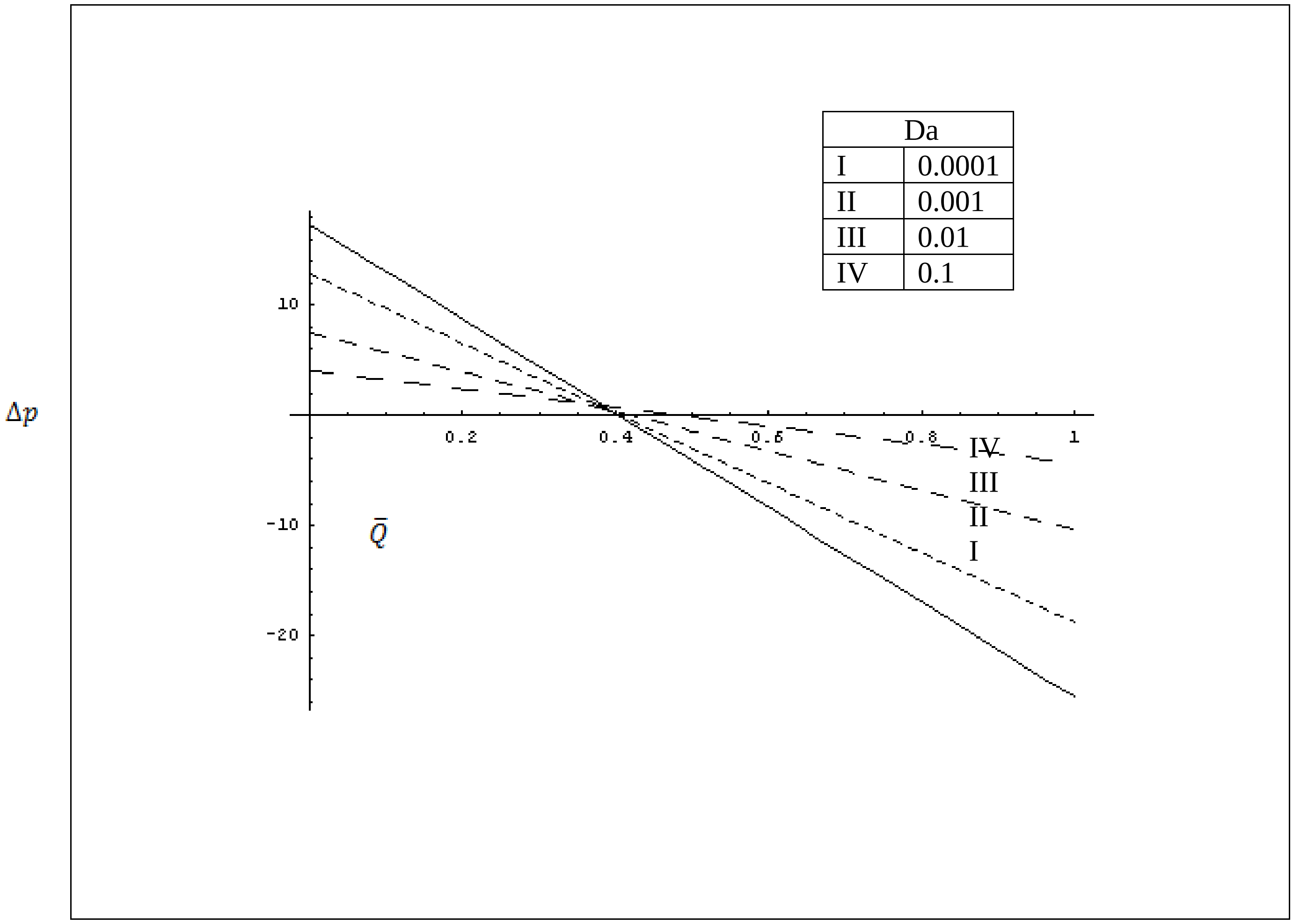

Fig: 4. The variation of Δp with $\bar{Q}$ for different values of Da for fixed α = 0.2; M =1.25; $\emptyset =$ 0.5;

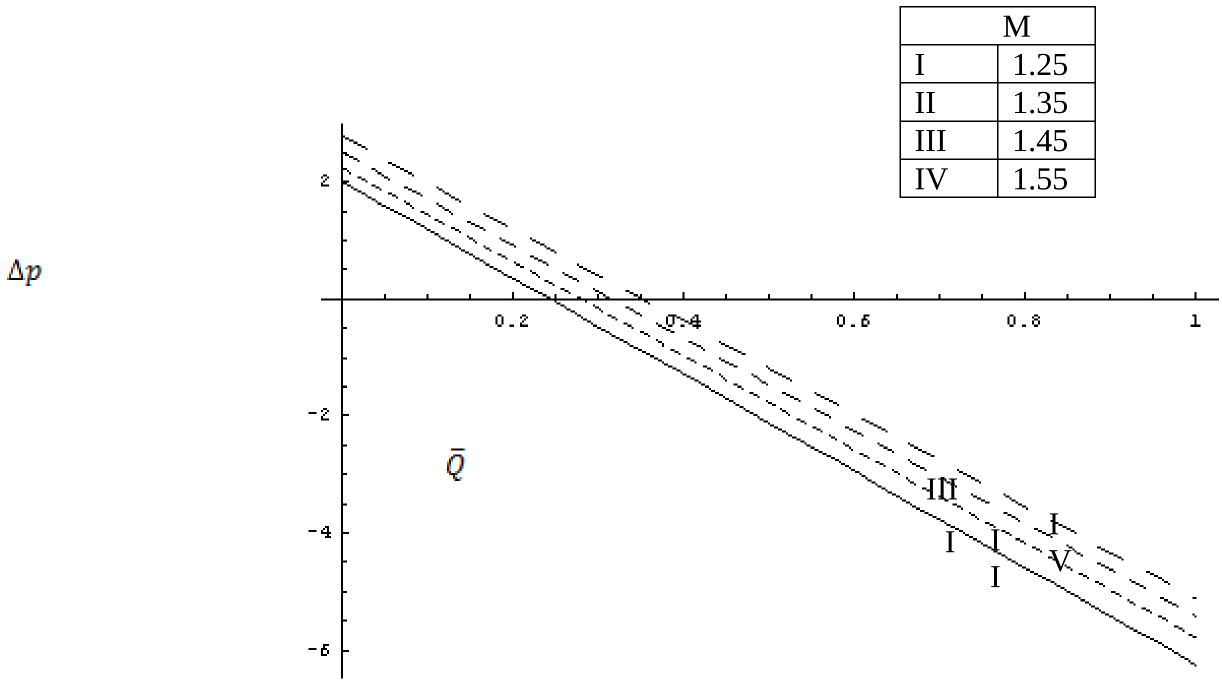

Fig: 5. The variation of Δp with $\bar{Q}$ for different values of M for fixed α = 0.2; Da =0.01; $\emptyset =$ 0.5;

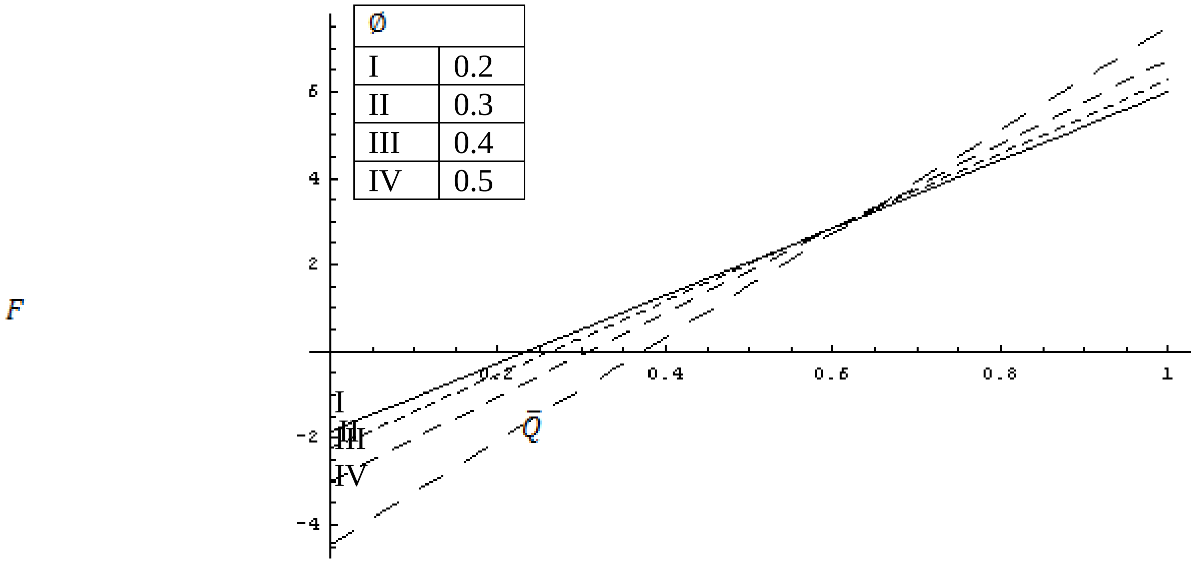

Fig: 6. The variation of F with $\bar{Q}$ for different values of $\emptyset$ for fixed α = 0.2; Da =0.01; M =1.25;

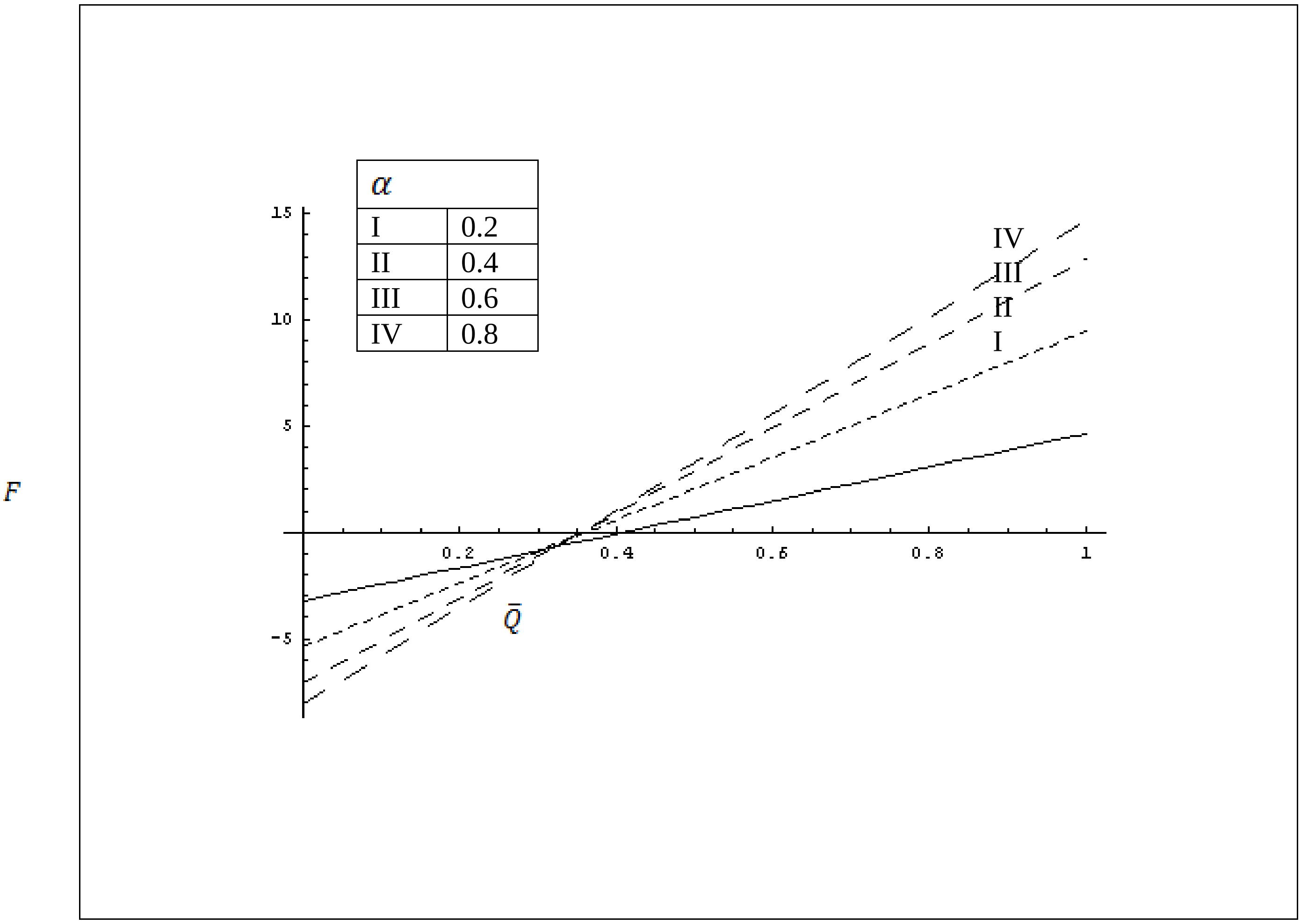

Fig: 7. The variation of F with $\bar{Q}$ for different values of α for fixed Da =0.01; M =1.25; $\emptyset =$ 0.5;

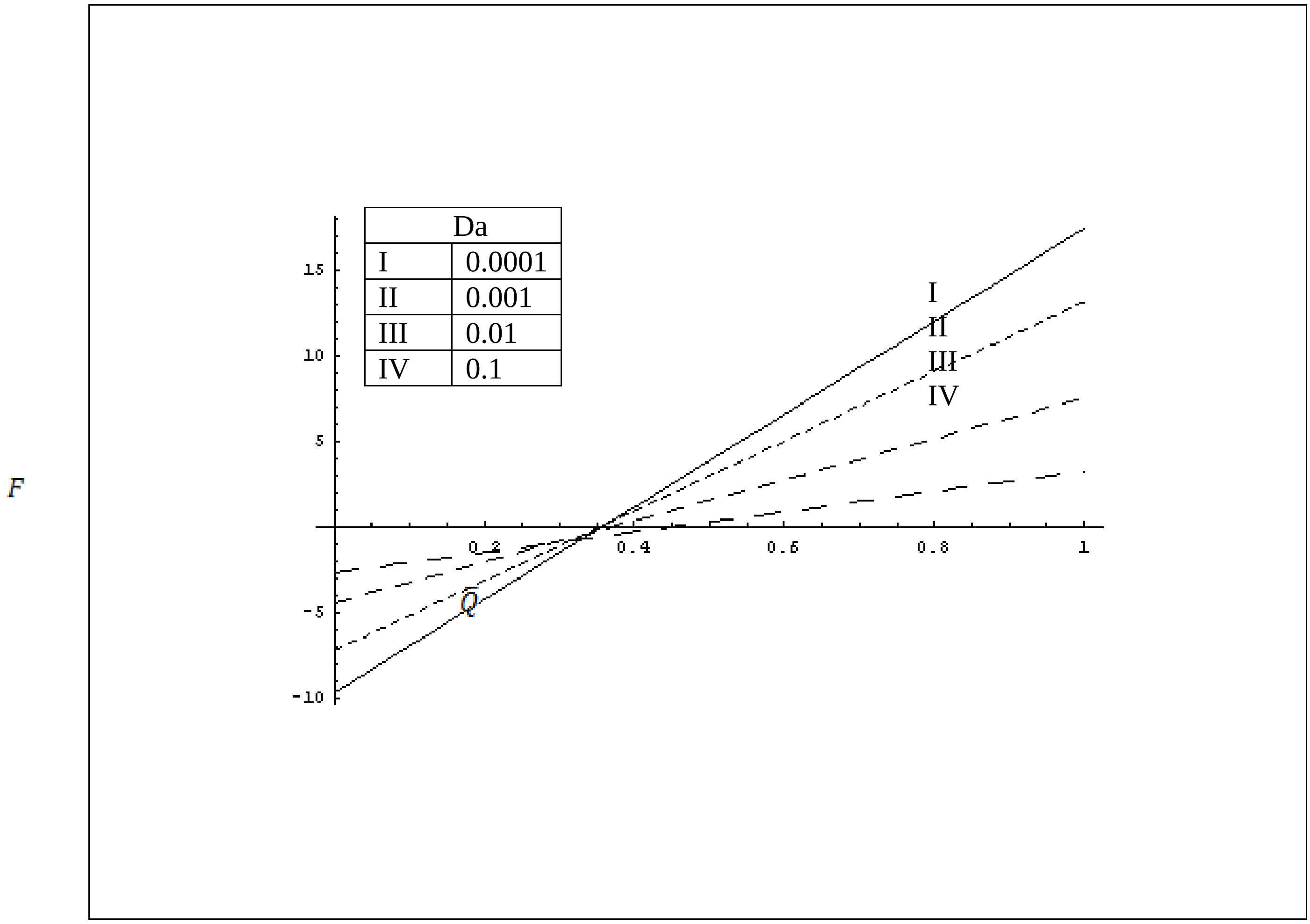

Fig: 8. The variation of F with $\bar{Q}$ for different values of Da for fixed α = 0.2; M =1.25; $\emptyset =$ 0.5;

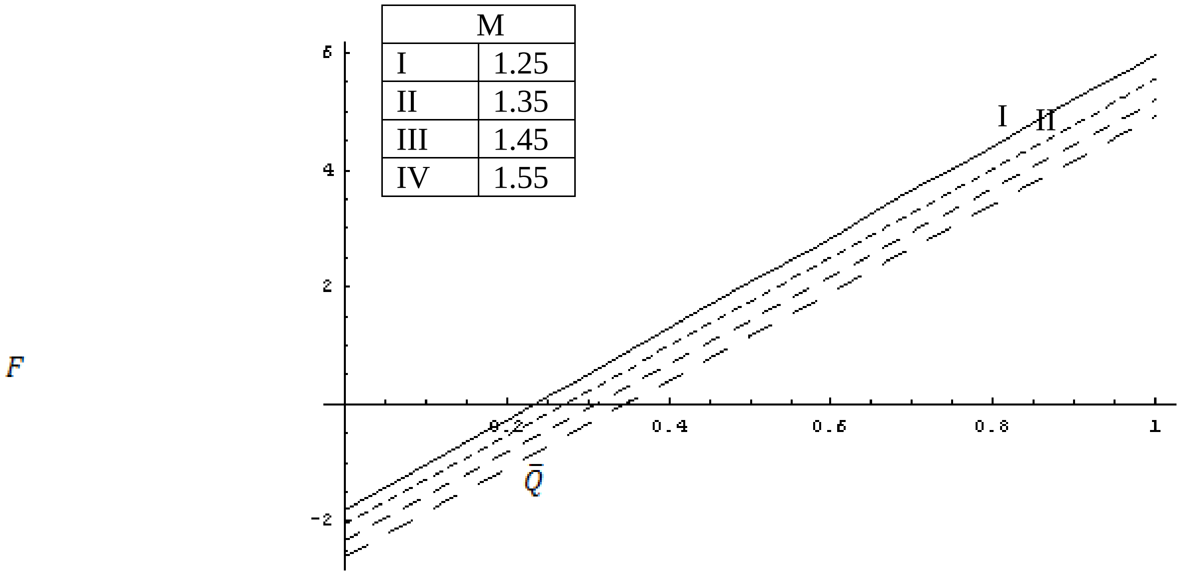

Fig: 9. The variation of F with $\bar{Q}$ for different values of M for fixed α = 0.2; Da =0.01; $\emptyset =$ 0.5;

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IV. CONCLUSIONS

In the present review an examination of MHD impacts on peristaltic stream of a Couple stretch liquid in a channel with porous dividers under long wave length and low Reynolds number approximations has been talked about for the instance of free pumping. The representing two-dimensional conditions are improved by utilizing long wave length presumptions. The correct arrangements of rearranged conditions are computed. The outcomes are talked about through diagrams. We close with the accompanying perceptions.

It is watched that in the peristaltic pumping district, the weight rise increments with an expansion in Hartmann number (M), adequacy proportion ($\emptyset$) and slip parameter (α).