Vital Annex: International Journal of Novel Research in Advanced Sciences
ISSN: 2751-756X
Volume 04 Number 09 (2025)
https://innosci.org/IJNRAS

Article

Effect of Heat Transfer on Oscillatory Flow Behavior of Magnetohydrodynamic (MHD) Bingham Fluid

Lqaa Tareq Hadi[1], Saif Razzaq Mohsin Al-Waily[2], Ahmed A. Hussein Al-Aridhee[3]

1. Department of Drilling techniques and Oil and gas Production, Al-samawa technical Institute, Al-Furat Al-Awsat Technical Uiversity, Samawa, Iraq
2. Ministry of Education, Directorate of Najaf Education, Iraq
3. Ministry of Education, Directorate of Kurbala Education, Iraq

* Correspondence: lqaa.hadi@atu.edu.iq, saif.r.m.1993@gmail.com, ahmedalardy@gmail.com, ma.post20@qu.edu.iq

Abstract: This study analyzes the flow phenomena of Bingham fluid (constant viscosity) in a flexible-walled magnetohydrodynamic (MHD) that occurs through magnetic field effects. Here, we consider flow in the presence of heat and its critical dependence on wall elasticity. The governing equations of the system were solved analytically for partial differential equations. The curves were drawn, and the effect of various parameters was illustrated as well as an analysis of fluid velocity and motion by Mathematica (version 12).

Keywords: Constant viscosity, MHD, inclined channel, Bingham fluid.

Citation: Hadi, L. T, Al-waily, S. R. M, Al-Aridhee, A. A. H. Effect of heat transfer on oscillatory flow behavior of magnetohydrodynamic (MHD) Bingham fluid. Vital Annex: International Journal of Novel Research in Advanced Sciences 2025, 4(9), 468-476

Received: 10th Aug 2025
Revised: 16th Sep 2025
Accepted: 24th Oct 2025
Published: 28th Nov 2025

1. Introduction

32 Electromagnostic fluid dynamics has numerabler appliCatioi1S in the various cn anengmeerig applications such as RefrMBeraGmagnbthvdrodinama'ic Plasma gonesrators and Me. 21k of ef! Fechtfm9fricton tttmtffrictwf fflct ifm and hetttranesfe r adifloat to c the bounda n ' layer oneU) the V place where = the flutdcomesin contact with a soli d surfa~ceX management in fluid dYrlaII \ \ \ \ecs [--il]. Fluid property i.e., viscosity) is a significant physical parameter in petroleum products (crude oils and lubricants due to their wide range of applications and also for engineering results, particularly in flow computations. The flow in porous media under temperature field effects is increasingly attracting attentions and has significant implications and applications to other areas of applied sciences, such as geophysics and engineering. Finally but of course not least, such a flow in sediments is also o f practical interest – as e.g. flow through packed layers, sedimentation,,c pollution and towards centifugal filtration. In the same vein, a research [2] focused on the asymmetric conical channel and also took into account worm-like flow of non-minimal aBingham fluid in presence of variable viscosity [4]. has studied the impedance of concentration/pulse with oscillating eect on ow Reynold viscous MHD by wateranimal in porous medium and tentanciòn layer, while [4] researched pressure gradient on climents eld at wedge ow through slip conditions inclined channel. There are also some works like [5] on Bingham flow in convergent channel with magnetic field and on blood flow to microvasculature [6], [7], [8]. have also studied the general behavior o f the wall collected and [9], applied to nanofluid flow in an inclined c hannel of small cross 2Problem Formulation Consider unsteady laminar flo w of a nanofluid along a infinite vertical p late with ultra slim configuration (= 01,∞ < uv) ∂v A B ∇u Ac Fig1 Configuration o f an inclined channel Emphasis on either growth by which significant di rects from elongation, contraction or lack thereof. Furthermore, the worm-like motion of the fluid was

also studied(10), (11) based on power law for particles in tubes with porosity. Our aim un this work is to establish themathemattical model to study the analytical effect of oscillωting sliding flow of aVuid influence by amagneticeld (MHD) througth an inclined channel of varivel viscocity constant -vicosity Binghamvfluid having heat difference. The solutions of the model are achieved by the mathematical perturbation approach and effects of different physical parameters on results through graphs are examined.

2. Materials and Methods

Mathematical Formulation.

This study investigates the peristaltic flow of the incompresseible aBingham fluid in an elastic channel. Sine waves propagate at constant velocity (c) a long a channel walls, inducing this flow.

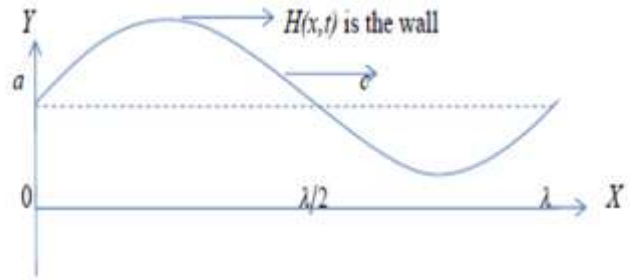


Fig. geometry of problem.

The wall a deformation is given by:

$\bar{H}(\bar{x},\bar{t}\,) = -\bar{\emptyset}\, cos^2 \frac{\pi}{\lambda}(\bar{x} - c\bar{t}) + a$ (1)

The system is described using the following symbols: $\bar{h}$ for the transferse avibration of the wall, $\bar{x}$ for the axial coordinates, $\bar{t}$ for time, $\bar{\emptyset}$ at the channel's half-width point, a for the wave amplitud, λ for a wavelength, and c for the wave propagation velocity.

Basic Equations.

The behavior of the system is described by the following set of equations:

The cont. eq. is given: $\frac{\partial \bar{u}}{\partial \bar{x}} + \frac{\partial \bar{v}}{\partial \bar{y}} = 0$ (2)

The momeentum eqs. are:

x_direcetion:$\rho\left(\frac{\partial \bar{u}}{\partial \bar{t}} + \bar{u}\frac{\partial \bar{u}}{\partial \bar{x}} + \bar{v}\frac{\partial \bar{u}}{\partial \bar{y}}\right) = -\frac{\partial \bar{p}}{\partial \bar{x}} + \frac{\partial \bar{S}_{\overline{xy}}}{\partial \bar{y}} - \sigma B_0^2 \bar{u} - \frac{\mu_c}{k}\bar{u},$ (3)

y _direcetion:$\rho\left(\frac{\partial \bar{v}}{\partial \bar{t}} + \bar{u}\frac{\partial \bar{v}}{\partial \bar{x}} + \bar{v}\frac{\partial \bar{v}}{\partial \bar{y}}\right) = -\frac{\partial \bar{p}}{\partial \bar{y}} + \frac{\partial \bar{S}_{\overline{xy}}}{\partial \bar{x}} - \sigma B_0^2 \bar{v} - \frac{\mu_c}{k}\bar{v},$ (4)

The temperature equetion is given by:

$c_T\rho\left(\frac{\partial T}{\partial \bar{t}} + \bar{u}\frac{\partial T}{\partial \bar{x}} + \bar{v}\frac{\partial T}{\partial \bar{y}}\right) = K_T\left(\frac{\partial^2 T}{\partial \bar{x}^2} + \frac{\partial^2 T}{\partial \bar{y}^2}\right) + \bar{S}.(grad\ \bar{V}) - \frac{\partial q}{\partial y}$ (5)

This model considers a velocity field defined by $V \equiv (u(y,t)$,0 ,0), alongside the fluid temperature $T(y,t)$. The governing equations incorporate several physical properties, including: the density of fluid (ρ),specific heat at constant pressure (c_T),and thermal horizon conductivity (K_T). The effects of a porous medium are accounted for by the permeability (k), while the effect of an external magnetic field (B_0) is included through the magnetic permeability (μ_c) and the fluid's electrical conductivity (σ). Furthermore, the model considers the contribution of a radioactive heat flux (q).

$$\left.\begin{aligned} &\frac{\partial \bar{u}}{\partial \bar{y}} = 0\,, T = T_0 \quad at\ \bar{y} = 0 \\ &\bar{u} = 0\,, T = T_1 \quad at\ \bar{y} = \bar{h} \end{aligned}\right\} \quad (6)$$

The temperature atthe walls of achannel are given by:

$T(0,\bar{t}) = T_0$, and $T(h,\bar{t}) = T_1$ (7)

radioactive heat flux is given:

$\frac{\partial q}{\partial y} = 4\eta^2(T_0 - T)$

(8)

here η the denotes of the aradiation absorption.

a basic of eq.for the **Bingham** fluid is given as:

$$\bar{\mathcal{S}} = \begin{cases} \mu_c \bar{\mathcal{X}} + \frac{\tau_0}{\bar{\dot{\gamma}}} \bar{\mathcal{X}} & \text{for} \quad \tau \geq \tau_0 \\ 0 & \text{for} \quad \tau < \tau_0 \end{cases}$$
(9)
where μ_c is a constant viscosity, τ_0 the yielde stress, and $\dot{\gamma}$ is dafined as:

$$\dot{\gamma} = \sqrt{\frac{1}{2}\sum_i \sum_j \dot{\gamma}_{ij}\dot{\gamma}_{ji}} = \sqrt{\frac{1}{2}\prod}$$

$\prod$ The second strain invariant.

The stress components are:

$$\bar{\mathcal{S}}_{\overline{xx}} = \bar{\mathcal{S}}_{\overline{yy}} = 0, \bar{\mathcal{S}}_{\overline{xy}} = \bar{\mathcal{S}}_{\overline{yx}} = \mu_c \bar{u}_y + \tau_0$$
(10)

and $\bar{\mathcal{S}}.(grad\ \bar{V}) = \bar{\mathcal{S}}_{xy}\bar{u}_{\bar{y}}$ (11)

So that the heat equation become

$$c_T \rho \frac{\partial T}{\partial \bar{t}} = K_T \frac{\partial^2 T}{\partial \bar{y}^2} + \bar{\mathcal{S}}_{xy}\bar{u}_{\bar{y}} - 4\eta^2(T_0 - T) \quad (12)$$

3. Results

Flexible Wall.

a governing eq. of the motion a flexible the wall expressed as:

$$L^* = \overline{P1} - \overline{P_0}$$

$$L^* = m\frac{\partial^2}{\partial t^2} - K\frac{\partial^2}{\partial x^2} + A\frac{\partial}{\partial t}$$

where K is a elastic eq. in the wall, m it is a mass perunit area.

$$\frac{\partial}{\partial \bar{x}} L^*(\bar{h}) = \frac{\partial \bar{p}}{\partial \bar{x}} = -\rho\left(\frac{\partial \bar{u}}{\partial \bar{t}} + \bar{u}\frac{\partial \bar{u}}{\partial \bar{x}} + \bar{v}\frac{\partial \bar{u}}{\partial \bar{y}}\right) + \frac{\partial \bar{\mathcal{S}}_{\overline{xy}}}{\partial \bar{y}} - \sigma B_0^2 \bar{u} - \frac{\mu_c}{k}\bar{u}, \quad (13)$$

Method of Solution.

We can give the non-dimensional terms through the eqs. of motion, as follows:

$$\left.\begin{array}{c} x = \frac{\bar{x}}{h}, y = \frac{\bar{y}}{h}, u = \frac{\bar{u}}{U}, \bar{t} = \frac{th}{U}, \ p = \frac{\bar{p}h}{\mu_c U}, M^2 = \frac{\sigma B_0^2 h^2}{\mu_c}, Da = \frac{k}{h^2}, \dot{\gamma} = \frac{h}{U}\bar{\dot{\gamma}}, \\ \Delta T = T_1 - T_0, \theta = \frac{T - T_0}{\Delta T}, Bn = \frac{h\tau_0}{\mu_c U}, \mathcal{S} = \frac{h}{\mu_c U}\bar{\mathcal{S}}, Pr = \frac{\mu_c c_p}{K_T}, Ec = \frac{U^2}{c_p\,\Delta T}, \\ Br = PrEc, Re = \frac{\rho h U}{\mu_c}, Pe = \frac{\rho h U c_p}{K_T}, N^2 = \frac{4\eta^2 h^2}{K_T}, Fr = \frac{U^2}{gh} \end{array}\right\} \quad (14)$$

The mathematical model incorporates the following dimensionless parameters: Da (Darcy number), (Reynolds number), (magnetic parameter), (Peclet number), (radiation parameter), (Bingham number), Brn (Brinkman number), Pr and Fr. Additionally, the model considers a chemical reaction parameter (Kr) and a distance-dependent fluid viscosity, μ(y), with U representing the mean flow velocity [12].

Substiteuting eq. (14) in to eqs. (1-13), we have a following of nondimensional eqs:

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \quad (15)$$

$$\frac{\partial p}{\partial x} = \frac{\partial}{\partial y}\left(\frac{\partial u}{\partial y} + Bn\right) - \left(M^2 + \frac{1}{Da}\right)u \quad (16)$$

$$Pe\frac{\partial \theta}{\partial t} = \frac{\partial^2 \theta}{\partial y^2} + N^2\theta + Br\left(\frac{\partial u}{\partial y}\right)^2 + BrBn\frac{\partial u}{\partial y} \quad (17)$$

and $\mathcal{S}_{xy} = \frac{\partial u}{\partial y} + \mathrm{Bn}$ (18)

$$\frac{\partial}{\partial y}\left(\frac{\partial u}{\partial y} + Bn\right) - \left(M^2 + \frac{1}{Da}\right)u = L_1\frac{\partial^3 h}{\partial x^3} + L_2\frac{\partial^3 h}{\partial x \partial t^2} + L_3\frac{\partial^2 h}{\partial x \partial t} \quad (19)$$

Where

$$L_1 = \frac{\kappa a^2}{\mu c \lambda^3}, \quad L_2 = \frac{m_1 c a^2}{\mu \lambda^3}, \quad L_3 = \frac{c a^2}{\mu \lambda^2}$$

and

$$h(x,t) = 1 - \emptyset \cos^2 \pi(x - t)$$

Solution of the Problem.

the Solution of the heat eq. and the motion eq.

1. Solution of motion equation..

$$U=\frac{\lambda}{T}+e^{\sqrt{T}\,y}\left(-\frac{e^{h\sqrt{T}}\lambda}{\left(1+e^{2h\sqrt{T}}\right)T}\right)+e^{-\sqrt{T}\,y}\left(-\frac{e^{h\sqrt{T}}\lambda}{\left(1+e^{2h\sqrt{T}}\right)T}\right) \quad (20)$$

Where

$\lambda=L_1 8\pi^3\emptyset\cos(\pi t-\pi x)\sin(\pi t-\pi x)+L_2 8\pi^3\emptyset\cos(\pi t-\pi x)\sin(\pi t-\pi x)+$
$L_3(-2\pi^2\emptyset\cos(\pi t-\pi x)^2+2\pi^2\emptyset\sin(\pi t-\pi x)^2)$

$h=1-\emptyset\cos(\pi x-\pi t)^2$

$T=\frac{M^2+1}{\mathrm{Da}}$

2. Solution of temperature equation.

$$\theta=\frac{B}{F}+\left(-\frac{B}{F}\right)\cos(\sqrt{F}\,y)+\left(-\frac{-B\cot(\sqrt{F})+B\csc(\sqrt{F})-FB\csc(\sqrt{F})}{F}\right)\sin(\sqrt{F}\,y) \quad (21)$$

Where

$$B=-\left(Br\left(\frac{e^{h\sqrt{T}-\sqrt{T}y}\lambda}{\left(1+e^{2h\sqrt{T}}\right)\sqrt{T}}-\frac{e^{h\sqrt{T}+\sqrt{T}y}\lambda}{\left(1+e^{2h\sqrt{T}}\right)\sqrt{T}}\right)^2+Br*Bn\left(\frac{e^{h\sqrt{T}-\sqrt{T}y}\lambda}{\left(1+e^{2h\sqrt{T}}\right)\sqrt{T}}-\frac{e^{h\sqrt{T}+\sqrt{T}y}\lambda}{\left(1+e^{2h\sqrt{T}}\right)\sqrt{T}}\right)\right)$$

$F=N^2-i*w*\mathrm{Pe}$

3. Solution of the shear stress.

$$S=\frac{e^{h\sqrt{T}-\sqrt{T}y}\lambda}{\left(1+e^{2h\sqrt{T}}\right)\sqrt{T}}-\frac{e^{h\sqrt{T}+\sqrt{T}y}\lambda}{\left(1+e^{2h\sqrt{T}}\right)\sqrt{T}}+Br \quad (22)$$

Numerical Results and Discussion.

Figures 3 and 4 are the nodal pattern according tothe numerical model results of undulating motion of a poraus flexible tube with elastic wall where the Bingham uids are considered involume compressible [13]. DIAGRAM OF MEANDERING FLOW FIELDSThe geometry of meandering flow fields is illustrated in Figure (1). The Bingham oscillatory flow for double porous medium (2) was also solved using Mathematics 12 [14]).

1. Distribution of Velocity.

According eq.(20), figs. (2-9) Clarification of the effects of parameters$L_1, L_2, L_3, \emptyset, t, \mathrm{Da}, x$ and M on the velocity distribution u versus y.

Figures 2,3,4,5 and 7 shows that of a velocity an increasing with the increasing of $L_1, L_2, L_3, \emptyset, \mathrm{Da}$ when $0<y\leq 0.9$, and decreases when $0.9\leq y<1$, Exactly the opposite is the case of Figure (9) for the variable M.

Figure (8) show that a velocityincreasing with a increasing of x when $0<y\leq 0.7$, and decreases when $0.7\leq y<1$, Exactly the opposite is the case of Figure (6) for the variable t.

2. Distribution of Temperature.

Based on eq. (21), figs. (10-23) depict of the influence of the parameters $L_1, L_2, L_3, \emptyset, t, \mathrm{Da}, x, M, N, \omega, p_e, B_r, B_n$ and R_e on a fluid temperature function θ vs. y.

The fluid of the temperature increases as a parameters $L_1, L_2, L_3, \emptyset, \mathrm{Da}, x, N$ and B_r increase, as seen in Figures 10, 11, 12, 13, 15, 16, 18 and 21.

Figures 14, 17, 19, 20, 22 and 23 shows that as t, M, ω, p_e, $B_n$and R_e are increased, a fluid of the temperature drops [15].

3. Distribution of Shear stress.

Based on eq. (22), figs. (24-33) depict the influence of parameters $L_1, L_2, L_3, \emptyset, t, \mathrm{Da}, x, M, \omega$ and B_n on the fluid Shear stress function u versus y.

The fluid's Shear stress increases as a parameters t, x, M, ω and B_n increase, as seen in Figures 28, 30, 31, 32 and 33.

Figures 24, 25, 26, 27 and 29 show that as $L_1, L_2, L_3, \emptyset$ and Da are increased, a fluid's Shear stress drops.

Here are all the constant parameter values used in plotting the velocity equation, temperature, and shear stress profiles $L_1=01$, $L_2=0.5$, $L_3=0.1$, $\emptyset=0.2$, $t=0.05$, $Da=0.9$, $x=3.75$, $M=1.1$, $N=1.25$, $\omega=1$, $p_e=2$, $B_r=1$, $B_n=2$, $R_e=1$..

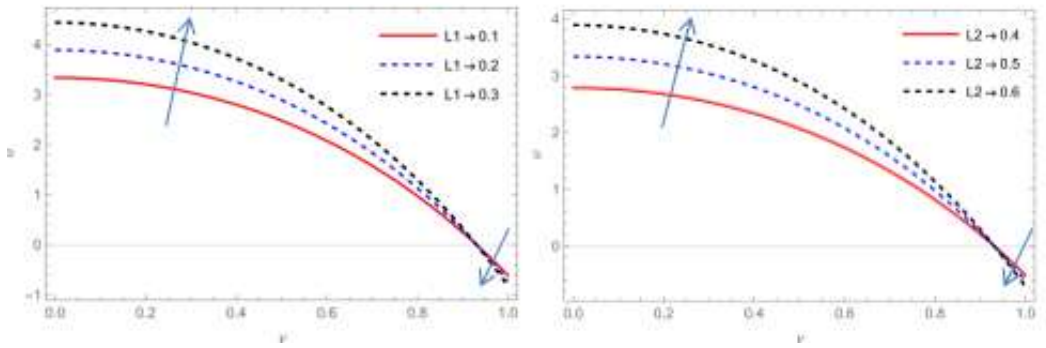


Figure 2 & 3. Velocity profile u(y) for varying magnetic parameter MMM at t=0t 0t=0.

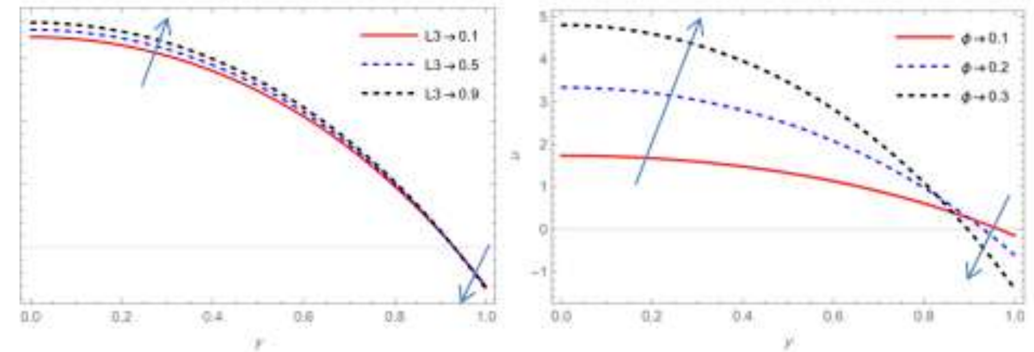


Figure 4 & 5. Velocity distribution for Different Bingham number Bn showing shear-thinning behavior.

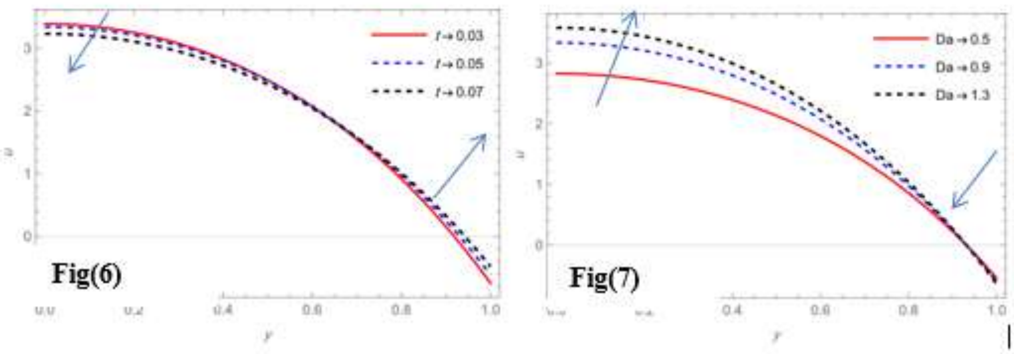


Figure 6 & 7. Influence of Reynolds number Re on velocity distributin u(y)

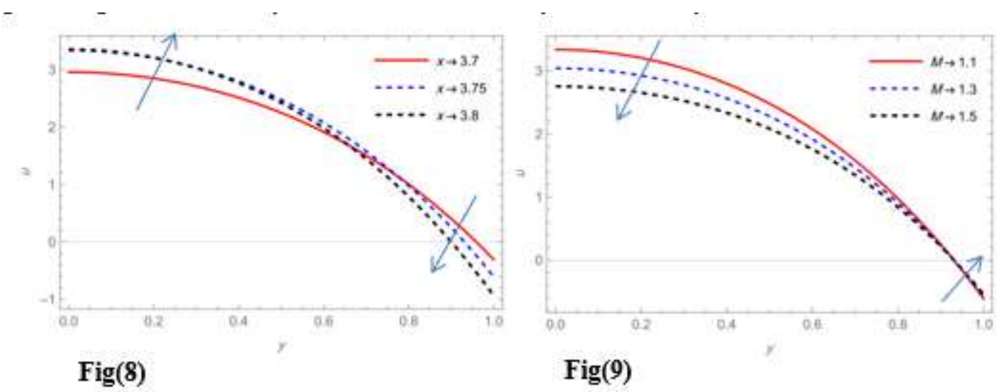


Figure 8 & 9. Velocity distribution versus y for varying wall elasticity parameter K.

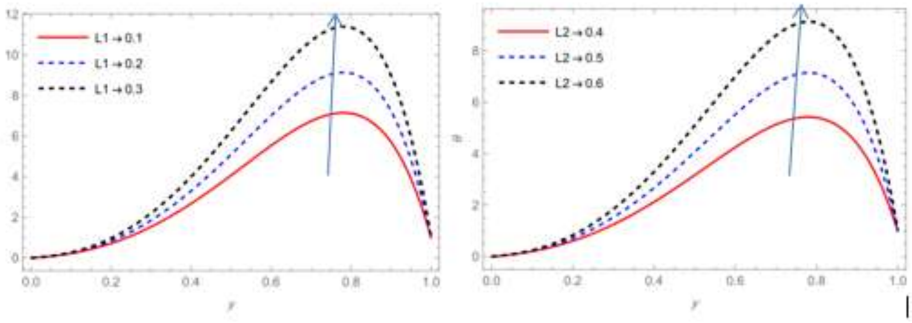


Figure 10 & 11. Temperature profile θ(y) for varying magnetic parameter M.

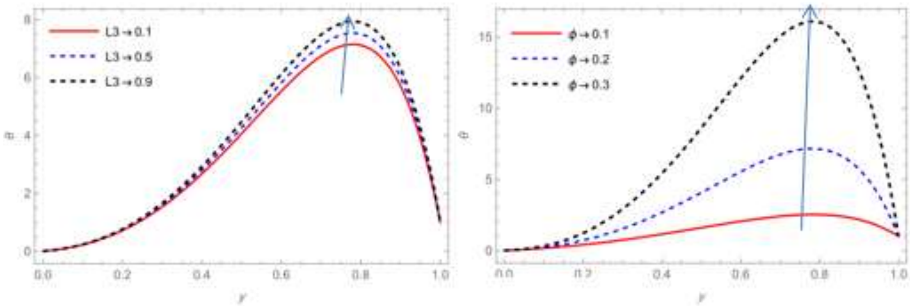


Figure 12 & 13. Effect of Prandtl number Pr on fluid temperature profile.

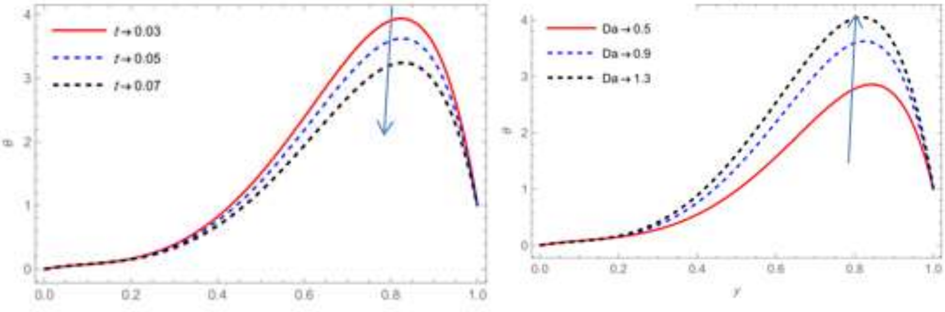
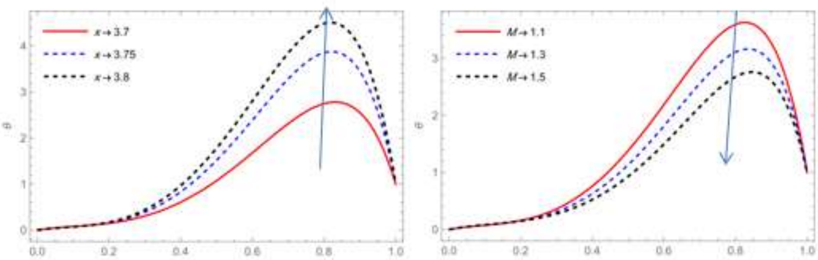
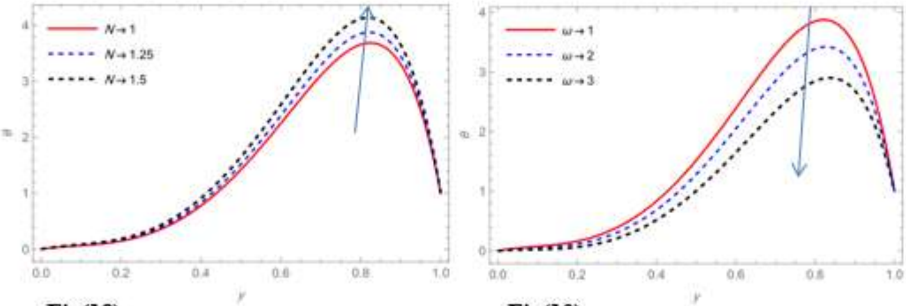


Figure 14 & 15. Influence of chemical reaction parameter Kr on temperature.



Fig(16) **Fig(17)**

Figure 16 & 17. Temperature profile for varying heat saouce parameter Q.



Fig(18) **Fig(19)**

Figure 18 & 19. Temperature variation with increasing Froude number Fr.

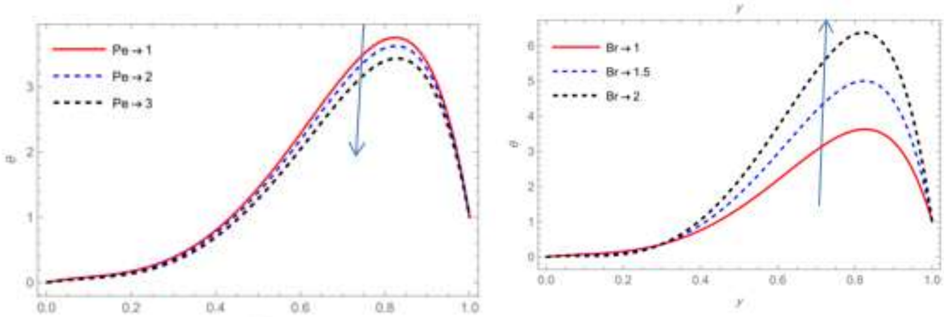


Figure 20 & 21. Temperature profile influenced ny oscillation amplitude.

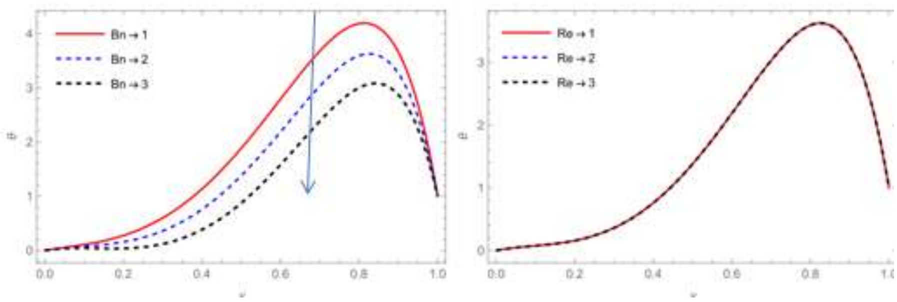


Figure 22 & 23. Comparative temperature profile for multiple physical parameters.

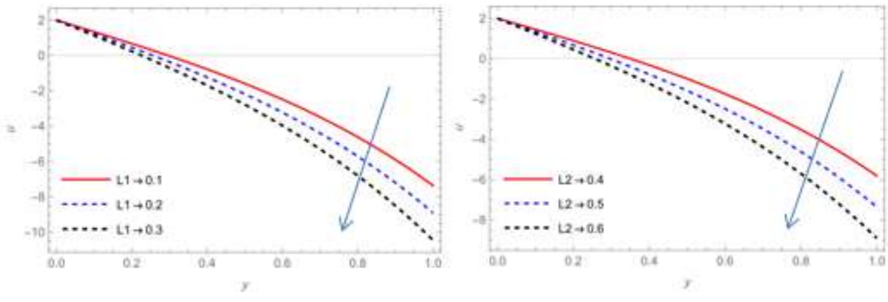
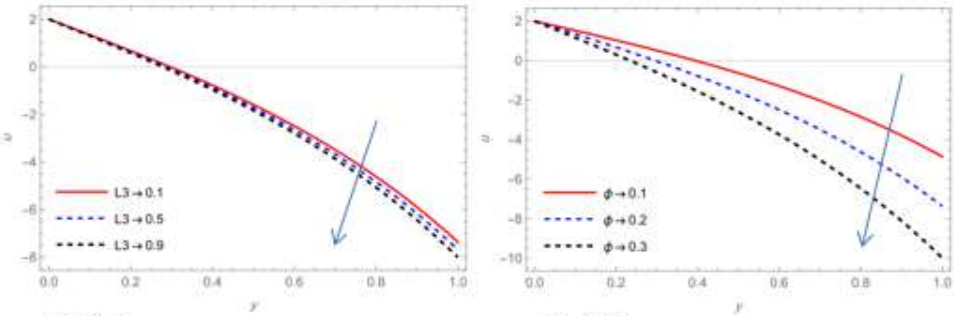
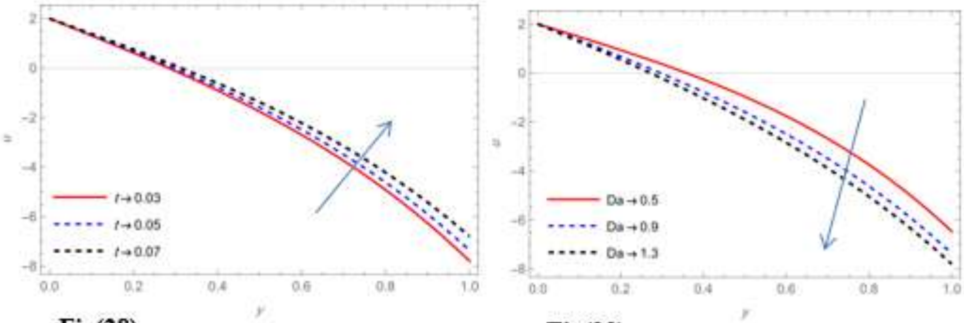


Figure 24 & 25. Shear stress variation under different Darcy number Da.



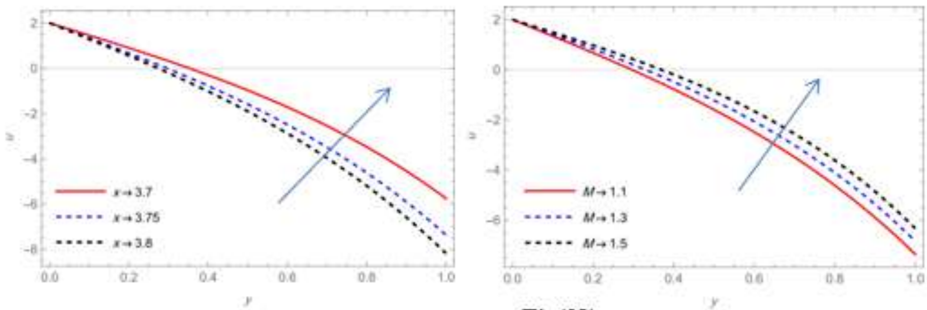
Fig(26) Fig(27)

Figure 26 & 27. Influence of reynolds number re on shear stress.



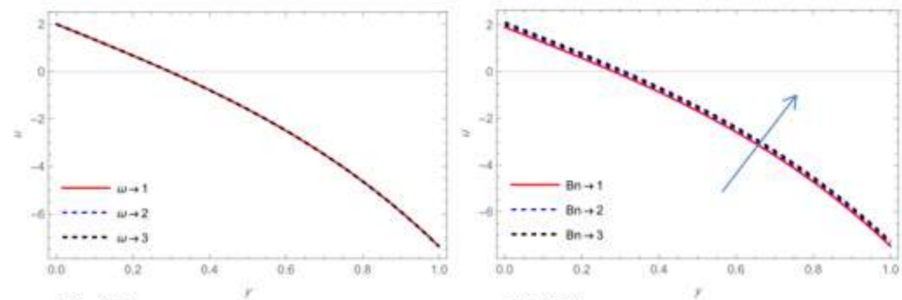
Fig(28) Fig(29)

Figure 28 & 29. Shear stress increase with higher brinkman number Br.



Fig(30) Fig(31)

Figure 30 & 31. Shear stress variation radiation parameters Rd.



Fig(32) Fig(33)

Figure 32 & 33. Combined effect of wall elasticity and magnetic field on shear stress.

4. Conclusion

An analysis of the steady flow of a Bingham liquid with constant viscosity subject to magnetic field (MH) and heat transfer in an inclined channel between flexible walls was carried out by [7]. A mathematical model which includes the influence of magnetic field strength, wall elasticity and thermal gradients was assumed and the solution also obtained by employing perturbation techniques. The results for velocity field, as depicted graphically via Mathematica, indicate that the velocity of Bingham fluid is influenced against variation in magnetic field intensity, wall flexibility and temperature gradient.

The fluid motion is damped as Lorentz forces resist the flow with higher magnetic field. The profile of the velocity is also dominated by thermal effects, which introduces a viscosity variation at the fluid layer. The compliance of the wall also has a major influence on flow modification effects, at least for oscillatory flows, which suggests that boundary mechanics can not be forgotten in relation to practical application pushers.

More generally, they provide insight as applied to the Bingham fluid flow in MHD systems and may have engineering applications of the presence of non-Newtonian fluids; namely crude oil pumping, biofluids delivery or cooling processes. Future work could extend the stiffness hypothesis to allow for a variable viscosity,non-linear efects of the wall and multi-phase flow systems to provide more accurate studies.

REFERENCES

[1] Y. J. Kim, "Analysis of heat transfer in a non-Newtonian fluid flow in a porous medium," Int. J. Eng. Sci., vol. 38, pp. 833–845, 2000.

[2] R. Y. Hassen and H. A. Ali, "Hall and Joule's heating influences on peristaltic transport of Bingham plastic fluid with variable viscosity in an inclined tapered asymmetric channel," Ibn Al-Haitham J. Pure Appl. Sci., vol. 34, no. 1, 2021.

[3] D. G. Al-Khafajy, "Effects of heat transfer on MHD oscillatory flow of Jeffrey fluid with variable viscosity through porous medium," Adv. Appl. Sci. Res., vol. 7, no. 3, pp. 179–186, 2016.

[4] F. A. Adnan and M. A. Abdulhadi, "Effect of an inclined magnetic field on peristaltic flow of Bingham plastic fluid in an inclined symmetric channel with slip conditions," Iraqi J. Sci., vol. 60, no. 7, pp. 1551–1574, 2019.

[5] H. Bénard, ``Les Tourbillons cellulaires dans une nappe liquide,'' Rev. Gén. Sci. Pures Appl., vol. 11, pp. 1261–1271, 1900.

[6] M. Kothandapani and S. Srinivas, {\em On the impact of wall properties in MHD peristaltic transport with heat transfer through porous medium}, Phys. Lett. A, vol. 372, pp. 4586–4591, 2008.

[7] C. Uma Devi, Y. V. K. Ravi Kumar and T. Kawkab, “Investigation of Jeffrey nanofluid through an inclined tube with permeable walls,” J.Xi'an Univ. Archit. Technol., vol. 12, pp. 115–123, 2020.

[8] N. Subadra, K. M. Prasad and S. R. P. Rao, “Effect of slip and heat as well as mass transfer on peristaltic flow of power-law fluid through porous medium in a planar channel,” J.Biol.Phys., vol.#27, no#3 (2011), pp 487-502. : Conf. Ser., vol. 1495, p. 012039, 2020.

[9] S. R. M. Al-Waily, A. Elnaby, and Khaled Ailabouni, "Ef-fect of variable temperature on magnetohydrodynamics peristaltic flow of a couple-stress Jeffrey fluid with constant viscosity through a flexible porous inclined channel," J ComputHa rzrP hy s,vol8 0 9 n99[1] Singh,Reinforcement theory. Anal. Appl., vol. 33, no. 5, pp. 138–152, 2024.

[10] G. R. Liu and J. Z. Wu, Peristaltic Transport of Fluids, Springer (2021).

[11] M. S. Takhar, RjsonsR entitiesenrorthehay.Fluid in a channel with compliant walls - an exact solution," --> Int. J. Heat Mass Transf., vol. 49, pp. 1738–1749, No 9-10,2006.

[12] A. M. Siddiqui, M. I. Asjad, S. Nadeem, "Peristaltic motion of non-Newtonian fluid in a non-uniform inclined channel with wall properties and slip conditions", Appl. Math. Comput., vol. 219, 7, pp. 3314–3329, 2012.

[13] M. M. Rashidi, S. K. N. Khalid, and B.Shankar, Peristaltic transport of a Bingham plastic fluid in an inclined asymmetric channel with slip conditions and heat transfer, J.Heat Transfer vol.. 136, no. 9, p. 094501, 2014.152

[14] S.M. Kamel, “Influence of thermal radiation and chem - ical reaction on peristaltic flow of a Bingham fluid in an inclined asymmetric channel,” Alexandria Eng. J., vol. 54, no. 3, pp. 557–566, 2015.

[15] T. Hayat, A. Alsaedi, and M. Awais,"Peristaltic transport of Jeffrey fluid in an inclined asymmetric channel with heat and mass transfer," Int. J. Heat Mass Transf., vol. 53, no. 21–22, pp.5030–5037, 2010.