Unsteady Transient Couette and Poiseuille Flow Under The effect Of Magneto-hydrodynamics and Temperature

Taza Gul¹, Mubarak Jan¹, Zahir Shah¹, S. Islam¹, M.A. Khan¹

¹Mathematics Department, Abdul Wali Khan University Mardan, KPK Pakistan.
²Mathematics Department, ISPaR/Bacha Khan University Charsadda, KPK Pakistan.

INTRODUCTION

Non-Newtonian fluids have got great importance great in the field of research, especially in applied and bio mathematics, industry and engineering problems. Examples of such types of fluids are plastic trade, food processing, movement of biological fluids, wire and fibres coating, paper production, gaseous diffusion transpiration cooling, drilling mud, heat pipes etc. Several complex fluids such as polymer melts, paint, shampoo, mud, ketchup, blood, certain oils and greases, and many emulsions are involved in the class of non-Newtonian fluids. Due to industrial and technological usages non-Newtonian fluids have become its significant part. That’s why researchers take a great interest in it. Islam et al. [1] studied Couette and Poiseuille flow and there generalized form under the effect of heat analysis. For the solution of the problem they used OHAM. Hayat et al. [2] worked on the MHD steady flow of oldroyd-6 constant fluid. HAM method was used in this work for the nonlinear differential equation of three different types of flows. Attia [3] examined the MHD non Newtonian unsteady couette and poisson flows. The effect of Hall term and physical parameters are discussed for velocity and temperature distributions. Aiyemesi et al. [4-5] calculated the solution of MHD Couette flow, Poiseuille flow problems of velocity and temperature profile by using regular perturbation method. Danish et al. [6] studied Poisuelle and Couette and poisson flow of third grade fluid. Rajagopal et al.[7], examined non-Newtonian fluids between two parallel and vertical plates in the form of a Natural Convection Flow. Bhargava et al. [8], investigated Numerical solution of free convection MHD micro polar fluid flow between two parallel porous vertical plates. They have discussed the effect of various physical parameters. In recent Gul et al. [9-13] worked out on differential type fluids in variations of articles. They discussed the effect of various physical parameters on flow fields. Volume flux, skin friction, average velocity, and the temperature distribution across the film were shown in there studied. In most of their work they used two analytical techniques (OHAM and ADM) to obtained best results. Dileep and kumar [14] investigates the unsteady second grade fluid in a porous channel. They give the effect of physical parameters on the fluid motion during porous and clear region. Salah et al. [15], examined the flow of second grade fluid in a porous and rotating frame. Constant and accelerated fluid flows cases are studied in their works. Nemati et al.[16], studied the unsteady thin film flow of non-Newtonian fluid over a moving belt. The approximate solutions of velocity profile have been shown by using HAM. Iftikhar [17], examined the unsteady boundary layer flow of a second grade fluid affected by an impulsively stretching sheet. HAM method is used to get the analytical solution and the effects of the physical parameters are discussed through graphs. Chauhan and Kumar [18], examined the unsteady shear flow of a second grade fluid between two horizontal parallel plates. In their work Laplace transform method is applied to find the solution of the flow problem. Abbas et al.[19], discussed the unsteady thin liquid film of second grade fluid through stretching surface. HAM method was used for analytical solution. Kumar and Parsad [20], discussed the heat effect in Stokes second problem in unsteady case under the effect of magnetic field. analytical result is shown for temperature field. Hameed and Ellahi [21], worked on thin film flow in a non-Newtonian fluid on a vertical moving belt. Fetecau
Taza Gul et al., 2015

[22], examined the longitudinal and torsional oscillations of second grade fluid circular cylinder. Tan et al.[23] studied Stoke first problem for a second grade fluid in a porous half space with heated boundary. They reported some good results. A variety of analytical techniques have been used by the researchers for the solution of differential equations. In the recent years the Adomian decomposition Method (ADM) and Optimal Homotopy Asymptotic Method (OHAM) are the two analytical techniques receiving more attention. The ADM was revised with some new results by Adomian [24], Wazwaz [25] and Sqqiqui et al [26] used Adomian decomposition method in their work to get attractive results. Application of the optimal homotopy asymptotic method for solving nonlinear equations arising in heat transfer was investigated by Marinca et al. [27-29]. In another investigation Marinca et al. [30] have used optimal homotopy asymptotic method for the steady flow of a fourth-grade fluid past a porous plate.

**Governing Equation**

The MHD and heat equation governing the problem (momentum, mass and second order fluid equation) can be written as

\[ \nabla \cdot \mathbf{U} = 0, \]

\[ \rho \frac{D\mathbf{U}}{Dt} = \nabla \cdot \mathbf{T} + \mathbf{J} \times \mathbf{B} + f_{g}. \]

\[ \rho C_r \frac{D\Theta}{Dt} = k \nabla^2 \Theta + tr(\mathbf{T} \cdot \mathbf{L}), \]

Here \( \mathbf{U} \) represent velocity of the flow, \( \rho \) is flow density, \( \frac{D}{Dt} \) is the material time derivative, and \( f_{g} \) is body force due to gravity. Thus, the Lorentz force per unit volume is

\[ \mathbf{J} \times \mathbf{B} = \left[ 0, -\sigma \mathbf{B}_0^2 \mathbf{u}, 0 \right]. \]

Where \( \mathbf{B}=(0, \mathbf{B}_0, 0) \) is the uniform magnetic filed, \( \mathbf{B}_0 \) is the applied magnetic field and \( \sigma \) is the electrical conductivity.

The current density \( \mathbf{J} \) is

\[ \mathbf{J} = \sigma(\mathbf{E} + \mathbf{U} \times \mathbf{B}), \quad \nabla \times \mathbf{B} = \mu_0 \mathbf{J}. \]

Here, \( \mu_0 \) is the magnetic permeability, \( \mathbf{E} \) is an electric field which we ignore in this work, and

The cauchy stress tensor, \( \mathbf{T} \) is

\[ \mathbf{T} = -\rho \mathbf{I} + \mathbf{S}, \]

Where \( \mathbf{S} \) is the extra stress tensor, \( \rho \mathbf{I} \) is the isotropic stress. For second grade fluid

\[ \mathbf{S} = \mu \mathbf{A}_1 + \alpha_1 \mathbf{A}_1 + \alpha_2 \mathbf{A}_1^2, \]

\[ \mathbf{A}_0 = \mathbf{I}, \quad \mathbf{A}_1 = \mathbf{L} + \mathbf{L}' \mathbf{L}, \quad \mathbf{L} = \text{grad} \mathbf{U}, \]

\[ \mathbf{A}_1 = (\nabla \mathbf{u}) + (\nabla \mathbf{u})^T, \quad \mathbf{A}_2 = \frac{D}{Dt} \mathbf{A}_{n-1} + \mathbf{A}_{n-1} (\nabla \mathbf{u}) + (\nabla \mathbf{u})^T \mathbf{A}_{n-1}, \quad n \geq 2 \]

\( \mathbf{A} \) is the Rivlin Ericksen stress tensor and \( \mu \) is the viscosity coefficient.

**Formulation of the Couette type flow Problem**

Consider two Vertical and parallel plates such that one of them is oscillating and moving with constant velocity \( \mathbf{U} \) and the other plate kept oscillating only. The total thickness of the fluid between the plates assumed to be “2h”. Moving and oscillating plate caries with itself a liquid of width “h”. The configuration of fluid flow is along the Y-axis and perpendicular to x-axis. A transverse magmatic field applied to the belt. Gravitational force and magnetics force causes the fluid motion. We assume that the flow is un-steady, laminar and incompressible.
The velocity field and boundary conditions for the problem is given as

\[ \mathbf{U} = \left(0, u(x,t), 0\right) \text{, and } \Theta = \Theta(x,t) \]  
\[ U(h,t) = U + UCos\omega t, \quad U(-h,t) = UCos\omega t, \]  
\[ \Theta(h,t) = \Theta_o, \quad \Theta(-h,t) = \Theta_1, \]  
\[ \Theta \] is for the Expressions the frequency of the oscillating plates.

Consuming (10) in (2) and (3) reduced to the form

\[ \rho \frac{\partial u}{\partial t} = \frac{\partial}{\partial x}(\sigma \frac{\partial u}{\partial x} - \rho g - \sigma B_o^2 u), \]  
\[ \rho c_p \left(\frac{\partial \Theta}{\partial t}\right) = k \frac{\partial^2 \Theta}{\partial x^2} + \frac{\partial}{\partial t} T_{xy}, \]  
\[ \rho c_p \left(\frac{\partial \Theta}{\partial t}\right) = k \frac{\partial^2 \Theta}{\partial x^2} + \mu \left(\frac{\partial u}{\partial x}\right)^2 + \alpha \frac{\partial}{\partial t} \left(\frac{\partial u}{\partial x}\right), \]  
\[ T_{xx} = -P + (2\alpha_1 + \alpha_2) \left(\frac{\partial u}{\partial x}\right)^2, \]  
\[ T_{xy} = \mu \frac{\partial u}{\partial x} + \alpha_1 \frac{\partial }{\partial t} \left(\frac{\partial u}{\partial x}\right), \]  
\[ T_{xy} = -P + \alpha_2 \left(\frac{\partial u}{\partial x}\right)^2, \]

Inserting of equation (14) in equation (12) and (13) give us

\[ \rho \frac{\partial u}{\partial t} = \mu \frac{\partial^2 u}{\partial x^2} + \alpha \frac{\partial}{\partial t} \left(\frac{\partial^2 u}{\partial x^2}\right) - \rho g - \sigma B_o^2 u, \]  
\[ \rho c_p \left(\frac{\partial \Theta}{\partial t}\right) = k \frac{\partial^2 \Theta}{\partial x^2} + \mu \left(\frac{\partial u}{\partial x}\right)^2 + \alpha \frac{\partial}{\partial t} \left(\frac{\partial u}{\partial x}\right), \]  

Using non-dimensional parameters

\[ \bar{u} = \frac{u}{U}, \bar{x} = \frac{x}{h}, \bar{t} = \frac{t}{h^2}, \bar{\Theta} = \frac{\Theta - \Theta_o}{\Theta_1 - \Theta_o}, \bar{B}_p = \frac{\mu U^2}{k(\Theta_1 - \Theta_o)}, M = \frac{\sigma B_o^2 \delta^2}{\mu}, \]  
\[ P_s = \frac{\rho c_p \delta^2 \bar{p}}{\mu}, \bar{\omega} = \frac{\omega \delta^2 \rho}{\mu}, S_s = \frac{\delta^2 \rho g}{\mu U}, \alpha = \frac{\alpha_1}{\rho \delta^2}, \Omega = \frac{h^2 \bar{\partial} \bar{p}}{\mu \bar{U} \bar{x}} \]
Where $\alpha$ is the non-dimensional variable, $B_r$ is the Brinkman number, $S_e$ is Stoke number and $P_r$ is the Prandtl number, $\omega$ is the oscillating parameter, $M$ is the magnetic parameter. Using the above dimensionless parameter in equation (18,19) and reducing bars we obtain

$$
\frac{\partial u}{\partial t} + \frac{\partial^2 u}{\partial x^2} + \alpha \frac{\partial}{\partial t} \left( \frac{\partial^2 u}{\partial x^2} \right) - S_t - Mu,
$$

(21)

$$
P_r \left( \frac{\partial \Theta}{\partial t} \right) = \frac{\partial^2 \Theta}{\partial x^2} + B_r \left( \frac{\partial u}{\partial x} \right)^2 + \alpha \left( \frac{\partial u}{\partial x} \right) \left( \frac{\partial^2 u}{\partial t \partial x} \right),
$$

(22)

And the boundary conditions are

$$
u(1,t) = 1 + \cos t, \quad u(-1,t) = \cos t,
$$

(23)

$$
\Theta(0,t) = 0, \quad \Theta(1,t) = 1,
$$

(24)

**ADM Solution for the Couette flow problem**

To obtained the analytical solution first we apply the ADM method using the above boundary conditions. The zero, first and second order problems and there is solution is given below in order

$$
P^0 : \frac{\partial^2 u_0(x,t)}{\partial x^2} = S_t,
$$

(25)

$$
\frac{\partial^2 \Theta_0(x,t)}{\partial x^2} = 0,
$$

(26)

$$
P^1 : \frac{\partial^2 u_1(x,t)}{\partial x^2} = \frac{\partial u_0}{\partial x} - \alpha [A_1] + Mu_0,
$$

(27)

$$
\frac{\partial^2 \Theta_1(x,t)}{\partial x^2} = \frac{\partial^2 \Theta_0}{\partial x^2} - B_r [B_1] + \alpha [C_1]),
$$

(28)

$$
P^2 : \frac{\partial^2 u_2(x,t)}{\partial x^2} = \frac{\partial u_1}{\partial x} - \alpha [A_2] + Mu_1,
$$

(29)

$$
\frac{\partial^2 \Theta_2(x,t)}{\partial x^2} = P_r \frac{\partial^2 \Theta_1}{\partial x^2} - B_r ([B_1] + \alpha [C_1]),
$$

(30)

The Adomian polynomials are defined as,

$$
A_0 = \frac{\partial}{\partial t} \left( \frac{\partial^2 u_0}{\partial x^2} \right), \quad A_1 = \frac{\partial}{\partial t} \left( \frac{\partial^2 u_1}{\partial x^2} \right),
$$

(31)

$$
B_0 = \left( \frac{\partial u_0}{\partial x} \right)^2, \quad C_0 = \left( \frac{\partial u_0}{\partial x} \right) \left( \frac{\partial^2 u_0}{\partial t \partial x} \right), \quad B_1 = 2 \frac{\partial^2 u_0}{\partial x} \frac{\partial u_0}{\partial x},
$$

$$
C_1 = \frac{\partial u_1}{\partial x} \frac{\partial^2 u_1}{\partial t \partial x} + \frac{\partial u_1}{\partial x} \frac{\partial^2 u_1}{\partial t \partial x},
$$

(32)

The solution of the above components is,

$$
P^0 : u_0(x,t) = \frac{1}{2} (1 + x) + \cos \omega t + \frac{1}{2} (x^2 - 1),
$$

(33)

$$
\theta_0(x,t) = \frac{1}{2} (1 + x).
$$

(34)

$$
P^1 : u_1(x,t) = \frac{1}{24} \left( M(-6 - 2x + 6x^2 + 2x^3) + 12MC_1 \cos \omega t + 12M \sin \omega t + 12M \sin \omega t \right)
$$

(35)

$$
\theta_1(x,t) = \frac{1}{24} \left( 3B_1(1 - x^2) + 4S_t x B_1(1 - x^2) + 2S_t B_1(1 - x^4) \right).
$$

(36)
\[ u_z(x,t) = \frac{1}{720} M^2 \{(75 + 7x - 90x^2 - 10x^3 + 15x^4 + 3x^5) + M^2 \cos \{t \omega \}(150 - 180x^2 + 30x^4) \\
+ M^2 \omega^2 \cos \{t \omega \}(150 - 180x^2 + 30x^4) + 360 \alpha \omega^2 \cos \{t \omega \}(x^2 - 1) + M \omega \sin \{t \omega \}(300 + 360x^2 + 30x^4) \]
\[ + 360 \alpha \omega^2 \sin \{t \omega \}(x^2 - 1) + S \omega M^2 (61 + 75x^2 - 15x^4 + x^6) \}. \]
\[ \theta_2(x,t) = \frac{1}{720} \{15\, MB_r \, (-1 + 4x + 2x^2 - 4x^3 - x^4) + 120\, B_r \, M \omega^2 \cos \{t \omega \}(1 - x^2) + 60\, B_r \, x \omega^2 \cos \{t \omega \}(x^2 - 1) + 60\, B_r \, S_r \, (60 - 56x + 80x^3 - 60x^4 - 24x^5) + 120\, S_r \, M \omega \sin \{t \omega \}(x^4 - 1) \} + 120\, S_r \, B_r \, \omega \sin \{t \omega \}(x^4 - 1) + 60\, M \, S_r \, \alpha \omega \sin \{t \omega \}(x^4 - 1) + M \, B_r \, S_r^2 \, (-52 + 60x^4 - 8x^6). \]

The series solutions of velocity profile is obtained as
\[ u(x,t) = u_0(x,t) + u_1(x,t) + u_2(x,t) \]
\[ u(x,t) = \frac{1}{2} (1 + x) + \frac{1}{2} \{M(-6 - 2x + 6x^2 + 2x^3) + 12 \omega \cos \{t \omega \} \}
\[ (1 - x^2) + 12 \omega \sin \{t \omega \} c_1(1 + x^2) + 12 \omega \sin \{t \omega \}(1 - x^2) + S \omega M (5 - 6x^2 + x^4) \} \]
\[ \{75 + 7x - 90x^2 - 10x^3 + 15x^4 + 3x^5 \} + M^2 \cos \{t \omega \}(150 - 180x^2 + 30x^4) + 360 \alpha \omega^2 \cos \{t \omega \}(x^2 - 1) + M \omega \sin \{t \omega \}(300 + 360x^2 + 30x^4) \]
\[ + 360 \alpha \omega^2 \sin \{t \omega \}(x^2 - 1) + S \omega M^2 (61 + 75x^2 - 15x^4 + x^6) \} \].

The series solutions of temperature profile is obtained as
\[ \theta(x,t) = \theta_0(x,t) + \theta_1(x,t) + \theta_2(x,t) \]
\[ \theta(x,t) = \frac{1}{2} (1 + x) + \frac{1}{2} \{3 B_r (1 - x^2) + 4 \omega^2 x B_r (1 - x^2) + 2 S_r M (5 - 6x^2 + x^4) \} \]
\[ \{15 MB_r \, (-1 + 4x + 2x^2 - 4x^3 - x^4) + 120 B_r \ M \omega \cos \{t \omega \}(1 - x^2) + 60 B_r \ x \omega \cos \{t \omega \}(x^2 - 1) \} + 120 \, \omega \sin \{t \omega \}(x^4 - 1) \}
\[ \{150 - 180x^2 + 30x^4 \} + 360 \alpha \omega^2 \cos \{t \omega \}(x^2 - 1) + M \omega \sin \{t \omega \}(300 + 360x^2 + 30x^4) \]
\[ + 360 \alpha \omega^2 \sin \{t \omega \}(x^2 - 1) + S \omega M^2 (61 + 75x^2 - 15x^4 + x^6) \}. \]

**OHAM Solution Couette flow problem**

Now we apply OHAM method to get the required solution. Zero and first component problem for velocity and temperature profiles are
\[ P^0 : \frac{\partial^2 u_0(x,t)}{\partial x^2} = S \]
\[ \frac{\partial^2 \theta_0(x,t)}{\partial x^2} = 0, \]
\[ P^1 : \frac{\partial^2 u_1(x,t)}{\partial x^2} = S_r (1 + c_1) + \frac{\partial^2 u_0}{\partial x^2} + \frac{\partial^2 u_0}{\partial t^2} - c_1 \frac{\partial u_0}{\partial t} - \alpha \omega^2 \left( \frac{\partial^2 u_0}{\partial t^2} \right) - M c_1 u_0, \]
\[
\frac{\partial^2 \Theta_1(x, t)}{\partial x^2} = -P_c \frac{\partial \Theta_0}{\partial t} + \frac{\partial^2 \Theta_0}{\partial x^2} + \frac{\partial^2 \Theta_0}{\partial t^2} - \frac{\partial \Theta_0}{\partial x} \left( \frac{\partial u_0}{\partial x} \right)^2 + \alpha B_c \frac{\partial u_0}{\partial t} \left( \frac{\partial^2 u_0}{\partial t \partial x} \right), \tag{46}
\]

\[
P^1 : \frac{\partial^2 u_2(x, t)}{\partial x^2} = S_c \frac{\partial \Theta_0}{\partial t} - \frac{\partial \Theta_0}{\partial x} \frac{\partial u_0}{\partial x} + \frac{\partial \Theta_0}{\partial t} \frac{\partial u_0}{\partial x} + \frac{\partial \Theta_0}{\partial x} \frac{\partial u_0}{\partial t} - \frac{\partial \Theta_0}{\partial t} \frac{\partial u_0}{\partial t} + \alpha \frac{\partial^2 \Theta_0}{\partial t^2} \left( \frac{\partial u_0}{\partial t} \right) 
\]

\[+ \alpha c_4 \frac{\partial^2 \Theta_0}{\partial t^2} \left( \frac{\partial u_1}{\partial t} \right) - Mc_c u_0 - Mc_c u_1, \tag{47}\]

\[
\frac{\partial^2 \Theta_2(x, t)}{\partial x^2} = \frac{\partial^2 \Theta_0}{\partial x^2} + \frac{\partial^2 \Theta_0}{\partial t^2} + \frac{\partial \Theta_1}{\partial x} \frac{\partial u_0}{\partial x} + \frac{\partial \Theta_1}{\partial t} \frac{\partial u_0}{\partial t} + \alpha \frac{\partial \Theta_1}{\partial t} \frac{\partial u_0}{\partial t} \left( \frac{\partial u_0}{\partial t} \right) 
\]

\[+ \alpha B_c \frac{\partial u_0}{\partial t} \left( \frac{\partial u_1}{\partial t} \right) + 2 B_c \frac{\partial u_1}{\partial x} + \alpha B_c \frac{\partial u_0}{\partial t} \left( \frac{\partial u_1}{\partial t} \right) \] 

\[+ \alpha B_c \frac{\partial u_0}{\partial t} \left( \frac{\partial u_1}{\partial t} \right) \]. \tag{48}\]

Solutions of zero, first and second components problem using boundary conditions from equation (24,25) of equations (43-48) are given as

\[
P^0 : u_0(x, t) = \frac{1}{2} (1 + x) + \cos \left( t \omega \right) \left[ \frac{1}{2} (x^2 - 1) \right], \tag{49}\]

\[
\theta_0(x, t) = \frac{1}{2} (1 + x). \tag{50}\]

\[
P^1 : u_1(x, t) = \frac{1}{24} \left( Mc_c (-6 - 2x + 6x^2 + 2x^3) + 12Mc_c \cos \left( t \omega \right) (1 - x^2) + 12c_4 \omega \sin \left( t \omega \right) (1 - x^2) + 12c_4 S_c (1 - x^2) + MS_c (-5 + 6x^2 - x^4) \right), \tag{51}\]

\[
\theta_1(x, t) = \frac{1}{24} \left( B_c c_4 \{3(-x^2) + 4S_c (1 - x^2) + 2S_c^2, (1 - x^4) \} \right). \tag{52}\]

\(u_2\) is and \(\Theta_2\) extremely large so we ignore to write. We can express it only graphically.

**Formulation of the Poiseuille type flow Problem**

In this Problem, we consider the second grade fluid in between two vertical plates \(y=h\) and \(y=-h\). We assumed that both plates are oscillating and the flow of fluid is due to the constant pressure gradient.

![Figure 2. Geometry of the Poiseuille type flow Problem.](image-url)

When pressure gradient is involved then the momentum and heat equation is
\[ \rho \frac{\partial u}{\partial t} = \frac{\partial p}{\partial x} + \mu \frac{\partial^2 u}{\partial x^2} + \alpha \frac{\partial}{\partial t} \left( \frac{\partial^2 u}{\partial x^2} \right) - \rho g - \sigma B_0^2 u, \]  
\[ \rho c_p \left( \frac{\partial \Theta}{\partial t} \right) = k \frac{\partial^2 \Theta}{\partial x^2} + \mu \left( \frac{\partial u}{\partial x} \right)^2 + \alpha \left( \frac{\partial u}{\partial x} \right) \frac{\partial}{\partial t} \left( \frac{\partial u}{\partial x} \right). \]  

Using the dimensionless parameter \( \omega \) in \( \Theta \) we obtained
\[ \frac{\partial \Theta}{\partial t} - \Omega + \frac{\partial^2 \Theta}{\partial x^2} \right) - S\_r - Mu, \]  
\[ P \left( \frac{\partial \Theta}{\partial t} \right) = \frac{\partial^2 \Theta}{\partial x^2} + B_r \left( \frac{\partial u}{\partial x} \right)^2 + \alpha \left( \frac{\partial u}{\partial x} \right) \frac{\partial^2 u}{\partial t \partial x}. \]  

And the boundary conditions are
\[ u(1, t) = \cos \omega t, \quad u(-1, t) = \cos \omega t, \]  
\[ \Theta(0, t) = 0, \quad \Theta(1, t) = 1, \]  

**ADM Solution for the Poiseuille type flow Problem**

The adomian polynomials of both problems are same
\[ P^0 : u_0(x, t) = \cos \omega t + \frac{1}{2} \left( x^2 - 1 \right) \left( S\_r + \Omega \right). \]  
\[ \theta_0(x, t) = \frac{1}{2} \left( 1 + x \right). \]  
\[ P^1 : u_1(x, t) = \frac{1}{24} \left( M(S\_r + \Omega)(5 - 6x^2 + x^4) + 12M \cos \omega t \left( 1 - x^2 \right) \right) \]  
\[ + 12 \omega \sin \omega t \left( 1 - x^2 \right) + S\_r M \left( 5 - 6x^2 + x^4 \right). \]  
\[ \theta_1(x, t) = \frac{1}{12} (S\_r + \Omega) B_r (1 - x^4). \]  
\[ P^2 : u_2(x, t) = \frac{1}{720} \left( M(S\_r + \Omega)(61 + 75x^2 - 15x^4 + x^4) + M^2 \cos \omega t \left( 150 - 180x^2 + 30x^4 \right) \right. \]  
\[ + \omega^2 \cos \omega t \left( -150 - 180x^2 - 30x^4 \right) + 360 \omega^2 \cos \omega t (x^2 - 1) + M \omega \sin \omega t \left( 240x^2 - 60x^4 \right) + 360 \omega \sin \omega t (x^2 - 1). \]  
\[ \theta_2(x, t) = \frac{1}{180} \left( 30 \cos \omega t \left( S\_r + \Omega \right) B_r (1 - x^4) + 15 \omega x^2 \cos \omega t \left( S\_r + \Omega \right) B_r (x^4 - 1) + \right. \]  
\[ 30 \omega \sin \omega t \left( S\_r + \Omega \right) B_r (x^4 - 1) + 15 \omega \sin \omega t \left( S\_r + \Omega \right) B_r (x^4 - 1) + \]  
\[ M \left( S\_r + \Omega \right)^2 B_r (-13 + 15x^4 - 1 - 1x^6) \right). \]  

The series solutions of velocity profile is obtained as
\[ u(x, t) = u_0(x, t) + u_1(x, t) + u_2(x, t) \]  
The series solutions of temperature profile is obtained as
\[ \theta(x, t) = \theta_0(x, t) + \theta_1(x, t) + \theta_2(x, t) \]  
\[ \theta(x, t) = \frac{1}{2} (1 + x) + \frac{1}{12} (S\_r + \Omega) B_r (1 - x^4) + \frac{1}{180} \left( 30 \cos \omega t \left( S\_r + \Omega \right) B_r (1 - x^4) + 15 \omega x^2 \cos \omega t \left( S\_r + \Omega \right) B_r (x^4 - 1) + \right. \]  
\[ 30 \omega \sin \omega t \left( S\_r + \Omega \right) B_r (x^4 - 1) + 15 \omega \sin \omega t \left( S\_r + \Omega \right) B_r (x^4 - 1) + \]  
\[ M \left( S\_r + \Omega \right)^2 B_r (-13 + 15x^4 - 1 - 1x^6) \right). \]  

**The OHAM Solution of Poiseuille type flow Problem.**
Here we apply OHAM method to get the required solution. Solutions of zero, first and second components problem using same boundary 

\[ P^0 : u_0(x,t) = \frac{1}{2}(1 + x) + \cos \left( t \omega \right) \cos \left( x^2 - 1 \right) S \]  

(68)

\[ \theta_0(x,t) = \frac{1}{2}(1 + x). \]  

(69)

\[ P^1 : u_1(x,t) = \frac{1}{24} \left[ \begin{array}{c}
M c_r (-6 - 2x + 6x^2 + 2x^3) + 12M c_r \cos \left( t \omega (1 - x^2) \right) + \\
12c_r \omega \sin \left( t \omega \right) (1 - x^2) + 12S_r (1 - x^2) + \\
12c_r S_r (1 - x^2) + MS c_r (-5 + 6x^2 - x^4) \end{array} \right], \]  

(70)

\[ \theta_1(x,t) = \frac{1}{2}(1 + x). \]  

(71)

\[ \theta_2(x,t) = \frac{1}{24} B_r c_r \{ 3(- x^2) + 4S_r x(1 - x^2) + 2S_r^2 (1 - x^4) \}. \]  

(72)

\[ u_2 \] is and \[ \theta_2 \] extremely large so we ignore to write. we can express it only graphically. The series solutions of velocity profile is obtained as

“Table 1” Comparison of OHAM and ADM for the velocity profile in case of Couette flow, when \( \omega = 0.2, \alpha = 0.02, M = 0.5, t = 1, S_r = 0.5, B_r = 0.4, c_1 = -1.001669146322, c_2 = -0.0001895412688948. 

<table>
<thead>
<tr>
<th>x</th>
<th>OHAM</th>
<th>ADM</th>
<th>Absolute Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>1.18356</td>
<td>1.18997</td>
<td>-0.0064089</td>
</tr>
<tr>
<td>0.1</td>
<td>1.23259</td>
<td>1.23867</td>
<td>-0.00627424</td>
</tr>
<tr>
<td>0.2</td>
<td>1.28762</td>
<td>1.29356</td>
<td>-0.00594404</td>
</tr>
<tr>
<td>0.3</td>
<td>1.34891</td>
<td>1.35435</td>
<td>-0.00543829</td>
</tr>
<tr>
<td>0.4</td>
<td>1.41674</td>
<td>1.42151</td>
<td>-0.00543829</td>
</tr>
<tr>
<td>0.5</td>
<td>1.49142</td>
<td>1.49541</td>
<td>-0.00398994</td>
</tr>
<tr>
<td>0.6</td>
<td>1.57328</td>
<td>1.5764</td>
<td>-0.00312076</td>
</tr>
<tr>
<td>0.7</td>
<td>1.66268</td>
<td>1.6649</td>
<td>-0.0022002</td>
</tr>
<tr>
<td>0.8</td>
<td>1.76</td>
<td>1.76134</td>
<td>-0.00134948</td>
</tr>
<tr>
<td>0.9</td>
<td>1.86565</td>
<td>1.86623</td>
<td>-0.000581616</td>
</tr>
<tr>
<td>1.0</td>
<td>1.98007</td>
<td>1.98007</td>
<td>1.97373 \times 10^{-17}</td>
</tr>
</tbody>
</table>

“Table 2” Comparison of OHAM and ADM for the velocity profile, when \( \omega = 0.2, \alpha = 0.02, M = 0.5, t = 0.5, B_r = 0.4, c_1 = -1.001669146322, c_2 = -0.0001895412688948. 

<table>
<thead>
<tr>
<th>x</th>
<th>OHAM</th>
<th>ADM</th>
<th>Absolute Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0</td>
<td>0.6337</td>
<td>0.628305</td>
<td>0.00539562</td>
</tr>
<tr>
<td>0.1</td>
<td>0.637212</td>
<td>0.631831</td>
<td>0.00538123</td>
</tr>
<tr>
<td>0.2</td>
<td>0.647771</td>
<td>0.642425</td>
<td>0.00534641</td>
</tr>
<tr>
<td>0.3</td>
<td>0.665414</td>
<td>0.660139</td>
<td>0.00527499</td>
</tr>
<tr>
<td>0.4</td>
<td>0.690196</td>
<td>0.685057</td>
<td>0.00513964</td>
</tr>
<tr>
<td>0.5</td>
<td>0.7222</td>
<td>0.717299</td>
<td>0.00490173</td>
</tr>
<tr>
<td>0.6</td>
<td>0.76153</td>
<td>0.757019</td>
<td>0.00451114</td>
</tr>
<tr>
<td>0.7</td>
<td>0.862698</td>
<td>0.804406</td>
<td>0.00390596</td>
</tr>
<tr>
<td>0.8</td>
<td>0.76153</td>
<td>0.859686</td>
<td>0.00301219</td>
</tr>
<tr>
<td>0.9</td>
<td>0.924862</td>
<td>0.923119</td>
<td>0.00174333</td>
</tr>
<tr>
<td>1.0</td>
<td>0.995004</td>
<td>0.995004</td>
<td>2.31296 \times 10^{-17}</td>
</tr>
</tbody>
</table>
“Figure 3” Graphical Comparison of OHAM and ADM for the velocity profile in Couette flow problem, when 
\[ \omega = 0.2, \alpha = 0.02, M = 0.5, t = 1, S = 0.5, B_r = 0.4, c_1 = -1.0016691, c_2 = -0.000189541, \]

Figure 4: Comparison graph of OHAM and ADM for the velocity profile of Poiseuille type flow Problem, when 
\[ \omega = 0.2, \alpha = 0.02, M = 0.5, t = 0.5, B_r = 0.4, c_1 = -1.001669146322, c_2 = -0.0001895412688948. \]

Figure 5: 3D graphs for the fluid flow during different time level in Couette flow problem. When 
\[ \omega = 0.2, \alpha = 0.02, M = 0.5, S, \Omega = 0.3, \]
Figure 6: Velocity distribution graphs during oscillation at different time level in Couette flow problem. When \( \omega = 0.2, \alpha = 0.02, M = 0.5, S, \Omega = 0.3, \)

Figure 7: 3D graph for temperature distribution in Couette flow problem. When \( \omega = 0.2, \alpha = 0.02, M = 0.5, S, B_r = 4, P_r = 0.6; \)

Figure 8: Temperature distribution at different time level in Couette flow problem. When \( \omega = 0.2, \alpha = 0.02, M = 0.5, S, B_r = 4, P_r = 0.6; \)
Figure 9: The fluid flow during different time level of Poiseuille type flow Problem. When 
\[ \omega = 0.2, \alpha = 0.02, M = 0.5, S, \Omega = 0.3, \]

Figure 10: Effect of velocity profile of Poiseuille type flow Problem. When 
\[ \omega = 0.2, \alpha = 0.02, M = 0.5, S, \Omega = 0.3, \]

Figure 11: 3D Effect of temperature in Poiseuille type flow Problem. When 
\[ \omega = 0.2, \alpha = 0.02, M = 0.5, S_I = 0.3, B_r = 4, P_r = 0.6, \]
Figure 12: Effect of temperature distribution at different time level in Poiseuille type flow Problem. When 
\[ \omega=0.2, \alpha=0.02, M=0.5, S_f=0.3, B_r=4, P_r=0.6; \]

Figure 13: Physical illustration of Magnetic parameter “M” for Poiseuille flow when 
\[ \omega=0.2, \alpha=0.02, M=0.5, S_f=0.3, P_r=0.6; \]

Figure 14: Physical illustration of Magnetic parameter “M” for Couette flow when 
\[ \omega=0.2, \alpha=0.02, M=0.5, S_f=0.3, P_r=0.6; \]
Figure 15: Physical illustration of Magnetic parameter “M” for poiseuille flow when
$$\omega=0.2, \alpha=0.02, S_t=0.3, t=10, \Omega=0.4$$

Figure 16: Physical illustration of Magnetic parameter “M” for Couette flow when
$$\omega=0.2, \alpha=0.02, S_t=0.3, t=5.$$  

Figure 17: Physical illustration of Stoke number “$$S_t$$” for poiseuille flow problems flow
Where $$\omega = 0.2, \alpha = 0.02, M = 0.5, \Omega = 0.4; t = 5$$
RESULTS AND DISCUSSION

Figures 1 and 2 show the geometry of Couette and poiseuille flow problems. Tables 1, 2 and Figures 3,4 are plotted for the comparison of ADM and OHAM methods. Figures 5-12 show the effect of velocity and temperature fields at different time level for both Couette and poiseuille flow problems respectively. The influence of different dimensionless physical parameters (Stock number $S_t$, Brinkman number $B_r$, and some other parameters are described in Figures.13–18. The effect of Brinkman number $B_r$ for both problems have been shown in Figures 13,14. Increasing Brinkman number increases fluid motion. The reason is that the cohesive forces reduces which increase the fluid motion. The effect of stock number and magnetic field for both problems have been shown in Figures 15-18. Increasing these parameters reduces fluid motion. Because the resistance force increases which decrease the fluid motion.

Conclusion

In this article, the modelled partial differential equations have been solved analytically by using ADM and OHAM methods. The comparison of these methods analysed numerically and graphically. We have concluded excellent agreement of these two methods.

REFERENCES


