AN UNSTEADY HM (HYDRO-MAGNETIC) STREAM OF A STICKY LIQUID BETWEEN TWO OSCILLATING PLATES BY ELZAKI TRANSFORM

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ABSTRACT

This paper focuses on the movement of a thick liquid between two oscillating plates. The equipped method called, Elzaki transform method derives accurate solutions for the liquefied velocity, wall shear stress as well as skin friction. The outcomes are exposed graphically for special values of a time phase of oscillations of the plates, and tables are presented for skin friction, wall shear stress with different periods.

KEYWORDS: Unsteady Hydromagnetic Flows, Elzaki Transform, Hydromagnetic Parameter, Wall Shear Stress & Skin Friction

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1. INTRODUCTION

Hydromagnetic incompressible viscous flow has a lot of significant engineering applications such as magneto hydrodynamic (MHD) control maker and the cooling of reactors. But in current time, the possessions of a crossway applied magnetic field on the run of an electrically conducting viscous solution have been discussed expansively using to its astrophysical, geophysical, and business applications.

We find a number of applications in the polymer manufacturing plus metallurgy, where HM techniques are being used. The uneven HM flood of a dusty gluey fluid between two oscillating plates is examined [1]. The HM flow at an oscillating plate is investigated [2]. An HM stream of a sandy visco-elastic flowing connecting two unbounded parallel plates is developed [3]. The Time-dependent pour of HM nanofluid in a rotating cone is examined [4].

The HM flow of an Oldroyd – B watery stuck between two oscillating plates was discussed by Arun Kumar Ghosh et al [5]. The numerical solution for HM gush of a filthy fluid involving two parallel plates calculated [6]. The HM Stokes run in a revolving fluid with balanced little particles discussed. Numerical technique of Hydromagnetic stream and heat transfer of a second- grade viscoelastic liquid calculated [7]. The uneven laminar, joint forced-free convection flow in a four-sided figure opening in the occurrence of interior heat creation or amalgamation, and a magnetic field is formulated by Chamkha [8]. HM two - dimensional border level flow with heat transfer of a viscous, incompressible, electrically conducting, heat- absorbing in addition to an optically wide heat-radiating fluid over a porous exponentially stretching leaf is investigated [9].

Numerical solution for HM current due to a revolving porous floppy in a nanofluid with internal heat absorption is derived [10]. The Hall property on Hydromagnetic free convection in a heated straight up channel in

the presence of an inclined magnetic field plus thermal energy is explained [11]. The surge of a tacky incompressible and electrically conducting liquid twisted by the harmonically oscillating partition of an inestimable area in the presence of a transverse magnetic field is explored [12]. An HM flow of a conducting micropolar fluid above a flat wall with heat transfer is studied [13]. A numerical form to study nanofluid film over an unsteady stretching sheet in the presence of Hydromagnetic flow is developed [14]. The warm and mass transport on the non-linear HM flow of a surface with inside heat generation as well as thermal stratification effects are studied [15]. Applications of new transformation Elzaki transform to partial differential equations are introduced by Tarig Elzaki et al [16]. The flows of a stratified watery from first to last the porous medium linking two oscillating saucers are discussed [17]. Unsteady free convection gush of viscous fluid due to non-coaxial rotation and fluid at perpetuity over an oscillating perpendicular plate with constant wall temperature is investigated [18]. The heat transmits analysis in mixed convection flow of Maxwell fluid above an oscillating plate is discussed [19]. Hydromagnetic oscillating convective run throughout a permeable standard in a rotating vertical porous channel with thermal radiation outcome is measured [20].

The effect of emission and hall current on an unsteady MHD free convective flow in a vertical channel with a porous medium is studied [21]. The differential geometry techniques to the flow of a viscous incompressible embedded two parallel oscillating plates are discussed [22]. The three-dimensional flow of a viscous incompressible electrically conducting fluid close to an unbounded plate of non-conductor is premeditated [23].

The unsteady MHD two- dimensional edge stratum flow of a second -grade viscoelastic fluid over an oscillatory stretching face is analyzed [24]. An unsteady Magneto Hydrodynamic free convection flow past a touching plate maintained at regular heat flux and set in a viscous fluid is offered [25].

Seeing the growth of the study in this field and its applications in various sectors, it has been chosen that the present work should be determined on the flow of viscoelastic fluid through oscillating plates under the effect of the Elzaki transform.

2. PROBLEM DESCRIPTION

Here, HM flow of a sticky liquid stuck between two oscillating plates is considered. The solution system is enclosed by two parallel plates at an expanse 'h' away from each other.

Figure 1: Flow Geometry.

Thus, the wavering action of an incompressible electrically conducting sticky fluid flow within $0 \leq y \leq h$ is generated by the equation

$$\frac{\partial u}{\partial t} = \nu \frac{\partial^2 u}{\partial y^2} - nu \quad (1)$$

Topic to no-slip boundary conditions at the plate are

$$u = a_{11}e^{i\omega_1 t} + b_{11}e^{-i\omega_1 t} \text{ at } y = 0, t > 0 \quad (2)$$

$$u = c_{11}e^{i\omega_2 t} + d_{11}e^{-i\omega_2 t} \text{ at } y = h, t > 0 \quad (3)$$

$$u = 0 \text{ at } t \leq 0 \text{ for all } y \text{ in } h \quad (4)$$

where u represents the velocity component of the fluid, $n = \frac{\sigma_0 B_0^2}{\rho}$ is the hydrodynamic parameter, σ_0 is electrical conductivity, B_0 is a magnetic field and ρ is the density of the fluid, $a, b, c,$ and d are complex constants.

We introduce the following dimensionless quantities

$$y' = \frac{y}{h}, u' = \frac{uh}{\nu}, t' = \frac{\gamma t}{h^2}, h' = \frac{nh^2}{\nu}, (\sigma_1, \sigma_2) = \frac{h^2}{\nu}(\omega_1, \omega_2) \quad (5)$$

3. ELZAKI TRANSFORM METHOD

Equations (1), (2) and (3), we get,

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial y^2} - nu \quad (6)$$

$$u = a_{11}e^{i\sigma_1 t} + b_{11}e^{-i\sigma_1 t} \text{ on } y = 0, t > 0 \quad (7)$$

$$u = c_{11}e^{i\sigma_2 t} + d_{11}e^{-i\sigma_2 t} \text{ on } y = 1, t > 0 \quad (8)$$

$$u = 0 \text{ at } t \leq 0 \text{ for all } y \quad (9)$$

let $\bar{T}(y, \nu)$ be the Elzaki transform of $u(y, t)$.

(i.e.) $E[u(y, t)] = \bar{T}(y, \nu)$.

Taking the Elzaki transform of (6) and on the use of (9), we have

$$\frac{\bar{T}(y, \nu)}{\nu} - \nu u(y, 0) = \frac{d^2 \bar{T}}{dy^2} - n\bar{T}(y, \nu) \quad (10)$$

$$\frac{d^2 \bar{T}}{dy^2} - \left(n + \frac{1}{\nu}\right) \bar{T}(y, \nu) = 0 \quad (11)$$

A solution of equation (11) is

$$\bar{T}(y, \nu) = A \cosh py + B \sinh py \quad (12)$$

$$\text{Where } \bar{T}(y, \nu) = \nu \int_0^{\infty} e^{\frac{t}{\nu}} u(y, t) dt \quad (13)$$

$$\text{and } p^2 = n + \frac{1}{\nu}$$

Equation (13) denotes the Elzaki transform of $u(y, t)$.

Apply Elzaki transform of (7) and (8), we get

$$\bar{T}(0, \nu) = \frac{a_{11}\nu^2}{1-i\nu\sigma_1} + \frac{b_{11}\nu^2}{1+i\nu\sigma_1} \quad (14)$$

$$\bar{T}(1, \nu) = \frac{c_{11}\nu^2}{1-i\nu\sigma_2} + \frac{d_{11}\nu^2}{1+i\nu\sigma_2} \quad (15)$$

Using equations (14) and (15) in eqn. (12), we have

$$\bar{T}(y, \nu) = \left(\frac{a_{11}\nu^2}{1-i\nu\sigma_1} + \frac{b_{11}\nu^2}{1+i\nu\sigma_1} \right) \cosh py + \left[\left(\frac{c_{11}\nu^2}{1-i\nu\sigma_2} + \frac{d_{11}\nu^2}{1+i\nu\sigma_2} \right) - \left(\frac{a_{11}\nu^2}{1-i\nu\sigma_1} + \frac{b_{11}\nu^2}{1+i\nu\sigma_1} \right) \cosh p \right] \frac{\sinh py}{\sinh p} \quad (16)$$

$$\bar{T}(y, \nu) = \nu \left\{ \left(\frac{a_{11}}{\frac{1}{\nu} - i\sigma_1} + \frac{b_{11}}{\frac{1}{\nu} + i\sigma_1} \right) \cosh py + \left[\left(\frac{c_{11}}{\frac{1}{\nu} - i\sigma_2} + \frac{d_{11}}{\frac{1}{\nu} + i\sigma_2} \right) - \left(\frac{a_{11}}{\frac{1}{\nu} - i\sigma_1} + \frac{b_{11}}{\frac{1}{\nu} + i\sigma_1} \right) \cosh p \right] \frac{\sinh py}{\sinh p} \right\} \quad (17)$$

By duality property of Elzaki and Laplace transform

$$\bar{u}(y, s) = \left(\frac{a_{11}}{s-i\sigma_1} + \frac{b_{11}}{s+i\sigma_2} \right) \cosh py + \left[\left(\frac{c_{11}}{s-i\sigma_2} + \frac{d_{11}}{s+i\sigma_2} \right) - \left(\frac{a_{11}}{s-i\sigma_1} + \frac{b_{11}}{s+i\sigma_2} \right) \cosh p \right] \frac{\sinh py}{\sinh p} \quad (18)$$

$$\bar{u}(y, s) = \left(\frac{a_{11}}{s-i\sigma_1} + \frac{b_{11}}{s+i\sigma_1} \right) \frac{\sinh p(1-y)}{\sinh p} + \left(\frac{c_{11}}{s-i\sigma_2} + \frac{d_{11}}{s+i\sigma_1} \right) \frac{\sinh py}{\sinh p} \quad (19)$$

$$u(y, t) = L^{-1} \left\{ \frac{\sinh p(1-y)}{\sinh p} \left(\frac{a_{11}}{s-i\sigma_1} + \frac{b_{11}}{s+i\sigma_1} \right) + \frac{\sinh py}{\sinh p} \left(\frac{c_{11}}{s-i\sigma_2} + \frac{d_{11}}{s+i\sigma_2} \right) \right\} \quad (20)$$

Equation (20) can be solved by the method of residues

$$\frac{1}{2\pi i} \int_{\gamma-i\infty}^{\gamma+i\infty} \frac{e^{st} \sinh(s+n)^{1/2} y}{\sinh(s+n)^{1/2}} \left(\frac{c_{11}}{s-i\sigma_2} \right) ds = \text{sum of the residues of the integrand at the pole} \quad (21)$$

$$\text{The residue at } s = i\sigma_2 = \frac{c_{11} e^{i\sigma_2} \sinh(n+i\sigma_2)^{1/2} y}{\sinh(n+i\sigma_2)} \quad (22)$$

$$\text{The residue at } s = s_n = \sum_{n=1}^{\infty} \frac{2c_{11} n \pi (-1)^n e^{-(n^2 \pi^2 + n)t} \sin \pi y}{n^2 \pi^2 + n + i\sigma_2} \quad (23)$$

$$\begin{aligned}
 &= a_{11} \left\{ \frac{e^{i\sigma_1 t} \sinh(n+i\sigma_2)^{1/2} (1-y)}{\sinh(n+i\sigma_2)} + 2\pi \sum_{n=1}^{\infty} \frac{(-1)^n n \sin n\pi (1-y) e^{-(n^2 \pi^2 + n) t}}{(n^2 \pi^2 + n + i\sigma_1)} \right\} \\
 &+ b_{11} \left\{ \frac{e^{-i\sigma_1 t} \sinh(n-i\sigma_2)^{1/2} (1-y)}{\sinh(n-i\sigma_2)} + 2\pi \sum_{n=1}^{\infty} \frac{n \sin n\pi (1-y) e^{-(n^2 \pi^2 + n) t}}{(n^2 \pi^2 + n - i\sigma_1)} \right\} \\
 &+ c_{11} \left\{ \frac{e^{i\sigma_2 t} \sinh(n+i\sigma_2)^{1/2} y}{\sinh(n+i\sigma_2)} + 2\pi \sum_{n=1}^{\infty} \frac{(-1)^n n \sin n\pi y e^{-(n^2 \pi^2 + n) t}}{(n^2 \pi^2 + n + i\sigma_2)} \right\} \\
 &+ d_{11} \left\{ \frac{e^{-i\sigma_2 t} \sinh(n-i\sigma_2)^{1/2} y}{\sinh(n-i\sigma_2)} + 2\pi \sum_{n=1}^{\infty} \frac{n \sin n\pi y e^{-(n^2 \pi^2 + n) t}}{(n^2 \pi^2 + n - i\sigma_2)} \right\} \quad (24)
 \end{aligned}$$

$$\begin{aligned}
 u(y,t) &= a_{11} \{ (A_1 \cos \sigma_1 t - B_1 \sin \sigma_1 t) + i(B_1 \cos \sigma_1 t + A_1 \sin \sigma_1 t) \} \\
 &+ b_{11} \{ (A_1 \cos \sigma_1 t - B_1 \sin \sigma_1 t) - i(B_1 \cos \sigma_1 t + A_1 \sin \sigma_1 t) \} \\
 &+ c_{11} \{ (A_2 \cos \sigma_2 t - B_2 \sin \sigma_2 t) + i(B_2 \cos \sigma_2 t + A_2 \sin \sigma_2 t) \} \\
 &+ d_{11} \{ (A_2 \cos \sigma_2 t - B_2 \sin \sigma_2 t) - i(B_2 \cos \sigma_2 t + A_2 \sin \sigma_2 t) \} \\
 &+ 2\pi \sum_{n=1}^{\infty} n (-1)^n \sin n\pi (1-y) (\Delta_1 + \Delta_2) e^{\lambda_1 t} + 2\pi \sum_{n=1}^{\infty} n (-1)^n \sin n\pi y (\Delta_3 + \Delta_4) e^{\lambda_1 t} \quad (25)
 \end{aligned}$$

Where

$$A_1 = \frac{1}{K_3} \{ K_1 \cosh a_2 (1-y) \sinh a_1 (1-y) + K_2 \cosh a_1 (1-y) \sinh a_2 (1-y) \} \quad (26)$$

$$B_1 = \frac{1}{K_3} \{ K_1 \sinh a_2 (1-y) \cosh a_1 (1-y) - K_2 \sinh a_1 (1-y) \cosh a_2 (1-y) \} \quad (27)$$

$$A_2 = \frac{1}{K_3} \{ K_1' \cosh a_4 y \sinh a_3 y + K_2' \sinh a_4 y \cosh a_3 y \} \quad (28)$$

$$B_2 = \frac{1}{K_3} \{ K_1' \sinh a_4 y \cosh a_3 y - K_2' \sinh a_3 y \cosh a_4 y \} \quad (29)$$

$$\text{Where } (a_1, a_2) = \left(\frac{\sqrt{n + \sigma_1^2} \mp n}{2} \right)^{1/2} \quad (30)$$

$$(a_3, a_4) = \left(\frac{\sqrt{n + \sigma_2^2} \mp n}{2} \right)^{1/2} \quad (31)$$

$$\text{Where } K_1 = \sinh a_1 \cos a_2; K_2 = \cosh a_1 \sin a_2 \quad (32)$$

$$K_1' = \sinh a_3 \cos a_4; K_2' = \cosh a_3 \sin a_4 \quad (33)$$

$$K_3 = K_1^2 + K_2^2; K_3' = K_1'^2 + K_2'^2 \quad (34)$$

$$\Delta_1 = \left(\frac{a_{11}}{\lambda_1 + i\sigma_1} \right); \Delta_2 = \left(\frac{b_{11}}{\lambda_1 - i\sigma_1} \right) \quad (35)$$

$$\Delta_3 = \left(\frac{c_{11}}{\lambda_1 + i\sigma_2} \right) \text{ and } \Delta_2 = \left(\frac{d_{11}}{\lambda_1 - i\sigma_2} \right) \quad (36)$$

The wall shear stress of the fluid at the lower plate is given by

$$\begin{aligned} -\left(\frac{\partial u}{\partial y} \right)_{y=0} = & a_{11}[(L_1 \cos \sigma_1 t - M_1 \sin \sigma_1 t) + i(M_1 \cos \sigma_1 t + L_1 \sin \sigma_1 t)] + b_{11}[(L_1 \cos \sigma_1 t - M_1 \sin \sigma_1 t) - i(M_1 \cos \sigma_1 t \\ & + L_1 \sin \sigma_1 t)] + c_{11}[(M_2 \sin \sigma_2 t - L_2 \cos \sigma_2 t) - i(M_2 \sin \sigma_2 t + L_2 \sin \sigma_2 t)] + d_{11}[(M_2 \sin \sigma_2 t - L_2 \cos \sigma_2 t) + i(M_2 \cos \sigma_2 t \\ & + L_2 \sin \sigma_2 t)] + 2\pi^2 \sum_{n=1}^{\infty} n^2 (\Delta_1 + \Delta_2) e^{\lambda_1 t} - 2\pi^2 \sum_{n=1}^{\infty} (-1)^n (\Delta_3 + \Delta_4) e^{\lambda_1 t} \end{aligned} \quad (37)$$

Where

$$L_1 = \frac{1}{K_3} \{ a_2 \cos a_2 \sin a_2 + a_1 \cosh a_1 \sinh a_1 \} \quad (38)$$

$$M_1 = \frac{1}{K_3} \{ a_2 \sinh a_1 \cosh a_1 - a_1 \cos a_2 \sin a_2 \} \quad (39)$$

$$L_2 = \frac{1}{K_3} \{ a_3 K_1' + a_4 K_2' \} \quad (40)$$

$$\text{And } M_2 = \frac{1}{K_3} \{ a_4 K_2' - a_3 K_1' \} \quad (41)$$

Skin friction of the fluid is given by

$$\left. \frac{\partial^2 u}{\partial y^2} \right|_{y=0} = a_{11} \{ (\dot{L}_2 \cos \sigma_1 t - \dot{M}_2 \sin \sigma_1 t) + i(\dot{M}_2 \cos \sigma_1 t + \dot{L}_2 \sin \sigma_1 t) \} + b_{11} \{ (\dot{L}_2 \cos \sigma_1 t - \dot{M}_2 \sin \sigma_1 t) - i(\dot{M}_2 \cos \sigma_1 t + \dot{L}_2 \sin \sigma_1 t) \} \quad (42)$$

$$\dot{L}_2 = \frac{1}{K_3} \{ (l_3^2 l_2^2 + l_4^2 l_1^2) (a_1^2 - a_2^2) \} \quad (43)$$

$$\dot{M}_2 = \frac{1}{K_3} (4a_1 a_2 l_3^2 l_2^2) \quad (44)$$

$$l_1 = \sin a_2; l_2 = \cos a_2; l_3 = \sinh a_1; l_4 = \cosh a_1 \quad (45)$$

Figure 2: Velocity Sketch for $n=0.5$, $T=1.0$ with $\sigma = 0.5$.

Figure 3: Velocity Sketch for $n=0.5$, $T=10.0$ with $\sigma = 0.5$.

Table 1: Wall Shear Stress of the Fluid

t	T = 1.0			T = 10.0		
	$\sigma = 0.5$	$\sigma = 1$	$\sigma = 1.5$	$\sigma = 0.5$	$\sigma = 1$	$\sigma = 1.5$
$\frac{T}{8}$	5.3861	25.4942	-51.6681	7.8458e+049	1.9323e+003	4.9970
$\frac{2T}{8}$	3.4702	-12.4946	-92.2923	1.6238e+047	1.6555e+003	5.1512
$\frac{3T}{8}$	1.2859	11.563-8	2.7328e+040	7.5579e+042	1.2733e+003	5.2810
$\frac{4T}{8}$	0.1918	18.5155	2.9911e+017	11223e+037	885.2723	5.3844
$\frac{5T}{8}$	-0.2054	2.0033e+003	-193.9769	8.5102e+029	562.5149	5.4596
$\frac{6T}{8}$	-0.2734	28.4464	-1.6760e+013	5.8547e+021	328.6581	5.5054
$\frac{7T}{8}$	-0.0397	-12.2314	9.6287e+042	7.0616e+012	172.6419	5.5209
$\frac{8T}{8}$	0.6579	-10.5047	-88.4185	3.1558e+003	79.1751	5.5060

Table 2: Skin Friction of the Fluid

t	T = 1.0			T = 10.0		
	$\sigma = 0.5$	$\sigma = 1$	$\sigma = 1.5$	$\sigma = 0.5$	$\sigma = 1$	$\sigma = 1.5$
$\frac{T}{8}$	-0.2372	-0.0278	1.1409e+003	-32.690	-0.1462	-0.4934
$\frac{2T}{8}$	-0.2666	-0.0397	454.4805	-58.9868	-0.2037	-0.6806
$\frac{3T}{8}$	-0.2963	-0.0525	-597.9239	253.7112	-0.1167	-0.7655
$\frac{4T}{8}$	-0.3260	-0.0658	-469.4783	373.4170	0.0031	-0.7832
$\frac{5T}{8}$	-0.3556	-0.0795	5.5980	-847.8426	-0.0143	-0.7357
$\frac{6T}{8}$	-0.3847	-0.0933	241.7083	928.1323	-0.1430	-0.6103
$\frac{7T}{8}$	-0.4133	-0.1071	-217.9592	725.1963	-0.2041	-0.3672
$\frac{8T}{8}$	-0.4410	-0.1207	126.6171	-1.5292e+003	-0.1202	-0.0913

4. RESULTS AND DISCUSSION

In figure 1, the velocity profile meant for the liquefied are shown for unusual values of t , when $T=1.0$, $n=0.5$, $\sigma = 0.5$. It is seen to the velocity increases while the time episode of the oscillation increases. But the reverse effect is also seen in figure 2 when $T=1.0$, $n=0.5$, $\sigma = 0.5$. It is clear that frequencies are high for the smaller point age of oscillation of the plate. On the other hand, frequencies are low on behalf of the larger instant stage of the oscillation of the plate. From table 1 and table 2, illustrate that the wall shear stress and skin friction of the solution for different values of t with three cases i) $\sigma < 1$ ii) $\sigma = 1$ iii) $\sigma > 1$. The wall shear stress on the lesser plate be calculated numerically with different parameters, and it is revealed that gradual decreases presented when $\sigma < 1$, $T=1.0$ and more oscillation for the leftover values of σ . But the converse inclination is obtained in support of the case, as made known in the table. Skin friction results are exposed in the table with different flow parameters.

5. CONCLUSIONS

In this article, we applied the analytical method Elzaki transform method for finding the velocity profile, wall shear stress and skin friction with different time periods oscillation parameter and the same hydromagnetic parameter, electrical conductivity parameter. The Elzaki transform could be used to solve mathematical problems without any alternative to a new frequency domain.

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