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Study of Effect of Visco-Elastic Convention Flow with Heat Radiation

Sumeet Upadhyay[1], Hrishikesh Pandey[2*]
[1]Research Scholar, University Department of Mathematics, J. P. University, Chapra, Bihar, India
[2*]Department of Mathematics, Kamla Ray College, Gopalganj, J. P. University, Chapra, Bihar, India

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ABSTRACT

In this present paper, we studied of effect of visco-elastic convention flow with heat radiation.The liquid stream between equal plates through Couette movement is an old style liquid mechanics issue that has applications in magnetohydrodynamic (MHD) power generators and siphons, gas pedals, streamlined features warming, electrostatic precipitation, polymer innovation, oil industry, sanitization of unrefined petroleum, and furthermore in numerous material handling applications, for example, expulsion, metal shaping, nonstop projecting, wire and glass fiber drawing, and so forth This issue has gotten impressive consideration on account of level equal plates [1] than vertical equal plates. An examination of stream arrangement in Couette movement between vertical equal plates was introduced by Schlichting and Gersten [2]. This issue is of crucial significance as it gives the specific arrangement and uncovers how the speed profiles changes with time, moving toward a direct dissemination asymptotically, and how the limit layer spreads all through the stream field.
Keywords : MHD, Fluids, Porous Medium, Heat Transfer.

I. INTRODUCTION

Free convection in vertical channels has been concentrated on broadly over the most recent couple of a very long time under various actual impacts because of its significance in many designing applications like cooling of electronic supplies, plan of latent nearby planet groups for energy transformation, cooling of atomic reactors, plan of hotness exchangers, synthetic gadgets and cycle hardware, geothermal frameworks and others. Be that as it may, not many papers manage free convection in Couette movement between vertical equal plates. Singh [3] concentrated on the impact of free convection in Couette movement. He has considered the insecure free convective progression of a thick incompressible liquid between two vertical equal plates at steady yet various temperatures and one of which is rashly begun in its own plane and the other is kept fixed.

Completely created laminar free convection Couette stream between two vertical equal plates with cross over sinusoidal infusion of the liquid at the fixed plate and its relating evacuation by consistent attractions through the plate in uniform movement has been investigated by Jain and Gupta [4]. The actual impact of outer shear as Couette stream of a Bingham liquid in an upward equal plane channel with consistent temperature differential across the dividers was explored scientifically by Barletta and Magyari [5]. Consistent completely evolved joined constrained and free convection Couette stream with gooey scattering in an upward channel has been researched systematically by Barletta et al. [6]. In their review, the moving divider is thermally protected and the divider very still is kept at a uniform temperature.

The liquids that are utilized widely in modern applications are displaying a yield pressure Ʈ, that must be surpassed before the liquid moves. Therefore, such liquids can't support a speed slope except if the greatness of the neighborhood shear pressure is higher than this yield pressure. Liquids that have a place with this classification incorporate concrete, boring mud, slop, oil, granular suspensions, fluid froths, slurries, paints, food items, plastics and paper mash [7]. Because of the developing utilization of these non - Newtonian materials in different assembling and handling enterprises, significant endeavors have been coordinated towards understanding their stream and hotness move attributes. A considerable lot of the yield non - Newtonian liquids experienced in compound designing cycles are known to follow the so – called "Bingham model". A Bingham liquid is a material with a limited yield pressure, trailed by a direct bend at a limited strain rate.

Many creators concentrated on the stream or/and heat move of a Bingham liquid in various calculations. Warm radiation consequences for hydromagnetic free convection stream assume a significant part in assembling processes occurring in ventures for the plan of blades, glass creation, steel rolling, projecting and levitation, heater plan, and so forth Additionally, a few designing cycles happen at exceptionally high temperatures where the information on radiative hotness move becomes fundamental for the plan of appropriate gear. Thermal energy stations, gas turbines and different impetus gadgets for airplane, rockets, satellites and space vehiclesare instances of such designing regions [8]. It is qualified to take note of that dissimilar to convection/conduction the administering conditions considering the impacts of warm radiation become very convoluted. Consequently, numerous troubles emerge while settling such conditions. In any case, a few sensible approximations are proposed to address the overseeingconditions with radiative hotness move.

Viskanta and Grosh [9] were one of the underlying agents to concentrate on the impacts of warm radiation on temperature appropriation and hotness move in a retaining and producing media streaming over a wedge. They involved Rosseland estimate for the radiative transition vector to improve on the energy condition. Cess [10] concentrated on laminar free convection along an upward isothermal plate with warm radiation. The course readings by Sparrow and Cess [11] and Howell et al. [12] present the most fundamental elements and cutting-edge utilizations of radiative hotness move.

Takhar et al. [13] broke down the impacts of radiation on MHD free convection stream of a gas past a semi - boundless vertical plate. Raptis and Massalas examined oscillatory magnetohydrodynamic stream of a dim, retaining transmitting liquid with non - dissipating medium beyond a level plate within the sight of radiation expecting the Rosseland transition model. Chamkha [14] talked about warm radiation and lightness impacts on hydromagnetic stream over a speeding up porous surface with heat source or sink. Cookey et al. considered the impact of thick dissemination and radiation on precarious MHD free convection stream past an endless warmed vertical plate in a permeable medium with time subordinate attractions. Ogulu and Makinde [14] considered flimsy hydromagnetic free convection stream of a dissipative and radiative liquidpast an upward plate with consistent hotness transition.

Mahmoud [15] explored the impacts of warm radiation on flimsy MHD free convection stream past an endless vertical permeable plate considering the impacts of gooey scattering. It is seen that when the thickness of an electrically directing liquid is low and additionally applied attractive field is solid, Hall flow is delivered in the stream field which assumes a significant part in deciding stream highlights of the issues since it incites optional stream in the stream field. Keeping in view this reality, critical examinations on hydromagnetic free convection stream past a level plate with Hall impacts under various warm circumstances are done by a few scientists before. Notice might be made of the examination investigations of Pop and Watanabe [16], Abo - Eldahab and Elbarbary [17], Takhar et al. [18] and Saha et al. [19]. It is qualified to take note of that Hall current incites optional stream in the stream field which is additionally the attributes of Coriolis force. Subsequently, it turns out to be vital to look into the impacts of these two organizations and furthermore to concentrate on their consolidated consequences for such liquid stream issues.

Satya Narayana et al. [20] concentrated on the impacts of Hall current and radiative retention on MHD regular convection hotness and mass exchange stream of a micropolar liquid in a pivoting edge of reference. Seth et al. [21] researched impacts of Hall momentum and revolution on flimsy hydromagnetic regular convection stream of a thick, incompressible, electrically directing and heat engrossing liquid beyond a hastily moving vertical plate with inclined temperature in a permeable medium considering the impacts of warm dissemination. The point of this part is to find mathematical arrangements of unstable magnetohydrodynamic the mathematical arrangement of insecure magnetohydrodynamic stream of an electrically leading gooey incompressible non - Newtonian Bingham liquid limited by two equals non - directing permeable plates is examined with warm radiation considering the Hall Effect. The dimensionless overseeing coupled, non - straight limit layer halfway differential conditions are addressed by a productive, exact, and broadly approved and genuinely stable limited distinction plan of the Crank Nicholson technique, which is more efficient according to a computational perspective.

These arrangements are helpful to acquire a more profound information on the hidden actual cycles and it gives the likelihood to get a benchmark for mathematical solvers concerning fundamental stream setups. The way of behaving of the speed, temperature, skin grinding coefficient and Nusselt number have been examined exhaustively for varieties in the actual boundaries.

II. METHODS AND MATERIAL

The unstable magnetohydrodynamic stream of an electrically directing gooey incompressible non - Newtonian Bingham liquid limited by two equals non - leading permeable plates with warm radiation considering the Hall Effect is examined. The liquid is thought to be laminar, incompressible and complying with a Bingham model and streams between two boundless flat plates situated at the $y' = \pm h$ planes and stretch out from $x' = 0$ to ∞ and from $z' = 0$ to ∞.The upper plate moves with a uniform speed Uo while the lower plate is fixed. The upper and lower plates are kept at two consistent temperatures T'2 and T'1 individually with T'2>T'1. The liquid is followed up on by a consistent strain slope dp'/dx' in the x'- bearing, and a uniform pull from a higher place and infusion from underneath which are applied at $t' > 0$. A uniform attractive field Bo is applied in the positive y'- course and is expected undisturbed as the prompted attractive field is dismissed by accepting a tiny attractive Reynolds number. The Hall Effect is thought about and subsequently a z'- part for the speed is relied upon to emerge. It is accepted that the outside electric field is zero and the electric field because of the polarization of charges is irrelevant.

The homogeneous compound response of first request with rate steady between the diffusing species and the liquid is dismissed. The centralization of the diffusing species in the paired combination is thought to be tiny in examination with the other synthetic species, which are available and subsequently Soret and Dufour impacts are immaterial. The uniform pull suggests that the y'- part of the speed is steady. Consequently, the liquid speed vector is given by

$$v(y',t') = u'(y',t')\bar{i} + v_o\bar{j} + w'(y',t')\bar{k}$$

It should be noticed that the issue emerges to be a straight issue. In the hydrodynamic case without attractions - infusion, the issue decreases to Poiseuille issue [139] the old style hydrodynamic straight issue. Without attractions - infusion and by disregarding the Hall current, it lessens to Hartmann - Poiseuille issue, the traditional MHD direct issue. The incorporation of the consistent attractions - infusion as well as the Hall expression [140] jelly linearity. So clearly does changing the Newtonian liquid to a non - Newtonian one in the current review. The classica; issues (Poiseuille and Hartmann - Poiseuille) of channel stream and the connected line stream of Newtonian liquid are known to be achievable practically speaking and to give brings about incredible concurrence with tests. The completely evolved profiles are noticed away from the gulf and the side - dividers of the channel. Utilizing a non - Newtonian liquid isn't relied upon to cause an issue.

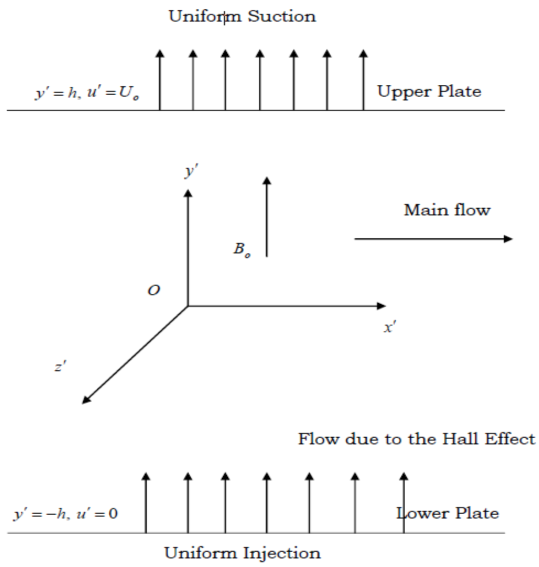


Figure 1 : Geometry of the issue

Utilizing a non - Newtonian liquid isn't relied upon to cause an issue. The smooth movement begins from rest at t' = 0, and the no - slip condition at the plates infers that the liquid speed has neither a z' nor a x'-part at y' +-h. The underlying temperature of the liquid is thought to be equivalent to T'1. Since the plates are endless in the x' and z' - headings, the actual amounts don't adjust in these bearings.

The flow of the fluid is governed by the momentum equation

$$\rho\frac{Dv}{Dt'} = \nabla.(\mu\nabla v) - \nabla p' + \bar{J}\times B_o \qquad (1)$$

Where ϱ the density of the fluid and μ is the apparent viscosity of the model and is given by

$$u' = K + \frac{\tau_o}{\sqrt{\left(\frac{\partial u'}{\partial y'}\right)^2 + \left(\frac{\partial w'}{\partial y'}\right)^2}} \qquad (2)$$

Where *K* the plastic viscosity of a Bingham fluid, *To* is the yield stress.

If the Hall term is retained, the current density *J* is given by

$$\bar{J} = \sigma\left[v\times B_o - \beta(\bar{J}\times B_o)\right] \qquad (3)$$

Where σ is the electric conductivity of the fluid and β is the Hall factor. Equation (3) may be solved in *J* to yield

$$\bar{J} \times B_o = -\frac{\sigma B_o^2}{1+m^2}\left[(u' + mw')\bar{i} + (w' - mu')\bar{k}\right] \tag{4}$$

Where *m* is the Hall parameter and $m = \sigma\beta Bo$. Thus, the two components of the momentum equation (1) read

$$\rho\frac{\partial u'}{\partial t'} + \rho v_o\frac{\partial u'}{\partial y'} = -\frac{\partial p'}{\partial x'} + \frac{\partial}{\partial y'}\left(\mu\frac{\partial u'}{\partial y'}\right) - \frac{\sigma B_o^2}{1+m^2}(u' + mw') \tag{5}$$

$$\rho\frac{\partial w'}{\partial t'} + \rho v_o\frac{\partial w'}{\partial y'} = \frac{\partial}{\partial y'}\left(\mu\frac{\partial w'}{\partial y'}\right) - \frac{\sigma B_o^2}{1+m^2}(w' - mu') \tag{6}$$

Where $\frac{\partial p'}{\partial x'} = \frac{dp'}{dx'}e^{-at}$ is the unsteady pressure gradient

The energy equation with viscous and Joule dissipations is given by

$$\rho C_p\frac{\partial T'}{\partial t'} + \rho C_p v_o\frac{\partial T'}{\partial y'} = \kappa\frac{\partial}{\partial y'}\left(\frac{\partial T'}{\partial y'}\right) + \mu\left[\left(\frac{\partial u'}{\partial y'}\right)^2 + \left(\frac{\partial w'}{\partial y'}\right)^2\right] + \frac{\sigma B_o^2}{1+m^2}(u'^2 + w'^2) - \frac{\partial q_r}{\partial y'} \tag{7}$$

Where *Cp*, k and *D* are respectively, the specific heat capacity, the thermal conductivity and thermal diffusivity of the fluid. The second and third terms on the right – hand side of (7) represent the viscous and Joule dissipations respectively. We notice that each of these terms has two components. This is because the Hall Effect brings about a velocity *w*' in the *z'*- direction.

The radiative heat flux term is simplified by making use of the Rosseland approximation as

$$q_r = -\frac{4\bar{\sigma}}{3k^*}\frac{\partial T'^4}{\partial y'} \tag{8}$$

Here σ is Stefan – Boltzmann constant and *k** is the mean absorption coefficient. It is assumed that the temperature differences within the flow are sufficiently small so that *T'4* can be expressed as a linear function of *T*' after using Taylor"s series to expand *T'4* about the free stream temperature *T'1* and neglecting higher – order terms. This results in the following approximation:

$$T'^4 \cong 4T_1'^3T' - 3T_1'^4 \tag{9}$$

Using equations (8) and (9) in the last term of equation (7), we obtain:

$$\frac{\partial q_r}{\partial y'} = -\frac{16\bar{\sigma}T_1'^3}{3k^*}\frac{\partial^2 T'}{\partial y'^2} \tag{10}$$

Introducing (10) in the equation (7), the energy equation becomes:

$$\rho C_p\frac{\partial T'}{\partial t'} + \rho C_p v_o\frac{\partial T'}{\partial y'} = \kappa\frac{\partial}{\partial y'}\left(\frac{\partial T'}{\partial y'}\right) + \mu\left[\left(\frac{\partial u'}{\partial y'}\right)^2 + \left(\frac{\partial w'}{\partial y'}\right)^2\right]$$

$$+\frac{\sigma B_o^2}{1+m^2}(u'^2 + w'^2) + \frac{16\bar{\sigma}T_1'^3}{3k^*}\frac{\partial^2 T'}{\partial y'^2} \tag{11}$$

The initial and boundary conditions of the problem are given by

$$\begin{Bmatrix} t' \le 0 : u' = w' = 0, T' = T_1' \ \ for\ all\ \ y' \\ t' > 0 : \begin{cases} u' = w' = 0, T' = T_1' \ at\ \ y' = -h \\ u' = U_o, \ w' = 0, T' = T_2' \ at\ \ y' = h \end{cases} \end{Bmatrix} \quad (11)$$

That the boundary conditions do not show dependence on *x'* suggests that the problem has a fully developed solution of the form:

$$u' = u'(y', t'), \ v = v_o, \ p' = P + Gx'$$

Where *P* is the pressure at *x'*= 0 (constant), *G* is the constant pressure gradient (negative). Under these conditions the continuity equation $\left(\frac{\partial u'}{\partial x'} + \frac{\partial v'}{\partial y'} = 0 \right)$ is automatically satisfied. It is expedient to write the above equations in the non – dimensional form. To do this, we introduce the following non – dimensional quantities

$$x = \frac{x'}{h}, \ y = \frac{y'}{h}, \ z = \frac{z'}{h}, \ t = \frac{t'U_o}{h}, \ u = \frac{u'}{U_o}, \ w = \frac{w'}{U_o}, \ p = \frac{p'}{\rho U_o^2}, \ \theta = \frac{T' - T_1'}{T_2' - T_1'}, \ \overline{\mu} = \frac{\mu}{K},$$

$\tau_D = \frac{\tau_O h}{K U_o}$ is the Bingham Number (Dimensionless yield stress),

$\alpha = \frac{dp'}{dx'}$ is the pressure gradient,

$\mathrm{Re} = \frac{\rho U_o h}{K}$ is the Reynolds number,

$S = \frac{\rho v_o h}{K}$ is the suction parameter,

$\Pr = \frac{\rho C_p U_o h}{\kappa}$ is the Prandtl number,

$Ec = \frac{U_o K}{\rho C_p h (T_2' - T_1')}$ is the Eckert number,

$R = \frac{\kappa k^*}{4 \sigma T_1'^3}$ is the thermal radiation parameter and

$M^2 = \frac{\sigma B_o^2 h^2}{K}$ is the Hartmann number squared

In terms of the above non – dimensional variables and parameters equations (5) – (6) and (11) are, respectively, written as (where the hats are dropped for convenience)

$$\frac{\partial u}{\partial t} + \frac{S}{\mathrm{Re}} \frac{\partial u}{\partial y} = -\frac{dp}{dx} + \frac{1}{\mathrm{Re}} \left[\frac{\partial}{\partial y} \left(\mu \frac{\partial u}{\partial y} \right) - \frac{M^2}{1 + m^2} (u + mw) \right] \quad (13)$$

$$\frac{\partial w}{\partial t} + \frac{S}{\mathrm{Re}} \frac{\partial w}{\partial y} = \frac{1}{\mathrm{Re}} \left[\frac{\partial}{\partial y} \left(\mu \frac{\partial w}{\partial y} \right) - \frac{M^2}{1 + m^2} (w - mu) \right] \quad (14)$$

$$\frac{\partial\theta}{\partial t}+\frac{S}{\mathrm{Re}}\frac{\partial\theta}{\partial y}=\frac{1}{\mathrm{Pr}}\left(\frac{3R+4}{3R}\right)\frac{\partial}{\partial y}\left(\frac{\partial\theta}{\partial y}\right)+(Ec)\mu\left[\left(\frac{\partial u}{\partial y}\right)^2+\left(\frac{\partial w}{\partial y}\right)^2\right]+\frac{M^2(Ec)}{1+m^2}(u^2+w^2) \quad (15)$$

And the corresponding boundary conditions are

$$\begin{Bmatrix} t\le 0: u=w=\theta=0 \quad for\ all\ y \\ t>0: \begin{cases} u=w=\theta=0\ at\ \ y=-1 \\ u=1,\ w=0,\ \theta=1\ \ at\ \ y=1 \end{cases} \end{Bmatrix} \quad (16)$$

Where $\mu=1+\dfrac{\tau_D}{\sqrt{\left(\frac{\partial u}{\partial y}\right)^2+\left(\frac{\partial w}{\partial y}\right)^2}}$ (17)

And $\dfrac{dp}{dx}=\alpha e^{-at}$ (18)

Crank Nicholson Method

Equations (13), (14), (17) represent coupled system of non – linear partial differential equations which are solved numerically under the initial and boundary conditions (16) using the finite difference approximations. A linearization technique is first applied to replace the non – linear terms at a linear stage, with the corrections incorporated in subsequent iterative steps until convergence is reached. Then the Crank Nicholson implicit method is used at two successive time levels. An iterative scheme is used to solve the linearized system of difference equations. The solution at a certain time step is chosen as an initial guess for next time step and the iterations are continued till convergence, within a prescribed accuracy. Finally, the resulting block tridiagonal system is solved using the generalized Thomas – algorithm.

The energy equation (15) is a linear non – homogeneous second order partial differential equation whose right-hand side is known from the solutions of the flow equations (13), (14), (17) subject to the conditions (16). The values of the velocity components are substituted in the right-hand side of equation (15) which is solved numerically with the initial and boundary conditions (16) using central differences and Thomas algorithm to obtain the temperature distribution. Finite difference equations relating the variables are obtained by writing the equations at the midpoint of the computational cell and then replacing the different terms by their second order central difference approximations in the y -direction. The diffusion terms are replaced by the average of the central differences at two successive time – levels. The computational domain is divided into meshes of dimension Δt and Δy in time and space respectively as shown in figure 5.2. We define the variables $B= uy$,$D=wy$ *and,* $L =\theta y$ to reduce the second order differential equations (13), (14), (17) to first order differential equations. The finite difference representations for the resulting first order differential equations (13), (14) take the following forms:

$$\left(\frac{u_{i+1,\,j+1}-u_{i,\,j+1}+u_{i+1,\,j}-u_{i,\,j}}{2(\Delta t)}\right)+\frac{S}{\mathrm{Re}}\left(\frac{B_{i+1,\,j+1}+B_{i,\,j+1}+B_{i+1,\,j}+B_{i,\,j}}{4}\right)=-\alpha e^{at}+\left(\frac{\overline{\mu}_{i+\frac{1}{2},\,j+\frac{1}{2}}}{\mathrm{Re}}\right)$$

$$\left(\frac{(B_{i+1,\,j+1}+B_{i,\,j+1})-(B_{i+1,\,j}+B_{i,\,j})}{2(\Delta y)}\right)+\left(\frac{\overline{\mu}'_{i+\frac{1}{2},\,j+\frac{1}{2}}}{\mathrm{Re}}\right)\left(\frac{B_{i+1,\,j+1}+B_{i,\,j+1}+B_{i+1,\,j}+B_{i,\,j}}{4}\right)-$$

$$\left(\frac{M^2}{1+m^2}\right)\left\{\left(\frac{u_{i+1,\,j+1}+u_{i,\,j+1}+u_{i+1,\,j}+u_{i,\,j}}{4\,\mathrm{Re}}\right)+m\left(\frac{w_{i+1,\,j+1}+w_{i,\,j+1}+w_{i+1,\,j}+w_{i,\,j}}{4\,\mathrm{Re}}\right)\right\} \quad (19)$$

$$\left(\frac{w_{i+1,\,j+1}-w_{i,\,j+1}+w_{i+1,\,j}-w_{i,\,j}}{2(\Delta t)}\right)+\frac{S}{\mathrm{Re}}\left(\frac{D_{i+1,\,j+1}+D_{i,\,j+1}+D_{i+1,\,j}+D_{i,\,j}}{4}\right)=\left(\frac{\overline{\mu}_{i+\frac{1}{2},\,j+\frac{1}{2}}}{\mathrm{Re}}\right)$$

$$\left(\frac{(D_{i+1,\,j+1}+D_{i,\,j+1})-(D_{i+1,\,j}+D_{i,\,j})}{2(\Delta y)}\right)+\left(\frac{\overline{\mu}'_{i+\frac{1}{2},\,j+\frac{1}{2}}}{\mathrm{Re}}\right)\left(\frac{D_{i+1,\,j+1}+D_{i,\,j+1}+D_{i+1,\,j}+D_{i,\,j}}{4}\right)-$$

$$\left(\frac{M^2}{1+m^2}\right)\left\{m\left(\frac{u_{i+1,\,j+1}+u_{i,\,j+1}+u_{i+1,\,j}+u_{i,\,j}}{4\,\mathrm{Re}}\right)-\left(\frac{w_{i+1,\,j+1}+w_{i,\,j+1}+w_{i+1,\,j}+w_{i,\,j}}{4\,\mathrm{Re}}\right)\right\} \quad (20)$$

Where $\overline{\mu}_{i+\frac{1}{2},\,j+\frac{1}{2}}=\dfrac{\overline{\mu}_{i+1,\,j+1}+\overline{\mu}_{i+1,\,j}+\mu_{i,\,j+1}+\mu_{i,\,j}}{4}$

and $\overline{\mu}'_{i+\frac{1}{2},\,j+\frac{1}{2}}=\dfrac{\overline{\mu}'_{i+1,\,j+1}+\overline{\mu}'_{i+1,\,j}+\mu'_{i,\,j+1}+\mu'_{i,\,j}}{4}$ (21)

The variables with bars are given initial guesses from the previous time step and an iterative scheme is used at every time to solve the linearized system of difference equations. Then the finite difference form for the energy equation (15) can be written as

$$\left(\frac{\theta_{i+1,\,j+1}-\theta_{i,\,j+1}+\theta_{i+1,\,j}-\theta_{i,\,j}}{2(\Delta t)}\right)+\frac{S}{\mathrm{Re}}\left(\frac{L_{i+1,\,j+1}+L_{i,\,j+1}+L_{i+1,\,j}+L_{i,\,j}}{4}\right)=$$

$$\frac{1}{\mathrm{Pr}}\left(\frac{3R+4}{3R}\right)\left(\frac{(L_{i+1,\,j+1}+L_{i,\,j+1})-(L_{i+1,\,j}+L_{i,\,j})}{4}\right)+QZFO \quad (22)$$

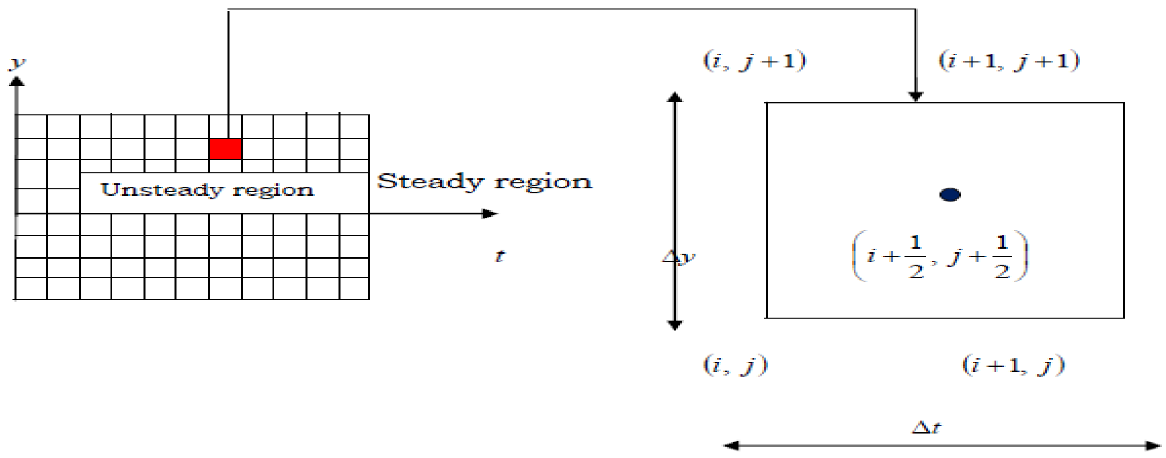
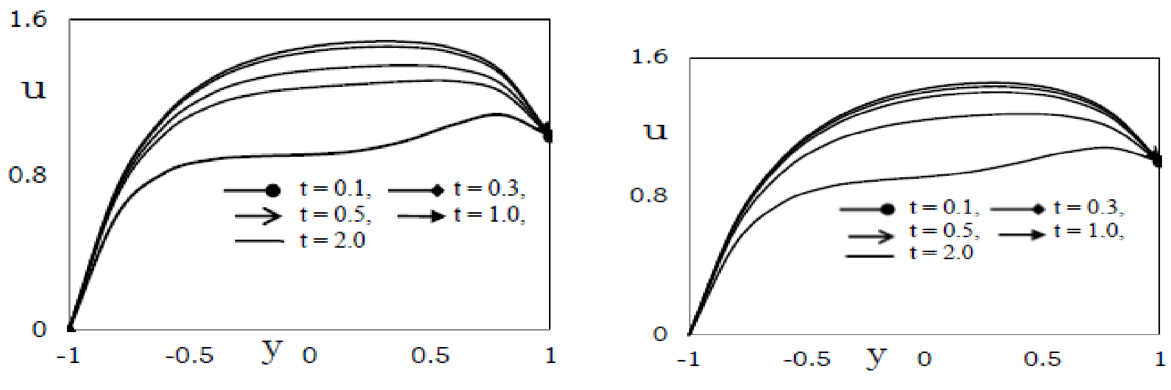


Figure 2: Mesh Layout

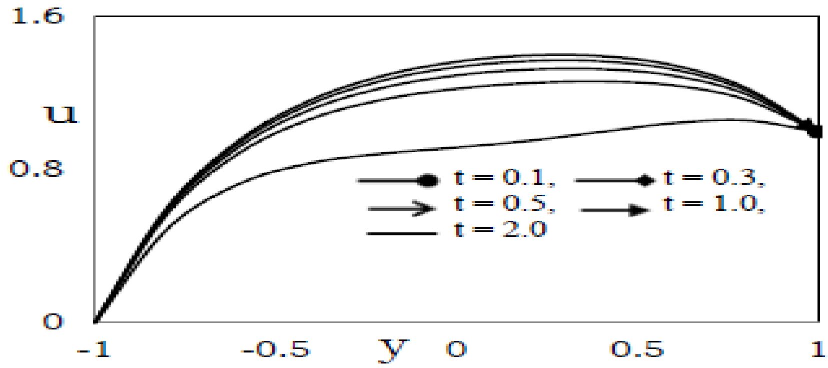
Where *QZFO* represents the Joule and viscous dissipation terms which are known from the solution of the momentum equations and can be evaluated at the midpoint $(i+\frac{1}{2}\ ,\ j+\frac{1}{2})$ of the computational cell. Computations have been made for α =2.0, Pr = 0.71, Re = 2.0, *M* = 2.0, *Ec* = 0.03 and *R* = 2.0. Grid – independence studies show that the computational domain $0 < t < \infty$ and $-1 < y < 1$ can be divided into intervals with step sizes Δt = 0.0001 and Δy = 0.005 for time and space respectively. The truncation error of the central difference schemes of the governing equations is $O(\Delta t^2, \Delta y^2)$. Stability and rate of convergence are functions of the flow and heat parameters. Smaller step sizes do not show any significant change in the results. Convergence of the scheme is assumed when all of the unknowns *u*, *B*, *w*, *D*, θ and *L* for the last two approximations differ from unity by less than 10^{-6} for all values of *y* in $-1 < y < 1$ at every time step. Less than 7 approximations are required to satisfy this convergence criteria for all ranges of the parameters studied here.

III. RESULTS AND DISCUSSION

Figures 5.3 – 5.5 present the profiles of the velocity components *u* and *w* and the temperature θ respectively for various values of time *t* and for τ_D = 0, 0.05, and 0.1. The figures are evaluated for *M* =3.0, *m* = 3.0, *S* =1.0 and *R* = 2.0.

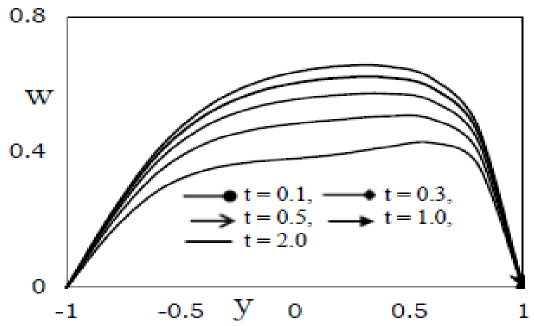


(a) $\tau_D = 0.0$ (b) $\tau_D = 0.05$

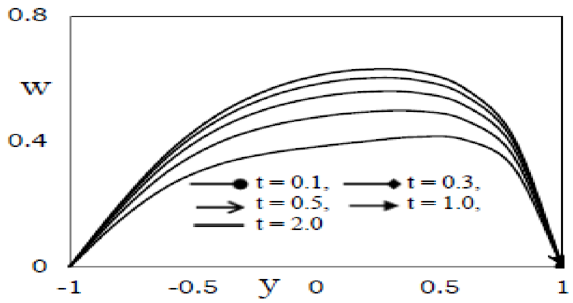


(c) $\tau_D = 0.10$

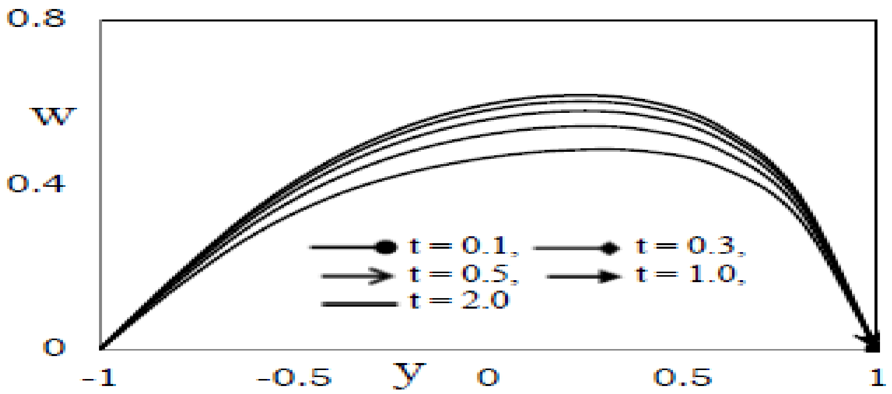
Figure 3: Time development of the velocity component *u* for *S* =1, *M* = 3 and *R* = 2



(a) $\tau_D = 0.0$



(b) $\tau_D = 0.05$



(c) $\tau_D = 0.10$

Figure 4: Time development of the velocity component w for *S=1, M=3, m=3 and R=2.*

It is clear from figures 3 and figure 4 that increasing the yield stress τ_D decreases the velocity components *u* and *w* and the time at which they reach their steady state values as a result of increasing the viscosity. The figures show also that the velocity components *u* and *w* do not reach their steady state monotonically. Both *u* and *w* increase with time up till a maximum value and then decrease up to the steady state. This behaviour is more pronounced for small values of the parameter τ_D and it is clearer for *u* than for *w*.

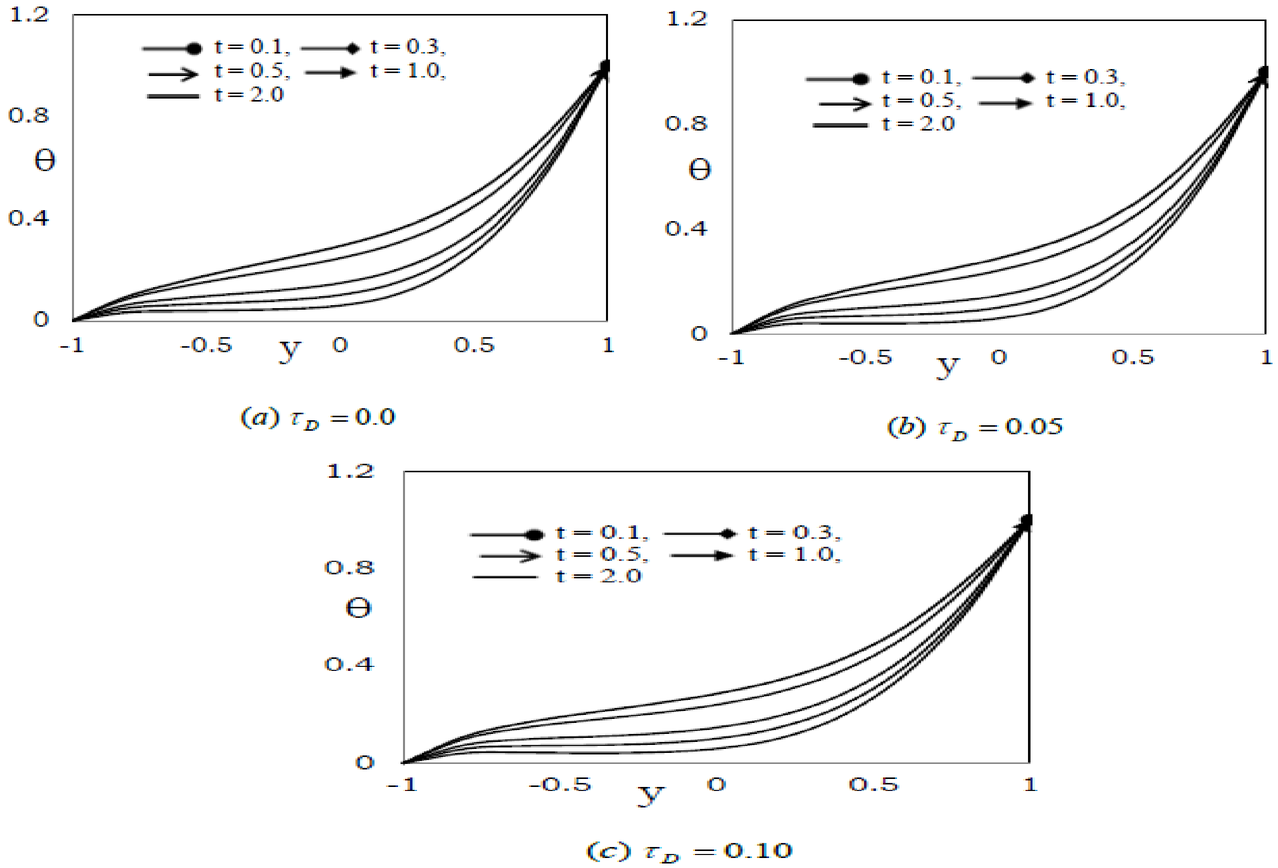


Figure 5: Time development of the temperature θ *for S=1, M=3, m=3 and R=2*

Figure 5 shows that the temperature profile reaches its steady state monotonically. It is observed also that the velocity component *u* reaches the steady state faster than *w* which, in turn, reaches the steady state faster than θ. This is expected as *u* is the source of *w*, while both *u* and *w* act as sources for the temperature.

Table 1: Comparison of the present results and the known results of Attia [30] for Newtonian fluid ($\tau_{D=}$ 0.0) and *R* =0 for *m* = 3, *M* =3, *S* =1 and *y* = 0

t	Values of u		Values of w	
	Present results	Attia [201]	Present results	Attia [201]
0.1	0.4678	0.4669	0.0627	0.0619
0.2	0.8093	0.8089	0.2069	0.2056
0.3	1.0171	1.0160	0.3699	0.3687
0.4	1.1267	1.1251	0.5184	0.5171
0.5	1.1722	1.1708	0.6378	0.6370
0.6	1.1801	1.1791	0.7262	0.7260
0.7	1.1689	1.1682	0.7873	0.7872
0.8	1.1510	1.1495	0.8266	0.8263
0.9	1.1305	1.1297	0.8501	0.8491
1.0	1.1129	1.1122	0.8615	0.8607

In order to examine the accuracy and correctness of the solutions, the results of the time development of the velocity components *u* and *w* at the center of the channel for the Newtonian case is compared and shown, as depicted Table 1, to have complete agreement with those reported by Attia. This ensures the satisfaction of all the governing equations; mass continuity, momentum and energy equations. While comparisons with previously published theoretical work on this problem were performed, no comparisons with experimental data were done because, as far as the author is aware, such data are lacking at the present time.

IV. CONCLUSIONS

A mathematical answer for a flimsy magnetohydrodynamic the mathematical arrangement of precarious magnetohydrodynamic stream of an electrically leading thick incompressible non - Newtonian Bingham liquid limited by two equal non - directing permeable plates is examined with warm radiation considering the Hall Effect have been determined. The dimensionless overseeing coupled, non - straight limit layer incomplete differential conditions are addressed by an effective, precise, and broadly approved and unequivocally stable limited contrast plan of the Crank Nicholson strategy, which is more practical according to a computational perspective. The impacts of the Bingham number ƬD, the Hall boundary m, warm radiation boundary R and the pull boundary S on the speed and temperature disseminations are examined. The Hall expression influences the primary speed part u in the x - bearing and leads to one more speed part w in the z - heading.

An overshooting in the speed parts u and w with time because of the Hall Effect is noticed for all upsides of ƬD. The stream record ƬD has an obvious impact in controlling the overshooting in u or wand the time at which it happens. The outcomes show that the impact of the boundary ƬD on u and w relies upon m and turns out to be more evident when m is enormous. It is found additionally that the impact of m on w relies upon t for all upsides of ƬD which represents a hybrid in the w-t diagram for different upsides of m. The impact of m on the extent of θ relies upon n and turns out to be more articulated in the event of little ƬD.

The time at which u and w arrive at the consistent state increments with expanding m, yet diminishes when ƬD increments. The time at which θ arrives at its consistent state increments with expanding m while it isn't significantly impacted by evolving ƮD. The impact of warm radiation boundary R on speed parts u, w and the temperature by changing the upsides of Bingham number ƮD. As warm radiation boundary R builds, the speed parts u, w and temperature θ fields are diminishes with expanding upsides of ƮD.

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