The Effect of Internal Heat Generation of a Reactive Hydromagnetic (MHD) Fluid Flow through a Vertical Plate

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Abstract
In this study, we discussed the flow of an electrically conducting fluid with internal heat generation over a vertical plate on a reactive MHD fluid. We obtained the semi analytical solutions of the dimensionless equations governing the fluid flow using the method of weighted residual by the collocation method. The parameters with their effect on velocity and temperature fields are discussed graphically using Maple 17 computer software. We showed that the internal heat generation, magnetic field intensity and the reactive rate have significant effects on the velocity profiles and temperature distributions.

Key words: Magnetohydrodynamics (MHD), vertical plate, reactive fluid, internal heat generation.
Introduction

Studies relating to flow of fluids between two parallel plates are on the increase in recent time due to its numerous applications in many industrial and engineering processes like in accelerators, aerodynamic heating, polymer technology, purification of crude oil and magnetohydrodynamics (MHD) generators. The study of heat generation or absorption effects in moving fluids is important in view of several physical problems, such as fluids undergoing exothermic and endothermic chemical reactions (Hassan and Gbadeyan, 2015).

Reactive hydro-magnetic fluid flows are often accompanied with heat transfer in many industrial and engineering applications. For instance, Makinde and Beg (2010) devoted their study to investigate the inherent irreversibility and thermal stability in a reactive electrically conducting fluid flowing steadily through a channel with isothermal walls under the influence of a transversely imposed magnetic field. Recently, Hassan and Gbadeyan (2015) investigated the entropy generation analysis of a reactive hydro-magnetic fluid flow through a channel with isothermal wall temperature under different chemical kinetics without taking into account the effects of internal heat generation within the flow system.

Lot of research works concerning the fluid flow between two vertical plates has been obtained under different physical and chemical conditions. Possible heat generation effects may alter the temperature distribution as well as the particle deposition rate of the fluid flow (Jha and Ajibade, 2009; Makinde and Beg, 2010; Hassan and Fenuga, 2011; Adesanya and Makinde, 2011; Hassan and Gbadeyan, 2015), this informed our study of the effects of internal heat generation within the flow system.

It is well known that the rate of heat transfer is temperature dependent, which increases the interaction of moving fluid and thus influence the internal energy of the flow regime. This interaction according to Frank-Kamenetski (1969), Makinde and Beg (2010) as well as Hassan and Gbadeyan (2014) bring about the condition of thermal runaway or ignition in the flow system to predict critical and unsafe situations.

The weighted residual method may be considered to be a unified version of a group of methods used to solve approximately boundary value, initial value and Eigen value problems. There are some simple and accurate approximation techniques for solving differential equations called the Weighted Residual Methods (WRMs). Collocation, Galerkin and Least Square are examples of the WRMs. Stern and Rasmussen (1996) used collocation method for solving a third order linear differential equation. Vaferti et al. (2012) studied the feasibility of applying Orthogonal Collocation method to solve diffusivity equation in the radial transient flow system. Hendi and Albugami (2010) used Collocation and Galerkin methods for solving Fredholm–Volterra integral equation. Recently least square method was introduced by Aziz and Bouaziz (2011) and applied for it in predicting the performance of a longitudinal fin. They found that least squares method is simple compared with other analytical methods. Shaoqin and Huoyuan (2008) developed and analyzed least-squares approximations for the incompressible magneto-hydrodynamic equations. Recently, Hatami et al. (2014) studied the third grade non-Newtonian blood conveying gold nanoparticles in a porous and hollow vessel by two analytical methods called Least Square Method (LSM) and Galerkin Method (GM).

Hence, in the present study we will use the weighted residual method by collocation method to discuss an electrically conducting fluid with internal heat generation over a vertical plate on a reactive MHD fluid.

Mathematical Formulation

Consider a steady flow of an incompressible viscous fluid flow between two vertical Channels of a reactive MHD flow with internal heat generation. Let the x-axis be directed upward along the plate and the y-axis normal to the plate. The flow is electrically conducting in the presence of an applied magnetic field and is maintained due to a constant pressure gradient. Let \( u \) and \( v \) be the velocity components along the x- and y- axes respectively. The continuity equation is given as

\[
\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0
\]  

(1)
If the flow is in the $x$-direction, $\frac{\partial \tilde{u}}{\partial x} = 0$, which implies $\frac{\partial v}{\partial y} = 0$. Then the steady equations of motion (momentum and energy equation) for the system is presented by

$$- \frac{\partial \tilde{p}}{\partial x} + \nu \frac{\partial^2 \tilde{u}}{\partial y^2} - \frac{\sigma B_0^2 \tilde{u}}{\rho} + g\beta(T - T_0) = 0 \quad (2)$$

$$\alpha \frac{\partial^2 \tilde{T}}{\partial y^2} + Ra - \lambda(T - T_0) = 0 \quad (3)$$

Where $\alpha$ is the thermal diffusivity, $\nu$ the kinematic viscosity, $\beta$ is the volumetric expansion coefficient for heat transfer, $\rho$ the density, $g$ is the acceleration due to gravity, $T$ is the temperature, $T_0$ is the reference or ambient temperature, $\lambda$ is the heat generation coefficient and $Ra$ is the reaction term.

With the following boundary conditions

$$\tilde{u}(0) = u_0, \quad \tilde{u}(L) = 0. \quad (4)$$

$$T(0) = T(L) = T_0 \quad (5)$$

$L$ is the width of the channel and $u_0$ is the velocity of the left plate.

**Dimensional Analysis**

By the scaling principle, we present the following dimensionless scales

$$\tilde{u} = \frac{u - u_0}{L}, \quad \tilde{y} = \frac{y}{L}, \quad Ra = QC_\alpha \ell \frac{E}{R}, \quad \text{and} \quad \theta = \frac{T - T_0}{\Delta T} \quad (6)$$

And reduced the dimensioned equations into dimensionless momentum and energy equations as

$$P + \frac{\partial^2 \tilde{u}}{\partial \tilde{y}^2} - Nu + Gr \theta = 0 \quad (7)$$

$$\frac{\partial^2 \theta}{\partial \tilde{y}^2} - \lambda_0 \theta + \lambda_1 \ell^{(\mu + 1)} = 0 \quad (8)$$

With the following boundary conditions

$$\tilde{u}(0) = 1, \quad \tilde{u}(1) = 0 \quad (9)$$

$$\theta(0) = \theta(1) = 0 \quad (10)$$

Where, $N$ is the Hartman Number, $Gr$ is the Grashof Number, $P$ is the Pressure force, $\lambda_0$ is the Internal heat generation and $\lambda_1$ is the Arrhenius term.

**Weighted Residual Method (WRM) by Collocation method**

In this method, the weighting functions are taken from the family of Dirac $\delta$ functions in the domain. That is, $W_i(y) = \delta(y - y_i)$. The Dirac $\delta$ function has the property that

$$\int_{y_i} W_i(y) \, dy = \delta(y_i) = \{1, \text{otherwise} \} \quad (11)$$

The idea in the WRM is to force the residual to zero in some average sense over the domain. That is

$$\int_{y_i} R(y) W_i \, dy = 0, \quad i = 1, 2, \cdots, n \quad (12)$$

where the number of weight functions $W_i$ is exactly equal the number of unknown constants $a_i$, in $u(y)$. The result is a set of $n$ algebraic equations for the unknown constants $a_i$ (Salih, 2016).

The fixed points $y_i \in [a_i, b_i]$ $(i = 1, 2, \cdots, n)$ are called collocation points. The number of collocation points selected must be equal to the number of unknown coefficients $a_i$’s in the definition of approximating function, $u(y)$.

Hence, the integration of the weighted residual statement results in the forcing of the residual to zero at specific points in the domain. That is, integration of (12) with $W_i(y) = \delta(y - y_i)$ results in $R(y_i) = 0$

Thus, by the collocation method, we will use a polynomial function as a basis. That is, let the approximating function $u(y)$ which can be chosen arbitrary be

$$u(y) = a_0 + a_1 y + a_2 y^2 + a_3 y^3 + a_4 y^4 \quad \theta(y) = b_0 + b_1 y + b_2 y^2 + b_3 y^3 + b_4 y^4 \quad (13)$$

**Solution to the dimensionless momentum and energy equations using the collocation method**

We will chose the trial functions in such a way that the assumed function $u(y)$ satisfies the global boundary conditions for (13) Thus,
Evaluating equations (16) and (17) at the following collocation points \((y = 0.25, y = 0.5, y = 0.75)\) gives the following relations.

\[
R_1(0.25) = P - 0.7500\alpha_1 + 1.2500\alpha_2 + 0.7500\alpha_3 - 0.7500
\]

\[
\begin{align*}
-N &\left[ 0.99609375 + 0.24609375\alpha_1 \\
&+ 0.05859375\alpha_2 + 0.01171875\alpha_3 \right] \\
+Gr &\left[ 0.24609375\beta_1 + 0.05859375\beta_2 \right. \\
&\left. + 0.01171875\beta_3 \right] = 0
\end{align*}
\]

\[
R_2(0.25) = -0.7500\beta_1 + 1.2500\beta_2 + 0.7500\beta_3
\]

\[
\begin{align*}
-\lambda_0 &\left[ 0.24609375\delta_1 + 0.05859375\delta_2 \right. \\
&\left. + 0.01171875\delta_3 \right] \\
+\lambda e &\left[ 0.24609375\epsilon_1 + 0.05859375\epsilon_2 \right. \\
&\left. + 0.01171875\epsilon_3 \right] = 0
\end{align*}
\]
\[ R_i(0.5) = P - 3.00 a_i - 1.00 a_2 - 3.00 \\
-\lambda_0 \left( 0.9375 + 0.4375 a_1 + 0.1875 a_2 \right) \\
+ \lambda_1 e^{(0.4375 a_1 + 0.1875 a_2 + 0.0625 a_3) t} = 0 \]

\[ R_i(0.75) = P - 6.7500 a_i - 4.7500 a_2 \\
-2.2500 a_3 - 6.7500 \\
-\lambda_0 \left( 0.68359375 + 0.43359375 a_1 + 0.10546875 a_2 + 0.010546875 a_3 \right) \\
+ \lambda_1 e^{(0.43359375 a_1 + 0.24609375 a_2 + 0.10546875 a_3) t} = 0 \]

The \( a'_i \)'s and \( b'_i \)'s are obtained from solving (18), (19) and (20) as a system of linear equations with suitable values of the dimensionless constants and with the help of maple 17 software we summarize the solution in the table together with the numerical solution of the momentum and energy equations as follows.

**Table 1: Coefficients of the Basis Functions with Increasing Internal Heat Generation \( \lambda_0 \) and \( (P = 1, N = 0.2) \) (\( Gr = 0.1, \varepsilon = 0.5 \) and \( \lambda_i = 1.2 \))**

<table>
<thead>
<tr>
<th>( \lambda_0 )</th>
<th>( a_1 )</th>
<th>( a_2 )</th>
<th>( a_3 )</th>
<th>( b_1 )</th>
<th>( b_2 )</th>
<th>( b_3 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2</td>
<td>-1.553547322</td>
<td>0.5994305394</td>
<td>-0.05864014171</td>
<td>0.5051908141</td>
<td>-0.5901416525</td>
<td>0.1699016768</td>
</tr>
<tr>
<td>1.4</td>
<td>-1.553659863</td>
<td>0.5994166552</td>
<td>-0.05848808951</td>
<td>0.4985351037</td>
<td>-0.5895618927</td>
<td>0.1820535781</td>
</tr>
<tr>
<td>1.6</td>
<td>-1.553686935</td>
<td>0.5994035487</td>
<td>-0.05834113393</td>
<td>0.4920813209</td>
<td>-0.5889325390</td>
<td>0.1937024362</td>
</tr>
</tbody>
</table>

**Table 2: Coefficients of the Basis Functions with Increasing Reactive Rate \( \lambda_i \) and \( (P = 1, N = 0.2, Gr = 0.1) \) (\( \varepsilon = 0.5 \) and \( \lambda_0 = 1.2 \))**

<table>
<thead>
<tr>
<th>( \lambda_i )</th>
<th>( a_1 )</th>
<th>( a_2 )</th>
<th>( a_3 )</th>
<th>( b_1 )</th>
<th>( b_2 )</th>
<th>( b_3 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2</td>
<td>-1.553547322</td>
<td>0.5994305394</td>
<td>-0.05864014171</td>
<td>0.5051908141</td>
<td>-0.5901416525</td>
<td>0.1699016768</td>
</tr>
<tr>
<td>1.4</td>
<td>-1.552936843</td>
<td>0.5993847083</td>
<td>-0.05976943689</td>
<td>0.5827246268</td>
<td>-0.6861007858</td>
<td>0.2067523180</td>
</tr>
<tr>
<td>1.6</td>
<td>-1.552340174</td>
<td>0.5993371739</td>
<td>-0.06086703593</td>
<td>0.6586871810</td>
<td>-0.7812463833</td>
<td>0.245184046</td>
</tr>
</tbody>
</table>
Table 3: Coefficients of the Basis Functions with Varying Hartman Number \( N \) and \((- P = 1, \lambda_1 = 1.2, \text{Gr} = 0.1), \) \((\varepsilon = 0.5 \text{and } \lambda_0 = 1.2)\)

<table>
<thead>
<tr>
<th>(N)</th>
<th>(a_1)</th>
<th>(a_2)</th>
<th>(a_3)</th>
<th>(b_1)</th>
<th>(b_2)</th>
<th>(b_3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.552605423</td>
<td>0.5996078885</td>
<td>-0.0606986375</td>
<td>0.5972991736</td>
<td>-0.6045225430</td>
<td>0.01444673890</td>
</tr>
<tr>
<td>2</td>
<td>-2.012818193</td>
<td>1.464122307</td>
<td>-0.5888827392</td>
<td>0.5972991736</td>
<td>-0.6045225430</td>
<td>0.01444673890</td>
</tr>
<tr>
<td>3</td>
<td>-2.231801428</td>
<td>1.9119487300</td>
<td>-0.9182288879</td>
<td>0.5972991736</td>
<td>-0.6045225430</td>
<td>0.01444673890</td>
</tr>
</tbody>
</table>

Table 4: Coefficients of the Basis Functions with Varying Pressure \( P \) and \((N = 0.2, \lambda_1 = 1.2, \text{Gr} = 0.1), \) \((\varepsilon = 0.5 \text{and } \lambda_0 = 1.2)\)

<table>
<thead>
<tr>
<th>(P)</th>
<th>(a_1)</th>
<th>(a_2)</th>
<th>(a_3)</th>
<th>(b_1)</th>
<th>(b_2)</th>
<th>(b_3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-1.769224197</td>
<td>0.9910133792</td>
<td>-0.281962032</td>
<td>0.5999624688</td>
<td>-0.6002005634</td>
<td>0.0004761892805</td>
</tr>
<tr>
<td>2.5</td>
<td>-2.462201562</td>
<td>1.739707517</td>
<td>-0.3933957494</td>
<td>0.5999624688</td>
<td>-0.6002005634</td>
<td>0.0004761892805</td>
</tr>
<tr>
<td>5</td>
<td>-3.617163837</td>
<td>2.987531081</td>
<td>-0.5791183263</td>
<td>0.5999624688</td>
<td>-0.6002005634</td>
<td>0.0004761892805</td>
</tr>
</tbody>
</table>

Table 5: Coefficients of the Basis Functions with Varying Grashorf Number \( \text{Gr} \) and \((N = 0.2, \lambda_1 = 1.2, P = 1), \) \((\varepsilon = 0.5 \text{and } \lambda_0 = 1.2)\)

<table>
<thead>
<tr>
<th>(\text{Gr})</th>
<th>(a_1)</th>
<th>(a_2)</th>
<th>(a_3)</th>
<th>(b_1)</th>
<th>(b_2)</th>
<th>(b_3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>-1.769224197</td>
<td>0.9910133792</td>
<td>-0.281962032</td>
<td>0.5999624688</td>
<td>-0.6002005634</td>
<td>0.0004761892805</td>
</tr>
<tr>
<td>0.5</td>
<td>-1.750979201</td>
<td>0.9905933793</td>
<td>-0.3176121851</td>
<td>0.5999624688</td>
<td>-0.6002005634</td>
<td>0.0004761892805</td>
</tr>
<tr>
<td>1</td>
<td>-1.728172955</td>
<td>0.9900683672</td>
<td>-0.3621746624</td>
<td>0.5999624688</td>
<td>-0.6002005634</td>
<td>0.0004761892805</td>
</tr>
</tbody>
</table>

Thus, by the collocation method, solution of the momentum and energy equations are given by

\[
u_{a_{4-1.2}}(y) = (1 - y^4) - 1.55354732 \varepsilon (1 - y^3) \\
+ 0.599430534 y^2 (1 - y^2) \\
- 0.05864041171 y (1 - y) \tag{21}
\]

\[
u_{a_{4-4.4}}(y) = (1 - y^4) - 1.55360946 \varepsilon (1 - y^3) \\
+ 0.599416652 y^2 (1 - y^2) \\
- 0.0584880951 y (1 - y) \tag{22}
\]

\[
u_{a_{4-4.6}}(y) = (1 - y^4) - 1.55366963 \varepsilon (1 - y^3) \\
+ 0.599403348 y^2 (1 - y^2) \\
- 0.0583411393 y (1 - y) \tag{23}
\]

and

\[
\theta_{a_{4-1.2}}(y) = 0.505190841 y (1 - y^3) \\
- 0.590141635 y^2 (1 - y^2) \\
+ 0.169901638 y (1 - y) \tag{24}
\]
\[ \theta_{\lambda_0=1.4}(y) = 0.49853510y(1-y^3) - 0.58956182y^2(1-y^3) + 0.1820535y^3(1-y) \]  
\[ \theta_{\lambda_0=1.6}(y) = 0.49208132y(1-y^3) - 0.58893253y^2(1-y^3) + 0.19370243y^3(1-y) \]  

Figure 1: Effect of the Increasing Internal Heat Generation \( \lambda_0 \) on the Velocity Profile.

\[ u_{d=1.2}(y) = (1-y^3) - 1.55354732y(1-y^3) + 0.59943053y^2(1-y^3) - 0.05864014y^3(1-y) \]  

Figure 2: Effect of the Increasing Internal Heat Generation \( \lambda_0 \) on the Temperature profile.
\[ u_{\lambda=1.4}(y) = (1 - y^4) - 1.55293684y(1 - y^3) \]
\[ + 0.599384703y^2(1 - y^2) \]
\[ - 0.059769436y^3(1 - y) \] \hspace{2cm} (28)

\[ u_{\lambda=1.6}(y) = (1 - y^4) - 1.55234017y(1 - y^3) \]
\[ + 0.599337179y^2(1 - y^2) \]
\[ - 0.060867709y^3(1 - y) \] \hspace{2cm} (29)

and

\[ \theta_{\lambda=1.2}(y) = 0.505190841y(1 - y^3) \]
\[ - 0.590141652y^2(1 - y^2) \]
\[ + 0.169901676y^3(1 - y) \] \hspace{2cm} (30)

\[ \theta_{\lambda=1.4}(y) = 0.582724628y(1 - y^3) \]
\[ - 0.686100795y^2(1 - y^2) \]
\[ + 0.206752380y^3(1 - y) \] \hspace{2cm} (31)

\[ \theta_{\lambda=1.6}(y) = 0.658687188y(1 - y^3) \]
\[ - 0.781246383y^2(1 - y^2) \]
\[ + 0.245118406y^3(1 - y) \] \hspace{2cm} (32)

Figure 3: Effect of the Reactive Rate $\lambda_1$ on the velocity Profile.
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Figure 4: Effect of the Reactive Rate $\lambda_1$ on the Temperature Profile

$$u_{N=1}(y) = (1 - y^4) - 1.55269542 y (1 - y^3)$$
$$+ 0.599607885 y^2 (1 - y^2)$$
$$- 0.06069863 y^3 (1 - y)$$

$$u_{N=2}(y) = (1 - y^4) - 2.01281819 y (1 - y^3)$$
$$+ 1.46412230 y^2 (1 - y^2)$$
$$- 0.58888270 y^3 (1 - y)$$

$$u_{N=3}(y) = (1 - y^4) - 2.23180142 y (1 - y^3)$$
$$+ 1.91948730 y^2 (1 - y^2)$$
$$- 0.91822885 y^3 (1 - y)$$

and

$$\theta_{N=1}(y) = 0.597299176 y (1 - y^3)$$
$$- 0.604522540 y^2 (1 - y^2)$$
$$+ 0.0144467890 y^3 (1 - y)$$

$$\theta_{N=2}(y) = 0.597299176 y (1 - y^3)$$
$$- 0.604522540 y^2 (1 - y^2)$$
$$+ 0.0144467890 y^3 (1 - y)$$

$$\theta_{N=3}(y) = 0.597299176 y (1 - y^3)$$
$$- 0.604522540 y^2 (1 - y^2)$$
$$+ 0.0144467890 y^3 (1 - y)$$
Figure 5: Effect of the Hartman Number $N$ on the Velocity Profile

$$u_{P,1}(y) = (1 - y^4) - 1.769224192 y(1 - y^3) + 0.99101337 y^2(1 - y^2) - 0.28196220 y^3(1 - y)$$

$$u_{P,2.5}(y) = (1 - y^4) - 2.46220152 y(1 - y^3) + 1.7397075 y^2(1 - y^2) - 0.39339574 y^3(1 - y)$$

$$u_{P,5}(y) = (1 - y^4) - 3.61716383 y(1 - y^3) + 2.98753108 y^2(1 - y^2) - 0.57911832 y^3(1 - y)$$

and

$$\theta_{P,1}(y) = 0.599962468 y(1 - y^3) - 0.60020556 y^2(1 - y^2) + 0.00476192 y^3(1 - y)$$

Figure 6: Effect of the Hartman Number $N$ on the Temperature Profile
\[ \theta_{p=2.5}(y) = 0.599962468y(1 - y^3) - 0.600200564y^2(1 - y^2) + 0.000476182805y^3(1 - y) \] (43)

\[ \theta_{p=5}(y) = 0.599962468y(1 - y^3) - 0.600200564y^2(1 - y^2) + 0.000476182805y^3(1 - y) \] (44)

Figure 7: Effect of the Pressure \( P \) on the Velocity Profile

\[ u_{Gr=1}(y) = (1 - y^4) - 1.7692241\,y(1 - y^3) + 0.9910133\,y^2(1 - y^2) - 0.2819622\,y^3(1 - y) \] (45)

Figure 8: Effect of the Pressure \( P \) on the Temperature Profile
\[ u_{Gr=0.5}(y) = (1 - y^4) - 1.7509792 \alpha y(1 - y^3) \\
+ 0.990593379 y^3(1 - y^2) \\
- 0.3176121 \beta y^3(1 - y) \]  
(46)

\[ u_{Gr=1}(y) = (1 - y^4) - 1.7281729 \beta y(1 - y^3) \\
+ 0.9906836 \gamma^2 y^3(1 - y^2) \\
- 0.3621746 \gamma^3 (1 - y) \]  
(47)

and

\[ \theta_{Gr=0.1}(y) = 0.5999624 \delta^8 y(1 - y^3) \\
- 0.6002005 \delta^4 y^3(1 - y^2) \\
+ 0.0004761 \delta^8 2805 y^3 (1 - y) \]  
(48)

\[ \theta_{Gr=0.5}(y) = 0.5999624 \delta^8 y(1 - y^3) \\
- 0.6002005 \delta^4 y^3(1 - y^2) \\
+ 0.0004761 \delta^8 2805 y^3 (1 - y) \]  
(49)

\[ \theta_{Gr=1}(y) = 0.5999624 \delta^8 y(1 - y^3) \\
- 0.6002005 \delta^4 y^3(1 - y^2) \\
+ 0.0004761 \delta^8 2805 y^3 (1 - y) \]  
(50)

Figure 9: Effect of the Grashof Number \(Gr\) on the Velocity Profile
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Discussion

We will discuss the effects of the internal heat generation together with other important flow parameters on the hydromagnetic fluid flow between two vertical plates with an isothermal wall temperature in this session. These are presented in tables and graphs using Maple 17 Mathematical software.

Figure 1 and 2 shows the effect of the increasing internal heat generation $\lambda_i$ on the velocity and temperature profile respectively. Increase in the internal heat generation parameter $\lambda_i$ reduces the temperature of the fluid and has no significant effect on the velocity profile while increase in the Reactive Rate $\lambda_1$ increases the temperature and shows no significant change in the velocity profile as can be seen by Figure 3 and 4. Increase in the Stuart Number $N$ reduces the velocity of the flow. The Stuart Number $N$ which is also known as the magnetic interaction parameter which is the ratio of electromagnetic to inertial forces on flow have no significant effect on the temperature profile as can be seen from figures 5 and 6 respectively. Figures 7 and 8 shows that the pressure forces $P$ which drives the flow also reduces the velocity and even goes beyond the boundary line at higher pressure forces while the temperature has no significant change with increase in the pressure forces. The Grashof Number $Gr$ which is a dimensionless number in fluid dynamics and heat transfer approximates the ratio of the buoyancy to the viscous force acting on a fluid, increases with increase in the velocity profile. It however does not affect the temperature as seen by figures 9 and 10.

Conclusion

The effect of internal heat generation on a steady hydromagnetic fluid flow between two Channels is investigated. Analytical solutions of the equations governing the fluid flow are obtained using the method of weighted residual by collocation method. In view of the above results, the following are the major contributions in this study:

i. The effect of the increasing Stuart Number $N$ and the pressure $P$ reduces the velocity while the increasing Grashof Number $Gr$ increases the fluid velocity and the temperature remains indifferent.

ii. Due to collision of the fluid particles, internal heat $\lambda_i$ is being generated which eventually leads to a decrease in the fluid temperature.

iii. The temperature increases as the reactive rate $\lambda_1$ which is the modification of the Arrhenius Number increases while the velocity remains indifferent.

Finally, we showed that the internal heat generation, magnetic field intensity and the reactive rate have significant effects on the velocity profiles and temperature distributions.

References


