Hall Effects on Unsteady Magneto Hydrodynamic Convection Flow of Nanofluids Past a Rotating Porous Plate

Pushpabaipavar, L. Harikrishna, M. Suryanarayana Reddy

Abstract: The effects of Hall current are considered for the convective rotational current free of nanofluid magnetohydrodynamics (copper and alumina) in a permeable medium with a vertical porous flat plate, semi-infinite rotation with stable state of the heat source and convection limit. The slip rate is expected to oscillate over time with a constant frequency so that the boundary layer solutions are of the equivalent oscillating type. The equations to regulate the flow are analytically solved by perturbation estimation. The effects of different parameters on the flow are investigated by means of diagrams and tables.

Keywords: Porous medium; Nanofluids; Convective flow; rotating frame; Heat transfer.

NOMENCLATURE

- $u, v, w$: velocity components along $x, y$ and $z$-axis respectively.
- $\beta_{nf}$: coefficient of the thermal expansion.
- $K_{nf}$: Thermal conductivity.
- $U_r$: The uniform reference velocity.
- $\varepsilon$: The small constant quantity.
- $\sigma$: Electric conductivity.
- $\rho_{nf}$: Density.
- $\mu_{nf}$: Viscosity.
- $(\rho C_p)_{nf}$: Heat capacitance.
- $g$: Acceleration due to gravity.
- $k$: Permeability of porous medium.
- $T$: Temperature.
- $Q$: Temperature dependent volumetric rate of heat source.
- $\alpha_{nf}$: Thermal diffusivity.
- $(\rho \beta_{nf})$: The thermal expansion coefficient of the nanofluid.
- $\phi$: Solid volume fraction of the nanoparticles.
- $w_0$: The normal velocity at the plate.
- $\nu_f$: Kinematic viscosity.
- $R$: Rotational parameter.
- $M$: Magnetic field parameter.
- $Pr$: Prandtl number.
- $S$: Suction ($S > 0$) or injection ($S < 0$) parameter.
- $K$: Permeability of the porous medium and
- $Q_H$: Heat source parameter.
- $B_0$: Magnetic induction.
- $k$: Permeability of porous medium.
- $\Omega$: Angular velocity.
- $\sigma$: Electrical conductivity of the fluid.
- $\gamma$: Convective parameter.
- $Re_s$: Local Reynolds number.
- $\tau$: Skin friction parameter.
- $Nu$: Nusselt number.
- $n$: Frequency of oscillation.
- $t$: Time.

Subscripts:

- $f$: Base fluid.
- $nf$: Nano-fluid.
- $s$: Nanosolid particles.

I. INTRODUCTION

There is very significant interest in science and technology for convective Nano fluid heat transfer. Ethylene glycol, Water, and engine oil are heating or cooling agents and play a decisive role in many industries’ thermal management with low thermal conductivity. We enhance thermal conductivity for extended surfaces, mini-channels and micro-channels. Concrete materials have higher thermal conductivities. The word nanofluid has been presented first by Choi [3]. Nano-particles are a viaduct between enormity materials and nuclear or molecular syntheses. Some of nano-particles have utilized are Al, Cu, Fe and Ti or their oxides. Progressed nuclear system [1] has great application utilizing of nanofluids. Micro-channel miniaturization and cooling of the system, heat transfer system size decrease, improved heat transfer and negligible clogging are the advantages of nanofluids. Conge do et al. [5], Das, Kalidas [11] and Ghasemi discussed on regular convection heat transfer in nanofluids. The 2-dimensional regular convection flow of a nanofluid in a walled in area has been discussed by Khaafar et al. [4]. MHD Non-Newtonian fluid rotating streams have various uses in turbo equipment, geophysics, meteorology, and a few areas. Das, Kalidas[11], Bakr6] and Das[9] investigated micropolar fluid free convection flow in a pivoting stream.

III. FORMULATION AND SOLUTION OF THE PROBLEM

We consider the effects of Hall on the unstable free convection flow of nanofluids at room temperature (copper and alumina) on a permeable plate in vertical semi-infinite movement embedded in a homogeneous porous medium under the influence of thermal buoyancy with a stable heat source and A special kind of boundary conditions. We assume that the nanoparticles had a uniform shape and size. There is also thermal equilibrium in both nanoparticle and liquid phase.

Image. Fig. 1 Images the physical problem model. It is assumed that the flow is in the x-direction obtained in the ascendant direction along the sheet, and it is usual for z-axis.

The basic conditions that depict the physical circumstances are given under the approximations of the limit layer

\[
\frac{\partial w}{\partial z} = 0
\]

\[
\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial z} + 2\Omega v = \frac{\mu_s}{\rho_s} \frac{\partial u}{\partial z} - \frac{\mu_s}{\rho_s} k + BJ, + g\beta_s (T - T_0)
\]

\[
\frac{\partial v}{\partial t} + u \frac{\partial v}{\partial z} + 2\Omega u = \frac{\mu_s}{\rho_s} \frac{\partial v}{\partial z} - \frac{\mu_s}{\rho_s} k - BJ, + g\beta_s (T - T_0)
\]

The conditions are determined by

\[
u = v = 0, \quad T = T_\infty \text{ for } t \leq 0
\]

\[
u = \nu_0, \quad T = T_\infty \text{ for } t > 0
\]

\[
u = 0, \quad v = 0, \quad T \rightarrow T_\infty \text{ as } z \rightarrow \infty
\]

At the point when the value of the magnetic field is enormous, the description of the law of Ohm is modified to integrate the condition of the Hall so that

\[
J + \frac{\alpha_s}{B_0} (J \times B) = \sigma \left[ E + V \times B + \frac{1}{\epsilon_n} \nabla P \right]
\]

Ionic and thermo-electric impacts are excluded. We press \(\alpha_s \tau_e \sim 0 \) and \(\alpha_s \tau_e << 1\), where \(\alpha_s\) and \(\tau_e\) are respectively the cyclotron frequency and the collision time for the ions. Likewise, we expect that \(E = 0\) under suspicions will decrease to

\[
J_x + m J_y = \alpha_s B_0 v
\]

\[
J_y - m J_x = -\alpha_s B_0 u
\]

Solving equations (8) and (8.a) we get,

\[
J_x = \frac{\alpha_s B_0}{1 + m} (v + mu)
\]

\[
J_y = \frac{\alpha_s B_0}{1 + m} (mv - u)
\]

We are replacing the equations (9) and (10) respectively in (3) and (2)

\[
\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial z} - 2\Omega v + \frac{\mu_s}{\rho_s} \frac{\partial u}{\partial z} - \frac{\mu_s}{\rho_s} k + \frac{\sigma B_0}{1 + m} \frac{(mv - u)}{\mu_s} + g\beta_s (T - T_0)
\]

\[
\frac{\partial v}{\partial t} + u \frac{\partial v}{\partial z} + 2\Omega u - \frac{\mu_s}{\rho_s} \frac{\partial v}{\partial z} - \frac{\mu_s}{\rho_s} k - \frac{\sigma B_0}{1 + m} \frac{(v + mu)}{\mu_s} - g\beta_s (T - T_0)
\]

The velocity of the oscillatory plate assumed in equation (6) The effective nanofluid density is determined by

\[
\rho_{nf} = \left(1 - \phi\right) \rho_f + \phi \rho_s
\]

Thermal diffusivity of the nanofluid is

\[
\alpha_{nf} = \frac{K_{nf}}{\rho C_{p nf}}
\]

Where, the nanofluid's heat capacitance \(C_p\)

\[
\langle \rho C_p \rangle_{nf} = \left(1 - \phi\right) \langle \rho C_p \rangle_f + \phi \langle \rho C_p \rangle_s
\]

The thermal conductivity of the nanofluid \(k_{nf}\) for spherical nanoparticles is as Maxwell

\[
k_{nf} = \frac{\left(k_f + 2k_j\right) - 2\phi \left(k_j - k_s\right)}{\left(k_s + 2k_f\right) + 2\phi \left(k_j - k_s\right)}
\]

The coefficient of thermal expansion of nanofluids is

\[
\beta_{nf} = \left(1 - \phi\right) \beta_f + \phi \beta_s
\]

Finally the effective dynamic viscosity of the given nanofluid

\[
\mu_{nf} = \frac{\mu_f}{\left(1 - \phi\right)^{\gamma_s}}
\]
The thermo-physical properties of the nanofluids are given in Table 1.

\[ W = -W_0 \]  

(19)

Where, \( W_0 \) is the normal velocity

Let us add variables that are dimensionless:

\[ u' = \frac{u}{U_r}, \quad v' = \frac{v}{U_r}, \quad z' = \frac{z}{U_r} \sqrt{\frac{\sigma v_f}{\rho_f}}, \quad t' = \frac{t U_r^2}{v_f}, \quad n' = \frac{n v_f}{U_r^2}, \]

\[ \theta = \left( \frac{T - T_a}{T_u - T_a} \right) \quad R = 2\Omega \frac{v_f}{U_r}, \quad M = \frac{B_0}{U_r} \sqrt{\frac{\sigma v_f}{\rho_f}}, \]

\[ \text{Pr} = \frac{v_f}{\alpha_f}, \quad S = \frac{W_0}{U_r}, \quad K = \frac{k U_r^2}{v_f^2} \quad Q_H = \frac{Q v_f^2}{U_r^2 k_f} \]

(20)

Using above non-dimensional variables in equations (2)-(4) we obtain the following dimensionless equations

\[ 1 - \phi + \phi \left( \frac{\rho}{\rho_f} \right) \left( \frac{\partial n}{\partial t} - \frac{\partial u}{\partial z} - R \right) = -\frac{1}{(1-\phi) \sqrt{\sigma}} \frac{\partial u}{\partial z} + \frac{1}{(1-\phi) \sqrt{\rho_f}} \right) \theta 

+ \frac{\sigma R^2 n}{1 + M(m_0 - u) \sqrt{\sigma}} \frac{u}{K} \]

(21)

\[ 1 - \phi + \phi \left( \frac{\rho}{\rho_f} \right) \left( \frac{\partial v}{\partial t} - \frac{\partial v}{\partial z} - R u \right) = -\frac{1}{(1-\phi) \sqrt{\sigma}} \frac{\partial v}{\partial z} + \frac{1}{(1-\phi) \sqrt{\rho_f}} \right) \theta 

+ \frac{\sigma R^2 n}{1 + M(m_0 - u) \sqrt{\sigma}} \frac{v}{K} \]

(22)

\[ 1 - \phi + \phi \left( \frac{\rho C_p}{\rho_f C_p} \right) \left( \frac{\partial \theta}{\partial t} - \frac{\partial \theta}{\partial z} - S \frac{\partial \theta}{\partial z} = \frac{1}{\text{Pr}} \left( k_f \frac{\partial^2 \theta}{\partial z^2} - Q \right) \theta \right) \]

(23)

The attribute of velocity is \( \text{Ur} \)

\[ \text{Ur} = \left[ \frac{g \beta_f (T_u - T_a)}{U_r} \right] \frac{1}{3} \]

(24)

The borders are

\[ u = v = 0, \quad \phi = 0, \quad \text{for} \quad t \leq 0 \]

\[ u = u_0 + \frac{v}{\sqrt{2}} \left( \exp \left( \text{int} \right) + \exp \left( -\text{int} \right) \right), \quad v = v_0, \quad \phi(0) = -\gamma(1 - \phi(0)) \text{at} \quad z = 0 \]

\[ \text{for} \quad t > 0 \]

\[ u = 0, \quad \phi = 0 \quad \text{as} \quad z \to \infty \]

(25)

Here

\[ \gamma = \frac{h_f v_f}{K_f U_r} \]

(26)

We now combining the equations (21) and (22) by substituting the fluid velocity in the form as \( \text{Ur} = (u + iv) \).

We’re having it

\[ 1 - \phi + \phi \left( \frac{\rho}{\rho_f} \right) \left[ \frac{1}{1-\phi} \frac{\partial (u + iv)}{\partial z} - 2R \right] = -\frac{1}{(1-\phi) \sqrt{\rho_f}} \frac{\partial (u + iv)}{\partial z} + \frac{1}{(1-\phi) \sqrt{\rho_f}} \right) \theta 

+ \frac{\sigma R^2 n}{1 + M(m_0 - u) \sqrt{\sigma}} \frac{\sqrt{u + iv}}{K} \]

(27)

\[ V(0) = 1 + \frac{\rho}{\rho_f} \left( \exp \left( \text{int} \right) + \exp \left( -\text{int} \right) \right), \quad \phi(0) = -\gamma(1 - \phi(0)) \]  

(28)

(29)

In order to locate the logical arrangements for the arrangement of partial differential conditions (23), (26) in

\[ q \left( z, t \right) = q_t + \frac{\rho}{2} \left[ \exp \left( \text{int} \right) q \left( z, t \right) + \exp \left( -\text{int} \right) q \left( z, t \right) \right] \]

\[ \theta(t) = \theta_0 + \frac{\rho}{2} \left[ \exp \left( \text{int} \right) \theta \left( z, t \right) + \exp \left( -\text{int} \right) \theta \left( z, t \right) \right] \]

(30)

For \( \varepsilon \ll 1 \). Recalling the previous equations (29) and (30) in equations (23) and (26) respectively. We obtain the following equations by matching non-harmonic and harmonic terms and neglecting the higher order conditions of \( \varepsilon^2 \). We get the following comparisons:

\[ \frac{1}{(1-\phi)} q \left( t \right) + \text{S} \left[ 1 - \phi + \phi \left( \frac{\rho}{\rho_f} \right) \right] q \left( t \right) + \frac{2R}{(1-\phi)} 1 - \phi + \phi \left( \frac{\rho}{\rho_f} \right) \right] \theta \left( t \right) = 0 \]

(31)

\[ \frac{1}{(1-\phi)} q \left( t \right) + \text{S} \left[ 1 - \phi + \phi \left( \frac{\rho}{\rho_f} \right) \right] q \left( t \right) + \frac{(2R + n)}{1 - \phi} 1 - \phi + \phi \left( \frac{\rho}{\rho_f} \right) \right] \theta \left( t \right) = 0 \]

(32)

\[ \frac{1}{(1-\phi)} q \left( t \right) + \text{S} \left[ 1 - \phi + \phi \left( \frac{\rho}{\rho_f} \right) \right] q \left( t \right) + \frac{(2R - n)}{1 - \phi} 1 - \phi + \phi \left( \frac{\rho}{\rho_f} \right) \right] \theta \left( t \right) = 0 \]

(33)

\[ \frac{k_f}{K_f} \text{Pr} \left[ 1 - \phi + \phi \left( \frac{\rho C_p}{\rho_f C_p} \right) \right] \theta \left( t \right) - Q_H \theta_0 = 0 \]

(34)

\[ \frac{k_f}{K_f} \text{Pr} \left[ 1 - \phi + \phi \left( \frac{\rho C_p}{\rho_f C_p} \right) \right] \theta \left( t \right) - \text{Pr} \left[ 1 - \phi + \phi \left( \frac{\rho C_p}{\rho_f C_p} \right) \right] \theta_0 = 0 \]

(35)

\[ \frac{k_f}{K_f} \text{Pr} \left[ 1 - \phi + \phi \left( \frac{\rho C_p}{\rho_f C_p} \right) \right] \theta \left( t \right) - \text{Pr} \left[ 1 - \phi + \phi \left( \frac{\rho C_p}{\rho_f C_p} \right) \right] \theta_0 = 0 \]

(36)

The boundary conditions are:

\[ q_t = q, \quad q_0 = 1, \quad \theta_t = -\gamma \left( 1 - \theta \right), \quad \theta_0 = \gamma \theta, \quad \theta_t = \gamma \theta \quad \text{at} \quad z = 0 \]

(37)

\[ q_t = 0, \quad q_0 = 0, \quad q_0 = 0, \quad \theta_t = 0, \quad \theta_t = 0, \quad \theta_t = 0 \quad \text{as} \quad z \to \infty \]

(38)

Conditions for solving (25) – (30) under conditions (31), (32) are expressed as temperature and velocity

\[ q = A \exp \left( -m_z \right) + \left( 1 - A \right) \exp \left( +m_z \right) + \frac{\varepsilon}{m_z + \text{int}} \exp \left( -m_z + \text{int} \right) \]

(39)

\[ \theta = \frac{\gamma}{m_z + \text{int}} \exp \left( -m_z \right) \]

(40)
We see the solution (39) and (40) approaching the constant surface temperature solutions as $\gamma \rightarrow \infty$ an alternative. From the boundary conditions this can be seen (28), which gives $\delta(0) = 1$ as $\gamma \rightarrow \infty$. It should also be noted that conditions (39) and (40) reduced to those of Hamad and Pop [7] when $m = 0, K \rightarrow \infty$ and $\gamma \rightarrow \infty$.

The coefficient of skin friction $C_f$ and Nusselt number $N_u$ described as

$$C_f = \frac{T_n}{P_f U_f^2} = \frac{1}{(1-\phi)^{2.5}} V'(0)$$

$$= \frac{1}{(1-\phi)^{2.5}} \left[ \frac{\sum (1+ \frac{m}{2} \exp(\int_{t_0}^{t_1} x(0-t) dt) + m \exp(-\int_{t_0}^{t_1} x(0-t) dt))} \right]$$

$$Nu = \frac{T_w - T_0}{z(0)} = - \frac{k_n}{k_f} Re_s \theta'(0)$$

Where $Re_s = \frac{U_f x}{v_f}$ is the Reynolds number.

Thus

$$\frac{Nu}{Re_s} = - \frac{k_n}{k_f} \theta'(0)$$

IV. RESULTS AND DISCUSSION

The numerical calculations are shown in FIG. Described to illustrate the excellent properties of the nanoparticle flow and heat transfer attributes. Table 2-3 and Table 2-3. We have used the information in Table 1 of the thermophysical properties of the base fluid and nanoparticles (copper and alumina) in the numerical calculations. We found the scope of nanoparticle volume fraction $0 \leq \phi \leq 0.2$ range of nanoparticles. The base fluid (water) Prandtl number $Pr$ is held steady at 6.785. We picked $n = 10, nt = \pi / 2$ and $\varepsilon = 0.001$ while $\phi, R, S, K, M, Q_H$ and $\gamma$ in the present review and are shifted over a distance. Fig.2 represents the impact of the Hartmann number $M$ of the velocity dissemination for Cu – water nanofluid velocity dissemination. It is clear from the calculations that the speed circulation over the boundary layer decreases with an expansion in the Hartmann $M$ number and decreases near the boundary layer. It reduces the thickness of the boundary layer. As a result, the thickness of the hydrodynamic boundary layer decreases as the magnetic field parameter $M$ increases for both normal and nanofluid, and therefore the surrounding speed decreases. The explanation for this miracle is that the use of the magnetic field for an electrically conductive fluid offers to rise to a resistance type force called Lorentz force. This pressure appears to impede the movement of the fluid within the boundary layer. The velocity dissemination on the permeable divider is plotted for Cu – water and Al$_2$O$_3$ in Fig.3 for different estimates of the penetrability parameter $K$. Clearly the expanded estimations of $K$ tend to expanding of the velocity on the permeable divider thus upgrade the momentum boundary layer thickness.

The Fig. 4 speaks to the velocity dissemination with the various estimations of Hall parameter $m$ for Cu–water and Al$_2$O$_3$. Expanded estimations of $m$ tend to expanding of the velocity thus improve the momentum boundary layer thickness. The contrary impact is seen with expanding rotation parameter $R$. Expanding the revolution diminishes the momentum boundary layer thickness (Fig. 5). From Fig. 6 means the velocity profile with the variation from Heat source parameter $Q_H$. The size of the velocity increments with expanding $Q_H$ all through the fluid locale. Figs.7 exhibits the impact of the suction/infusion parameter $S$ on the fluid velocity for both nanofluids. The velocity of the fluid over the boundary layer diminishes by expanding suction parameter $S$ for both nanofluids. Likewise, we find that the velocity is still approaching the corresponding asymptotic motivation for big $x$ estimates to be $S$ builds. It merits referencing here that the impact of $S$ on the velocity is increasingly compelling for nanofluids with nanoparticles Cu and Al$_2$O$_3$. Thus thickness of the layer diminishes as the suction parameter $S$. Image. Fig. 8 illustrates the variety of the velocity dispersion for different estimations of $\phi$. From this, the velocity dissemination over the boundary layer diminishes with the expansion of $\phi$. Fig. 9 talks with the different estimates of the convection parameter $\gamma$ for Cu – water and Al$_2$O$_3$ – water to the velocity appropriation. Expanded estimations of $\gamma$ tend to expanding of the velocity thus upgrade the energy boundary layer thickness.

Fig.10 exhibits the profiles of temperature for different estimations of $Q_H$ for copper and alumina. The temperature in the limit layer district diminishes with the expansion in the warmth generation parameter $Q_H$ and diminishes thickness of Heat layer. These side perspectives fulfill the far field limit conditions asymptotically, which bear the numerical outcomes got.

Figure 11 presents the normal profile for temperature diffusion for various estimates of copper and alumina. The figures showed that the temperature in the liquid field decreases as it spreads around the boundary layer and is more extreme outside the plate for both nanoparticles. Consequently, when scaling $\gamma$, the thickness improvements of the thermal boundary layer. In this way we can decipher that the speed of heat transfer decreases with the increase of the convective parameter. This miracle is gradually seen in view of the volume fraction of the nanofluid molecule $\phi$.

These outcomes are in concurrence with the outcomes got by Hamad and Pop[7]. Fig. 12 shows that the variety of suction parameter $S$ on temperature for both nanofluids. Temperature diminishes with expanding suction parameter $S$. While expanding S then thickness of heat layer decreases all through the liquid region. The impact of nanoparticle volume fraction parameter $\phi$ on the temperature is appeared in Fig.13 for Cu–water and Al$_2$O$_3$ - water. The profile of temperature increments with the expansion in in the fraction of nanoparticles denoted by $\phi$. In this way, an increment is found in temperature and reaches to zero far away from the plate layer.
Table 2 and Table 3 demonstrate separately the differences in skin friction coefficient $C_f$ and Nusselt number $Nu$ with $M$, $K$, $m$, $R$, $\gamma$, $Q_H$, $S$, $\phi$. Table 2 shows changes in the skin friction coefficient $C_f$ and finds that it decreases with expanding parameters $K$, $m$ and $Q_H$ increases in the skin friction coefficient with expanding $M$, $R$, $S$, $\gamma$, $\phi$ for both nanofluids with Cu and $Al_2O_3$ nanoparticles. In fact, the Nusselt number increases in both nanofluids with the change in all parameters $\gamma$, $Q_H$, $S$, $\phi$.

With nanofluids, the variation of the Nusselt number is substantially greater. It should be noted that due to high thermal conductivity compared with $Al_2O_3$, the highest heat transfer value is obtained for $Cu$. These results are great understanding who are accounted for by Hamad and Pop 7] (Table 4).
Hall Effects on Unsteady Magneto Hydrodynamic Convection Flow of Nanofluids Past a Rotating Porous Plate

Fig. 8 The velocity frequency with $\phi$
$M = 0.5, K = 0.5, m = 1, R = 0.5, \gamma = 2, Q_H = 1, S = 1$

Fig. 9 The velocity frequency with $\gamma$
$M = 0.5, K = 0.5, m = 1, R = 0.5, \phi = 0.05, Q_h = 1, S = 1$

Fig. 10 The temperature frequency with $Q_H$
$\gamma = 2, S = 1, \phi = 0.05$

Fig. 11 The temperature frequency with $\gamma$
$Q_H = 1, S = 1, \phi = 0.05$

Fig. 12 The temperature frequency with $S$
$\gamma = 2, Q_H = 1, \phi = 0.05$

Fig. 13 The temperature frequency with $\phi$
$\gamma = 2, Q_H = 1, S = 1$

Table 1: Standard fluid and nanoparticles have thermo-physical properties

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<th>Thermo Physical properties</th>
<th>Regular fluid</th>
<th>Cu</th>
<th>Al2O3</th>
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<td>$C_p (J/kg K)$</td>
<td>4179</td>
<td>385</td>
<td>765</td>
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<td>$\rho (g/L)$</td>
<td>997.1</td>
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<td>$k (W/m K)$</td>
<td>0.613</td>
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<td>$\alpha \times 10^6 (m^2/s)$</td>
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<td>$\beta \times 10^{-6} (1/K)$</td>
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Table 2 Skin friction coefficient

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<th>$K$</th>
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<th>$\gamma$</th>
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Table 3 Local Nusselt number

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Table 4 Local Nusselt number ($Nu / Re_x$)

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V. CONCLUSIONS

In this paper, we consider the impact of the Cu and Al$_2$O$_3$ metal nanoparticles on an unstable free MHD convection flow and the hot transfer of the fluid guiding incompressible along a semi-endangered, vertical, penetrable platform that is inserted into the rotating frame of the uniform permeable medium. The ends rising out of this examination are as per the following:

1. The fluid velocity diminishes with the expansion in Hartmann number, nanoparticle volume tiny proportion, suction and rotation parameter yet impact is invert for Hall and penetrability parameters.

2. An increment in the convective and volume proportion lead to expand the thickness of Heat layer yet inverse impact happens for heat source parameter.

3. The values of $\gamma, Q_H, S, \phi$ is increase and to increase the wall temperature gradient for both Copper and Alumina throughout the fluid region.

4. The skin contact coefficient increments with the expansion in the nanoparticle volume part, suction, Hartmann number, rotation parameter and lessens with Hall effects.

REFERENCES


AUTHORS PROFILE

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