Scrutiny of heat and mass transport in oscillatory hydromagnetic nanofluid flow within two verticals alternatively conducting surfaces

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1. INTRODUCTION & OBJECTIVE

The hydromagnetic flow through a porous medium is a subject of active research in the recent years due to its exhaustive applications in geothermal power extraction from the earth's interior, water circulation by ion-exchange beds, chemical reactor for economic isolation or mixture purification, the penetration of drugs into human skin etc. The basis for the characterization of the flow in a porous regime is its permeability and porosity. The permeability exerts the stabilizing force to the flow in porous medium. Brinkman [1] presented a model to characterize fluid flow through a dense cluster of particles, which is one of the popular models proposed to examine the manner of flow in a porous medium. Many scientists [2-7] explored the manner of hydromagnetic flows in porous medium by implementing the Darcy-Brinkman model. Nanofluid plays a vital role in development of nanoscience and nanotechnology. The thermal behavior of nanofluid makes it technologically more efficient in comparison to any other fluids. The dependency of thermal conductivity of the nanofluid to the shape and size of nanoparticles and number of nanoparticles are experimentally proven by Choi and Eastman [8]) and Chon and Kihm [9]. This specific thermal nature motivated the research world to examine the flow nature of nanofluid and to discover its applications in engineering and technology. Khan and Alqahtani [10] modeled the hydrodynamic convective nanofluid flow in a channel with permeable wall and expressed that suction causes the higher fluid velocity intensity compare to the injection. Dutta et al. [11] considered the hydromagnetic free convection flow of Cu-water nanofluids in a rhombic enclosure and scrutinized the heat transport and entropy generation. They explored that the nature of Hartmann number is to weaken the rate of entropy generation. In the recent years, the mathematical model for hydromagnetic nanofluid flows within different geometrical setup are developed and explored by many researchers, namely, Mourad et al. [12], Askari et al. [13], Abd-Alla et al. [14], EL-Zahar [15] and Govindarajulu and Subramanyam Reddy [16]. It is ascertained from the meticulous literature review that not much literature considered the impacts of motional generated magnetic field and Hall current simultaneously on oscillatory hydromagnetic nanofluid flows. Therefore, the key attention is to explore the motional indication and Hall current effect to oscillatory hydromagnetic Titanium alloy suspended water nanofluid flow within two vertical alternatively non-conducting and conducting walls enclosing Darcy-Brinkman porous medium and its heat and mass transport nature. An analytical approach called separation of variables are used for extraction the solution from the flow model. It is important to note from the study that the volume concentration of nanofluid and magnetic diffusion produce resistivity in the flow and tends to slower down the fluid flow. The magnetic diffusion weakens the strength of the primarily motional induced magnetic field.

2. THE EQUATIONS GOVERNING THE MOTION

The equations governing the motion of the fluid under consideration are as follows

$$\rho_{nf}\frac{\partial v_1}{\partial \tau}=-\frac{\partial p}{\partial y_1}+\mu_{nf}\left(\frac{\partial^2 v_1}{\partial y_3^2}-\frac{v_1}{k_p}\right)+\frac{h_0}{\mu_e}\frac{\partial h_1}{\partial y_3}+2\rho_{nf}\Omega v_2+\rho_{nf}g\left[\beta_{nf}(\theta-\theta_l)+\beta_{nf}^*(\phi-\phi_l)\right], \quad (1)$$

$$\rho_{nf}\frac{\partial v_2}{\partial \tau}=\mu_{nf}\left(\frac{\partial^2 v_2}{\partial y_3^2}-\frac{v_2}{k_p}\right)+\frac{h_0}{\mu_e}\frac{\partial h_2}{\partial y_3}-2\rho_{nf}\Omega v_1, \quad (2)$$

$$\frac{\partial h_1}{\partial \tau}=h_0\frac{\partial v_1}{\partial y_3}+\frac{1}{\sigma_{nf}\mu_e}\left(\frac{\partial^2 h_1}{\partial y_3^2}+Hc\frac{\partial^2 h_2}{\partial y_3^2}\right), \quad (3)$$

$$\frac{\partial h_2}{\partial \tau}=h_0\frac{\partial v_2}{\partial y_3}+\frac{1}{\sigma_{nf}\mu_e}\left(\frac{\partial^2 h_2}{\partial y_3^2}-Hc\frac{\partial^2 h_1}{\partial y_3^2}\right), \quad (4)$$

$$\left(\rho C_p\right)_{nf}\frac{\partial \theta}{\partial \tau}=k_{nf}\frac{\partial^2 \theta}{\partial y_3^2}-R(\theta-\theta_l), \quad (5)$$

$$\frac{\partial \phi}{\partial \tau}=D_{nf}\frac{\partial^2 \phi}{\partial y_3^2}-Cr(\phi-\phi_l). \quad (6)$$

The boundary conditions (BCs) designated at the contact walls of the symmetric channel are

$$\left.\begin{array}{ll} v_1=v_2=0,\ \ h_1=h_2=0,\ \ \theta=\theta_l,\ \ \phi=\phi_l & \text{at } y_3=-y_0/2; \\ v_1=v_0(1+\varepsilon\cos(n\tau)),\ \ v_2=0,\ \ \dfrac{\partial h_1}{\partial y_3}=\dfrac{\partial h_2}{\partial y_3}=0, & \\ \theta=\theta_r+(\theta_r-\theta_l)\cos(n\tau),\ \phi=\phi_r+(\phi_r-\phi_l)\cos(n\tau) & \text{at } y_3=y_0/2. \end{array}\right\} \quad (7)$$

3. RESULTS & HIGHLIGHTS OF IMPOINTANT POINTS

The results derived from this research investigation is supportive in studying the heat and mass transport nature of nanofluids and consequences of motional induction, Hall current, revolving of the flow system and oscillations on these. The explored results may find significant chemical and thermal engineering applications. The noteworthy features of the flow are highlighted below:

- The volume concentration of nanofluid produce resistivity in the flow and tends to slower down the fluid flow. It enhances the motional generated magnetic field in the principal direction of the fluid flow and lowers the fluid temperature and concentration.
- Hall current stabilizes the main flow as its direction is normal to main flow and implemented magnetic field. It significantly grows the secondary motional generated magnetic field while it brings drop in the principal motional generated magnetic field.
- Magnetic diffusion brings rigidness in the flow and lessens the flow velocity. It weakens the strength of the primarily motional induced magnetic field.
- Revolving flow system tends to improve the flow velocity by inducing a gyratory force along secondary flow. Further it improves the secondarily motional generated magnetic.

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