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Unsteady Electro-osmotic analysis of Multiphase immiscible nanofluids (Casson-Jeffrey) under the magnetic field in an asymmetric channel

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1. OBJECTIVE

To investigate the convective multiphase time-dependent flow of Casson-Jeffrey and Newtonian nanofluids in an asymmetric channel under the effect of electroosmotic force along with the magnetic field. The surface of the conduit is assumed to be insulated and homogenous in nature. The mathematical model has been formulated using the governing system of continuity, momentum and temperature equations. The present model was analysed analytically using periodic function to obtain the velocity profiles, temperature distribution and entropy generation. Furthermore, a parametric study was performed to analyse the traits of different nanoparticle volume fractions and their transport characteristics over the (engine, oil, and ethylene glycol) base fluids with (gold, silver, copper, palladium, titanium oxide and Iron) nanoparticles examined and the results are demonstrated in graphical aspects.

2. INTRODUCTION

For the past three decades, diverse traits of fluids have been analysed in the form of nanofluids. The significant performance of nanofluids was very efficient compared to the normal fluids in the form of heat carriers in the thermal engineering fields to utilized in applications such as power plants, cooling systems, thermal management in the building, vehicle air-conditioning systems in transportation, heat pipes in-space propulsions, solar collector systems and geo-thermic systems. To enhance the thermal conductivity, Choi[1] introduced the nanofluid for the substitution of conventional fluids by incorporating the nano-sized particles which are probably metallic in nature into the base fluid like oil, water and other fluids. Apart from single-phase fluid, multiphase fluids have a wide range of applications in the form of immiscible behaviour on the combination of non-Newtonian fluid and Newtonian fluid[2,3]. Moreover, the additional body force effect such as external electric and magnetic field will make the motion of the fluid amicable along with the presence of nanoparticles[5].

3. PROBLEM FORMULATION

The electroosmotic effect of time-dependent multiphase immiscible nanofluid flowing through the asymmetric channel under the magnetic field has been studied. The fluid was characterized as laminar, incompressible and viscous in motion. The nature of the immiscibility can be studied by the fluid present in the lower region being taken as non-Newtonian (Casson-Jeffrey) fluid which is electrically non-conducting whereas, the fluid present in the upper region is taken as electrically conducting Newtonian fluid. The electric and magnetic fields were applied externally to the channel. The governing equation of the above model can be transformed into a dimensionless form by using suitable non-dimensional quantities.

To obtain the analytical solution of the governed equation, the boundary conditions can be chosen as physically acceptable and mathematically constructible.

The momentum equations:

$$\rho_1^*\left(\frac{\partial w_1^*}{\partial t^*}\right) = -\frac{\partial p^*}{\partial z^*} + \mu_1^*\left[\frac{1}{1+\lambda} + \frac{1}{\beta}\right]\frac{\partial^2 w_1^*}{\partial y^{2^*}} - \sigma B_0^{2^*} w_1^* + (\rho\alpha_T)^* g^* (T_1^* - T_w^*);\ -h_1 \le y \le 0.$$

$$\rho_2^*\left(\frac{\partial w_2^*}{\partial t^*}\right) = -\frac{\partial p^*}{\partial z^*} + \mu_2^*\frac{\partial^2 w_c^*}{\partial y^{2^*}} - \sigma B_0^{2^*} w_2^* + \rho_e^* E_z^* + (\rho\alpha_T)^* g^* (T_2^* - T_w^*); 0 \le y \le h_{2.}$$

The temperature profiles:

$$(\rho C_P)_1^*\left(\frac{\partial T_1^*}{\partial t^*}\right) = K_1^*\left(\frac{\partial^2 T_1^*}{\partial y^{2^*}}\right) - \frac{\partial q_1^*}{\partial y^*};\ -h_1 \le y \le 0.$$

$$(\rho C_P)_2^*\left(\frac{\partial T_2^*}{\partial t^*}\right) = K_2^*\left(\frac{\partial^2 T_2^*}{\partial y^{2^*}}\right) - \frac{\partial q_2^*}{\partial y^*};\ 0 \le y \le h_{2.}$$

The boundary conditions are taken as follows

i) At the upper and lower walls of an asymmetric channel, the velocity and the temperature of corresponding fluids possess a no-slip condition.

ii) At the interfacial region, the velocity, the temperature and the shear stress of Newtonian and non-Newtonian fluids are equal.

4. METHOD OF SOLUTION

From the dimensionless governed equations, the solution for the velocity distribution, temperature profiles, Nusselt number, skin friction coefficient and entropy analysis can be expressed analytically. The presence of different types of nanoparticles in the different base fluids was examined and the validation of each type of nanoparticles were displayed graphically.

5. CONCLUSIONS

The investigation was carried out on the influence of nanofluids on combined non-newtonian (electrically non-conducting) and Newtonian (conducting) fluids in an asymmetric channel under the effect of electroosmotic technique along with magnetic field in the form of velocity profiles, temperature distribution, heat flux, skin friction coefficient and entropy generation. The outcomes of the present study are summarized as follows:

- The influence of the electric field, Magnetic field, Grashof number, Prandtl number, nano-volume fraction and nano-particle sizes was observed and found that the velocities increased for the electric field, nano-volume fraction and nano-particle sizes increased whereas increasing the magnetic field tended to reduce the velocity of fluids.
- In temperature distribution, we noticed the temperature decreased for the larger size and shapes of the nanoparticles.
- The effect of an external electric field possesses a dual nature in the interfacial region and the wall region
- Jeffery-Newtonian, Casson-Newtonian and Newtonian-Newtonian models can be deduced from the present work.
- The effectiveness of palladium nanofluids was much more efficient than the rest of the nanoparticles which was studied in this research.

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