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Analytical Study on Magnetohydrodynamic Nanofluid Flow Influenced by Electrical Conductivity in a Baffled Vertical Channel

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The theoretical analysis of the steady fully developed electrically conducting flow of water based nanofluid in a vertical double passage channel is studied. The governing equations are respectively solved analytically and semi-analytically for each flow using perturbation method and the differential transformation method (DTM). The effects of flow governing parameters on the flow and velocity fields are numerically evaluated and presented in the graphical form. The outcome obtained by semi analytical method is confirmed by comparing with the aid of perturbation method and good agreement is found.

KEYWORDS: Nano Fluid, Regular Perturbation Method, Differential Transforms Method.

1. INTRODUCTION

Nanotechnology[1] has been used extensively in a variety of industrial applications. Its objective is to manipulate the structure of matter in flow. The goal is to analyze heat transfer characteristics and its applications in nearly all industries and utilities, including life sciences, physical sciences, and electronic refrigeration, transportation, and homeland security. The low thermal conductivity of the process fluid hinders the high compactness and efficiency of the heat exchanger, despite the application of various techniques to improve heat transfer. The technique of suspending nanosized solid particles in fluid is a way to improve the thermal conductivity of the fluid. Different types of powders (example: metallic, non-metallic, and polymer particles) are added to the fluid to form a suspension. Nanofluids exhibit exceptionally high thermal conductivity. Compared with the base fluid, the properties such as viscosity and specific heat have changed significantly. These properties fascinated many authors to work in applications of engineering. The frequent applications of nanofluids have been manipulated by many researchers and found in their literature.[2–11] The flow of conductive fluids has important applications in many branches of engineering science, such as electromagnetic propulsion, MHD generators, plasma research, geothermal energy extraction, nuclear reactors, boundary layer control in the field of aerodynamics etc.

It is observed that an enhancement of heat transfer in mixed convective flow by inserting baffle in an open ended vertical channel and found its applications in heat exchangers.[12,13] When the channel is divided into several channels by a flat baffle, as is often the case in heat exchangers, by adjusting each position and position of the baffle, it is very possible to improve the rate of heat transfer between the wall and the fluid. The force that separates the flow. In this configuration, a thin, fully conductive baffle can be used to avoid a notable increase in lateral thermal resistance. Comparing with the perturbation method, the mixed convection solution obtained by DTM is reasonable and a good agreement is found.[14] Umavathi et al. investigated the first order chemical reaction in double passage channel which is vertical by applying the electric field. Researcher studied that how the heat and mass transfer will be affected in a vertical channel by introducing a conducting baffle which is thin, and the baffle consist of a fluid which is electrically conductive and chemically reactive. By using the differential transform method and perturbation method governing equations are solved. Researcher concluded that increase in

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brinkman number, mass grashof number & Grashof number enhances the flow in all streams at all positions.[15–17]

Ameer Ahamad et al.[18] analyzed that unsteady laminar MHD flow of a second-grade fluid on a porous plate which is vertical. Parameters analyzed are Nusselt number, shear stress & Sherwood number. From the analysis the researcher concluded that, due to influence of fluid oscillation & chemical reaction the concentration distribution is reduced in the complete liquid region, Shear stress decreased due to rotation effect, but it is increased in the permeability of porous medium through the impact of second grade fluid parameter. Mixed convective magneto hydrodynamic water based nanofluid is studied in different geometries. The different geometries are vertical channel, stretching sheet, inclined duct, cylinder, inclined cylinder & wavy channel etc., are considered for analysis, and observed that enhancement in heat transfer.[19–24]

The literature reports the effects of baffle on heat transfer of MHD nanofluids flow in a vertical channel. Due to its wide range of applications, much research has been done on the understanding of variations in flow pattern of heat transfer of water based nanofluid in presence of magnetic field.

2. MATHEMATICAL FORMULATION

Consider laminar, fully developed, and steady flow of mixed convection in vertical open ended parallel plates. The thin conducting baffle divided channel into two passages. The axis X is parallel to the flat wall and has taken upwards opposite to the force of gravitational. The axis Y has drawn perpendicular to the axis X and y^* is position of baffle. The temperature and velocity gradient for fully developed flow in the axial direction are zero. The equation of state and Boussinesq approximation are also be adopted. Considered water based nanofluid containing nanoparticles of three types, namely, Silver, Copper and Titanium Oxide see Table 1 for thermophysical properties. The base fluid and suspended nanoparticles are in thermal equilibrium is considered. Considered all fluid properties are constant except density in buoyancy forces.

According to the above assumptions, the physical model shown in Figure 1.

The momentum balance and energy equations along X and Y under these assumptions yield

Table I. Water and nanoparticles thermo physical properties.

Physical properties	Water (base fluid)	Titanium oxide	Cu (copper)	Silver
ρ	997.1	4250	8933	10500
k	0.613	8.9538	400	429
β	207	0.17	17	18
σ	$5*10^{-6}$	$2.38*10^{6}$	$5.96*10^{7}$	$6.3*10^{7}$

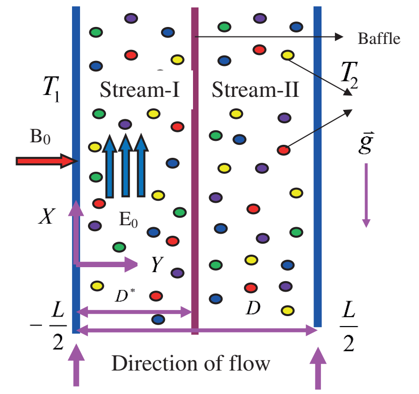

Fig. 1. Physical configuration.

Stream-I

$$g\,(\rho\beta)_{nf}(T_1 - T_0) - \frac{\partial P}{\partial X} + \mu_{nf}\frac{d^2U_1}{dY^2} - \sigma_{nf}B_0{}^2U - \sigma_{nf}E_0B_0 = 0 \tag{1}$$

$$\frac{\partial^2 T_1}{\partial Y^2} = -\frac{\mu_{nf}}{(\rho\beta)_{nf}g}\frac{d^4U_1}{dY^4} + \frac{\sigma_{nf}B_0{}^2}{(\rho\beta)_{nf}g}\frac{d^2U_1}{dY^2} \tag{2}$$

Stream-II

$$g\,(\rho\beta)_{nf}(T_1 - T_0) - \frac{\partial P}{\partial X} + \mu_{nf}\frac{d^2U_1}{dY^2} - \sigma_{nf}B_0{}^2U - \sigma_{nf}E_0B_0 = 0 \tag{3}$$

$$\frac{\partial^2 T_2}{\partial Y^2} = -\frac{\mu_{nf}}{(\rho\beta)_{nf}g}\frac{d^4U_2}{dY^4} + \frac{\sigma_{nf}B_0{}^2}{(\rho\beta)_{nf}g}\frac{d^2U_2}{dY^2} \tag{4}$$

where μ_{nf}, ρ_{nf}, β_{nf} and k_{nf} are given by

$$\mu_{nf} = \frac{\mu_f}{(1-\phi)^{2.5}} \text{ and } (\rho\beta)_{nf} = \rho_{nf}\beta_{nf} = (1-\phi) \times(\rho\beta)_f + (\rho\beta)_s\phi, \text{ and } k_{nf} = k_f\left[\frac{k_s + 2k_f - 2\phi(k_f - k_s)}{k_s + 2k_f + \phi(k_f - k_s)}\right]$$

and $\rho_{nf} = (1-\phi)\rho_f + \rho_s\phi$.

Subject to the boundary and interface conditions on velocity, temperatures are

$$U_1 = 0,\ T_1 = T_0,\ \text{at } Y = -h$$

$$U_2 = 0,\ T_2 = T_0,\ \text{at } Y = h,\ U_1 = U_2 = 0$$

$$T_1 = T_2,\ \frac{dT_1}{dY} = \frac{dT_2}{dY},\ \text{at } Y = y^* \tag{5}$$

Plug the following dimensionless variables into the equations governing the velocity and temperature fields,

$$u=\frac{U}{U_0},\quad y=\frac{Y}{D},\quad Gr=\frac{g\beta_f\Delta TD^3}{\upsilon_f^2},\quad \mathrm{Re}=\frac{U_0D}{\upsilon},$$
$$Br=\frac{U_0^2\mu_f}{k\Delta T},\quad \Lambda=\frac{Gr}{\mathrm{Re}},\quad \theta=\frac{T-T_0}{\Delta T},\ Bi_1=\frac{h_1D}{k},$$
$$Bi_2=\frac{h_2D}{k},\quad S=\frac{Bi_1Bi_2}{Bi_1Bi_2+2Bi_1+2Bi_2},$$
$$M^2=\frac{\sigma_e{B_0}^2D^2}{\mu_f}, Pr=\frac{\gamma}{\alpha},\quad E=\frac{E_0}{U_0B_0} \tag{6}$$

Considered the channel walls of are isothermal. Assumed T_1 is the temperature at $Y=-h_1/2$, while T_2 is the temperature of the boundary at $Y=h_2/2$ with $T_2>T_1$. Pressure gradient is independent on X if and only if these boundary conditions are congenial with Eqs. (1) and (3). Therefore, there exists a constant A such that

$$\frac{dP}{dX}=A \tag{7}$$

The reference temperature and Velocity are given by

$$U_0=-\frac{AD^2}{48\mu_f}\quad T_0=\frac{T_1+T_2}{2}+S\left(\frac{1}{Bi_1}-\frac{1}{Bi_2}\right)(T_2-T_1) \tag{8}$$

The obtained momentum balance, energy equations of Stream-I & stream-II as

Stream-I

$$\frac{d^4U_1}{dY^4}=\frac{\sigma_{nf}{B_0}^2}{\mu_{nf}}\frac{d^2U_1}{dY^2}+\frac{(\rho\beta)_{nf}g}{k_{nf}}\left(\frac{dU_1}{dY}\right)^2+\frac{(\rho\beta)_{nf}g\sigma_{nf}}{\mu_{nf}k_{nf}}(B_0U_1+E_0)^2 \tag{9}$$

Stream-II

$$\frac{d^4U_2}{dY^4}=\frac{\sigma_{nf}{B_0}^2}{\mu_{nf}}\frac{d^2U_2}{dY^2}+\frac{(\rho\beta)_{nf}g}{k_{nf}}\left(\frac{dU_2}{dY}\right)^2+\frac{(\rho\beta)_{nf}g\sigma_{nf}}{\mu_{nf}k_{nf}}(B_0U_2+E_0)^2 \tag{10}$$

Subject to the boundary and interface conditions,

$$u_1=0\quad\text{at}\quad y=-\frac{1}{4},\quad u_2=0\quad\text{at}\quad y=\frac{1}{4}$$
$$u_1=0,\quad u_2=0\quad\text{at}\quad y=y^*$$
$$-\frac{1}{Bi_1}\frac{d^3u_1}{dy^3}-\frac{1}{E_3}\frac{d^2u_1}{dy^2}-\frac{M^2}{Bi_1}\frac{E_5}{E_1}\frac{du_1}{dy}-\frac{M^2E_5}{E_1E_3}u_1=Bc_3\quad\text{at}\quad y=\frac{1}{4}$$
$$\frac{1}{Bi_2}\frac{d^3u_2}{dy^3}+\frac{1}{E_3}\frac{d^2u_2}{dy^2}-\frac{M^2}{Bi_2}\frac{E_5}{E_1}\frac{du_2}{dy}-\frac{M^2E_5}{E_1E_3}u_2=Bc_4\quad\text{at}\quad y=-\frac{1}{4}$$
$$\frac{d^2u_1}{dy^2}=\frac{d^2u_2}{dy^2},\quad\text{at}\quad y=y^*$$
$$\frac{d^3u_1}{dy^3}-M^2\frac{E_5}{E_1}\frac{du_1}{dy}=\frac{d^3u_2}{dy^3}-M^2\frac{E_5}{E_1}\frac{du_2}{dy}\quad\text{at}\quad y=y^* \tag{11}$$

2.1. Solutions

By using the regular perturbation method, the approximate solutions can be found from coupled nonlinear differential Eqs. (9) and (10). Perturbation method can be strongly justified with the perturbation parameter ε ($\varepsilon=\Lambda Br$) is small. Solutions for velocity and temperature by adopting this technique are envisioned in the form

$$u_i(y)=u_{i0}(y)+\varepsilon u_{i1}(y)+\varepsilon^2u_{i2}(y)+\cdots \tag{12}$$

Substituting Eq. (12) into Eqs. (9), (10) and (11) and we obtain the first and zeroth order equations by equating like power of ε to 0 and 1.

Stream-I

Zeroth order equations

$$\frac{d^4u_{10}}{dy^4}=p^2\frac{d^2u_{10}}{dy^2} \tag{13}$$

First order equations

$$\frac{d^4u_{11}}{dy^4}=p^2\frac{d^2u_{11}}{dy^2}+k_1\left(\frac{du_{10}}{dy}\right)^2+p^2k_1{u_{10}}^2+p^2k_1E^2+p^2k_12Eu_{10} \tag{14}$$

Stream-II

Zeroth order equations

$$\frac{d^4u_{20}}{dy^4}=p^2\frac{d^2u_{20}}{dy^2} \tag{15}$$

First order equations

$$\frac{d^4u_{21}}{dy^4}=p^2\frac{d^2u_{21}}{dy^2}+k_1\left(\frac{du_{20}}{dy}\right)^2+p^2k_1{u_{20}}^2+p^2k_1E^2+p^2k_12Eu_{20} \tag{16}$$

Both stream-I and stream-II corresponding boundary and interface conditions are

Zeroth order

$$u_{10}=0\quad\text{at}\quad y=-\frac{1}{4},\quad u_{20}=0\quad\text{at}\quad y=\frac{1}{4},$$
$$-\frac{1}{Bi_1}\frac{d^3u_{10}}{dy^3}+\frac{1}{E_3}\frac{d^2u_{10}}{dy^2}+\frac{p^2}{Bi_1}\frac{du_{10}}{dy}=Bc_3\quad\text{at}\quad y=-\frac{1}{4}$$

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$$\frac{1}{Bi_2}\frac{d^3u_{20}}{dy^3}+\frac{1}{E_3}\frac{d^2u_{20}}{dy^2}-\frac{p^2}{Bi_2}\frac{du_{20}}{dy}=Bc_4 \quad \text{at} \quad y=\frac{1}{4}$$

$$u_{10}=0, \quad u_{20}=0 \quad \text{at} \quad y=y^*$$

$$\frac{d^2u_{10}}{dy^2}=\frac{d^2u_{20}}{dy^2} \quad \text{at} \quad y=y^*,$$

$$\frac{d^3u_{10}}{dy^3}-p^2\frac{du_{10}}{dy}=\frac{d^3u_{20}}{dy^3}-p^2\frac{du_{20}}{dy} \quad \text{at} \quad y=y^* \tag{17}$$

First order

$$u_{11}=0 \quad \text{at} \quad y=-\frac{1}{4}, \quad u_{21}=0 \quad \text{at} \quad y=\frac{1}{4},$$

$$-\frac{d^3u_{11}}{dy^3}\frac{1}{Bi_1}+\frac{1}{E_3}\frac{d^2u_{11}}{dy^2}+\frac{p^2}{Bi_1}\frac{du_{11}}{dy}=0$$

$$\frac{1}{Bi_2}\frac{d^3u_{21}}{dy^3}+\frac{1}{E_3}\frac{d^2u_{21}}{dy^2}-\frac{p^2}{Bi_2}\frac{du_{21}}{dy}=0$$

$$\frac{d^2u_{11}}{dy^2}-\frac{1}{Bi_1}\frac{d^3u_{11}}{dy^3}+\frac{M^2}{Bi_1}\frac{du_{11}}{dy}-M^2u_{11}=0 \quad \text{at} \quad y=-\frac{1}{4}$$

$$\frac{d^2u_{21}}{dy^2}+\frac{1}{Bi_2}\frac{d^3u_{21}}{dy^3}-\frac{M^2}{Bi_2}\frac{du_{21}}{dy}-M^2u_{21}=0 \quad \text{at} \quad y=\frac{1}{4}$$

$$u_{11}=0, \quad u_{21}=0 \quad \text{at} \quad y=y^*$$

$$\frac{d^2u_{11}}{dy^2}=\frac{d^2u_{21}}{dy^2} \quad \text{at} \quad y=y^*,$$

$$\frac{d^3u_{11}}{dy^3}-M^2\frac{du_{11}}{dy}=\frac{d^3u_{21}}{dy^3}-M^2\frac{du_{21}}{dy} \quad \text{at} \quad y=y^* \tag{18}$$

Zeroth and first order solutions of Eqs. (13)–(16) using the boundary and interface condition (17) and (18) are given as

Zeroth order solutions

Stream-I

$$u_{10}=H_1+H_2\,y+H_3\,Cosh[B_1y]+H_4\,Sinh[B_1y] \tag{19}$$

Stream-II

$$u_{20}=H_5+H_6\,y+H_7\,Cosh[B_1y]+H_8\,Sinh[B_1y] \tag{20}$$

First order solutions

Stream-I

$$\begin{aligned}u_{11}&=c_1+c_2y+c_3Cosh[m_1y]+c_4Sinh[m_1y]\\&+p_{10}Cosh[2m_1y]+p_{11}Sinh[2m_1y]+p_{12}y^2Cosh[m_1y]\\&+p_{13}y^2Sinh[m_1y]+p_{14}yCosh[m_1y]+p_{15}ySinh[m_1y]\\&+p_{16}y^4+p_{17}y^3+k_{18}y^2\end{aligned} \tag{21}$$

Stream-II

$$\begin{aligned}u_{21}&=c_5+c_6y+c_7Cosh[m_1y]+c_8Sinh[m_1y]\\&+R_{10}Cosh[2m_1y]+R_{11}Sinh[2m_1y]+R_{12}y^2Cosh[m_1y]\\&+R_{13}y^2Sinh[m_1y]+R_{14}yCosh[m_1y]+R_{15}ySinh[m_1y]\\&+R_{16}y^4+R_{17}y^3+R_{18}y^2\end{aligned} \tag{22}$$

Using non dimensional parameters (6), Eqs. (1) and (3) can be written as

Stream-I

$$\theta_1=-\frac{1}{\Lambda E_2}\left(48-M^2E_5[E+u_1]+\frac{1}{E_1}\frac{d^2u_1}{dy^2}\right) \tag{23}$$

Stream-II

$$\theta_2=-\frac{1}{\Lambda E_2}\left(48-M^2E_5[E+u_2]+\frac{1}{E_1}\frac{d^2u_2}{dy^2}\right) \tag{24}$$

3. DIFFERENTIAL TRANSFORM METHOD (DTM)

Differential Transform Method has applied to Eqs. (1) and (3).

$$\begin{aligned}&(n_1+1)(n_1+2)(n_1+3)(n_1+4)u_1[n_1+4]=\frac{M^2E_5}{E_1}\\&\times(n_1+1)(n_1+2)u_1[n_1+2]+\varepsilon\frac{E_2}{E_3}\left(\sum_{n_2=0}^{n_1}(n_2+1)u_1\right.\\&\left.\times[n_2+1](n_1-n_2+1)u_1[n_1-n_2+1]\right)+p_1\varepsilon M^2\\&\times\left(\sum_{n_2=0}^{n_1}u_1[n_2]u_1[n_1-n_2]\right)+p_1\varepsilon M^2E^2\delta[n_1]\\&+2p_1\varepsilon M^2Eu_1[n_1]\end{aligned} \tag{25}$$

$$\begin{aligned}&(n+1)(n+2)(n+3)(n+4)\,u_2[n+4]=\frac{M^2E_5}{E_1}\\&\times(n+1)(n+2)u_2[n+2]+\varepsilon\frac{E_2}{E_3}\left(\sum_{m=0}^{n}(m+1)\,u_2[m+1]\right.\\&\left.\times(n-m+1)\,u_2[n-m+1]\right)+p_1\,\varepsilon\,M^2\\&\times\left(\sum_{m=0}^{n}u_2[m]\,u_2[n-m]\right)+p_1\,\varepsilon\,M^2E^2\,\delta[n]\\&+2p_1\,\varepsilon\,M^2E\,u_2[n]\end{aligned} \tag{26}$$

The initial conditions are as follows

$$\begin{aligned}&u_1[0]=a1, \quad u_1[1]=a2, \quad u_1[2]=a3, \quad u_1[3]=a4,\\&u_2[0]=b1, \quad u_2[1]=b2, \quad u_2[2]=b3, \quad u_3[3]=b4\end{aligned} \tag{27}$$

The constants assigned in Eq. (27) can be calculated using transformed equations with boundary conditions and interface conditions. By substituting the values obtained from the constants, the system of equations is solved.

4. RESULTS AND DISCUSSION

In this paper, the effect water-based nanoparticles on electrically conducting mixed convective flow of fluid in open ended baffled vertical plates are studied. Using Robin boundary conditions, the problem solved by applying differential transform method and regular perturbation method. The flow is analyzed for fixed values of governing parameters, $\Lambda = 500$, $Bi_1 = 10$, $Bi_2 = 10$, $E = -1$, $M = 4$, $\varepsilon = 0.1$, $\phi = 0.02$ for water based copper nanoparticle except the varying parameter for all the Figures from 2 to 7.

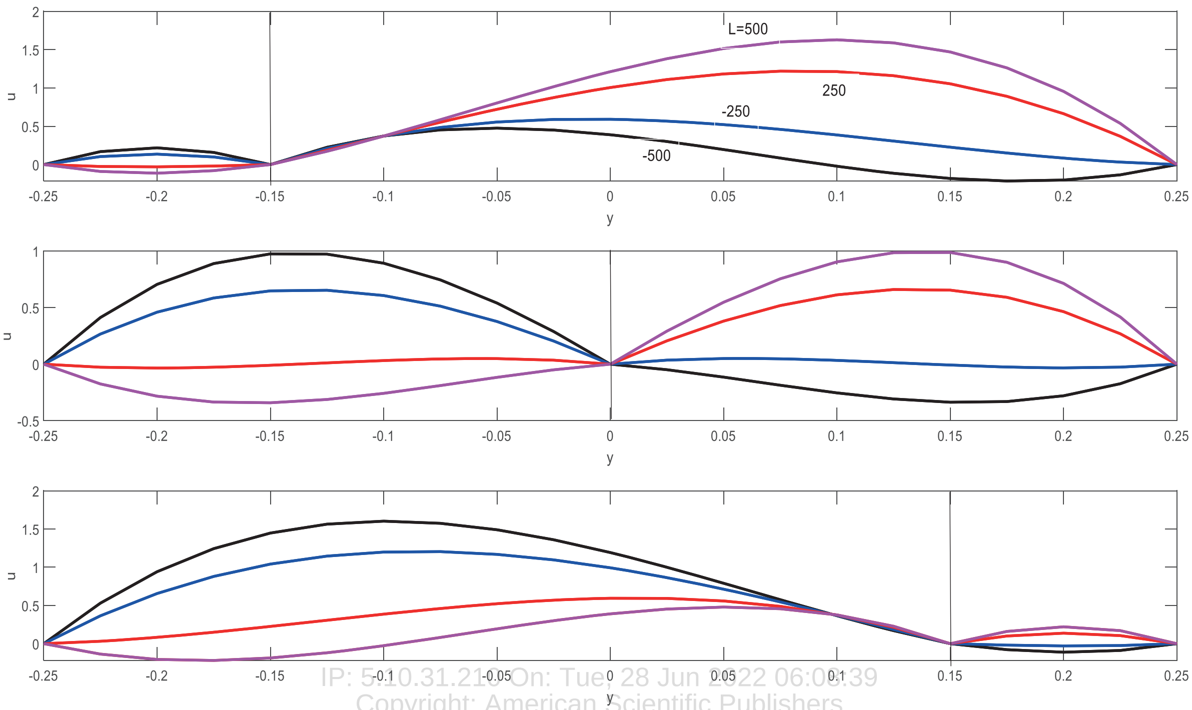

Fig. 2. Velocity field for different values of Λ.

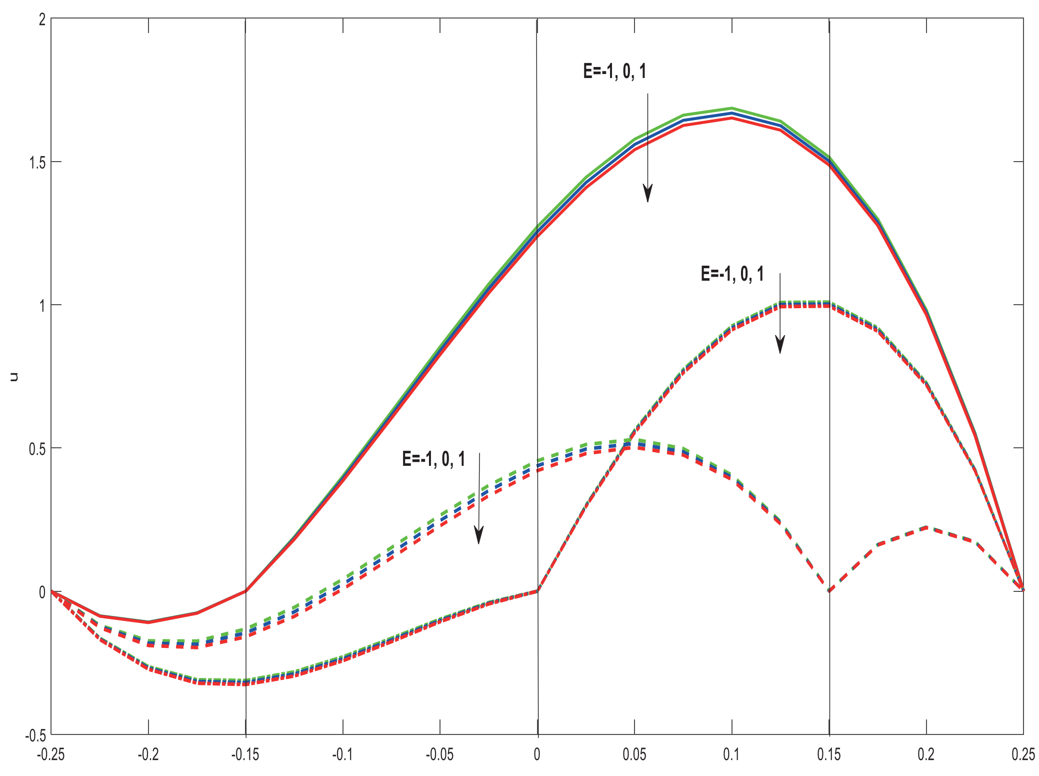

Fig. 3. Velocity field for different values of E.

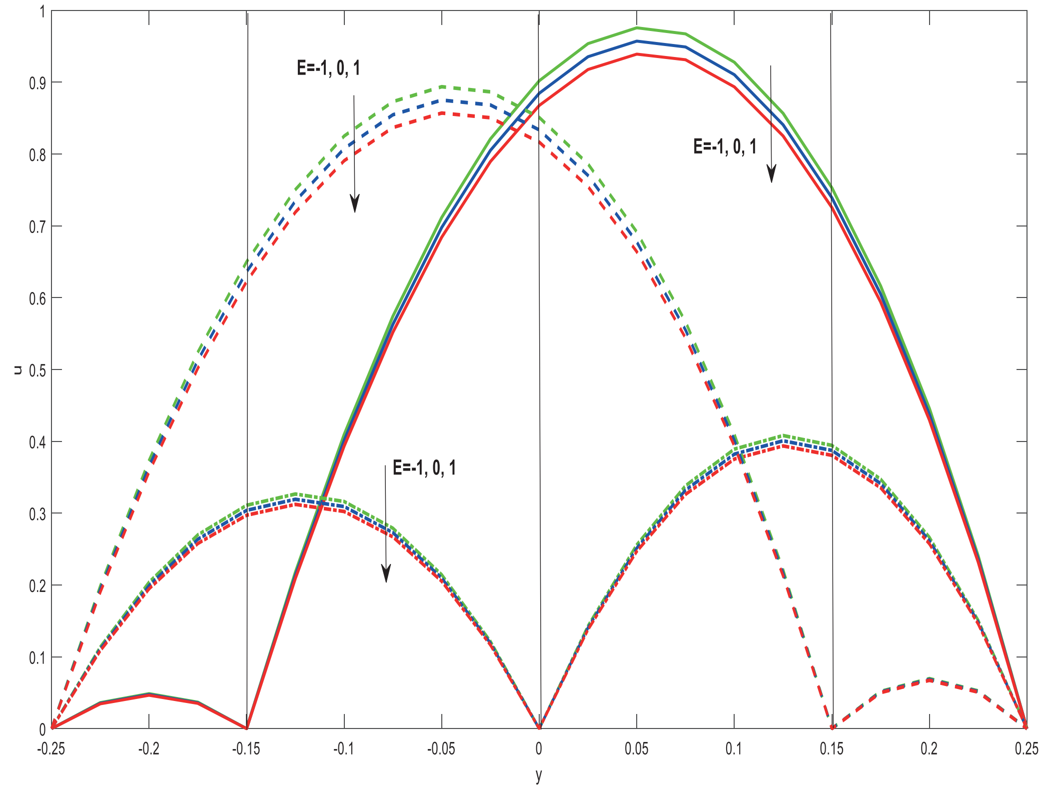

Fig. 4. Velocity field for different values of E.

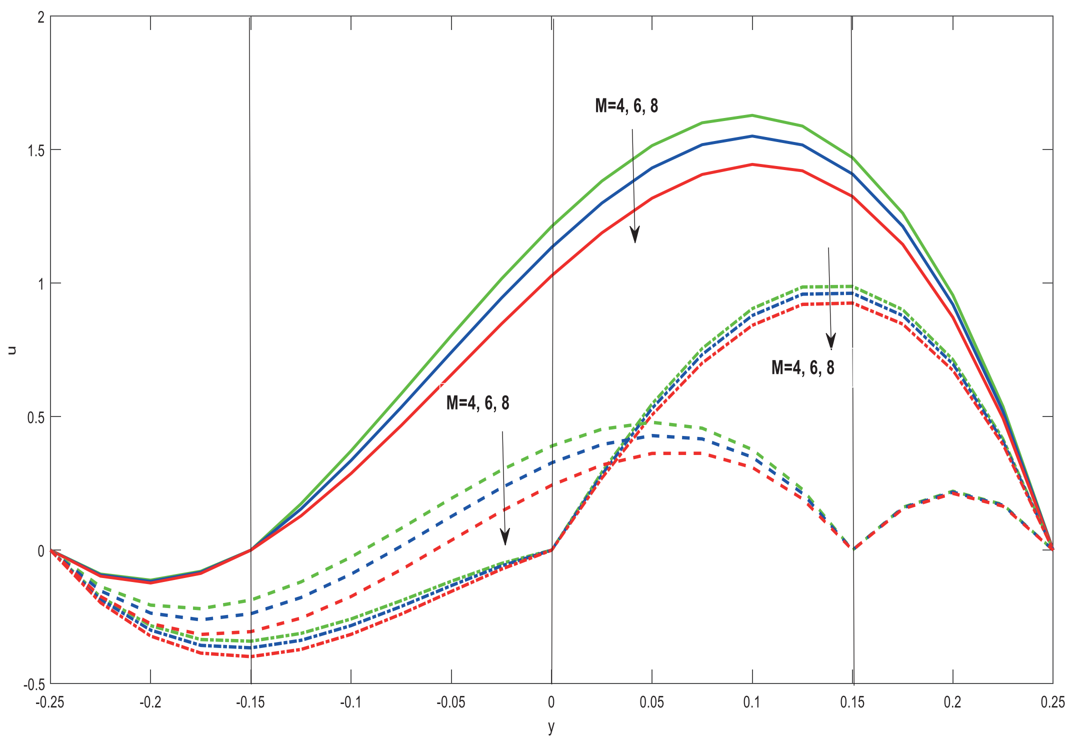

Fig. 5. Velocity field for different values of M.

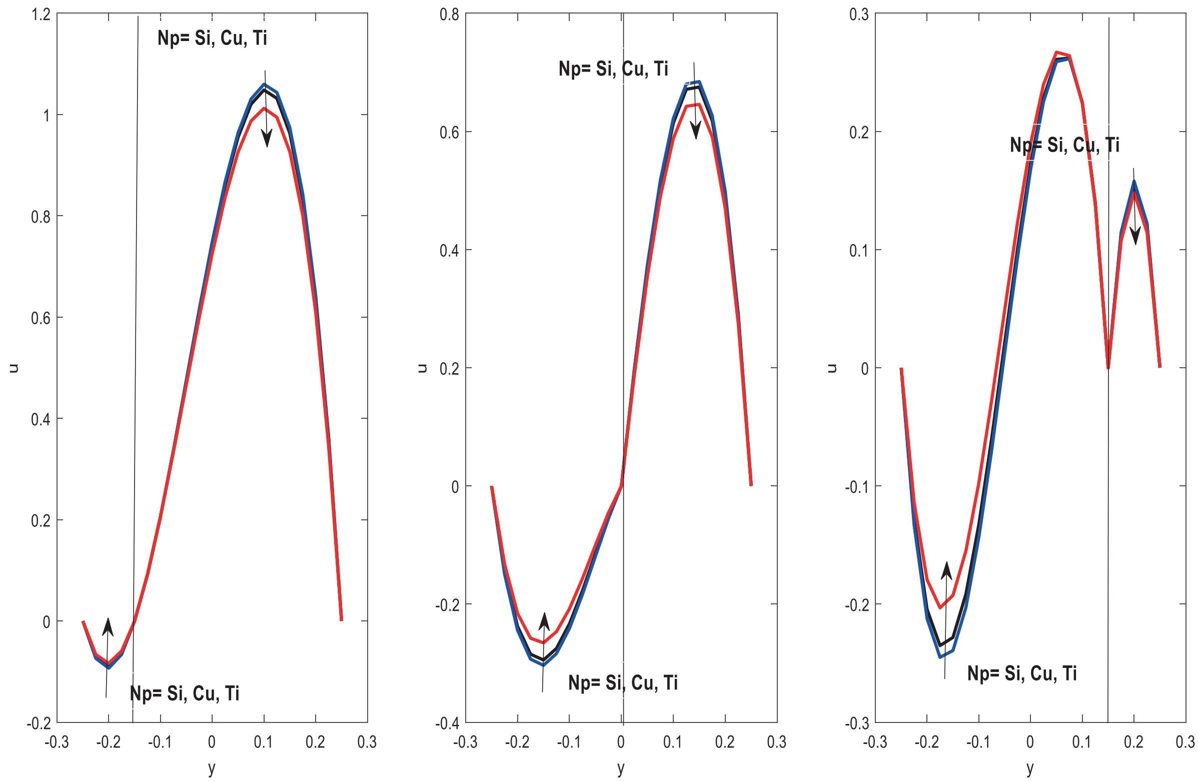

Fig. 6. Velocity field for different values of *Np*.

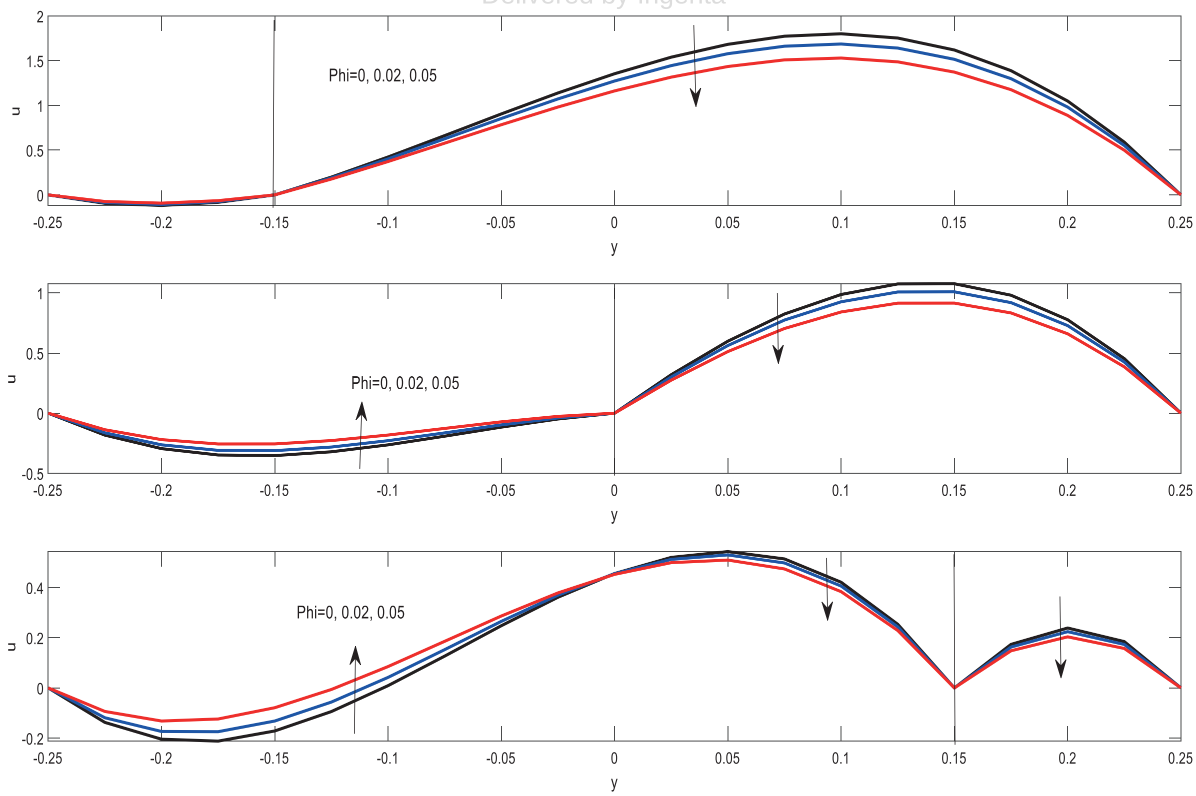

Fig. 7. Velocity field for different values of ϕ.

Figure 2 shows that the velocity profile for different values of mixed convection parameter at different places of the baffle. Considered $\Lambda < 0$ and $\varepsilon < 0$ for downward flow and $\Lambda > 0$ and $\varepsilon > 0$ for upward flow. It can be seen from the figure that as the mixing convection parameters increase, the upstream and downstream flow velocity at all positions of the baffle is suppressed in Stream-I, but increases in Stream-II. Figures 3 and 4 show the effect of E on flow velocity for equal and unequal ($Bi_1 = 0.1$, $Bi_2 = 10$) Biot numbers at some places of the baffle. As it can be observed from the Figures 3 and 4 that the velocity profile suppresses in both the streams as increment in E at all baffle positions both unequal and equal Biot numbers. The maximum point of the velocity observed in Stream-II when baffle is moved near to the left wall for equal Biot numbers, and it is occurred in a wide passage for unequal Biot numbers.

Figure 5 display the effect of Hartman number on velocity profile when Biot numbers are same at different places of baffle. Due to the existing Lorentz force, Increment in M reduces flow velocity in both streams at all positions of baffle. The flow velocity for different nanoparticles for same Biot numbers is shown in Figure 6. It is observed from the figure that the maximum point of the velocity is occurred for silver nanoparticle in Stream-II when the baffle closes to the cold wall and into center of the channel. And it is appeared in Stream-I for Titanium oxide when the baffle is close to the right wall. Figure 7 show the effect of solid volume fraction on profile of velocity for same Biot numbers at different places of the baffle. It is seen from the Figure 7 that the values of velocity profile decrease in Stream-II and increases in Stream-I when the baffle is placed near to cold wall and in middle channel, and the velocity profile raises in left half of the channel and suppresses in right half of the channel when the baffle positioned near the right wall as increases in ϕ. The maximum point of the velocity field is occurred in Stream-II when the baffle is positioned near the cold wall. Temperature profiles do not show much variation for the effect of different parameters at all positions of the baffle and hence the figures are not shown here.

Table II show the heat transfer rate for different values of some non-dimensional parameters, Λ, Bi_1, Bi_2, E, M, ϕ and different nanoparticles. The heat transfer rate decreases at cold wall and raises at hot wall as raises in values of Λ, and it increases at both walls as increases in Biot numbers and reduces at both walls as increment in M and ϕ. It does not vary significantly as increases in values of E and the heat transfer maximum rate appears

Table II. Nusselt number for different parameters at different positions of baffle.

	Nu at y = −0.25			*Nu* at y = 0.25		
Nu for different values of	y* = −0.15	y* = 0	y* = 0.15	y* = −0.15	y* = 0	Y* = 0.15
Λ						
100	1.26942	1.26811	1.27267	1.23743	1.24523	1.24916
250	1.26369	1.26196	1.26277	1.24733	1.25138	1.25489
500	1.26211	1.2606	1.26011	1.24999	1.25274	1.25647
M						
4	1.26211	1.2606	1.26011	1.24999	1.25274	1.25647
6	1.25148	1.24908	1.24886	1.23371	1.23738	1.24333
8	1.23939	1.23557	1.23551	1.2147	1.21927	1.22821
Bi_1						
1	0.54131	0.54103	0.54158	0.53317	0.53572	0.53719
5	1.09938	1.09808	1.09793	1.08818	1.09094	1.09422
10	1.26211	1.2606	1.26011	1.24999	1.25274	1.25647
Bi_2						
1	0.54385	0.54254	0.54279	0.53653	0.53771	0.53899
5	1.10021	1.09864	1.09819	1.08944	1.09172	1.09469
10	1.26211	1.2606	1.26011	1.24999	1.25274	1.25647
E						
−1	1.2707	1.26924	1.26879	1.25973	1.26257	1.26633
0	1.27066	1.26918	1.26872	1.25981	1.26263	1.26639
1	1.27069	1.2692	1.26873	1.25981	1.26262	1.26636
N_p						
cu	1.26211	1.2606	1.26011	1.24999	1.25274	1.25647
ag	1.26207	1.26056	1.26007	1.24993	1.25269	1.25643
ti	1.26601	1.26449	1.26403	1.25386	1.25663	1.26036
ϕ						
0.0	1.43157	1.43049	1.42948	1.42242	1.42484	1.42725
0.02	1.2707	1.26924	1.26879	1.25973	1.26257	1.26633
0.05	1.05478	1.0512	1.0527	1.02871	1.03527	1.04709

for Titanium Oxide nanoparticle near cold wall when the baffle is fixed near cold wall.

5. CONCLUSIONS

Mixed convective eclectically conducting water based nanofluid influenced by thin conducting baffle in a vertical channel is studied analytically for Robin boundary conditions. The velocity field reaches its extreme value when baffle moves toward left wall of the channel. The reverse flow is occurred by placing a baffle in between parallel plates is observed in the effect of Λ. The flow depreciates when raises in values of M, E and ϕ. The optimal values of different nanoparticles are changing by changing the positions of the baffle. Optimum rate of heat transfer observed at left wall for titanium oxide when baffle moves towards left wall. The solutions obtained by using perturbation method and differential transform method are agreed well with Zanchini[25] for regular fluid.

NOMENCLATURE

P Dimensional pressure
K Thermal conductivity
C_p Specific heat at constant pressure
h_1 Width of stream-I
h_2 Width of stream-II
u Velocity
U_0 Reference velocity
T Reference temperature
θ_1 Temperature in stream-I
θ_2 Temperature in stream-II
θ Temperature
Re Reynolds number (hU_0/υ)
Gr Grashof number $(g\beta h^3\Delta T/\upsilon^2)$
Br Brinkman number $(\mu U_0/K\Delta T)$
Λ Dimensionless parameter (Gr/Re)
g Acceleration due to gravity

Greek Symbols

α Thermal diffusivity
ε Dimensionless parameter
ΔT Difference in temperature $(T_2 - T_1)$
σ Electrical conductivity
υ Kinematics viscosity
β Coefficient of thermal expansion
θ Non dimensional temperature
μ Viscosity
ρ Density of fluid

Sufix

s Nanoparticle
f Base fluid
nf Nanofluid

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