ANALYSIS OF CONVECTIONAL HEAT TRANSFER OF AG- MGO (WATER BASE) HYBRID NANOFLUID OVER STRETCHING SHEET WITH MHD

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ABSTRACT

The steady two dimensional laminar, boundary layer flow of incompressible, viscous hybrid Nano-fluid over a stretching sheet with MHD is studied. Water is taken as the base fluid and volume fraction of nanoparticle is considered between 0 to 0.06(50% of silver and 50% magnesium oxide). PDE is transformed into ODE. The solution of equations is obtained from MATLAB using bvp4c. Various physical parameters such as Reynold’s number, Nusselt number, skin friction coefficient are calculated. It was found that hybrid Nanofluid has better heat transfer capacity than single nanoparticle (silver) fluid.

KEYWORDS: Hybrid Nanofluids, Stretching Sheet, MATLAB & MHD

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1. INTRODUCTION

Nanofluids have brought the great revolution in the field of cooling process of instruments. They were first discovered by Choi [1]. Fluids showed tremendous enhancement in thermophysical properties when small Nanosized particles were suspended in base fluid. Some commonly used based fluids are Water, ethylene whereas Nanoparticles may be metals (Al, Cu, Ag, Au, Fe), their oxides (Al2O3, CuO, TiO2), their carbide, (SiC), Nitride (AlN, SiN) or even non-metals (graphite carbon nanotubes). Due to their highly efficient cooling property, Nanofluids have gained tremendous importance in almost all fields. Nanofluids are used for cooling in industries, vehicle cooling, cooling of medical instruments etc. It was found that by dispersing 1-5% Nanofluids in the base fluid, thermal conductivity increases by 150%.

Boundary layer flow is studied widely due to their large area of practical importance. Boundary layer flow was discovered by Prandtl. Boundary layer problem along stretching sheet has attracted the attention of many researchers due to its practical applicability. Stretching sheet is used in many industrial processes like drawing continuous filament and fiber spinning, glass fiber production, extrusion of polymer and many more. During the process of manufacturing these sheets, metal is stretched to achieve a desired thickness. The quality of final product is determined by the rate of cooling and stretching rate. This can be done by using an electrically conducting fluids and applying MHD. Buogiorno [3] explained the significant increase in thermal conductivity. Khan and Pop [10] discussed boundary layer flow of Nano fluids over a stretching sheet and investigated it numerically.
Nanofluids emerged as the solution for a heating problem. There are many investigations regarding the use of nanofluid in conventional heat transfer method. [21-26] It tackled heating issues of fluids in a more efficient way than base fluid. But, the need for better fluid for cooling still persist. Hybrid Nanofluids catered the need of the situation. Many practical experiments are done on hybrid Nanofluids in recent years. It was observed that among all hybrid Nanofluids, Ag and Al₂O₃ / water is most effective coolant. They showed a significant increase in heat transfer coefficient. Ag and MgO/ water hybrid Nanofluid with volume fraction between 0- 2% was analysed by Hemmat et al. [19]. Moghadassi et al [20] numerically studied about Cu- Al₂O₃ /water in a horizontal circular tube. The nusselt number showed a significant increase. Nuim Labib et.al. [7] Numerically solved problem of forced convection on hybrid Nanofluid. Mixed convection along inclined tube with hybrid Nanofluid was analysed by Momin [11]. Suresh et.al. Studied [12] role of Cu- Al₂O₃ /water in heat transfer.

In present study our aim is to study effect of Ag-MgO/water (50% of silver and 50% magnesium oxide) Nanofluid with MHD along linear stretching sheet. Partial Differential Equations are converted to Ordinary Differential Equations. Then these equations are solved with MATLAB software. Graphical result is demonstrated for various physical parameters.

**Nomenclature**

Cp: Specific heat  
β: Thermal expansion coefficient  
T: temperature  
k: thermal conductivity  
Nu: local Nusselt number  
Re: Reynold’s number  
α: thermal diffusibility  
β: thermal expansion coefficient  
ϕ: solid volume fraction  
θ: dimensionless temperature  
η: similarity variable  
f: fluids  
 nf: nanofluids  
s: solid particles  
μ:dynamic viscosity  
B₀: Magnetic field
2. MATHEMATICAL MODELING

A two–dimensional steady, laminar, incompressible and electronically conducting Ag-MgO/water is passed over a hot linear stretching plate. The x-axis is assumed to coincide with the direction of sheet and y-axis is taken as the direction perpendicular to the sheet. A uniform magnetic field is of strength B0 is applied along Y axis. The velocity of the stretching sheet is given by equation u = ax where a are positive and is considered as constant acceleration parameter. Taking Prandtl boundary layer equations based on principle of conservation of mass, energy and momentum, reducing equations in 2D for hybrid Nanofluids we get following set of equations:

\[ \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0 \]  
\[ u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} = \frac{\partial T}{\partial y} + \frac{\sigma B_0^2 u}{\rho_{nf}} \]  
\[ u \frac{\partial T}{\partial x} + v \frac{\partial T}{\partial y} = \alpha_{nf} \frac{\partial^2 T}{\partial y^2} \]

Along with boundary conditions for velocity and temperature:

\[ y = 0, u = u_w, v = 0, T = T_w + a x \]
\[ y \rightarrow \infty, u \rightarrow 0, T \rightarrow T_\infty \]

Where u and v are components of velocity along x and y directions respectively, T is temperature, \( \theta_{nf} \) is kinematic viscosity of Nanofluids, \( \alpha_{nf} \) is thermal insufibility of Nanofluids, \( k_{nf} \) thermal conductivity, \( (C_p)_{nf} \) is specific heat, B0 is applied magnetic field and \( \rho_{nf} \) density of hybrid Nanofluids.

Along with boundary condition:

\[ y = 0, u = Uw(x) = ax \]
\[ y \rightarrow \infty, u \rightarrow 0, T \rightarrow T_\infty \]

The, density , specific heat and heat capacitance of hybrid nanofluid:

\[ \rho_{nf} = [(1-\phi_2)\rho_f + \phi_1 \rho_{s1}] + \phi_2 s_2 \]  
\[ (\rho C_p)_{nf} = [(1-\phi_2)\rho_f C_p + \phi_1 (\rho C_p)_{s1}] + \phi_2 (\rho C_p)_{s2} \]

The dynamic viscosity of hybrid nanofluid as formulated by Brickman :

\[ \mu = \frac{\mu_f}{(1-\phi_2)^{2.5} (1-\phi_1)^2} \]

### Table 1: Physical Properties of Base Fluid Water, Silver, Titanium Oxide

<table>
<thead>
<tr>
<th>Fluid</th>
<th>Density (kg/m^3)</th>
<th>Specific Heat (J/kg K)</th>
<th>Thermal Conductivity (W/m K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>997.1</td>
<td>4179</td>
<td>0.613</td>
</tr>
<tr>
<td>Silver</td>
<td>10,500</td>
<td>234</td>
<td>429</td>
</tr>
<tr>
<td>Magnesium Oxide</td>
<td>3,560</td>
<td>955</td>
<td>45</td>
</tr>
</tbody>
</table>

P. D. E are converted into ODE using similarity variable \( \eta \).

\[ \psi = (a \theta_{nf})^{1/2} x f(\eta) \]
\[ \eta = \left( \frac{a}{\alpha_{nf}} \right)^{1/2} y \]  
\[ u = ax f'(\eta) \]  
\[ v = -\left( a \psi_{nf} \right)^{1/2} f(\eta) \]  
Where \( \psi(x, y) \) is stream function and \( u = \frac{\partial \psi}{\partial y} \) and \( v = -\frac{\partial \psi}{\partial x} \),

and , \( \theta(\eta) = \frac{T-T_{\infty}}{T_{w}-T_{\infty}} \)  

Equations (2) and (3) are transformed into ordinary differential equation given below:

\[ f''' = \left\{ (1 - \theta_2) (1 - \psi_2) + \psi_2 \psi_3 \right\} f^{1/2} - f^{1/2} - M^2 f' \]  
\[ \theta'' = -\left( \frac{k_f}{k_{nf}} \right) \left\{ (1 - \theta_2) \left[ (1 - \psi_2) + \frac{(\rho p_{nf})}{(\rho p_f)} + \psi_2 \frac{(\rho p_{nf})}{(\rho p_f)} \right] \right\} Pr f \theta' \]  

Where \( M^2 = \frac{\sigma B^2}{\alpha_{nf}} \)

Along with boundary conditions:

\[ \eta = 0, \ y = 0, \ f = 0, \ f' = 1, \ \theta = 1 \]  
\[ \eta \to \infty, \ y \to \infty, \ \theta' = 0, \ \theta = 0 \]  

The variables are defined as

\[ Pr_{nf} = \frac{\theta_{nf}}{\alpha_{nf}} \]  

Kinematic viscosity and thermal diffusivity of the hybrid nanofluids are respectively:

\[ \theta_{nf} = \frac{\mu_{nf}}{\rho_{nf}} \]  

and

\[ \alpha_{nf} = \frac{k_{nf}}{\rho_{nf}(c_p)_{nf}} \]  

And thus \( (Pr)_{nf} \), the Prandtl number of hybrid nanofluid

\[ Pr_{nf} = \frac{\mu_{nf}(c_p)_{nf}}{k_{nf}} \]  

Skin Friction Coefficient

The skin friction coefficient \( c_f \) is given by \( C_f = \frac{\tau_w}{\rho_f u_{w}^2} \), where \( \tau_w = \mu_{nf} \frac{\partial u}{\partial y} \big|_{y=0} \). Using (9), we get

\[ C_f Re_x^{1/2} = \frac{1}{(1-\psi)^{1/2}} f''(0). \]
Nusselt Number

Nusselt number is defined by: \( Nu = \frac{x q_w}{k_f (\theta_0 - \theta_f)} \) Where \( q_w = -k_n f \left( \frac{\partial \theta}{\partial y} \right) \). Using (9) we get \( Nu Re_x^{-1/2} = -\frac{k_n f}{k_f} \theta'(0) \).

Solution of the Equations

Equations 13 and 14 were solved using boundary conditions 15 using MATLAB software with bvp4c. Equations 13 and 14 were converted into five equations each of first order. The value of \( \eta \) was calculated at each iteration loop by \( \eta_{n+1} = \eta_n + \Delta \eta \). The step size \( \Delta \eta = 0.001 \) was used. The numerical solution with \( \eta_{\text{max}} = 10 \) was obtained and the six decimal place was considered as a criterion for convergence. Graphs were plotted for results obtained.
RESULTS AND DISCUSSIONS

Laminar flow of hybrid nanofluid over a stretching sheet is studied. Solutions for equations depicting thermophysical properties of both hybrid as well as plane (Ag) nanofluids is obtained.

In absence of nanoparticles results shows excellent agreement with previous studies. Prandtl number is taken as 6.2. By taking values of $\phi_1 = 0$ and $\phi_2 = 0$ the results shows an excellent agreement with previous study.

It was observed that the velocity of the fluid decreases by adding nanoparticles. Hybrid nanofluid further retards velocity as the concentration of nanoparticles increases. Temperature also drops significantly by adding nanoparticles. Nanoparticles exert energy in form of the heat. Hybrid nanofluid further drops the temperature. $M$ was taken as 2.

Graph 3 shows an effect of the magnetic parameter over dimensionless velocity for nanofluids. Due to magnetic field Lorentz force is induced which results in decrease of velocity i.e. increase in magnetic field results in the decrease in velocity. Hybrid nanofluid further retards the velocity. Effect of magnetic field on temperature profile is depicted in Graph 4. This figure shows that by increasing value of magnetic field increases temperature. Thermal boundary layer thickness increases due to increase in magnetic field. Further hybrid nanofluid produces a better result by increasing MHD.

REFERENCES


