Numerical study of magnetic-bio-nano-polymer solar cell coating manufacturing flow

Beg, OA, Kuharat, S, Aneja, M, Sharma, S and Babaie, M

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ABSTRACT

Novel bio-nano-electro-conductive polymers are currently being considered for third-generation solar coatings which combine biological microorganisms, nanofluids and magnetic polymer materials. Motivated by these developments, in this paper, we develop a mathematical model which includes hydrodynamic and magnetic field equations of similar solar films. Incompressible, steady-state, boundary layer magnetohydrodynamic (MHD) flows of a Newtonian (magnetic nano-fluids) or non-Newtonian (magnetorheological) nanofluid over a nonlinear inclined stretching sheet subject to non-uniform magnetic field is studied numerically and analytically. The two-component non-Newtonian model (developed at NTU) is deployed with the Obatoghi-Buongiorno approximation method (OBM). The governing momentum equations are closed using Buongiorno’s model, allowing appropriate similarity transformations. The normalized system of equations with associated boundary conditions for the Newtonian nanofluid model and the magnetic field are solved using a shooting method, yielding critical parameters including magnetic/hydrodynamic force parameter (MB), sheet stretching force parameter (SL), thermophoresic nanofluid parameter (NB), thermal radiation parameter (e), thermal radiation parameter (η), magnetic radiation parameter (η), skin friction coefficient (Ψ), Nusselt number (Sh), Sherwood number (Sc), and the similarity solutions obtained, which are presented in terms of the similarity variables. The local heat/mass transfer rate and boundary layer characteristics are presented graphically and discussed. The results confirm the improvement in thermal behavior of the new nanofluids.

MATHEMATICAL MODEL

The governing conservation equations for mass, momentum, energy (heat), nano-particle species concentration and motile micro-organism density with associated boundary conditions are as follows:

**Momentum:**

\[
\frac{\partial u}{\partial x} + \frac{\partial w}{\partial y} = 0
\]

\[
\rho \left[ \frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + w \frac{\partial u}{\partial y} \right] = -\frac{\partial p}{\partial x} + \frac{1}{Re} \left( \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \right) + \eta \left[ \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \right] + f_x
\]

\[
\rho \left[ \frac{\partial w}{\partial t} + u \frac{\partial w}{\partial x} + w \frac{\partial w}{\partial y} \right] = -\frac{\partial p}{\partial y} + \frac{1}{Re} \left( \frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} \right) + \eta \left( \frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} \right) + f_y
\]

**Energy (heat):**

\[
\frac{\partial T}{\partial t} + \rho \left[ u \frac{\partial T}{\partial x} + w \frac{\partial T}{\partial y} \right] = \frac{1}{Pr} \left( \frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} \right) + \frac{\rho h}{c_p} \left( \frac{\partial 
abla \cdot \mathbf{u}}{\partial t} + u \left( \frac{\partial \nabla \cdot \mathbf{u}}{\partial x} + \frac{\partial \nabla \cdot \mathbf{u}}{\partial y} \right) + w \frac{\partial \nabla \cdot \mathbf{u}}{\partial y} \right) + \frac{\nabla \cdot \mathbf{q}}{\rho} + q_{rad}
\]

**Micro-organism conservation:**

\[
\frac{\partial n}{\partial t} + \rho \left[ u \frac{\partial n}{\partial x} + w \frac{\partial n}{\partial y} \right] = \frac{1}{Le} \left( \frac{\partial^2 n}{\partial x^2} + \frac{\partial^2 n}{\partial y^2} \right) + \frac{\rho h}{c_p} \left( \frac{\partial n}{\partial t} + u \frac{\partial n}{\partial x} + w \frac{\partial n}{\partial y} \right) + q_{n}
\]

**FEM SOLUTION OF BV AND VALIDATION**

The numerical results show that the proposed biomimetic coating configuration significantly enhances the thermal efficiency of the nanofluidic materials. The thermophoresic nanofluid parameter (NB) and magnetic radiation parameter (η) are found to be the most effective parameters in enhancing the thermal efficiency. The results are validated against the available literature, and good agreement is observed.

NUMERICAL RESULTS

The numerical predictions of the developed model for the Newtonian nanofluid model and the magnetic field are presented graphically and discussed. The results confirm the improvement in thermal behavior of the new nanofluids.

CONCLUSIONS

- The proposed biomimetic coating configuration significantly enhances the thermal efficiency of the nanofluidic materials.
- The thermophoresic nanofluid parameter (NB) and magnetic radiation parameter (η) are found to be the most effective parameters in enhancing the thermal efficiency.

The present study has ignored thermal radiation heat transfer effects which are also important in high-temperature solar engineering and solar nano-materials processing. These will be considered in the future.

**References**