Simulating entropy generation in solar magnetohydrodynamic heat ducts with Eringen’s micropolar model and Bejan thermodynamic optimization

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Magnetic hydrodynamic (MHD) solar power has recently been developed in the USA and is an exciting novel area in renewable power. In this hybrid solar energy design, high-precision solar cells are combined and augmented with magnetic systems. The power is harvested and transmitted by energy harvesting systems from high-potential sites and then transmitted to the power grid. The significant higher efficiencies generated in solar power systems demonstrates the potential of magnetic systems in solar thermal technologies that work at a much lower temperature. The working fluids in solar MHD designs may be non-Newtonian and are electrically conducting and are strong thermal convective effects may also be present. To optimize thermal performance, Bég's advanced energy generation technique is a powerful approach. The present paper describes for the first time a novel analytical and computational model for entry generation of magnetohydrodynamic (MHD) fluids due to constant pressure gradient in a vertical-parallel plate channel as a simulation of an MHD solar power system. To more accurately simulate the thermal engineering effect, the novel model penetrates into the MHD microfluidic material model which employs features that quality motions of micro-fluids (suspended particles). This is a new approach to real fluids in MHD pumps. The normalized conservation equations are solved with the powerful spatially explicit method (H) with physically valid boundary conditions at the channel (d) walls. Numerical simulations are conducted in MATLAB symbolic software. Impact of selected parameters e.g. non-Newtonian couple stress parameter, Reynolds number, Grashof (thermal buoyancy) number, Reynolds number and Brinkman (viscous heating) number on the dimensional thermofluidic characteristics (velocity, temperature, Nusselt number) and on entry generation number and Bejan number are studied. The prescribed range of parameters is used to study the flow effect of couple stress parameter, Reynolds number, and Nusselt number on the entry generation number and Bejan number. These equations are used to determine the entry generation production in solar MHD systems, that leads designers in achieving thermally more efficient solar MHD Duct performance.

MATHMATICAL MODEL

The equations are non-dimensionalized and the non-dimensional ordinary differential equation boundary value problem (ODE BVP) reduces to

\[
\begin{align*}
&\frac{d^2 \psi}{dx^2} + \beta(1 - x^2) = 0, \\
&\psi(0) = 1, \quad \psi(1) = 1.
\end{align*}
\]

Here \( \beta \) is the couple stress parameter, \( \xi \) is the coupling number or Eringen microfluidic parameter, \( \gamma \) is the Brinkman number, \( \varepsilon \) is the Reynolds number, \( \mu / \rho \) is the Brinkman number, \( \varepsilon \) is the Eringen number, \( \Pr \) is the Prandtl number, \( H \) is the aspect of the Herglotz number (magnetic parameter), \( \psi \) is a mechanical parameter, and \( \psi \) is the pressure gradient.

HOMOTOPY NUMERICAL SOLUTION

The coupled non-linear ODE BVP is solved with HAM. This method has generated exceptional results from biomimetics due to its non-linear equations and its ability to solve complex systems. The HAM has been successfully utilized successfully to obtain solutions for a diverse range of multiphase flows with rotation. The HAM has been used to solve the flow problem with rotation (MHD). HAM has the advantage of not requiring small or large parameters (with perturbation technique), and it can be adapted to solve non-linear problems without such restrictions. The method is a base semi-numerical technique which achieves very high accuracy. The homotopy series expansions are implemented with symbolic software, e.g., MAPLE, MATHEMATICA etc. HAM further provides greater choice to select auxiliary linear, non-Newtonian operators and initial approximations. This method introduces a parameter known as homotopy embedding parameter (\( \eta \)), which assumes values from 0 to 1. When \( \eta = 0 \), then the used under study get a simple form which gives us a closed form analytical solution to the initial guess satisfying boundary conditions at the walls. When \( \eta = 1 \) and is increased and finally takes the value one. The basic result to the actual problem is recovered. A significant advantage of the approach is that it is analytical. Also, this method uses two other parameters, a convergence controlling parameter \( \eta \) and a number \( \mathcal{N} \), the choices of which are to simulate different solutions. The homotopy deformation equations for velocity, \( \psi \), micro-rotation \( \nu \) and temperature \( \theta \) are derived as follows:

\[
\begin{align*}
&\frac{d^2 \psi}{dx^2} + \beta(1 - x^2) = \eta, \\
&\psi(0) = 1, \quad \psi(1) = 1.
\end{align*}
\]

CONCLUSIONS

Selected HAM computations are shown in Figs. 5-8. The main observations of the present study can be summarized as follows:

- Increasing couple stress effect in the working fluid decreases the velocity.
- An elevation in micropolar (nurita viscosity) parameter decreases the velocity in comparison with the Newtonian fluid case. Further, it is noted that micropolar parameter can be used to control the flow motion.
- The energy generation production is maximum near the solar duct plate as compared to that of the duct channel. This demonstrates that the frictional heat produced is dominant near the channel plates and thus enhance energy generation. Conversely, Bejan numbers have minimum values near the plates and maximum control occurs near the channel centres.
- Bejan number is a maximum at the centre point of the channel. This reveals that the amount of available energy for work is more and invaritiveness is less.
- A strong increase in the energy generation distribution (\( \mathcal{N} \)) is noted with an increase in couple stress parameter \( \xi \), Bejan number \( \mathcal{N} \), Reynolds number \( \mathcal{R} \) and group parameter (\( \varepsilon \)).
- The micropolar parameter \( \xi \) and magnetic parameter \( \mu \) have decreasing effect on energy generation production.

The present study has demonstrated the powerful ability of HAM in simulating entry generation problems in non-Newtonian magneto-hydrodynamics solar duct systems. However, it has neglected thermal interface heat effects. (\( \gamma \)) which are presently under consideration with galvanic fluxes and differentiable models (Rachilion, PT, Chamardh et al.).

References


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