Title: Study of thermo-fluid dynamics of magnetised hybrid nanofluids over a *Bi*-directional surface using ANN-optimization

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Abastact: This study investigates the thermo-fluidic dynamics of a magnetised hybrid Ag-TiO_2/EG-water nanofluid over a bi-directionally stretching/shrinking surface, a configuration relevant to advanced thermal management in biomedical, aerospace, and electronics cooling. To address the limitations of traditional numerical approaches in multi-parameter optimization, novel Artificial Neural Network (ANN) optimized with the Levenberg–Marquardt algorithm (LMA) is developed. The model incorporates realistic physical effects, including temperature-dependent viscosity and thermal conductivity, surface suction, and Joule heating. A high-fidelity dataset was generated by solving the transformed governing equations using MATLAB's bvp4c solver, covering the parameter ranges: magnetic parameter ($1 \le M \le 5$), mixed convection ($-1 \le \lambda \le 6$), variable viscosity ($0.1 \le a \le 1.5$), thermal conductivity ($0.1 \le b \le 0.5$), stretching ratio($0.1 \le \varepsilon \le 1$), suction parameter ($-1 \le S \le 1$), and nanoparticle volume fraction ($0.01 \le \varphi \le 0.1$). The velocity and temperature data, varying with M, ε, λ, a, and b, were divided into 70% training, 15% validation, and 15% testing sets for ANN-LMA modelling. The framework achieved absolute 10^{-3}–10^{-9} and MSE between 10^{-10}–10^{-7}, demonstrating high predictive accuracy. Results reveal that the magnetic field enhances vertical velocity in shrinking flows but reduces it in stretching flows, while horizontal velocity is suppressed in both cases. Temperature rises with magnetic and mixed convection effects, and variable conductivity causes hybrid nanofluids to exhibit up to 45% higher thermal elevation than mono nanofluids. Notably, a 10% Ag + TiO_2 mixture enhances heat transfer by 45%, compared to 18.6% for 10% Ag alone. The novelty of this work lies in its integrated AI-driven framework that accurately captures coupled multiphysics interactions, providing a rapid and reliable predictive tool for the design of advanced thermal-MHD systems.

Keywords: Hybrid Nano fluid Artificial neural networks Bi-directional surface Variable thermophysical properties Magnetic force

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