Physics-informed Neural Networks for Numerical Solution of Nanofluid Swirling Flow over an Exponentially Stretching Cylinder

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Background: The study of nanofluid swirling flow over an exponentially stretching cylinder has significant applications in industries where efficient heat transfer and flow control are critical. These include cooling systems, polymer extrusion, and chemical processing, where enhanced thermal conductivity and optimized flow behavior can improve energy efficiency and product quality.

Purpose: This study examines the impact of flow parameters, such as the Reynolds number, magnetic parameter, and nanofluid concentration, on velocity and temperature distributions. For the analysis we assume the cylinder is exponentially stretching in the axial direction and influence of magnetic field in the radial direction. In this work, graphene oxide/water is used as the nanofluid. Investigating fluid dynamics over an exponentially stretching surface is crucial due to its ability to capture nonlinear effects and enhance heat transfer efficiency. The applicability of wavelet based physics informed neural networks is studied on the intricate fluid flow problem.

Methodology: The governing partial differential equations (PDEs) for the fluid flow are transformed into ordinary differential equations (ODEs) for simplification. To enhance convergence, the input variables are further converted into an exponential form, resulting in a new set of ODEs. These ODEs are then solved using physics-informed neural networks, where Gaussian wavelets are applied through three separate neural networks, each dedicated to a specific solution. For the axial velocity model, a neural network with 7 layers and neuron configurations of 24, 22, 15, 15, 23, 14, and 26 is used. The swirl velocity model utilizes a 3-layer network with 30, 26, and 8 neurons, while the temperature model employs a 6-layer network with neurons configured as 21, 13, 22, 29, 6, and 18. Optimization is performed using the Adam optimizer with a decaying learning rate to ensure efficient training.

Novelty: The primary objective of this study is to apply physics-informed neural networks to obtain a numerical solution for the nanofluid swirling flow over an exponentially stretching cylinder. We employ a wavelet-based PINN approach to solve the governing differential equations, without any prior knowledge of the numerical solution or the need for labeled datasets.

Findings: The validation of the methodology demonstrates that PINN effectively provides solutions for the fluid flow model. The study also explores the impact of various flow parameters. It was found that increasing the Reynolds number and nanoparticle concentration leads to higher skin friction coefficients and Nusselt numbers. Conversely, as the magnetic parameter increases, the skin friction coefficient rises, while the Nusselt number decreases.

Keywords: PINNs, nanofluid, exponentially stretching cylinder, swirling flow

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