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Optimization of thermophysical properties of nanofluids using a hybrid procedure based on machine learning, multi-objective optimization, and multi-criteria decision-making

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Highlights

- A novel hybrid strategy is proposed to optimize water-based hybrid nanofluids.
- Machine learning techniques model density, viscosity, specific heat capacity, and thermal conductivity.
- Applying multi-objective optimization on the developed models leads to Pareto points.
- Multi-criteria decision-making presents desirable designs according to various scenarios.

Abstract

The rheological and thermal behavior of nanofluids in real-world scenarios is significantly affected by their thermophysical properties (TPPs). Therefore, optimizing TPPs can remarkably improve the performance of nanofluids. In this regard, in the present study, a hybrid strategy is proposed that combines machine learning (ML), multi-objective optimization (MOO), and multi-criteria decision-making (MCDM) to select optimal parameters for water-based multi-walled carbon nanotubes (MWCNTs)-oxide hybrid nanofluids. In the first step, four critical TPPs, including density ratio (DR), viscosity ratio (VR), specific heat capacity ratio (SHCR), and thermal conductivity ratio (TCR), are modeled using two efficient ML techniques, the group method of data handling neural network (GMDH-NN) and combinatorial (COMBI) algorithm. In the next step, the superior models are subjected to a four-objective optimization by the well-known non-dominated sorting genetic algorithm II (NSGA-II), which aims to minimize DR/VR and maximize SHCR/TCR. This study considers volume fraction (VF), oxide nanoparticle (NP) type, and system temperature as optimization variables. In the final step, two prominent MCDM techniques, TOPSIS and VIKOR, were used to identify the desirable optimal points from the Pareto fronts generated by the MOO algorithm. ML results reveal the COMBI algorithm's superior reliability in accurately modeling various TPPs. The pattern of Pareto fronts for all oxide-NPs indicated that over one-third of the optimal points have a VF= 1.5%. On the other hand, the distribution of optimal points across different temperature ranges varied significantly depending on the type of oxide-NPs. For Al_2O_3-based nanofluid, around 50% of the optimal points were within 40–50°C. Conversely, for nanofluids containing CeO_2 NPs, only approximately 24% of the optimal points were found within the same temperature range. Considering diverse scenarios for weighting TPPs in the MCDM process implied that combining CeO_2/ZnO oxide-NPs with MWCNTs in water-based nanofluids is highly effective across various real-world applications.