Predicting Specific Heat Capacity of Nanofluids Using Machine Learning Methods: Applications in Thermophysics

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1. Introduction

Nanofluids, consisting of nanoparticles suspended in base fluids, exhibit enhanced thermophysical properties, making them highly promising for heat transfer applications. Among these properties, specific heat capacity plays a critical role in determining thermal efficiency, yet its experimental measurement is often time-consuming and resource-intensive. Machine learning (ML) techniques, such as Random Forest, Artificial Neural Networks (ANNs), and Support Vector Regression (SVR), have emerged as powerful tools for predicting thermophysical properties, offering superior accuracy and efficiency compared to traditional methods. This study develops a predictive model for specific heat capacity using the Random Forest Regressor method, optimized with GridSearchCV, to address the challenges of experimental determination. The model is validated on experimental data for isopropyl alcohol with Al_2O_3 nanoparticles [1].

2. Substantial section

The study leverages a dataset from Kaggle, containing parameters such as nanoparticle size, composition, concentration, temperature, and base fluid type. Data preprocessing included removing outliers, standardizing numerical features, and performing correlation analysis. The Random Forest model was trained on 80% of the data, with hyperparameters optimized using GridSearchCV. The final model achieved exceptional performance, with minimal deviations from experimental values.

2.1 Related work

Machine learning techniques have shown promise in predicting thermophysical properties of nanofluids, outperforming traditional methods [2, 3]. Previous studies have employed Artificial Neural Networks (ANNs) and Support Vector Regression (SVR) for similar tasks [4, 5]. This work builds on these advancements by introducing a highly accurate Random Forest-based model.

2.2 Figures and tables

Figure 1 shows the correlation between the variables on which the model was trained

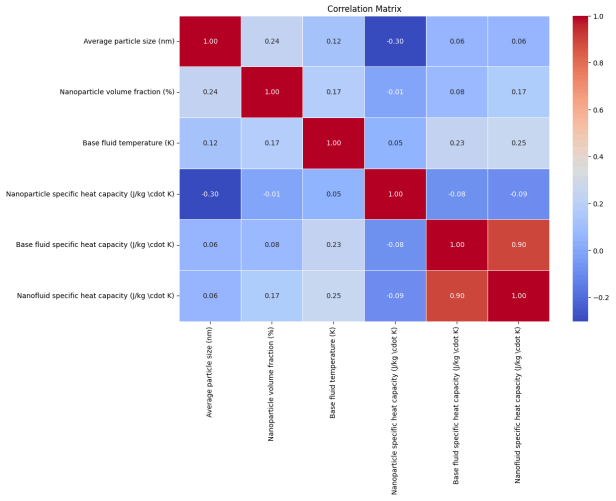

Fig. 1: . Correlation matrix of variables in the studied dataset

For model tuning, the following parameter set was chosen: number of trees (n_estimators=1000), earning rate (learning_rate=0.01), and a fixed random state (random_state=80). The final parameters of the model's learning quality are as follows: the mean squared error (MSE) was 0.0138, the mean absolute error (MAE) was 0.0855, and the coefficient of determination (R^2) reached a value of 0.9999999734.

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