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Effectiveness of Soft Computing Tools to Discover the Pattern in Thermal Properties of Nanofluids - A Review

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Abstract: ***Soft computing tools plays a vital role in extracting the hidden pattern knowledge of any complex data. The main objectives of the tools are, for accurate prediction and classification. Nanofluids have many applications in various fields. The enhancement of nanofluids is due to its thermal properties. Mathematical models and experimental models were developed to predict the thermal properties of nanofluids. Discrepancies between these models lead to go for soft computing tools for prediction. This paper is to review the evaluation and validation techniques used by different soft computing tools. This review paper looks forward to simplify the financial strength required for test runs of nanofluids and exhibiting the effectiveness of soft computing tools by extracting the hidden patterns in it.***

Keywords: Nanofluids, Thermal Conductivity, Soft computing tools

1. Introduction

Knowledge discovery from large databases is a significant subtask in knowledge management. A soft computing tool intersects artificial intelligence, machine learning, statistics and database system. Soft computing tools are used to analyze the data thoroughly and extract the hidden knowledge. Accurate prediction and classification of data is achieved by exploring the hidden pattern knowledge from the large data set.

Nanofluids exhibits excellent growth in various fields like automobile applications, solar applications, nuclear applications, nano drug delivery and cancer therapeutics. The potential of nanofluids reside in its thermo-physical properties such as thermal conductivity, viscosity and heat transfer coefficient, these properties depends on many factors like shape of the particle, particle volume concentration, temperature, size of the particle, particle materials, method of production of nano particles.

Mathematical models and experimental models were developed to examine the thermal properties of nanofluids. These two models reveal controversies between them which hinder the potential growth of nanofluids. Moreover both the models are time consuming and expensive. To overcome these hindrances, researchers started to utilize the soft computing tools to determine accurately thermal properties of nanofluid.

Soft computing tools use the logics of artificial neural networks, genetic algorithms, fuzzy logics, decision tree concepts, rule induction methods to analyze the data. Neural networks are computational model based on connectionist approach, Genetic algorithm are adaptive methods for global optimizations. The efficiencies of these methods are to explore and uncover the pattern knowledge about the data. The purpose of this paper is to review the research publications about the effectiveness of soft computing tools to analyze the data which affect their thermal and flow performance of nanofluids using intelligent techniques.

2. Nanofluids- An Overview

Nanofluids posses many unique features like enhancement in thermal conductivity, stability, particles size dependencies and maintaining highly Newtonian behavior. The thermal conductivity depends on various factors like particle size, particle shape, base fluid, pH value, temperature, particle volume concentration, particle materials, thermal conductivity of base materials .As a result of these desirable features it is widely used in applications start from energy production applications to cosmetics applications.

A nano particle shape is one of the factors that improve the thermal conductivity of nanofluids. Different shapes of nanoparticles are spherical nanosphere, rod like nano bar, nano beam, 2 dimensional polygonal, pentagon , nano ring, 3 dimensional polyhedral cube, octahedron, branched monopod, tetrapod, complex nano pyramid ,Hollow nanoshell, nano cage. Kavitha et. al.[1], stated the improvement in thermal conductivity by using spherical nanospheres.

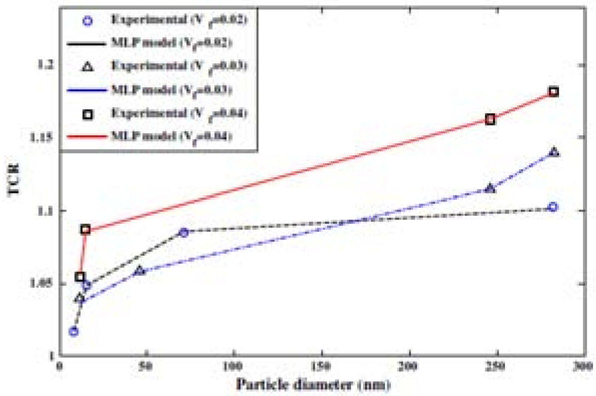

Figure 1: Effect of nanoparticle size on the variation of thermal conductivity of nanofluids [2]

M.Beck et.al. [2], experimented and shown the effect of nanoparticle size in Al_2O_3/H_2O nanofluid. Thermal Conductivity Ratio (TCR) versus Nanoparticle diameter were taken and found a direct proportional between them. Decrease in the particle size decreases the thermal conductivity ratio. Murshed et. al. [3], agreed the statement that, enhancement of thermal conductivity is depend upon nanoparticle size.

Tajik and Zam Zamian [4], experimented using non linear optimization methods, stated that volume fraction, nanoparticle size , basefluids and temperature are the various factors that affect the enhancement of thermal conductivity.

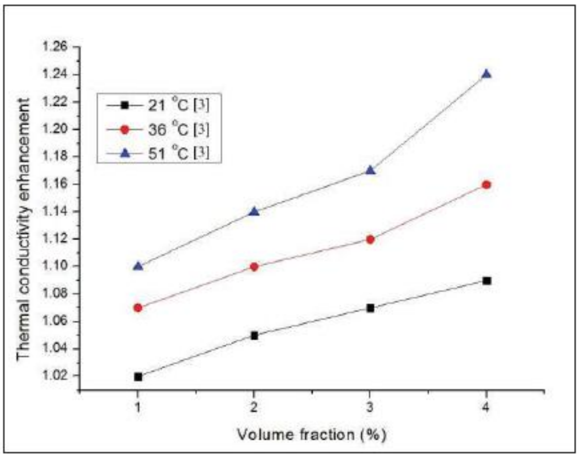

Figure 2: Influence of temperature on the enhancement in thermal conductivity of nanofluids [4]

Hojjat et. al.[5], informs that the thermal conductivity of nanofluids increases with the nanoparticle concentration and increases with the temperature. Liu et. al. [6], examined and affirmed that both particles volume fraction and thermal conductivity of nanofluids collectively goes together.

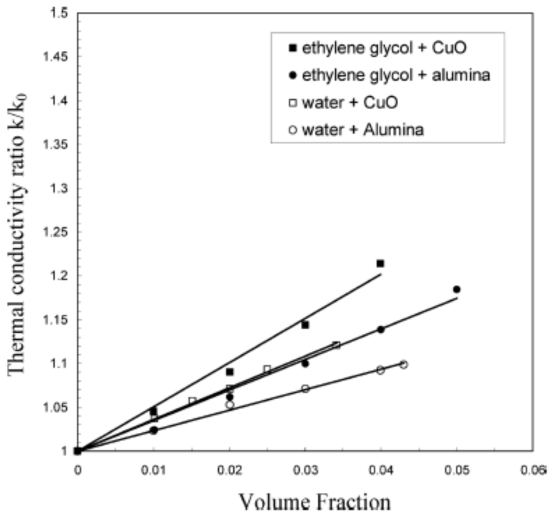

Figure 3: Enhancement in thermal conductivity of oxide nanofluids systems [7]

Lee et. al. [7], experimented the enhancement in thermal conductivity of nanofluids with nanoparticle volume fraction. Through investigation [8],[9] stated, that thermal conductivity of nanofluids is increased with increasing temperature. Shung-Wen Kang et. al.[10], stated thermal resistance and the size of the nanoparticles are the important factor to induce thermal conductivity of nanofluid.

O. Manna et. al. [11], conducted experiment using traditional transient hot wire method and concluded that enrichment in thermal conductivity of nanofluids is depending upon nanoparticles volume, shape of the nanoparticles. In addition, it is stated that, increasing the concentration of nanoparticles will lead to improvement in thermal conductivity of Nanofluids.

3. Soft Computing Tools - An Overview

Soft computing tools use intelligent techniques which combine the knowledge, techniques and methods to extract the patterns from imprecise data set. Machine learning system is the fundamental to artificial neural networks, fuzzy systems, simulated annealing, rough sets, and genetic algorithms to learn and predict the hidden patterns from the unstructured large data sets.

Artificial neural networks is a layered structure, comprise of elements operated in parallel. The basic model of ANN has three layers namely input layer, hidden layer and output layer.

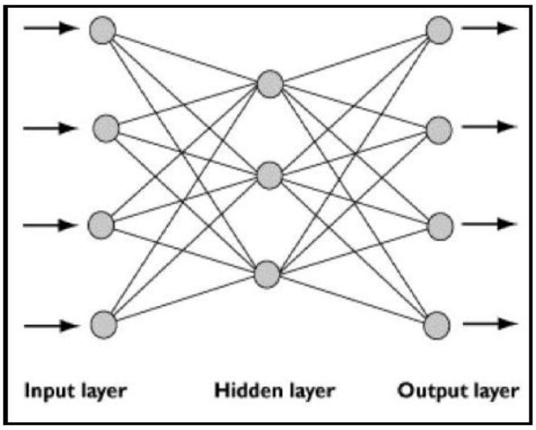

Figure 4: Artificial Neural Network [12]

The data set used in neural network is classified in to three different sets namely training set, testing set and validation set. The training data is used to learn the patterns of the given data. To evaluate the ability of the trained network is done by using testing data. The performance of the trained network is test out by the validation set data.

Genetic algorithm is a search algorithm. Initialization, selection, crossover and mutation are the major principles. Initialize the population, selecting the best sample from the population, exchange between different best samples and to find the best fittest survival are the best sample and change the value with probability.

Artificial Neural networks and Genetic algorithm combining these two methodologies will mitigate the local optima and convergence problems by eliminating the weak individuals and support the survival of the best ones.

4. Prediction of Thermal Properties of Nanofluids Using Artificial Neural Networks – An Overview

M.Afrand et.al.[13] stated that, feed forward artificial neural network model is more accurate in predicting the relative viscosity of multi walled carbon nano tubes with water nano fluid (MW-CNTs/H_2 O) . Mohanraj et. al.[14], used multi layer feed forward network for thermal analysis of heat exchangers .Analysis of heat exchangers using ANN revealed the results accurately.

Ali Aminian , presented a neuromorphic model to predict the thermal conductivity of nanofluids. He concluded that the models using ANN were accurately predicted and has excellent agreement with experimental data having 3.06% as average absolute deviation defined value (AAD) and 0.9309 as correlation coefficient value (R).

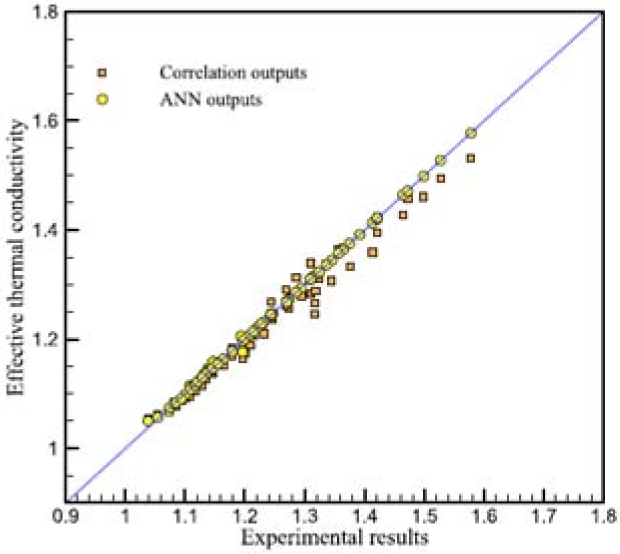

Figure 5: Compatability between experimental data, correlation outputs and ANN outputs [19]

Hemmat Esfe et. al.[16,17,18,19], examined experimentally the thermal conductivity of nano fluid by using Zinc oxide with ethylene glycol (ZnO/EG) and also using copper and titanium di oxide hybrid nanofluids with water/ethylene glycol(Cu/TiO_2 –H_2O/EG) at different volume fraction and at various temperatures .Further by using Multilayer perceptron neural network they studied the thermal conductivity of nanofluids same and concluded both the models were possessing good agreement. In their another research to observe the thermal conductivity, they used Double walled carbon nano tube-Zinc oxide (DWCNT-ZnO/H_2O/EG) and Multi walled carbon nano tubes (MWCNT/H_2O) experimented and used artificial neural networks both revealed good accordance between them.

Ali sadollah et. al.[20], studied the stability parameters for titanium oxide nanofluid (TiO) by experiment using response surface methodology and also predicted through a artificial neural network. They concluded about the performance of the ANN is more accurate than the RSM in terms of accuracy and prediction.

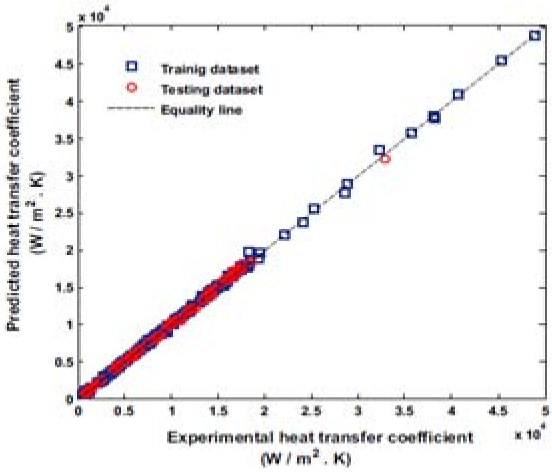

Figure 6: Schematic representation of MLP network capability in estimating heat transfer coefficient over training and testing datasets [21]

B.Vaferi et.al [21], stated that Multi layer perceptron- Feed Forward structure is an optimized training algorithm in prediction when compared with cascade –forward back propagation, radial basis function and generalized regression. They reported that Multi Layer Perceptron- Feed Forward shown $1.7*10^{-5}$ as mean square error(MSE), 2.41% as absolute average relative deviation percentage (AARD%) and 0.99966 as regression coefficient (R^2).

Azari and Marhemati [22], developed a hybrid model GMDH-PNN (Group Method of Data Handling – Polynomial Neural Networks) to predict the thermal conductivity of various group of Nanofluids, the researchers results revealed by the experimental values and by the hybrid model have a good accordance.

There are several literatures given by various researchers by using the combination of artificial neural networks with genetic algorithm to overcome the limitation of ANN. Karimi et. al.[23], found that combination of genetic algorithm and neural network(GA-NN model) is efficient in predicting the thermal properties of nanofluids in terms of accuracy and simplicity.

Salehi et. al. [24], observed the accuracy in prediction of thermal efficiency and thermal resistance by using genetically trained multi-layer perceptron neural network.

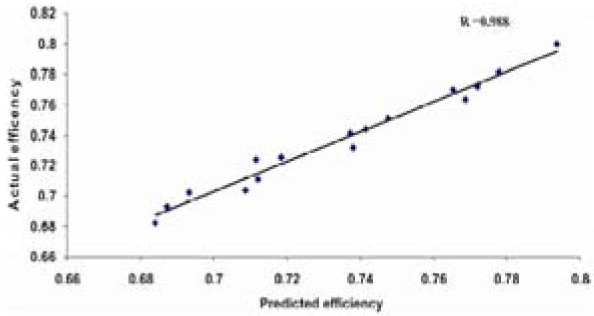

Figure 7: Thermal efficiency measurements versus GA-MLP network predictions for the test data. [24]

Fallah et. al.[25] used a combination of Resultant Polynomial Neural Networks (RPNN) with non-dominated sorting genetic algorithm(NSGA) to predict the objectives and various parameter values for heat transfer and pressure drop.

5. Conclusion

Nanofluids have great potential in all engineering applications and also in bio-medical applications due to its enriched thermo physical properties. Enrichment of thermal properties depends upon various parameters such as particle size, shape, temperature, volume concentration. Many mathematical models and experimental models were developed to predict the thermal properties of nanofluids. The major challenges exist are the discrepancies between the models and the financial requirements for the test runs. To mitigate the financial strength, now a day's various researchers investigating the thermal properties of nanofluids using soft computing tools. This paper is to review the soft computing tools used by various researchers to evaluate and validate the thermal properties of nanofluids. The goal of the this review paper is to gather the fundamental information about the thermal conductivity of nanofluids in a wide range and make use of those information in to knowledge and acquire the pattern hidden in the data. We conclude that few research works about the thermal conductivity and viscosity is reported using data mining soft computing tools and there is much scale is to investigate the nanofluids with soft computing tool.

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