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ARTICLE

Comparative analysis for the prediction of boiling heat transfer coefficient of R134a in micro/mini channels using artificial intelligence (AI)-based techniques

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ABSTRACT

Refrigerant R134a has been extensively used in the past because of its zero ozone depletion potential (ODP). In the present research, artificial intelligence (AI)-based gene expression programming (GEP), artificial neural networks (ANN) and support vector regression (SVR) models have been developed for the prediction of heat transfer coefficient for the boiling of R134a in micro/mini channels. The performances of developed models were compared and evaluated against the experimental results in terms of statistical parameters such as coefficient of determination (R^2) and average absolute relative error (AARE). The obtained results and findings from this research reveal that SVR is an effective technique for predicting the heat transfer coefficient of R134a, with lowest AARE value of 3.62% and a high R^2 value of 0.9749 in comparison with other AI-based models. Furthermore, performance of the ε-SVR with four different kernels: linear, polynomial, sigmoid and radial basis functions (RBF) have also been assessed in this paper.

Abbreviations: AARE: Average absolute relative error; AI: Artificial intelligence; ANN: Artificial neural networks; GEP: Gene expression programming; MRE: Mean relative error; RMSE: Root mean square error; SD: Standard deviation; SVM: Support vector machines; SVR: Support vector regression

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Ozone depletion potential (ODP); artificial intelligence (AI); support vector regression (SVR); coefficient of determination (R^2); average absolute relative error (AARE)

1. Introduction

In the past, hydrofluorocarbons (HFCs) were used for a variety of applications such as refrigerants for air-conditioning and refrigeration systems, in the production of polymer foams, as metered dose inhalers for asthma patients, as a fire extinguishing agent, as a solvent in plastics and metals cleaning, etc. R134a (Tetrafluoroethane) is the most widely used refrigerant in air-conditioning and refrigeration systems and is an able substitute for R-12 and R-21. R134a has zero ozone depletion potential (ODP) with high global warming potential (GWP). It is due to the high global warming effect that there is a need for refrigerants like R717 (ammonia), R170 (Ethane), R600a (Isobutane), R290 (Propane), R1270 (Propylene), etc. Besides being environmental-friendly, these refrigerants possess high flammability. Water (R718) with zero ODP and zero GWP can also be used as a natural refrigerant. It is non-toxic, non-flammable, non-explosive and the cheapest refrigerant. But water is more reactive and leads to corrosion and oxidation of various metals. Therefore, it requires special attention while choosing the right material for the R718 system during the design phase. Air (R729) can also be an alternative to HFCs having zero ODP and zero GWP but the coefficient of performance (COP) value of air is low. In spite of low COP, air has also been used as a refrigerant because of safety, non-toxicity, low weight, etc.

In the recent past, research efforts were devoted to environmental-friendly flow boiling hydrocarbons and many correlations in this regard can be found in the literature for predicting the heat transfer coefficient of these fluids [1–3]. Neither of the existing correlations predicts the heat transfer coefficient satisfactorily. The reason may be attributed to the fact that these correlations are not general and have been developed under different flow boiling conditions for different fluids. Shiferaw et al. [4] had conducted experiments and studied the flow boiling heat transfer mechanism of R134a with tube internal diameters of 4.26 mm and 2.01 mm for a wide range of parameters: mass flux 100–500 kg/m^2s; pressure 8–12 bar; quality up to 0.9; heat flux 13–150 kW/m^2. Further, Shiferaw et al. [5] extended their work for the same fluid R134a with 1.1 mm tube by varying the parameters in the range: mass flux 100–600 kg/m^2.s, heat flux 16–150 kW/m^2 and pressure 6–12 bar. A comparison of their experimental results with some of the existing correlations

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