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Research Paper

Using machine learning algorithms to predict the pressure drop during evaporation of R407C

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HIGHLIGHTS

- Pressure drop during evaporation of R407C has been studied experimentally.
- Machine learning algorithms have been developed to predict the pressure drop.
- MLFFNN, SVR, and GMDH methods have been implemented as intelligent methods.
- Pressure drop has been decreased by increasing in mass flux.
- MLFFNN and GMDH models outperform the SVR.

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ABSTRACT

The calculation of the pressure drop for two-phase flow in evaporation and condensation processes is required by a variety of design practices. In recent years, many correlations were developed in order to determine the pressure drop for two-phase flow. This process needs many experimental tests. Hence, in this study, it is proposed to apply machine learning algorithms (MLAs) to forecast the pressure drop for two-phase flow of R407C. Three methods of MLAs are developed with the purpose of pressure drop prediction in a smooth horizontal copper tube, for 4.5 mm and 8 mm inner diameter. These methods are multilayer feed-forward neural network (MLFFNN), support vector regression (SVR), and group method of data handling (GMDH) type neural network. Mass flux, tube diameter, saturation pressure, and vapor quality of the refrigerant are used as input variables of the models and the target is selected to be the pressure drop of evaporation. The results show that although the developed models can successfully predict the pressure drop of two-phase flow, MLFFNN and GMDH models outperform the SVR model in term of the correlation coefficient close to 1.

1. Introduction

In recent years, many investigations have been developed to increase the system efficiency in industrial applications [3,4]. The significant parameters to evaluate the performance of the heat exchangers are heat transfer coefficient along with pressure drop [5]. Phase change is often associated with heat transfer coefficients, but the affect on pressure drop should not be neglected, and it may be even more complicated than in the former [6]. Due to the two-phase flow complexity, the prediction of pressure drop is mostly done with empirical correlations and need many experimental tests. The effects of various parameters (such as vapor quality, saturation temperature, mass flux, heat flux, saturation pressure, tube diameter, and working fluid) on the pressure drop of two-phase flow have been investigated by many studies [7–9]. But the fact is that the high non-linearity of the two-phase flow makes the cause-effect relation difficult to assimilate, and the exam of numerical methods to estimate and predict friction losses has been frequently used. Pressure drop in two-phase flow has been investigated by several studies [10–14]. MLAs are defined as a new method to estimate the two-phase flow of pressure drop that create a non-linear relationship between the inputs to estimate the outputs.

Three methods of MLAs that have been considered to estimate the pressure drop in this study are MLFFNN, SVR, and GMDH models. Artificial neural networks are a new method of programming computers and are exceptionally good at performing pattern recognition and other tasks that are very difficult to program using conventional techniques. An ANN is a data processing pattern that is inspired by human brain [15]. The key element of this pattern is the novel structure of the data processing system [16]. The ANNs are able to catch hidden and strongly non-linear dependencies of two-phase flow [17]. Moreover, the wide

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Nomenclature

D	diameter (mm)
G	mass flux (kg/m^{2}s)
P_{sat} =	saturation pressure (bar)
R	correlation coefficient
x =	vapor quality
dp/dz	pressure gradient

Abbreviations

ANN	artificial neural network
GMDH	group method of data handling
MLA	machine learning algorithm
MLFFNN	multilayer feed-forward neural network
MAPE	mean absolute percentage error
MSE	mean square error
Purelin	linear transfer function
RMSE	root mean square error
SVR	support vector regression
SVM	support vector machine
Tansig	hyperbolic-tangent sigmoid

range of studies (such as heat transfer coefficient of two-phase flow [21]) have been developed based on ANNs methods. Support Vector Machines (SVMs) that have been developed by Vapnik [22] are classification and regression techniques, which optimize its structure based on the input data. This method has been applied in many applications of engineering systems, for example, for solar power forecasting [23–25] and wind speed prediction [26–29]. GMDH for the first time was introduced by Ivakhnenko [30] as a multivariate analysis approach for complicated systems modeling and recognition. This method with the algebraic approach of the progression avoids the complexity of obtaining former information [31]. Therefore this method will be applied to simulate complicated systems without having particular information of the systems. The main goal of GMDH network is actually to construct a function in a feed-forward network on the basis of a second-degree transfer function [32]. This investigation concentrates on pressure drop during evaporation of R407C refrigerant. R407C is an alternative to R22 that is a zeotropic blend of R32/R125/R134a (23/25/52 by wt%) and R32/R125 (50/50 by wt%) respectively. This refrigerant will be phased out in developed countries by 2020 and for developing countries in 2030 [33]. A great number of papers over forecasting pressure drop under two phase-flow have been published that a short summary of recent efforts of this subject is presented in the following.

Bar et al. [34] used artificial neural network (ANN) in order to predict the pressure drop for non-Newtonian liquid flow through piping components. They used multilayer perceptron (MLP) neural network that was trained with the backpropagation algorithm. Their proposed model accurately predicted the pressure drop with a regression coefficient more than 0.99. Alizadehdakhel et al. [35] implemented CFD simulation and ANN in order to predict the two-phase flow pressure drop. Gas and liquid velocities and tube slope were considered as inputs of the network and the pressure drop was selected as target. The comparison between the developed ANN and CFD simulation with experimental values illustrated that the CFD results are more accurate than ANN results. Also, prediction of two-phase frictional pressure drop using ANN for the air-water flow was done by Bar et al. [36]. Three different algorithms of MLPs (Backpropagation, Levenberg-Marquardt, and Scaled Conjugate gradient) were developed by them for predicting the target. The proposed model of ANN was accurately predicted the two-phase frictional pressure drop. Azizi et al. [37] used ANN to forecast the heat transfer coefficient during condensation of R134a in an inclined tube. The inputs parameters of the ANN were inclination angle, mass flux, saturation temperature, and mean vapor quality. Also, an MLP neural network was selected as the predicting model. It is reported the mean absolute percent error (MAPE) and correlation coefficient (R) respectively by 1.48% and 0.997 for training data and 1.94% and 0.995 for testing data.

In another study Azizi et al. [38] implemented ANN in order to obtain the void fraction for gas-liquid flow in horizontal, upward, and downward inclined pipes. A three-layer backpropagation algorithm was used to predict the target. The proposed model successfully predicted the target with MAPE of 1.81% and coefficient of determination (R^2) of 0.9976 for training data and MAPE of 1.52% and R^2 of 0.9948 for testing data. Deng et al. [39] proposed a neural network based on genetic algorithm for forecasting the normal boiling point of pure refrigerants. The calculated results that are based on the developed forecasting model illustrate a good agreement with the experimental results by reporting the MAPE for training, validating, and testing data

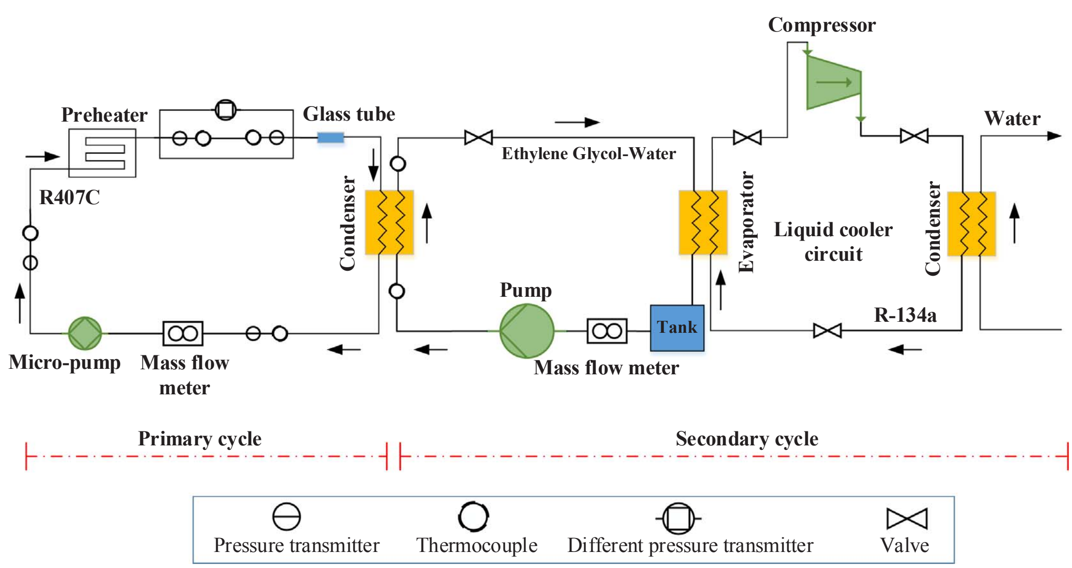

Fig. 1. Schematic diagram of the experimental setup.