chemengineering

MDPI

Article

Development and Analyses of Artificial Intelligence (AI)-Based Models for the Flow Boiling Heat Transfer Coefficient of R600a in a Mini-Channel

Nusrat Parveen, Sadaf Zaidi * and Mohammad Danish

Department of Chemical Engineering, Z.H. College of Engineering and Technology, Aligarh Muslim University, Aligarh, UP 202002, India; nusratalig@gmail.com (N.P.); mohddanish.chem@gmail.com (M.D.)

* Correspondence: sadaf63in@yahoo.com; Tel.: +91-941-121-2432

Received: 6 April 2018; Accepted: 11 June 2018; Published: 13 June 2018

check for updates

Abstract: Environmental friendly refrigerants with zero ozone depletion potential (ODP) and zero global warming potential (GWP) are in great demand across the globe. One such popular refrigerant is isobutane (R600a) which, having zero ODP and negligible GWP, is considered in this study. This paper presents the two most popular artificial intelligence (AI) techniques, namely support vector regression (SVR) and artificial neural networks (ANN), to predict the heat transfer coefficient of refrigerant R600a. The independent input parameters of the models include mass flux, saturation temperature, heat flux, and vapor fraction. The heat transfer coefficient of R600a is the dependent output parameter. The prediction performance of these AI-based models is compared and validated against the experimental results, as well as with the existing correlations based on the statistical parameters. The SVR model based on the structural risk minimization (SRM) principle is observed to be superior compared with the other models and is more accurate, precise, and highly generalized; it has the lowest average absolute relative error (AARE) at 1.15% and the highest coefficient of determination (R^2) at 0.9981. ANN gives an AARE of 5.14% and a R^2 value of 0.9685. Furthermore, the simulated results accurately predict the effect of input parameters on the heat transfer coefficient.

Keywords: ozone depletion potential; global warming potential; artificial intelligence; support vector regression; average absolute relative error

1. Introduction

The increasing demand for microelectronic devices in industrial and household applications, such as air-conditioning, refrigeration, and heat pumps, requires efficient heat removal techniques through micro- and mini-channels to resist high heat fluxes. Based on the hydraulic diameter, researchers have classified the flow channels as conventional channels (Dh $\geq$ 3 mm), mini-channels (3 mm $\geq$ Dh $\geq$ 200 µm), and micro-channels (200 µm $\geq$ Dh $\geq$ 10 µm) [1,2]. To better understand the boiling phenomenon in micro- and mini-channels, several studies have been done [3–5]. However, accurately modelling the boiling heat transfer coefficient in micro- and mini-channels is still a difficult task.

In the recent past, support vector machines (SVMs) have emerged as an artificial intelligence (AI) technique developed for classification purposes. However, its application has now been extended to regression [6–8]. Moreover, support vector regression (SVR) enjoys a lot of benefits over the traditional neural networks, such as the need to choose only a few parameters for modeling; avoiding over-fit to the data; and being a unique, global, and optimal solution.

In open literature, SVR has many applications for the prediction of many real-world problems, such as permeability predictions for hydrocarbon reservoirs [9], wind speed forecasting for wind farms [10], predicting for carbon monoxide in the atmosphere [11], predicting the heat transfer