Ingeniería Investigación y Tecnología, volumen XV (número 1), enero-marzo 2014: 93-101
ISSN 1405-7743 FI-UNAM
(artículo arbitrado)

Use of Artificial Neural Networks for Prediction of Convective Heat Transfer in Evaporative Units

Determinación de coeficientes del proceso de transferencia de calor en unidades de evaporación utilizando redes neuronales

Romero-Méndez Ricardo
Faculty of Engineering
Universidad Autónoma de San Luis Potosí
E-mail: rromerom@uaslp.mx

Durán-García Héctor Martín
Arid Zones Research Institute
Universidad Autónoma de San Luis Potosí
E-mail: hduran@uaslp.mx

Hidalgo-López Juan Manuel
Faculty of Engineering
Universidad Autónoma de San Luis Potosí
E-mail: juan_manuel_hidalgo@mailcity.com

Pacheco-Vega Arturo
Department of Mechanical Engineering
California State University-Los Angeles
E-mail: apacheco@calstatela.edu

Information on the article: received: July 2012, reevaluated: August 2012, accepted: February 2013

Abstract

Convective heat transfer prediction of evaporative processes is more complicated than the heat transfer prediction of single-phase convective processes. This is due to the fact that physical phenomena involved in evaporative processes are very complex and vary with the vapor quality that increases gradually as more fluid is evaporated. Power-law correlations used for prediction of evaporative convection have proved little accuracy when used in practical cases. In this investigation, neural-network-based models have been used as a tool for prediction of the thermal performance of evaporative units. For this purpose, experimental data were obtained in a facility that includes a counter-flow concentric pipes heat exchanger with R134a refrigerant flowing inside the circular section and temperature controlled warm water moving through the annular section. This work also included the construction of an inverse Rankine refrigeration cycle that was equipped with measurement devices, sensors and a data acquisition system to collect the experimental measurements under different operating conditions. Part of the data were used to train several neural-network configurations. The best neural-network model was then used for prediction purposes and the results obtained were compared with experimental data not used for training purposes. The results obtained in this investigation reveal the convenience of using artificial neural networks as accurate predictive tools for determining convective heat transfer rates of evaporative processes.

Keywords:

- artificial neural network
- thermal system
- heat transfer
- evaporative processes

Resumen

La predicción de la transferencia de calor en procesos de evaporación es una tarea complicada comparada con la de un proceso sin cambio de fase, ya que la física del fenómeno de evaporación es mucho más diversa y se modifica continuamente conforme la calidad del vapor aumenta. Las correlaciones tradicionales basadas en leyes de potencia que se utilizan para la determinación de la transferencia de calor en evaporadores han probado su falta de efectividad cuando se requiere la predicción correcta de absorción de calor del proceso de evaporación. En este trabajo se utilizaron modelos basados en redes neuronales artificiales para predecir el desempeño térmico de unidades evaporadoras y, para ello, se obtuvieron datos experimentales en un módulo de pruebas consistente en un evaporador tipo intercambiador de calor de doble tubo a contraflujo, por cuya sección circular fluye refrigerante R134a y por cuya sección anular fluye agua a una temperatura mayor controlada. Para determinar los datos experimentales se construyó un banco de pruebas basado en el ciclo Rankine inverso, el cual se equipó con instrumentos de medición, sensores y una tarjeta de adquisición de datos para el monitoreo de señales. Una parte de los datos obtenidos en los experimentos se usaron para entrenar a distintas configuraciones de redes neuronales a fin de obtener el mejor modelo. Este modelo se usó para efectos predictivos y los resultados obtenidos se compararon con datos experimentales que no fueron usados durante el entrenamiento de la red neuronal artificial. Los resultados obtenidos en esta investigación demuestran la conveniencia de usar redes neuronales artificiales para la determinación correcta de la transferencia de calor en procesos de evaporación de refrigerantes.

Descriptores:

- *redes neuronales artificiales*
- *sistemas térmicos*
- *transferencia de calor*
- *procesos de evaporación*

Introduction

Thermal systems are engineering systems that involve temperature differences. Heat transfer is devoted to the analysis, design and control of these systems, and has a long history of development in response to the needs of a great variety of applications. One of the modern technologies that has been successful as an analysis tool is the technique of artificial neural networks. This technique has been applied for pattern recognition, decision making, control systems, information processing, symbolic mathematics, computer vision and robotics. The use of artificial neural networks can be extended to a wide variety of disciplines, among which are the thermal sciences, because it allows to study complex thermal systems that otherwise would be impossible to characterize with conventional analytical techniques. Heat transfer is part of daily life of human beings; there is a need for buildings and homes that provide comfort minimizing energy losses. Artificial neural networks have been studied over the last decades and are an excellent option for modeling complex systems. Some of the thermal systems that have been studied with this technique are the prediction of heat transfer coefficients (Jambunathan *et al*., 1996), determination of Nusselt number (Thibault and Grandjean, 1991), prediction of heat transfer in heat exchangers (Díaz *et al*., 1996; Pacheco-Vega *et al*., 2002, 2001a, 2001b), estimation of heat transfer in the transition region of a circular tube (Ghajar *et al*., 2004), the thermal performance of cooling towers (Islamoglu, 2005), analysis of shell and tube heat exchangers (Wang *et al*., 2006), phase change in finned tubes (Ermis *et al*., 2007), friction and heat transfer in helically finned tubes (Zdaniuk *et al*., 2007), the modeling of evaporative air coolers (Hosoz *et al*., 2008), the characterization of compact heat exchangers (Ermis, 2008), the estimation of thermal performance of plate and tube heat exchangers (Peng and Ling, 2009), evaluation of finned tube condensers (Zhao and Zhang, 2010), performance of finned tube evaporators (Zhao *et al*., 2010) and indirect evaporative cooling (Kiran and Rajput, 2011). The *artificial neural network* (ANN) is a procedure that permits the modeling of complex systems that cannot be described with simple mathematical models. One of the main advantages is that it does not require a detailed knowledge of the physical phenomena describing the system under analysis. The principle of the ANN is based on the structure and functioning of neural systems, where the neuron is the fundamental element. There are neurons of different