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Hybrid evaporator model: Analysis under uncertainty by means of Monte Carlo method

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ABSTRACT

Error propagation from Monte Carlo method is applied to the heat transfer rate (Q) predicted by a hybrid model. This heat transfer rate permitted us to evaluate an evaporator used in a vapor compression refrigeration system. A hybrid model reported in literature was used in order to obtain error propagation in heat transfer rate prediction. The hybrid model used temperatures, mass flow rates and enthalpies from the evaporator. A correlation for the calculation of relative standard deviation (%RSD) of Q as a function of experimental Q (Q_{exp}) and %$RSD_{instrument}$ was obtained. The effect of each operation variable over standard deviation of the heat transfer rate is presented. Greater efforts in calibration and high-precision equipment in evaporator pressure are recommended in order to obtain meaningful heat transfer rate hybrid prediction with relatively small errors of less than 2.85%.

1. Introduction

Evaporator is a main component of several thermal and energy systems ranging from heat pumps, air conditioning system to power cycle. The modeling of an evaporator is complicated due to the presence of different characteristics: pressure drop, dry-out and subcooled regions, different liquid and vapor velocities, structure of void fraction, or thermal–hydraulic instabilities. Hydrofluorocarbon refrigerants are currently used in many evaporators as working fluids. R134a is receiving support from the refrigeration process due to its performance and because it is environment friendly. According to Ding et al. [1], evaporators have been modeled with different levels of complexity: black-box models, ε-NTU models based on [2,3] and distributed models, for instance the model presented by Morales et al. [4], all previous widely discussed in advantages and limitations by Ding et al. [1]. Several works reported in the literature are aimed to control and optimization of thermal devices, for instance, Vasickaninova et al. [5] described a control strategy based on artificial neural networks (ANN) and one simplified nonlinear dynamic model of heat exchanger.

The hybrid approach is a reasonable alternative for modeling, optimization and control of thermal devices. The methodology involves energy and material balance, structure of empirical models and a solution with a method of optimization. Wang et al. [6] and Jing et al. [7] developed a hybrid model for cooling coils and cooling towers considering single-phase flow. Ding et al. [1,8] presented a hybrid model to describe the heat transfer rate of an evaporator and condenser. In many cases, validation of physical models (empirical or theoretical) is based on simply comparing the predicted with the experimental results, without taking into account the respective uncertainties. To be able to solve this situation, appropriate confidence intervals of Q should be experimentally determined.

Traditionally, error propagation is determined with equations proposed by Bevington and Robinson [9]. Up to the Authors knowledge, several works applied a traditional or Monte Carlo method to calculate error propagation for their experimental results. Nevertheless, another alternative is to calculate error propagation of the model aimed to obtain the prediction quality. Monte Carlo method represents an alternative that involves repeated calculation of a quantity, varying each time the input data randomly within their stated prediction limits [10]. Anderson [10] described the Monte Carlo Method as inefficient due to long calculation time, but today due to the availability of faster computers, application of this procedure is not a difficult task. Indeed, Colorado et al. [11] used the Monte Carlo method to

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