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Coefficient of performance prediction by a polynomial of a heat transformer with two-duplex components

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HIGHLIGHTS

- Four polynomial models were developed to predict COP.
- Models presented an excellent agreement between experimental and simulated COP.
- The polynomial methodology could be used to simulate others absorption systems.

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ABSTRACT

Polynomial models were developed to predict the coefficient of performance of a heat transformer with a new compact design consisting of a generator-condenser and an absorber-evaporator with a heat load of 2 kW. The operational coefficients of performance ranged from 0.100 to 0.369. Temperature, pressure and concentration of a water lithium bromide solution were measured at different points of the inlet and outlet streams of the main components of the heat transformer. In order to build four polynomial models we calculated a correlation matrix and selected the best independent variables. The best polynomial model included inlet temperature in the generator, absorber-generator, and evaporator; output temperature in the absorber-generator, and pressure in the generator. The developed models showed an excellent correlation between experimental and simulated values of the coefficient of performance with a coefficient of determination $R^2 \geqslant 0.9910$.

1. Introduction

This research shows the use of a polynomial fitting method to predict the coefficient of performance of an absorption heat transformer built with compact components. The experimental database is obtained from the new design of an absorption heat transformer operating with a lithium/bromide solution mixture used by Morales et al. [1]. The purpose of this work is to provide faster and simpler solutions in order to obtain accurate predictions during the analysis of the heat transformer, instead of using complex equations.

Polynomial fitting is an attractive technique employed to estimate the degree of relationship between independent and dependent variables. Recently, thermal engineering processes and heat transfer problems have been solved with the aid of polynomial approaches. For instance, Bogdan and Constantin [2,3] used a polynomial fitting method to compute the solution of differential equations describing heat transfer by introducing a squared remainder minimization method (SRMM) as a straightforward and efficient way to compute approximate polynomial solutions for nonlinear heat transfer problems. Polynomials of 2nd, 3rd, 4th and 8th order are found and compared with others methods reported in the literature getting errors below 0.01. Bogdan and Constantin [3] computed analytical approximate polynomial solutions for some classes of Lane-Emden type equations. Polynomial results were

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Nomenclature

COP	coefficient of performance [–]
FM	mass flow $\left[\frac{kg}{s}\right]$
GTL	gross temperature lift
P	pressure [inHg]
P_{AB}	pressure in the absorber
P_{GE}	pressure in the generator
Q	heat load
R^2	coefficient of determination [–]
T	temperature [°C]
TinAB-GE	inlet temperature in the absorber-generator
TinCO	inlet temperature in the condenser
TinEV	inlet temperature in the evaporator
TinGE	inlet temperature in the generator
TinGE-AB	inlet temperature in the generator-absorber
ToutAB-GE	output temperature in the absorber-generator
ToutCO	output temperature in the condenser
ToutGE-AB	output temperature in the generator-absorber
X	concentration $\left[\%\frac{w}{w}\right]$
x	generic variable
XinAB-GE	inlet concentration in the absorber-generator
XoutAB	output concentration in the absorber
XoutGE	output concentration in the generator

Subscript

AB	absorber
AB-EV	absorber-evaporator
CO	condenser
EV	evaporator
exp	experimental
EXT	external
GE	generator
GE-CO	generator-condenser
in	entry
INT	internal
out	exit
sys	system

compared to analytical solutions, when available, and to numerical solutions using a Runge-Kutta 4th order method.

To the best of our knowledge, only the results obtained in [4,5,1] are comparable to ours. Castilla et al. [4] proposed the use of approximate models to reduce the required computing cost while allowing its use in real-time control systems, and decreasing the size of the sensor. Artificial neural networks and polynomials are compared and integrated in a control system with minimum energy consumption. Escobedo-Trujillo et al. [5] developed a polynomial model to predict the coefficient of performance of a water purification process integrated to an absorption heat transformer. The goodness of fit of the polynomial model is expressed by the coefficient of determination R^2 that was found to be 0.9919. The polynomial model is compared to an artificial neural network, reported in the literature, with a coefficient of determination R^2 of 0.9981. Morales et al. [1] presented an artificial neural network model with 127 adjusted coefficients (weight and bias) that predicts the coefficient of performance of an absorption heat transformer coupled to a water purification process with two duplex compounds. That model presented a coefficient of determination of 0.9969.

The differences between studies done in [4,5,1] and the present work are:

- The polynomial model of 7th order suggested by Castilla et al. [4] while we proposed a maximum polynomial model of 3rd order.
- A polynomial function to predict the coefficient of performance was heuristically determined by Escobedo-Trujillo et al. [5]. A matrix correlation suggestion was used to find the best possible polynomial function in this work. This way, the heuristic aspect decreased in the method performed by [5].
- In contrast with the analysis of one polynomial model performed by Escobedo-Trujillo et al. [5], our studies show the possibility of calculating several polynomial functions with higher coefficients of determination in relation with the experimental coefficient of performance.
- In [1], the coefficient of performance in the absorption heat transformer with duplex-function was predicted using artificial neural network model considering 16 operation variables in the input layer. In this research, we presented polynomial models for the same heat transformer using fewer operation variables to predict predict coefficient of performance.

2. System description and experimental

This section introduces the experimental system of our interest.

2.1. Main equipment

The experimental equipment consists of two duplex units: Absorber-Evaporator (AB-EV) and Generator-Condenser (GE-CO); that work by falling film contact. Both units contain concentric helical coils that are fed by a drop distributor; the coils have a rough finish to increase the heat transfer area. The Generator-Condenser, has two chambers that are joined by a cap that allows the flow of steam to the condenser, but prevents the condensate to return into the generator. The Absorber-Evaporator consists of a single camera that has two concentric coils and theirs respective distributors. Temperature sensors were installed in the shell side of both units to obtain the temperature profile of the film in different turns of the coil. Each unit has an eyehole to monitor the internal levels of solution in operation. The construction material is stainless Steel 316L. The equipment was designed for a heat load of 2 kW. Fig. 1 illustrates a schematic representation of the experimental equipment, an absorption heat transformer for water purification (AHTWP) with both duplex components. The main components stand upright to reduce the surface area. The approximate dimensions of the experimental equipment are (2.3 × 2 × 2) m^3. The whole unit was insulated with Armaflex to reduce heat losses.

Limiting conditions for the heat flux are shown in Table 1. Intervals of experimental temperature and solution concentration conditions are displayed in Table 2. The ranges of experimental mass flow and pressure conditions are shown in Table 3.

2.2. Auxiliary services

Auxiliary services fed heat and cold water to the AHTWP, while the heat source was simulated with two separate tanks that supply hot water by electric heaters, and heat was supplied to the generator and the evaporator. The heat source has a resistor connected to a voltage inverter to control the heat level. The system has a magnetic type process pump with a stainless steel body and a head of pump of 0.07 hp. The vacuum pump has a capacity of 0.1 Pa, with an air volumetric flow displacement of 5.3 $\frac{m^3}{h}$. Heat pumps

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