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Modelling the performance parameters of a horizontal falling film absorber with aqueous (lithium, potassium, sodium) nitrate solution using artificial neural networks

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ABSTRACT

An ANN (artificial neural network) model was developed to determine the efficiency parameters of a horizontal falling film absorber at operating conditions of interest for absorption cooling systems. The aqueous nitrate solution $LiNO_3 + KNO_3 + NaNO_3$ with salt mass percentages of 53%, 28% and 19%, respectively, was used as a working fluid. The authors created the ANN from the database they had compiled with the results of experiments that they had performed in a set-up designed and built for this purpose. The ANN structure consisted of 6 input variables: inlet solution and cooling water temperatures, cooling water and solution mass flow rates, absorber pressure and inlet solution concentration; 4 output variables which facilitated the assessment of the performance of the absorber: heat and mass transfer coefficients, absorption mass flux and the degree of subcooling of the solution leaving the absorber. The hidden layer contained 9 neurons which were determined by training and test procedures. The results showed that the deviation between the experimental data and the estimated values was well adjusted. This indicated that the ANN model was an effective tool for predicting the efficiency parameters of the absorber. The solution flow rate was also observed to be the most significant operating variable which affected the performance of the absorber.

1. Introduction

Recent research works reported on absorption cooling systems focus on improving the COP (coefficient of performance) by using advanced cycle configurations and compact equipment. Triple-effect absorption cooling cycles represent a substantial improvement in performance when compared with double-effect absorption cycles. Nevertheless, triple-effect cycles face more difficulties with working fluids and construction materials because they need to support temperatures of over 180 °C. Álvarez et al. [1] developed a simulation model for the triple-effect absorption cooling cycle called “Alkitrate topping cycle” shown in Fig. 1. The triple-effect cycle consists of a parallel double-effect cycle with $H_2O/LiBr$ as a working fluid and a single-effect cycle with an aqueous nitrate solution as a working fluid. These are coupled through the heat exchanged between external streams. The aqueous nitrate solution composed of $LiNO_3$, KNO_3, $NaNO_3$ with mass percentages of 53%, 28% and 19%, respectively, was used. Davidson and Erickson [2] proposed the use of this mixture as a working fluid in absorption chillers driven by high temperature heat sources. Later, Erikson and Howe [3] called this working fluid “Alkitrate”.

The absorber is usually the largest component in absorption cooling systems. An improvement in the absorption process leads to a reduction in area of the heat exchangers, and therefore a significant reduction in the costs of absorption chillers. For this reason, many researchers have focused their theoretical and experimental studies on the simultaneous processes of heat and mass transfer which take place in the absorber. In those absorption cooling systems which use water as a refrigerant and a non-volatile substance as an absorbent, the falling film absorber is generally the most frequently used design. This is because it achieves high values of heat and mass transfer coefficients in the falling film region of the solution and the pressure drop values are acceptable for the pressure conditions of this equipment. Therefore, many experimental

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Nomenclature

a_{exp}	experimental value (target)
a_{sim}	value obtained from the simulation with the neural network
b	intercept in the slope-intercept statistical test
b_1	bias vector of the ANN input layer
b_2	bias vector of the ANN output layer
COP	coefficient of performance
h_s	falling film heat transfer coefficient ($W.m^{-2}.°C^{-1}$)
i	counter of the number of data
I	total number of input variables to the ANN
IR	relative influence of an input variable on the output variable of the ANN (%)
IW	matrix weight of the ANN hidden layer
J	total number of neurons in the hidden layer
k_m	overall mass transfer coefficient ($m.s^{-1}$)
LW	matrix weight of the ANN hidden layer
m	slope in the slope-intercept statistical test
m_{abs}	absorption mass flux ($kg.s^{-1}.m^{-2}$)
m_c	cooling water mass flow rate ($kg.s^{-1}$)
N	number of data
P_{abs}	absorber operating pressure (kPa)
P_i	normalized input variable
r^2	linear regression coefficient
rmse	root mean square error
$T_{c,in}$	cooling water temperature at the absorber entrance (°C)
$T_{s,in}$	solution temperature at the absorber entrance (°C)
$x_{s,in}$	solution concentration in salts at the absorber entrance (mass fraction)

Greek letters

$\Delta T_{sub,out}$	degree of sub-cooling of the solution leaving the absorber (°C)
Γ	solution mass flow rate per unit of wetted tube ($kg.m^{-1}.s^{-1}$)

Subscripts

I	number of neurons in the inlet layer
Inf	lower limit
J	number of neurons in the hidden layer
K	number of neurons in the output layer
min	minimum value
max	maximum value
sup	upper limit

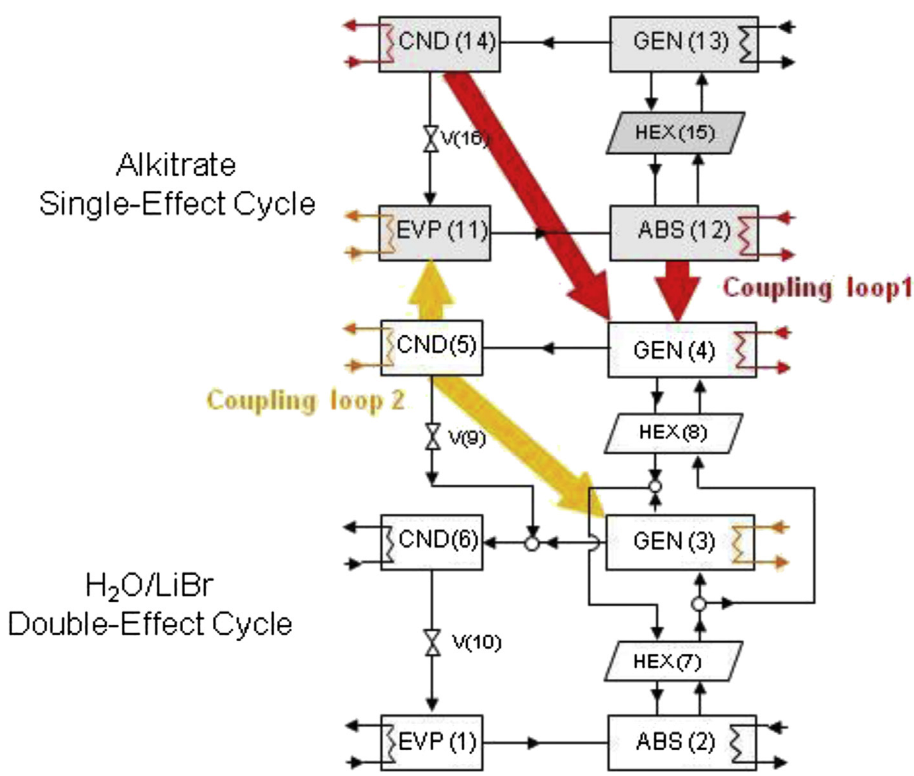

Fig. 1. Configuration of the triple-effect absorption cooling cycle with a high temperature Alkitrate stage [1].

investigations focus on falling film absorbers with horizontal tubes and most use H_2O/LiBr as a working fluid.

The most complex aspect of the study of absorbers is the heat and mass transfer processes which occur simultaneously. One of the main difficulties encountered in developing a mathematical model for the absorption process is the definition of the boundary conditions at the liquid–vapour interphase. The thermal effects associated with mass transfer during the absorption process also affect the pressure, the concentration and in turn the mass transfer. Some authors proposed the use of experimental correlations to describe heat and mass transfer processes. These correlations require the calculation of dimensionless numbers, the type of equation that defines the relation between these parameters and finally an analysis of the regression between the variables [4]. It is