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A dynamic simulation model for transient absorption chiller performance. Part II: Numerical results and experimental verification

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ABSTRACT

This paper is the second paper out of two which present the development of a dynamic model for single-effect LiBr/water absorption chillers. The first part describes the model in detail with respect to the heat and mass balances as well as the dynamic terms. This second part presents a more detailed investigation of the model performance, including performance analysis, sensitivity checks and a comparison to experimental data. General model functionality is demonstrated.

A sensitivity analysis gives results which agree very well to fundamental expectations: it shows that an increase in both external and internal thermal mass results in a slower response to the step change but also in smaller heat flow oscillations during the transient period. Also, the thermal mass has been found to influence the heat flow transients more significantly if allocated internally. The time shift in the solution cycle has been found to influence both the time to reach steady-state and the transients and oscillations of the heat flow. A smaller time shift leads to significantly faster response.

A comparison with experimental data shows that the dynamic agreement between experiment and simulation is very good with dynamic temperature deviations between 10 and 25 s. The total time to achieve a new steady-state in hot water temperature after a 10 K input temperature step amounts to approximately 15 min. Compared to this, the present dynamic deviations are in the magnitude of approximately 1–3%.

Modèle de simulation dynamique utilisé pour la performance transitoire d'un refroidisseur de liquide. Partie II : résultats numériques et vérification expérimentale

Mots clés : Refroidisseur de liquide ; Système à absorption ; Eau-bromure de lithium ; Modélisation ; Performance ; Régime transitoire ; Comparaison ; Simulation ; Expérimentation

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Nomenclature

Variables

A	area (m^2)
A	Duehring factor (°C)
B	Duehring factor (–)
c	specific heat capacity ($kJ\,kg^{-1}\,K^{-1}$)
c	number of simulation steps representing time constants for transport delay (–)
D	dew point temperature (°C)
g	gravity constant ($N\,m^2\,kg^{-2}$)
h	height difference between generator outlet and absorber inlet (m)
h	enthalpy ($kJ\,kg^{-1}$)
l	specific heat of solution ($kJ\,kg^{-1}$)
$m, \dot{m}$	mass flow rate ($kg\,s^{-1}$)
M	mass (kg)
p	pressure (Pa)
$\dot{Q}$, Q	heat flux (kW)
r	evaporation enthalpy ($kJ\,kg^{-1}$)
R	gas constant for water vapour ($J\,kg^{-1}$)
T	temperature (°C)
t	time (s)
UA	heat transfer coefficient ($kW\,K^{-1}$)
x	solution mass fraction ($kg_{Salt}\,kg_{Sol}^{-1}$)
X	mole ratio (–)
z	solution level in generator sump (m)

Greek letters

η	effectiveness (–)
ρ	density ($kg\,m^{-3}$)
Δ	difference (–)
ϑ	temperature (°C)

Indices

A	absorber
Acc	cooling water inlet
Ach	cooling water outlet
C	condenser
d	Duehring
E	evaporator
Eh	chilled water inlet
Ec	chilled water outlet
ext	external
G	generator
Gc	hot water outlet
in	inlet
int	internal
meas	measured
p	pump
p, pc	at constant pressure
s	strong
sim	simulated
sol	solution
st	storage
SHX	solution heat exchanger
sG	strong solution leaving the generator tube bundle
sA	strong solution leaving the generator sump and entering the absorber
t	tube
tb	tube bundle
out	outlet
v	vapour
w	water, weak
wA	weak solution leaving the absorber tube bundle
wG	weak solution leaving the absorber sump and entering the generator
X	general index for vessels ($X = A, C, E, G$)

1. Introduction

This paper describes the performance and experimental verification of a dynamic absorption chiller model. In Kohlenbach and Ziegler (2007), the model itself was described with regard to dynamic effects, such as transport delays in the solution circuit, thermal storage and mass storage. In detail, the size of the solution sumps in absorber and generator, the time for the solution to flow from absorber to generator and vice versa and the thermal mass of the main components has been accounted for. As a special feature, the thermal mass of the components has been split into two parts, one which responds to the temperature of the external fluids, and the other which responds to the temperature of the solution and the refrigerant (internal fluids). These are the main parameters which determine the dynamic behaviour of the chiller.

This second paper is looking at internal consistency, sensitivity and accuracy of the model. Results of a performance analysis using ideal conditions to prove correct model behaviour are shown. A sensitivity analysis on thermal storage and solution transport delay has been performed to investigate the influence of the dynamic parameters on the chiller performance. Finally, a model verification using experimental results is also given in this paper.

2. Performance analysis

The internal consistency of the model can be analysed by applying a step change to one of the external parameters in the model. A step from 75 °C to 85 °C in the hot water inlet temperature has been used for this purpose. Cooling and chilled water inlet temperatures have been kept constant at 27 °C and 18 °C, respectively. The simulation interval was 1 s. The temperature step was set at 200 s after simulation starts. This time period is necessary because the preset steady-state is not exactly met by the model: after starting the simulation first the steady-state with the given input values has to be reached. Two hundred seconds are enough in order to equalize the differences between initial and steady-state values.