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Modelling an absorption system assisted by solar energy

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ABSTRACT

This paper studies the global modelling of an absorption system working with LiBr–H_2O assisted by solar energy. It satisfies the air-conditioning necessities of a classroom in an educational centre in Puerto Lumbreras, Murcia, Spain. The absorption system utilises a set of solar collectors to satisfy the thermal necessities of the vapour generator. Several models have been developed for the characterisation of the absorption equipment, one of them based on the manufacturer data catalogue and the others based on neural networks. These are based on the Adaptive Resonance Theory. They are proved to predict the outlet temperature of the absorption system with efficiency. The experimental data obtained during two years of performance have been used for training and validation. For the dynamical simulation of the global system, TRNSYS software is proposed. The model can easily be programmed in Fortran and included in TRNSYS code. The paper is closed drawing some conclusions.

1. Introduction

The main concern of this paper is the study and development of robust models for carrying out the energy analysis of refrigeration equipments assisted by solar thermal energy. The framework in which this development is included, began to be defined in 2005, through a collaboration agreement signed between the Energy Management Agency of the Region of Murcia (ARGEM) and the companies Isofotón S.A. (www.isofoton.com) and Rotartica (www.rotartica.com). The aim of this is to construct and monitor an absorption refrigeration system assisted by solar thermal energy and settle down in the Region of Murcia with the objective of promoting the development and use of such equipments in the Region. The high levels of insolation in the Southeast of Spain during the whole year make the use of thermal energy equipments very attractive, especially for solar assisted air-conditioning systems. As a result of this, a collaboration agreement was signed between ARGEM and the Puerto Lumbreras City Hall. A system with these characteristics which supplies air-conditioning for several classrooms in a local Education Centre was decided to be constructed.

The interest in absorption refrigeration systems has increased in recent decades due to the possibility of using waste heat from gas and steam turbines or renewable energies, solar energy in this case. In addition, they do not contribute to the ozone depletion or to global warming. Aware of the interest in these equipments, a more ambitious plan promoted by ARGEM and the Institute for Diversification and Energy Saving was developed during 2007. Due to this plan, several facilities following the same principles as those in Puerto Lumbreras have been designed and are going to be constructed. One of them is being constructed at the Technical University of Cartagena, Spain which will satisfy the heating and air-conditioning in classroom N.0.1, in block no.2 on the Alfonso XIII Campus. Considering the experience of Puerto Lumbreras and the availability of data, a model was thought to be helpful in the design process of the new facilities. Other experiences with Rotartica systems should also stand out [1,2].

In this paper, several models for single-effect absorption systems which work with a mixture of LiBr–H_2O are studied. They use solar energy to separate the refrigerant from the absorbent in the vapour generator and utilise air as heat sink for the condensation. As mentioned above, the system satisfies the cooling necessities of three classrooms in a Puerto Lumbreras education centre. To carry out the modelling, the manufacturer data catalogue and the experimental data measured during the equipment operation in 2006 and 2007 are used. TRNSYS modules, IISIBAT and PREBID will also be used in future works to model the global system and analyse the refrigeration loads of the building. The absorption system model developed can be integrated in a global model and be used during the air-conditioning system design.

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Nomenclature

a	FasArt/FasBack input vector
b	FasArt/FasBack output vector
c_p	specific heat at constant pressure (J/(kg K))
COP	coefficient of performance
F	unit level
h	convective heat transfer coefficient (W/(m^2 K))
I	solar irradiation (W/m^2)
I	normalized vector
k	thermal conductivity (W/(m K))
L	length (m)
$\dot{m}$	mass flow rate (kg/s)
Q	heat transfer (kW)
r	radius (m)
R	regression coefficient
T	temperature (°C, K)
U	overall heat transfer coefficient (W/(m^2 K))
x	unit activation
y	general variable
y	unit activation
W	unit weight vector

Subscripts

a	inertia circuit
a	ARTMAP module
b	ARTMAP module
amb	outdoor conditions
c	cold fluid, cold water circuit
frio	related to refrigeration
gen	related to vapour generator
h	hot fluid
i	input, inlet
i	unit number
k	unit number
max	maximum
min	minimum
o	outlet
w	water

Greek symbols

ρ	matching parameter
ϵ	efficiency
$\varnothing$	diameter

Weather data have been provided by the centre of the National Institute of Meteorology in Guadalupe, Murcia. In particular, a database of radiation, humidity and dry-bulb temperature with series of about 10 years has been used.

The system analysed does not use another energy resource when the absorption equipment cannot provide the necessary energy to the vapour generator. In addition, it has not got a cooling tower which makes it quite appealing from the legionella point of view.

In this work, three different models are provided to analyse the absorption system. One of them is based on the manufacturer data and the others are based on neural networks. The use of neural networks for the characterisation of thermal systems and the estimation of thermal variables is not new [3–6]. The internal behaviour of the absorption system is not known, but despite this, global models are expected to be enough to help the designer throughout the design stage. These models are restricted to systems based on the ROTARTICA system.

A further objective of the work carried out is to analyse several improvements which could be included in the new designs. This will be included in a future work. To do so, the program TRNSYS will be used as was said above. The models presented herein will be used for this study.

The paper has been structured as follows: the facility and the different elements which comprise it are briefly described; special attention is paid to the absorption machine modelling; three different approximations are proposed and will be implemented in TRNSYS in the future; these models with those corresponding to the rest of the devices which compose the facility can be assembled in the IIsiBat environment to study the global system, and finally, several improvements of the system are analysed and some conclusions are drawn.

2. Global system description

To model the thermal behaviour of the system, the elements shown in Fig. 1 will be taken into account. The objective is to develop a global model which assists the designer in the study of refrigeration systems like this, based on the Rotartica's absorption systems.

Three different circuits may clearly be differentiated: Circuit 1 which connects the solar collectors to the inertia tank; Circuit 2 which connects the tank to the absorption system; and finally, and Circuit 3 which is used to send cold water to the fan-coils inside the classrooms.

The weather conditions of the place where the facility is settled are introduced by using the data provided by the centre of the National Institute of Meteorology in Murcia. They will be used to determine the outdoor conditions (solar radiation, long wave radiation, temperature, humidity, sky fictive temperature, and so on).

The solar collectors used in this facility are characterised by an efficiency curve

$$\epsilon = 0.75 - 4.5\frac{T_i - T_{amb}}{I}$$

For the sake of simplicity and as they are not known, the fan-coils in the systems have been modelled by using a simple model just considering constant efficiency heat exchangers. Thus, if the mass flow rates $\dot{m}_c \dot{m}_h$, and the input temperatures T_{ci}, and T_{hi} are known and the energy balance equations are taken into account

$$Q = \dot{m}_h c_{ph}(T_{hi} - T_{ho})$$

$$Q = \dot{m}_c c_{pc}(T_{co} - T_{ci})$$

$$\epsilon = \frac{Q}{(\dot{m}c_p)_{min}(T_{hi} - T_{ci})}$$

If $Q_{max} = (\dot{m}c_p)_{min}(T_{hi} - T_{ci})$ the outlet conditions can be calculated by

$$T_{ho} = T_{hi} - \frac{\epsilon Q_{max}}{\dot{m}_h c_{ph}} \text{ y } T_{co} = T_{ci} + \frac{\epsilon Q_{max}}{\dot{m}_c c_{pc}}$$

The inertia tank has a volume of 1500 l. The tank is isolated and its loss overall heat transfer coefficient is 0.014 W/(m^2 K). The stratification of the tank has been taken into account.

The flow rates in the circuits have been considered constant in the analysis of the global system. A value of 33 l/min is considered in Circuits 1 and 2 and 40 l/min in Circuit 3.