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Simulation studies on GAX absorption compression cooler

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Abstract

This paper presents simulation studies conducted on a GAX absorption–compression (hybrid) cycle using ammonia–water as working fluid for air conditioning applications. The degassing range of the cycle has been optimized for maximum COP. The effect of absorber pressure on the heat duties of the cycle has also been studied. It is found that the maximum COP occurs at an optimum degassing range of about 0.4 kg of ammonia per kg of strong solution. Comparison of hybrid and conventional GAX cycle was conducted, and it was found that the hybrid GAX cycle has an average of 30% higher value of COP than the conventional GAX cycle. A reasonable agreement is observed between the results and performance parameter trends obtained from the present study and the published results available in the literature.

Keywords: GAX; Ammonia–water; Degassing range; Compression–absorption; Simulation

1. Introduction

The GAX (generator absorber exchange) absorption cycle is an elegant way of achieving higher coefficient of performance (COP) with a cycle configuration that essentially appears to be a single stage absorption system. In the absorber and generator, the pressures and concentrations are maintained in such a way as to cause a temperature overlap between the absorber and the generator. This provides the possibility that some of the heat of absorption may be rejected to the generator. Several theoretical and experimental works have been performed on the GAX cycle and reported in the literature. Using ABSIM-OSU software Priedeman and Christensen [1] modeled a GAX cycle ammonia–water absorption chiller of 5 ton capacity and calibrated the simulation model using experimental data. In the first stage, the cycle was optimized by parametric variations. In the second stage, the model was calibrated using the experimental data. The calibrated model was readjusted to get the desired results in the final stage. Experimental validation showed a 0.5 percentage difference of COP value between the simulation and experiment. Staicovici [2] introduced a new method to analyze a polybranched regenerative GAX cycle. NH_3/H_2O–LiBr was selected as a working fluid due to its increased solubility at elevated temperatures. The author claims that the three stage polybranched regenerative GAX cycle gives 1.9 times higher COP and 82% of the Carnot cooling efficiency for the lift of 47 °C. However, economic analysis for the choice of working fluid was not justified. Also, The Carnot COP does not address the internal heat exchange in the GAX cycle [3].

Velázquez and Best [4] proposed a methodology to evaluate the thermodynamic performance of an air cooled GAX cycle driven by natural gas and solar energy. For the specified design conditions, they calculated the properties at different state points and the energy transfer of the components based on external currents. The methodology also using an iterative procedure for the internal currents and convergence was achieved. The model does not consider the pressure losses. A COP value of 0.86 for cooling

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Nomenclature

Q	heat flow (kW)
f	circulation ratio
T	temperature (C or K)
P	pressure (kPa)
C	specific heat (kJ/kg K)
W	power (kW)
U	overall heat transfer coefficient (W/m^2K)
A	heat exchanger area (m^2)
CW	compressor work (kW)
v	specific volume (m^3/kg)
h	specific enthalpy (kJ/kg)
m	mass flow rate (kg/s)
rc	refrigerant concentration
ssc	strong solution concentration
wsc	weak solution concentration
e	effectiveness of heat exchanger
n	compression index
k	clearance ratio
RHX	condensate pre-cooler
GAX	generator absorber heat exchange
GAX A	GAX absorber
GAX D	GAX desorber
PGAX	panel heating GAX cycle
PSE	panel heating single effect cycle

Greek symbols

η	efficiency
ξ	degassing range

Subscripts

a	absorber
g	generator
e	evaporator
p	pump
c	condenser
hf	hot fluid
cf	cold fluid
gt	total generator
rq	required
at	total absorber
av	available
r	refrigerant
s	strong solution
w	weak solution
L	liquid
V	vapour

and 1.86 for heating together with an energy integration of 16.9 kW was obtained for a 10.6 kW cooling capacity. Garimella et al. [5] studied the performance of a GAX heat pump for both cooling and heating modes using the OSU-ABSIM simulation program. It was shown that for a given capacity, the gas input based COP can be maximized based on the UA variation of heat exchanging components of the cycle. Also, it was demonstrated that the choice of desorber bypass fraction primarily depends on the design requirements of the adiabatic analyzer, rather than being based on the potential heat duty matching between the GAX absorber and desorber. A performance simulation considering both the cooling and heating modes as functions of the operating parameters using ABSIM was investigated on a Phillips configuration GAX heat pump by Grossman et al. [6]. They identified the effect on COP of the heat rejection temperature and equilibrium deviations. Three control schemes were attempted to maintain a fixed COP. With the assistance of a Lorentz type plot, they arrived at the optimum flow rate of coolant in the GAX heat transfer loop.

Kang et al. [7] established a theoretical model for the rectifier in the GAX absorption heat pump. Three different rectifier configurations were considered for study in this work. Their investigations revealed that a minimum temperature difference between the interface and bulk regions and a high heat transfer coefficient in the vapour region reduces the size of the rectifier. Hanna et al. [8] analyzed the GAX cycle processes by introducing the pinch point technique. They showed that by knowing the closeness of the state points of the heat recovery processes, an economic design trade off of cycle components could be achieved. Scharfe et al. [9] analyzed the advantages and limitations of the GAX cycle. An equation for the heat of desorption was derived, and it showed that at any temperature interval, the heat demand in the desorber is higher than the heat supplied by the absorber. It was observed that the exergy losses were high due to the high temperature range of the heat exchange process. Kang et al. [10] developed an advanced GAX cycle for utilization of waste heat, which was called the waste heat GAX (WGAX) cycle. They reported that the generator outlet could be reduced to 172 °C with a higher COP of the WGAX cycle than that of the standard GAX (SGAX) cycle. They presented that the corrosion problem in the standard GAX cycle at higher T_g than 200 °C could be solved by adopting the WGAX cycle. Sabir et al. [11] studied the GAX-resorption refrigeration cycle model. They showed that the COP of the GAX-resorption cycle is higher than that of the simple absorption and resorption cycle. Although the cost analysis was not reported, it is understood from the discussion that the simple GAX cycle is less expensive and gives a better COP than the GAX-Resorption cycle. Kang and Kashiwagi [12] developed a GAX cycle for panel heating, which was called the PGAX cycle. They studied the effects of UA ratio and coolant split ratio on COP in the PGAX and PSE cycles and concluded that there is an optimum UA ratio that gives the highest COP in the PGAX cycle