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Heat transfer studies on a GAXAC (generator-absorber-exchange absorption compression) cooler

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ABSTRACT

A detailed heat transfer model of GAXAC (generator-absorber-exchange absorption compression) cycle using ammonia–water as working fluid is reported. The effect of UA (heat transfer conductance, kW/K) of each component on COP and cycle capacity is investigated. The results show that UA of the absorber and high temperature generator (HTG) have significant impact on COP and cycle capacity. For a capacity of 11.56 kW, the maximized COP with minimum UA value for all heat exchanging components is found to be 1.185. Further the effect of mass flow rate and inlet temperatures of hot fluid, chilled water and cooling water are also investigated.

1. Introduction

In recent times several investigations of GAXAC (generator-absorber-exchange absorption compression) cycle get reported in the literature [1–4]. Medrano et al. [5] discussed the potential of the organic fluid mixtures trifluoroethanol (TFE)–tetraethylenglycol dimethylether (TEGDME) and methanol–TEGDME as working pairs in series-flow and vapor exchange double-lift absorption cycles. They found that in vapor exchange double-lift cycle, TFE-TEGDME pair gives better COP and in the series-flow double-lift cycle, methanol-TEGDME pair gives best COP. However, low circulation rate and low minimum generator temperature requirement of the TFE-TEGDME makes it in to the most promising working fluid. Wu and Eames [6] described operation and design of innovative vapor absorption cycles. They discussed the merits and the limitations of the multi-stage, multi-effect absorption cycles, GAX absorption cycles, Hybrid absorption cycles and ejector in the absorption cycles. Also they discussed the recent work on the binary working fluids for the absorption cycles. These works discuss the thermodynamic performance of the cycle. For a more complete understanding of absorption cycle, it is necessary to analyze the system based on heat exchanger model. McGahey and Christensen [7] employed ABSIM (absorption simulation) to simulate 35.2 kW GAX (generator-absorber-exchange) heat pump cycle which employs counter flow heat and mass exchange between the liquid and vapor in both the GAX absorber and GAX desorber. In this cycle an external liquid loop is used to transfer the heat from the GAX absorber to GAX desorber. They optimized the heat exchanger size using LMTD (log mean temperature difference) in conjunction with UA (heat transfer conductance, kW/K) to characterize them.

A detailed investigation using ABSIM was conducted on GAX heat pump by Hanna and Whitacre [8] based on the cycle configuration of Modahl and Hayes [9]. This configuration omits external loop between the GAX absorber and GAX desorber. Thus it employs co flow mass and heat exchange in the GAX desorber while maintaining counter flow mass and heat exchange in the GAX absorber. 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. [10]. 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.

Garimella et al. [11] 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,

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rather than being based on the potential heat duty matching between the GAX absorber and desorber. Yoon and Kwon analyzed [12] an air-cooled, double-effect absorption system using the new $H_2O/LiBrHO(CH_2)_3OH$ solution. The simulation of heat exchangers revealed that the UA values of absorber and evaporator were relatively more important for an air-cooled system compared with the condenser and the low temperature generator.

Kang et al. [13] compared absorption cycles using H_2O–LiBr and NH_3–H_2O solutions are to the solution transportation absorption system applications. They found that in the H_2O–LiBr solution transportation absorption system, the overall conductance (UA) of the system has greater effect on the capacity than it does on the COP. The UA of the rectifier has the most significant effect on the COP and the capacity of the NH_3–H_2O solution transportation absorption system. Kang and Kashiwagi [14] 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 (panel heating single effect) cycles and concluded that there is an optimum UA ratio that gives the highest COP in the PGAX cycle for a given split ratio. For a 61.25 kW capacity, this analysis gives the optimum UA values of the absorbers for the split ratio of 0.87.

Anand et al. [15] provided a comprehensive analytical screening of secondary fluids performance in GAX heat pump based on their thermo physical properties. With the specified value of UAs, and other operating parameters, they found that calcium chloride and potassium formate solutions are promising secondary fluids. Kang et al. [1] developed four different GAXAC cycles. In this modeling, UA of each component is fixed for parametric analysis. By controlling the pressure of the heat exchanging components, their study showed that a higher COP, very low evaporator temperature with reasonable COP, corrosion minimization at higher generator temperatures and an increase of hot water outlet temperature can be achieved.

The above literature review reveals that although many works have been conducted to analyze the performance of the basic GAX cycle based on heat transfer model, few attempts have been made to analyze the GAXAC cycle. In an absorption cycle, increases in UA of different heat exchangers affect the system COP and capacity. Thus, a judicious choice of a set of heat exchangers for an absorption system requires that the system performance be investigated for different combinations of heat exchanger sizes [11]. It is also necessary to analyze the GAXAC system by varying the values of hot fluid, cooling and chilled water flow rates for maximizing the performance. Further the effect of generator heat input temperature in the modeling of the GAXAC system is yet not well documented. Thus in the present study the ammonia–water GAXAC system is modeled as a function of UAs, mass flow rates and input temperatures of hot fluid, cooling water and chilled water.

2. Description of GAXAC cycle

Fig. 1 illustrates the main components of the GAXAC refrigeration cycle. Hot ammonia weak solution leaves the generator (1) and cold ammonia strong solution leaves the absorber (23) and saturated ammonia liquid is assumed to leave the condenser (16). Saturated vapor is assumed to leave the evaporator (21). The high purity ammonia vapor evolved in the rectifier by partial condensation and heat rejection, enters (15) the condenser. The saturated ammonia liquid from the condenser (16) get sub cooled in the condensate pre-cooler (17) and then enter into the evaporator in two phase cooled mixture (18) through an expansion valve that reduces the pressure of the refrigerant to the evaporator pressure. The liquid refrigerant vaporizes in the evaporator by absorbing heat from the room being conditioned and the resulting low-pressure saturated vapor (21) goes to the compressor (22)

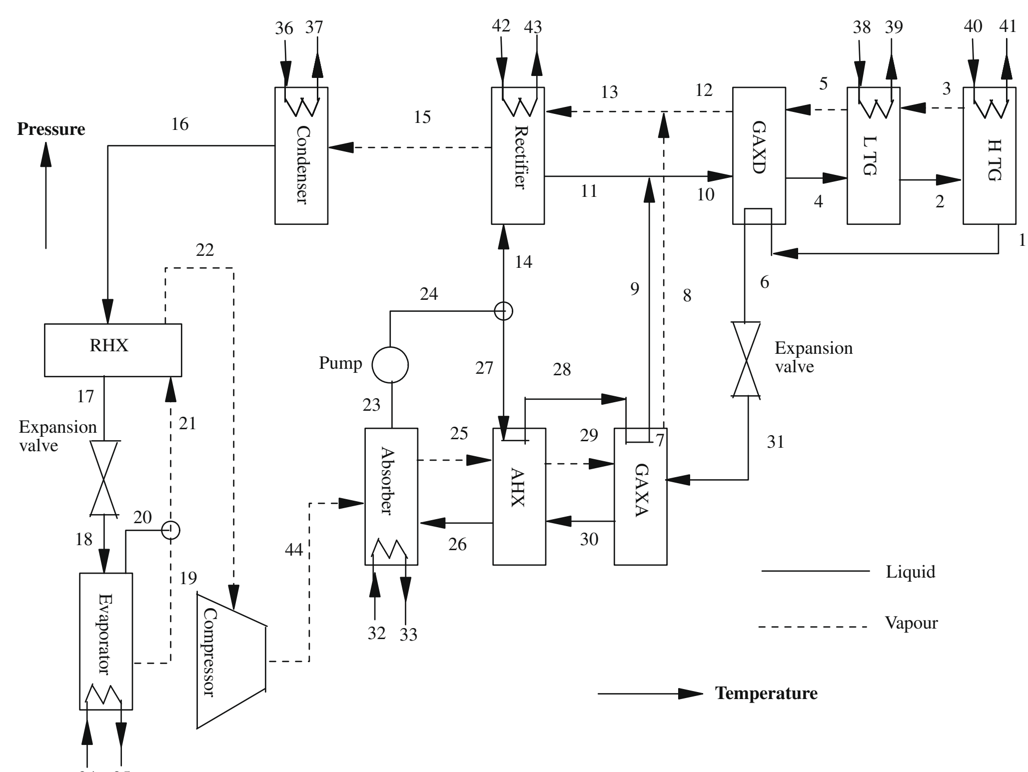

Fig. 1. Schematic diagram of GAXAC cycle.