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Performance analysis of advanced hybrid GAX cycles: HGAX

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Abstract

The objectives of this paper are to develop advanced hybrid GAX cycles (HGAX) using NH_3–H_2O by combining absorption and vapor compression cycles, and to perform parametric analysis of system pressures and component sizes for performance enhancement. Four different HGAX cycles are developed—Type A (Performance improvement), Type B (Low temperature applications) Type C (Reduction of desorption temperature) and Type D (Hot water temperature applications). A compressor is placed between the evaporator and the absorber in Type A and Type B, and placed between the desorber and the condenser in Type C and Type D. It is found that the COP can be improved by 24% compared with the standard GAX cycle (in Type A) and the evaporation temperature of as low as −80 °C can be obtained from the HGAX cycle (Type B). In Type C, the maximum desorption temperature can be reduced down to 164 °C. Therefore, the corrosion problem, which becomes severe at higher temperature 200 °C, can be completely removed. The maximum desorption temperature for the standard GAX cycle ranges 190–200 °C. In Type D, the hot water temperature of as high as 106 °C could be obtained. Therefore, Type D can be applied for space heating and panel or floor heating applications.

Keywords: Absorption system; Ammonia–water; Mechanical vapour compression; Modelling; Performance

Recherche avancée : analyse de la performance des cycles hybrides GAX (HGAX)

Mots clés : Système à absorption ; Ammoniac–eau ; Compression mécanique de vapeur ; Modélisation ; Performance

1. Introduction

The internal heat exchange due to the temperature glide of NH_3–H_2O mixture provides the fundamental basis for the Generator Absorber heat eXchange (GAX) cycle [1]. The GAX cycle essentially appears to be a single stage configuration. However, it provides a higher coefficient of performance (COP) than any other single effect cycle due to the temperature overlap between the generator and the absorber. Fig. 1 shows the fundamental concept of the GAX cycle–temperature overlap. The dotted lines represent the single stage cycle of the low pressure side while the solid lines represent the GAX cycle. As the absorber pressure increases, the corresponding absorber temperature increases in the ammonia–water absorption cycles. The temperature ranges partially overlap between the absorber and

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Nomenclature

COP	Coefficient of performance
GAXA	GAX absorber
GAXD	GAX desorber
GFD	Gas fired desorber
HCA	Hydronically cooled absorber
SCA	Solution cooled absorber
SHD	Solution heated desorber
P	Pressure (kPa)
Q	Heat transfer rate (kW)
T	Temperature (°C)
x	concentration
UA	Overall conductance (kW/K)
W	Work (kJ)

Subscript

a	absorber
c	cooling, condenser
comp	compressor
d	desorber
e	evaporatoe
gaxa	GAX absorber
h	heating
h,t	heating total
out	outlet

generator as the absorber exit temperature increases. The ''overlapped'' heat is internally transferred from the absorber to the generator leading to a higher COP. This overlapped heat is an attractive characteristic of the GAX cycle using NH_3–H_2O, which can not be realized in LiBr–H_2O absorption systems. The term ''generator'' is replaced by ''desorber'' from now since the term ''desorber'' is academically proper for a binary mixture such as NH_3–H_2O. Many papers have been found on the standard GAX cycle [2–7]. Recently, the GAX cycle is adopted in many applications such as space heating, space cooling and refrigeration. It can be also combined with a vapor compression process to obtain a higher COP or to obtain a lower refrigeration temperature. This cycle was called GAX hybrid cycle [8]. Kang et al. [9] developed an advanced GAX cycle for utilization of waste heat which was called WGAX cycle. They reported that the generator outlet temperature 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_d than 200 °C could be solved by adopting the WGAX cycles with a comparable COP. Kang et al. [10] developed an environmentally friendly GAX cycle using NH_3–H_2O for panel heating applications which was called the PGAX cycle. For space heating applications, 45 °C of coolant is high enough since room temperature is typically about 26 °C. However, 65 °C of coolant is required for panel heating in which the coolant flows through pipes under the wall or floor. The PGAX cycle can be operated in three different modes with just one-hardware—cooling, space heating and panel heating applications.

The objectives of this paper are to develop the advanced GAX cycles named Hybrid GAX (HGAX) cycles, and to study the effect of key parameters on the cycle performance and the evaporation temperature. Four different advanced HGAX cycles are developed—Type A (Performance improvement), Type B (Low temperature applications) Type C (Reduction of desorption temperature) and Type D (Hot water temperature applications). A compressor is placed between the evaporator and the absorber in Type A and Type B, and placed between the desorber and the condenser in Type C and Type D. In Type A and Type B, the evaporator pressure and the absorber pressure are controlled according to its application purpose. In Type C and Type D, the condenser pressure and the generator pressure are controlled according to its application purpose.

2. Description of HGAX cycle

Fig. 2 shows the HGAX cycles—Type A and Type B. In the HGAX cycles, the compressor is placed between the evaporator and the absorber. The goals of Type A and Type B are to obtain a high cycle COP (performance improvement) and to provide a low evaporation temperature (low temperature application), respectively. In Type A, the evaporator pressure is same as the pressure in the standard GAX cycle while the absorber pressure becomes higher than the evaporator pressure. The cycle of Type A cycle provides a wide temperature overlap between the absorber and the desorber leading to a high cycle performance. In Type B, the absorber pressure is same as the pressure in the standard GAX cycle while the evaporator pressure becomes lower than the absorber pressure leading to a low evaporation temperature.

Fig. 3 shows the HGAX cycles—Type C and Type D. In the HGAX cycles, the compressor is placed between the condenser and the desorber. The goals of Type C and Type D are to reduce the desorption temperature (reduction of desorption temperature) and to obtain a high hot water temperature (hot water temperature applications), respectively. In Type C, the condenser pressure is same as the pressure in the standard GAX cycle while the desorber pressure becomes lower than the condenser pressure. The cycle of Type C provides a low desorption temperature and therefore the corrosion problem due to the high solution temperature in the desorber can be removed. In Type D, the desorber pressure is same as the pressure in the standard GAX