Incorporating the VX concept in a commercial GAX heat pump: a numerical study

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ABSTRACT

In this work a numerical study is carried out on the addition of the VX concept to the GAX cycle implemented in a commercial gas driven absorption heat pump (GAHP). The performance of the two cycles are compared in terms of Gas Utilization Efficiency (GUE) over a wide range of water temperature and for air temperature ranging from -10°C to 10 °C. The calculations show that the VX can improve the GUE from about 4% to 8% GUE of the GAX cycle. Moreover, it is observed that the GUE is scarcely influenced by the split ratio, leaving room for optimizing the pumping power and the mass flux at the heat exchangers.

1. INTRODUCTION

Gas driven absorption heat pumps (GAHP) using water-ammonia as working pair represent a promising technology for reducing the energy consumption for space heating and DHW production, especially in existing buildings equipped with high temperature emitters.
Focusing on small residential applications, the GAX cycle was found to be the most suitable to cope with the requirements, i.e. the use of a simple cycle, possibly with a single solution pump, requiring a small number of components and with limited high pressure [1].
Among the weakness of the GAX cycle, we can mention the heat mismatch between GAX absorber and GAX generator and the loss of temperature overlap at a high lift. A possible solution to the former is the branched-GAX cycle, which consist in branching the rich solution to reduce the mass flow rate at the GAX generator and increase the flow at the GAX absorber [2]. A solution to the latter is provided by the vapor-exchange duplex GAX-VX cycle [3,4], which enable higher mass fraction in the rich solution.
In this work, the GAX cycle implemented in commercial heat pumps is modified to introduce the VX concept. The performance of the two cycles are compared numerically keeping constant the gas input and the cycle parameters. In order to have a behavior close to a real appliance, the cycle is optimized at the design conditions (T_{air}=-10°C and T_{w_inl}=50°C), eventually allowing sub-optimal operation at smaller lifts.

2. CYCLE IMPLEMENTATION

Domestic size GAHP approaching the GAX concept are available on the market since few decades. The need of keeping the appliance simple and reliable brought to a modification of the original GAX embodiment. This lead to the substitution of the GAX absorber and generator, coupled with an oil circuit, with a solution cooled absorber (SCA), where the rich solution is directly heated up by the heat of absorption.
The introduction of the VX concept is done following the same principle and using heat exchangers with the same configuration. The solution side of the cycle is represented in Fig. 1, neglecting the rectifier to keep the figure simple. The solution leaving the low pressure absorber is split in two streams. The first goes toward the VX heat exchanger and is heated and partially evaporated by the heat of absorption released by the solution leaving the SCA. The generated vapor is absorbed

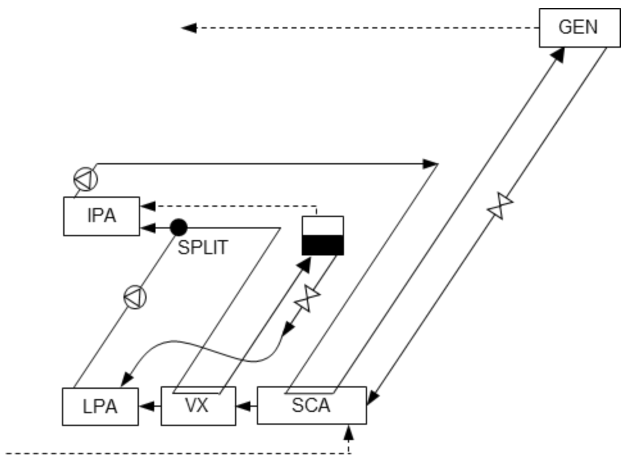

Figure 1: simplified scheme of the solution circuit.

in the Intermediate Pressure Absorber (IPA) by the second stream leaving the split, which is furtherly enriched. The liquid solution is recirculated through a restrictor at low pressure. The split ratio is defined as the fraction of solution split towards the Low Pressure Absorber (LPA).

3. RESULTS AND DISCUSSION

The GUE for both the GAX and VX appliances is calculated for three air temperatures (-10 °C, 0 °C and 10 °C) and inlet water temperature ranging between 30 °C and 50 °C. The results, reported in Fig. 1, show an upgrade of the GUE of the GAHP over the investigated Gross Thermal Lift (GTL). The results are obtained with a split ratio of 0.5, but, as displayed in Fig. 2, both at low lift (LL) conditions, i.e. T_{air}=-10°C, T_{w_in}=50°C and at high lift (HL), i.e. T_{air}=10°C, T_{w_in}=30°C, the GUE variation with the spit ratio is very small. It is expected that this feature makes the appliance easy to be controlled. Moreover, as the mass flow rate at the LPA decreases with the split ratio, the split can be set to optimize the cycle, aiming at minimizing the pump work or, alternatively, at improving the mass flux at the low pressure absorber.

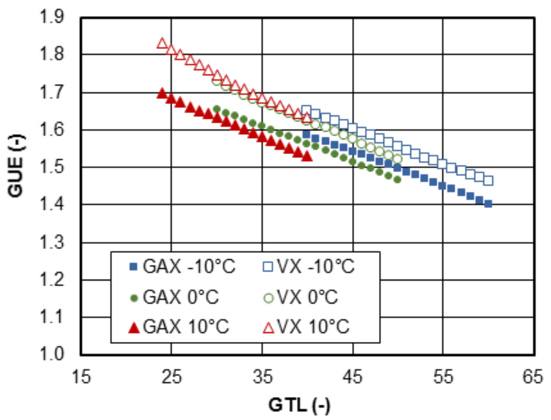

Figure 2: GUE vs. GTL for GAX and VX cycles at T_{air} of -10°C, 0°C and 10°C.

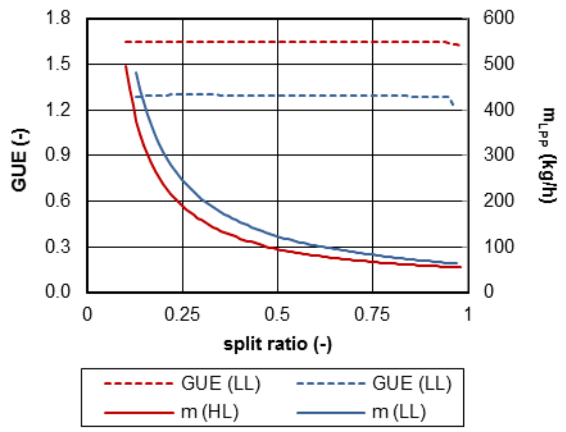

Figure 3: GUE and mass flow rate at the LPP vs. split ratio for a high and low lift cases.

4. CONCLUSIONS

- The VX concept looks promising as a mean to improve the efficiency of a commercial GAHP based on the GAX cycle.
- The VX increases the GAX GUE of about 8% at low lifts and 4% at high lifts.
- The impact of the split ratio on the cycle performances and on the heat duty at the heat exchanger is low, making the control of the variable split simple.
- The possibility to freely choose the split ratio enable optimizations aiming at the reduction of the pumping work or improvement of the mass flux and heat transfer rate at the absorber.

NOMENCLATURE

GUE	Gas Utilization Efficiency	(-)	T_{w_in}	inlet water temperature	(°C)
m_{LPP}	mass flow rate at the low pressure pump	(kg/h)	T_{air}	air temperature	(°C)
GTL	Gross Thermal Lift=T_{w_in}-T_{air}	(°C)			

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