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Second law analysis of double effect vapour absorption cooler system

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ABSTRACT

In this paper, exergy analysis of double effect lithium bromide/water absorption refrigeration system is presented. The system consists of a second effect generator between the generator and condenser of the single effect absorption refrigeration system, including two solution heat exchangers between the absorber and the two generators.

In order to simulate the refrigeration system by using a computer, a new set of computationally efficient formulations of thermodynamic properties of lithium bromide/water solution developed is used. The exergy analysis is carried out for each component of the system. All exergy losses that exist in double effect lithium bromide/water absorption system are calculated. In addition to the coefficient of performance and the exergetic efficiency of the system, the number of exergy of each component of the system is also estimated.

This study suggests the component of the absorption refrigeration system that should be developed. The results show that the performance of the system increases with increasing low pressure generator (LPG) temperature, but decreases with increasing high pressure generator (HPG) temperature. The highest exergy loss occurs in the absorber and in the HPG, which therefore makes the absorber and HPG the most important components of the double effect refrigeration system.

1. Introduction

Absorption cooling systems have become increasingly popular in recent years from the viewpoints of energy and environment. Despite a lower coefficient of performance (COP) as compared to the vapour compression cycle, absorption refrigeration systems are attractive for using inexpensive waste heat, solar, geothermal or biomass energy sources for which the cost of supply is negligible in many cases. In addition absorption refrigeration use natural substances, which do not cause ozone depletion and global warming as working fluids [1–4].

A number of researchers have used exergy analysis of absorption refrigeration system. A particular attention was given to simple effect absorption refrigeration system [5–7]. However, the few relatively works available on analysis of double effect refrigeration system consider only the analysis by the first law of thermodynamic [8–12].

In this paper, exergy analysis of double effect lithium bromide/water absorption system is presented.

The exergy analysis is carried out for each component of the system. All exergy losses that exist in double effect lithium bromide/water absorption system are calculated. In addition to the coefficient of performance and the exergetic efficiency of the system, the number of exergy of each component of the system is also estimated.

2. Description of absorption system

The double effect absorption refrigeration system as shown in Fig. 1 consists of two generators, condenser, evaporator, absorber, pump, two solution heat exchangers, two solution reducing valves and two refrigerant expansion valves. As shown in Figs. 1 and 2, the system is a five temperature (temperature in LPG, temperature in HPG, evaporator temperature, condenser temperature, and absorber temperature) and three pressure level (low pressure in the evaporator and absorber, medium pressure in the condenser and the low pressure generator, the high pressure in the high pressure generator). In the system operation, the strong solution is pumped from the absorber to the HPG where it is heated at relatively high temperature to boil out the refrigerant vapour from the solution. The primary vapour, from the HPG comes into the LPG heating the medium concentration solution from the HPG and then being condensed. At the outlet of LPG secondary vapour is produced, which together with the condensed water of primary vapour flows into the condenser in which the heat rejection takes place. The heat of condensation of the primary vapour from the HPG is used in the LPG to get the secondary vapour. Thus, the total amount of liquid refrigerant leaving condenser is the sum of refrigerant originating from HPG and LPG. The refrigerant liquid from the condenser, on

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Nomenclature

e	specific total exergy (kJ/kg)
Ex	exergy (kW)
E_{xd}	exergy destruction (kW)
HEX	heat exchanger
HPG	high pressure generator
LPG	low pressure generator
m	mass flow rate (kg/s)
N_{exergy}	number of exergy
P	pressure, Pa
Q	heat transfer rate (kW)
T	temperature (°C)
W	mechanical power (kW)
x	mass fraction of lithium bromide (%)
Greek symbols	
ε	effectiveness
η	efficiency
θ_{Carnot}	Carnot factor (Carnot efficiency)
ρ	mass density (kg/m^3)
Subscripts	
0	reference value
ab	absorber
cd	condenser
ev	evaporator
gh	high pressure generator
gl	low pressure generator
i	the ith chemical species
j	heat source number
m	medium
p	pump

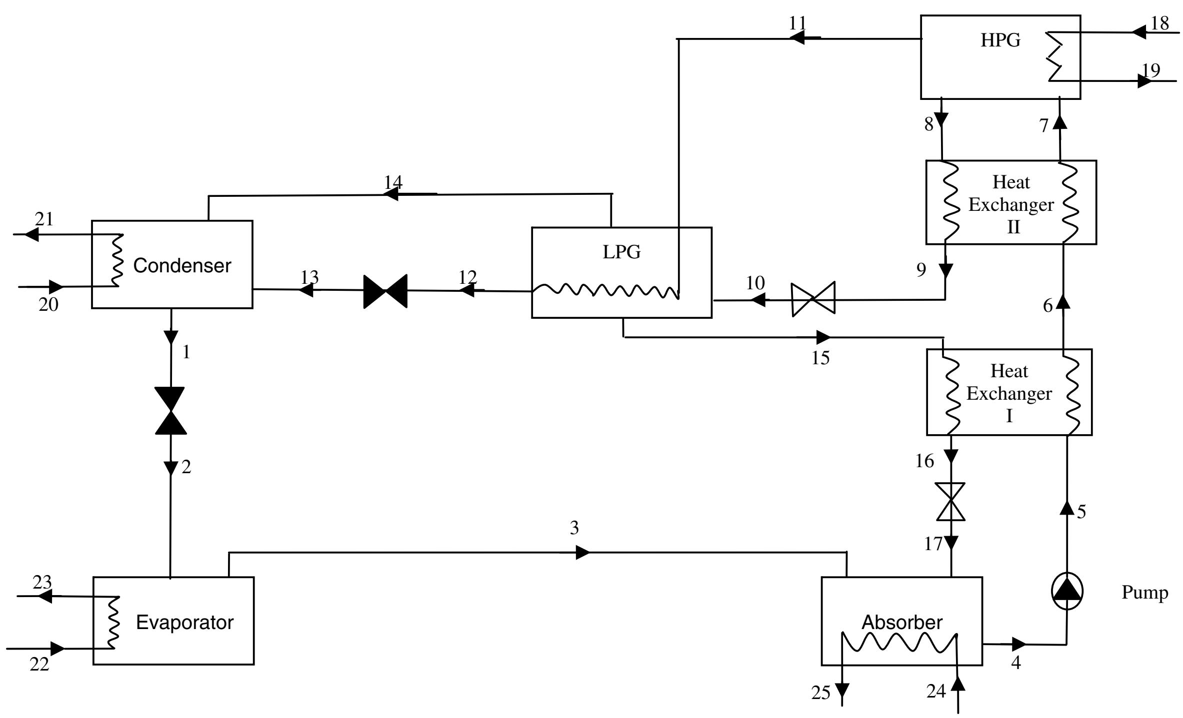

Fig. 1. The schematic illustration of double effect absorption refrigeration system.

expansion, continues to the evaporator where it is evaporated at low pressure, extracting the heat of vaporization from the medium to be cooled. This cold vapour is then dissolved in weak solution coming from the LPG through the solution heat exchanger (HEX-I), thereby rejecting its heat of absorption in the absorber. The resulting strong solution is then pumped to HPG through HEX-I and HEX-II, respectively.

3. Procedure for modelling a double effect refrigeration system

- The operating parameters are: evaporator temperature T_{ev}, condenser temperature T_{cd}, absorber temperature T_{ab}, HPG temperature T_{hg}, effectiveness of heat exchangers (ε_I, ε_{II}), efficiency of the solution pump η_p and refrigeration load Q_{ev}.
- Strong solution concentration, pressure condenser P_{cd}, evaporator pressure P_{ev}, absorber pressure P_{ab} ($P_{ab} = P_{ev}$) and LPG pressure P_{gl} ($P_{gl} = P_{cd}$) are calculated.
- Assuming the temperature in the LPG, the concentration of the weak solution leaving LPG is calculated.
- Assume initial value of medium solution concentration (X_m) and find the pressure in HPG: $P_{gh} = f(X_m, T_{gh})$.
- Find enthalpy and mass flow rate of all points in the system.
- Verify the energy balance for LPG (energy balance in the LPG less or equal to 10^{-4} kW). If energy balance is not occurred to the desired accuracy, increase X_m and repeat calculation with the new value of X_m, till energy balance occurs across the LPG.
- If energy balance is occurred, to the desired accuracy, calculate
  - energy flow at the various components of the system,