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Energy and Exergy Analyses for Optimization of the Operating Temperatures in Double Effect Absorption Cycle

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Abstract

Energy and exergy analyses of double effect lithium bromide-water vapour absorption cycle has been carried out to optimize the operating temperatures in the main generator and the secondary condenser/ generator for maximum coefficient of performance (COP) and exergetic efficiency. There exists maximum COP and also maximum exergetic efficiency as the temperature in the secondary generator and the main generator are varied, thus leading to the optimum temperatures. Because of two generators in the double effect cycle, the optimization has been done in two steps. Since the secondary generator operates by using the heat of condensation release in the secondary condenser, the temperature in the secondary condenser will be nearly same as in the secondary generator. The analysis has been done for fixed temperatures in the evaporator, main condenser and the absorber. Results show that the COP increases while the exergetic efficiency decreases with increases in the evaporator temperature. The optimum parameters such as temperatures in the main generator, secondary generator and condenser, including the LiBr-Salt concentrations in the two generators, are presented for different values of the evaporator, main condenser and the absorber temperatures. A computer program has been developed for simulating the cycle.

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Keywords: LiBr-water; Double effect; Coefficient of performance; Optimum temperature; Exergetic efficiency

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1. Introduction

Recently the absorption cooling technology has become very popular. The attractive feature of this technology is, it uses low grade energy to drive the system. The huge amount of heat that go wasted from the industries, can thus be utilized by this system. Moreover, this system is environmentally safe due to the use of natural working fluid, such as NH_3-H_2O and LiBr-H_2O etc. The single-effect absorption system has relatively low COP due to which it is not competing economically with the conventional vapour compression system, except in case of waste heat applications where the input energy is virtually free of cost. To reduce size of the equipment and operating cost of the absorption cycle, it is desirable to increase the COP. Therefore, multi-effect absorption systems with high temperature heat sources have now been developed [1]. The double effect system was first patented by Loweth [2] and commercialized by TRANE in 1970 which was later modified and improved by Saito and Inoue [3] and by Alefed [4].

Siddiqui [5], Saghiruddin and Siddiqui [6,7], Malik and Siddiqui [8] have carried thermodynamic and economic analysis of single effect cycle with LiBr-H_2O, NH_3-H_2O, NH_3-$LiNO_3$ and NH_3-NaSCN combinations using different sources of energy like, Biogas, LPG and Solar Collectors. Arora and Kaushik [9] and Marcos et al. [10] performed energy and exergy analysis of single effect and double effect absorption LiBr-H_2O system. Lee and Sherif [11] and Sencan et al. [12] carried thermodynamic analysis of single effect absorption system for cooling and heating applications using pressurised hot water as the source of energy. Samanta and Basu [13] have performed the first and second law optimization of single effect absorption system.

So far the studies carried on the double effect cycle, discuss optimization of the main generator temperature to some extent without any focus on the secondary condenser / generator temperature. The present analysis is therefore carried to optimize the secondary condenser / generator temperatures along with the main generator temperature for maximum COP and exergetic efficiency.

Nomenclature

A	Absorber
C	Main condenser at Pressure P_2
C_s	Secondary condenser at pressure P_3
COP	Coefficient of performance [-]
E	Evaporator
G	Main generator at Pressure P_1
G_s	Secondary generator at pressure P_2
h	Specific enthalpy [kJ kg^{-1}]
LiBr	Lithium bromide salt
m	Mass flow rate [kg s^{-1}]
P	Pressure [kPa]
PH1, PH2	Preheaters
Q	Rate of heat transfer [kJ s^{-1}]
T	Temperature [°C or K]
TV	Throttle valve
W_p	Work of pump [kW]
X, X_c	Mass concentration and Crystallization value of lithium bromide salt [%]

Subscripts

a	Absorber
c	Main condenser
cs	Secondary condenser
e	Evaporator
g	Main generator
gs	Secondary generator
i	Inlet
o	Outlet

Greek Symbols

ε	Effectiveness of heat exchanger
η	Exergetic Efficiency

2. Description of The Double Effect Absorption Cycle

The schematic diagram of a double effect vapour absorption cycle is shown in Fig. 1; the absorption process of which is shown on P-T-X diagram in Fig. 2. It consists of two generators: a main generator (G) and a secondary generator (G_s), and two condensers: a secondary condenser (C_s) and a main condenser (C). The heat is to be rejected to the surrounding from the main condenser C. The main generator (G) and the secondary condenser (C_s) operate at high pressure ($P_3 = P_g = P_{cs}$) while the secondary generator (G_s) and the main condenser (C) operate at medium pressure (P_2