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Energy and Exergy Investigation of Small Capacity Single Effect Lithium Bromide Absorption Refrigeration System

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Abstract

In the present study, the energy and exergy investigation of absorption refrigeration system (ARS) in LiBr - H_2O solution is modelled and analysed for each component. An optimization criterion applied to the generator temperature in order to enhance energy and rational efficiency and also, most exergy destruction components are identified. The results propose that generator and absorber are the essential components according to the design aspect. Likewise, it is highlighted that COP and rational efficiency are fluctuated regarding the component temperature of ARS. It is also found that the COP of heating increased with increment in generator temperature while the circulation ratio showed the inverse pattern.

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Keywords: ARS; LiBr-H_2O; Exergy; Rational efficiency; EES

1. Introduction

In the last decades, an impressive number of studies have been carried out by many researchers to explore different aspects of absorption refrigeration system (ARS) [1]. ARS is becoming more important because it can be fuelled by renewable energy (like waste heat rejected by industry, solar, geothermal, bio-mass, etc.) other than electricity [2]. In addition, the solar and geothermal are environment friendly energy sources and water is utilized as a refrigerant which does not bring ozone depletion. Therefore, the COP of the framework is concerned, it is always a challenge for the researcher to improve the COP value for ARS. The most renewable mainstream refrigeration and air conditioning systems are present those based on ARS. These systems are prevalent because they are reliable, relatively inexpensive

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Nomenclature

COP	coefficient of performance	h	specific enthalpy (kJ/kg)
ARS	absorption refrigeration system	$\dot{I}$	exergy destruction/ irreversibility (kW)
SHX	solution heat exchanger	e	specific exergy (kJ/kg)
PRV	pressure reducing valve	W	work (kW)
EES	engineering equation solver	Q	heat transfer rate (kW)
TR	ton of refrigerant (kW)	$\dot{m}$	mass flow rate (kg/sec)
η	first law efficiency	C_p	specific heat (kJ/kg˚C)
η_{II}	second law efficiency/ rational efficiency	P	pressure (kPa)
ξ	mass fraction (%)	T	temperature (˚C)
Subscripts			
eva	evaporator	1,2,3 ...	represent state points
gen	generator	r	refrigerant (Water)
abs	absorber	s	strong solution
exv	expansion valve	w	weak solution
$cond$	condenser	p	pump

and their technology is well established [3–5].

In comparison to LiBr-H_2O, NH_3-H_2O is unstable, a rectifier generally required to separate water vapour from ammonia, which increases the heat loss and reduces the efficiency. The major disadvantage of NH_3-H_2O as an aqueous solution is its toxicity, high working pressure and corrosive reaction over copper/copper alloys, limiting its utilization to material like carbon steel [6]. In contrast, LiBr-H_2O cost of refrigerant (water) is quiet substantial and inexpensive. In addition, boiling point temperature difference for LiBr and H_2O is higher so no need of rectifier and analyser, and pump work is less due to the lower pressure difference between generator and absorber [7].

Numerous analyses have been examined for exergy investigation of ARS [8–10]. The method of rational efficiency (exergetic efficiency) analysis is more complicated than energy efficiency analysis [11]. It is a novel methodology permitted us to compare different energy system's performance. Moreover, both the methods are utilized. Energy analysis provides an initial investigation and exergy analysis should be used as a more detailed examination of ARS [12].

In the present work, a mathematical model of ARS has been developed and analysed at various operating parameters. The exergy losses for all components are obtained from a mathematical model as portrayed in model governing equation. The COP and rational efficiency are evaluated for each component of ARS.

2. Description of VAR cycle

As it can be seen from Fig. 1 that ARS system consists of mainly four components like generator, absorber, condenser and evaporator. The aqueous solution (LiBr-H_2O) in the generator is heated by any renewable source (solar, geothermal, biomass, etc.) or industrial waste heat. Due to higher boiling temperature differences in aqueous solution, only water vaporized and it then enters the condenser. Where it is cooled by the external cooling source, and it converts from vapour phase to liquid phase, then it passes through the expansion valve where pressure and temperature get reduced. The liquid-vapour mixture of water is passed through the evaporator where heat transfer from the cold chamber causes complete vaporization of water refrigerant. The water vapour generated in the evaporator then enters the absorber where it is absorbed in the strong solution of LiBr coming from the generator after being cooled in the heat exchanger.

3. Model governing equations

The energy and exergy equations are based upon first and second laws of thermodynamic, respectively. The second law equation is recognized destruction losses at specific component due to entropy generation.