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Exergetic Analysis of a LiBr-H2O Single Effect Absorption Refrigeration System

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Abstract : In this article, an exergetic analysis was performed to evaluate the exergetic efficiency and exergy destroyed in an single effect absorption refrigeration cycle, in order to identify the opportunities to improve the performance of this system when the lithium-water bromide solution is used as working coolant. The study was conducted by varying the ambient temperature in the range of 10 to 50 °C and evaluating the exergetic behavior of the components in this range. As a result of this study, there was a greater exergy destruction in the components where there is greater heat exchange such as the heat exchanger. The results of this article wants to help the scientific community to analyze and observe points of improvement in the performance of new refrigerants in order to increase the efficiency of absorption cooling systems.
Keywords : Exergetic analysis, absorption refrigeration system, lithium bromide-water solution.

1. Introduction

The increase in the temperature of the planet earth has been sufferinga very rapid changes recently, as a result of industrialization and the increase in the human population, generating an uncontrolled shipment of greenhouse gases to the atmosphere (1)-(3). Studies show that the surface temperature will increase between 1.5 and 5°C, generating a disorder in the planet's cycles and negatively affecting the environment. Simultaneously to this problem, an energy deficit has arisen, generating the search for a solution to this problem by the international scientific community through renewable and green energy sources (4)-(7), focusing on reducing the use of conventional sources to meet the world's energy demand.

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With the growing demand for industrial refrigeration and air conditioning for the comfort and good development of processes, the scientific has looked for ways to implement technological advances for the conversion and use of energy from the sun resulting in solar cooling systems (8)-(12), generating a non-destructive response and mitigating the use of fossil fuels by reducing emissions of polluting gases to the atmosphere.

Solar cooling systems have different configurations depending on the characteristics (13) of the system, such as adsorption systems, single-acting absorption and double-acting absorption (14), which represent a solution for cooling in industrial processes and air conditioning, using pollution-free refrigerants that help to maintain ecosystems.

Research has been conducted to optimize absorption cooling systems (15) using a lithium-water bromide solution (LibBr-H2O) (16) as a refrigerant and solar collectors where important results are observed in the continuity and reliability of the system. The LibBr-H2O solution has been subjected to an energy and energy analysis in single and double effect cooling systems (17), showing that the irreversibilities in absorption cooling systems are greater than in conventional systems.

The main contribution of this article is to evaluate the exergetic efficiency of the system components by analyzing the possible behaviors in the destruction of the exergy in order to look for possible improvements that can be made in the absorption refrigeration cycle by limiting the temperatures and behavior with the LiBr-H2O solution as working fluid.

2. Materials and Methods

Below is a detailed description of the process, showing the components of the system and the equations used to develop an exergetic analysis, where is calculated the exergetic efficiency and the exergy destroyed in each of the elements

2.1 Description of the process

In the study carried out for the single effect absorption system, water and lithium bromide were used as the working fluid in a system composed of a condenser, an expansion valve and an evaporator. On the other hand, when the working fluid is in solution, the mixture is arranged by the thermal compressor consisting of a generator, an absorber, an expansion valve, a pump and a heat exchanger as shown in Figure 1.

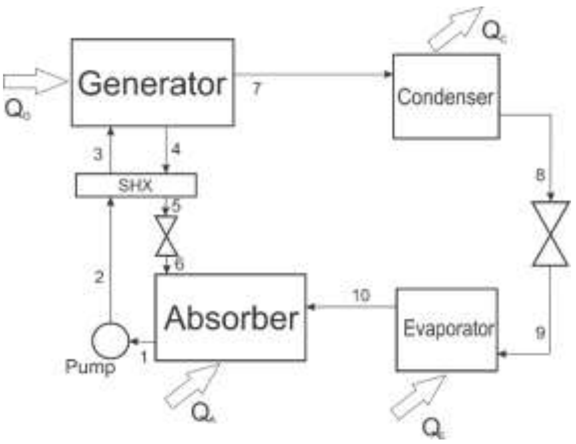

Figure 1. Diagram process

2.2 Exergetic analysis of the system

The second law of thermodynamics determines and quantifies the irreversibilities that occur in thermodynamic processes, helping to understand the viability of processes where an energy balance is presented. This principle makes it possible to identify the nature in the direction of the processes, analyzing whether one works from a hot heat source to a cold source, or whether additional energy is required for processes such as cooling, heating or power generation.

The thermodynamic performance in a system states that every process will always have heat investments towards its surroundings, reducing the useful work available. Therefore, the concept of exergy is generated that allows the identification of the available work of the systems where the quantity and quality of energy is taken into account, by means of the union in the concepts of the first and second law of thermodynamics, establishing the exergy balance for open systems as it is observed in the equation (1).

$$\sum \dot{m}_i e_i - \sum \dot{m}_o e_o + \dot{Q}\left(1 - \frac{T_0}{T}\right) - \dot{W} - \dot{E}_D = 0 \quad (1)$$

Where the first two terms refer to the exergy entering and leaving the system, $\dot{Q}$ is the amount of heat supplied to the system, $\dot{W}$ is the mechanical work transferred to or from the system and $\dot{E}_D$ is the term directly related to the destruction of exergy in the system, which is equivalent to the generation of entropy or unusable work.

Exergetic efficiency can be calculated based on the definition proposed by the second law of thermodynamics, as presented in equation (2)

$$\eta_{ex} = \frac{\dot{E}_{Prod}}{\dot{E}_{Sum}}, \quad (1)$$

where$\dot{E}_{Sum}$ is the exergy that is supplied to the system and $\dot{E}_{Prod}$ is the exergy that the system can produce, analysing that the availability of the exergy produced cannot be greater than the exergy supplied. To analyze the exergetic efficiency with respect to the exergy destroyed by the system, as shown in equation (3)

$$\eta_{ex} = 1 - \frac{\dot{E}_D}{\dot{E}_{Sum}}, (3)$$

where$\dot{E}_D$istheexergydestroyedbythesystem.

For single-acting absorption refrigeration systems, the exergetic efficiency is presented in equation (4)

$$\eta_{ex} = \frac{\dot{Q}_E\left|1 - \frac{T_0}{T_E}\right|}{\dot{Q}_G\left(1 - \frac{T_0}{T_G}\right)}, (4)$$

where$\dot{Q}_E$is the heat flow from the system evaporator, $\dot{Q}_G$is the heat from the generator.

3. Results and Discussion

In table 1 are the results of the simulation in the cycle for a temperature of 50°C as explained in the methodology proposed for this system.

Table 1. Results of the simulation for the refrigerant cycle

State	T (K)	P (bar)	x (%LiBr)	h (kJ/kg)	s (kJ/kg K)	Exergy
1	353,2	0,05945	1	2650	8,584	-5,125
2	309,2	0,05945	0	150,8	0,5185	0,1831
3	278,2	0,008726	0,05214	150,8	0,5427	-0,2034
4	278,2	0,008726	1	2510	9,024	-19,05
5	307,2	0,008726	0,5476	81,38	0,2077	19,73
6	307,2	0,05945	0,5476	81,38	0,2077	19,73
7	331,55	0,05945	0,5476	131,2	0,3642	19,31
8	353,2	0,05945	0,5975	193,3	0,4544	35,46
9	325,6	0,05945	0,5975	140	0,2972	62,98
10	317,1	0,008726	0,5975	140	0,2471	42,88
11	373,2	1,0133	-	2676	7,355	171,7
12	353,2	1,0133	-	335	1,075	2,976
13	300,2	1,0133	-	113,2	0,3949	1,947
14	305,2	1,0133	-	134,1	0,464	1,18
15	258,2	1,0133	-	50,46	0,1804	5,498
16	293,2	1,0133	-	83,93	0,2962	3,365
17	300,2	1,0133	-	113,2	0,3949	1,947
18	305,2	1,0133	-	134,1	0,464	1,18

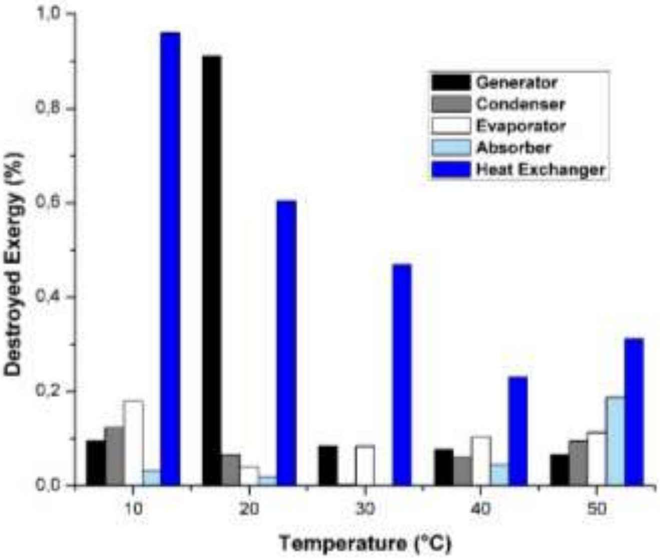

Figure 2. Destroyed Exergy by components

To analyze the performance of the process one of the parameters analyzed is the exergy destroyed that is presented by thesystem, Figure 2 shows what percentage of exergydestroyed by component evaluating them at different temperatures, showing the heat exchanger the highest peaks in each temperature range, but destroys more exergy at 10°C with 94% meaning that there is greater heat exchange which is the largest contributor to the destruction of exergy in a system.

In this process was also found the exergetic efficiency of each component as shown in figure 3, where it is observed that the heat exchanger is the least efficient element of the systemma due to the internal processes that are presented in it. The capacitor is the second element that maintains a constant efficiency with respect to the system since there is no major variation in its behavior. The evaporator and the absorber are the elements that present a significant variation in their efficiencies depending on the temperature range in which they operate, one in an upward and the other in a downward direction respectively. The element with the highest exergetic efficiency is the generator, due to its operating characteristics it has a higher efficiency at 10 °C with 28,56 kW, decreasing its value not so significantly in the different temperature ranges.

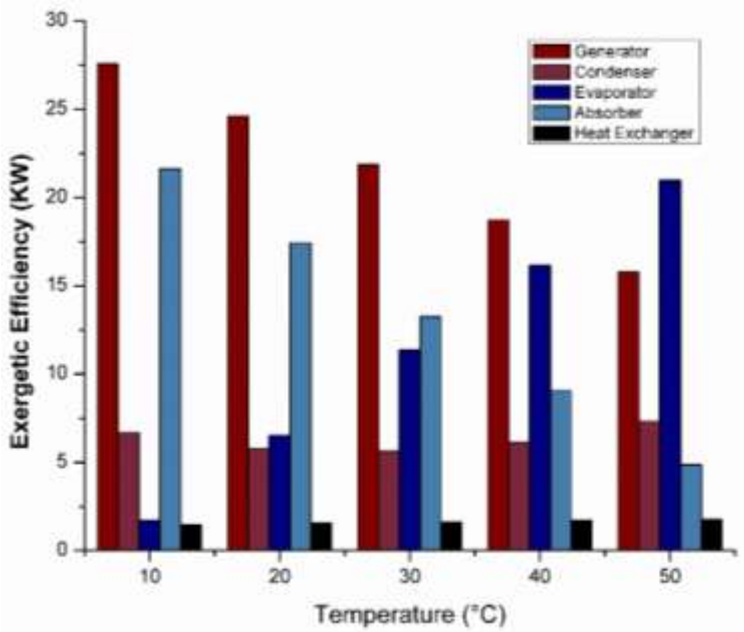

Figure 3. Exergetic efficiency by components

4. Conclusion

Finally, it was observed how the efficiency of the cycle was improved with the LiBr-H2O solution as the system refrigerant, analyzing the exergetic efficiency by component and observing its behaviour in the temperature range analyzed. The exergy destroyed by component in the system was analyzed and as it presents significant changes depending on its thermodynamic properties and its internal processes, presenting a greater destruction of exergy the components where greater heat exchange was carried out in the process, varying the characteristics of the output substance with respect to the input one.

The results of this article are expected to enable the scientific community to analyze and observe points of improvement in the performance of new refrigerants in order to increase the efficiency of absorption cooling systems.

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