Thermodynamic Analysis for a Solar Assisted Absorption Cooling System: Energy and Exergy Base

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Abstract- Solar energy is one of the most popular field for high potential countries such as Turkey where the cooling is a serious need for ventilating purposes in many residences. Using the solar energy in cooling systems reduces the cost of energy and greenhouse gases emission. So, solar assisted absorption cooling systems have become considerably charming in nowadays due to its sustainability. In this study, energy and exergy analysis on a solar assisted single effect absorption cooling system is carried out. Heat transfer rates at each component and the coefficient of performance (COP) of the system are calculated. Additionally, exergy analysis of the system is performed. The energy and exergy analysis of the system components is undertaken by using the EES program. COP of the system is computed as 74.43%. COP difference results between this study and the reference studies are compared. Fuel exergy, product exergy, exergy loss, exergy destruction is calculated at each components of the system by using related equations. The exergy analysis results show that the highest exergy destruction and exergy loss occurs at evaporator assembly. So, evaporator assembly has the minimum exergetic efficiency as 23.88%. The maximum exergetic efficiency exists in the generator as 74.39%. Exergetic efficiency of the overall system is obtained as 16.75%. The exergy destruction ratio, exergy loss ratio and exergetic efficiency difference of the system results between this study and the reference studies are compared.

Keywords: Absorption cooling, Solar assisted, Energy analysis, Exergy analysis, Thermodynamic analysis

1. Introduction

A large proportion of the energy consumption in the world provided by solar energy. The amount of solar energy coming to the earth in a year is 160 times the energy provided from fossil fuel sources. It is also 15,000 times more than the energy provided by power plants using fossil fuels, nuclear fuels and hydroelectric plants on the world. Also, it is an abundant, continuous, renewable and free energy source. So, it is an alternative to fossil fuels [1], [2].

Using the solar energy for cooling purposes such as food protection or providing in cooling comfort conditions in the commercial buildings and residences. Also, cheap sources of energy such as geothermal and waste energy, which are renewable, coming from many industrial plants are used in absorption cooling systems. Accordingly, the solar energy is used in an absorption cooling system with many advantages. Small numbers of the moving parts of the system, the low maintenance costs, make the absorption systems quite attractive. Additionally, the use of abundant, cheap, low carbon dioxide emission and non-destructive refrigerants is one of the advantages of solar assisted absorption systems[3], [4].

Single effect is the basic configuration of the absorption refrigeration system. Analytical, numerical and experimental study of absorption systems with different working fluid pairs under a variety of operating conditions are investigated on various studies[5]–[7]. Also, in order to develop a cycle design and improve the system efficiency, double effect [8]–[10] and multi effect cycle [11], [12] are studied. In addition to these cycle designs, it is observed that the addition of components such as heat exchanger, compressor, flash tank, and ejector [13] are also improve the efficiency.

The selection of absorbent (sorbent) and refrigerant is significantly important for the efficiency of absorption cooling system[13]. In some researches, $LiBr/H_2O$couple is used for their prominent advantages[14]–[17]. On the other handNH_3/H_2O couple is used for the absorption cooling system [18]–[23]and additional researches compared these couples in terms of various aspects[24]- [25]. Although there are several studies on NH_3/H_2O, $NH_3/LiNO_3$ and

NH_3/NaSCN they are not seen much in the literature[13], [26]- [27].

The performance of the absorption cooling systems has been widely studied within the scope of first and second laws of the thermodynamics[7], [28]–[35]. In this research, analytical, numerical and experimental studies are used from the literature [36]. Kılıç et al. studied the first and the second law of thermodynamics for a single stage solar absorption system. The COP, exergy loss of each component and total exergy loss of all components, exergetic efficiency and efficiency ratio of the system are calculated from the thermodynamic properties of the working fluids at various operating conditions [7]. Daşkın and Aksoy studied is about the simulation of a solar assisted absorption cooling system design for an air conditioning unit. Authors used HAP (Hourly Analysis Program) for calculation of cooling capacity of a building. Working liquids are selected asLiBr/H_2O. They found that the inclination angle ofthe collector influences the maximum amount of the sunlight received. The solar utilization rates depending on the various collector areas, tank volumes and secondary (assistant) heat sources are calculated according to the months of a year in this research [37]. Şencan investigated the design and construction of the absorption cooling systems. They also usedLiBr/H_2O as a working fluid. In their study Artificial Neural Network (ANN) is used for determination of thermodynamic properties of the LiBr/ H_2O solution. Effect of the system parameters on the COP was investigated. Also, for determining the optimal design parameters of the absorption system for cooling and heating applications, authors used Genetic Algorithm method (GA) was carried out [38].

On the other hand, economic analysis is also investigated widely in the literature. At this content Şahin et al. studied absorption chiller systems at the wood pencil factory in terms of energy, exergy and economic analysis. Single-effect, double-effect series, double-effect parallel and double-effect reverse parallel were compared to find the best solution. Variation of generator temperature on COP, exergetic performance of the single effect, all double effect absorption chiller system is investigated. According to results recommended that the double-effect parallel absorption chiller systems might be preferred for the factories having waste heat source. Additionally, average payback period was calculated. Double-effect parallel absorption chiller systems are recommended by the authors for the facilities having wood chips waste sources instead of double-effect reverse parallel absorption chiller systems because of the maintenance costs [39]. Misra et al. carried out an optimization for a single effect absorption cooling system. The study aimed to minimize overall product cost rate. Simplified cost minimization methodology was applied. Optimum design conditions were obtained by using sequential optimization method. The results were compared for base and optimum case [30].

Also, solar assisted absorption cooling systems can be searched in terms of design of the system [21], [33], [35],[40]-[41]. Goortani et.al. studied the direct effects of solar irradiance on solar assisted single effect ammonia/water absorption cooling system during the day and all seasons. The effect of the collector area and solar irradiance variations on the cooling capacity, generator load and temperature, and heat storage tank mass are determined. Overall collector efficiency is calculated [21]. Abusaibaa et al. investigated optimum solar air-conditioner design parameters. TRNSYS simulation is used to selection of system parameters and optimization. Optimal system evacuated tube collector area, number and tilt angle is calculated[33].

Also, economic analysis is done on the optimal system. Saving energy bills, cost of electricity per kW and simple payback period are calculated for optimal system[33].

Boyaghchi investigated thermodynamic and thermo economic analysis of solar absorption refrigeration for cooling of an office building. Coefficient of performance (COP), exergetic coefficient of performance (COPexe) and cost per exergy unit of the change for whole system according to hourly and seasonally was performed [34].

In this study, the first and second law of thermodynamic analysis are applied to the absorption cooling system. Heat transfer rate of the components and COP of the system are calculated. Then, detailed exergy analysis carried out by using the EES program. Exergy destruction, exergy loss and exergetic efficiency for both the components and the system are calculated. At the end of the study, obtained results are compared to other studies. The aim and the novelty of this study is to present the variation of the generator and absorber temperature on the exergetic efficiency of system components such as generator, evaporator assembly and heat exchanger.

2. System Description

This study mainly purposed to achieve numerically by using the first and second laws of thermodynamics for the solar assisted single effect absorption cooling system. System’s mass flow rate, temperatures and pressures are taken from the literatures[36], [42]. Temperature difference of the pump is neglected.

The solar assisted single effect LiBr/H_2O absorption cooling system scheme is given in Figs. 1 and 2. Water and LiBr are used as refrigerant and absorbent, respectively. Evaporator assembly consists of the condenser, evaporator, absorber, expansion valve and throttling valve in order to analyze the system more easily as seen in Fig. 2 [30]. The working mechanism is explained in detail below.

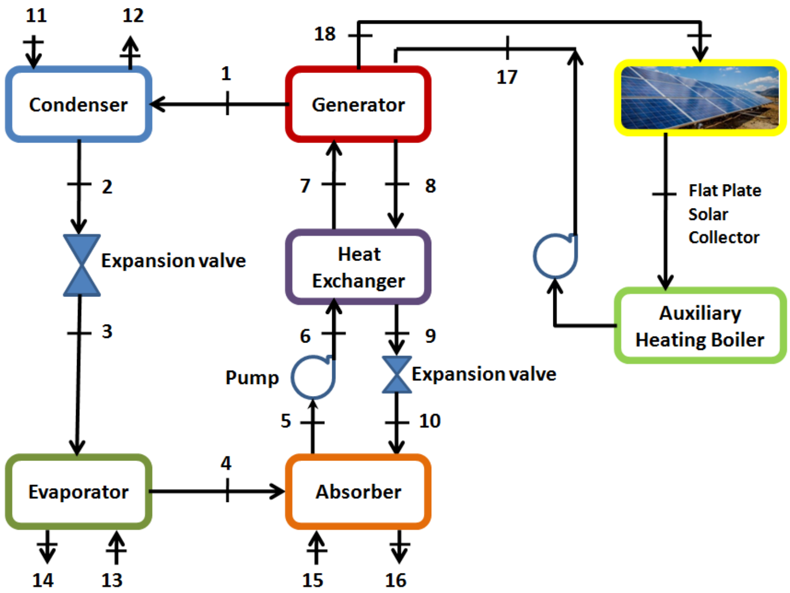


Fig. 1. Solar assisted absorption cooling system scheme[43]

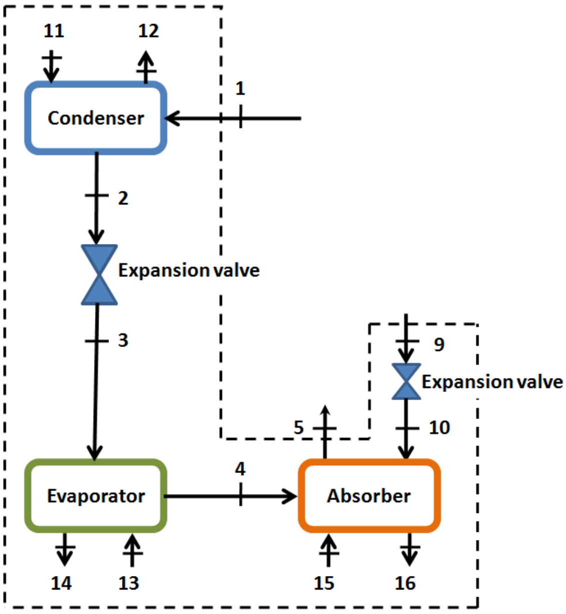


Fig. 2. Evaporator assembly scheme[30], [36],[44]

Solar collectors are used for supplying steam to the generator as seen in Fig. 1. Superheated steam exits into the generator and then it enters the condenser. The vaporized refrigerant becomes liquid by transferring heat to the cooling water in it. After that, it comes to the expansion valve where the refrigerant pressure is lowered at exit pressure of the valve. Low-pressure refrigerant enters the evaporator and is evaporated by heat absorbed from the cooled are by using water. The refrigerant vapor enters the absorber and is mixed with a weak solution. The solution is becoming a strong solution. Then, the strong solution is pumped to the generator by passing the heat exchanger where strong solution is transferred heat from the weak solution [30], [36], [38]. As a result, LiBr/H_2Omixture returns to the generator, where it is separated and then the cycle starts again.

The assumptions used in the absorption cooling system calculation are given as below [17].

1) The system is working in a steady state.

2) The refrigerant existing the condenser and evaporator is in a saturated liquid and a steam respectively.

3) The strong solution of the refrigerant leaving the absorber is saturated.

4) The weak solution of the refrigerant leaving the generator is saturated.

5) LiBr/water solutions in the generator and absorber are assumed in equilibrium at their respective temperatures and pressures.

6) Pressure losses in pipelines are neglected.

7) The reference state for the system is water at 25°C and 1 atm pressure.

3. Thermodynamic Analysis of the System

Energy transformation in a process occurs from one form to another as a work and heat. Total amount of energy is conserved during a process. The equations regarding with thermodynamic analysis of the system for all equipment are given in Equations 1-20 [37]. The formulas related to mass and energy conservation laws are given as follows.

$$\sum \dot{m}_{in} = \sum \dot{m}_{out} \quad (1)$$
$$\sum(\dot{m}h)_{in} + \sum \dot{Q}_{in} = \sum(\dot{m}h)_{out} + \sum \dot{Q}_{out} \quad (2)$$

Where $\dot{m}_{in}$ and $\dot{m}_{out}$ are the mass flow rate of the fluid for inlet and outlet point (kg/s), h_{in} and h_{out} are the enthalpies for the inlet and exit point of the fluid (kJ/kg), $\dot{Q}_{in}$ and $\dot{Q}_{out}$ are the heat transfer rate for inlet and outlet point (kW), respectively. Mass and energy balance of the equations for the generator, condenser, evaporator, absorber and heat exchanger are given as follows respectively [37][44]:

$$\dot{m}_7 = \dot{m}_8 + \dot{m}_1 \quad (3)$$
$$\dot{m}_1 = \dot{m}_2 \quad (4)$$
$$\dot{m}_3 = \dot{m}_4 \quad (5)$$
$$\dot{m}_5 = \dot{m}_{10} + \dot{m}_4 \quad (6)$$
$$\dot{m}_6 = \dot{m}_7 \quad (7)$$
$$\dot{m}_8 = \dot{m}_9 \quad (8)$$
$$\dot{Q}_{gen} = -(\dot{m}_7 h_7) + (\dot{m}_1 h_1) + (\dot{m}_8 h_8) \quad (9)$$
$$\dot{Q}_{cond} = (\dot{m}_1 h_1) - (\dot{m}_2 h_2) \quad (10)$$
$$\dot{Q}_{evap} = (\dot{m}_4 h_4) - (\dot{m}_3 h_3) \quad (11)$$
$$\dot{Q}_{abs} = (\dot{m}_4 h_4) + (\dot{m}_{10} h_{10}) - (\dot{m}_5 h_5) \quad (12)$$
$$\dot{Q}_{hex} = (\dot{m}_6 h_6) + (\dot{m}_8 h_8) = (\dot{m}_7 h_7) + (\dot{m}_9 h_9) \quad (13)$$

The mass and work equations of the pump are given as follows [37] [44].

$$\dot{m}_5 = \dot{m}_6 \quad (14)$$
$$\dot{w}_p = \frac{(P_{out} - P_{in})}{\rho \eta_P} \quad (15)$$
$$\dot{W}p = \dot{m}_p \frac{(P_{out} - P_{in})}{\rho \eta_P} \quad (16)$$

where $\dot{w}_p$ is specific work of the pump (kJ/kg), P_{out} is pressure of the fluid at outlet point (kPa), P_{in} is pressure of the fluid at inlet point (kPa), ρ is the density of the fluid (kg/ m3), η_P is the efficiency of pump, $\dot{W}p$ is work of the pump (kW), $\dot{m}_p$ is the mass flow rate of the fluid (kg/s). The mass balance equations for expansion valves are given as follows [37], [44].

$$\dot{m}_9 = \dot{m}_{10} \quad (17)$$
$$\dot{m}_2 = \dot{m}_3 \quad (18)$$
$$h_2 = h_3 \quad (19)$$

In order to evaluate the system, coefficient of Performance (COP) is essentially important which formula is given as follows [37], [44].

$$COP = \frac{\dot{Q}_E}{\dot{Q}_G + \dot{W}_P} \quad (20)$$

where $\dot{Q}_E$(kW) and is $\dot{Q}_G$(kW) are heat transfer rate at evaporator and generator, respectively. $\dot{W}_P$ is the pump power (kW).

3.1. *Exergy Analysis*

Exergy is briefly described as an available energy to be used. The only physical (Ex^{Ph}) and chemical exergy (Ex^{Ch}) in the absorption cooling system is considered. The total exergy (Ex)equation is given as below [45].

$$Ex = Ex^{Ph} + Ex^{Ch} \quad (21)$$

The physical exergy (Ex^{Ph}) is associated with the obtainable work from initial state to thermal and mechanical equilibrium state with the environment. Formula of it is given as below [45].

$$Ex^{Ph} = \dot{m}((h - h_0) - T_0 (s - s_0)) \quad (22)$$

where h_0 is enthalpy at environmental conditions (kJ/kg), T_0 is environment temperature (K), s_0 is entropy at environmental conditions ($kJkg^{-1}K^{-1}$).

The chemical is also defined by using literatures. According to literatures the chemical exergy (Ex^{Ch}) is associated with the obtainable work from thermal and mechanical equilibrium with the environment to most stable configuration equilibrium with environment[30], [45]. General chemical exergy ($\bar{e}_{Ch}^{0}$) can be calculated by using the formula given as follows [46], [47].

$$\bar{e}_{Ch}^{0} = x_i(\mu_{i0} - \mu_{i00}) \quad (23)$$

where x_i is mole fraction, μ_{i0} is chemical exergy potential per unit of material at ambient condition (J/mol), μ_{i00} is chemical exergy potential per unit of material at dead state (J/mol).

The LiBr chemical exergy is neglected because of fact that the chemical state of the absorbent remains constant throughout the absorber circuit. Chemical exergy of water (Ex_{H2o}^{Ch}) is determined from the below equation. Chemical exergy ($\bar{e}_{Ch}^{0}$,$_{H2O}$) of water is obtained as 45 kJ/kmol[45].

$$Ex_{H2o}^{Ch} = \dot{m}\left(\frac{z_{H2o}}{M_{H2o}}\right)\bar{e}_{Ch}^{0},_{H2O} \quad (24)$$

Where z, M are water concentration and molecular weight(kg/kmol), respectively. $\bar{e}_{Ch}^{0}$,H_2O is standard chemical exergy of water (kJ/kmol).

In a steady state-steady flow system, the balance of exergy is given as follows [30], [44].

$$\sum Ex_{in} - \sum Ex_{out} - Q\left(1 - \frac{T_0}{T}\right) - W - (Ex_F - Ex_P - Ex_L) = 0 \quad (25)$$

Where Ex_{in} is exergy of the fluid at inlet (kW), $Ex_{,out}$ is the exergy of the fluid at outlet (kW), T_0 and T are the environment temperature (K) and temperature of the fluid (K), respectively, W is work (kW), Ex_F is fuel exergy (kW), Ex_P is product exergy, Ex_L is loss exergy (kW)[30], [44].

Fuel can be defined as a resource spent in order to generate the product. It can be represented in terms of exergy as fuel exergy(Ex_F). Product can be defined as a desired result produced by the system. It can be represented in terms of exergy as product exergy (Ex_P) [30], [44].

Exergy destruction (Ex_D) represents the amount of exergy which is loss to environment. Also, exergy loss (Ex_L) represents an amount of exergy which is transferred from the analyzed system to some other system(s) [45].Exergy destruction (Ex_D) can be calculated from the following formula [30], [44].

$$Ex_D= Ex_F-Ex_P-Ex_L \qquad (26)$$

Fuel and product exergies, exergy loss and exergy destruction of the components and overall system can be calculated by using given expressions in Table1. Calculation of total exergy (Ex) for components and overall system is done by using Equation 21.

3.1.1. Exergetic Efficiency (Ɛ) and Exergy Destruction Ratios **(Y_D, Y_L):**

Exergetic efficiency (Ɛ) is a ratio of product exergy to fuel exergy. It is defined as follows [30], [44]

$$\mathcal{E}=\frac{Ex_P}{Ex_F}=1-\left(\frac{Ex_D+Ex_L}{Ex_F}\right) \qquad (27)$$

Exergy destruction ratio (Y_D) represents the ratio of the exergy destruction to the exergy of the fuel for the components in the system. It is expressed as follows [30], [44]

$$Y_D=\frac{Ex_D}{Ex_F} \qquad (28)$$

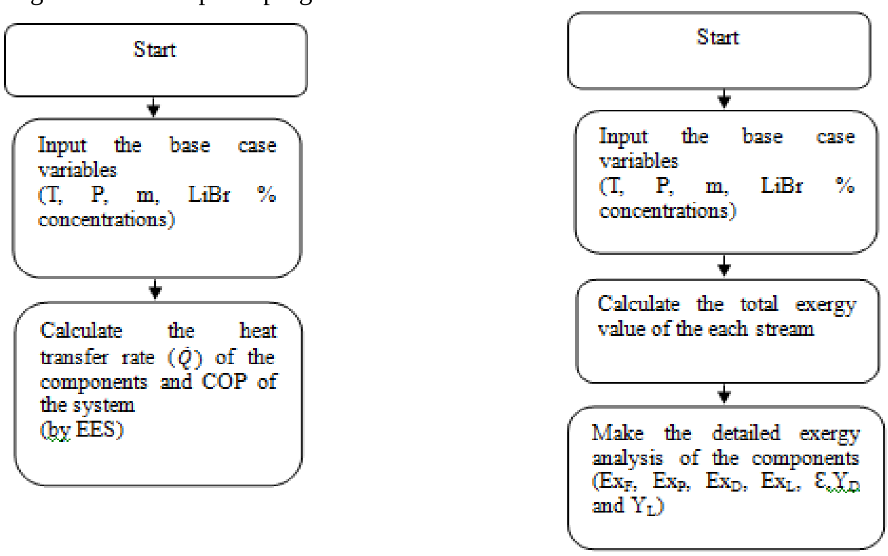
Exergy loss ratio (Y_L) represents the ratio of exergy loss to the exergy of the fuel for the components in the system. It is expressed as follows [30], [44].

$$Y_L=\frac{Ex_L}{Ex_F} \qquad (29)$$

Table 1. Fuel, product, loss and destruction of exergy formulas for the system[30], [36], [44]

Component	**Fuel Exergy (kW)**	**Product Exergy (kW)**	**Exergy Loss (kW)**	**Exergy Destruction (kW)**
Generator	$Ex_{17}-Ex_{18}$	$Ex_1+Ex_8-Ex_7$	–	$(Ex_{17}-Ex_{18})-(Ex_1+Ex_8-Ex_7)$
Evaporator Assembly	$Ex_1+Ex_9-Ex_5$	$Ex_{14}-Ex_{13}$	$(Ex_{12}-Ex_{11})+(Ex_{16}-Ex_{15})$	$(Ex_1+Ex_9-Ex_5)-(Ex_{14}-Ex_{13})-((Ex_{12}-Ex_{11})+(Ex_{16}-Ex_{15}))$
Pump	W_E	Ex_6-Ex_5	–	$W_E-(Ex_6-Ex_5)$
Heat Exchanger	Ex_8-Ex_9	Ex_7-Ex_6	–	$(Ex_8-Ex_9)-(Ex_7-Ex_6)$
Overall System	$Ex_{17}-Ex_{18}$	$Ex_{14}-Ex_{13}$	$(Ex_{12}-Ex_{11})+(Ex_{16}-Ex_{15})$	$(Ex_{17}-Ex_{18})-(Ex_{14}-Ex_{13})-((Ex_{12}-Ex_{11})+(Ex_{16}-Ex_{15}))$

The results obtained after energy and exergy analyses are determined by using the EES computer program. The flow charts about these analyses are given in Figure 3.



(a) Energy and (b) Exergy[44]

Fig. 3. Flow charts for energy and exergy analysis of the system:

4. Results

Table 2 presents the heat transfer rate of the components and COP of the system. Heat transfer rates of the generator, condenser, evaporator, absorber and heat exchanger are obtained from Equations 9-13. Also, COP of the system is obtained according to Equation 20 [44].

Table 3 presents the results of exergy for the system. Physical exergy, chemical exergy and total exergy results are obtained from Equation 21-24.

Table 2. Heat transfer rate of components and COP[44]

Components	Heat Transfer Rate (kW)	COP(%)
Generator	249.1	
Condenser	199.6	
Evaporator	185.4	
Absorber	231:6	
Heat Exchanger	64.77	
COP	-	74.43

Table 3. Exergy results [44]

No	T (°C)	P (kPa)	$\dot{m}$ (kgs^{-1})	Chemical Comp.	LiBrConcent. (%)	Ex^{Ph} (kW)	Ex^{C} (kW)	Ex (kW)
1	100	10	0.08	Superheated Steam	-	13.85	0.20	14.05
2	45.8	10	0.08	Water	-	0.232	0.20	0.432
3	5	0.872	0.08	Water	-	-0.747	0.20	-0.547
4	5	0.872	0.08	Water Vapor	-	-14.08	0.20	-13.88
5	40	0.800	0.81	Water/LiBr	58	34.94	0.85	35.79
6	40.003	10	0.81	Water/LiBr	58	34.94	0.85	35.79
7	80	10	0.81	Water/LiBr	58	41.58	0.85	42.43
8	100	10	0.73	Water/LiBr	64	72.97	0.66	73.63
9	51	10	0.73	Water/LiBr	64	63.77	0.66	64.42
10	49	0.800	0.73	Water/LiBr	64	63.58	0.66	64.23
11-12	37.5/35	101.325	19.10	Water	-	7.54	0.00	7.54
13-14	7/12	101.325	8.87	Water	-	10.20	0.00	10.20
15-16	35/32	101.325	17.84	Water	-	6.44	0.00	6.44
17-18	111.37	149	0.11	Steam	-	60.84	0.00	60.84

Table 4 presents exergy analysis results for the components and overall system. This table includes fuel exergy (Ex_F), product exergy (Ex_P), exergy loss (Ex_L) and exergy destruction (Ex_D) of the components and overall system, exergetic efficiency (Ɛ), exergy destruction ratio (Y_D) and exergy loss ratio (Y_L) [44].Fuel exergy (Ex_F), product exergy (Ex_P), exergy loss (Ex_L), exergy destruction (Ex_D) are calculated from Table 1. Also, exergetic efficiency (Ɛ), exergy destruction ratio (Y_D) and exergy loss ratio (Y_L) are calculated from 27-29 equations.

Maximum exergetic efficiency is calculated from the generator as expected (74.38%). The second most exergetic efficiency is obtained from the heat exchanger as 71.99 % [44].

Evaporator assembly has the maximum exergy destruction (18.50 kW and Y_D =43.36 %). And, exergy loss is considered only for the evaporator assembly (13.98 kW and Y_L=32.76%). So, overall exergetic efficiency of the system is calculated as 16.75% [44].

Table 4. Analysis of exergy results of components and overall system [44].

Components	Ex_F (kW)	Ex_P (kW)	Ex_D (kW)	Ex_L (kW)	Y_D (%)	Y_L (%)	Ɛ (%)
Generator	60.84	45.25	15.58	0.00	25.61	0.00	74.38
Evaporator Assembly	42.68	10.19	18.50	13.98	43.36	32.76	23.88
Heat Exchanger	9.21	6.63	2.57	0.000	27.95	0.000	71.99
Overall System	60.84	10.19	36.67	13.98	60.27	22.98	16.75

COP and exergy destruction, exergy loss and exergetic efficiency results of this study are compared to the other studies. According to comparison results, COP of this study is greater than the five other studies and less than two other studies. The comparison results are presented in Tables 5 and 6.COP difference results between this study and the reference studies are shown in Table 6-7.The exergy destruction ratio, exergy loss ratio and exergetic efficiency difference results between this study and the reference studies are shown in Table 7-8.

Table 5. ComparisonCOP results [44].

COP	**Kaya**[48]	**Mohtaram et al.** [49]	**Panahizadeh** [50]	**Misra et al.**[30]	**Sencan** [38]	**This study**	**Daşkın** [37]	**Erden** [10]
(%)	66.16	70.00	71.17	71.63	74.30	74.43	75.80	84.00

Table 6. ComparisonofCOPresults with other studies(%) [44].

	Kaya [48]	**Mohtaram et al.** [49]	**Panahizadeh** [50]	**Misra et al.**[30]	**Sencan** [38]	**Daşkın** [37]	**Erden** [10]
(%)	12.5	6.33	4.58	3.91	0.175	-1.81	-11.39

Table 7. Exergy destruction, exergy loss and exergetic efficiency comparison results [44]

Results (%)	**Sencan** [38]	**Misra** [30]	**Kaya** [48]	**Panahizadeh** [50]	**This study**	**Mohtaram** [49]
Y_D	88.13	76.35	75.95	77.19	60.27	57.42
Y_L	2.40	12.52	9.87	8.19	22.98	25.74
Ɛ	9.47	11.13	14.19	14.62	16.75	16.83

Table 8. Exergy destruction, exergy loss and exergetic efficiencycomparisonresults (%)[44]

Results comparison (%)	**Sencan** [38]	**Misra** [30]	**Kaya** [48]	**Panahizadeh** [50]	**Mohtaram** [49]
Y_D	-0.32	-0.21	-0.21	-0.22	0.05
Y_L	8.60	0.84	1.33	1.81	-0.12
Ɛ	0.77	0.50	0.18	0.15	0.00

Exergetic efficiency (Ɛ) of the generator is slowly increases in parallel with increasing of the generator temperature. However, exergetic efficiency of the evaporator assembly and heat exchanger decreases slightly with the increasing of generator temperature as seen in Figure 4 [44].

Exergetic efficiency (Ɛ) of the heat exchanger decreases with the increasing of the absorber temperature. However, exergetic efficiency of the evaporator assembly increases slightly with the increasing absorber temperature as seen in Figure 5 [44].

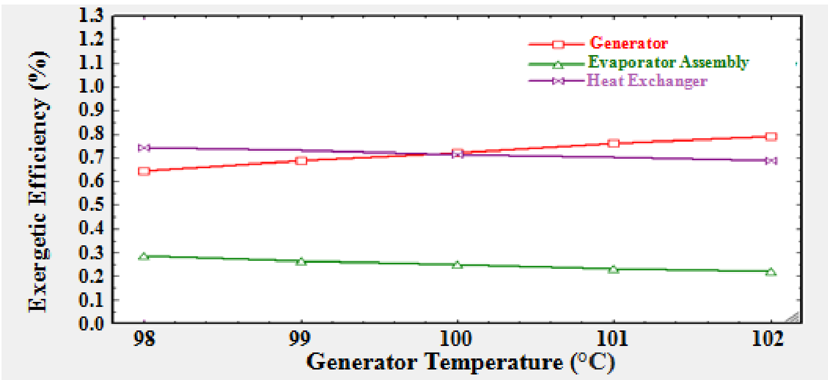


Fig. 4. Variation of exergetic efficiency of the components for different generator temperatures[44]

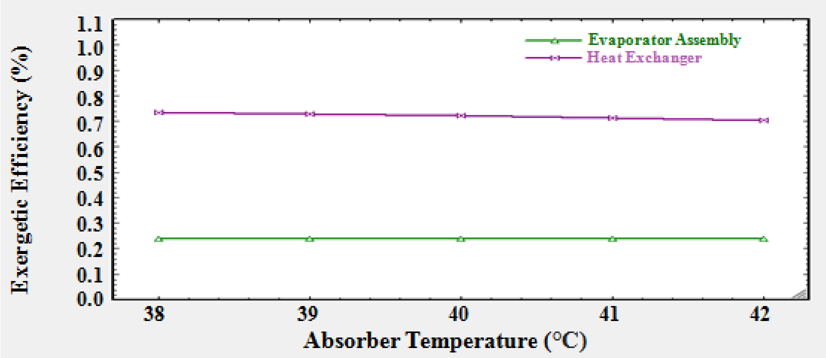


Fig. 5. Variation of exergetic efficiency of the components for different absorber temperatures [44]

Y_D (%) of evaporator assembly slightly increases with the increasing of generator temperature. However, Y_D (%) of the generator decreases slightly with the increasing generator temperature as seen in Figure 6 [44]

Figure 7 presents the variation of Y_D (%) of the components for different absorber temperatures. It shows that Y_D of the evaporator assembly decreases with the increasing of the absorber temperature. However, Y_D of the heat exchanger increases with the increasing of the absorber temperature [44]

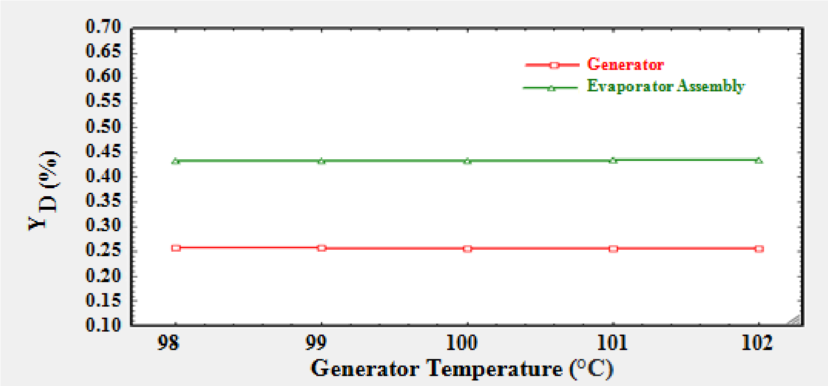


Fig. 6. Variation of Y_D of the components for different generator temperatures [44]

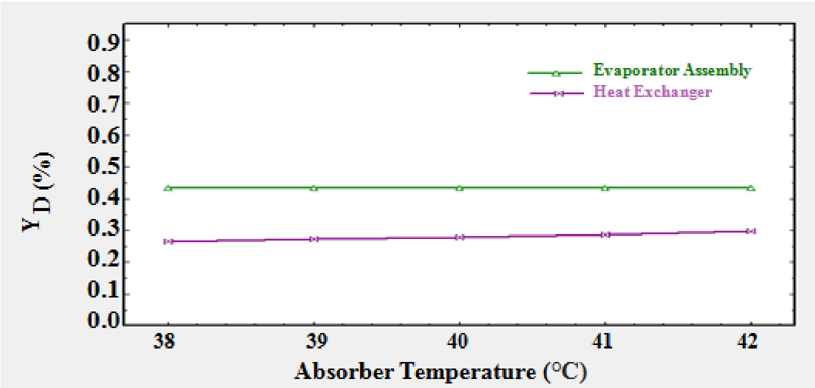


Fig. 7. Variation of Y_D of the components for different absorber temperatures [44]

5. Conclusion

In this study, the first and second laws of thermodynamics are applied to a solar assisted single effect absorption cooling system. According to the first law of thermodynamics, heat transfer rate of the components and the COP of the system are calculated from the thermodynamic properties of the working fluid. COP of the system is calculated as 74.43%. When COP of system is compared with literaturereview it was seen that the result of or study is notonly larger than the result of much more that of four studies but also smaller than two studies.

According to the second law of thermodynamics, exergy is calculated for the system which includes physical and chemical exergy, separately. According to these results taken from of exergy analysis of this study presented that the highest exergy destruction and loss arise at the evaporator assembly. At this content the system has the minimum exergetic efficiency as 23.88%. On the other hand, the maximum and overall exergetic efficiency occurred in the generator as 74.38% and the overall exergetic efficiency of the system is obtained as 16.75%. Within the scope of these results, the novelty and important aspects of our study are explained in detail below.

Detailed exergy analysis includes examination of the exergy destruction, exergy loss, exergetic efficiency and exergy destruction ratio for overall system and each component of the system. The variation of the exergetic efficiency and exergy destruction ratio for the different generator and absorber temperatures are investigated in this study; exergetic efficiency (Ɛ) of the generator is slowly increases in parallel with the temperature increase on the generator. However, exergetic efficiency of the evaporator assembly and heat exchanger decreases slightly with the increasing of generator temperature. Exergetic efficiency (Ɛ) of the heat exchanger decreases with the temperature increase on the absorber.

With the elevation of absorber temperature, exergetic efficiency of the evaporator assembly slightly increases. Similarly, exergy destruction ratio of evaporator assembly slightly increases with the generator temperature. However, exergy destruction ratio of the generator decreases slightly with the increasing generator temperature. In addition to these results, exergy destruction ratio of the evaporator assembly decreases and exergy destruction ratio of the heat exchanger increases with the increasing of the absorber temperature.

Finally, this study draws attention to a detailed thermodynamic analysis and guides the way to improve thermal systems. Thus, the analysis can be applied as a useful tool for the evaluation and improvement of the solar assisted absorption cooling system systems.

In the future work, optimum design temperatures could be found to optimize the system. Also, exergy based thermoeconomic analysis can be done.

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