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Analytical optimization of a solar absorption cooling system

Mehdi Jahangard[1], Afshin Mohseni Arasteh[2*]
1- Department of Mechanical Engineering, Islamic Azad University – North Tehran Branch, Tehran, Iran.
2- Department of Mechanical Engineering, Islamic Azad University - North Tehran Branch, Tehran, Iran
* P.O.B. 123456789 Tehran, Iran, A_mohseni@iau-tnb.ac.ir

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Abstract
In this research, the pressure in the low pressure region in one of the problems and the pressure in the high pressure region in the other problems are constant. According to the conditions of this problem, the best operation conditions for this selected solar absorption system were evaporator temperature of 7°C and heat flux of 530W/m^2. Finally, some important parameters of the solar collector (glass cover thickness, distance between the absorber pipes, distance between the absorber plate and the glass cover, specific heat capacity of the fluid, heat transfer coefficient of air, heat transfer coefficient of fluid) are optimized to supply the required load of the absorption system. According to the results, the glass cover thickness, the distance between the absorber plate and the glass cover, and the heat transfer coefficient of the fluid are in the optimal conditions. But, the heat absorbed in the collector can be increased by about 10% by changing the distance between the absorber pipes, the specific heat capacity of the fluid, and the heat transfer coefficient of the air. Also, the present results error were about 1% and 1.5% for modeling of the solar collector and the absorption system, respectively.

Keywords: Solar collector, Solar absorption cooling system, Online coupling Matlab to EES Software

1. INTRODUCTION

Solar collector systems can be used in the absorption systems. Many works have been done to investigate these systems. Alfred and Erich [1] tested and simulated of a solar-powered absorption cooling machine in 1997. Zinian and Ning [2] investigated a solar absorption air-conditioning plant using heat-pipe evacuated tubular collectors in 1999. They used lithium bromide fluid. They concluded that cooling, heating of ambient, and water heating efficiency are 40%, 35, and 50% respectively. Sheikhani and et al. [3] reviewed the solar absorption cooling systems combined with various auxiliary energy devices in 2018. They concluded that using a water-lithium bromide absorption system with a flat plate collector could yield good results. Bellos and Tzivanidis [4] reviewed the concentrating solar thermal collectors with and without nanofluids in 2019. They concluded that the use of nanofluids could increase system efficiency.

2. MATERIAL AND METHODS

In the present study, the results for the solar collector and the absorption system have been analytically investigated. For this purpose, MATLAB and EES software have been paired together. Figure 1 shows a one-step LiBr-Water absorption cooling cycle. According to this figure, the governing equations of this system are given in Table 1. In these relations, $\dot{m}$ (Kg/s), h (j) , and x are mass flow, enthalpy and mass fraction. Also, Q (w/m^2) and W (w) are Heat flux and pump power [5] [6].

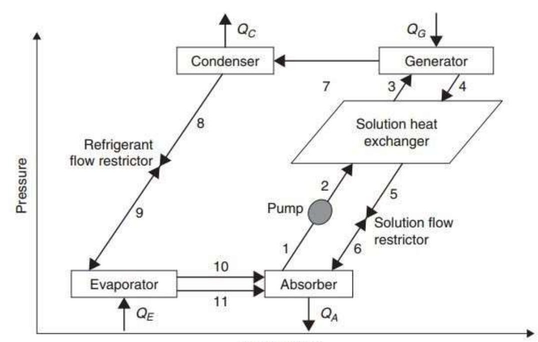

Figure 1. Temperature-pressure diagram of a one-step LiBr-Water absorption system [6].

Table 1. Equations of the absorption system [6]

	Mass balance	Energy balance
pump	$\dot{m}_1 = \dot{m}_2 , x_1 = x_2$	$w = \dot{m}_2 h_2 - \dot{m}_1 h_1$
Heat exchanger	$\dot{m}_2 = \dot{m}_3 , x_2 = x_3$ $\dot{m}_4 = \dot{m}_5 , x_4 = x_5$	$\dot{m}_2 h_2 + \dot{m}_4 h_4 = \dot{m}_3 h_3 + \dot{m}_5 h_5$
Absorption system suppression valve	$\dot{m}_4 = \dot{m}_5 , x_4 = x_5$	$h_5 = h_6$
Absorber	$\dot{m}_1 = \dot{m}_4 + \dot{m}_7 + \dot{m}_{11}$ $\dot{m}_1 x_1 = \dot{m}_6 x_6 + \dot{m}_{10} x_{10} + \dot{m}_{11} x_{11}$	$Q_A = \dot{m}_6 h_6 + \dot{m}_{10} h_{10} + \dot{m}_{11} h_{11} - \dot{m}_1 h_1$
Generator	$\dot{m}_3 = \dot{m}_4 + \dot{m}_7$ $\dot{m}_3 x_3 = \dot{m}_4 x_4 + \dot{m}_7 x_7$	$Q_G = \dot{m}_4 h_4 + \dot{m}_7 h_7 - \dot{m}_3 h_3$
Condenser	$\dot{m}_7 = \dot{m}_8 , x_7 = x_8$	$Q_C = \dot{m}_7 h_7 - \dot{m}_8 h_8$
Refrigerant suppression valve	$\dot{m}_8 = \dot{m}_9 , x_8 = x_9$	$h_8 = h_9$
Evaporator	$\dot{m}_9 = \dot{m}_{10} + \dot{m}_{11} , x_9 = x_{11}$	$Q_E = \dot{m}_{10} h_{10} + \dot{m}_{11} h_{11} - \dot{m}_9 h_9$

Analytical relations of flat plate collector and absorption system have been programmed in the MATLAB software. In order to call EES in MATLAB, the following commands are used.

```
propinfo={'lithium-bromide'Temperature mass_fraction};
EESInput='Address bar\fromMatlab.dat';
EESOutput="Address bar \toMatlab.dat;'
fid=fopen(EESInput,'w');
fprintf(fid,'%s %d %d\r\n',propinfo{1,:});
fclose(fid);
system ('c:\ees32\ees.exe '    Address bar \a4.ees /solve');
out4=dlmread(EESOutput);
Pressure=out4(1);
Antalpy=out4(2);
```

In this research, the EES software has been used for table reading. Some of this commands are as follows.

```
$UnitSystem SI C kPa kJ mass
$Import 'FromMatLab.dat' F$ T X
P=P_LiBrH2O(T,X)
h=h_LiBrH2O(T,X)
$Export 'ToMatLab.dat'  P h
```

The results of the flat plate collector and the absorption system were compared to the results of Khorasanizade et al. and Florides et al. respectively. Also, two absorption systems are selected and the results are analyzed based on that.

3. Results and Discussion

Figure 2 compares the present paper results and the experimental results [7] for the solar collector. According to the Figure 2, the difference in results of outlet temperature is about %1.

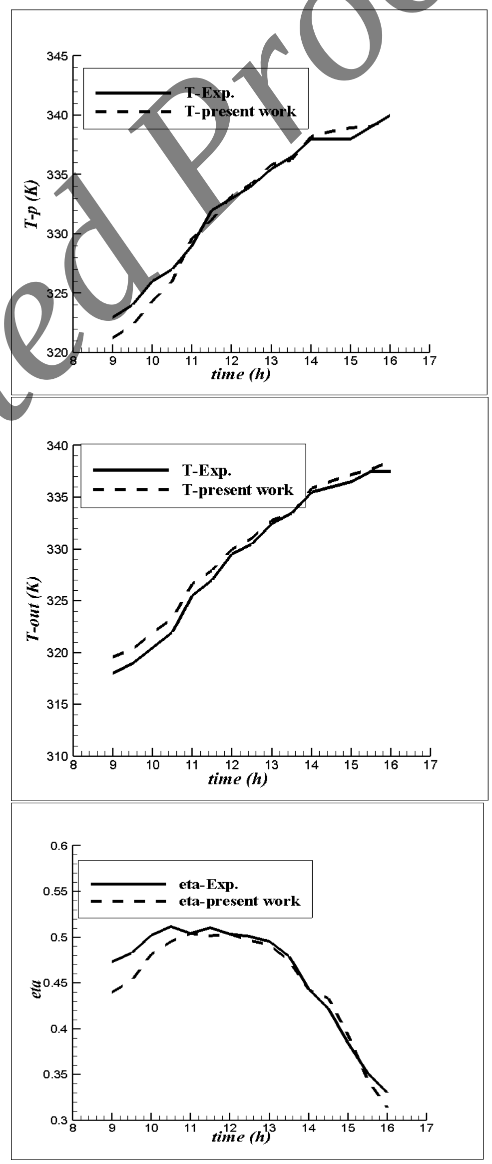

Figure 2. Compared the flat plate collector results. (Plate temperature, outlet temperature, and efficiency) [7]

Also, Table 2 compares the present paper results and the analytical results for the absorption system. According to the Table. 2, the difference in results of COP is about %.1.5 [8].

Table 2. Compare absorption system results [8]

	Present results	Paper results
Evaporator (kw)	$\dot{Q}_e = 10$	$\dot{Q}_e = 10$
Absorber (kw)	$\dot{Q}_a = 13.49$	$\dot{Q}_a = 13.42$
Generator (kw)	$\dot{Q}_g = 14.40$	$\dot{Q}_g = 14.20$
Condenser (kw)	$\dot{Q}_c = 10.92$	$\dot{Q}_c = 10.78$
Efficiency	0.694	0.704

The purpose of selected absorption systems was to change the pressure in the high and low pressure level of the system. The general schematic of the results is shown in Figure 3, respectively. According to the results, the evaporator can cool the fluid to lower temperatures by reducing the low pressure level. However, this pressure change has no effect on the heat absorbed by the evaporator. The heat absorbed on the evaporator side can be increased by reducing the high pressure level. This maximum pressure is limited by the selected system.

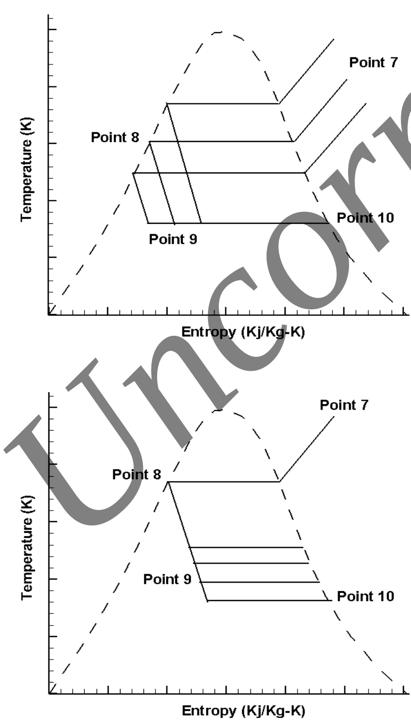

Figure 3. Temperature-entropy diagram for the change in e high and low pressure level

Also, in order to optimization the flat plate collector results by changing cp, h_wind, and h_water, the results are shown in Figures 4-6. According to the results, less input flux is required to supply the 460 W load by increasing the Cp value. In fact, this study shows that using nanomaterials has a good effect on this system.

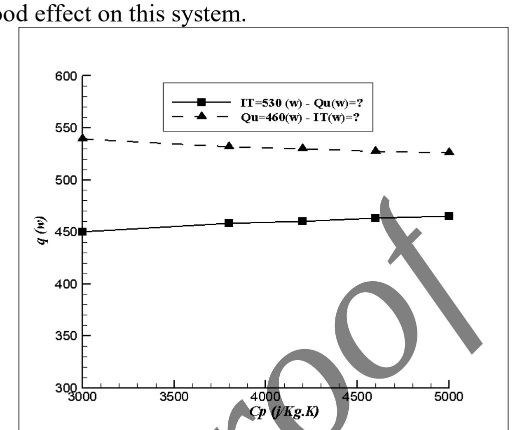

Figure 4. Compared of required flux and input flux to generator by changing Cp.

According to the results, the loss in the system increased by increasing h_wind and so the absorbed heat decreased.

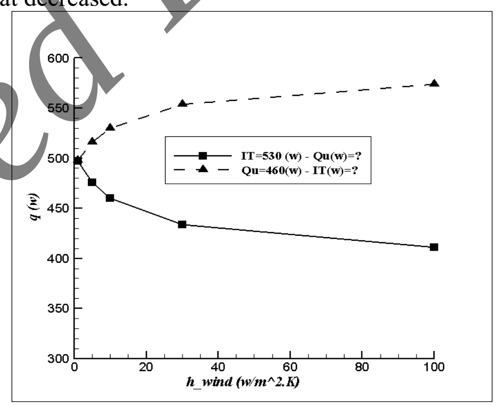

Figure 5. Compared of required flux and input flux to generator by changing h_wind.

Also, decreasing the h_water has a much greater effect than increasing it on the heat absorbed by the collector.

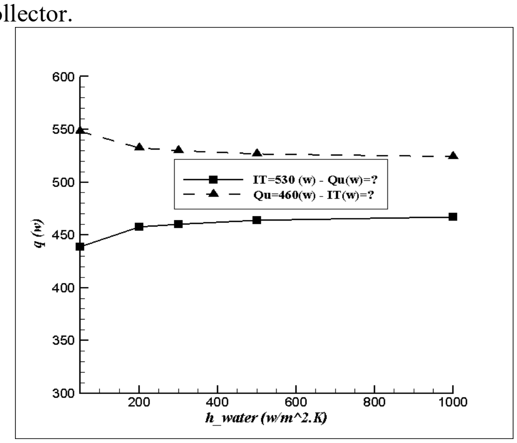

Figure 6. Compared of required flux and input flux to generator by changing h_water.

4. Conclusions

- The low and high pressure can be changed by changing the mass fraction of the weak side by considering different conditions for the absorption system.
- The evaporator can cool the fluid to lower temperatures by reducing pressure level. However, this pressure change has no effect on the heat absorbed by the evaporator.
- The heat absorbed on the evaporator side can be increased by reducing the high pressure level. This maximum pressure is limited due to the selected system.

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