Parametric Theoretical Study of Solar Assisted Cooling System Using Lithium Bromide-Water Pair

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Abstract: In this paper, the effect of parameters of solar absorption system such as evaporator, absorber, condenser, generator temperatures and the mass of the solution on the evaporator cooling load and the coefficient of performance has been explained theoretically. The results show that, increasing of evaporator and condenser temperatures increase the evaporator cooling load, performance coefficient and the Ratio of Circulation while increasing the temperature of condenser and absorber decreases the evaporator cooling load, performance coefficient and the Circulation Ratio. In addition, increasing the solution mass increases the refrigeration power while the performance coefficient and the Circulation Ratio was constant at increasing the solution mass. The reached maximum cooling load was (1.932 kW) at 15 kg solution mass and 100 °C generator temperature, the maximum COP was 0.774 at (10 °C) temperature of evaporator and the peak Circulation Ratio was 0.3066 at (30 °C) temperature of absorber and (100 °C) temperature of generator.

Keywords: Water; Lithium Bromide; Generator Temperature; Evaporator Cooling Load; Coefficient of Performance

1. Introduction
Solar power is one of the most major renewable energy resources. In Comparison to other sources, solar power can be described by the reality that it is obtainable, almost, anywhere. Moreover, it is neat and has no poor impacts on the atmosphere. It could be used in one of the next two methods: by converting irradiance directly to electric power, by utilizing photovoltaic cells, or by converting irradiance into frontal thermal power utilizing collectors. Climatic conditions decrease the level of solar irradiance that hits the Earth's surface before dissipating about 20% to 30% of the incident light and adjusting its spectrum. After crossing meantime, the atmosphere of Earth, about one half of the solar radiation is in the visible electromagnetic spectrum with the other half is mostly in the infrared and ultraviolet spectrum [1].

Gonzalez-Gil et al. [2] assessed the efficiency of an absorption cooler cooled directly by air in summer 2010, centered on test outcomes of many days in Madrid. The system was working effectively, with COP of about 0.6. Refrigeration capacity ranged from 2 kW to 3.8 kW, that accounted for around 85% of the total output of the prototype. The temperatures of cooled water varied mainly between 14°C and 16°C with 12.8 °C minimum calculated value. The system was capable to fulfill an average of 65% of the refrigeration request corresponds to 40 m² space. During around one hundred hours of process no signs of crystallization were found.

Shirazi [3] concentrated on the combination of LiBr-H₂O single, dual and triple-acting absorption coolers with collectors. He observed that the SHC triple-acting cooler has the more power-sufficient and eco-friendly environment quality which led to decrease energy consumption between 47% and 62%. It was revealed that systems could provide satisfying payback durations within 2 to 6 years. The
parabolic pipe collectors and evacuated flat plate collectors have been proposed for such implementations and the chiller worked with a performance coefficient of about 0.9-1.1 at a temperature of steady supply of ~168 °C, generating 6-7 kW cooling.

Hussein [4] developed and simulated the unit of absorption cooling using a solar receiver of flat-plate type with a mixture of (LiBr-H₂O) as an operating fluid, and to choose the best possible form of absorption refrigeration system that is suitable for use in Iraq. The weather conditions for the city of Erbil has been chosen. Performance Coefficient(COP) for single, double (series and parallel), triple and half absorption cooling impacts were computed and configured. Programs of TRNSYS and EES were used to simulate and represent COP Estimation, hot water temperature and rate of heat transfer. The receiver effective field of solar flat-plate has also been calculated and optimized for five proposed areas (140, 150, 160, 170 and 180 m²). The indicated results that the preferred form of the four absorption-chilling systems had a single effect with a COP of 0.80 at a temperature of generator 81 °C. The outcomes also demonstrated that the optimal field of the receiver of solar flat-plate was 160 m² since it had accomplished the peak cooling and consuming capability of the generator (50 and 62.5 kW respectively).

Barrera et. al [5] investigated the analysis of the experimental examinations done with the advanced Solar-GAX absorption cooling device, configured for chilling capacity of 10.5 kW (3 ton) with the mixture of aqua-ammonia. The device developed to work at about 200 °C heat source temperatures, comprised of a generator and absorber of a falling layer kind and an absorber and condenser cooled by air of the finned tube type, which is a choice to areas with water lack. Temperatures of energy source of 160 °C have been developed to simulate the circumstances in which solar thermal concentration technology was used to provide heat to the system. A 3.17 kW partial load with a 0.15 COP have achieved when the Solar-GAX device was controlled at a 120 °C temperature of generator at a 200 °C generator operating temperature with a10.5 kW design power. The absorption device that was air-cooled has been tested at temperatures of ambient higher than 30°C. In addition, at temperatures of ambient 28 °C, a cooling power of 7 kW was reached, with such a 0.35 kg/min flow rate of ammonia mass and a rate of water flow 15 kg/min, for diluted solution temperatures at 140 °C, a 0.2 to 0.3 COP on the side of water and 0.25 to 0.45 on the side of ammonia was obtained under the conditions.

Mezher et al [6] built, installed and operated a prototype of solar refrigeration device using the flat plate collector. The studied device displayed a chilling power of 0.15 ton with a performance coefficient of 0.48, and the obtained minimum temperature of evaporator was 14.2 °C. The outcomes provided a better explanation for the usage of methanol as a refrigerant with the solar absorption device, and the device could operate in a continuous cycle of operation. That analysis provided a fundamental explanation for the solar refrigeration device design. The study outcomes were employed to model a one-ton air cooling device utilizing solar power and the refrigerant used was the methanol.

Prakash et al [7] designed, constructed and analyzed the output of a one stage Vapour absorption system with 1kW refrigeration power. The installed heat exchanger in the unit was of spiral tube and shell kind. The employed condenser was of forced horizontal tube heat exchanger kind in the unit configuration. The unit generator was a pool boiling kind. The theoretical outcomes that include the coefficient of overall heat transfer were compared with the examination outcomes for the unit with 1kW output. The unit real COP was enhanced by 15% with the solution concentration reduction at absorber inlet.

Mussati et al [8] conducted a results for optimization which gained for a dual-acting H₂O-LiBr absorption cooling unit with regard to the overall cost as a criterion for minimization, for a wider range of refrigeration power values. It has noted that the overall cost has tremendously decreased when the heat exchanger working at lower temperature is cancelled in comparison to the construction which included it. As well as, it has discovered that the acting of deleting the heat exchanger was comparatively most important at raising refrigeration power levels. A decreasing of 9.8% in the overall cost was gained.
for a refrigeration power of 16 kW (11,537.2 $\text{year}^{-1}$ vs. 12,794.5 $\text{year}^{-1}$), while a decreasing of 12% has gained for a 100 kW refrigeration power (31,338.1 $\text{year}^{-1}$ vs. 35,613.9 $\text{year}^{-1}$).

Moreover, Fischer et al [9] developed a thermodynamic modeling of a single acting absorption cooler focused on mass, energy and species equilibriums in steady state condition for analyzing the acting of the external rates of flow in the cooler. The enhancement of the flow rate of hot water or cooling water produced a good output of the cooler. They found that, if the flow rate of chilled water reduced, the output improved, the best output construction was with 120% of flow rate of hot water and chilling water, 80 % of flow rate of chilled water and the higher temperatures of inlet hot water resulted in a high coefficient of performance (COP) and heat removal as well as low temperature of inlet chilling water.

Uçkan et. al. [10] designed a single-acting solar-powered unit and used lithium bromide as an absorber and water as a refrigerant at 35.17 kW cooling power, consisting of an evacuated pipe collector using 95 m$^2$ space of aperture, and a collector's inclination of 30° with the horizon. The hot water storage capacity was 3 m$^3$. The system cooled a ground area of 270 m$^2$. The outcome was that the COP of the chiller oscillated between 0.69 and 0.67 between 8:00 a.m. and 14:00 pm, afterwards, the COP of chiller gradually decreased from 14:00 to 18:00 between 0.69 and 0.57. The cooler absorption average output was noticed to be 0.63. The unit optimization results revealed that the unit provided a building air cooling of 270 m$^2$. The mean absorption COP was about 0.62.

Zeiny et al. [11] investigated the proposal of mixing the solution of lithium bromide (LiBr) with nanoparticles. The experiments were accomplished for appraising the nanoparticles acting addition, i.e. carbon black (CB) and multiwall carbon nanotubes (MWCNTs), on the optical properties, viscosity, thermal conductivity, steam absorption and photo-thermal conversion of LiBr solutions. On the Contrary to once reported, the absorption rate of steam was not improved by addition of nanoparticles to the aqueous LiBr solution, which disclosed that grazing and Brownian motion have neglected acting on the mass transfer. A neglected nanoparticle acting on the effective thermal conductivity was also remarked. However, a lower nanoparticle concentration of 0.005 wt.% reduced the aqueous LiBr solution transparency to 0%, that importantly enhanced the photo-thermal conversion of the samples. On the contrary to CB, MWCNTs enhance the viscosity importantly. Therefore, seeding cheap commercial CB in aqueous LiBr solution has the possibility for contribution into the evolution of solar-led cooling technique.

Aramesh et al [12] analyzed the output of a dual-acting LiBr-H$_2$O absorption cooling loop and the unit was enhanced by applying solar energy and using nanofluids. A trough collector has utilized for preheating the operating fluid before entering the cycle generator. In addition, four various nanofluids were considered as the heat transfer fluid of the collector: Al$_2$O$_3$, Ag, Cu, and CuO. Various concentrations of the nanoparticles from 0 to 2.5% were used for the nanofluids. The outcomes showed that, in all the concentrations, Ag nanoparticles would have a good output in comparison to other kinds. Also, it was deduced that the high nanoparticles concentrations and along with it the higher inlet generator temperature would reduce the generator heat production rate up to 4%. As well as, considering the cycle constant refrigeration power, utilizing of the Ag nanoparticles in the concentration of 2.5% enhanced the value of COP up to 3.9%, with respect to the pure water.

Abdul Ameer et. al [13] carried out a theoretical and experimental study for the performance of a solar-powered continuous flow absorption refrigeration unit using a compound parabolic concentrator (CPC) solar collector and two types of working fluids, LiBr-H$_2$O and diethyl ether-ethanol in Iraq. The experimental outcomes revealed that the peak thermal efficiency of the CPC was obtained at approximately 12:00 p.m. at 21$^\text{st}$ day of each month from January to June (0.48, 0.512, 0.57, 0.606, 0.618 and 0.67) respectively when the water flow rate was about 0.0277 kg/s and the efficiency was boosted at higher water flow rates. Hot water temperature as high as 98 °C was obtained. In the mathematical model, the thermal efficiency at 12:00 p.m. for the 21$^\text{st}$ day of each month ranged from (0.67-0.73) at water flow rate of (0.0277 kg/s) at the same climate conditions. The theoretical and experimental coefficient of performance of the absorption system for two pairs and at different solution concentrations are ((0.31-0.72) for lithium bromide/water while (0.6-82) for Diethyl Ether/Ethanol).
Hamzah et al [14] manufactured an interrupted absorption cooling unit under Hillah weather in Iraq. The absorption system comprised of parabolic trough solar concentrator (PTSC) was utilized as a reflector of solar mirror with 2 m² aperture area, carbon steel tube, a vacuum glass envelope with a 1.5 in diameter as a receiver, a tank for water storing, condenser and an evaporator. The solution of ammonia-water (NH₄OH) was utilized as an operating fluid with various concentrations (25%, 30%, 35%, 40%). The quality and vision of the system were assessed during a year from May 2014 to July 2015 by measuring pressure and temperature at various components of the unit. The peak temperature and pressure at generator were approximately 120 °C and 12 bar respectively. The performance coefficient was about from 0.01 to 0.09. The performance coefficient was about from 0.01 to 0.09. As well as, Bellos et. al [15] tested numerically the efficiency of Linear Fresnel Reflector thermal power in existence of the Nanofluid Syltherm 800/CuO for the 2, 4 and 6% concentration by using CFD technique. Collector reflectors are flat mirrors of a 27 m² total pure area of aperture, while the supplementary reflector has a parabolic form. The temperature of inlet was between 350 K and 650 K for the study. He noticed that the thermal efficiency improvement was approximately 0.28 % when nanofluids were used as a working fluids.

Ammonia-water absorption refrigeration device with parabolic trough collector, which concentrates solar power in a receiver tube for heating water was tried by Stanciu et al [16]. Time-dependence of refrigeration load was regarded for a domestic two-story home cooling. The outcomes stated that there was a particular size for storage tank combined with a particular collector dimension that guarantee the longest continual refrigeration device working at considered permanent rates of mass flow within the device.

The low residential silica gel-water adsorption refrigeration efficiency of a device in existence of a reflective concentrator parabolic collector domain powered adsorption (silica gel-water) refrigeration device at hot and arid climate experimentally investigated by Reda et al [17]. The system consisted of a 36 m² entire space, an 8 kW refrigeration power adsorption cooler with silica gel-water. The findings of the domain test of the summer period showed that at daily solar irradiance ranging from 21 to 27 MJ/m², the utilized collectors had a higher and often constant efficiency of thermal power. The daily output of solar collectors through the device operation varied from approximately 50-78%.

In Iraq, due to the high temperatures encountered, an important share of generated electric power is employed for air conditioning sector. Due to Iraq geographical location the availability of maximum solar radiation and the maximum power demand approach simultaneously peak rates. Iraq obtains a large quantity of energy from the sun more than (6.5-7) kWh/m², in comparison to the United States that is 3.6 kWh/m² and Europe's 2.5 kWh/m² [18]. The refrigeration systems that depend on solar radiation have a great potential since the solar radiation is obtainable all year round. The advantage of utilizing solar radiation to operate the units of air conditioning is that the solar radiation availability and the demand for cooling have reached peak rates simultaneously and relatively.

It is noticed from the above sighted literature that most papers concentrated on a single operating parameter and its effect on performance. This work shall involve parameters that affect the absorption cooling system as a whole and each single components of system such as evaporator, absorber, condenser and generator. The EES software will be utilized for analyzing the solar refrigeration loop.

2. Modeling of Used System
The used lithium bromide-water absorption cooling loop is explained in Figure 1. In this loop, high pressure Liquid water passes the expansion valve where its pressure decreases and its condition become a mixture of liquid and gas. This mixture enters the evaporator and absorbs heat from the volume to be cooled and it becomes water vapor at low pressure. The low pressure steam passes to absorber and lithium bromide absorbs it. The mixture crosses the pump with increase in its pressure. The weak lithium bromide mixture with high pressure gains heat in the heat exchanger and leaves to the generator. This solution gets heat from the solar power and higher pressure steam and strong lithium bromide mixture leaves the generator. This strong lithium bromide mixture crosses to the heat exchanger and the higher
pressure steam passes to the condenser. At the condenser, a heat transfers from the higher pressure steam to the circumstances and the higher pressure steam becomes a liquid.

![Diagram of absorption refrigeration cycle]

Figure 1. A scheme of an absorption refrigeration cycle [13]

3. Thermodynamic Analysis

The system is analyzed by considering the main elements i.e. the generator, condenser, evaporator, absorber and heat exchanger as a single control volume. The adding or removing of heat at each element is gained by considering an energy equilibrium at each part.

The design calculation is based on the following assumptions:
1. Neither the generator releases any heat to the surroundings nor the evaporator receive heat from the surroundings.
2. The refrigerant is considered to be in the saturated vapor state at the evaporator exit and generator exit.
3. The refrigerant is considered to be in the saturated liquid state at the condenser exit.
4. The pump work is negligible.
5. There is no pressure drop in the pipes.
6. Generator and condenser are assumed as same pressure and equal to high pressure of the system.
7. Evaporator and absorber are assumed as same pressure and equal to low pressure of the system.
8. Lithium bromide – water solution is used as working pair in design system.
9. The fluid temperature is constant inside the components.

The heat transfers rate from condenser to surrounding is given by,

\[ \dot{Q}_{\text{cond}} = \dot{m}_7 \times (h_7 - h_8) \]  

where " \( \dot{m} \) " is the rate of mass flow of water, and "h" is the enthalpy. At the expansion valve, the expansion occurs at constant enthalpy,
The evaporator heat removing rate is obtained as
\[ Q_{\text{evap}} = \dot{m}_9 (h_{10} - h_9) \] (3)

The absorber heat transfer rate to surrounding is gotten from
\[ Q_{\text{abs}} = \dot{m}_{10} h_{10} + \dot{m}_1 h_1 - \dot{m}_4 h_4 \] (4)

The mass balance in the absorber is,
\[ \dot{m}_4 = \dot{m}_{10} + \dot{m}_3 \] (5)

The input power for pump is obtained by
\[ \dot{W}_p = \dot{m}_4 (h_5 - h_4) = \dot{m}_4 v_4 (P_5 - P_4) \] (6)

where "v" is the specific volume, and "p" is the pressure. For heat exchanger, the energy balance can be obtained as
\[ \dot{m}_3 (h_6 - h_3) = \dot{m}_1 (h_2 - h_1) \] (7)

The heat exchanger effectiveness can be put in the form
\[ HX = \frac{T_G - T_2}{T_G - T_5} \] (8)

The rate of heat transfer in generator is found by
\[ Q_{\text{gen}} = \dot{m}_7 h_7 + \dot{m}_1 h_1 - \dot{m}_6 h_6 \] (9)

The mass balance equation in the generator is,
\[ \dot{m}_6 = \dot{m}_1 + \dot{m}_7 \] (10)

The governing equations used to evaluate the solution mass in each component is,
\[ \dot{m}_{w1} = \dot{m}_{w3} + \dot{m}_w \] (11)

This equation is the same as the mass balance equation in the generator (10). The coefficient of performance is expressed as:
\[ \text{COP} = \frac{Q_{\text{Evaporator}}}{Q_{\text{Generator}} + \dot{W}_P} \] (12)

4. Results and Discussions

4.1 Evaporator Cooling Load

Figure 2 shows the relation between the cooling load and the temperature of generator at various refrigerant temperatures at exit of evaporator. It can be noticed that raising the temperature of generator enhances the cooling load at all refrigerant exit temperatures and the increase of refrigerant exit temperatures at evaporator also raises the refrigeration capacity because of raising the enthalpy difference at the evaporator, so the maximum value of the cooling load at temperature of generator of about (100 °C) and refrigerant exit temperatures of (6 °C) that is about (1.685 Kw). Also, Figure 3 explains the relation between the cooling load and the temperature of generator at various temperatures of condenser. It was noted that increasing the temperature of condenser decreases the refrigeration load because of decreasing the enthalpy difference at the evaporator, so the maximum value of the cooling load at temperature of generator of about (100 °C) and temperature of condenser of (30 °C) of about (1.689 kW). Moreover, Figure 4 shows the relation between the cooling load and the temperature of generator at various temperatures of absorber. It was remarked that the increase of absorber temperature decreases the cooling load, so the maximum value of the cooling load at temperature of generator of about (100 °C) and temperature of absorber of (30 °C) of about (1.853 kW). As well as, in Figure 5, the relationship between the cooling load and generator temperature at different solution masses at constant other parameters has been explained. It can be remarked that, increasing the mass solution increases the cooling load because of increasing the vaporized water at evaporator, so the maximum value of the cooling load at temperature of generator of (100 °C) and mass solution of (15 Kg) of about (1.932 Kw).
Figure 2. The relation between the cooling load and temperature of generator at various refrigerant temperatures at exit of evaporator.

Figure 3. The relation between the cooling and temperature of generator at various temperatures of condenser.
Figure 4. The relation between the coaling load and temperature of generator at various temperatures of absorber.

Figure 5. The relation between the coaling load and temperature of generator at various mass solutions.
4.2 Coefficient of Performance

Figure 6 shows the relation between COP and generator temperature at different refrigerant exit temperatures at evaporator. It can be noticed that raising the temperature of refrigerant at evaporator exit raises COP due to the increase of water enthalpy difference at evaporator, and the increase of generator temperature also increases COP because of increasing the vaporized water at the generator, so the maximum value of COP at (100 °C) temperature of generator and (6 °C) temperature of evaporator that is about (0.762). Also Figure 7 explains the relation between COP and temperature of generator at various temperatures of condenser. It can be noted that increasing the condenser temperature reduces COP because of decreasing the enthalpy difference at the evaporator, so the peak value of COP at (100 °C) temperature of generator and (30 °C) temperature of condenser that is about (0.762). Moreover, Figure 8 shows the relation between COP and temperature of generator at various temperatures of absorber. It was remarked that the increase of absorber temperature decreases COP due to decreasing the vaporized water at the generator, so the maximum value of COP at (100 °C) temperature of generator and (30 °C) temperature of absorber that is about (0.765). The increase of solution mass does not increase COP because of the proportional increase of cooling load and generator heat at constant COP.

Figure 6. The relationship between COP and temperature of generator at various refrigerant temperatures at exit of evaporator.
Figure 7. The relation between COP and temperature of generator at various temperatures of condenser.

Figure 8. The relation between COP and temperature of generator at various temperatures of absorber.
4.3 Circulation Ratio

The ratio of circulation can be expressed as (the proportion between the rate of mass flow of refrigerant to the rate of mass flow of strong solution).

Figure 9 shows the relation between Circulation Ratio and temperature of generator at various refrigerant exit temperatures at evaporator. It can be remarked that, raising the temperature of generator raises the Circulation Ratio at all refrigerant exit temperatures because of increasing the vaporized water, and the increase of refrigerant exit temperatures also raises the Circulation Ratio, so the maximum value of Circulation Ratio at (100 °C) temperature of generator and (6 °C) temperature of evaporator that is about (0.2706). Also, Figure 10 explains the relationship between Circulation Ratio and generator temperature at various temperatures of condenser. It was noted that the increase of condenser temperature decreases Circulation Ratio due to decreasing the vaporized water, so the maximum value of Circulation Ratio at (100 °C) temperature of generator and (30 °C) temperature of condenser that is about (0.2701). Moreover, Figure 11 shows the relation between Circulation Ratio and temperature of generator at various temperatures of absorber. It was remarked that raising the absorber temperature reduces the Circulation Ratio due to decreasing the vaporized water, so the maximum value of the Circulation Ratio at (100 °C) temperature of generator and (30 °C) temperature of absorber that is about (0.3066). As well as, in Figure 12, the relation between the Circulation Ratio and refrigerant exit temperatures at evaporator has been shown. It was noted that, raising refrigerant exit temperatures raises the Ratio of Circulation because increasing the vaporized water at the generator, so the maximum value of the Circulation Ratio at refrigerant exit temperature of (10 °C) and generator temperature of (100 °C) of about (0.1761).

Figure 13 explains the relation between the Circulation Ratio and condenser temperature. It was seen that, increasing the condenser temperature decreases the Circulation Ratio due to decreasing the vaporized water at generator, so the maximum value of the Circulation Ratio at condenser temperature of (25 °C) of about (0.1717). Also, Figure 14 shows the relationship between the Circulation Ratio and temperature of absorber. It was noted that, increasing the temperature of absorber decreases the Circulation Ratio due to decreasing the vaporized water, so the maximum value of the Circulation Ratio at absorber temperature of (25 °C) of about (0.2219).
Figure 10. The relationship between the Circulation Ratio and temperature of generator at various temperatures of condenser.

Figure 11. The relationship between the Circulation Ratio and temperature of generator at various absorber temperatures.
Figure 12. The relationship between the Circulation Ratio and the refrigerant exit temperatures from evaporator.

Figure 13. The relation between the Circulation Ratio and the temperature of condenser.
5. Conclusions
The absorption cooling system is studied theoretically using lithium bromide-water mixture using EES software under Iraq weather conditions. Different parameters that affect the absorption cooling system are considered such as the variation of temperature of generator, condenser, evaporator and absorber. Moreover, the effect of rising the size of the system is considered. The maximum obtained cooling load is (1.932 kW) at 15 kg solution mass and 100 °C generator temperature, the maximum COP was 0.774 at refrigerant exit temperature from evaporator of (10 °C) and the peak Circulation Ratio was 0.3066 at 30 °C absorber temperature and 100 °C temperature of generator. From the results, it was concluded that:

1- Increasing of generator temperature improves the cooling load, system COP and circulation ratio due to increasing the vaporized water at the generator.
2- Increasing of refrigerant exit temperature at evaporator improves the refrigeration capacity, system COP and circulation ratio due to increasing the enthalpy difference at the evaporator.
3- Increasing condenser temperature reduces cooling load, system COP and circulation ratio due to decreasing the enthalpy difference at the evaporator.
4- It is also concluded that increasing absorber temperature reduces both system COP and circulation ratio due to decreasing the vaporized water at the generator.

Figure 14. The relation between the Circulation Ratio and the temperature of absorber.
5- In addition, raising the size of the system improves the refrigeration capacity while the performance coefficient and the Circulation Ratio remain constant.

References

[1] Wald L 2007 Solar radiation energy (fundamentals) Solar Energy Conv. and Photoenergy Systems 1.
[2] Gonzalez-Gil A Izquierdo M Marcos J D and Palacios E 2011 Experimental evaluation of a direct air-cooled lithium bromide-water absorption prototype for solar air conditioning J. Appl. Thermal Eng. 31 16 pp 3358–3368.
[3] Shirazi A 2017 Feasibility of Solar-Assisted Absorption Chillers for Air-Conditioning Applications PhD dissertation School of Mechanical and Manufacturing Engineering University of New South Wales.
[4] Hussein H A 2017 Modeling and Simulation of an Absorption Solar Cooling System Under Iraqi Weather Conditions Eng. Tech. J. 35 4 pp 356-364.
[5] Barrera M A Best R Gómez V H García-Valladares O Velázquez N and Chana J 2012 Analysis of the performance of a GAX hybrid (Solar - LPG) absorption refrigeration system operating with temperatures from solar heating sources Enery Procedia 30 pp 884 – 892.
[6] Mezher W M Awadh A A and Mohammed A A 2014 Solar Powered Air-Conditioning Using Absorption Refrigeration Technique J. Eng. 20 10 PP 47-59.
[7] Prakash CH J Kumar K D Rao T S 2019 Fabrication and Experimental Analysis of Absorber Based LiBr – Water Absorption Refrigeration System Int. J. Eng. Adv. Techn. 8 6 pp. 4094-4103.
[8] Mussati S F Mansouri S S Gernaey K V Morosuk T and Mussati M C 2019 Model-Based Cost Optimization of Double-Effect Water-Lithium Bromide Absorption Refrigeration Systems Processes 7 1 pp. 1-16.
[9] Fischer Y R Silva I S Dutra J C C 2019 the influence of the external flow rates on an absorption chiller Aust. J Basic Appl. Sci. 13 9 pp. 92-98.
[10] Uckan I and Yousif A A 2019 Simulation of a solar absorption cooling system in Dohuk city of the Northern Iraq, Energy Sources, Part A: Recovery, Utilization, and Environmental Effects pp1-17.
[11] Zeiny A Haruna M A and Wen D 2019 Aqueous lithium bromide nanosolution for solar absorption refrigeration systems AIP Conf. Proceed. 2123, 020088.
[12] Aramesh M Pourfayaz F Haghir M Kasaeian A and Ahmadi M H 2019 Investigating the effect of using nanofluids on the performance of a double-effect absorption refrigeration cycle combined with a solar collector J. power energy pp. 1-13.
[13] Abdul Ameer S A 2018 Experimental and Theoretical Study of Absorption Cooling System Integrated with Solar Concentrated Collector PhD dissertation Department of Mechanical Engineering College of Engineering University of Babylon.
[14] Hamzah D A and Shahad H A K 2015 Investigation on an Intermittent Absorption Refrigeration prototype powered by Solar Irradiation Al-Qadisiyah J. for Eng. Sci. 8 4 PP. 513-525.
[15] Bellos E Tzivanidis C and Papadopoulos A Enhancing the performance of a linear Fresnel reflector using nanofluids and internal finned absorber J. Thermal Analysis and Calorimetry PP.1–19.
[16] Stanciu C Stanciu D and Gheorghian A T 2017 Thermal Analysis of a Solar Powered Absorption Cooling System with Fully Mixed Thermal Storage at Startup Energies 10 pp.1-19.
[17] Reda A M Ali A H H 2017 Performance of a small-scale solar-powered adsorption cooling system, Int. J. Green Energy 14 1 pp.75–85.
[18] Abass K I 2007 Is Iraq Ready to Use Solar Energy Applications: A Review, Int. J. Eng. Sci. Inv. 6 10 pp. 27-42.