Optimization of solar adsorption refrigeration systems

BENRAMDANE Mohammed[1*], BERREZOUG Hiba Imane[2], GHRICI Adenane[3], BOUYELFANE Asmaa[4], CHIKH Mohammed El Amine[5], BENMANSOUR Sid Ahmed[6]

[1,3,5] *ETAP Laboratory, Department of Mechanical Engineering, faculty of technology, University of Tlemcen, Algeria
[2] Theoretical Physics Laboratory, Abou-Bekr Belkaïd University, Tlemcen, Algeria.
[4] URMER Laboratory, Abou Bakr Belkaid University of Tlemcen, Algeria
[6] Ecole Supérieure en Sciences Appliquées de Tlemcen, ESSA -Tlemcen– Material and corrosion researching Equip, LAEPO, research Laboratory University of Tlemcen, Algeria

* Corresponding Author Email : benramdane2006@yahoo.fr

Abstract

Most of the energy consumed comes from fossil fuels, a real threat to the environment. This threat manifests itself mainly through global warming of the Earth caused by pollution and the greenhouse effect. In fact, today's world is most concerned with reducing this pollution by trying to ensure that conventional energy sources meet very strict standards.
Refrigeration and air conditioning systems are big energy consumers. These systems are usually powered by electricity generated from fossil fuels, and adsorption refrigeration systems powered by low-temperature heat sources have been developed as an economical and environmentally friendly alternative.
Research has shown that solar energy is an excellent alternative to fossil fuels. In all these systems, the consumption of mechanical energy is minimized, and they can operate using low temperature heat from different sources, such as waste heat or solar energy. Absorption cooling systems, such as those using LiBr-H2O or H2O-NH3 as working pairs, have many advantages for specific applications. They offer better cooling system efficiency than adsorption systems.
However, these systems also have many limitations in operating conditions. The biggest advantage of adsorption systems over absorption systems is that they can operate without moving parts, which is less expensive than maintenance.
This study would be of appreciable contribution for new designs of this type of machine or to optimize the economic indices of exploitation of solar energy for the production of cold, while taking into account the constraints which can be generated by the presence unsuitable climatic conditions.

Keywords
Solar refrigeration, Adsorption, Adsorbent, Adsorbate, Coefficient of performance, Activated carbon / Methanol, Zeolite / Water, Composite / Ethanol.

1. Introduction

Many countries in the world are moving towards the exploitation of renewable energies; among them solar energy which is used in the building sector to provide electricity, air conditioning or heating [1].[2],[3].[4],[5],[6]

Adsorption refrigeration systems powered by low temperature heat sources have been developed as an economical and environmentally friendly alternative.

Another very important aspect in the study of adsorption phenomena, in particular of refrigerators, is the choice of the adsorbent/adsorbate couple. This choice is dictated by certain physical and chemical criteria related to the torque itself and to the operating conditions of the machines [1], [4], [7], [8], [9].

2. Principle of adsorption

The phenomenon of adsorption was first described by Fantana and Schelle in 1711, Adsorption is a fluid (gas or liquid). Known as adsorbate in general or refrigerant in the process of generating cold air. Attaches to a solid surface called an adsorbent. The term surface of the solid corresponds to all of the external and internal surfaces generated by the network of pores and cavities inside the adsorbent. The adsorption of gases by solids involves three main steps (Figure.1):

The gas phase made up of gas molecules.
The adsorption phase (adsorbate) formed by molecules adsorbed on the surface.
Solid phase which is the adsorbent [10].

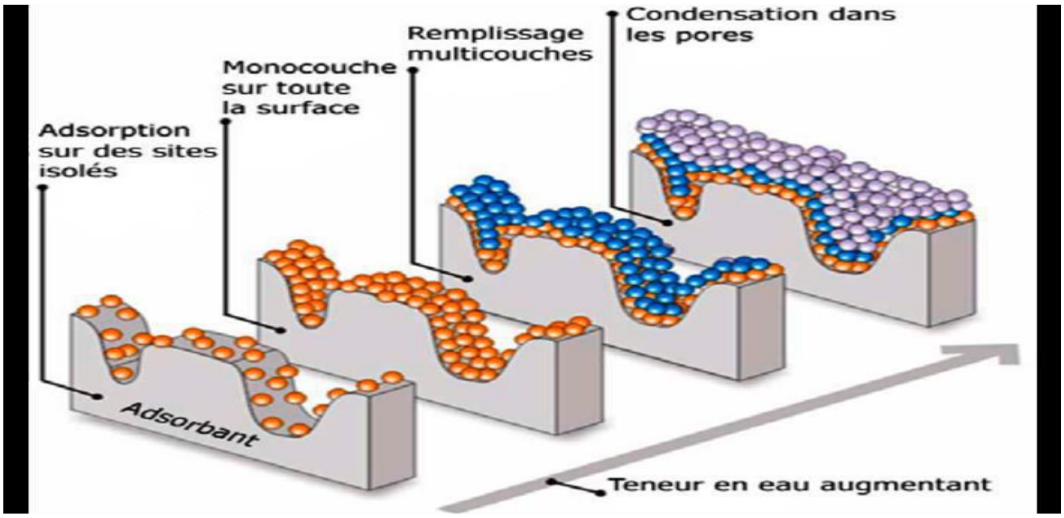

Fig.1. Adsorption phenomenon [11].

3. Principle of operation of a solar adsorption refrigeration machine

Adsorption is a reaction that occurs between adsorbent and adsorbate, this reaction is characterized by molecules attached to a surface. According to the above installation instructions, the working principle of this machine for cold production can be described as follows [12], [13].

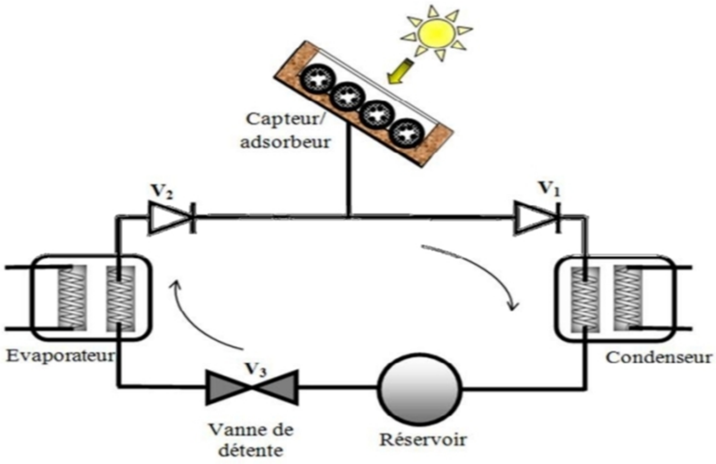

Fig.2. Diagram of a solar adsorption machine [12].

At sunrise, the collector / solar adsorber is located at low temperature Tad is equal to the ambient temperature (Tad =Tamb) and the pressure corresponds to the saturation pressure Ps of methanol at the evaporator temperature Tev.

At this point, the valve and the collector/adsorber isolation flap are closed. The solar panel heats the collector/adsorber by gradually increasing its temperature, which causes an increase in the vapor pressure of the adsorbate in the adsorber, while the total mass of the adsorbed adsorbate remains constant. This phase is equivalent to compression in the classic compression cycle.

In the middle of the morning, when the pressure in the collector/adsorber reaches the saturation pressure corresponding to the temperature of the condenser Tc, valve 1 is opened. The desorption process starts and the adsorbate vapors condense in the condenser. The solar energy received by the collector/adsorber is used to increase its temperature and to desorb the adsorbate contained in the adsorbent.

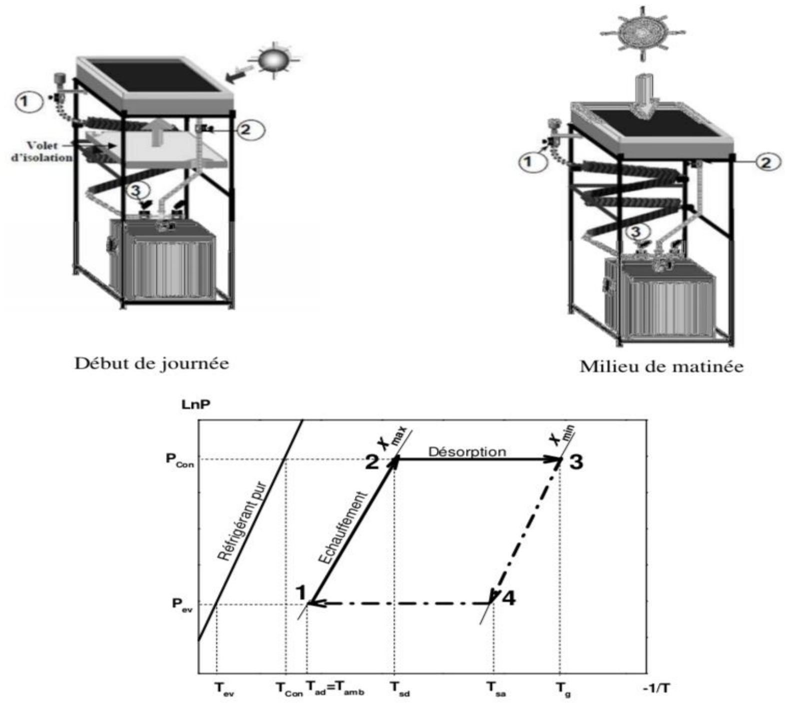

Fig.3. Heating and desorption phase [12].

At the end of the afternoon, the solar flux decreases, valve 1 is closed and the rear insulation of the collector/adsorber is removed. In the latter, the temperature decreases according to the isobars (3-4), this causes a pressure drop to reach the pressure of the evaporator. The condensates were completely transferred to the evaporator through the expansion valve. This valve is then closed to isolate the evaporator from the condenser and valve 2 is opened. At night the sensor/adsorber is cooled by natural convention with the ambient air, the pressure decreases and ends up reaching the saturation pressure Ps corresponding to the evaporator temperature Tev.

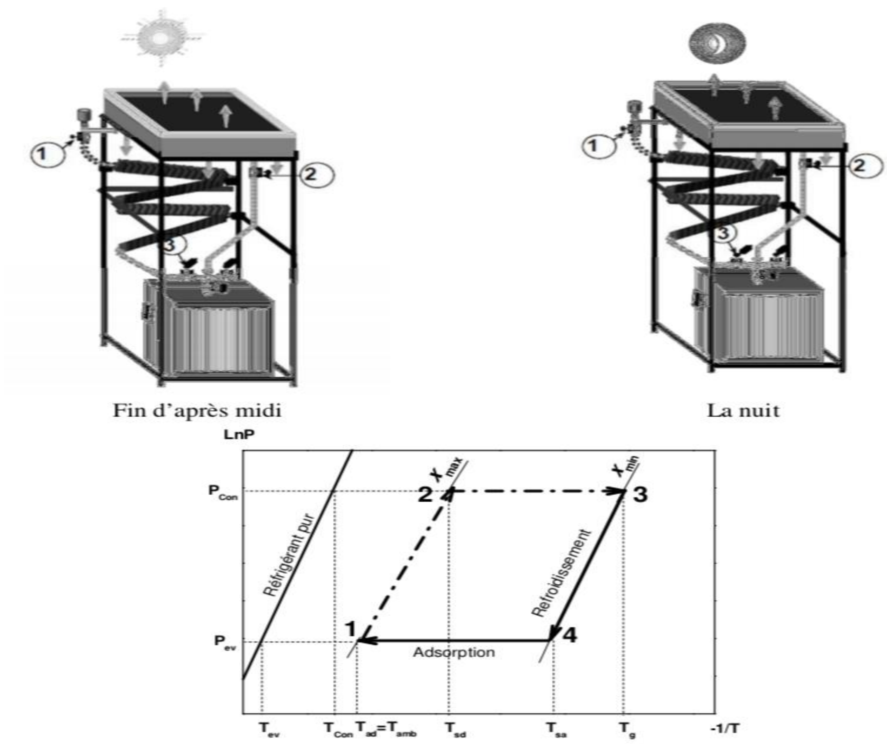

Fig.4. Cooling and adsorption phase [12].

3.1. Thermodynamic cycle

As part of the optimization of solar adsorption chillers, a thermodynamic study of the basic cycles associated with this machine is necessary. The figure shows the installation of the main components of the solar adsorption machine and its basic ideal thermodynamic cycle in the Clapeyron diagram (LnP, -1/T) As shown in the figure, the whole two stages (1 -2) and (2-3) corresponds to the first stage (heating/desorption), and the other two stages (3-4) and (4-1) cycle (cooling/adsorption). Moreover, the thermodynamic cycle fully defined by four operating temperatures [12], [14].

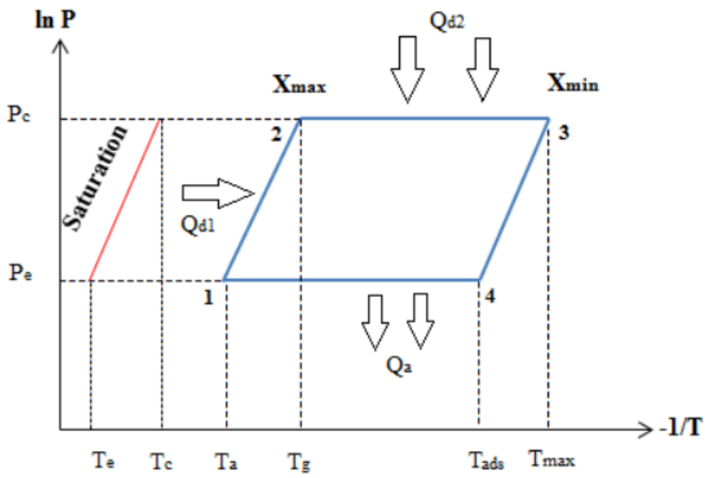

Fig.5. Ideal thermodynamic cycle of the machine in a Clausius diagram Clapeyron [12]

- Adsorption temperature (Tad=Tamb): the minimum temperature reached by the mixture AC/methanol.
- Regeneration temperature Tg: the maximum temperature reached by the mixture.
- Condensing temperature T (con).
- Evaporation temperature T (ev).

The definition of the thermodynamic cycle of a machine is completed when the two critical points (thresholds) of this cycle are determined and defined, The desorption threshold temperature Tsd is defined as the desorption phenomenon begins, it corresponds to the appearance of the first liquid drop in the condenser. The adsorption threshold temperature Tsa is defined as the temperature from which the adsorption phenomenon begins, it corresponds to the evaporation of the first liquid drop in the evaporator. However, when calculating the coefficient of thermal performance (COPth) we only need the threshold temperature Tsd desorbed and Tsa adsorbed [15].

4. Modeling of adsorption solar refrigeration machines

The modeling makes it possible to establish the different mass and heat transfer balances in the components of the system in order to establish the final expression of the performance for the optimization calculations defined in this study.

4.1. Machine Component Balance Sheets

The modeling of the operating cycle of an adsorption refrigerator in the heating and cooling phases is given by the following expressions.

• Adsorber (the generator)

An adsorber containing the solid adsorbent, in contact with a hot source, it plays for the adsorption cycle, the role played by the compressor (suction and compression) in a vapor.

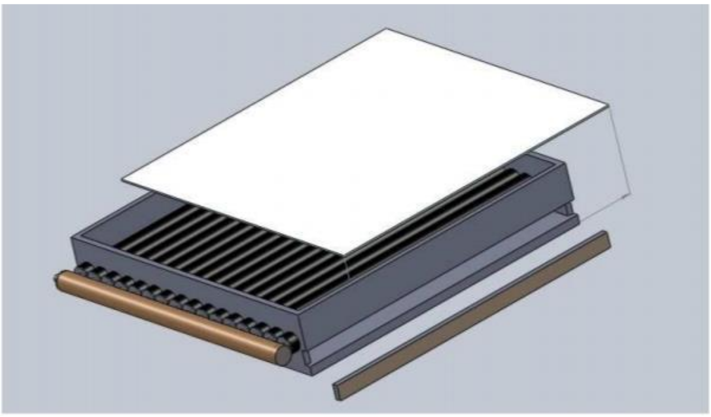

Fig.6. Perspective view of a box [16].

During the desorption-condensation phase, we have:

$$\dot{m}_{air} c_{p,air} E_g (T_{ex} - T_a) = m_{ch}\left(c_{p,ch} + m_{des} c_{p,a}\right)\frac{dT_{ch}}{dt} + +m_g c_{p,g}\frac{dT_g}{dt} + \frac{d(m_{ch}.m_{des}.q_{st})}{dt} \quad (1)$$

With :

$\dot{m}_{air}$ The air flow

E_g The energy efficiency of the adsorber (generator)

$c_{p,air}$ The specific heat of air

T_{ex} Outside temperature

T_a The adsorption temperature

m_{ch} The mass of the adsorbent

$c_{p,ch}$ The specific heat of the adsorbent

m_{des} The desorbed mass

$c_{p,a}$ The specific heat of the adsorbate

During the adsorption-evaporation phase we have:

$$\dot{m}_{air} c_{p,air} E_g (T_{ex} - T_a) = m_{ch}\left(c_{p,ch} + m_a c_{p,ad}\right)\frac{dT_{ch}}{dt} + m_g c_{p,g}\frac{dT_g}{dt} + \frac{d(m_{ch}.m_{ad}.q_{st})}{dt} \quad (2)$$

With :

m_{ad} is the adsorbed mass

In the previous equation, the term on the left side of the equation represents the power exchanged with the air in the efficient generator. The first two terms on the right side of the equation represent the sensible thermal balance of the adsorbent/adsorbate pair, and the last term represents the thermal energy required for desorption or adsorption during the cycle.

- **Condenser**

The condenser is a heat exchanger in which the refrigerant gradually changes from gaseous to liquid state. The refrigerant transfers its energy to a secondary fluid called a "hot source" at a temperature a few degrees lower than the condensation temperature [15].

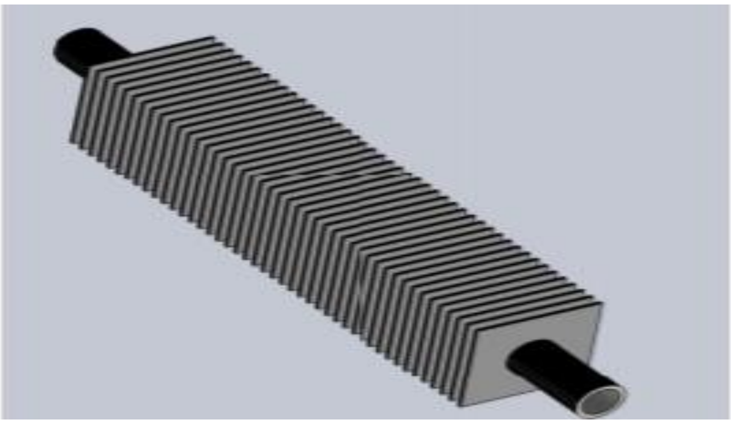

Fig.7. An example of a condenser [15].

$$m_{cd}c_{p,cd}\frac{dT_c}{dt} + \dot{m}_{eau}c_{p,eau}E_g(T_{ee} - T_{se}) = \dot{m}_a[l(T_c) + c_{p,a}(T_g - T_c)] \quad (3)$$

With :

m_{cd} The mass of the condenser

$c_{p,cd}$ The specific heat of the condenser

$\dot{m}_{eau}$ Condensation water flow

T_{ee} et T_{se} Water inlet and outlet temperatures

$l(T_c)$ Latent heat of condensation

T_c Condensing temperature

The first term on the left is the sensible heat relative to the condenser, and the second term represents the heat transferred to the cooling water. The term to the right of the equal sign represents the latent heat of condensation and cooling of the generator sorbent.

Evaporator

The liquid refrigerant gradually changes from liquid to gas by absorbing the energy of the secondary fluid called "cold source" [15].

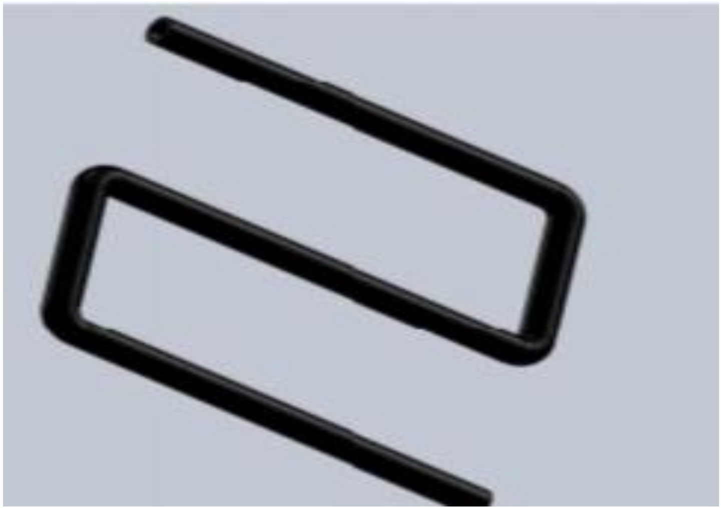

Fig.8. Diagram of an evaporator [15]

$$m_{ref}c_{ref}\frac{dT_{ref}}{dt} + \dot{m}_a c_{p,a}(T_c - T_{ev}) = \dot{m}_a l(T_e) + m_{ev}c_{p,ev}\frac{dT_{ev}}{dt} \quad (4)$$

With :

m_{ref} The cooled mass

c_{ref} The specific heat of the cooled fluid

T_{ev} Evaporation temperature

$l(T_e)$ Latent heat of evaporation
m_{ev} The mass of the evaporator
$c_{p,ev}$ The specific heat of the evaporator

The first term to the left of the equality represents the cooling effect produced, and the second term is the sensible heat of the condensate coming from the condenser. The first term to the right of the equality is the latent heat of vaporization, and the second term is the sensible heat of the evaporator.

4.2. Coefficient of performance

The performance of the adsorption refrigeration machine given in this study is characterized by the coefficient of performance COP.

The coefficient of performance and the heat quantities in the other parts of our study do not take into account the metal parts of the various components of the machine, such as the adsorber and the condenser, and are expressed in terms of thermodynamic relations without taking into account mass and heat transfers of the system [17].

In this case, the coefficient of performance is given by the following relationship:

$$COP = \frac{Q_f}{Q_c} \tag{5}$$

Q_f The amount of cold produced or the cold production of the evaporator (adsorption)
Q_c The amount of useful heat supplied to the adsorber

6.2.1. Expression of Q_f

The quantity of cold produced at the level of the evaporator (adsorption) is given by the following expression [17]:

$$Q_f = m_a \Delta m[l(T_e) - \int_{T_e}^{T_c} cp_l(T)dT] \tag{6}$$

With :
m_a The mass of the adsorbent containing in the adsorber
Δm The cycled mass of the adsorbate calculated by the following relationship :

$$\Delta m = m_{max} - m_{min} \tag{7}$$

$$m_{max} = m(T_a, P_e) = m\left(T_g, P_c\right) \tag{8}$$

$$m_{min} = m(T_{ads}, P_e) = m(T_{max}, P_c) \tag{9}$$

Both mass quantities are calculated using the Dubinin-Astakhov (D-A) relationship.
$l(T)$ and $cp_l(T)$ represent, respectively, the latent heat of evaporation and the specific heat of the adsorbate in the liquid state.
The first term of this equation represents the latent heat extracted for the evaporation of the refrigerant at the evaporation temperature T_e. The second term represents the sensible heat necessary to bring the condenser from its condensation temperature to that of evaporation T_e.

6.2.2. Expression of Q_c

The adsorber receives a quantity of heat from the hot source (solar energy in this case) which is used to heat: the adsorbent, the metal parts of the adsorber, the adsorbate, and for desorption [17].

So the expression of Q_c is given by:

$$Q_c = Q_1 + Q_2 + Q_3 + Q_{des} \quad (10)$$

Avec :

Q_1, Q_2 and Q_3 Are the quantities of sensible heat used to heat respectively: the metal parts of the adsorber, the adsorbate, the adsorbent Q_{des} the heat necessary for desorption which corresponds to the mass of the desorbed adsorbate.

- **Expression de la chaleur sensible de l'adsorbant Q_1**

It is the quantity of heat necessary to heat the adsorbent and therefore to bring it from the temperature T_a to T_{max} (the steam generation temperature).

$$Q_1 = m_a \int_{T_a}^{T_{max}} cp_2(T)dT = m_a cp_2(T_{max} - T_a) \quad (11)$$

With :

m_a The mass of the adsorbent

cp_2 The specific heat of the adsorbent, so $m_a cp_2$ is the heat capacity of the adsorbent

- **Expression of the sensible heat of the metal parts of the adsorber Q_2**

This quantity corresponds to the heat which brings the metal parts of the adsorber from the temperature T_a to T_{max}. It is given by the following relationship:

$$Q_2 = m_g \int_{T_a}^{T_{max}} cp_g(T)dT = m_g cp_g(T_{max} - T_a) \quad (12)$$

With :

m_g The mass of the metal parts of the adsorber

cp_g The specific heat of the metal parts of the adsorber, so $m_g cp_g$ is the heat capacity of the metal parts of the adsorber

- **Expression of the sensible heat of the adsorbate Q_3**

Q_3 is the amount of heat required to heat the adsorbate from the temperature T_a to T_{max}.
This quantity is expressed by:

$$Q_3 = m_a \int_{T_a}^{T_{max}} m(T)cp_l(T)dT = m_a m_{max} \int_{T_a}^{T_g} cp_l(T)dT + m_a \int_{T_g}^{T_{max}} m(T)cp_l(T)dT \quad (13)$$

$m(T)$ is the adsorbed mass calculated at a given temperature T and at a condensation pressure P_c.

- **Expression of the heat of desorption Q_{des}**

This amount of heat is given by [17]:

$$Q_{des} = m_a \int_{m_{max}}^{m_{min}} q_{st} dm \quad (14)$$

q_{st} is the isosteric heat of adsorption.

The differentiation of m the adsorbed mass gives the following expression :

$$dm = nDmT^n (ln \frac{P_s(T)}{P})^{n-1} \left[dlnP - \frac{q_{st}}{RT^2} dT \right] \quad (15)$$

n and D are the parameters of the Dubinin-Astakhov equation.

- ***Intensité solaire et température ambiante***

L'évolution de l'irradiation solaire transitoire est donnée par l'équation suivante [18] :

$$I(t) = I_{c.max} \sin(\frac{\pi(t - t_{sunrise})}{(t_{sunrise} - t_{sunset})}) \quad (16)$$

With :

$I_{c.max}$: The maximum total solar irradiation composed of direct, diffuse and reflected irradiation by the ground (reflected irradiation is assumed to be negligible compared to the other two components). This is expressed by the following equation [18]:

$$I_c = I_b \cos\theta + I_d + I_r \quad (17)$$

θ : The angle of incidence of direct solar radiation.

The total irradiation received by any surface of the solar collector is given by [18]

$$Qs = A\alpha\gamma\eta \int_{sunrise}^{sunset} I(t)dt \quad (18)$$

With :

A : The surface of the solar collector, α is the absorptivity of the collector, γ is the reflectivity, η is the efficiency of the solar collector

L'équation (19) est utilisée pour l'estimation de la température ambiante.[18]

$$T_{amb}(t) = \frac{T_{amb.max}+T_{amb.min}}{2} + \frac{T_{amb.max}-T_{amb.min}}{2}\sin\left(\frac{\pi(t-t_{sunrise})}{(t_{sunrise}-t_{sunset})}\right) \quad (19)$$

With:

$T_{amb.max}$ Maximum ambient temperature.

$T_{amb.min}$ Minimum ambient temperature

5. Results and interpretation

Finally, it is important to test the system under real conditions to validate the modeling and optimization results. Experiments can be used to refine the mathematical model and improve system design.

5.1. Climatic condition

5.1.1. Geographic location

- Ghardaïa is a city located in southern Algeria, The geographical coordinates of Ghardaïa are approximately 32.4883 degrees north latitude and 3.6735 degrees east longitude. The region is characterized by high temperatures and low annual rainfall.
- Tlemcen is a city located in the northwest of Algeria. The geographical coordinates of Tlemcen are approximately 34.8783 degrees north latitude and 1.3150 degrees west longitude.
- Tamanrasset is a city located in the south of Algeria (Sahara) the largest desert region in the world. The geographical coordinates of Tamanrasset are approximately 22.7854 degrees north latitude and 5.5228 degrees east longitude. The region is characterized by very high temperatures and very low annual rainfall.
- Constantine is a city located in the northeast of Algeria. The geographical coordinates of Constantine are approximately 36.3650 degrees north latitude and 6.6147 degrees east longitude.
- Algiers is the capital of Algeria and is located on the north coast of the country, on the western shore of the Bay of Algiers, bordering the Mediterranean Sea. The geographical coordinates of Algiers are approximately 36.7538 degrees north latitude and 3.0588 degrees east longitude. The region is characterized by a Mediterranean climate with hot, dry summers and mild, wet winters.

Tab.1. Climate data of Algerian cities

Ville	Ic (max)	Tam(min)	Tam(max)
Alger	975	15	29
Tlemcen	980	18	30
Constantine	940	12	28
Ghardaïa	1060	22	36
Tamanrasset	1074	25	39

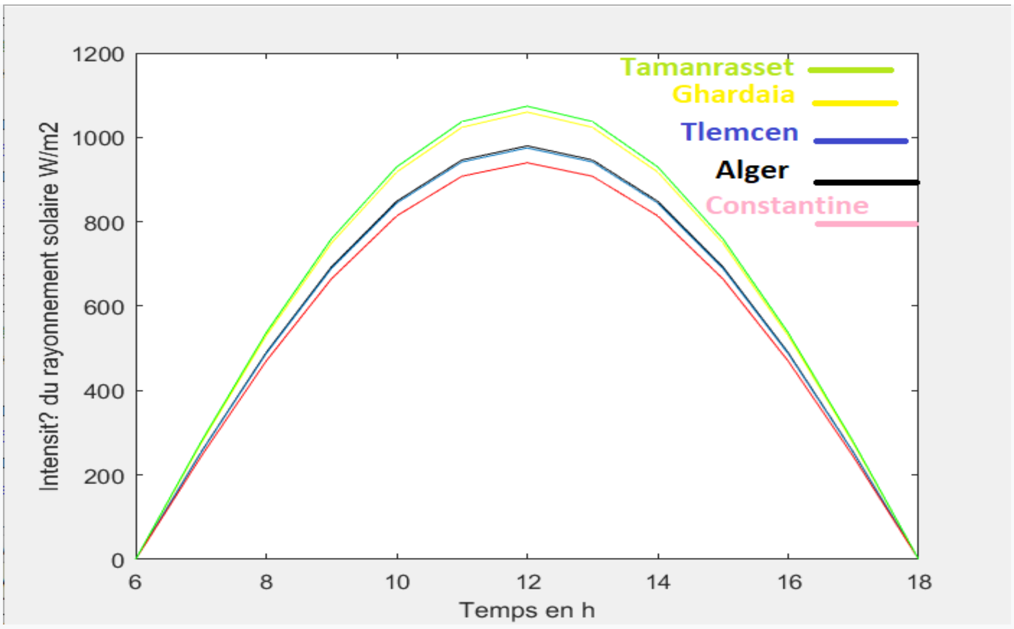

Fig.9. Variation of radiation intensity as a function of time

Figure 9 shows that in the five cities mentioned the intensity of solar radiation varies proportionally to time at the beginning of the day and then decreases at the end of the day, i.e. it increases at sunrise to reach a maximum at noon. (12h) before descending until it ends at sunset. We notice that the intensity reaches its maximum at 12:00h. This change recorded and due to the position of the sun during the day.

It is observed that for the site of Tamanrasset the intensity of solar radiation exceeds 1000w/m² and the lowest intensity was recorded in Constantine where its value equal to 920 w/m². Note that among the five curves, the evolution of the global solar radiation is the same, the difference lies only in the slope of the curve.

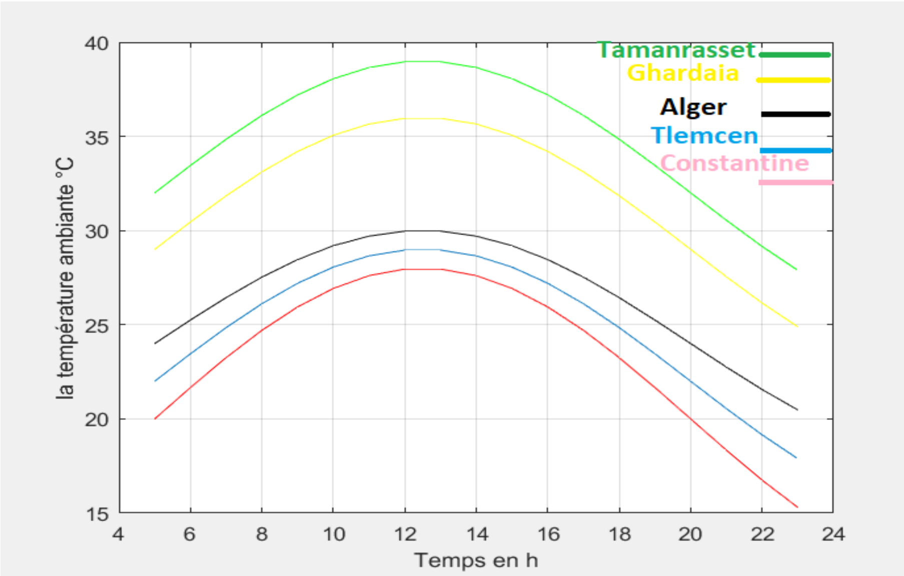

Fig.10. Variation of temperature as a function of time

Figure 10 represents the evolution of the temperature as a function of time. We observe that the temperature reaches its maximum at noon for the five cities. We note that the city of Tamanrasset, the temperature is maximum at noon which approaches 40°C, and the lowest temperature compared to the 4 cities was recorded in Constantine 27°C. This temperature difference is due to the geographical location of each city.

5.2. Thermophysical parameters and data

5.2.1. D/A Parameter

Tab.2. D/A parameter of couples

AC/ Methanol	Zeolite/Water	Composite/Ethanol
n=2,15	n=2	n=1.8
$D=5.02.10^{-7}$	$D=1,8.10^{-7}$	$D=2,67.10^{-7}$
X_0=0,425(l/Kg)	X_0=0.265(l/kg)	X_0=0.81(l/kg)

AC : Activated Carbon is a porous carbonaceous material that has been activated to increase its porosity and therefore its adsorption capacity

Composite : it is an assembly of two or more immiscible materials with different characteristics.

5.3. Curves and interpretations

a) AC/Methanol

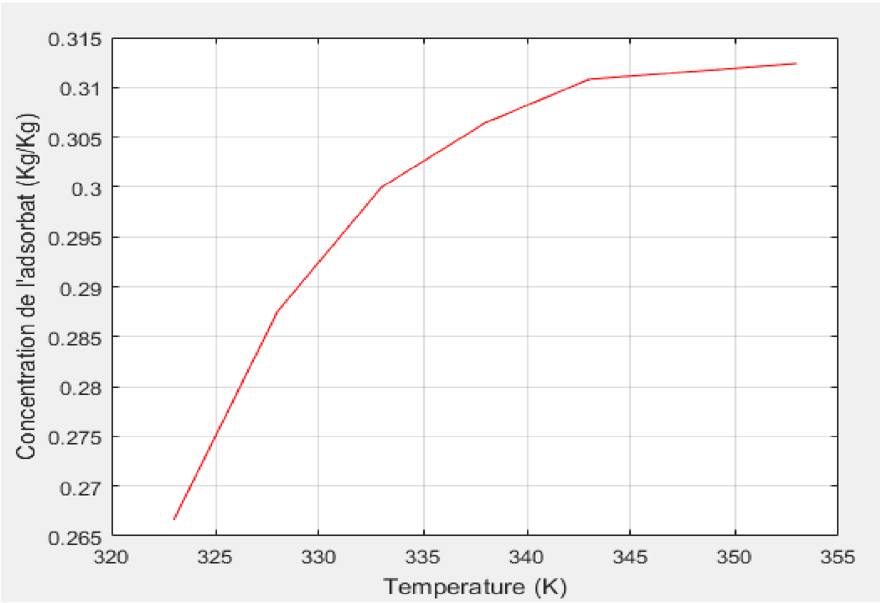

Fig.11. Variation of the concentration of the adsorbate (methanol) according to the temperature

Figure 11 represents the evolution of the concentration as a function of the temperature. It is noted that the concentration of the adsorbate (methanol) stabilizes at 345K. The methanol concentration requires a temperature that exceeds 340K to have stability.

b) Zeolite/Water

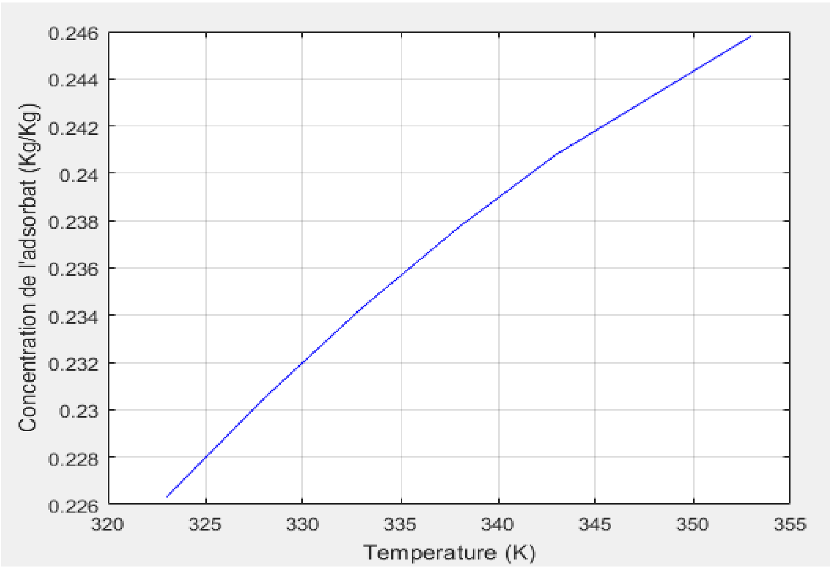

Fig.12. Variation of the concentration of the adsorbate (water) according to the temperature.

Figure 12 shows the variation of the concentration of the adsorbate (zeolite/water) as a function of the temperature. It is noted that the concentration of this couple is not stable because it will need high temperature to reach stability.

c) Composite/Ethanol

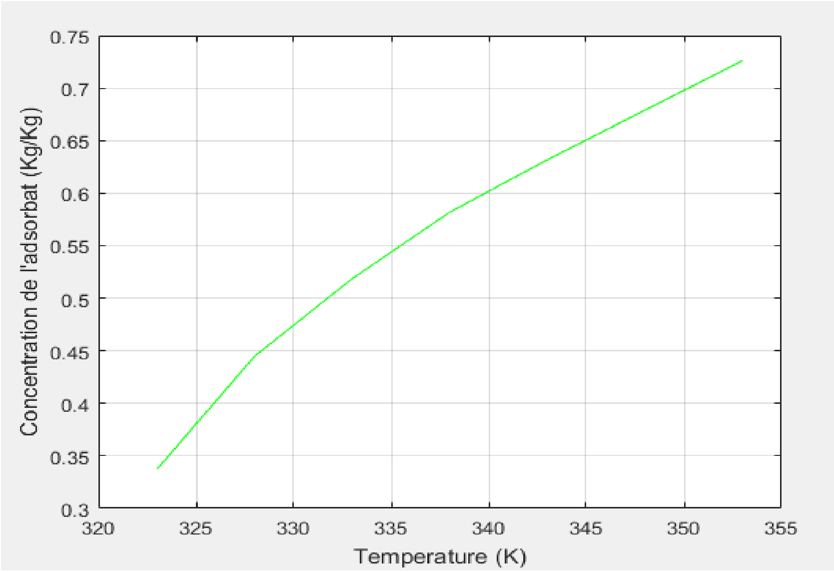

Fig.13. Variation of the concentration of the adsorbate (ethanol) according to the temperature.

Figure 13 represents a change in the concentration of the adsorbate (Ethanol) by increasing the temperature. Concentration stability was not recorded because ethanol requires a higher temperature

5.3.1. Thermophysical data [19]

a) Zeolite/Eau

Tab.3. Thermophysical characteristic of water

Temperature (°C)	**Volumic mass (Kg/m^3)**	**Vapor pressure (bar)**
50	0,988	0,12334
55	0.9857	0,15739
60	0,9832	0,19917
65	0,9805	0,25006
70	0,9777	0,31165
80	0,9718	0,47356

Tab.4. Thermophysical characteristic of water for different evaporation temperature

Temperature (°C)	Heat The tent (KJ/Kg)	Massic heat Liquid (KJ/Kg °C)
0	2500,7	4,22
2.5	2494,85	4,2153
5	2489	4,2107
7.5	2483,15	4,2062
10	2477,3	4,2015

Tab.5. Thermophysical characteristic of water for different condensation temperature

Temperature (°C)	Heat The tent (KJ/Kg)	Massic heat Liquid (KJ/Kg °C)
15	2465,6	4,1922
17.5	2459,5	4,1877
20	2453,4	4,183
22.5	2612,55	4,182
25	2771,7	4,181

AC/Methanol

Tab.6. Thermophysical characteristic of methanol

Temperature (°C)	Volumic mass (Kg/m^3)	Vapor pressure (bar)
50	0 ,7641	0,55
55	0,75962	0,74
60	0,75515	0,93
65	0,75067	1,11
70	0,7462	1,31
80	0,7353	2

Tab.7. Thermophysical characteristic of methanol for different evaporation temperature

Temperature (°C)	Heat The tent (KJ/Kg)	Massic heat Liquid (KJ/Kg °C)
0	1178,5	2,42
2.5	1177,62	2,4258
5	1176,5	2,4316
7.5	1175,87	2,4575
10	1175	2,443

Tab.8. Thermophysical characteristic of methanol for different condensation temperature

Temperature (°C)	Heat The tent (KJ/Kg)	Massic heat Liquid (KJ/Kg °C)
15	1170	2,455
17.5	1167,5	2,4608
20	1165	2,4666
22.5	1162,5	2,472
25	1160	2,478

b) Composite/Ethanol

Tab.9. Thermophysical characteristic of ethanol

Temperature (°C)	Volumic mass (Kg/m^3)	Vapor pressure (bar)
50	0,7622	0,29
55	0,7574	0,41
60	0,7526	0,52
65	0,7479	0,64
70	0,7431	0,76
80	0,7342	1,09

Tab.10. Thermophysical characteristic of ethanol for different evaporation temperature

Temperature (°C)	Heat The tent (KJ/Kg)	Massic heat Liquid (KJ/Kg °C)
0	916,75	2,303
2.5	913,76	2,323
5	910,77	2,344
7.5	907,78	2,365
10	904,8	2,386

Tab.11. Thermophysical characteristic of ethanol for different condensation temperature

Temperature (°C)	Heat The tent (KJ/Kg)	Massic heat Liquid (KJ/Kg °C)
15	900 ,75	2,428
17.5	898,72	2,449
20	896,7	2,47
22.5	894,67	2,501
25	892,65	2,532

5.3.1.1 cycle data

In this study, we imposed the following cycle data:

T_g (°C)	T_c (°C)	T_{ads} (°C)	T_{max} (°C)	T_e (°C)
50	15	20	80	5

5.3.1.2. Solar collector data [20]

A (m^2)	α	ɤ	ma(kg)	P(bar)	ɳ
1	0.95	0.7	12.5	2	0.935

5.4. Coefficient of performance

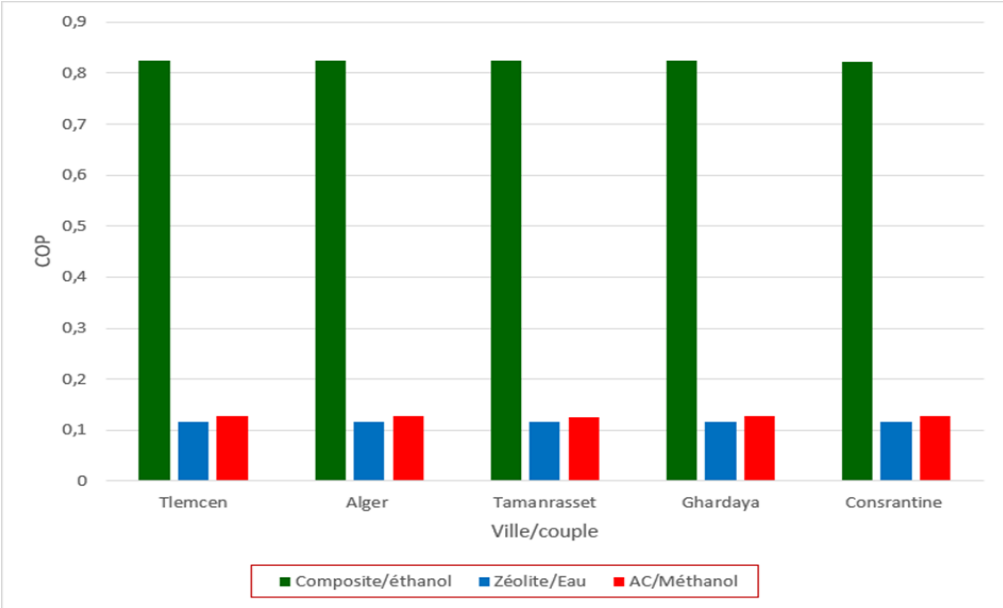

Fig.14. Variation of COP as a function of torque in each city.

Figure 14 presents the variation in the coefficient of performance cop according to different couples in the cities. It is noted that according to the study of the couples in each one of the following cities: Tlemcen, Algiers, Constantine, Ghardaïa and Tamanrasset we could note that composite / ethanol is the best couple in our analysis since it has a yield invaluable when compared with the other couples.

6. Optimization

Composite/ethanol was chosen as the best pair because of its performance in figure 16. We take the composite/ethanol pair in our city (Tlemcen) in order to optimize the coefficient of performance.

6.1. Evaporation temperature effect

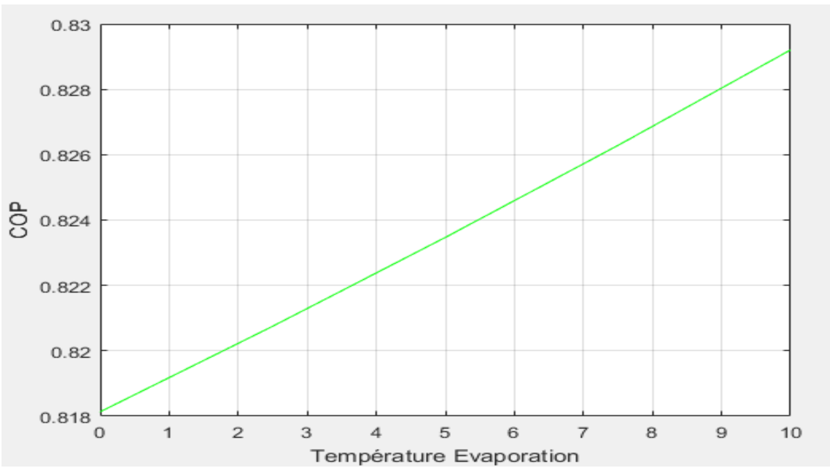

Fig.15. Variation of the COP according to the evaporation temperature (°C).

Figure 15 illustrates the effect of evaporation temperature on the solar coefficient of performance COP. Indeed, the increase in Te means that the pressure and the adsorption mass in the reactor are at max increases at the start of the cycle, which leads to a cycle mass Δm and consequently, an increase in the COP.

6.2. Condensation temperature effect

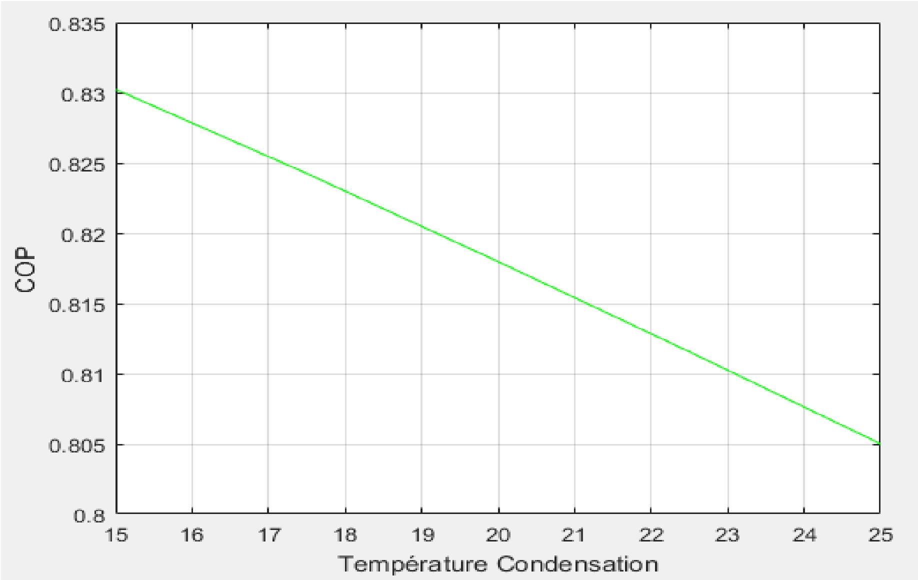

Fig.16. Variation of the COP according to the condensation temperature (°C).

Influence of the condensation temperature Tc on the COP of the machine. Figure 16 shows the effect of condensation temperature on the solar coefficient of performance COP. It can be seen that when the condensation temperature Tc increases, the COP decreases.

6.3. Solar collector surface effect

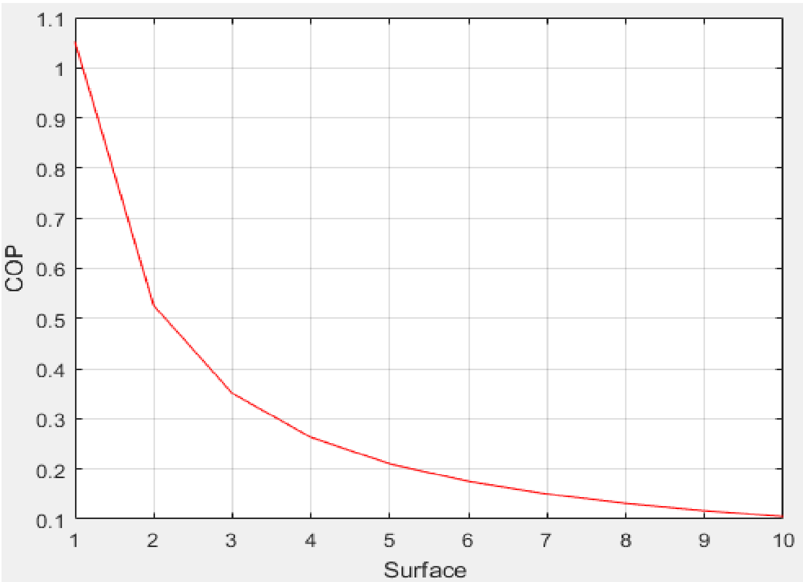

Fig.17. Variation of the COP according to the surface of the solar collector (m^2).

It can be seen that the COP increases with increasing concentration ratio. This increase in the COP is justified that the increase in the concentration rate will increase the production of cold and this is due in fact that the increase in the adsorption rate of the adsorbent will increase the rate of the adsorbed mass of the adsorbate at fix on the microporous of the adsorbent, which means more adsorbed mass and more cold production. So the COP mainly depends on the concentration ratio.

7. Conclusion

Adsorption refrigeration machines offer a wide range of coverage of refrigeration needs. They have several advantages such as simplicity, reliability and the ability to use various energy sources. However, compared to compression systems, they suffer from low energy efficiency.

Solar adsorption refrigeration systems are considered the second solar cooling technology behind absorption machines. This technique can be used to produce cold for various purposes.

In the present work, we began the study of the phenomenon of adsorption with these different types and fields of application. We were able to observe the operation of a refrigerating machine with these main components and its thermodynamic cycle (Clapeyron). We have given a comparison between Three couples AC / Methanol, Water / Zeolite and Composite / Ethanol on the basis of the ideal cycle of adsorption refrigeration machines.

The results obtained thanks to this model showed that the performance of the machine, expressed by the coefficient of thermal performance, strongly depends on several parameters. To improve this performance, it is essential to make a good choice of criteria for these parameters. Among the most important parameters are:

- The operating temperatures of the cycle, such as the temperature of condensation, evaporation. Increasing the condensation and adsorption temperature leads to a decrease in thermal performance. On the other hand, the increase in the evaporation temperature leads to an improvement in the thermal performance of the machine.

- The adsorbate itself also plays a significant role in achieving good performance. Our research shows that ethanol remains the best adsorbate compared to other options mentioned in the literature, and it always leads to good performance. This is why it is used as an adsorbate in the paragraph dealing with the influence of the adsorbent.

- The solar collector area has a significant influence on the performance of solar adsorption refrigeration system.

In general, the coefficient of performance depends not only on the operating temperatures in the adsorber and its properties, but also on the efficiencies of the evaporator and the condenser. Therefore, models describing the heat transfer process in these two components can be studied to understand their influence on the efficiency of the adsorption machine. The optimization carried out in this work for the solar reactor and the solar adsorption refrigerating machine is limited to energy optimization.

8. References

[1] Ghrici, A ‟Contribution to the optimization of the energy efficiency of solar adsorption refrigeration systems" Doctoral thesis.

[2] Mohammed BENRAMDANE*1, Zakaria SARI HASOUN2, ALIANE Abdennour1, "Simulation and parametric analysis of low pressure on the operation of a concentrated solar thermal installation"; International journal of advanced studies in computer science & engineering ijascse volume 12 issue 02, 2023

[3] Stoyanov, L. Structures of hybrid systems with renewable energy sources". Journal of Industrial Engineering 2010, 5, 1-19.

[4] The 2014 barometer of renewable energies 5th edition produced and edited by Observ'ER

[5] Mohammed Benramdane1*, Saïd Abboudi2, Mea Ghernaout1 "Contribution to the Simulation and Parametric Analysis of the Operation of a Solar Concentration Thermal

Installation" International Journal of Heat and Technology; Flight. 37, No. 2, June, 2019, p. 446-456
[6] Mohammed Benramdane1, Said Abboudi2 et Mea Ghernaout1 « Thermodynamic study of an absorption solar refrigeration system operating at medium temperatures », Revue ElWahat pour les Recherches et les EtudesVol.10 n°1 (2017): 76-86
[7] E. Bellos, C. Tzivanidis, "Energetic and financial analysis of solar cooling systems with single effect absorption chiller in various climates". Applied Thermal Engineering (2017), doi: http://dx.doi.org/ 10.1016/j.applthermaleng.2017.08.005.
[8] E. Bellos, C. Tzivanidis, K.A. Antonopoulos, "A detailed working fluid 587 investigation for solar parabolic trough collectors", Applied Thermal Engineering 588 2017;114:374-386.
[9] Sarbu I, Sebarchievici C. "Review of solar refrigeration and cooling systems". Energy Build 2013:1–24.
[10] A. Rouag, study of heat exchangers in solar adsorption refrigeration (dimensioning of a condenser), master's dissertation on energy systems, Mohamed Kheider Biskra University, pp 7-8, (2012).
[11] V. Thibaut, Solar cooling by desiccation applied to buildings: Proposal for a system regulation strategy, doctoral thesis, University Lyon1, pp 40, (2007).
[12] Ghrici Adenane, Benramdane Mohammed, Ghernaout M.E.A. "Effect of operating temperatures and working pairs on performance of solar adsorption cooling system", International Journal of Heat and Technology, (2021) ; 39 (4), 1280-1286.
[13] Chekirou. W, study and analysis of a solar adsorption refrigeration machine, doctoral thesis, Constantine, 2008.
[14] Sneha Patil, S. G. Dambhare, "Review on Study of Solar Powered Adsorption refrigeration System", International Journal of Innovative and Emerging Research in Engineering, vol. 2, 2394 – 5494 (2015).
[15] G. Cacciola and G. Restuccia, Réversible adsorption heat pump : a thermodynamic model. Int. Journal of refrigeration,18 (1995) 100-106.
[16] A. M. Amziane, comparative study between conventional and solar air conditioning systems, application to the air conditioning of a building, 2013-2014
[17] M. Billel. Magister's thesis « Study and analysis of a cold production system using solar energy for air conditioning ». 2013. pp-09B.
[18] E. Passos,. Study of activated carbon – methanol couples and their application to solar refrigeration PhD. Thesis, federal Polytechnic College of Lausanne, Switzerland, 1986
[19] Ghrici Adenane, Benramdane Mohammed, Ghernaout M.E.A. "Parametric study of solar adsorption cooling machine under the climatic conditions of Algeria", Communication Science Et Technologie Vol.11, Nº01, pp.9-18, January2022
[20] Bejan A and Kraus A D 2003 heat transfer handbook John wiley and Sons New York.