Devising an absorber chiller for Laboratories implementing refined solid absorber

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Abstract. Generating thermal energy for temperatures more than 100 degrees centigrade, especially for high capacities, is not easy nor cost efficient. Absorbing chillers with liquid absorber could be used for this application yet there is a limitation for the thermal source which should be in a high temperature. Thus, the desired situation is to use absorbing chillers with least limitations so that the cost for cooling systems would significantly decrease. To this end, we substituted "solid absorbers" instead of liquid absorbers in the absorbing chillers. Beside the advantages of the proposed chillers, e.g. the required temperature for this chiller is low hence the costs would be less, there are some draw backs in implementing the solid absorbers. Hence, the Scientific Air conditioning institute of Iran Technical & Vocation University – Mohajer center, started to work on reducing the absorbing cycle problems. The results of five years researches in this institute came to devising new absorbing chiller using 'solid absorber'. Main novelties of this system could be mentioned as: the type of the used absorber, the increase of controlling accuracy, efficiency coefficient, the life time, and also the decrease in running time of cycle. In this paper we discuss absorbing chillers with solid absorbers thoroughly. Moreover, the mechanical cycle, thermodynamic cycles and thermodynamic processes are numerically analyzed. We compared our results with the commonly used chillers. The design method, advantages and disadvantages of cycle are illustrated briefly.

Keywords: Solid Absorber, liquid absorber, temporal range, waste energy, numerical computation, renatable energy

1. Introduction

The low electricity consumption beside the heat source has made the absorption chillers as a good choice for industrial and home base utilizations [1]. Developing a high temperature heat source and high manufacturing cost are the challenges in devising such chillers. One of the main drawbacks of absorption chillers is the use of liquid in their generators. because this generator for doing his duty in the absorption cycle needs a lot of heat in the high temperature and so making the heat in high temperature need high costs. But in adsorption chiller solid absorber is used instead of liquid absorber, the solid absorber is used and this change in the chiller cycle caused to the advantages of these chillers has been increased, [2] As the main advantages of Adsorption chiller [1], the significant reduction of the least heat and generator temperature, can be referred. This advantage let us use solar energy for making cooling in summer in many areas in the world, [3].

2. The Adsorption chiller

2.1. The principles of absorption chiller using the solid absorber

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[1] absorption chiller using the solid absorber

In the absorption chiller which is using the solid absorber (adsorption), water is used as the operative fluid which is vaporized in a vacuum enclosure and ambient temperature. As a result, the heat energy inters from the ambient to the enclosure and due to this the cooling is made. Now, the vapor is condensed in the system. The adsorption systems are closed systems and because of thermodynamically reasons, condensing the vapor directly is not possible empirically.

So, the water is absorbed by solid absorber. These materials include the silica gel or the materials related to quarts or sand. In cooling engineering the absorber materials are used for dehumidifying air. In the next step the absorber is saturated. So, for continuing the process and making the cooling cycle, at first the vapor pass to the first absorber enclosure is confined and go throw the second enclosure which is refined or reduced and the process is done according to its procedure. Now for refining or reducing the absorber materials through heating and go to the next process.
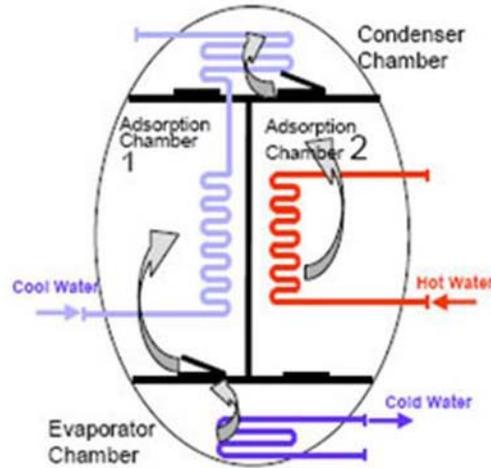
Fig. 1: Schematic view of the absorption chiller using the solid absorber [4].

Now, collecting the obtained vapor and pass it to the condenser, in the 0.1 atm pressure, and after condensing the vapor and reducing the pressure it is used again in the evaporator in the 0.01 atm pressures.

In this case, after saturating the absorber materials in the second enclosure, the first reduced enclosure is used and the saturated enclosure for the reduction or refining exit from the line. The full schematic figure of the absorption chiller using the solid absorber is shown in the Fig. 1.

3. The Cycle Operation

All In the running the system, the pressure of enclosure is vacuumed by a vacuum pump which is fixed on the system for vacuuming. This pump works automatically and the time of operating is about 7 seconds and is made of four steps:

1. **Step 1:** The water enters to the evaporator and vaporized and duo to this reason, the water which is rotating in the evaporator (the chiller water) is cooled.
2. **Step 2:** The obtained vapor in the first step is absorbed in the receiver.
3. **Step 3:** The absorbed water through refining the absorbers, by heating, is returned to the cycle and receiver is returned to the generator.
4. **Step 4:** The obtained vapor from the generator is condensed in the condenser and ready to enter to the evaporator. The cycle by returning the water from the first step (from condenser to evaporator) in completed. Note that receiver and generator are cooled and heated, steadily and also changing them is done with the pneumatic actuating valves.

4. The numerical computation of the adsorption chiller

In this section the numerical computation of the adsorption chiller is made which in that the water is used as the chiller and silica gel is used as the absorber. This type of chiller includes the three vacuum enclosures, two surface absorption enclosures and vacuum repaying and a hot pipe as the evaporator. Here the parametric model is used. All the used parameters in this mathematical model are prepared in the table 1-2 respectively and the basic assumptions are as the following [5]:

- The temperature and pressure is equal all over the surface absorber.
- The cooling fluid is absorbed in the surface absorber the same and it's fluidic in the absorber material.

- The pressure difference between the surface absorber and condenser or evaporator is neglected.
- The conduction heat transfer through the surface absorber to condenser or evaporator is neglected and there isn't any heat transfer between two evaporators.

The equation of surface absorption:

The equation of equilibrium the surface absorber used in this mathematical model is developed by Bolmen.

$$X = 0.34 \left(\frac{P_S T_W}{P_S T_S} \right)^{\frac{1}{1.16}} \tag{1}$$

In this equation Ps (Tw) and Ps(Ts) are the saturated vapour pressure of the vapour and silica gel, respectively.

The Energy Equation

Not the same as other two bed systems, the equations of condenser and evaporator are more complicated here. Due to lower temperature of evaporator from the condenser temperature and also the chiller saturated vapor temperature, in the process of rejection and repaying, the distillation process is done in the evaporator at first. The distillation process is done only in the condenser after the evaporator temperature become higher than saturation temperature [6].

1- The equilibrium of energy for the surface absorber or rejection and or repaying:

$$\frac{\mathbf{d}}{\mathbf{d}t} \{ [\mathbf{Ma}(\mathbf{Ca} + \mathbf{Cp}w\mathbf{X}) + \mathbf{Ccu\ Mtube, ad} + \mathbf{CalMfin, ad}]\mathbf{Ta} \}$$

$$= \mathbf{Ma}\partial\mathbf{H}\frac{\mathbf{dx}}{\mathbf{dt}} + (1-\mathbf{\delta})\mathbf{CwvMa}\frac{\mathbf{dxads}}{\mathbf{dt}}(\mathbf{Te} - \mathbf{Ta}) + \mathbf{M_0wCPw}(\mathbf{Tad, in} - \mathbf{Tad, out}) \tag{2}$$

$$\frac{Tad, out - Ta}{Tad, in - Ta} = exp\frac{-KA\,ad}{\text{m}wCp, w} \tag{3}$$

The properties of the used parameters are obtained from table [1].

2- the equilibrium of energy for the condenser:

$$\mathbf{\delta} = [-\mathbf{L.Ma.} + \mathbf{Cwv.a}..(\mathbf{Tc} - \mathbf{Ta}) + \mathbf{Mcool.Cp.w}(\mathbf{Tco.in} - \mathbf{Tco.out})] \tag{4}$$

$$\frac{Tco, out - Te}{Tco, in - Te} = exp(\frac{-KAc}{m^0 co.Cp, w}) \tag{5}$$

3- The equilibrium of energy for the evaporator which the hot pipes are assumed as one part and the inner process of mass and heat transfer are not done in the calculations.

$$\frac{\mathbf{d}}{\mathbf{d}t}\left[\left(C_{p,w}M_{e,w} + C_{cu}M_e\right)T_e\right] = (1-\delta)[-LM_a + m^0_{child}Cp_{,w}\left(T_{child.in} - T_{child.out}\right)] + \delta[C_{p,w}\left(T_e - T_c\right)M_a - (1-)LM_a\frac{\mathbf{dxdes}}{\mathbf{dt}}] \tag{6}$$

$$\frac{Tchild, out - Te}{Tchild, in - Te} = exp(\frac{-KAe}{m^0 ch.Cp, w}) \tag{7}$$

Where:

$$\theta = \begin{cases} 1, Tc <= Te \\ 0, Tc > Te \end{cases} \tag{8}$$

The equilibrium of chiller liquid is in the evaporator.

The equilibrium equations in the process of mass retrieving:

$$\frac{dm_{ew}}{dt} = M_e, -M_a\frac{\mathbf{dx}}{\mathbf{d}t} \tag{9}$$

The equilibrium equations in the evaporator:

$$-M_a\frac{\mathbf{dxdes}}{\mathbf{dt}} + m^0_{c.cond} + M_a\frac{\mathbf{dxads}}{\mathbf{dt}} = m^0_{mr} \tag{10}$$

The equilibrium equations in the evaporator:

$$\frac{\mathbf{d}}{\mathbf{d}t}\left[\left(C_{p.w}M_{e.w} + C_{cu}M_c\right)T_e\right] = -L\dagger + vm^0_{ch}C_{p.w} - \left(T_{ch.in} - T_{ch.out}\right) \tag{11}$$

Where, [7]:

$$\dagger = \begin{cases} m^0_{e,evap}, for\ desorbing\ camber \\ m^0_{e,evap}, for\ adsorbing\ camber \end{cases} \tag{12}$$

$$v = \begin{cases} 1, Te \le Tchil, in \\ 0, Te > Tchi, in \end{cases} \tag{13}$$

Where the coolant mass flow rates are in the refining enclosure and coolant distilled in the surface absorption enclosure, vapor is supposed as an in compressible fluid and the resistance of water vapor stream is neglected. The pressure in chambers can be measures as the following in accordance to simulated pressure [7].

$$Pwv, des - Pwv, ads = \frac{v_{wv} \dot{m}^2_{mr}}{2A^2} \tag{14}$$

Where, A, in the section area of the mass retrieving canal. The Wandervals equation can be defined for the vapour state parameters,[8].

$$(\mathbf{P}wv + \frac{a}{v^2})(v-b) - \mathbf{R}Twv \tag{15}$$

Table (1)-

Symbol	Value	Unit
A	1714.2	Pa m^6 kg^{-2}
B	1.7×10^{-3}	m^3
C$_{p.w}$	4.180	Kj kg^{-1} k^{-1}
C$_a$	0.924	Kj kg^{-1} k^{-1}
C$_{al}$	0.905	Kj kg^{-1} k^{-1}
C$_{cu}$	0.386	Kj kg^{-1} k^{-1}
C$_{w.v}$	1.850	Kj kg^{-1} k^{-1}
ΔH	2800	Kj kg^{-1}
KA$_{ad}$ (heating)	3570	W k^{-1}
KA$_{ad}$ (cooling)	3290	W k^{-1}
KA$_c$	6090	W k^{-1}
KA$_e$	3420	W k^{-1}
L	2500	Kj kg^{-1}
M$_a$	50.0	kg
M$_{tube,ad}$	21.8	Kg
Kg	10.9	
M$_c$	15.2	Kg
M$_e$	65.1	Kg
R	461.5	J kg^{-1} k^{-1}

Fig. 2

And also the operation of cooling capacity can be obtained:

$$Q_{ref} = \frac{\int_0^{t\ cycle} m^0_{child}(T_{ch,in} - T_{ch,out})dt}{t_{cycle}} \tag{16}$$

$$Q_{ref} = \frac{\int_0^{t\ cycle} C_{p,w} m^0_h (T_{h,in} - T_{h,out})dt}{t_{cycle}} \tag{17}$$

$$COP = \frac{Q_{ref}}{Q_h} \tag{18}$$

5. Design and development

To obtain the manufacturing technology of the absorption chiller using the solid absorber and to better understand of this chiller, a laboratorial sample of this chiller should be prepared. So we at first try to manufacture the first sample of this type of chillers in the Iran and can made this sample and then go to manufacturing this chiller. Although the researches on the first sample has been continued and we hope that we can refined and revised it for better efficiency steadily. The manufactures sample of the chiller is shown in the figures 2 which in that the water is used as the coolant and a solid absorber act as a absorber in this cycle.

6. Comparing the adsorption chiller to absorption chiller

The main notes are prepared in the following. As a whole it can be said that the adsorption chiller have the advantages like easier repairing and keeping, no corrosion in the inner surfaces, non crystallizing the water in the cycle, less consumption of electricity and lower hot water temperature. Also its disadvantages are high volume of device, high cost of preparing and less supports and services, [9]. In the figure (3), the curve of cooling capacity of adsorption and abruption according to the experimental quantities which they are measured in our lab is seen.

7. The thermodynamic process

W After manufacturing the first experimental sample of the device we could draw the thermodynamic processes of the cycle:

In the figure (4), the variations of pressure and specific volume in the cycle of chiller and in the figure (5) the variation of temperature and entropy is drawn.
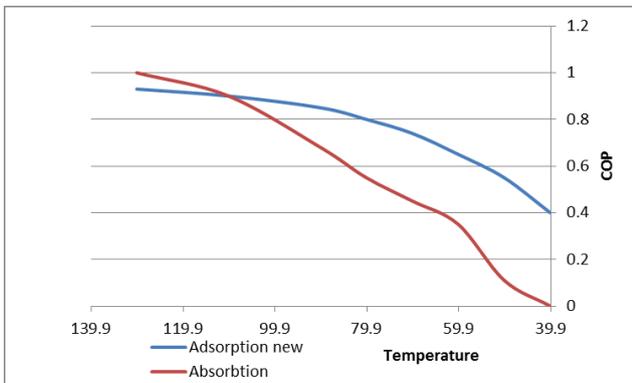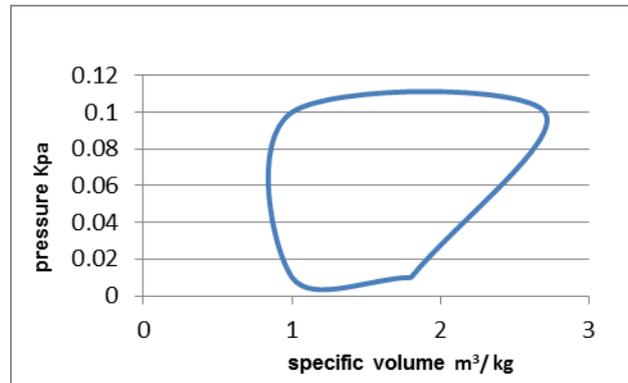

Fig. 3: Cooling capacity of adsorption and abruption.
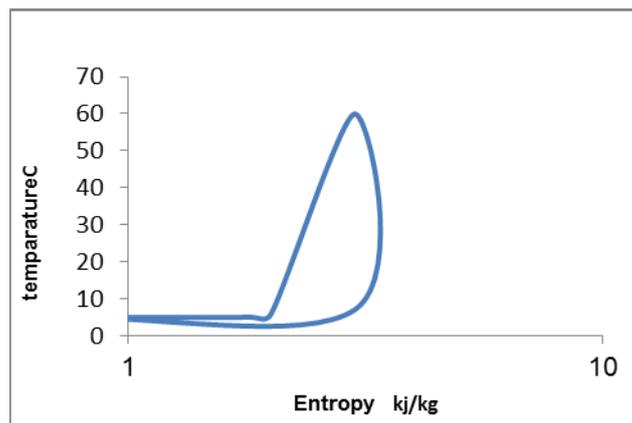
Fig. 4: The variations of pressure and specific volume.

Fig. 5: Variation of temperature and entropy.

8. Comparison between our new adsorption chiller and ordinary solid absorber chillers in the industries:

With Comparison between our new adsorption chiller and ordinary solid absorber chillers in the industries it can be said:

- Reducing the temperature of reducing and refining the absorber: this is caused the less consumption of electricity and facilitate the use of sun energy systems.

- Increasing the life time of absorber about 30 years.
- Reducing the cost of absorber due to using better row materials
- Reducing the refining time and cooling and increasing the operating coefficient
- Increasing the power of absorption
- Reducing the volume of generators
- Reducing the weight of the chiller

9. Conclusion and suggestion

The aim of the papers is to research for preparing, conserving and use of lost energies in other processes and also the sun energy in the air conditioning cycles. In many countries due to industrial and geographical conditions, there are the high potentials of using this method. In the field of air conditioning the best choice for the combination with the cycles which they have the heat energy losses or the cycles using sun energy, are the absorption systems using the refined solid absorbers. The main reason of this choose are the ability of direct using the heating energy obtained from the sun, the ability of using the low temperature heat source, repairing and keeping more easily in comparison to other liquid and ordinary solid absorbers. Also its depreciation and brake down is low. The other purposes to making a bed and introduction to export the technology of manufacturing this systems to the other countries and participating to keeping the earth safe and health for next generations.

10. References

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