A Simulation of Solar Ice-maker in Indonesia -2 (Influence Parameters and Data Processing)

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ABSTRACT

The simulation of the adsorption refrigeration method with the solar heating technique so called Solar Ice-maker is tested using Indonesian solar irradiation data prediction. In this report, diagrams generated from the Matlab simulink are analyzed with the modification of parameters to characterize and to see the performance of the system.

1. INTRODUCTION

To test the ice-maker system, the influence of the different parameters must be checked. The mass dependency and the condenser temperature will be examined as the influence parameters. In this section, several data have been taken to support this process.

2. EVALUATION OF THE SYSTEM

2.1. *Coefficient of Performance*

A measure of the steady state performance or energy efficiency of heating, cooling and refrigeration appliances is called Coefficient of Performance (COP). The COP determines the ratio of the work or useful energy output of a system versus the amount of work or energy put into the system as established by using the same energy equivalents for energy in and out [1].
For an ideal cycle of an adsorption cooling system, Leite [2] gives a thermodynamic analysis that Carnot's COP can be approximately written as:

$$COP \cong \frac{T_{con}}{T_{reg}}$$

where T_{con} is the condenser temperature (K) and T_{reg} is the regeneration temperature (K).

For the efficiency of the solar adsorption heat pump, the COP_{solar} is a measure which involving the performance of the collector is equal to the ratio of the useful effect to the total incident solar energy [3].
It can be formulated as:

$$COP_{solar} = \frac{Q_u}{A\int Idt}$$

where
Q_u = Useful heat [J]
I = Incident Solar Flux in an hour [W/m²]
A = Collector's surface area [m²]

The useful heat is obtained in the evaporator and can be stated by this formula:

$$Q_u = \Delta CM_{ad}L - C_{pmet}\Delta CM_{ad}(T_c - T_e)$$

those are:
ΔC = Total amount of methanol circulating in the system [no unity]
M_{ad} = Mass of adsorbent [kg]

L = Latent heat of methanol [J/kg]
C_{pmet} = Specific heat capacity [J/kgK]
T_c = Condenser temperature [K]
T_e = Evaporator temperature [K]

3. INFLUENCE PARAMETERS AND PERFORMANCE

3.1. *Mass Effect*

In order to compare the result, the data will be presented in a day with two different months. Those data are data in a month June 15th and December 15th.
The adsorbent masses that have been selected for this test are 15, 20, 25, 30 and 50 kg of adsorbent. The other parameters remain the same.

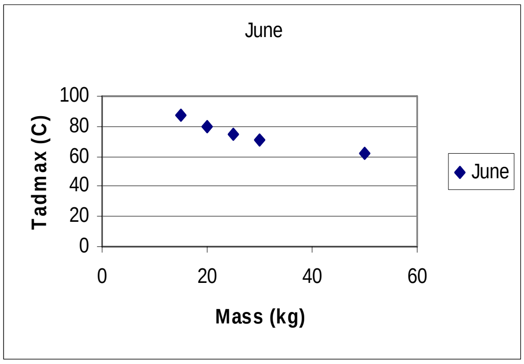

Figure 3.1. Adsorbent temperature vs adsorbent mass in June

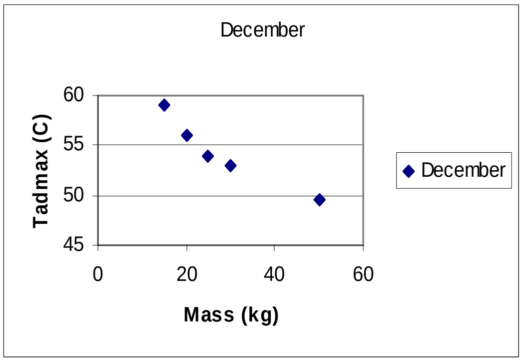

Figure 3.2. Adsorbent temperature vs adsorbent mass in December

The picture above is a diagram of the adsorbent temperature versus the mass adsorbent using solar intensity data for June 15th(figure 3.1). The recorded temperature is the highest or peak temperature in a day. In this data, the peak of temperature will show a value of about 90°C (363K) as a maximum temperature of the day by using 15 kg of adsorbent.

An increase of the adsorbent mass will result in a lower peak temperature of the activated carbon. Based on that diagram, it starts to decline almost linearly until 30 kg of mass. A mass addition after that point will affect in a lower temperature result but not significant. From the figure, adding up from 30kg to 50 kg of mass will result in lowering the temperature but only about 10K. In the range from 15kg to 30kg of adsorbent the peak temperature decreases almost 10K every 5kg of the adsorbent.

Using December 15th data (figure 3.2), the peak temperature of the adsorbent reaches only about 60°C (333K) as a maximum value in a day for 15 kg of the activated carbon because of a lower solar intensity.

It can be concluded that a higher mass of the adsorbent will automatically lead to lower temperatures of the adsorbent and thus will result in a lesser methanol desorbed by the activated carbon. This situation also effects in the adsorption process because in the ideal process, the desorption heat and the adsorption heat are alike. The cooling process will be low in performance due to the heat carried by the refrigerant is lesser.
According to the simulation, a mass of around 20 to 25 kg is the best choice with the selected components and parameters. With those masses, the peak temperature will not be higher than 423K to prevent the toxic reaction in the methanol.

3.2. *Condenser Temperature*

Another test of simulation is a test with the variation of the condenser temperature. Three different values are chosen, 10°C (283 K), 20°C (293 K) and 30°C (303 K). The result will be presented in a diagram correlated with the adsorbent temperature, the metal temperature and also the concentration of methanol contained in the adsorbent.
The other values remain the same (such as the mass, the solar irradiation intensity) to observe the dependency of the condenser temperature to the system directly.

a. A setting of the condenser temperature to 10°C (283 K) will result in a change of other parameters such as the pressure. The maximum pressure will be around 72 mbar and thus results in the maximum temperature of adsorbent. With an input of the solar data for the month of February, the response of the system is displayed in figure 3.3.

The adsorbent temperature climbs from a position around 33°C (306K) to 88°C (361K). About 55K temperature increment has been reached for the condenser temperature of 10°C (283K).

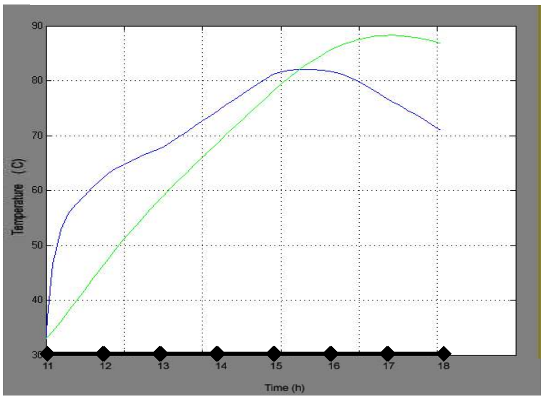

Figure 3.3. Metal temperature and adsorbent temperature for Tc = 10°C on February 15th

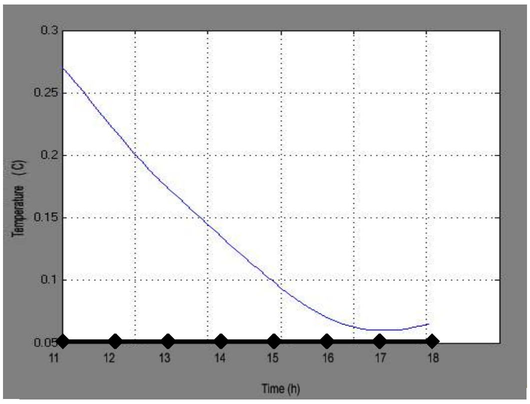

Figure 3.4. Concentration of methanol contained in the adsorbent Tc = 10°C

The influence on the concentration of methanol is shown in figure 3.4. With this condenser temperature, about 80% of methanol has been desorbed. It takes about five and a half hours to release the refrigerant from the adsorbent.

b. For the condenser temperature of 20°C (293 K) using the Clapeyron diagram, the pressure is changed to 126 mbar. Below are the calculated curves for the temperature and the concentration of the methanol.

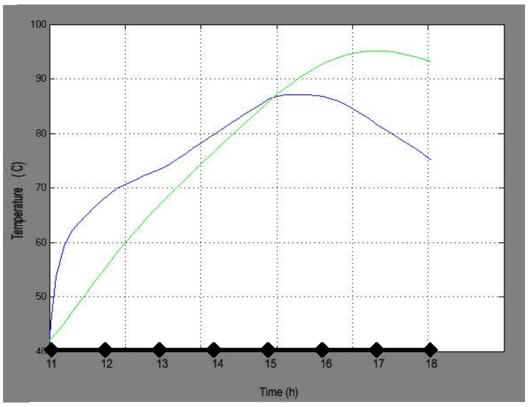

Figure 3.5. Temperature of metal and Temperature of adsorbent with Tc= 20°C

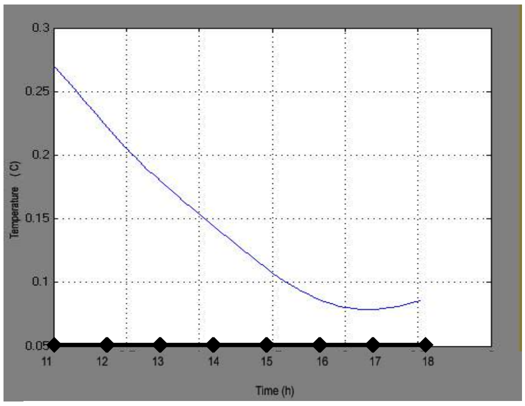

Figure 3.6. Concentration of methanol contained in adsorbent with Tc=20°C

On figure 3.5, the adsorbent temperature increases from 42°C (315K) up to 95°C (368K).

The methanol concentration in the adsorbent reacts slower (see figure 3.6). The change of the methanol concentration indicates a decrease in amount. It is observed that around 70% of the methanol from its maximum value has been desorbed at this temperature of condenser.

The influence of the condenser temperature on the adsorbent temperature is summarized in figure 3.7 below.

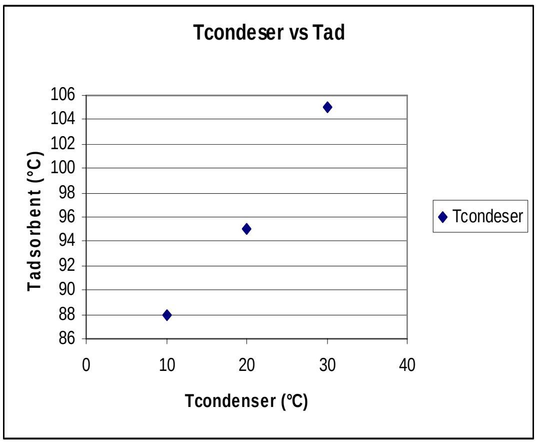

Figure 3.7. Relationship between condenser temperature and adsorbent peak temperature

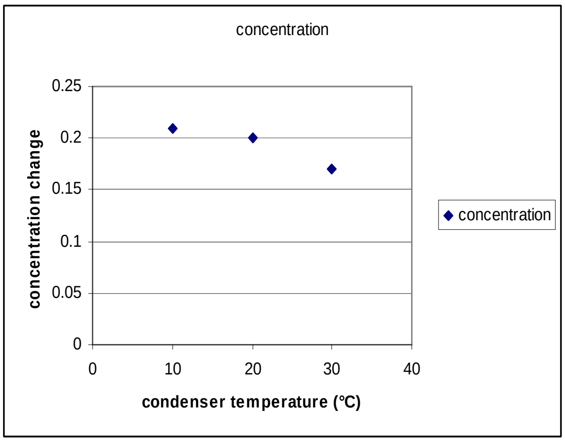

Figure 3.8. Relationship of condenser temperature and methanol concentration changes

It is seen that an increase of the condenser temperature will affect the peak temperature of the adsorbent. Although the adsorbent temperature is higher with an increasing condenser temperature, it doesn't mean that this will result in a higher desorption outcome. We also have to consider at what temperature the desorption process starts.

In this simulation, the initial value of the adsorbent temperature and the metal temperature are predefined. By using the clapeyron diagram as a look up table, those values can be obtained. Of course in the real case, they cannot be simply defined by some values. They are automatically obtained by the increasing solar intensity during the pre-heating stage. So the diagram above is achieved by an assumption of an ideal initial temperature of the desorption.

In contradiction with concentration of the methanol contained in the adsorbent, it is summarized in the figure 3.8.

Even though the condenser temperature is increased, the change in concentration of the methanol contained in the adsorbent reacts in different way. It shows a decline curve with a increasing values of the condenser's temperature. This means, a smaller amount of methanol for an increasing condenser temperature.

3.3. *Methanol Desorption*

Using 6.75 kg of methanol as an input of this experiment, we can determine the amount of refrigerant that can be used as a heat carrier in the cooling process.

Table 3.1. Amount of desorbed methanol related to the changed concentration

month	change of concentration	Methanol (kg)
2	0.195	4.875
4	0.1	2.5
6	0.12	3
8	0.2	5
10	0.25	6.25
12	0.045	1.125

In this table, it is shown that the desorption process in October leads to the highest values. Around 6 kg of methanol is released from the adsorbent. The lowest methanol desorption happens in December. Only about 1 kg methanol is liberated from the adsorbent. These facts are related proportionally with the amount of methanol that is trapped in the evaporator.

3.4. *Ice Production*

The production of ice is an important factor since we need the ice to preserve the vaccine (or even the food). The plan is that we have to produce the ice, so that it can cover the requirements to make vaccine box remain at the lower temperature (0-8 °C).

Table 4.4. Amount of ice production related to the change concentration

month	meth (kg)	ice product (kg)
2	4.875	11.2125
4	2.5	5.75
6	3	6.9
8	5	11.5
10	6.25	14.375
12	1.125	2.5875

As it is shown in the table above, the ice production in October 15th, August 15th and February 15th are the highest.
The lowest result will be in a month of December 15th. It only produces 2.5 kg of ice in that day.

3.5. *COP*

To see the performance of the system, another measure such an indicator should be considered. The coefficient of performance of a system defines the reliability of a system to do a work such as refrigeration.

Table 4.3. COP of system in a day in several months

month	COP
2	0.18890625
4	0.123295455
6	0.135625
8	0.150694444
10	0.135625
12	0.1220625
average	0.142701441

It is noted that the highest COP is reached in February 15th. It was described in the previous section that the solar irradiation has a big impact on the system. As for the COP that is although we can see that the peak solar irradiation of October is the highest, the COP of the system in that day is not the maximum value. In fact, it only appears in the third position of the highest COP. The reason of that condition is because of the solar irradiation of the day is rapidly declining from the peak of 1000 W/m² to 100 W/m² in only about 5 hours, thus resulting in a lower performance. In other word is that the system needs a constant value of solar irradiation for a better result.

4. SUMMARY

- The variation of the mass of the adsorbent also changes the peak temperature of the adsorbent. The higher mass addition in this system eventually will lower the peak temperature of the adsorbent. The efficient amount of the adsorbent must be determined in order to increase the performance.

- The change of the condenser temperature will affect the concentration of the methanol contained in the adsorbent. A higher condenser temperature will result in a lower concentration change in the desorption process.
- The Coefficient of Performance was reached on 15^{th} of February. The reason is because the solar irradiation data show a relatively constant trend.
- The ice production is correlated to the amount of the desorbed methanol in the adsorbent. The higher amount of the desorbed methanol will create the lower value of temperature in the evaporator, and thus higher ice production.
- Lower solar irradiation intensity in several months can be covered by a hybrid system. It could be coupled with the waste heat from the engine such from a car or a boat.

REFFERENCES

[1] http://www.daviddarling.info/encyclopedia/C/AE_coefficient_of_performance.html

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[3] Melkon Thather, Ayse Erdem Senatalar, The effects of thermal gradients in a solar adsorption heat pump utilizing the zeolite-water pair, Applied Thermal Engineering, October 1998.